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WMU Design Guidelines Instructions: These guidelines are to be used by the Design Professional to inform the design process and outline WMU-specific desires for all University projects. These guidelines have been edited to reflect WMU preferences, and the intent is for the Design Professional to use this information to guide their normal specifications-writing process. Straying from what is indicated in the guidelines is not prohibited, but shall be discussed with WMU during the development of the project.

SECTION 23 0500 - COMMON WORK RESULTS FOR HVAC

PART 1 - GENERAL

1.1 SUMMARY

A. This Section includes the following:

1. Piping materials and installation instructions common to most piping systems.
2. Transition fittings.
3. Dielectric fittings.
4. Sleeve-seal systems.
5. Sleeves.
7. Escutcheons.
8. Floor plates.
10. HVAC demolition.
11. Equipment installation requirements common to equipment sections.
12. Painting and finishing.
13. Concrete bases.

B. Related Sections:

1. Division 01 Section "Alternates" for requirements of alternates that relate to this Division.

1.2 DEFINITIONS

1.3 ACTION SUBMITTALS

A. Product Data: For dielectric fittings.

1.4 QUALITY ASSURANCE

A. Provide HVAC systems, equipment, and materials in accordance with Michigan Mechanical Code and other applicable codes and regulations, and with authorities having jurisdiction.

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

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.

1.5 DELIVERY, STORAGE, AND HANDLING

A. Deliver pipes and tubes with factory-applied end caps. Maintain end caps through shipping, storage, and handling to prevent pipe end damage and to prevent entrance of dirt, debris, and moisture.

B. Store plastic pipes protected from direct sunlight. Support to prevent sagging and bending.

C. Deliver products to project properly identified with names, model numbers, types, grades, compliance labels, and similar information needed for distinct identifications; adequately packaged and protected to prevent damage during shipment, storage, handling, and up to substantial completion. Coordinate deliveries of mechanical materials and equipment to minimize construction site congestion.

1.6 COORDINATION

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

B. Coordinate installation of required supporting devices and sleeves in structural components.

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

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

1. In inmate occupied areas, provide security type access doors and panels. [Refer to Drawing A110.]

1.7 PROJECT COMMISSIONING

A. Project is attempting to obtain LEED Certification and has an independent commissioning authority (CxA). Contractors for this project shall meet CxA requirements and shall coordinate with and participate in commissioning activities.
1.8 PERFORMANCE REQUIREMENTS

A. Seismic Requirements:
   1. Installation of hangers and supports shall comply with SEI/ASCE 7 requirements for Site Class C in accordance with International Building Code.

B. SEI: Structural Engineering Institute

C. ASCE: American Society of Civil Engineers

PART 2 - PRODUCTS

2.1 MANUFACTURERS

2.2 PIPE, TUBE, AND FITTINGS

   A. Refer to individual Division 23 piping Sections for pipe, tube, and fitting materials and joining methods.

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

   C. All grooved joint couplings, fittings, valves, and specialties shall be the products of a single manufacturer. Grooving tools shall be of the same manufacturer as the grooved components.

      1. All castings used for coupling housings, fittings, valve bodies, etc., shall include listing/approval stamp, label, or other markings made to specified standards.

2.3 JOINING MATERIALS

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

   B. 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.

         a. Full-Face Type: For flat-face, Class 125, cast-iron and cast-bronze flanges.

         b. Narrow-Face Type: For raised-face, Class 250, cast-iron and steel flanges.

      2. AWWA C110, rubber, flat face, 1/8 inch thick, unless otherwise indicated; and full-face or ring type, unless otherwise indicated.

   C. Flange Bolts and Nuts: ASME B18.2.1, carbon steel, unless otherwise indicated.
D. Plastic, Pipe-Flange Gasket, Bolts, and Nuts: Type and material recommended by piping system manufacturer, unless otherwise indicated.

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

F. Brazing Filler Metals: AWS A5.8, BCuP Series, copper-phosphorus alloys for general-duty brazing, unless otherwise indicated; and AWS A5.8, BAg1, silver alloy for refrigerant piping, unless otherwise indicated.

G. Welding Filler Metals: Comply with AWS D10.12 for welding materials appropriate for wall thickness and chemical analysis of steel pipe being welded.

H. 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.

I. Fiberglass Pipe Adhesive: As furnished or recommended by pipe manufacturer.

2.4 TRANSITION FITTINGS

2.5 DIELECTRIC FITTINGS

A. Dielectric Connections: Ground joint, copper unions, ASME B16.18, cast-copper-alloy body, hexagonal stock, with ball-and-socket joint, metal-to-metal seating surfaces, and solder-joint, threaded, or solder-joint and threaded ends; and suitable system fluid, pressure and temperature.

B. Dielectric Flanges: Factory-fabricated, companion-flange assembly, for 150-psig minimum working pressure as required to suit system pressures.

C. Description: Combination fitting of copper alloy and ferrous materials with threaded end connections that match piping system materials.

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

D. Dielectric Unions: Factory-fabricated, union assembly, for 250-psig minimum working pressure at 180 deg F with threaded end connections.

E. Dielectric Flanges: Factory-fabricated, companion-flange assembly, for 150- or 300-psig minimum working pressure as required to suit system pressures.

F. Dielectric-Flange Kits: Companion-flange assembly for field assembly. Include flanges, full-face- or ring-type neoprene or phenolic gasket, phenolic or polyethylene bolt sleeves, phenolic washers, and steel backing washers.

1. Separate companion flanges and steel bolts and nuts shall have 150- or 300-psig minimum working pressure where required to suit system pressures.
G. Dielectric Couplings: Galvanized-steel coupling with inert and noncorrosive, thermoplastic lining; threaded ends; and 300-psig minimum working pressure at 225 deg F.

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

2.6 SLEEVE-SEAL SYSTEMS

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

1. Advance Products & Systems, Inc.
2. CALPICO, Inc.
3. Metraflex Company (The).
4. Pipeline Seal and Insulator, Inc.
5. Proco Products, Inc.
6. Thunderline

B. Description: Modular sealing-element unit, designed for field assembly, for filling annular space between piping and sleeve.

1. Sealing Elements: EPDM-rubber interlocking links shaped to fit surface of pipe. Include type and number required for pipe material and size of pipe.
2. Sealing Elements: [EPDM-rubber] [NBR] interlocking links shaped to fit surface of pipe. Include type and number required for pipe material and size of pipe.
4. Pressure Plates: [Carbon steel] [Plastic] [Stainless steel].
5. Connecting Bolts and Nuts: Carbon steel, with corrosion-resistant coating, of length required to secure pressure plates to sealing elements.
6. Connecting Bolts and Nuts: [Carbon steel, with corrosion-resistant coating,] [Stainless steel] of length required to secure pressure plates to sealing elements.

2.7 SLEEVES

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

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

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


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

F. Molded-PE or -PP Sleeves: Removable, tapered-cup shaped, and smooth outer surface with nailing flange for attaching to [wooden forms].
G. Molded-PVC Sleeves: With nailing flange for attaching to wooden forms.

2.8 STACK-SLEEVE FITTINGS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   2. Zurn Specification Drainage Operation; Zurn Plumbing Products Group.

B. Description: Manufactured, cast-iron sleeve with integral clamping flange. Include clamping ring, bolts, and nuts for membrane flashing.
   1. Underdeck Clamp: Clamping ring with setscrews.

2.9 ESCUTCHEONS

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

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

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

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

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

F. Split-Plate, Stamped-Steel Type: With chrome-plated finish, concealed or exposed-rivet hinge, and spring-clip fasteners.

2.10 FLOOR PLATES

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

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

C. One-Piece Floor Plates: Cast-iron flange[ with holes for fasteners].

D. Split-Casting Floor Plates: Cast brass with concealed hinge.
2.11 GROUT


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

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

D. Packaging: Premixed and factory packaged.

2.12 MECHANICAL ROOF PENETRATIONS

A. Roof Curbs for Duct Penetrations: Prefabricated heavy-gage galvanized steel or aluminum curb with mitered and welded corners, minimum 1 1/2 inch thick rigid fiberglass insulation adhered to inside walls, built-in cant and mounting flange for roof decks, and wood nailer. Size as required to suit roof opening and ductwork. Overall minimum height shall be 12 inches above roof insulation. Provide curbs with level tops and bottoms to match roof slope. Provide galvanized steel flashing and seal water tight. Provide insulation on interior flashing surfaces exposed to building air. Pate or equivalent.

B. Pipe Curbs for Single or Multiple Pipe Penetrations: Prefabricated heavy-gage galvanized steel or aluminum curb with mitered and welded corners, minimum 1 1/2 inch thick rigid fiberglass insulation adhered to inside walls, built-in cant and mounting flange for roof decks, wood nailer, and acrylic clad ABS plastic cover(s), PVC boot(s), and stainless steel clamps. Size as required to suit roof opening and piping. Overall minimum height shall be 12 inches above roof insulation. Provide curbs with level tops and bottoms to match roof slope. Pate or equivalent.

C. Pipe Curbs for Single Pipe Penetrations: All roof pipe penetrations up to 10" O.D. shall be flashed and sealed using a Pate or equivalent pipe seal, consisting of a spun aluminum base having a minimum five inch roof surface flange, a stepped polyvinyl chloride boot to be secured to the base and the pipe with adjustable stainless steel clamps as furnished.

PART 3 - EXECUTION

3.1 HVAC DEMOLITION

A. Disconnect, demolish, and remove HVAC systems, equipment, and components indicated to be removed.

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.
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.
5. Equipment to Be Removed: Disconnect and cap services and remove 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.

7. Equipment to Be Removed and Salvaged: Disconnect and cap services and remove equipment and deliver to Owner.

B. 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 Sections specifying piping systems.

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

1. Drawings are diagrammatic with no attempt made to show every ell, tee, transition, fitting, or appurtenance. Provide installations that are complete in every detail, compliant with all applicable codes, and as required to provide a fully functional and operational system even though every item is not specifically indicated.

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

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

G. Install piping to permit valve servicing.

H. Install piping at indicated slopes.

I. Install piping free of sags and bends.

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

K. Install piping to allow application of insulation.

L. Select system components with pressure rating equal to or greater than system operating pressure.
3.3 ESCUTCHEON INSTALLATION

A. Install escutcheons for penetrations of walls, ceilings, and finished floors according to the following:

1. Escutcheons for New Piping:
   a. Piping with Fitting or Sleeve Protruding from Wall: One-piece, deep-pattern type.
   b. Chrome-Plated Piping: One-piece, cast-brass or split-casting brass type with polished, chrome-plated finish.
   c. Insulated Piping: One-piece, stamped-steel type or split-plate, stamped-steel type with concealed hinge.
   d. Insulated Piping: One-piece, stamped-steel type[ or split-plate, stamped-steel type with concealed hinge] [ or split-plate, stamped-steel type with exposed-rivet hinge].
   e. Bare Piping at Wall and Floor Penetrations in Finished Spaces: One-piece, cast-brass or split-casting brass type with polished, chrome-plated finish.
   f. Bare Piping at Wall and Floor Penetrations in Finished Spaces: One-piece, stamped-steel type[ or split-plate, stamped-steel type with concealed hinge] [ or split-plate, stamped-steel type with exposed-rivet hinge].
   g. Bare Piping at Ceiling Penetrations in Finished Spaces: One-piece, cast-brass or split-casting brass type with polished, chrome-plated finish.
   h. Bare Piping at Ceiling Penetrations in Finished Spaces: One-piece, stamped-steel type[ or split-plate, stamped-steel type with concealed hinge] [ or split-plate, stamped-steel type with exposed-rivet hinge].
   i. Bare Piping in Unfinished Service Spaces: One-piece, cast-brass or split-casting brass type with polished, chrome-plated or rough-brass finish.
   j. Bare Piping in Unfinished Service Spaces: One-piece, stamped-steel type[ or split-plate, stamped-steel type with concealed hinge] [ or split-plate, stamped-steel type with exposed-rivet hinge].
   k. Bare Piping in Equipment Rooms: One-piece, cast-brass or split-casting brass type with polished, chrome-plated or rough-brass finish.
   l. Bare Piping in Equipment Rooms: One-piece, stamped-steel type[ or split-plate, stamped-steel type with concealed hinge] [ or split-plate, stamped-steel type with exposed-rivet hinge].

2. Escutcheons for Existing Piping:
   a. Chrome-Plated Piping: Split-casting brass type with polished, chrome-plated finish.
   b. Insulated Piping: Split-plate, stamped-steel type with concealed or exposed-rivet hinge.
   c. Bare Piping at Wall and Floor Penetrations in Finished Spaces: Split-casting brass type with polished, chrome-plated finish.
   d. Bare Piping at Wall and Floor Penetrations in Finished Spaces: Split-plate, stamped-steel type with [concealed] [or] [exposed-rivet] hinge.
   e. Bare Piping at Ceiling Penetrations in Finished Spaces: Split-casting brass type with polished, chrome-plated finish.
   f. Bare Piping at Ceiling Penetrations in Finished Spaces: Split-plate, stamped-steel type with [concealed] [or] [exposed-rivet] hinge.
   g. Bare Piping in Unfinished Service Spaces: Split-casting brass type with polished, chrome-plated or rough-brass finish.
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h. Bare Piping in Unfinished Service Spaces: Split-plate, stamped-steel type with concealed [or] exposed-rivet hinge.
i. Bare Piping in Equipment Rooms: Split-casting brass type with polished, chrome-plated or rough-brass finish.
j. Bare Piping in Equipment Rooms: Split-plate, stamped-steel type with concealed [or] exposed-rivet hinge.

3.4 FLOOR PLATE INSTALLATION

A. Install floor plates for piping penetrations of equipment-room floors.
   1. New Piping: One-piece, floor-plate type.
   2. Existing Piping: Split-casting, floor-plate type.

3.5 SLEEVE INSTALLATION

A. Install sleeves for piping passing through penetrations in floors, partitions, roofs, and walls.
   1. Sleeves are not required for core-drilled holes.

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

C. Install sleeves in concrete floors, concrete roof slabs, and concrete walls as new slabs and walls are constructed.
   1. Permanent sleeves are not required for holes in slabs formed by molded-PE or -PP sleeves.
   2. Cut sleeves to length for mounting flush with both surfaces.
      a. Exception: Extend sleeves installed in floors of mechanical equipment areas or other wet areas 2 inches above finished floor level.
   3. Using grout, seal the space outside of sleeves in slabs and walls without sleeve-seal system.

D. Install sleeves for pipes passing through interior partitions.
   1. Cut sleeves to length for mounting flush with both surfaces.
   2. Install sleeves that are large enough to provide 1/4-inch annular clear space between sleeve and pipe or pipe insulation.
   3. Seal annular space between sleeve and piping or piping insulation; use joint sealants appropriate for size, depth, and location of joint.

E. Fire-Barrier Penetrations: Maintain indicated fire rating of walls, partitions, ceilings, and floors at pipe penetrations. Seal pipe penetrations with firestop materials.
3.6 STACK-SLEEVE-FITTING INSTALLATION

A. Install stack-sleeve fittings in new slabs as slabs are constructed.
   1. Install fittings that are large enough to provide 1/4-inch annular clear space between sleeve and pipe or pipe insulation.
   2. Secure flashing between clamping flanges for pipes penetrating floors with membrane waterproofing.
   3. Install section of cast-iron soil pipe to extend sleeve to 2 inches above finished floor level.
   4. Extend cast-iron sleeve fittings below floor slab as required to secure clamping ring if ring is specified.
   5. Using grout, seal the space around outside of stack-sleeve fittings.

B. Fire-Barrier Penetrations: Maintain indicated fire rating of floors at pipe penetrations. Seal pipe penetrations with firestop materials.

3.7 SLEEVE-SEAL-SYSTEM INSTALLATION

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

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

3.8 SLEEVE AND SLEEVE-SEAL SCHEDULE

A. Use sleeves and sleeve seals for the following piping-penetration applications:
   1. Exterior Concrete Walls Above Grade:
      a. Piping Smaller Than NPS 6: Cast-iron wall sleeves, galvanized-steel wall sleeves, or galvanized-steel-pipe sleeves.
      b. Piping Smaller Than [NPS 6] <Insert pipe size>: [Cast-iron wall sleeves] [Galvanized-steel wall sleeves] [Galvanized-steel-pipe sleeves] [Sleeve-seal fittings] <Insert material>.
      c. Piping NPS 6 and Larger: Cast-iron wall sleeves, galvanized-steel wall sleeve, or galvanized-steel-pipe sleeves.
      d. Piping [NPS 6] <Insert pipe size> and Larger: [Cast-iron wall sleeves] [Galvanized-steel wall sleeves] [Galvanized-steel-pipe sleeves] <Insert material>.
   2. Exterior Concrete Walls below Grade:
      a. Piping Smaller Than NPS 6: Cast-iron wall sleeves with sleeve-seal system.
      b. Piping Smaller Than [NPS 6] <Insert pipe size>: [Cast-iron wall sleeves with sleeve-seal system] [Galvanized-steel wall sleeves with sleeve-seal system] [Galvanized-steel-pipe sleeves with sleeve-seal system] [Sleeve-seal fittings] <Insert material>. 
1) Select sleeve size to allow for 1-inch annular clear space between piping and sleeve for installing sleeve-seal system.

c. Piping NPS 6 and Larger: Cast-iron wall sleeves with sleeve-seal system.

d. Piping [NPS 6] <Insert pipe size> and Larger: [Cast-iron wall sleeves with sleeve-seal system] [Galvanized-steel wall sleeves with sleeve-seal system] [Galvanized-steel-pipe sleeves with sleeve-seal system] <Insert material>.

3. Concrete Slabs-on-Grade:

a. Piping Smaller Than NPS 6: Cast-iron wall sleeves with sleeve-seal system.

b. Piping Smaller Than [NPS 6] <Insert pipe size>: [Cast-iron wall sleeves with sleeve-seal system] [Galvanized-steel wall sleeves with sleeve-seal system] [Galvanized-steel-pipe sleeves with sleeve-seal system] [Sleeve-seal fittings] <Insert material>.

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

3. Concrete Slabs-on-Grade:

a. Piping Smaller Than NPS 6: Cast-iron wall sleeves with sleeve-seal system.

b. Piping Smaller Than [NPS 6] <Insert pipe size>: [Cast-iron wall sleeves with sleeve-seal system] [Galvanized-steel wall sleeves with sleeve-seal system] [Galvanized-steel-pipe sleeves with sleeve-seal system] [Sleeve-seal fittings] <Insert material>.

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

c. Piping NPS 6 and Larger: Cast-iron wall sleeves with sleeve-seal system.

d. Piping [NPS 6] <Insert pipe size> and Larger: [Cast-iron wall sleeves with sleeve-seal system] [Galvanized-steel wall sleeves with sleeve-seal system] [Galvanized-steel-pipe sleeves with sleeve-seal system] [Galvanized-steel-pipe sleeves] <Insert material>.

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

4. Concrete Slabs above Grade:

a. Piping Smaller Than NPS 6: Stack-sleeve fittings.

b. Piping Smaller Than [NPS 6] <Insert pipe size>: [Galvanized-steel-pipe sleeves] [PVC-pipe sleeves] [Stack-sleeve fittings] [Sleeve-seal fittings] [Molded-PE or -PP sleeves] [Molded-PVC sleeves] <Insert material>.

c. Piping NPS 6 and Larger: Stack-sleeve fittings.

d. Piping [NPS 6] <Insert pipe size> and Larger: [Galvanized-steel-pipe sleeves] [PVC-pipe sleeves] [Stack-sleeve fittings] <Insert material>.

5. Interior Partitions:


3.9 PIPING 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.


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. PE Piping Heat-Fusion Joints: Clean and dry joining surfaces by wiping with clean cloth or paper towels. Join according to ASTM D 2657.
   1. Plain-End Pipe and Fittings: Use butt fusion.
   2. Plain-End Pipe and Socket Fittings: Use socket fusion.
M. Fiberglass Bonded Joints: Prepare pipe ends and fittings, apply adhesive, and join according to pipe manufacturer’s written instructions.

3.10 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. Wet Piping Systems: Connect piping materials of dissimilar metals as follows:
   a. In piping NPS 2(DN 50) and smaller, install ground joint unions.
   b. In piping NPS 2-1/2(DN 65) and larger, install dielectric flanges.
4. Dry Piping Systems: Install dielectric unions and flanges to connect piping materials of dissimilar metals.
5. Wet Piping Systems: Install dielectric unions, dielectric couplings, or dielectric nipple fittings to connect piping materials of dissimilar metals.

3.11 EQUIPMENT INSTALLATION - COMMON REQUIREMENTS
A. Sequence, coordinate, and integrate installations of mechanical equipment, giving particular attention to large equipment requiring positioning prior to closing in the building.

B. Sequence, coordinate, and integrate installations of mechanical equipment, giving particular attention to large equipment requiring positioning prior to closing in the building.

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

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

E. Install HVAC equipment to facilitate service, maintenance, and repair or replacement of components. Connect equipment for ease of disconnecting, with minimum interference to other installations.

   1. Extend grease fittings to accessible locations.

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

G. Installing contractor shall bear all additional costs, including that of Architect/Engineer redesign and that of other trades, incurred as a result of installation of other than scheduled equipment.

H. Verify final equipment locations for roughing-in.
I. Refer to equipment specifications in other Sections of these Specifications for roughing-in requirements.

3.12 PAINTING
A. Painting of HVAC systems, equipment, and components is specified in Division 09 painting sections.
B. Painting of HVAC systems, equipment, and components is specified in Division 09 Sections "Interior Painting" and "Exterior Painting."
C. Damage and Touchup: Repair marred and damaged factory-painted finishes with materials and procedures to match original factory finish.

3.13 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 4 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 Division 03 section for cast-in-place concrete.
8. Use [3000-psi] <Insert other>, 28-day compressive-strength concrete and reinforcement as specified in Division 03 Section "[Cast-in-Place Concrete] [Miscellaneous Cast-in-Place Concrete]."

3.14 ERECTION OF METAL SUPPORTS AND ANCHORAGES
A. Refer to Division 05 Section "Metal Fabrications" for structural steel.
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.
3.15 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.

3.16 GROUTING

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

1. Clean surfaces that will come into contact with grout.
2. Provide forms as required for placement of grout.
3. Avoid air entrapment during placement of grout.
4. Place grout, completely filling equipment bases.
5. Place grout on concrete bases and provide smooth bearing surface for equipment.
6. Place grout around anchors.
7. Cure placed grout.

B. Mix and install grout for HVAC installations.

1. Clean surfaces that will come into contact with grout.
2. Provide forms as required for placement of grout.
3. Avoid air entrapment during placement of grout.
4. Cure placed grout.

3.17 MECHANICAL ROOF PENETRATIONS

A. Install mechanical roof penetrations in accordance with roof curb manufacturer’s recommendations and in strict compliance with roofing manufacturer’s requirements.

1. Roofs with Warranty: Roof penetrations and curbs shall be installed in such a manner to maintain roofing warranty.

B. Roof Curbs for Duct Penetrations: Provide galvanized steel flashing and seal water tight. Provide insulation on interior flashing surfaces exposed to building air.

C. Pipe Curbs for Pipe Penetrations: Secure boot to curb base and secure boot to pipe with adjustable stainless steel clamps.

3.18 INSTALLATION OF ACCESS DOORS

A. Where lay-in ceilings are used, the access to ceiling space is provided through the removable ceiling panels. Where access is required to valves, pipes, dampers or other devices in spaces
above non-removable ceilings or in chases, the Contractor requiring the access doors shall provide access doors. Access doors required in rated walls and ceiling shall bear the same rating.

1. Set frames accurately in position and securely attached to supports, with face panels plumb and level in relation to adjacent finish surfaces.
2. Adjust hardware and panels after installation for proper operation.

3.19 FIELD QUALITY CONTROL

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

END OF SECTION 23 0500
SECTION 23 0523 – GENERAL DUTY VALVES FOR HVAC PIPING

PART 1 - GENERAL

1.1 SUMMARY

A. This Section includes the following general-duty valves:

1. Bronze ball valves.
2. Ferrous-alloy butterfly valves.
5. Bronze gate valves.
6. Cast-iron gate valves.
7. Bronze globe valves.
8. Cast-iron globe valves.

B. Related Sections include the following:

1. Division 21 fire-suppression piping Sections for fire-protection valves.
2. Division 23 piping Sections for specialty valves applicable to those Sections only.
3. Division 23 Section "Identification for HVAC Piping and Equipment" for valve tags and charts.
4. Division 23 Section "Instrumentation and Control for HVAC" for control valves and actuators.

1.2 ACTION SUBMITTALS

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

1.3 QUALITY ASSURANCE

A. ASME Compliance: ASME B31.9 for building services piping valves and ASME B31.1 for power piping valves.

B. ASME Compliance for Ferrous Valves: ASME B16.10 and ASME B16.34 for dimension and design criteria.
1.4 DELIVERY, STORAGE, AND HANDLING

A. Prepare valves for shipping as follows:
   1. Protect internal parts against rust and corrosion.
   2. Protect valve ends from damage.
   3. Set gate, and globe valves closed to prevent rattling.
   4. Set ball valves open to minimize exposure of functional surfaces.
   5. Set butterfly valves closed or slightly open.
   6. Block check valves in either closed or open position.

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

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

PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. In other Part 2 articles where subparagraph titles below introduce lists, the following requirements apply for product selection:
   1. Manufacturers: Subject to compliance with requirements, provide products by the manufacturers specified.

2.2 VALVES, GENERAL

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

B. Bronze Valves: NPS 2 and smaller with threaded ends, unless otherwise indicated.

C. Ferrous Valves: NPS 2-1/2 and larger with flanged ends, unless otherwise indicated. Grooved allowed if Alternate No. 1 is selected.

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

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

F. Valve Actuators:
   1. Lever Handle: For quarter-turn valves NPS 4(DN 100) and smaller.
   2. Gear Drive: For quarter-turn valves NPS 6(DN 150) and larger.
   3. Handwheel: For valves other than quarter-turn types.
4. **Chainwheel:** For attachment to valves, of size and mounting height, as indicated in the "Valve Installation" Article in Part 3.

G. **Extended Valve Stems:** On insulated valves.

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

I. **Valve Grooved Ends:** AWWA C606.

J. **Valve Solder Ends:** Solder joint with sockets according to ASME B16.18.

1. Caution: Use solder with melting point below 840 deg F (454 deg C) for angle, check, gate, and globe valves; below 421 deg F (216 deg C) for ball valves.

K. **Valve Threaded Ends:** Threaded with threads according to ASME B1.20.1.

L. **Valve Bypass and Drain Connections:** MSS SP-45.

### 2.3 BRONZE BALL VALVES

A. **Manufacturers:**

1. Apollo.
2. Hammond.
3. Milwaukee.
4. Jamesbury

B. **High Performance Hydronic System Ball Valves, NPS 2 and Smaller:** ASTM B62, 400psi WOG pressure, two piece bronze body, full port, stainless steel ball, replaceable “TFE” seats and seal, blowout proof stem, vinyl covered handle, and threaded ends.

C. **Ball Valves, NPS 2 and Smaller:** 600psi WOG pressure, 150 SWP, two piece bronze body, full port, stainless steel ball, replaceable “TFE” seats and seal, blowout proof stem, vinyl covered handle, and threaded ends.

D. **Manufacturers:**

1. **Two-Piece, Copper-Alloy Ball Valves:**
   b. Crane Co.; Crane Valve Group; Crane Valves.
   c. Crane Co.; Crane Valve Group; Jenkins Valves.
   d. Crane Co.; Crane Valve Group; Stockham Div.
   e. Tyco / Grinnell.
   f. Hammond Valve.
   g. Jamesbury, Inc.
   h. Jomar International, LTD.
   i. Legend Valve & Fitting, Inc.
   j. Milwaukee Valve Company.
   k. NIBCO INC.
   l. Red-White Valve Corp.
m. Watts Industries, Inc.; Water Products Div.

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

F. Two-Piece, Copper-Alloy Ball Valves: B584 Cast bronze threaded two-piece body with full-port, chrome-plated bronze ball; PTFE or TFE seats; and 600-psig minimum CWP rating and blowout-proof stem.

2.4 FERROUS-ALLOY BUTTERFLY VALVES

DESIGNER NOTE: Revise High Performance Butterfly Valve based on duty. HVAC applications shall be ductile iron. Steam applications shall be cast steel.

A. Manufacturers:

1.
2. Nibco
3. Jamesbury
5. Jenkins.< CRANE SUBSIDARY - VERIFY THEY STILL MAKE BUTTERFLY'S> YES
7. Apollo

B. High Performance Butterfly Valves, NPS 2-1/2 and Larger: 200 psi WOG [ductile iron][cast steel ]bodies, lug style, stainless steel disc, RTFE/stainless garter spring seats, stainless steel stem. Valves shall have a minimum Class IV Leakage Rate.

C. Manufacturers:

1. Flangeless, Ferrous-Alloy Butterfly Valves:
   a. Apollo Valves.
   b. American Valve, Inc.
   c. Crane Co.; Crane Valve Group; Center Line.
   d. Crane Co.; Crane Valve Group; Stockham Div.
   e. General Signal; DeZurik Unit.
   f. Tyco / Grinnell.
   g. Hammond Valve.
   h. Legend Valve & Fitting, Inc.
   i. Milwaukee Valve Company.
   j. NIBCO INC.
   k. Red-White Valve Corp.
   l. Watts Industries, Inc.; Water Products Div.

2. Grooved-End, Ductile-Iron Butterfly Valves:
   a. Anvil International, Inc.
   b. Central Sprinkler Co.; Central Grooved Piping Products.
   c. Tyco / Grinnell.
   d. Hammond Valve.
   e. McWane, Inc.; Kennedy Valve Div.
   f. Milwaukee Valve Company.
g. Mueller Steam Specialty.

h. NIBCO INC.

i. Victaulic Co. of America.

D. Ferrous-Alloy Butterfly Valves, General: MSS SP-67, Type I, for tight shutoff.

E. Flangeless, 200-psig CWP Rating, Ferrous-Alloy Butterfly Valves: Lug type with one- or two-piece stem.

F. Flangeless, 200-psig CWP Rating, Ferrous-Alloy Butterfly Valves: Wafer type with one [one] or two [two]-piece stem.

G. Grooved-End, 300-psig CWP Rating, Ferrous-Alloy Butterfly Valves: Ductile-iron body with grooved or shouldered ends.

2.5 BRONZE CHECK VALVES

A. Manufacturers:

1. Hammond.

2. Jenkins.

3. Milwaukee.

B. Swing Check Valves, NPS 2 and Smaller: ASTM B61, class 150 bronze body, disc and cap, y-pattern with threaded ends.

C. Manufacturers:

1. Type 4, Bronze, Swing Check Valves with Nonmetallic Disc:
   a. Cincinnati Valve Co.
   b. Crane Co.; Crane Valve Group; Crane Valves.
   c. Crane Co.; Crane Valve Group; Jenkins Valves.
   d. Crane Co.; Crane Valve Group; Stockham Div.
   e. Tyco / Grinnell.
   f. Hammond Valve.
   g. McWane, Inc.; Kennedy Valve Div.
   h. Milwaukee Valve Company.
   i. NIBCO INC.
   j. Red-White Valve Corp.
   k. Walworth Co.
   l. Watts Industries, Inc.; Water Products Div.

D. Bronze Check Valves, General: MSS SP-80.

E. Type 4, Class 125, Bronze, Swing Check Valves: Bronze body with nonmetallic disc and bronze seat.

F. Type 4, Class 150, Bronze, Swing Check Valves: Bronze body with nonmetallic disc and bronze seat.
2.6 GRAY-IRON SWING CHECK VALVES

A. Manufacturers:
   1. Stockham.
   2. Milwaukee.

B. Swing Check Valves, NPS 2-1/2 and Larger: ASTM A126, class 125 cast iron body and cap, renewable bronze disc and seat rings, flanged ends.

C. Manufacturers:
   1. Type II, Gray-Iron Swing Check Valves:
      a. Crane Co.; Crane Valve Group; Crane Valves.
      b. Crane Co.; Crane Valve Group; Stockham Div.
      c. Mueller Co.
      d. NIBCO INC.
      e. Watts Industries, Inc.; Water Products Div.

   2. Grooved-End, Ductile-Iron Swing Check Valves:
      a. Anvil International, Inc.
      b. Tyco / Grinnell.
      c. Mueller Co.
      d. Victaulic Co. of America.


E. Type II, Class 125, gray-iron, swing check valves with composition to metal seats.

F. Type II, Class 250, gray-iron, swing check valves with metal seats.

G. 175-psig CWP Rating, Grooved-End, Swing Check Valves: Ductile-iron body with grooved or shouldered ends.

2.7 BRONZE GATE VALVES

A. Manufacturers:
   1. Grinnell.
   2. Jenkins.

B. Gate Valves, NPS 2 and Smaller: ASTM B62, class 125 body, bonnet and union ring with threaded ends, solid disc, copper silicon stem and malleable iron handwheel.

C. Manufacturers:
   1. Type 2, Bronze, Rising-Stem, Solid-Wedge Gate Valves:
      a. American Valve, Inc.
      b. Cincinnati Valve Co.
c. Crane Co.; Crane Valve Group; Crane Valves.
d. Crane Co.; Crane Valve Group; Jenkins Valves.
e. Crane Co.; Crane Valve Group; Stockham Div.
f. Tyco / Grinnell.
g. Hammond Valve.
h. Milwaukee Valve Company.
i. NIBCO INC.
j. Powell, Wm. Co.
k. Red-White Valve Corp.
l. Watts Industries, Inc.; Water Products Div.
m. Walworth Co.

D. Bronze Gate Valves, General: MSS SP-80, with ferrous-alloy handwheel.

E. Type 2, Class 125, Bronze Gate Valves: Bronze body with rising stem and bronze solid wedge and union-ring bonnet.

F. Type 2, Class 150, Bronze Gate Valves: Bronze body with rising stem and bronze solid wedge and union-ring bonnet.

2.8 CAST-IRON GATE VALVES

A. Manufacturers:

1. Grinnell.
2. Jenkins.

B. Gate Valves, NPS 2-1/2 and Larger: ASTM A126, class 125 cast iron body, bolted bonnet, OS&Y solid wedge disc, bronze trim with flanged ends.

C. Manufacturers:

1. Type I, Cast-Iron, Rising-Stem Gate Valves:
   a. Cincinnati Valve Co.
   b. Crane Co.; Crane Valve Group; Crane Valves.
   c. Crane Co.; Crane Valve Group; Jenkins Valves.
   d. Crane Co.; Crane Valve Group; Stockham Div.
   e. Tyco / Grinnell.
   f. Hammond Valve.
   g. Legend Valve & Fitting, Inc.
   h. Milwaukee Valve Company.
   i. NIBCO INC.
   j. Powell, Wm. Co.
   k. Red-White Valve Corp.
   l. Walworth Co.
   m. Watts Industries, Inc.; Water Products Div.

D. Cast-Iron Gate Valves, General: MSS SP-70, Type I.
2.9 BRONZE GLOBE VALVES

A. Manufacturers:
   1. Grinnell.
   2. Jenkins.

B. Globe Valves, NPS 2 and Smaller: ASTM B62, class 150 bronze body, copper-nickel alloy disc, teflon impregnated packing, copper-silicon alloy stem and malleable iron wheel.

C. Manufacturers:
   1. Type 2, Bronze Globe Valves with Nonmetallic Disc:
      a. Cincinnati Valve Co.
      b. Crane Co.; Crane Valve Group; Crane Valves.
      c. Crane Co.; Crane Valve Group; Jenkins Valves.
      d. Crane Co.; Crane Valve Group; Stockham Div.
      e. Grinnell Corporation.
      f. Hammond Valve.
      g. McWane, Inc.; Kennedy Valve Div.
      h. Milwaukee Valve Company.
      i. NIBCO INC.
      j. Powell, Wm. Co.
      k. Red-White Valve Corp.
      l. Walworth Co.
      m. Watts Industries, Inc.; Water Products Div.

D. Bronze Globe Valves, General: MSS SP-80, with ferrous-alloy handwheel.

E. Type 2, Class 125, Bronze Globe Valves: Bronze body with PTFE or TFE disc.

F. Type 2, Class 150, Bronze Globe Valves: Bronze body with PTFE or TFE disc and union-ring bonnet.

2.10 CAST-IRON GLOBE VALVES

A. Manufacturers:
   1. Grinnell.
   2. Jenkins.
B. Globe Valves, NPS 2-1/2 and Larger: ASTM A126, class 125 iron body, bronze disc, teflon impregnated packing, copper-silicon alloy stem.

C. Manufacturers:

1. Type I, Cast-Iron Globe Valves with Metal Seats:
   a. Cincinnati Valve Co.
   b. Crane Co.; Crane Valve Group; Crane Valves.
   c. Crane Co.; Crane Valve Group; Jenkins Valves.
   d. Crane Co.; Crane Valve Group; Stockham Div.
   e. Grinnell Corporation.
   f. Hammond Valve.
   g. Milwaukee Valve Company.
   h. NIBCO INC.
   i. Powell, Wm. Co.
   j. Red-White Valve Corp.
   k. Walworth Co.


E. Type I, Class 125, Cast-Iron Globe Valves: Gray-iron body with bronze seats.

F. Type I, Class 250, Cast-Iron Globe Valves: Gray-iron body with bronze seats.

2.11 CHAINWHEEL ACTUATORS

A. Manufacturers:

1. Babbitt Steam Specialty Co.
2. Roto Hammer Industries, Inc.

B. Description: Valve actuation assembly with sprocket rim, brackets, and chain.

   1. Sprocket Rim with Chain Guides: Ductile iron, of type and size required for valve.
   2. Brackets: Type, number, size, and fasteners required to mount actuator on valve.
   3. Chain: Hot-dip, galvanized steel, of size required to fit sprocket rim.

PART 3 - EXECUTION

3.1 EXAMINATION

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

B. Operate valves in positions from fully open to fully closed. Examine guides and seats made accessible by such operations.
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C. Examine threads on valve and mating pipe for form and cleanliness.

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

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

3.2 VALVE APPLICATIONS

A. Refer to piping Sections for specific valve applications. If valve applications are not indicated, use the following:

1. For hydronic systems:
   a. NPS 2 and Smaller:
      1) Shutoff Service: Ball valves.
      2) Throttling Service: Ball valves.
   b. NPS 2-1/2 and Larger:
      1) Shutoff Service: Butterfly valves.
      2) Throttling Service: Butterfly valves.

   DESIGNER NOTE: University preference is to utilize High Performance Ball Valves and High Performance Butterfly Valves on steam and condensate in lieu of Gate and Globe Valves. All butterfly valves shall have slow-open gear operators, and warm-up valves.

2. For steam and steam condensate systems:
   a. NPS 2 and Smaller:
      1) Shutoff Service: High performance ball valves.
      2) Throttling Service: High performance ball valves.
   b. NPS 2-1/2 and Larger:
      1) Shutoff Service: High performance butterfly valves.
      2) Throttling Service: High performance butterfly valves.

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. Hydronic Water piping: For hot water heating and chilled water piping systems, use the following types of valves:

D. Hydronic Water piping: For hot water heating, chilled water, condenser water, dual temperature water, heat recovery water piping systems, 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: Flangeless, 200-psig CWP rating, ferrous alloy, with nickel coated ductile iron disc and EPDM rubber seat and seals.
3. Grooved-End, Ductile-Iron Butterfly Valves, NPS 2-1/2 and Larger: 300-psig CWP rating, with nickel coated ductile iron disc and EPDM rubber seat and seals.
4. Swing Check Valves, NPS 2 and Smaller: Type 4, Class 125 or 150, bronze.
5. Swing Check Valves, NPS 2-1/2 and Larger: Type II, Class 125, gray iron.

E. Low-Pressure Steam Piping (0 psig to maximum 15 psig): Use the following types of valves:

1. Swing Check Valves, NPS 2 and Smaller: Type 4, Class 125, bronze.
2. Swing Check Valves, NPS 2-1/2 and Larger: Type II, Class 125, gray iron.
3. Gate Valves, NPS 2 and Smaller: Type 2, Class 125 or 150, bronze.
4. Gate Valves, NPS 2-1/2 and Larger: Type I, Class 125, OS&Y, bronze-mounted cast iron.
5. Globe Valves, NPS 2 and Smaller: Type 2, Class 125, bronze.
6. Globe Valves, NPS 2-1/2 and Larger: Type I, Class 125, bronze-mounted cast iron.

F. Medium-Pressure Steam Piping (16 psig to maximum 125 psig): Use the following types of valves:

1. Swing Check Valves, NPS 2 and Smaller: Type 4, Class 150, bronze.
2. Swing Check Valves, NPS 2-1/2 and Larger: Type II, Class 250, gray iron.
3. Gate Valves, NPS 2 and Smaller: Type 2, Class 150, bronze.
4. Gate Valves, NPS 2-1/2 and Larger: Type I, Class 250, OS&Y, bronze-mounted cast iron.
5. Globe Valves, NPS 2 and Smaller: Type 2, Class 150, bronze.
6. Globe Valves, NPS 2-1/2 and Larger: Type I, Class 250, bronze-mounted cast iron.

G. Low Pressure Steam Condensate Piping (0 psig to maximum 15 psig): Use the following types of valves:

1. Swing Check Valves, NPS 2 and Smaller: Type 4, Class 125, bronze.
2. Swing Check Valves, NPS 2-1/2 and Larger: Type II, Class 125, gray iron.
3. Gate Valves, NPS 2 and Smaller: Type 2, Class 125 or 150, bronze.
4. Gate Valves, NPS 2-1/2 and Larger: Type I, Class 125, OS&Y, bronze-mounted cast iron.
5. Globe Valves, NPS 2 and Smaller: Type 2, Class 125, bronze.
6. Globe Valves, NPS 2-1/2 and Larger: Type I, Class 125, bronze-mounted cast iron.

H. Medium Pressure Steam Condensate Piping (16 psig to maximum 125 psig): Use the following types of valves:

1. Swing Check Valves, NPS 2 and Smaller: Type 4, Class 150, bronze.
2. Swing Check Valves, NPS 2-1/2 and Larger: Type II, Class 250, gray iron.
3. Gate Valves, NPS 2 and Smaller: Type 2, Class 150, bronze.
4. Gate Valves, NPS 2-1/2 and Larger: Type I, Class 250, OS&Y, bronze-mounted cast iron.
5. Globe Valves, NPS 2 and Smaller: Type 2, Class 150, bronze.
6. Globe Valves, NPS 2-1/2 and Larger: Type I, Class 250, bronze-mounted cast iron.
I. Select valves, except lug types, with the following end connections:

1. For Copper Tubing, NPS 2 and Smaller: Solder-joint or threaded ends.
2. For Steel Piping, NPS 2 and Smaller: Threaded ends.
3. For Steel Piping, NPS 2-1/2 and larger: Flanged ends with weld-neck flanges.
4. For Steel Piping, NPS 2-1/2 to NPS 4: Flanged ends.
5. For Steel Piping, NPS 5 and Larger: Flanged ends.
6. For Grooved-End, Steel Piping: Valve ends may be grooved. Do not use for steam or steam condensate piping.

3.3 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.
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.
E. Install valves in position to allow full stem movement.
F. Install chainwheel operators on valves NPS 4 and larger and more than 120 inches above floor. Extend chains to 60 inches above finished floor elevation.
G. Install check valves for proper direction of flow and as follows:

3.4 JOINT CONSTRUCTION

A. Refer to Division 23 Section "Common Work Results for HVAC" for basic piping joint construction.
B. Grooved Joints: Assemble joints with keyed coupling housing, gasket, lubricant, and bolts according to coupling and fitting manufacturer's written instructions.
C. 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.

3.5 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 23 0523
WMU Design Guidelines Instructions: These guidelines are to be used by the Design Professional to inform the design process and outline WMU-specific desires for all University projects. These guidelines have been edited to reflect WMU preferences, and the intent is for the Design Professional to use this information to guide their normal specifications-writing process. Straying from what is indicated in the guidelines is not prohibited, but shall be discussed with WMU during the development of the project.

SECTION 23 0529 - HANGERS AND SUPPORTS FOR HVAC PIPING AND EQUIPMENT

PART 1 - GENERAL

1.1 SUMMARY

A. This Section includes the following hangers and supports for HVAC system piping and equipment:

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

B. Related Sections include the following:

1. Division 05 Section "Metal Fabrications" for structural-steel shapes and plates for trapeze hangers for pipe and equipment supports.
2. Division 21 fire-suppression sections for pipe hangers for fire-protection piping.
3. Division 23 Section "Expansion Fittings and Loops for HVAC Piping" for pipe guides and anchors.
4. Division 23 Section "Vibration and Seismic Controls for HVAC Piping and Equipment" for vibration isolation devices.
5. Division 23 Section(s) "Metal Ducts" for duct hangers and supports.
6. Division 23 Section(s) "[Metal Ducts] [Metal Ducts] and "Nonmetal Ducts] [Nonmetal Ducts]" for duct hangers and supports.

1.2 DEFINITIONS

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

B. Terminology: As defined in MSS SP-90, "Guidelines on Terminology for Pipe Hangers and Supports."
1.3 PERFORMANCE REQUIREMENTS

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

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

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

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

1.4 ACTION SUBMITTALS

A. Product Data: For the following:

1. Steel pipe hangers and supports.
2. Fiberglass pipe hangers.
3. Thermal-hanger shield inserts.
4. Powder-actuated fastener systems.

B. Shop Drawings:[ Signed and sealed by a qualified professional engineer.] Show fabrication and installation details and include calculations for the following:

1. Trapeze pipe hangers. Include Product Data for components.
2. Metal framing systems. Include Product Data for components.
3. Fiberglass strut systems. Include Product Data for components.
4. Pipe stands. Include Product Data for components.
5. Equipment supports.

1.5 INFORMATIONAL SUBMITTALS

A. Welding certificates.
1.6 QUALITY ASSURANCE


B. Welding: Qualify procedures and personnel according to the following:

1. AWS D1.1, "Structural Welding Code--Steel."
4. AWS D1.4, "Structural Welding Code--Reinforcing Steel."
5. ASME Boiler and Pressure Vessel Code: Section IX.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

2.2 METAL PIPE HANGERS AND SUPPORTS

A. Carbon-Steel Pipe Hangers and Supports:

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

B. Stainless-Steel Pipe Hangers and Supports:

1. Description: MSS SP-58, Types 1 through 58, factory-fabricated components.
2. Padded Hangers: Hanger with fiberglass or other pipe insulation pad or cushion to support bearing surface of piping.

C. Copper Pipe Hangers:

1. Description: MSS SP-58, Types 1 through 58, copper-coated-steel, factory-fabricated components.
2. Hanger Rods: Continuous-thread rod, nuts, and washer made of [copper-coated steel] [stainless steel] <Insert material>.
2.3 TRAPEZE PIPE HANGERS

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

2.4 FIBERGLASS PIPE HANGERS

A. Clevis-Type, Fiberglass Pipe Hangers: Similar to MSS Type 1, steel pipe hanger except hanger is made of fiberglass and continuous-thread rod and nuts are made of polyurethane <Insert other>.

B. Strap-Type, Fiberglass Pipe Hangers: Made of fiberglass loop with stainless-steel continuous-thread rod, nuts, and support hook.

2.5 METAL FRAMING SYSTEMS

A. MFMA Manufacturer Metal Framing Systems:

1. Description: Shop- or field-fabricated pipe-support assembly for supporting multiple parallel pipes.
3. Channels: Continuous slotted steel channel with inturned lips.
4. Channel Nuts: Formed or stamped steel nuts or other devices designed to fit into channel slot and, when tightened, prevent slipping along channel.
6. Hanger Rods: Continuous-thread rod, nuts, and washer made of <Insert material>.
7. Metallic Coating: [Electroplated zinc] [Hot-dipped galvanized] [Mill galvanized] [In-line, hot galvanized] [Mechanically-deposited zinc].
8. Paint Coating: [Vinyl] [Vinyl alkyd] [Epoxy] [Polyester] [Acrylic] [Amine] [Alkyd] <Insert paint type>.
9. Plastic Coating: [PVC] [Polyurethane] [Epoxy] [Polyester] <Insert plastic type>.
10. Combination Coating: <Insert coating materials in order of application>.

B. Non-MFMA Manufacturer Metal Framing Systems:

1. Description: Shop- or field-fabricated pipe-support assembly made of steel channels, accessories, fittings, and other components for supporting multiple parallel pipes.
3. Channels: Continuous slotted steel channel with inturned lips.
4. Channel Nuts: Formed or stamped steel nuts or other devices designed to fit into channel slot and, when tightened, prevent slipping along channel.
6. Hanger Rods: Continuous-thread rod, nuts, and washer made of <Insert material>.
7. Coating: [Zinc] [Paint] [PVC] <Insert coating>.
2.6 FIBERGLASS STRUT SYSTEMS

A. Description: Shop- or field-fabricated pipe-support assembly similar to MFMA-4 for supporting multiple parallel pipes.

1. Channels: Continuous slotted fiberglass [or other plastic] channel with inturned lips.
2. Channel Nuts: Fiberglass nuts or other devices designed to fit into channel slot and, when tightened, prevent slipping along channel.
3. Hanger Rods: Continuous-thread rod, nuts, and washer made of [fiberglass] [stainless steel] <Insert material>.

2.7 THERMAL-HANGERSHIELD INSERTS

A. Insulation-Insert Material for Cold Piping: ASTM C 552, Type II cellular glass with 100-psig (688-kPa) or ASTM C 591, Type VI, Grade 1 polyisocyanurate with 125-psig (862-kPa) minimum compressive strength and vapor barrier.

B. Insulation-Insert Material for Cold Piping: [ASTM C 552, Type II cellular glass with 100-psig (688-kPa)] or [ASTM C 591, Type VI, Grade 1 polyisocyanurate with 125-psig (862-kPa)] minimum compressive strength and vapor barrier.

C. Insulation-Insert Material for Hot Piping: Water-repellent treated, ASTM C 533, Type I calcium silicate with 100-psig ASTM C 552, Type II cellular glass with 100-psig or ASTM C 591, Type VI, Grade 1 polyisocyanurate with 125-psig minimum compressive strength.

D. Insulation-Insert Material for Hot Piping: [Water-repellent treated, ASTM C 533, Type I calcium silicate with 100-psig] [ASTM C 552, Type II cellular glass with 100-psig] [or] [ASTM C 591, Type VI, Grade 1 polyisocyanurate with 125-psig] minimum compressive strength.

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.

2.8 FASTENER SYSTEMS

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

B. Mechanical-Expansion Anchors: Insert-wedge-type zinc-coated 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.
2.9 PIPE STAND FABRICATION

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

B. Compact Pipe Stand: Plastic unit with top configuration to support pipe for roof installation without membrane penetration.

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

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

1. Base: Plastic or stainless steel.
2. Vertical Members: Two or more cadmium-plated-steel or stainless-steel, continuous-thread rods.
3. 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. Bases: One or more plastic.
2. Vertical Members: Two or more protective-coated-steel channels.
3. Horizontal Member: Protective-coated-steel channel.

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 carbon-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.

2. Design Mix: 5000-psi, 28-day compressive strength.
PART 3 - EXECUTION

**DESIGNER NOTE:** Revise hangers and supports as required for the installation environment and service duty.

### 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.

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

F. Use [stainless-steel pipe hangers] [and] [fiberglass pipe hangers] [and] [fiberglass strut systems] and [stainless-steel] [or] [corrosion-resistant] attachments for hostile environment applications.

G. Use [stainless-steel pipe hangers] [and] [fiberglass pipe hangers] [and] [fiberglass strut systems] and [stainless-steel] [or] [corrosion-resistant] attachments for hostile environment applications.

H. Use copper-plated pipe hangers and [copper] [or] [stainless-steel] attachments for copper piping and tubing.

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

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

K. 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. Yoke-Type Pipe Clamps (MSS Type 2): For suspension of 120 to 450 deg F pipes, NPS 4 to NPS 16, requiring up to 4 inches of insulation.
3. 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.
4. Steel Pipe Clamps (MSS Type 4): For suspension of cold and hot pipes, NPS 1/2 to NPS 24, if little or no insulation is required.
5. Pipe Hangers (MSS Type 5): For suspension of pipes, NPS 1/2 to NPS 4, to allow off-center closure for hanger installation before pipe erection.
6. Adjustable, Swivel Split- or Solid-Ring Hangers (MSS Type 6): For suspension of noninsulated stationary pipes, NPS 3/4 to NPS 8.
7. Adjustable, Steel Band Hangers (MSS Type 7): For suspension of noninsulated stationary pipes, NPS 1/2 to NPS 8.
8. Adjustable Band Hangers (MSS Type 9): For suspension of noninsulated stationary pipes, NPS 1/2 to NPS 8.
9. Adjustable, Swivel-Ring Band Hangers (MSS Type 10): For suspension of noninsulated stationary pipes, NPS 1/2 to NPS 2.
10. Split Pipe-Ring with or without Turnbuckle-Adjustment Hangers (MSS Type 11): For suspension of noninsulated stationary pipes, NPS 3/8 to NPS 8.
11. Extension Hinged or 2-Bolt Split Pipe Clamps (MSS Type 12): For suspension of noninsulated stationary pipes, NPS 3/8 to NPS 3.
12. U-Bolts (MSS Type 24): For support of heavy pipes, NPS 1/2 to NPS 30.
13. Clips (MSS Type 26): For support of insulated pipes not subject to expansion or contraction.
14. 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.
15. Pipe Stanchion Saddles (MSS Type 37): For support of pipes, NPS 4 to NPS 36, with steel pipe base stanchion support and cast-iron floor flange and with U-bolt to retain pipe.
16. Adjustable, Pipe Saddle Supports (MSS Type 38): For stanchion-type support for pipes, NPS 2-1/2 to NPS 36, if vertical adjustment is required, with steel pipe base stanchion support and cast-iron floor flange.
17. 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.
18. Adjustable Roller Hangers (MSS Type 43): For suspension of pipes, NPS 2-1/2 to NPS 20, from single rod if horizontal movement caused by expansion and contraction might occur.
19. 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.
20. Pipe Roll and Plate Units (MSS Type 45): For support of pipes, NPS 2 to NPS 24, if small horizontal movement caused by expansion and contraction might occur and vertical adjustment is not necessary.
21. Adjustable Pipe Roll and Base Units (MSS Type 46): For support of pipes, NPS 2 to NPS 30, if vertical and lateral adjustment during installation might be required in addition to expansion and contraction.

L. 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.

M. Hanger-Rod Attachments: Unless otherwise indicated and except as specified in piping system Sections, install the following types:
1. Steel Turnbuckles (MSS Type 13): For adjustment up to 6 inches for heavy loads.
2. Steel Clevises (MSS Type 14): For 120 to 450 deg F piping installations.
3. Swivel Turnbuckles (MSS Type 15): For use with MSS Type 11, split pipe rings.
4. Malleable-Iron Sockets (MSS Type 16): For attaching hanger rods to various types of building attachments.
5. Steel Weldless Eye Nuts (MSS Type 17): For 120 to 450 deg F piping installations.

N. Building Attachments: Unless otherwise indicated and except as specified in piping system Sections, install the following types:

1. Steel or Malleable [Concrete Inserts](MSS Type 18): For upper attachment to suspend pipe hangers from concrete ceiling.
2. Top-Beam C-Clamps (MSS Type 19): For use under roof installations with bar-joist construction to attach to top flange of structural shape.
3. Side-Beam or Channel Clamps (MSS Type 20): For attaching to bottom flange of beams, channels, or angles.
4. Center-Beam Clamps (MSS Type 21): For attaching to center of bottom flange of beams.
5. Welded Beam Attachments (MSS Type 22): For attaching to bottom of beams if loads are considerable and rod sizes are large.
6. C-Clamps (MSS Type 23): For structural shapes.
7. Top-Beam Clamps (MSS Type 25): For top of beams if hanger rod is required tangent to flange edge.
8. Side-Beam Clamps (MSS Type 27): For bottom of steel I-beams.
9. Steel-Beam Clamps with Eye Nuts (MSS Type 28): For attaching to bottom of steel I-beams for heavy loads.
10. Linked-Steel Clamps with Eye Nuts (MSS Type 29): For attaching to bottom of steel I-beams for heavy loads, with link extensions.
11. Malleable Beam Clamps with Extension Pieces (MSS Type 30): For attaching to structural steel.
12. Welded-Steel Brackets: For support of pipes from below, or for suspending from above by using clip and rod. Use one of the following for indicated loads:
   a. Light (MSS Type 31): 750 lb.
   b. Medium (MSS Type 32): 1500 lb.
   c. Heavy (MSS Type 33): 3000 lb.
13. Side-Beam Brackets (MSS Type 34): For sides of steel or wooden beams.
14. Plate Lugs (MSS Type 57): For attaching to steel beams if flexibility at beam is required.
15. Horizontal Travelers (MSS Type 58): For supporting piping systems subject to linear horizontal movement where headroom is limited.

O. 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.

P. Spring Hangers and Supports: Unless otherwise indicated and except as specified in piping system Sections, install the following types:

1. Restraint-Control Devices (MSS Type 47): Where indicated to control piping movement.
2. Spring Cushions (MSS Type 48): For light loads if vertical movement does not exceed 1-1/4 inches.
3. Spring-Cushion Roll Hangers (MSS Type 49): For equipping Type 41 roll hanger with springs.
4. Spring Sway Braces (MSS Type 50): To retard sway, shock, vibration, or thermal expansion in piping systems.
5. Variable-Spring Hangers (MSS Type 51): Preset to indicated load and limit variability factor to 25 percent to absorb expansion and contraction of piping system from hanger.
6. Variable-Spring Base Supports (MSS Type 52): Preset to indicated load and limit variability factor to 25 percent to absorb expansion and contraction of piping system from base support.
7. Variable-Spring Trapeze Hangers (MSS Type 53): Preset to indicated load and limit variability factor to 25 percent to absorb expansion and contraction of piping system from trapeze support.
8. Constant Supports: For critical piping stress and if necessary to avoid transfer of stress from one support to another support, critical terminal, or connected equipment. Include auxiliary stops for erection, hydrostatic test, and load-adjustment capability. These supports include the following types:
   a. Horizontal (MSS Type 54): Mounted horizontally.
   b. Vertical (MSS Type 55): Mounted vertically.
   c. Trapeze (MSS Type 56): Two vertical-type supports and one trapeze member.

Q. Comply with MSS SP-69 for trapeze pipe hanger selections and applications that are not specified in piping system Sections.
R. Comply with MFMA-103 for metal framing system selections and applications that are not specified in piping system Sections.
S. Use powder-actuated fasteners or mechanical-expansion anchors instead of building attachments where required in concrete construction.

1. Use powder-actuated fasteners only in concrete construction that is suitable for their installation.

3.2 HANGER AND SUPPORT INSTALLATION

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

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

1. Pipes of Various Sizes: Support together and space trapezes for smallest pipe size or install intermediate supports for smaller diameter pipes as specified above for individual pipe hangers.
2. Field fabricate from ASTM A 36/A 36M, steel shapes selected for loads being supported. Weld steel according to AWS D1.1.

C. Fiberglass Pipe Hanger Installation: Comply with applicable portions of MSS SP-69 and MSS SP-89. Install hangers and attachments as required to properly support piping from building structure.
D. Metal Framing System Installation: Arrange for grouping of parallel runs of piping and support together on field-assembled metal framing systems.

E. Fiberglass Strut System Installation: Arrange for grouping of parallel runs of piping and support together on field-assembled fiberglass struts.

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

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

H. Pipe Stand Installation:
   1. Pipe Stand Types except Curb-Mounting Type: Assemble components and mount on smooth roof surface. Do not penetrate roof membrane.
   2. Curb-Mounting-Type Pipe Stands: Assemble components or fabricate pipe stand and mount on permanent, stationary roof curb. Refer to Division 07 Section “Roof Accessories” for curbs.

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


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

L. 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.

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

N. 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.]

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

Q. 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.

R. 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.
   a. Option: Thermal-hanger shield inserts may be used. Include steel weight-distribution plate for pipe NPS 4 and larger if pipe is installed on rollers.

3. Install MSS SP-58, Type 40, protective shields on cold piping with vapor barrier. Shields shall span an arc of 180 degrees.
   a. Option: Thermal-hanger shield inserts may be used. Include steel weight-distribution plate for pipe NPS 4 and larger if pipe is installed on rollers.

4. Shield Dimensions for Pipe: Not less than the following:
   a. NPS 1/4 to NPS 3-1/2: 12 inches long and 0.048 inch thick.
   b. NPS 4: 12 inches long and 0.06 inch thick.
   c. NPS 5 and NPS 6: 18 inches long and 0.06 inch thick.
   d. NPS 8 to NPS 14: 24 inches long and 0.075 inch thick.
   e. NPS 16 to NPS 24: 24 inches long and 0.105 inch thick.

5. [Pipes NPS 8(DN 200) and Larger: Include wood or reinforced calcium-silicate-insulation 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 [trapeze pipe hangers] [and] [equipment supports].

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

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

B. Trim excess length of continuous-thread hanger and support rods to 1-1/2 inches maximum.

3.6 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 23 0529
WMU Design Guidelines Instructions: These guidelines are to be used by the Design Professional to inform the design process and outline WMU-specific desires for all University projects. These guidelines have been edited to reflect WMU preferences, and the intent is for the Design Professional to use this information to guide their normal specifications-writing process. Straying from what is indicated in the guidelines is not prohibited, but shall be discussed with WMU during the development of the project.

SECTION 23 0553 - 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. Ceiling markers.
7. Warning tags.

1.2 ACTION SUBMITTALS

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

B. Samples: For color, letter style, and graphic representation required for each identification material and device.

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

D. Valve numbering scheme.

E. Valve Schedules: For each piping system.

1.3 COORDINATION

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

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

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

A. Comply with ANSI A13.1 “Pipe Labeling Guide” for color scheme, length of field and letter height.


PART 2 - PRODUCTS

2.1 ACCEPTABLE MANUFACTURERS:

A. Manufacturer: Subject to compliance with requirements, provide mechanical identification materials by one of the following:

1. Allen Systems, Inc.
2. Brady.
5. Brimar.

2.2 EQUIPMENT LABELS

A. Metal Labels for Equipment:

1. Material and Thickness: [Brass, 0.032-inch] [Stainless steel, 0.025-inch] [Aluminum, 0.032-inch] [or] [anodized aluminum, 0.032-inch] minimum thickness, and having predrilled or stamped holes for attachment hardware.
2. Minimum Label Size: Length and width vary for required label content, but not less than 2-1/2 by 3/4 inch.
3. Minimum Letter Size: 1/4 inch for name of units if viewing distance is less than 24 inches, 1/2 inch for viewing distances up to 72 inches, and proportionately larger lettering for greater viewing distances. Include secondary lettering two-thirds to three-fourths the size of principal lettering.
4. Fasteners: Stainless-steel [rivets] [rivets or self-tapping screws] [self-tapping screws].
5. Adhesive: Contact-type permanent adhesive, compatible with label and with substrate.

B. Plastic Labels for Equipment:

1. Material and Thickness: Multilayer, multicolor, plastic labels for mechanical engraving, 1/16 inch thick, and having predrilled holes for attachment hardware.
2. Material and Thickness: Multilayer, multicolor, plastic labels for mechanical engraving, \([1/16 \text{ inch}] [1/8 \text{ inch}] <\text{Insert dimension}>\) thick, and having predrilled holes for attachment hardware.
4. Letter Color: [Black] [Blue] [Red] [White] [Yellow] <Insert color>.
6. Background Color: [Black] [Blue] [Red] [White] [Yellow] <Insert color>.
7. Maximum Temperature: Able to withstand temperatures up to 160 deg F.
8. Minimum Label Size: Length and width vary for required label content, but not less than 2-1/2 by 3/4 inch.
   a. Size of label shall be proportional to equipment size.

9. Minimum Label Size: Length and width vary for required label content, but not less than 4 by 2 inch.

10. Minimum Letter Size: 1 inch for name of units.

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


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

C. Label Content: Include equipment's Drawing designation or unique equipment number.

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

E. Equipment Label Schedule: For each item of equipment to be labeled, on 8-1/2-by-11-inch bond paper. Tabulate equipment identification number and identify Drawing numbers where equipment is indicated (plans, details, and schedules), plus the Specification Section number and title where equipment is specified. Equipment schedule shall be included in operation and maintenance data.

2.3 WARNING SIGNS AND LABELS

A. Material and Thickness: Multilayer, multicolor, plastic labels for mechanical engraving, [1/16 inch] [1/8 inch] <Insert dimension> thick, and having predrilled holes for attachment hardware.

B. Letter Color: [Black] [Blue] [Red] [White] [Yellow] <Insert color>.

C. Background Color: [Black] [Blue] [Red] [White] [Yellow] <Insert color>.

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: 1/4 inch for name of units if viewing distance is less than 24 inches, 1/2 inch for viewing distances up to 72 inches, and proportionately larger lettering for greater viewing distances. Include secondary lettering two-thirds to three-fourths the size of principal lettering.

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

2.4 PIPE LABELS

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

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

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

D. Self-Adhesive Pipe Labels: Printed plastic label with contact-type, permanent-adhesive backing. Include wrap around flow arrow tape with contact-type, permanent-adhesive backing.

E. Self-Adhesive Pipe Labels: Printed plastic with contact-type, permanent-adhesive backing.

F. Pipe Label Contents: Include identification of piping service matching designations or abbreviations as used on Drawings.

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

1. Flow-Direction Arrows: Integral with piping system service lettering to accommodate both directions, or as separate unit on each pipe label to indicate flow direction.

2. Lettering Size: At least 1-1/2 inches high.

2.5 DUCT LABELS

A. Material and Thickness: Multilayer, multicolor, plastic labels for mechanical engraving, 1/16 inch thick, and having predrilled holes for attachment hardware.

B. Letter Color: Black.

C. Background Color: White.

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: 1/4 inch for name of units if viewing distance is less than 24 inches, 1/2 inch for viewing distances up to 72 inches, and proportionately larger lettering for greater viewing distances. Include secondary lettering two-thirds to three-fourths the size of principal lettering.

G. Fasteners: Stainless steel rivets, self-tapping screws.
H. **Adhesive:** Contact-type permanent adhesive, compatible with label and with substrate.

I. **Duct Label Contents:** Include identification of duct service using same designations or abbreviations as used on Drawings, duct size, and an arrow indicating flow direction.
   1. **Flow Direction Arrows:** Integral with duct system service lettering to accommodate both directions, or as separate unit on each duct label to indicate flow direction.
   2. **Lettering Size:** At least 1-1/2 inches high.

2.6 **STENCILS**

A. **Stencils:** Prepared with letter sizes according to ASME A13.1 for piping; minimum letter height of 1-1/4 inches for ducts; and minimum letter height of 3/4 inch for access panel and door labels, equipment labels, and similar operational instructions.
   1. **Stencil Material:** Fiberboard or metal.
   2. **Stencil Paint:** Exterior, gloss, black enamel unless otherwise indicated. Paint may be in pressurized spray-can form.
   3. **Identification Paint:** Exterior enamel in colors according to ASME A13.1 unless otherwise indicated.

2.7 **VALVE TAGS**

A. **Valve Tags:** Stamped or engraved with 1/4-inch letters for piping system abbreviation and 1/2-inch numbers.
   1. **Tag Material:** Brass, 0.032-inch minimum thickness, and having predrilled or stamped holes for attachment hardware.
   2. **Tag Material:** [Brass, 0.032-inch] [Stainless steel, 0.025-inch] [Aluminum, 0.032-inch] [or] [anodized aluminum, 0.032-inch] minimum thickness, and having predrilled or stamped holes for attachment hardware.
   3. **Fasteners:** Brass wire-link or beaded chain; or S-hook.
   4. **Fasteners:** Brass [wire-link or beaded chain; or S-hook] [wire-link chain] [beaded chain] [S-hook].

B. **Valve Schedules:** For each piping system, on 8-1/2-by-11-inch bond paper. Tabulate valve number, piping system, system abbreviation (as shown on valve tag), location of valve (room or space), normal-operating position (open, closed, or modulating), and variations for identification. Mark valves for emergency shutoff and similar special uses.
   1. **Provide glass front frame with screws for removable mounting on masonry walls for each valve schedule.**
   2. **Valve-tag schedule shall be included in operation and maintenance data.**

2.8 **CEILING MARKERS**

A. **Material and Thickness:** Multicolor, vinyl markers.
B. Colors: Green and blue.

C. Colors: Blue, red, yellow, and green.

D. Marker Size: 3/4 inch diameter.

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

2.9 WARNING TAGS

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

1. Size: [3 by 5-1/4 inches minimum] [Approximately 4 by 7 inches] <Insert size>.

2. Fasteners: [Brass grommet and wire] [Reinforced grommet and wire or string].

3. Nomenclature: Large-size primary caption such as “DANGER,” “CAUTION,” or “DO NOT OPERATE.”


PART 3 - EXECUTION

3.1 PREPARATION

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

3.2 EQUIPMENT LABEL INSTALLATION

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

B. Locate equipment labels where accessible and visible.

3.3 PIPE LABEL INSTALLATION

A. Pipe Label Applications: Install pipe labels as follows:

1. Use pretensioned pipe labels or self-adhesive pipe labels.

2. For 10 inches (250 mm) and smaller outside diameter including insulation, use pretensioned pipe labels.

3. For larger than 10 inches (250 mm) outside diameter including insulation, use self-adhesive pipe labels.

B. Piping Color Coding: Painting of piping is specified in Division 09 Section “[Interior Painting] [High-Performance Coatings].”
C. **Stenciled Pipe Label Option**: Stenciled labels may be provided instead of manufactured pipe labels, at Installer’s option. Install stenciled pipe labels, complying with ASME A13.1, on each piping system.

D. **Stenciled Pipe Label Option**: Stenciled labels may be provided instead of manufactured pipe labels, at Installer’s option. Install stenciled pipe labels [with painted, color-coded bands or rectangles] complying with ASME A13.1, on each piping system.

1. **Identification Paint**: Use for contrasting background.
2. **Stencil Paint**: Use for pipe marking.

E. Locate pipe labels where piping is concealed above ceilings or exposed in unfinished mechanical rooms; accessible maintenance spaces such as shafts, tunnels, and plenums as follows:

1. Near each valve and control device.
2. Near each branch connection, excluding short takeoffs for fixtures and terminal units. Where flow pattern is not obvious, mark each pipe at branch.
3. Near penetrations through walls, floors, ceilings, and inaccessible enclosures.
4. At access doors, manholes, and similar access points that permit view of concealed piping.
5. Near major equipment items and other points of origination and termination.
6. Spaced at maximum intervals of 50 feet along each run.

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

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

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

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

H. Locate pipe labels where piping is exposed in finished spaces as follows:

1. Near penetrations through walls, floors, ceilings, and inaccessible enclosures.

I. Pipe Label Color Schedule:

1. Chilled-Water Piping:
   a. Background Color: [Black] [Blue] [Red] [White] [Yellow] <Insert color>.
   b. Letter Color: [Black] [Blue] [Red] [White] [Yellow] <Insert color>.

2. Condenser-Water Piping:
   a. Background Color: [Black] [Blue] [Red] [White] [Yellow] <Insert color>.
   b. Letter Color: [Black] [Blue] [Red] [White] [Yellow] <Insert color>.

3. Heating Water Piping:
   a. Background Color: [Black] [Blue] [Red] [White] [Yellow] <Insert color>.
   b. Letter Color: [Black] [Blue] [Red] [White] [Yellow] <Insert color>.

4. Refrigerant Piping:
   a. Background Color: [Black] [Blue] [Red] [White] [Yellow] <Insert color>.
   b. Letter Color: [Black] [Blue] [Red] [White] [Yellow] <Insert color>.

5. Low-Pressure Steam Piping:
   a. Background Color: [Black] [Blue] [Red] [White] [Yellow] <Insert color>.
   b. Letter Color: [Black] [Blue] [Red] [White] [Yellow] <Insert color>.

6. High-Pressure Steam Piping:
   a. Background Color: [Black] [Blue] [Red] [White] [Yellow] <Insert color>.
   b. Letter Color: [Black] [Blue] [Red] [White] [Yellow] <Insert color>.

7. Steam Condensate Piping:
   a. Background Color: [Black] [Blue] [Red] [White] [Yellow] <Insert color>.
   b. Letter Color: [Black] [Blue] [Red] [White] [Yellow] <Insert color>.

3.4 DUCT LABEL INSTALLATION

A. Install self-adhesive duct labels with permanent adhesive on air ducts in the following color codes:

1. Blue: For cold-air supply ducts.
2. Yellow: For hot-air supply ducts.
4. ASME A13.1 Colors and Designs: For hazardous material exhaust.

B. Stenciled Duct Label Option: Stenciled labels, showing service and flow direction, may be provided instead of plastic-laminated duct labels, at Installer’s option, if lettering larger than 1 inch high is needed for proper identification because of distance from normal location of required identification.
C. Locate labels near points where ducts enter into concealed spaces and at maximum intervals of [50 feet] <Insert dimension> in each space where ducts are exposed or concealed by removable ceiling system.

3.5 VALVE-TAG INSTALLATION

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

B. Install glass front frame valve schedule in building mechanical room. Locate at Owners representative approved location.

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

1. Valve-Tag Size and Shape:
   a. Chilled Water: [1-1/2 inches] [2 inches], [round] [square] <Insert shape>.
   b. Condenser Water: [1-1/2 inches] [2 inches], [round] [square] <Insert shape>.
   c. Refrigerant: [1-1/2 inches] [2 inches], [round] [square] <Insert shape>.
   d. Hot Water: [1-1/2 inches] [2 inches], [round] [square] <Insert shape>.
   e. Gas: [1-1/2 inches] [2 inches], [round] [square] <Insert shape>.
   f. Low-Pressure Steam: [1-1/2 inches] [2 inches], [round] [square] <Insert shape>.
   g. High-Pressure Steam: [1-1/2 inches] [2 inches], [round] [square] <Insert shape>.
   h. Steam Condensate: [1-1/2 inches] [2 inches], [round] [square] <Insert shape>.

2. Valve-Tag Color:
   a. Chilled Water: [Natural] [Green] <Insert color>.
   b. Condenser Water: [Natural] [Green] <Insert color>.
   c. Refrigerant: [Natural] [Green] <Insert color>.
   d. Hot Water: [Natural] [Green] <Insert color>.
   e. Gas: [Natural] [Yellow] <Insert color>.
   f. Low-Pressure Steam: [Natural] [Yellow] <Insert color>.
   g. High-Pressure Steam: [Natural] [Green] <Insert color>.
   h. Steam Condensate: [Natural] [Green] <Insert color>.

3. Letter Color:
   a. Chilled Water: [Black] [White] <Insert color>.
   b. Condenser Water: [Black] [White] <Insert color>.
   c. Refrigerant: [Black] [White] <Insert color>.
   d. Hot Water: [Black] [White] <Insert color>.
   e. Gas: [Black] [White] <Insert color>.
   f. Low-Pressure Steam: [Black] [White] <Insert color>.
   g. High-Pressure Steam: [Black] [White] <Insert color>.
   h. Steam Condensate: [Black] [White] <Insert color>.
3.6 CEILING MARKER INSTALLATION

A. Install ceiling markers on t-bar ceiling grids and ceiling access panels to indicate locations of shut-off and balancing valves in main heating water and chilled water supply and return piping lines and at branches.

B. Install ceiling markers on t-bar ceiling grids and ceiling access panels to indicate locations of VAV terminal units and fan powered VAV terminal units.

C. Color:
   
   1. Water: Green.
      a. No color differentiation between services required.
   
   2. VAV Terminal Units: Blue.
      a. No color differentiation between types of equipment required.

3.7 WARNING-TAG INSTALLATION

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

END OF SECTION 23 0553
WMU Design Guidelines Instructions: These guidelines are to be used by the Design Professional to inform the design process and outline WMU-specific desires for all University projects. These guidelines have been edited to reflect WMU preferences, and the intent is for the Design Professional to use this information to guide their normal specifications-writing process. Straying from what is indicated in the guidelines is not prohibited, but shall be discussed with WMU during the development of the project.

SECTION 23 0593 - TESTING, ADJUSTING, AND BALANCING FOR HVAC

DESIGNER NOTE: TAB Services are a direct hire by the University with Quality Air Service. Coordinate and edit TAB section as required per project requirements.

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:

   a. Constant-volume air systems.
   b. Dual-duct systems.
   c. Variable-air-volume systems.
   d. Multizone systems.
   e. Induction-unit systems.

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

3. Balancing steam systems.

   a. Heat exchangers.
   b. Motors.
   c. Chillers.
   d. Cooling towers.
   e. Condensing units.
   f. Boilers.
   g. Heat-transfer coils.

5. Testing, adjusting, and balancing existing systems and equipment.

6. Sound tests.

7. Vibration tests.

8. Duct leakage tests.

9. Control system verification.

1.2 DEFINITIONS

BAS: Building automation systems.

NEBB: National Environmental Balancing Bureau.

TAB: Testing, adjusting, and balancing.

TABB: Testing, Adjusting, and Balancing Bureau.

TAB Specialist: An independent entity meeting qualifications to perform TAB work.

TDH: Total dynamic head.

1.3 PREINSTALLATION MEETINGS

A. TAB Conference: If requested by the Owner, conduct a TAB conference at [Project site] <Insert location> after approval of the TAB strategies and procedures plan to develop a mutual understanding of the details. Provide a minimum of [14] <Insert number> days' advance notice of scheduled meeting time and location.

1. Minimum Agenda Items:
   b. The TAB plan.
   c. Needs for coordination and cooperation of trades and subcontractors.
   d. Proposed procedures for documentation and communication flow.

1.4 ACTION SUBMITTALS

A. LEED Submittals:

1. Air-Balance Report for Prerequisite IEQ 1: Documentation indicating that work complies with ASHRAE 62.1, Section 7.2.2 - "Air Balancing."

2. TAB Report for Prerequisite EA 2: Documentation indicating that work complies with ASHRAE/IESNA 90.1, Section 6.7.2.3 - "System Balancing."

1.5 INFORMATIONAL SUBMITTALS

A. Qualification Data: Within [30] [60] [90] <Insert number> days of Contractor's Notice to Proceed, submit documentation that the TAB specialist and this Project's TAB team members meet the qualifications specified in "Quality Assurance" Article.


C. Contract Documents Examination Report: Within [30] [60] [90] <Insert number> days of Contractor's Notice to Proceed, submit the Contract Documents review report as specified in Part 3.


F. System Readiness Checklists: Within 90 days of Contractor's Notice to Proceed, submit system readiness checklists as specified in "Preparation" Article.

G. System Readiness Checklists: Within [30] [60] [90] <Insert number> days of Contractor's Notice to Proceed, submit system readiness checklists as specified in "Preparation" Article.

H. Examination Report: Submit a summary report of the examination review required in "Examination" Article.

I. Certified TAB Reports: Submit four copies of reports prepared, as specified in this Section, on approved forms certified by TAB firm.

J. Certified TAB reports.

K. Sample report forms.

L. Instrument calibration reports, to include the following:
   1. Instrument type and make.
   2. Serial number.
   3. Application.
   4. Dates of use.
   5. Dates of calibration.

1.6 QUALITY ASSURANCE

A. TAB Specialists Qualifications: Certified by [AABC] [NEBB] [or] [TABB].
   1. TAB Field Supervisor: Employee of the TAB specialist and certified by [AABC] [NEBB] [or] [TABB].
   2. TAB Technician: Employee of the TAB specialist and certified by [AABC] [NEBB] [or] [TABB] as a TAB technician.

B. Instrumentation Type, Quantity, Accuracy, and Calibration: Comply with requirements in ASHRAE 111, Section 4, "Instrumentation."

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

D. ASHRAE/IESNA Compliance: Applicable requirements in ASHRAE/IESNA 90.1, Section 6.7.2.3 - "System Balancing."
1.7 FIELD CONDITIONS

A. Owner Occupancy: Owner will occupy the site and existing building during TAB period. Cooperate with Owner during TAB operations to minimize conflicts with Owner's operations.

B. Full Owner Occupancy: Owner will occupy the site and existing building during entire TAB period. Cooperate with Owner during TAB operations to minimize conflicts with Owner's operations.

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

1.8 COORDINATION

A. 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 distribution systems have been satisfactorily completed.

1.9 PROJECT COMMISSIONING

A. Project is attempting to obtain Leed Certification and has an independent commissioning authority (CxA). TAB Specialists for this project shall meet CxA requirements and shall coordinate with and participate in commissioning activities.

PART 2 - PRODUCTS (Not Applicable)

PART 3 - EXECUTION

3.1 TAB SPECIALISTS

A. Subject to compliance with requirements, [engage one of the following] [available TAB specialists that may be engaged include, but are not limited to, the following]:

B. TAB Services are a direct contract with the University with Quality Air Service.
   a. Enviro-Aire/Total Balance Co.
   b. Air Flow Testing Inc.
   c. Absolute Balancing Co.
   d. Hi-Tech Testing and Balancing Inc.
   e. Pro-MEC Engineering Services, Inc
   f. Kinetix Testing and Commissioning
   g. Environmental Test and Balancing, Inc.
3.2 EXAMINATION

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

B. Examine installed systems for balancing devices. Verify that locations of these balancing devices are applicable for intended purpose and are accessible.

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

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

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

F. Examine ceiling plenums and underfloor air plenums used for supply, return, or relief air to verify that they are properly separated from adjacent areas. Verify that penetrations in plenum walls are sealed and fire-stopped if required.

G. Examine ceiling plenums and underfloor air plenums used for supply, return, or relief air to verify that they are properly separated from adjacent areas. Verify that penetrations in plenum walls are sealed and fire-stopped if required.

H. Examine equipment performance data.

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

1. Relate performance data to Project conditions and requirements, including system effects that can create undesired or unpredicted conditions that cause reduced capacities in all or part of a system.

2. Calculate system-effect factors to reduce performance ratings of HVAC equipment when installed under conditions different from the conditions used to rate equipment performance. To calculate system effects for air systems, use tables and charts found in AMCA 201, "Fans and Systems," or in SMACNA's "HVAC Systems - Duct Design." Compare results with the design data and installed conditions.

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

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

L. Examine HVAC equipment and verify that equipment with functioning controls is ready for operation.

M. Examine HVAC equipment and verify that bearings are greased, belts are aligned and tight, filters are clean, and equipment with functioning controls is ready for operation.
N. Examine terminal units, such as variable-air-volume boxes, and verify that they are accessible and their controls are connected and functioning.

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

P. Examine strainers. Verify that startup screens have been replaced by permanent screens with indicated perforations.

Q. Examine control valves for proper installation for their intended function of throttling, diverting, or mixing fluid flows.

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

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

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

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

3.3 PREPARATION

A. Prepare a TAB plan that includes the following:

1. Equipment and systems to be tested.
3. Instrumentation to be used.
4. Sample forms with specific identification for all equipment.

B. Perform system-readiness checks of HVAC systems and equipment to verify system readiness for TAB work. Include, at a minimum, the following:

1. Airside:
   a. Verify that leakage and pressure tests on air distribution systems have been satisfactorily completed.
   b. Duct systems are complete with terminals installed.
   c. Volume, smoke, and fire dampers are open and functional.
   d. Clean filters are installed.
   e. Fans are operating, free of vibration, and rotating in correct direction.
   f. [Variable-frequency controllers' startup is complete and safeties are verified.
   g. Automatic temperature-control systems are operational.
   h. Ceilings are installed.
   i. Windows and doors are installed.
   j. Suitable access to balancing devices and equipment is provided.

2. Hydronics:
a. Verify leakage and pressure tests on water distribution systems have been satisfactorily completed.
b. Piping is complete with terminals installed.
c. Water treatment is complete.
d. Systems are flushed, filled, and air purged.
e. Strainers are pulled and cleaned.
f. Control valves are functioning per the sequence of operation.
g. Shutoff and balance valves have been verified to be 100 percent open.
h. Pumps are started and proper rotation is verified.
i. Pump gage connections are installed directly at pump inlet and outlet flanges or in discharge and suction pipe prior to valves or strainers.
j. [Variable-frequency controllers'] startup is complete and safeties are verified.
k. Suitable access to balancing devices and equipment is provided.

3.4 GENERAL PROCEDURES FOR TESTING AND BALANCING

A. Perform testing and balancing procedures on each system according to the procedures contained in AABC's "National Standards for Total System Balance"; ASHRAE 111; NEBB's "Procedural Standards for Testing, Adjusting, and Balancing of Environmental Systems"; SMACNA's "HVAC Systems - Testing, Adjusting, and Balancing"; and in this Section.

B. Perform testing and balancing procedures on each system according to the procedures contained in [AABC's "National Standards for Total System Balance"] [ASHRAE 111] [NEBB's "Procedural Standards for Testing, Adjusting, and Balancing of Environmental Systems"] [SMACNA's "HVAC Systems - Testing, Adjusting, and Balancing"] and in this Section.

C. Cut insulation, ducts, pipes, and equipment cabinets for installation of test probes to the minimum extent necessary for TAB procedures.

D. Cut insulation, ducts, pipes, and equipment cabinets for installation of test probes to the minimum extent necessary for TAB procedures.

1. After testing and balancing, patch probe holes in ducts with same material and thickness as used to construct ducts.

2. After testing and balancing, install test ports and duct access doors that comply with requirements in Section 23 3300 "Air Duct Accessories."

3. Install and join new insulation that matches removed materials. Restore insulation, coverings, vapor barrier, and finish according to Section 23 0700 "HVAC Insulation."

4. Install and join new insulation that matches removed materials. Restore insulation, coverings, vapor barrier, and finish according to Section 23 0713 "Duct Insulation," Section 23 0716 "HVAC Equipment Insulation," and Section 23 0719 "HVAC Piping Insulation."

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

F. Mark equipment and balancing devices, including damper-control positions, valve position indicators, fan-speed-control levers, and similar controls and devices, with paint or other suitable, permanent identification material to show final settings.
G. Take and report testing and balancing measurements in inch-pound (IP) units.

H. Take and report testing and balancing measurements in [inch-pound (IP)] [and] [metric (SI)] units.

3.5 GENERAL PROCEDURES FOR BALANCING AIR SYSTEMS

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

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

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

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

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

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

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

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

I. Check for airflow blockages.

J. Check condensate drains for proper connections and functioning.

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

L. Verify that air duct system is sealed as specified in Section 23 3113 "Metal Ducts."

3.6 PROCEDURES FOR CONSTANT-VOLUME AIR SYSTEMS

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

1. Measure total airflow.

   a. Set outside-air, return-air, and relief-air dampers for proper position that simulates minimum outdoor-air conditions.
   
   b. Where duct conditions allow, measure airflow by Pitot-tube traverse. If necessary, perform multiple Pitot-tube traverses to obtain total airflow.
   
   c. Where duct conditions are not suitable for Pitot-tube traverse measurements, a coil traverse may be acceptable.
   
   d. If a reliable Pitot-tube traverse or coil traverse is not possible, measure airflow at terminals and calculate the total airflow.
2. Measure fan static pressures as follows:
   a. Measure static pressure directly at the fan outlet or through the flexible connection.
   b. Measure static pressure directly at the fan inlet or through the flexible connection.
   c. Measure static pressure across each component that makes up the air-handling system.
   d. Report artificial loading of filters at the time static pressures are measured.

3. Review Record Documents to determine variations in design static pressures versus actual static pressures. Calculate actual system-effect factors. Recommend adjustments to accommodate actual conditions.

4. Obtain approval from [Engineer] [Construction Manager] [commissioning authority] for adjustment of fan speed higher or lower than indicated speed. Comply with requirements in HVAC Sections for air-handling units for adjustment of fans, belts, and pulley sizes to achieve indicated air-handling-unit performance.

5. Obtain approval from [Architect] [Owner] [Construction Manager] [commissioning authority] for adjustment of fan speed higher or lower than indicated speed. Comply with requirements in HVAC Sections for air-handling units for adjustment of fans, belts, and pulley sizes to achieve indicated air-handling-unit performance.

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 occurs. Measure amperage in full-cooling, full-heating, economizer, and any other operating mode to determine the maximum required brake horsepower.

B. Adjust volume dampers for main duct, submain ducts, and major branch ducts to indicated airflow.
   1. Measure airflow of submain and branch ducts.
   2. Adjust submain and branch duct volume dampers for specified airflow.
   3. Re-measure each submain and branch duct after all have been adjusted.

C. Adjust air inlets and outlets for each space to indicated airflow.
   1. Set airflow patterns of adjustable outlets for proper distribution without drafts.
   2. Measure inlets and outlets airflow.
   3. Adjust each inlet and outlet for specified airflow.
   4. Re-measure each inlet and outlet after they have been adjusted.

D. Verify final system conditions.
   1. Re-measure and confirm that minimum outdoor, return, and relief airflows are within design. Readjust to design if necessary.
   2. Re-measure and confirm that total airflow is within design.
   3. Re-measure all final fan operating data, rpms, volts, amps, and static profile.
   4. Mark all final settings.
   5. Test system in economizer mode. Verify proper operation and adjust if necessary.
   6. Measure and record all operating data.
   7. Record final fan-performance data.
3.7 PROCEDURES FOR DUAL-DUCT SYSTEMS

A. Adjust the dual-duct systems as follows:

1. Verify that the system static pressure sensor is located two-thirds of the distance down the duct from the fan discharge. On systems with separate hot-deck and cold-deck fans, verify the location of the sensor on each deck.

2. Verify that the system is under static pressure control.

3. Select the terminal unit that is most critical to the supply-fan airflow. Measure inlet static pressure, and adjust system static pressure control set point so the entering static pressure for the critical terminal unit is not less than the sum of the terminal-unit manufacturer's recommended minimum inlet static pressure plus the static pressure needed to overcome terminal-unit discharge system losses.

4. Calibrate and balance each terminal unit's hot deck and cold deck for maximum and minimum design airflow as follows:
   a. Adjust controls so that terminal is calling for full cooling. Some controllers require starting with minimum set point. Verify calibration procedure for specific project.
   b. Measure airflow and adjust calibration factors as required for design cold-deck maximum airflow and hot-deck minimum airflow. Record calibration factors.
   c. When maximum airflow is correct, balance the air outlets downstream from terminal units.
   d. Adjust controls so that terminal is calling for full heating.
   e. Measure airflow and adjust calibration factors as required for design cold-deck minimum airflow and hot-deck maximum airflow. Record calibration factors. If no minimum calibration is available, note any deviation from design airflow.

5. After terminals have been calibrated and balanced, test and adjust system for total airflow. Adjust fans to deliver total design airflows within the maximum allowable fan speed listed by fan manufacturer.
   a. Set outside-air, return-air, and relief-air dampers for proper position that simulates minimum outdoor-air conditions.
   b. Set terminals for maximum airflow. If system design includes diversity (cooling coil or fan), adjust terminals for maximum and minimum airflow so that connected total matches cooling coil or fan selection and simulates actual load in the building. In systems with separate hot-deck and cold-deck fans, diversity consideration applies to each individual fan.
   c. Where duct conditions allow, measure airflow by Pitot-tube traverse. If necessary, perform multiple Pitot-tube traverses to obtain total airflow.
   d. Where duct conditions are not suitable for Pitot-tube traverse measurements, a coil traverse may be acceptable.
   e. If a reliable Pitot-tube traverse or coil traverse is not possible, measure airflow at terminals and calculate the total airflow.

6. Measure the fan(s) static pressures as follows:
   a. Measure static pressure directly at the fan outlet or through the flexible connection.
   b. Measure static pressure directly at the fan inlet or through the flexible connection.
   c. Measure static pressure across each component that makes up the air-handling system.
   d. Report any artificial loading of filters at the time static pressures are measured.

7. Set final return and outside airflow to the fan(s) while operating at maximum return airflow and minimum outdoor airflow.
   a. systems.
b. Verify that all terminal units are meeting design airflow under system maximum flow.

8. Re-measure the inlet static pressure at the most critical terminal unit and adjust the system static pressure set point to the most energy-efficient set point to maintain the optimum system static pressure. Record set point and give to controls contractor.

9. Verify final system conditions as follows:
   a. Re-measure and confirm that minimum outdoor, return, and relief airflows are within design. Readjust to match design if necessary.
   b. Re-measure and confirm that total airflow is within design.
   c. Re-measure final fan operating data, rpms, volts, amps and static profile.
   d. Mark final settings.
   e. Test system in economizer mode. Verify proper operation and adjust if necessary. Measure and record all operating data.
   f. Verify tracking between supply and return fans.

10. Record final fan-performance data.

3.8 PROCEDURES FOR VARIABLE-AIR-VOLUME SYSTEMS

A. Single Zone Variable-Air-Volume Systems: After the fan systems have been adjusted, adjust the variable-air-volume systems as follows:

1. Balance systems similar to constant-volume air systems.
2. Set air inlets, air outlets, and supply fan at full-airflow condition.
3. Adjust air outlets to indicated airflow.
4. Readjust fan airflow for final maximum readings.
5. Measure operating static pressure at the sensor that controls the supply fan and verify operation of the static-pressure controller.
6. Set supply fan at minimum airflow if minimum airflow is indicated. Measure static pressure to verify that it is being maintained by the controller.
7. 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 the outlets balanced for maximum airflow.
8. Measure 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.

B. Adjust the variable-air-volume systems as follows:

1. Verify that the system static pressure sensor is located two-thirds of the distance down the duct from the fan discharge.
2. Verify that the system is under static pressure control.
3. Select the terminal unit that is most critical to the supply-fan airflow. Measure inlet static pressure, and adjust system static pressure control set point so the entering static pressure for the critical terminal unit is not less than the sum of the terminal-unit manufacturer's recommended minimum inlet static pressure plus the static pressure needed to overcome terminal-unit discharge system losses.
4. Calibrate and balance each terminal unit for maximum and minimum design airflow as follows:
   
a. Adjust controls so that terminal is calling for maximum airflow. Some controllers require starting with minimum airflow. Verify calibration procedure for specific project.
   b. Measure airflow and adjust calibration factor as required for design maximum airflow. Record calibration factor.
   c. When maximum airflow is correct, balance the air outlets downstream from terminal units.
   d. Adjust controls so that terminal is calling for minimum airflow.
   e. Measure airflow and adjust calibration factor as required for design minimum airflow. Record calibration factor. If no minimum calibration is available, note any deviation from design airflow.
   f. When in full cooling or full heating, ensure that there is no mixing of hot-deck and cold-deck airstreams unless so designed.
   g. On constant volume terminals, in critical areas where room pressure is to be maintained, verify that the airflow remains constant over the full range of full cooling to full heating. Note any deviation from design airflow or room pressure.

5. After terminals have been calibrated and balanced, test and adjust system for total airflow. Adjust fans to deliver total design airflow within the maximum allowable fan speed listed by fan manufacturer.
   
a. Set outside-air, return-air, and relief-air dampers for proper position that simulates minimum outdoor-air conditions.
   b. Set terminals for maximum airflow. If system design includes diversity, adjust terminals for maximum and minimum airflow so that connected total matches fan selection and simulates actual load in the building.
   c. Where duct conditions allow, measure airflow by Pitot-tube traverse. If necessary, perform multiple Pitot-tube traverses to obtain total airflow.
   d. Where duct conditions are not suitable for Pitot-tube traverse measurements, a coil traverse may be acceptable.
   e. If a reliable Pitot-tube traverse or coil traverse is not possible, measure airflow at terminals and calculate the total airflow.

6. Measure fan static pressures as follows:
   
a. Measure static pressure directly at the fan outlet or through the flexible connection.
   b. Measure static pressure directly at the fan inlet or through the flexible connection.
   c. Measure static pressure across each component that makes up the air-handling system.
   d. Report any artificial loading of filters at the time static pressures are measured.

7. Set final return and outside airflow to the fan while operating at maximum return airflow and minimum outdoor airflow.
   
a. Balance the return-air ducts and inlets the same as described for constant-volume air systems.
   b. Verify that terminal units are meeting design airflow under system maximum flow.
8. Re-measure the inlet static pressure at the most critical terminal unit and adjust the system static pressure set point to the most energy-efficient set point to maintain the optimum system static pressure. Record set point and give to controls contractor.

9. Verify final system conditions as follows:
   a. Re-measure and confirm that minimum outdoor, return, and relief airflows are within design. Readjust to match design if necessary.
   b. Re-measure and confirm that total airflow is within design.
   c. Re-measure final fan operating data, rpms, volts, amps, and static profile.
   d. Mark final settings.
   e. Test system in economizer mode. Verify proper operation and adjust if necessary. Measure and record all operating data.
   f. Verify tracking between supply and return fans.

3.9 PROCEDURES FOR MULTIZONE SYSTEMS

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

B. The procedures for multizone systems will utilize the zone balancing dampers to achieve the indicated airflow within the zone.

C. After balancing, place the unit's automatic zone dampers for maximum heating flow. Retest zone airflows and record any variances.

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

1. Measure total airflow.
   a. Set outside-air, return-air and relief-air dampers for proper position that simulates minimum outdoor air conditions.
   b. Where duct conditions allow, measure airflow by Pitot-tube traverse. If necessary, perform multiple Pitot-tube traverses to obtain total airflow.
   c. Where duct conditions are not suitable for Pitot-tube traverse measurements, a coil traverse may be acceptable.
   d. If a reliable Pitot-tube traverse or coil traverse is not possible, measure airflow at terminals and calculate the total airflow.

2. Measure fan static pressures as follows:
   a. Measure static pressure directly at the fan outlet or through the flexible connection.
   b. Measure static pressure directly at the fan inlet or through the flexible connection.
   c. Measure static pressure across each component that makes up the air-handling system.
   d. Report artificial loading of filters at the time static pressures are measured.

3. Review Record Documents to determine variations in design static pressures versus actual static pressures. Calculate actual system-effect factors. Recommend adjustments to accommodate actual conditions.

4. Obtain approval from [Engineer] [Construction Manager] [commissioning authority] for adjustment of fan speed higher or lower than indicated speed. Comply with requirements in HVAC Sections for air-handling units for adjustment of fans, belts, and pulley sizes to achieve indicated air-handling-unit performance.
5. Obtain approval from [Architect] [Owner] [Construction Manager] [commissioning authority] for adjustment of fan speed higher or lower than indicated speed. Comply with requirements in HVAC Sections for air-handling units for adjustment of fans, belts, and pulley sizes to achieve indicated air-handling-unit performance.

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 occurs. Measure amperage in full-cooling, full-heating, economizer, and any other operating mode to determine the maximum required brake horsepower.

E. Adjust volume dampers for main duct, submain ducts, and major branch ducts to indicated airflows.

1. Measure airflow of submain and branch ducts.
2. Adjust submain and branch duct volume dampers for specified airflow.
3. Re-measure each submain and branch duct after all have been adjusted.

F. Adjust air inlets and outlets for each space to indicated airflows.

1. Set airflow patterns of adjustable outlets for proper distribution without drafts.
2. Measure inlets and outlets airflow.
3. Adjust each inlet and outlet for specified airflow.
4. Re-measure each inlet and outlet after they have been adjusted.

G. Verify final system conditions.

1. Re-measure and confirm that minimum outdoor, return, and relief airflows are within design. Readjust to match design if necessary.
2. Re-measure and confirm that total airflow is within design.
3. Re-measure all final fan operating data, rpms, volts, amps, and static profile.
4. Mark all final settings.
5. Test system in economizer mode. Verify proper operation and adjust if necessary.
6. Measure and record all operating data.
7. Record final fan-performance data.

3.10 PROCEDURES FOR INDUCTION-UNIT SYSTEMS

A. Balance primary-air risers by measuring static pressure at the nozzles of the top and bottom units of each riser to determine which risers must be throttled. Adjust risers to indicated airflow within specified tolerances.

B. Adjust each induction unit.

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

1. Measure total airflow.
   a. Set outside-air, return-air, and relief-air dampers for proper position that simulates minimum outdoor-air conditions.
   b. Where duct conditions allow, measure airflow by Pitot-tube traverse. If necessary, perform multiple Pitot-tube traverses to obtain total airflow.
c. Where duct conditions are not suitable for Pitot-tube traverse measurements, a coil traverse may be acceptable.
d. If a reliable Pitot-tube traverse or coil traverse is not possible, measure airflow at terminals and calculate the total airflow.

2. Measure fan static pressures as follows:
a. Measure static pressure directly at the fan outlet or through the flexible connection.
b. Measure static pressure directly at the fan inlet or through the flexible connection.
c. Measure static pressure across each component that makes up the air-handling system.
d. Report artificial loading of filters at the time static pressures are measured.

3. Review Record Documents to determine variations in design static pressures versus actual static pressures. Calculate actual system-effect factors. Recommend adjustments to accommodate actual conditions.

4. Obtain approval from [Engineer] [Construction Manager] [commissioning authority] for adjustment of fan speed higher or lower than indicated speed. Comply with requirements in HVAC Sections for air-handling units for adjustment of fans, belts, and pulley sizes to achieve indicated air-handling-unit performance.

5. Obtain approval from [Architect] [Owner] [Construction Manager] [commissioning authority] for adjustment of fan speed higher or lower than indicated speed. Comply with requirements in HVAC Sections for air-handling units for adjustment of fans, belts, and pulley sizes to achieve indicated air-handling-unit performance.

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 occurs. Measure amperage in full-cooling, full-heating, economizer, and any other operating mode to determine the maximum required brake horsepower.

D. Adjust volume dampers for main duct, submain ducts, and major branch ducts to indicated airflows.

1. Measure airflow of submain and branch ducts.
2. Adjust submain and branch duct volume dampers for specified airflow.
3. Re-measure each submain and branch duct after all have been adjusted.

E. Balance airflow to each induction unit by measuring the nozzle pressure and comparing it to the manufacturer's published data for nozzle pressure versus cfm. Adjust the unit's inlet damper to achieve the required nozzle pressure for design cfm.

F. Verify final system conditions.

1. Re-measure and confirm that minimum outdoor, return, and relief airflows are within design. Readjust to match design if necessary.
2. Re-measure and confirm that total airflow is within design.
3. Re-measure all final fan operating data, rpms, volts, amps, and static profile.
4. Mark all final settings.
5. Test system in economizer mode. Verify proper operation and adjust if necessary.
6. Measure and record all operating data.
7. Record final fan-performance data.
3.11 GENERAL PROCEDURES FOR HYDRONIC SYSTEMS

A. Prepare test reports for pumps, coils, and heat exchangers. Obtain approved submittals and manufacturer-recommended testing procedures. Crosscheck the summation of required coil and heat exchanger flow rates with pump design flow rate.

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

C. In addition to requirements in "Preparation" Article, prepare hydronic systems for testing and balancing as follows:
   1. Check liquid level in expansion tank.
   2. Check highest vent for adequate pressure.
   3. Check flow-control valves for proper position.
   4. Locate start-stop and disconnect switches, electrical interlocks, and motor starters.
   5. Verify that motor starters are equipped with properly sized thermal protection.
   6. Check that air has been purged from the system.

3.12 PROCEDURES FOR CONSTANT-FLOW HYDRONIC SYSTEMS

A. Adjust pumps to deliver total design gpm.
   1. Measure total water flow.
      a. Position valves for full flow through coils.
      b. Measure flow by main flow meter, if installed.
      c. If main flow meter is not installed, determine flow by pump TDH or exchanger pressure drop.
   2. Measure pump TDH as follows:
      a. Measure discharge pressure directly at the pump outlet flange or in discharge pipe prior to any valves.
      b. Measure inlet pressure directly at the pump inlet flange or in suction pipe prior to any valves or strainers.
      c. Convert pressure to head and correct for differences in gage heights.
      d. Verify pump impeller size by measuring the TDH with the discharge valve closed. Note the point on manufacturer’s pump curve at zero flow, and verify that the pump has the intended impeller size.
      e. With valves open, read pump TDH. Adjust pump discharge valve until design water flow is achieved.

B. Adjust flow-measuring devices installed in mains and branches to design water flows.
   1. Measure flow in main and branch pipes.
   2. Adjust main and branch balance valves for design flow.
   3. Re-measure each main and branch after all have been adjusted.
C. Adjust flow-measuring devices installed at terminals for each space to design water flows.
   1. Measure flow at terminals.
   2. Adjust each terminal to design flow.
   3. Re-measure each terminal after it is adjusted.
   4. Position control valves to bypass the coil, and adjust the bypass valve to maintain design flow.
   5. Perform temperature tests after flows have been balanced.

D. For systems with pressure-independent valves at terminals:
   1. Measure differential pressure and verify that it is within manufacturer's specified range.
   2. Perform temperature tests after flows have been verified.

E. For systems without pressure-independent valves or flow-measuring devices at terminals:
   1. Measure and balance coils by either coil pressure drop or temperature method.
   2. If balanced by coil pressure drop, perform temperature tests after flows have been verified.

F. Verify final system conditions as follows:
   1. Re-measure and confirm that total water flow is within design.
   2. Re-measure final pumps' operating data, TDH, volts, amps, and static profile.
   3. Mark final settings.

G. Verify that memory stops have been set.

3.13 PROCEDURES FOR VARIABLE-FLOW HYDRONIC SYSTEMS

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

B. Adjust the variable-flow hydronic system as follows:
   1. Verify that the differential-pressure sensor is located as indicated.
   2. Determine whether there is diversity in the system.

C. For systems with no diversity:
   1. Adjust pumps to deliver total design gpm.
      a. Measure total water flow.
         1) Position valves for full flow through coils.
         2) Measure flow by main flow meter, if installed.
         3) If main flow meter is not installed, determine flow by pump TDH or exchanger pressure drop.
b. Measure pump TDH as follows:

1) Measure discharge pressure directly at the pump outlet flange or in discharge pipe prior to any valves.
2) Measure inlet pressure directly at the pump inlet flange or in suction pipe prior to any valves or strainers.
3) Convert pressure to head and correct for differences in gage heights.
4) Verify pump impeller size by measuring the TDH with the discharge valve closed. Note the point on manufacturer's pump curve at zero flow and verify that the pump has the intended impeller size.
5) With valves open, read pump TDH. Adjust pump discharge valve until design water flow is achieved.


2. Adjust flow-measuring devices installed in mains and branches to design water flows.

a. Measure flow in main and branch pipes.
b. Adjust main and branch balance valves for design flow.
c. Re-measure each main and branch after all have been adjusted.

3. Adjust flow-measuring devices installed at terminals for each space to design water flows.

a. Measure flow at terminals.
b. Adjust each terminal to design flow.
c. Re-measure each terminal after it is adjusted.
d. Position control valves to bypass the coil and adjust the bypass valve to maintain design flow.
e. Perform temperature tests after flows have been balanced.

4. For systems with pressure-independent valves at terminals:

a. Measure differential pressure and verify that it is within manufacturer's specified range.
b. Perform temperature tests after flows have been verified.

5. For systems without pressure-independent valves or flow-measuring devices at terminals:

a. Measure and balance coils by either coil pressure drop or temperature method.
b. If balanced by coil pressure drop, perform temperature tests after flows have been verified.

6. Prior to verifying final system conditions, determine the system differential-pressure set point.

7. If the pump discharge valve was used to set total system flow with [variable-frequency controller] at 60 Hz, at completion open discharge valve 100 percent and allow [variable-frequency controller] to control system differential-pressure set point. Record pump data under both conditions.

8. Mark final settings and verify that all memory stops have been set.
9. Verify final system conditions as follows:
   a. Re-measure and confirm that total water flow is within design.
   b. Re-measure final pumps’ operating data, TDH, volts, amps, and static profile.
   c. Mark final settings.

10. Verify that memory stops have been set.

D. For systems with diversity:

   1. Determine diversity factor.
   2. Simulate system diversity by closing required number of control valves, as approved by the design engineer.
   3. Adjust pumps to deliver total design gpm.
      a. Measure total water flow.
         1) Position valves for full flow through coils.
         2) Measure flow by main flow meter, if installed.
         3) If main flow meter is not installed, determine flow by pump TDH or exchanger pressure drop.
      b. Measure pump TDH as follows:
         1) Measure discharge pressure directly at the pump outlet flange or in discharge pipe prior to any valves.
         2) Measure inlet pressure directly at the pump inlet flange or in suction pipe prior to any valves or strainers.
         3) Convert pressure to head and correct for differences in gage heights.
         4) Verify pump impeller size by measuring the TDH with the discharge valve closed. Note the point on manufacturer’s pump curve at zero flow and verify that the pump has the intended impeller size.
         5) With valves open, read pump TDH. Adjust pump discharge valve until design water flow is achieved.

4. Adjust flow-measuring devices installed in mains and branches to design water flows.
   a. Measure flow in main and branch pipes.
   b. Adjust main and branch balance valves for design flow.
   c. Re-measure each main and branch after all have been adjusted.

5. Adjust flow-measuring devices installed at terminals for each space to design water flows.
   a. Measure flow at terminals.
   b. Adjust each terminal to design flow.
   c. Re-measure each terminal after it is adjusted.
   d. Position control valves to bypass the coil, and adjust the bypass valve to maintain design flow.
e. Perform temperature tests after flows have been balanced.

6. For systems with pressure-independent valves at terminals:
   a. Measure differential pressure, and verify that it is within manufacturer's specified range.
   b. Perform temperature tests after flows have been verified.

7. For systems without pressure-independent valves or flow-measuring devices at terminals:
   a. Measure and balance coils by either coil pressure drop or temperature method.
   b. If balanced by coil pressure drop, perform temperature tests after flows have been verified.

8. Open control valves that were shut. Close a sufficient number of control valves that were previously open to maintain diversity, and balance terminals that were just opened.

9. Prior to verifying final system conditions, determine system differential-pressure set point.

10. If the pump discharge valve was used to set total system flow with \textbf{variable-frequency controller} at 60 Hz, at completion open discharge valve 100 percent and allow \textbf{variable-frequency controller} to control system differential-pressure set point. Record pump data under both conditions.

11. Mark final settings and verify that memory stops have been set.

12. Verify final system conditions as follows:
   a. Re-measure and confirm that total water flow is within design.
   b. Re-measure final pumps' operating data, TDH, volts, amps, and static profile.
   c. Mark final settings.

13. Verify that memory stops have been set.

3.14 PROCEDURES FOR PRIMARY-SECONDARY HYDRONIC SYSTEMS

A. Balance the primary circuit flow first.

B. Balance the secondary circuits after the primary circuits are complete.

C. Adjust pumps to deliver total design gpm.

1. Measure total water flow.
   a. Position valves for full flow through coils.
   b. Measure flow by main flow meter, if installed.
   c. If main flow meter is not installed, determine flow by pump TDH or exchanger pressure drop.

2. Measure pump TDH as follows:
   a. Measure discharge pressure directly at the pump outlet flange or in discharge pipe prior to any valves.
b. Measure inlet pressure directly at the pump inlet flange or in suction pipe prior to any valves or strainers.
c. Convert pressure to head and correct for differences in gage heights.
d. Verify pump impeller size by measuring the TDH with the discharge valve closed. Note the point on manufacturer’s pump curve at zero flow and verify that the pump has the intended impeller size.
e. With valves open, read pump TDH. Adjust pump discharge valve until design water flow is achieved.


D. Adjust flow-measuring devices installed in mains and branches to design water flows.
   1. Measure flow in main and branch pipes.
   2. Adjust main and branch balance valves for design flow.
   3. Re-measure each main and branch after all have been adjusted.

E. Adjust flow-measuring devices installed at terminals for each space to design water flows.
   1. Measure flow at terminals.
   2. Adjust each terminal to design flow.
   3. Re-measure each terminal after it is adjusted.
   4. Position control valves to bypass the coil and adjust the bypass valve to maintain design flow.
   5. Perform temperature tests after flows have been balanced.

F. For systems with pressure-independent valves at terminals:
   1. Measure differential pressure and verify that it is within manufacturer’s specified range.
   2. Perform temperature tests after flows have been verified.

G. For systems without pressure-independent valves or flow-measuring devices at terminals:
   1. Measure and balance coils by either coil pressure drop or temperature method.
   2. If balanced by coil pressure drop, perform temperature tests after flows have been verified.

H. Verify final system conditions as follows:
   1. Re-measure and confirm that total water flow is within design.
   2. Re-measure final pumps’ operating data, TDH, volts, amps, and static profile.
   3. Mark final settings.

I. Verify that memory stops have been set.

3.15 PROCEDURES FOR STEAM SYSTEMS

A. Measure and record upstream and downstream pressure of each piece of equipment.
B. Measure and record upstream and downstream steam pressure of pressure-reducing valves.

C. Check settings and operation of automatic temperature-control valves, self-contained control valves, and pressure-reducing valves. Record final settings.

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

E. Verify the operation of each steam trap.

3.16 PROCEDURES FOR HEAT EXCHANGERS

A. Adjust water flow to within specified tolerances.

B. Measure inlet and outlet water temperatures.

C. Measure inlet steam pressure.

D. Check settings and operation of safety and relief valves. Record settings.

3.17 PROCEDURES FOR MOTORS

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

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

3.18 PROCEDURES FOR CHILLERS

A. Balance water flow through each evaporator[ and condenser] to within specified tolerances of indicated flow with all pumps operating. With only one chiller operating in a multiple chiller installation, do not exceed the flow for the maximum tube velocity recommended by the chiller manufacturer. Measure and record the following data with each chiller operating at design conditions:

   1. Evaporator-water entering and leaving temperatures, pressure drop, and water flow.
   2. For 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 kilowatts.
5. Kilowatt input if factory-installed instrumentation is furnished for measuring kilowatts.
7. For air-cooled chillers, verify condenser-fan rotation and record fan and motor data including number of fans and entering- and leaving-air temperatures.

3.19 PROCEDURES FOR COOLING TOWERS
A. Balance total condenser-water flows to towers. Measure and record the following data:
   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. Condenser-water flow rate recirculating through the cooling tower.
   6. Cooling-tower spray pump discharge pressure.
   7. Condenser-water flow through bypass.
   8. Fan and motor operating data.

3.20 PROCEDURES FOR CONDENSING UNITS
A. Verify proper rotation of fans.
B. Measure entering- and leaving-air temperatures.
C. Record fan and motor operating data.

3.21 PROCEDURES FOR BOILERS
A. Hydronic Boilers:
   1. Measure and record entering- and leaving-water temperatures.
   2. Measure and record water flow.
   3. Record relief valve pressure setting.
B. Steam Boilers:
   1. Measure and record entering-water temperature.
   2. Measure and record feed water flow.
   3. Measure and record leaving-steam pressure and temperature.
   4. Record relief valve pressure setting.

3.22 PROCEDURES FOR HEAT-TRANSFER COILS
A. Measure, adjust, and record the following data for each water coil:
   1. Entering- and leaving-water temperature.
   2. Water flow rate.
3. Water pressure drop for major (more than 20 gpm) equipment coils, excluding unitary equipment such as reheat coils, unit heaters, and fan-coil units.
4. Dry-bulb temperature of entering and leaving air.
5. Wet-bulb temperature of entering and leaving air for cooling coils.
6. Airflow.

B. Measure, adjust, and record the following data for each electric heating coil:
   1. Nameplate data.
   2. Airflow.
   3. Entering- and leaving-air temperature at full load.
   4. Voltage and amperage input of each phase at full load.
   5. Calculated kilowatt at full load.
   6. Fuse or circuit-breaker rating for overload protection.

C. Measure, adjust, and record the following data for each steam coil:
   1. Dry-bulb temperature of entering and leaving air.
   2. Airflow.
   3. Inlet steam pressure.

D. Measure, adjust, and record the following data for each refrigerant coil:
   1. Dry-bulb temperature of entering and leaving air.
   2. Wet-bulb temperature of entering and leaving air.
   3. Airflow.

3.23 PROCEDURES FOR COMMERCIAL KITCHEN HOODS

A. 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 also 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.

B. 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 any 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.
C. Visually inspect the hood exhaust duct throughout its entire length in compliance with authorities having jurisdiction. Begin at the hood connection and end at the point it discharges outdoors. Report findings.

   1. Check duct slopes as required.
   2. Verify that duct access is installed as required.
   3. Verify that point of termination is as required.
   4. Verify that duct air velocity is within the range required.
   5. Verify that duct is within a fire-rated enclosure.

D. Report deficiencies.

3.24 PROCEDURES FOR LABORATORY FUME HOODS

A. Before performing laboratory fume hood testing, measure, adjust and record the supply airflow and airflow patterns of each supply air outlet that is located in the same room as the hood. Adjust the air outlet flow pattern to minimize turbulence and to achieve the desired airflow patterns at the face and inside the hood. Verify that adequate makeup air is available to achieve the indicated flow of the hood.

B. Measure, adjust, and record the airflow of each laboratory fume hood by duct Pitot-tube traverse with the laboratory fume hood sash in the design open position.

   1. For laboratory fume hoods installed in variable exhaust systems, measure, adjust, and record the hood exhaust airflow at maximum and at minimum airflow conditions.
   2. For laboratory fume hoods designed with integral makeup air, measure, adjust, and record the exhaust and makeup airflow.

C. For laboratory fume hoods that are connected to centralized exhaust systems using automatic dampers, adjust the damper controller to obtain the indicated exhaust airflow.

D. After balancing is complete, do the following:

   1. Measure and record the static pressure at the hood duct connection with the hood operating at indicated airflow.
   2. Measure and record the face velocity across the open sash face area. Measure the face velocity at each point in a grid pattern. Perform measurements at a maximum of 12 inches between points and between any point and the perimeter of the opening.
      a. For laboratory fume hoods designed to maintain a constant face velocity at varying sash positions, also measure and record the face velocity at 50 and 25 percent of the design open sash position.
      b. Calculate and report the average face velocity by averaging all velocity measurements.
      c. Calculate and report the exhaust airflow by multiplying the calculated average face velocity by the sash open area. Compare this quantity with the exhaust airflow measured by duct Pitot-tube traverse. Report differences.
      d. If the average face velocity is less than the indicated face velocity, retest the average face velocity and adjust hood baffles, fan drives, and other parts of the system to provide the indicated average face velocity.
3. Check each laboratory fume hood for the capture and containment of smoke by using a hand-held emitting device. Observe the capture and containment of smoke flow pattern across the open face and inside the hood. Make adjustments necessary to achieve the desired results.

E. With the room and laboratory fume hoods operating at indicated conditions, perform an "as-installed" performance test of the laboratory fume hood according to ASHRAE 110. Test [each <insert number>] laboratory fume hood(s) and document the test results.

3.25 PROCEDURES FOR EXHAUST HOODS

A. Measure, adjust, and record the airflow of each exhaust hood. Measure airflow by duct Pitot-tube traverse. If a duct Pitot-tube traverse is not possible, explain why, in the report, and explain the test method used.

B. After balancing is complete, do the following:

1. Measure and record the static pressure at the hood exhaust-duct connection.
2. Check the hood for capture and containment of smoke using a smoke emitting device. Observe the smoke pattern. Make adjustments to achieve optimum results.

3.26 PROCEDURES FOR SPACE PRESSURIZATION MEASUREMENTS AND ADJUSTMENTS

A. Before testing for space pressurization, observe the space to verify the integrity of the space boundaries. Verify that windows and doors are closed and applicable safing, gaskets, and sealants are installed. Report deficiencies and postpone testing until after the reported deficiencies are corrected.

B. Measure, adjust, and record the pressurization of each room, each zone, and each building by adjusting the supply, return, and exhaust airflows to achieve the indicated conditions.

C. Measure space pressure differential where pressure is used as the design criteria, and measure airflow differential where differential airflow is used as the design criteria for space pressurization.

1. For pressure measurements, measure and record the pressure difference between the intended spaces at the door with all doors in the space closed. Record the high-pressure side, low-pressure side, and pressure difference between each adjacent space.
2. For applications with cascading levels of space pressurization, begin in the most critical space and work to the least critical space.
3. Test room pressurization first, then zones, and finish with building pressurization.

D. To achieve indicated pressurization, set the supply airflow to the indicated conditions and adjust the exhaust and return airflow to achieve the indicated pressure or airflow difference.

E. For spaces with pressurization being monitored and controlled automatically, observe and adjust the controls to achieve the desired set point.

1. Compare the values of the measurements taken to the measured values of the control system instruments and report findings.
2. Check the repeatability of the controls by successive tests designed to temporarily alter the ability to achieve space pressurization. Test overpressurization and underpressurization, and observe and report on the system's ability to revert to the set point.

3. For spaces served by variable-air-volume supply and exhaust systems, measure space pressurization at indicated airflow and minimum airflow conditions.

F. In spaces that employ multiple modes of operation, such as normal mode and emergency mode or occupied mode and unoccupied mode, measure, adjust, and record data for each operating mode.

G. Record indicated conditions and corresponding initial and final measurements. Report deficiencies.

3.27 SOUND TESTS

A. After the systems are balanced and construction is Substantially Complete, measure and record sound levels at locations as designated by the Architect.

B. Instrumentation:
   1. The sound-testing meter shall be a portable, general-purpose testing meter consisting of a microphone, processing unit, and readout.
   2. The sound-testing meter shall be capable of showing fluctuations at minimum and maximum levels, and measuring the equivalent continuous sound pressure level (LEQ).
   3. The sound-testing meter must be capable of using 1/3 octave band filters to measure mid-frequencies from 31.5 Hz to 8000 Hz.
   4. The accuracy of the sound-testing meter shall be plus or minus one decibel.

C. Test Procedures:
   1. Perform test at quietest background noise period. Note cause of unpreventable sound that affects test outcome.
   2. Equipment should be operating at design values.
   3. Calibrate the sound-testing meter prior to taking measurements.
   4. Use a microphone suitable for the type of noise levels measured that is compatible with meter. Provide a windshield for outside or in-duct measurements.
   5. Record a set of background measurements in dBA and sound pressure levels in the eight un-weighted octave bands [63 Hz to 8000 Hz (NC)] [31.5 Hz to 4000 Hz (RC)] with the equipment off.
   6. Take sound readings in dBA and sound pressure levels in the eight un-weighted octave bands [63 Hz to 8000 Hz (NC)] [31.5 Hz to 4000 Hz (RC)] with the equipment operating.
   7. Take readings no closer than 36 inches from a wall or from the operating equipment and approximately 60 inches from the floor, with the meter held or mounted on a tripod.
   8. For outdoor measurements, move sound-testing meter slowly and scan area that has the most exposure to noise source being tested. Use A-weighted scale for this type of reading.

D. Reporting:
   1. Report shall record the following:
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2. Plot sound pressure levels on \([\text{NC}] [\text{RC}]\) worksheet with equipment on and off.

3.28 VIBRATION TESTS

A. After systems are balanced and construction is Substantially Complete, measure and record vibration levels on equipment having motor horsepower equal to or greater than [10] [15] [25]<Insert number>.

B. Instrumentation:

1. Use portable, battery-operated, and microprocessor-controlled vibration meter with or without a built-in printer.
2. The meter shall automatically identify engineering units, filter bandwidth, amplitude, and frequency scale values.
3. The meter shall be able to measure machine vibration displacement in mils of deflection, velocity in inches per second, and acceleration in inches per second squared.
4. Verify calibration date is current for vibration meter before taking readings.

C. Test Procedures:

1. To ensure accurate readings, verify that accelerometer has a clean, flat surface and is mounted properly.
2. With the unit running, set up vibration meter in a safe, secure location. Connect transducer to meter with proper cables. Hold magnetic tip of transducer on top of the bearing, and measure unit in mils of deflection. Record measurement, then move transducer to the side of the bearing and record in mils of deflection. Record an axial reading in mils of deflection by holding nonmagnetic, pointed transducer tip on end of shaft.
3. Change vibration meter to velocity (inches per second) measurements. Repeat and record above measurements.
4. Record CPM or rpm.
5. Read each bearing on motor, fan, and pump as required. Track and record vibration levels from rotating component through casing to base.

D. Reporting:

1. Report shall record location and the system tested.
2. Include horizontal-vertical-axial measurements for tests.
3. Verify that vibration limits follow Specifications, or, if not specified, follow the General Machinery Vibration Severity Chart or Vibration Acceleration General Severity Chart from the AABC National Standards. Acceptable levels of vibration are normally "smooth" to "good."
4. Include in report General Machinery Vibration Severity Chart, with conditions plotted.
3.29 DUCT LEAKAGE TESTS

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

3.30 CONTROLS VERIFICATION

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

B. Reporting: Include a summary of verifications performed, remaining deficiencies, and variations from indicated conditions.

3.31 PROCEDURES FOR TESTING, ADJUSTING, AND BALANCING EXISTING SYSTEMS

A. Contractor shall balance the entire hydronic heating system including all new and all existing systems and equipment. Contractor shall balance all new air systems and equipment. Contractor shall balance all existing air equipment as noted. Contractor shall perform pre-construction / pre-demolition tests on systems to remain as described below.

B. Prior to demolition of air and water HVAC distributions systems and equipment, measure and record existing air and water flow conditions for all equipment, ductwork and hydronic piping systems serving area being modified during the project.

   1. Measure and record the operating speeds and flow rates of existing equipment.
      a. Perform an ultrasonic flow measurement on each heating water system branch within boiler room down stream from circulation pump common header.
   2. Measure and record the flow rates at interconnection points between existing and new work.
   3. Measure motor voltage and amperage of effected equipment. Compare the values to motor nameplate information.
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C. After revisions are complete, measure all the HVAC air and water systems modified and restore the systems to their original or scheduled capacities.

1. Compare the indicated flow rates of the renovated work to the measured flow rates and determine the new equipment flow rates.
2. Verify that the indicated flows of the renovated work result in conditions that are within the acceptable limits defined by equipment manufacturer.
3. Re-measure, record and verify the flow rates at interconnection points between existing and new work.
4. If calculations increase or decrease the flow rates by more than 5 percent, make equipment adjustments to achieve the calculated airflow and water flow rates. If 5 percent or less, equipment adjustments are not required.
5. Balance each affect branch and main.

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

1. Measure and record the operating speed, airflow, and static pressure of each fan.
2. Measure motor voltage and amperage. Compare the values to motor nameplate information.
3. Check the refrigerant charge.
4. Check the condition of filters.
5. Check the condition of coils.
6. Check the operation of the drain pan and condensate-drain trap.
7. Check bearings and other lubricated parts for proper lubrication.

E. Before performing testing and balancing of existing systems, inspect existing equipment that is to remain and be reused to verify that existing equipment has been cleaned and refurbished. Verify the following:

1. 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. Deficiencies noted in the preconstruction report are corrected.

F. Perform testing and balancing of existing systems to the extent that existing systems are affected by the renovation work.

1. Compare the indicated airflow of the renovated work to the measured fan airflows, and determine the new fan speed and the face velocity of filters and coils.
2. Verify that the indicated airflows of the renovated work result in filter and coil face velocities and fan speeds that are within the acceptable limits defined by equipment manufacturer.
3. If calculations increase or decrease the airflow rates and water flow rates by more than 5 percent, make equipment adjustments to achieve the calculated rates. If increase or decrease is 5 percent or less, equipment adjustments are not required.
4. Balance each air outlet.
3.32 TOLERANCES

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

B. Set HVAC system's airflow rates and water flow rates within the following tolerances:

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

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

3.33 PROGRESS REPORTING

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

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

3.34 FINAL REPORT

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

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

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

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

C. General Report Data: In addition to form titles and entries, include the following data:
1. Title page.
2. Name and address of the TAB specialist.
3. Project name.
4. Project location.
5. Architect’s name and address.
6. Engineer’s name and address.
7. Contractor’s name and address.
9. Signature of TAB supervisor who certifies the report.
10. Table of Contents with the total number of pages defined for each section of the report.
11. Number each page in the report.
12. Summary of contents including the following:
   a. Indicated versus final performance.
   b. Notable characteristics of systems.
   c. Description of system operation sequence if it varies from the Contract Documents.
13. Nomenclature sheets for each item of equipment.
14. Data for terminal units, including manufacturer’s name, type, size, and fittings.
15. Notes to explain why certain final data in the body of reports vary from indicated values.
16. Test conditions for fans and pump performance forms including the following:
   a. Settings for outdoor-, return-, and exhaust-air dampers.
   b. Conditions of filters.
   c. Cooling coil, wet- and dry-bulb conditions.
   d. Face and bypass damper settings at coils.
   e. Fan drive settings including settings and percentage of maximum pitch diameter.
   f. Inlet vane settings for variable-air-volume systems.
   g. Settings for supply-air, static-pressure controller.
   h. Other system operating conditions that affect performance.

D. System Diagrams: Include schematic layouts of air and hydronic distribution systems. Present each system with single-line diagram and include the following:
1. Quantities of outdoor, supply, return, and exhaust airflows.
2. Water flow rates.
4. Duct, outlet, and inlet sizes.
5. Pipe and valve sizes and locations.
6. Terminal units.

E. Air-Handling-Unit Test Reports: For air-handling units with coils, include the following:
1. Unit Data:
   a. Unit identification.
   b. Location.
   c. Make and type.
   d. Model number and unit size.
   e. Manufacturer’s serial number.
f. Unit arrangement and class.
g. Discharge arrangement.
h. Sheave make, size in inches, and bore.
i. Center-to-center dimensions of sheave and amount of adjustments in inches.
j. Number, make, and size of belts.
k. Number, type, and size of filters.
l. Variable frequency drive information.

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

3. Test Data (Indicated and Actual Values):
   a. Total airflow rate in cfm.
   b. Total system static pressure in inches wg.
   c. Fan rpm.
   d. Discharge static pressure in inches wg.
   e. Filter static-pressure differential in inches wg.
   f. Preheat-coil static-pressure differential in inches wg.
   g. Cooling-coil static-pressure differential in inches wg.
   h. Heating-coil static-pressure differential in inches wg.
   i. Outdoor airflow in cfm.
   j. Return airflow in cfm.
   k. Outdoor-air damper position.
   l. Return-air damper position.
   m. Variable frequency drive information.
   n. Vortex damper position.

F. Apparatus-Coil Test Reports:

1. Coil Data:
   a. System identification.
   b. Location.
   c. Coil type.
   d. Number of rows.
   e. Fin spacing in fins per inch o.c.
   f. Make and model number.
   g. Face area in sq. ft.
   h. Tube size in NPS.
   i. Tube and fin materials.
   j. Circuiting arrangement.

2. Test Data (Indicated and Actual Values):
   a. Airflow rate in cfm.
b. Average face velocity in fpm.
c. Air pressure drop in inches wg.
d. Outdoor-air, wet- and dry-bulb temperatures in deg F.
e. Return-air, wet- and dry-bulb temperatures in deg F.
f. Entering-air, wet- and dry-bulb temperatures in deg F.
g. Leaving-air, wet- and dry-bulb temperatures in deg F.
h. Water flow rate in gpm.
i. Water pressure differential in feet of head or psig.
j. Entering-water temperature in deg F.
k. Leaving-water temperature in deg F.
l. Refrigerant expansion valve and refrigerant types.
m. Refrigerant suction pressure in psig.
n. Refrigerant suction temperature in deg F.
o. Inlet steam pressure in psig.

G. Energy Recovery Wheel Reports:

1. Unit Data:
   a. Unit identification.
   b. Location.
   c. Service.
   d. Make and type.
   e. Model and serial numbers.

2. Test Data (Indicated and Actual Values):
   a. Total exhaust airflow rate in cfm(L/s).
   b. Purge exhaust airflow rate in cfm(L/s).
   c. Outside airflow rate in cfm(L/s).
   d. Total exhaust fan static pressure in inches wg(Pa).
   e. Total outside-air fan static pressure in inches wg(Pa).
   f. Pressure drop on each side of heat exchanger in inches wg(Pa).
   g. Exhaust air temperature entering in deg F(deg C).
   h. Exhaust air temperature leaving in deg F(deg C).
   i. Outside-air temperature entering in deg F(deg C).
   j. Outside-air temperature leaving in deg F(deg C).
   k. Calculate sensible and total heat capacity of each airstream in MBh(kW).

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

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

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

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

1. Unit Data:
a. System identification.
b. Location.
c. Coil identification.
d. Capacity in Btu/h.
e. Number of stages.
f. Connected volts, phase, and hertz.
g. Rated amperage.
h. Airflow rate in cfm.
i. Face area in sq. ft..
j. Minimum face velocity in fpm.

2. Test Data (Indicated and Actual Values):
a. Heat output in Btu/h.
b. Airflow rate in cfm.
c. Air velocity in fpm.
d. Entering-air temperature in deg F.
e. Leaving-air temperature in deg F.
f. Voltage at each connection.
g. Amperage for each phase.

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

1. Fan Data:
a. System identification.
b. Location.
c. Make and type.
d. Model number and size.
e. Manufacturer's serial number.
f. Arrangement and class.
g. Sheave make, size in inches, and bore.
h. Center-to-center dimensions of sheave and amount of adjustments in inches.
i. Variable frequency drive information.

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

3. Test Data (Indicated and Actual Values):
   a. Total airflow rate in cfm.
   b. Total system static pressure in inches wg.
   c. Fan rpm.
   d. Discharge static pressure in inches wg.
   e. Suction static pressure in inches wg.
   f. Variable frequency drive setpoint.

K. Duct Traverse Reports: Include a diagram with a grid representing the duct cross-section and record the following:

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

1. Report Data:
   a. System and air-handling-unit number.
   b. Location and zone.
   c. Traverse air temperature in deg F.
   d. Duct static pressure in inches wg.
   e. Duct size in inches.
   f. Duct area in sq. ft..
   g. Indicated airflow rate in cfm.
   h. Indicated velocity in fpm.
   i. Actual airflow rate in cfm.
   j. Actual average velocity in fpm.
   k. Barometric pressure in psig.

M. Air-Terminal-Device Reports:

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

2. Test Data (Indicated and Actual Values):
   a. Airflow rate in cfm.
   b. Air velocity in fpm.
   c. Preliminary airflow rate as needed in cfm.
   d. Preliminary velocity as needed in fpm.
   e. Final airflow rate in cfm.
   f. Final velocity in fpm.
   g. Space temperature in deg F.

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

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

2. Test Data (Indicated and Actual Values):
   a. Airflow rate in cfm.
   b. Entering-water temperature in deg F.
   c. Leaving-water temperature in deg F.
   d. Water pressure drop in feet of head or psig.
   e. Entering-air temperature in deg F.
   f. Leaving-air temperature in deg F.

O. Packaged Chiller Reports:

1. Unit Data:
   a. Unit identification.
   b. Make and model number.
   c. Manufacturer's serial number.
   d. Refrigerant type and capacity in gal..
   e. Starter type and size.
   f. Starter thermal protection size.
   g. Compressor make and model number.
   h. Compressor manufacturer's serial number.

2. Water-Cooled Condenser Test Data (Indicated and Actual Values):
a. Refrigerant pressure in psig.
b. Refrigerant temperature in deg F.
c. Entering-water temperature in deg F.
d. Leaving-water temperature in deg F.
e. Entering-water pressure in feet of head or psig.
f. Water pressure differential in feet of head or psig.

3. Air-Cooled Condenser Test Data (Indicated and Actual Values):
   a. Refrigerant pressure in psig.
   b. Refrigerant temperature in deg F.
   c. Entering- and leaving-air temperature in deg F.

4. Evaporator Test Reports (Indicated and Actual Values):
   a. Refrigerant pressure in psig.
   b. Refrigerant temperature in deg F.
   c. Entering-water temperature in deg F.
   d. Leaving-water temperature in deg F.
e. Entering-water pressure in feet of head or psig.
   f. Water pressure differential in feet of head or psig.

5. Compressor Test Data (Indicated and Actual Values):
   a. Suction pressure in psig.
   b. Suction temperature in deg F.
   c. Discharge pressure in psig.
   d. Discharge temperature in deg F.
   e. Oil pressure in psig.
   f. Oil temperature in deg F.
   g. Voltage at each connection.
   h. Amperage for each phase.
   i. Kilowatt input.
   j. Crankcase heater kilowatt.
   k. Chilled-water control set point in deg F.
   l. Condenser-water control set point in deg F.
   m. Refrigerant low-pressure-cutoff set point in psig.
   n. Refrigerant high-pressure-cutoff set point in psig.

6. Refrigerant Test Data (Indicated and Actual Values):
   a. Oil level.
   b. Refrigerant level.
   c. Relief valve setting in psig.
   d. Unloader set points in psig.
   e. Percentage of cylinders unloaded.
   f. Bearing temperatures in deg F.
   g. Vane position.
   h. Low-temperature-cutoff set point in deg F.

P. Compressor and Condenser Reports: For refrigerant side of air-cooled condensing units, include the following:
Q. Compressor and Condenser Reports: For refrigerant side of unitary systems, stand-alone refrigerant compressors, air-cooled condensing units, or water-cooled condensing units, include the following:

1. **Unit Data:**
   - a. Unit identification.
   - b. Location.
   - c. Unit make and model number.
   - d. Compressor make.
   - e. Compressor model and serial numbers.
   - f. Refrigerant weight in lb.
   - g. Low ambient temperature cutoff in deg F.

2. **Test Data (Indicated and Actual Values):**
   - a. Inlet-duct static pressure in inches wg.
   - b. Outlet-duct static pressure in inches wg.
   - c. Entering-air, dry-bulb temperature in deg F.
   - d. Leaving-air, dry-bulb temperature in deg F.
   - e. Condenser entering-water temperature in deg F.
   - f. Condenser leaving-water temperature in deg F.
   - g. Condenser-water temperature differential in deg F.
   - h. Condenser entering-water pressure in feet of head or psig.
   - i. Condenser leaving-water pressure in feet of head or psig.
   - j. Condenser-water pressure differential in feet of head or psig.
   - k. Control settings.
   - l. Unloader set points.
   - m. Low-pressure-cutout set point in psig.
   - n. High-pressure-cutout set point in psig.
   - o. Suction pressure in psig.
   - p. Suction temperature in deg F.
   - q. Condenser refrigerant pressure in psig.
   - r. Condenser refrigerant temperature in deg F.
   - s. Oil pressure in psig.
   - t. Oil temperature in deg F.
   - u. Voltage at each connection.
   - v. Amperage for each phase.
   - w. Kilowatt input.
   - x. Crankcase heater kilowatt.
   - y. Number of fans.
   - z. Condenser fan rpm.
   - aa. Condenser fan airflow rate in cfm.
   - bb. Condenser fan motor make, frame size, rpm, and horsepower.
   - cc. Condenser fan motor voltage at each connection.
   - dd. Condenser fan motor amperage for each phase.

R. Cooling Tower or Condenser Test Reports: For cooling towers or condensers, include the following:

1. **Unit Data:**
   - a. Unit identification.
b. Make and type.
c. Model and serial numbers.
d. Nominal cooling capacity in tons.
e. Refrigerant type and weight in lb.
f. Water-treatment chemical feeder and chemical.
g. Number and type of fans.
h. Fan motor make, frame size, rpm, and horsepower.
i. Fan motor voltage at each connection.
j. Sheave make, size in inches, and bore.
k. Sheave dimensions, center-to-center, and amount of adjustments in inches.
l. Number of belts, make, and size.
m. Pump make and model number.
n. Pump manufacturer's serial number.
o. Pump motor make and frame size.
p. Pump motor horsepower and rpm.

2. Pump Test Data (Indicated and Actual Values):
   a. Voltage at each connection.
   b. Amperage for each phase.
   c. Water flow rate in gpm.

3. Water Test Data (Indicated and Actual Values):
   a. Entering-water temperature in deg F.
   b. Leaving-water temperature in deg F.
   c. Water temperature differential in deg F.
   d. Entering-water pressure in feet of head or psig.
   e. Leaving-water pressure in feet of head or psig.
   f. Water pressure differential in feet of head or psig.
   g. Water flow rate in gpm.
   h. Bleed water flow rate in gpm.

4. Air Data (Indicated and Actual Values):
   a. Duct airflow rate in cfm.
   b. Inlet-duct static pressure in inches wg.
   c. Outlet-duct static pressure in inches wg.
   d. Average entering-air, wet-bulb temperature in deg F.
   e. Average leaving-air, wet-bulb temperature in deg F.
   f. Ambient wet-bulb temperature in deg F.

S. Water to Air Heat Pump Test Reports: For water to air heat pumps, include the following:

1. Unit Data:
   a. Unit identification.
   b. Location.
   c. Service.
   d. Make and type.
   e. Model and serial numbers.
   f. Ratings.
   g. Record compressor data.

2. Water Test Data (Indicated and Actual Values):
   a. Entering-water temperature in deg F.
   b. Leaving-water temperature in deg F.
c. Entering-water pressure in feet of head or psig.
d. Water pressure differential in feet of head or psig.
e. Water flow rate in gpm.

3. Refrigerant Coils: Measure the following data for each coil:
a. Airflow.
b. Air pressure drop.
c. Refrigerant suction pressure and temperature.
d. Refrigerant expansion valve and refrigerant types.

T. Water to Water Heat Pump Test Reports: For water to water heat pumps, include the following:

1. Unit Data:
a. Unit identification.
b. Location.
c. Service.
d. Make and type.
e. Model and serial numbers.
f. Ratings.

2. Primary Water Test Data (Indicated and Actual Values):
a. Entering-water temperature in deg F.
b. Leaving-water temperature in deg F.
c. Entering-water pressure in feet of head or psig.
d. Water pressure differential in feet of head or psig.
e. Water flow rate in gpm.

3. Secondary Water Test Data (Indicated and Actual Values):
a. Entering-water temperature in deg F.
b. Leaving-water temperature in deg F.
c. Entering-water pressure in feet of head or psig.
d. Water pressure differential in feet of head or psig.
e. Water flow rate in gpm.

U. Heat-Exchanger/Converter Test Reports: For steam and hot-water heat exchangers, include the following:

1. Unit Data:
a. Unit identification.
b. Location.
c. Service.
d. Make and type.
e. Model and serial numbers.
f. Ratings.

2. Steam Test Data (Indicated and Actual Values):
a. Inlet pressure in psig.
b. Condensate flow rate in lb/h.

3. Primary Water Test Data (Indicated and Actual Values):
a. Entering-water temperature in deg F.
b. Leaving-water temperature in deg F.
4. Secondary Water Test Data (Indicated and Actual Values):
   a. Entering-water temperature in deg F.
   b. Leaving-water temperature in deg F.
   c. Entering-water pressure in feet of head or psig.
   d. Water pressure differential in feet of head or psig.
   e. Water flow rate in gpm.

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

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

2. Test Data (Indicated and Actual Values):
   a. Static head in feet of head or psig.
   b. Pump shutoff pressure in feet of head or psig.
   c. Actual impeller size in inches.
   d. Full-open flow rate in gpm.
   e. Full-open pressure in feet of head or psig.
   f. Final discharge pressure in feet of head or psig.
   g. Final suction pressure in feet of head or psig.
   h. Final total pressure in feet of head or psig.
   i. Final water flow rate in gpm.
   j. Voltage at each connection.
   k. Amperage for each phase.
   l. Variable frequency drive setpoint.

W. Boiler Test Reports:

1. Unit Data:
WMU Design Guidelines

2. Test Data (Indicated and Actual Values):
   a. Operating pressure in psig.
   b. Operating temperature in deg F.
   c. Entering-water temperature in deg F.
   d. Leaving-water temperature in deg F.
   e. Number of safety valves and sizes in NPS.
   f. Safety valve settings in psig.
   g. High-limit setting in psig.
   h. Operating-control setting.
   i. High-fire set point.
   j. Low-fire set point.
   k. Voltage at each connection.
   l. Amperage for each phase.
   m. Draft fan voltage at each connection.
   n. Draft fan amperage for each phase.
   o. Manifold pressure in psig.

X. Air-to-Air Heat-Recovery Unit Reports:

1. Unit Data:
   a. Unit identification.
   b. Location.
   c. Service.
   d. Make and type.
   e. Model and serial numbers.

2. Motor Data:
   a. Make and frame type and size.
   b. Horsepower and rpm.
   c. Volts, phase, and hertz.
   d. Full load amperage and service factor.
   e. Sheave make, size in inches, and bore.
   f. Sheave dimensions, center-to-center, and amount of adjustments in inches.

3. If fans are an integral part of the unit, include the following for each fan:
   a. Make and type.
   b. Arrangement and size.
   c. Sheave make, size in inches, and bore.
   d. Sheave dimensions, center-to-center, and amount of adjustments in inches.
4. Test Data (Indicated and Actual Values):
   a. Total exhaust airflow rate in cfm.
   b. Purge exhaust airflow rate in cfm.
   c. Outside airflow rate in cfm.
   d. Total exhaust fan static pressure in inches wg.
   e. Total outside-air fan static pressure in inches wg.
   f. Pressure drop on each side of recovery wheel in inches wg.
   g. Exhaust air temperature entering in deg F.
   h. Exhaust air temperature leaving in deg F.
   i. Outside-air temperature entering in deg F.
   j. Outside-air temperature leaving in deg F.
   k. Calculate sensible and total heat capacity of each airstream in MBh.

Y. Vibration Measurement Reports:
   1. Date and time of test.
   2. Vibration meter manufacturer, model number, and serial number.
   3. Equipment designation, location, equipment, speed, motor speed, and motor horsepower.
   4. Diagram of equipment showing the vibration measurement locations.
   5. Measurement readings for each measurement location.
   7. Description of predominant vibration source.

Z. Sound Measurement Reports:
   Record sound measurements on octave band and dBA test forms and on an NC or RC chart indicating the decibel level measured in each frequency band for both "background" and "HVAC system operating" readings. Record each tested location on a separate NC or RC chart. Record the following on the forms:
   1. Date and time of test. Record each tested location on its own NC curve.
   2. Sound meter manufacturer, model number, and serial number.
   3. Space location within the building including floor level and room number.
   4. Diagram or color photograph of the space showing the measurement location.
   5. Time weighting of measurements, either fast or slow.
   6. Description of the measured sound: steady, transient, or tonal.
   7. Description of predominant sound source.

AA. Indoor-Air Quality Measurement Reports for Each HVAC System:
   1. HVAC system designation.
   2. Date and time of test.
   3. Outdoor temperature, relative humidity, wind speed, and wind direction at start of test.
   4. Room number or similar description for each location.
   5. Measurements at each location.
   6. Observed deficiencies.

BB. Instrument Calibration Reports:
   1. Report Data:
      a. Instrument type and make.
      b. Serial number.
      c. Application.
d. Dates of use.
e. Dates of calibration.

3.35 VERIFICATION OF TAB REPORT

A. The TAB specialist's test and balance engineer shall conduct the inspection in the presence of Engineer[ and commissioning authority].

B. The TAB specialist's test and balance engineer shall conduct the inspection in the presence of [Architect] [Owner] [Construction Manager] [commissioning authority].

C. Engineer[ and commissioning authority] shall randomly select measurements, documented in the final report, to be rechecked. Rechecking shall be limited to either 10 percent of the total measurements recorded or the extent of measurements that can be accomplished in a normal 8-hour business day.

D. [Architect] [Owner] [Construction Manager] [Commissioning authority] shall randomly select measurements, documented in the final report, to be rechecked. Rechecking shall be limited to either 10 percent of the total measurements recorded or the extent of measurements that can be accomplished in a normal 8-hour business day.

E. If rechecks yield measurements that differ from the measurements documented in the final report by more than the tolerances allowed, the measurements shall be noted as "FAILED."

F. If the number of "FAILED" measurements is greater than 10 percent of the total measurements checked during the final inspection, the testing and balancing shall be considered incomplete and shall be rejected.

G. If TAB work fails, proceed as follows:
   
   1. TAB specialists shall recheck all measurements and make adjustments. Revise the final report and balancing device settings to include all changes; resubmit the final report and request a second final inspection.
   
   2. If the second final inspection also fails, Owner may contract the services of another TAB specialist to complete TAB work according to the Contract Documents and deduct the cost of the services from the original TAB specialist's final payment.
   
   3. If the second verification also fails, [Owner] [design professional] [Architect] may contact AABC Headquarters regarding the AABC National Performance Guaranty.

H. Prepare test and inspection reports.

3.36 ADDITIONAL TESTS

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

B. Seasonal Periods: If initial TAB procedures were not performed during near-peak summer and winter conditions, perform additional TAB during near-peak summer and winter conditions.
WMU Design Guidelines Instructions: These guidelines are to be used by the Design Professional to inform the design process and outline WMU-specific desires for all University projects. These guidelines have been edited to reflect WMU preferences, and the intent is for the Design Professional to use this information to guide their normal specifications-writing process. Straying from what is indicated in the guidelines is not prohibited, but shall be discussed with WMU during the development of the project.

SECTION 23 0700 - HVAC INSULATION

PART 1 - GENERAL

1.1 SUMMARY

A. Section includes insulation materials for HVAC systems.

B. Related Sections:
   1. Division 21 Section "Fire-Suppression Systems Insulation."
   2. Division 22 Section "Plumbing Insulation."
   3. Division 23 Section "Metal Ducts" for duct liners.
   4. Division 33 Section "Underground Hydronic Energy Distribution" for pipe insulation on underground piping outside the building.
   5. Division 33 Section "Underground Steam and Condensate Distribution Piping" for pipe insulation on underground piping outside the building.

1.2 ACTION SUBMITTALS

A. Product Data: For each type of product indicated below:
   1. Mineral fiber.
   2. Flexible elastomeric.
   3. Polyolefin.
   5. Polyisocyanurate.
   6. Field installed jackets

B. LEED Submittal:
   1. Product Data for Credit EQ 4.1: For adhesives and sealants, including printed statement of VOC content.

C. Shop Drawings:

D. Field quality-control reports.
1.3 QUALITY ASSURANCE

A. Installer Qualifications: Skilled mechanics who have successfully completed an apprenticeship program or another craft training program.

B. Fire-Test-Response Characteristics: Insulation and related materials shall have fire-test-response characteristics indicated, as determined by testing identical products per 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 and inspecting 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.

1.4 DELIVERY, STORAGE, AND HANDLING

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

1.5 COORDINATION

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

B. Coordinate installation and testing of heat tracing.

1.6 SCHEDULING

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

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

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

PART 2 - PRODUCTS

2.1 INSULATION MATERIALS

A. Comply with requirements in Part 3 schedule articles for where insulating materials shall be applied.
B. Products shall not contain asbestos, lead, mercury, or mercury compounds.

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

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

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

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

1. Block Insulation: ASTM C 552, Type I.
2. Special-Shaped Insulation: ASTM C 552, Type III.
3. Board Insulation: ASTM C 552, Type IV.
4. Preformed Pipe Insulation without Jacket: Comply with ASTM C 552, Type II, Class 1.
5. Preformed Pipe Insulation with Factory-Applied ASJ: Comply with ASTM C 552, Type II, Class 2.
6. Factory fabricate shapes according to ASTM C 450 and ASTM C 585.

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

H. Flexible Elastomeric with Factory Applied Jacket: Closed-cell, sponge- or expanded-rubber materials with laminated membrane on exterior surface, and with or without pressure sensitive adhesive. Comply with ASTM C 534, Type II for sheet materials.

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

J. 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 [I] with factory-applied vinyl jacket, Type [II with factory-applied FSK jacket]. Factory-applied jacket requirements are specified in "Factory-Applied Jackets" Article.

K. High-Temperature, Mineral-Fiber Blanket Insulation: Mineral or glass fibers bonded with a thermosetting resin. Comply with ASTM C 553, Type V, without factory-applied jacket.

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

M. Mineral-Fiber, Semi-Rigid Insulation: Mineral or glass fibers bonded with a thermosetting resin. Semi-rigid board material with factory-applied FSK jacket complying with ASTM C 1393, Type II or Type IIIA Category 2, or with properties similar to ASTM C 612, Type IB. Nominal density is 2.5 lb/cu. ft. or more. Thermal conductivity (k-value) at 100 deg F is 0.29 Btu x in./h x sq. ft. x
deg F or less. Factory-applied jacket requirements are specified in "Factory-Applied Jackets" Article.

N. Mineral-Fiber Board Insulation: Mineral or glass fibers bonded with a thermosetting resin. Comply with ASTM C 612, Type IA or Type IB. For duct and plenum applications, provide insulation [without factory-applied jacket] [with factory-applied ASJ] [with factory-applied FSK jacket]. For equipment applications, provide insulation [without factory-applied ASJ] [with factory-applied FSK jacket]. Factory-applied jacket requirements are specified in "Factory-Applied Jackets" Article.

O. High-Temperature, Mineral-Fiber Board Insulation: Mineral or glass fibers bonded with a thermosetting resin. Comply with ASTM C 612, Type III, without factory-applied jacket.

P. Mineral-Fiber, Preformed Pipe Insulation:

1. 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 or ASJ-SSL jacket. Factory-applied jacket requirements are specified in "Factory-Applied Jackets" Article.

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, [without factory-applied jacket] [with factory-applied ASJ] [with factory-applied ASJ-SSL]. Factory-applied jacket requirements are specified in "Factory-Applied Jackets" Article.

3. Type II, 1200 deg F Materials: Mineral or glass fibers bonded with a thermosetting resin. Comply with ASTM C 547, Type II, Grade A, [without factory-applied jacket] [with factory-applied ASJ] [with factory-applied ASJ-SSL]. Factory-applied jacket requirements are specified in "Factory-Applied Jackets" Article.

Q. 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.

R. Mineral-Fiber, Pipe and Tank Insulation: Mineral or glass fibers bonded with a thermosetting resin. Semi-rigid board material with factory-applied ASJ complying with ASTM C 1393, Type II or Type IIIA Category 2, or with properties similar to ASTM C 612, Type IB. Nominal density is 2.5 lb/cu. ft. or more. Thermal conductivity (k-value) at 100 deg F is 0.29 Btu x in./h x sq. ft. x deg F or less. Factory-applied jacket requirements are specified in "Factory-Applied Jackets" Article.

S. Mineral-Fiber, Pipe and Tank Insulation: Mineral or glass fibers bonded with a thermosetting resin. Semi-rigid board material with factory-applied [ASJ] [FSK jacket] complying with ASTM C 1393, Type II or Type IIIA Category 2, or with properties similar to ASTM C 612, Type IB. Nominal density is 2.5 lb/cu. ft. or more. Thermal conductivity (k-value) at 100 deg F is 0.29 Btu x in./h x sq. ft. x deg F or less. Factory-applied jacket requirements are specified in "Factory-Applied Jackets" Article.

T. Polyolefin: Unicellular, polyethylene thermal plastic insulation. Comply with ASTM C 534 or ASTM C 1427, Type I, Grade 1 for tubular materials and Type II, Grade 1 for sheet materials.

U. Polystyrene: Rigid, extruded cellular polystyrene intended for use as thermal insulation. Comply with ASTM C 578, Type IV or Type XIII, except thermal conductivity (k-value) shall not
V. Polyisocyanurate: Unfaced, rigid cellular polyisocyanurate board material intended for use as thermal insulation.

1. Thermal conductivity (k-value) shall not exceed 0.19 Btu \times \text{in.}/\text{h} \times \text{sq. ft} \times \text{deg F}(0.027 \ W/\text{m} \times \text{K}) at 75 \text{deg F}(24 \text{deg C}) after 180 days of aging.

2. Flame-spread index shall be 25 or less and smoke-developed index shall be 50 or less for thickness up to 1-1/2 inches(38 mm) as tested by ASTM E 84.

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] [2]-hour fire rating by a NRTL acceptable to authority having jurisdiction.

2.3 INSULATING CEMENTS

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

2.4 ADHESIVES

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

B. [Cellular-Glass][, ][Polyisocyanurate ][, ][and ][Polystyrene ]Adhesive: Solvent-based resin adhesive, with a service temperature range of minus 75 to plus 300 deg F.

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

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


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

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

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

F. Polystyrene Adhesive: Solvent- or water-based, synthetic resin adhesive with a service temperature range of minus 20 to plus 140 deg F.
G. ASJ Adhesive: Comply with MIL-A-3316C, Class 2, Grade A for bonding insulation jacket lap seams and joints.


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

J. PVC Jacket Adhesive: Compatible with PVC jacket.

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

2.5 MASTICS

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

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

1. Water-Vapor Permeance: ASTM E 96, Procedure B, 0.013 perm at 43-mil dry film thickness.
2. Service Temperature Range: Minus 20 to plus 180 deg F.

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

1. Water-Vapor Permeance: ASTM F 1249, 3 perms at 0.0625-inch dry film thickness.
2. Service Temperature Range: Minus 20 to plus 200 deg F.
3. Solids Content: 63 percent by volume and 73 percent by weight.

2.6 SEALANTS

A. Joint Sealants:

1. Materials shall be compatible with insulation materials, jackets, and substrates.
2. Permanently flexible, elastomeric sealant.
3. Service Temperature Range: Minus 100 to plus 300 deg F.
5. For indoor applications, use sealants that have a VOC content of 250 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
6. Joint Sealants for Cellular-Glass Products: Subject to compliance with requirements, [provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:
   a. Childers Products, Division of ITW; CP-76.
   b. Foster Products Corporation, H. B. Fuller Company; 30-45.
   c. Marathon Industries, Inc.; 405.
   d. Mon-Eco Industries, Inc.; 44-05.
   e. Pittsburgh Corning Corporation; Pittseal 444.
   f. Vimasco Corporation; 750.
   g. <Insert manufacturer's name; product name or designation.>

7. Joint Sealants for Polystyrene Products: Subject to compliance with requirements, [provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:
   a. Childers Products, Division of ITW; CP-70.
   c. Marathon Industries, Inc.; 405.
   d. Mon-Eco Industries, Inc.; 44-05.
   e. Vimasco Corporation; 750.
   f. <Insert manufacturer's name; product name or designation.>

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


10. Service Temperature Range: Minus 100 to plus 300 deg F.

11. Color: White or gray.

12. For indoor applications, use sealants that have a VOC content of 250 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).

B. FSK and Metal Jacket Flashing Sealants:

C. FSK Jacket Flashing Sealants:

1. Sealants: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:
   a. Childers Products, Division of ITW; CP-76-8.
   b. Foster Products Corporation, H. B. Fuller Company; 95-44.
   c. Marathon Industries, Inc.; 405.
   d. Mon-Eco Industries, Inc.; 44-05.
   e. Vimasco Corporation; 750.

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 250 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).

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

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

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

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:
6. PVDC Jacket for Outdoor Applications
7. PVDC-SSL Jacket:

2.8 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. inch, in a Leno weave, for duct, equipment, and pipe.

2.9 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 Fitting 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. Adhesive: As recommended by jacket material manufacturer.
3. Color: [White] [Color-code jackets based on system. Color as selected by Architect].
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, traps, and mechanical joints.
   b. 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.
5. Factory-fabricated tank heads and tank side panels.

D. Aluminum Jacket: Comply with ASTM B 209, Alloy 3003, 3005, 3105 or 5005, Temper H-14.

1. Sheet and roll stock ready for shop or field sizing or factory cut and rolled to size.
2. Finish and thickness are indicated in field-applied jacket schedules.
3. Moisture Barrier for Indoor Applications: [1-mil- thick, heat-bonded polyethylene and kraft paper] [3-mil- thick, heat-bonded polyethylene and kraft paper] [2.5-mil- thick Polysurlyn].
4. Moisture Barrier for Outdoor Applications: [3-mil- thick, heat-bonded polyethylene and kraft paper] [2.5-mil- thick Polysurlyn].
5. 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. Self-Adhesive Outdoor Jacket: Minimum 40-mil- thick, laminated vapor barrier and waterproofing membrane for installation over insulation located aboveground outdoors; consisting of a rubberized bituminous resin on a crosslaminated polyethylene film covered with aluminum-foil facing.

1. Coordinate color of optional colors with Architect and Owner.
3. Products: Subject to compliance with requirements, provide products by one of the following:
   a. Polyguard; Alumaguard.
   b. MFM Building Products; Flex Clad 400

F. PVDC Jacket for Indoor Applications:

G. PVDC Jacket for Outdoor Applications

H. PVDC-SSL Jacket

I. Underground Direct-Buried Jacket: 125-mil- thick vapor barrier and waterproofing membrane consisting of a rubberized bituminous resin reinforced with a woven-glass fiber or polyester scrim and laminated aluminum foil.

2.10 TAPES

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

1. Width: 3 inches.
2. Thickness: 11.5 mils.
4. Elongation: 2 percent.
5. Tensile Strength: 40 lbf/inch in width.
6. ASJ Tape Disks and Squares: Precut disks or squares of ASJ tape.

B. FSK Tape: Foil-face, vapor-retarder tape matching factory-applied jacket with acrylic adhesive; complying with ASTM C 1136.
   1. Width: 3 inches.
   2. Thickness: 6.5 mils.
   4. Elongation: 2 percent.
   5. Tensile Strength: 40 lbf/inch in width.
   6. FSK Tape Disks and Squares: Precut disks or squares of FSK tape.

C. PVC Tape: White vapor-retarder tape matching field-applied PVC jacket with acrylic adhesive. Suitable for indoor and outdoor applications.
   1. Width: 2 inches.
   2. Thickness: 6 mils.
   3. Adhesion: 64 ounces force/inch in width.
   4. Elongation: 500 percent.
   5. Tensile Strength: 18 lbf/inch in width.

D. Aluminum-Foil Tape: Vapor-retarder tape with acrylic adhesive.
   1. Width: 2 inches.
   2. Thickness: 3.7 mils.
   3. Adhesion: 100 ounces force/inch in width.
   4. Elongation: 5 percent.
   5. Tensile Strength: 34 lbf/inch in width.

E. PVDC Tape for Indoor Applications:

F. PVDC Tape for Outdoor Applications:

2.11 SECUREMENTS

A. Stainless Steel: ASTM A 167 or ASTM A 240/A 240M, Type 304; 0.015 inch thick, 1/2 inch wide with wing seal.

B. Aluminum Bands: ASTM B 209, Alloy 3003, 3005, 3105, or 5005; Temper H-14, 0.020 inch thick, 1/2 inch or 3/4 inch wide with wing or closed seal.

C. Aluminum Bands: ASTM B 209, Alloy 3003, 3005, 3105, or 5005; Temper H-14, 0.020 inch thick, [1/2 inch] [3/4 inch] wide with [wing seal] [closed seal] [wing or closed seal].

D. Insulation Pins and Hangers:
   1. Metal, Adhesively Attached, Perforated-Base Insulation Hangers: Baseplate welded to projecting spindle that is capable of holding insulation, of thickness indicated, securely in
position indicated when self-locking washer is in place. Comply with the following requirements:

a. **Baseplate**: Perforated, galvanized carbon-steel sheet, 0.030 inch thick by 2 inches square.

b. **Spindle**: Copper- or zinc-coated, low carbon steel, aluminum, or stainless steel; fully annealed, 0.106-inch- diameter shank, length to suit depth of insulation indicated.

c. **Spindle**: [Copper- or zinc-coated, low carbon steel] [Aluminum] [Stainless steel], fully annealed, 0.106-inch- diameter shank, length to suit depth of insulation indicated.

d. **Adhesive**: Recommended by hanger manufacturer. Product with demonstrated capability to bond insulation hanger securely to substrates indicated without damaging insulation, hangers, and substrates.

2. **Nonmetal, Adhesively Attached, Perforated-Base Insulation Hangers**: Baseplate fastened to projecting spindle that is capable of holding insulation, of thickness indicated, securely in position indicated when self-locking washer is in place. Comply with the following requirements:

a. **Baseplate**: Perforated, nylon sheet, 0.030 inch thick by 1-1/2 inches in diameter.

b. **Spindle**: Nylon, 0.106-inch- diameter shank, length to suit depth of insulation indicated, up to 2-1/2 inches.

c. **Adhesive**: Recommended by hanger manufacturer. Product with demonstrated capability to bond insulation hanger securely to substrates indicated without damaging insulation, hangers, and substrates.

3. **Self-Sticking-Base Insulation Hangers**: Baseplate welded to projecting spindle that is capable of holding insulation, of thickness indicated, securely in position indicated when self-locking washer is in place. Comply with the following requirements:

a. **Baseplate**: Galvanized carbon-steel sheet, 0.030 inch thick by 2 inches square.

b. **Spindle**: Copper- or zinc-coated, low carbon steel, aluminum, or stainless steel; fully annealed, 0.106-inch- diameter shank, length to suit depth of insulation indicated.

c. **Adhesive**: Adhesive-backed base with a peel-off protective cover.

4. **Insulation-Retaining Washers**: Self-locking washers formed from 0.016-inch- thick, galvanized-steel, aluminum, or stainless-steel sheet, with beveled edge sized as required to hold insulation securely in place but not less than 1-1/2 inches in diameter.

5. **Insulation-Retaining Washers**: Self-locking washers formed from 0.016-inch- thick, [galvanized-steel] [aluminum] [stainless-steel] sheet, with beveled edge sized as required to hold insulation securely in place but not less than 1-1/2 inches in diameter.

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

6. **Nonmetal Insulation-Retaining Washers**: Self-locking washers formed from 0.016-inch-thick nylon sheet, with beveled edge sized as required to hold insulation securely in place but not less than 1-1/2 inches in diameter.

E. **Staples**: Outward-clinching insulation staples, nominal 3/4-inch- wide, stainless steel or Monel.

F. **Wire**: 0.062-inch soft-annealed, stainless steel.
G. Wire: [0.080-inch nickel-copper alloy] [0.062-inch soft-annealed, stainless steel] [0.062-inch soft-annealed, galvanized steel].

2.12 CORNER ANGLES
A. PVC Corner Angles: 30 mils thick, minimum 1 by 1 inch, PVC according to ASTM D 1784, Class 16354-C. White or color-coded to match adjacent surface.
B. Aluminum Corner Angles: 0.040 inch thick, minimum 1 by 1 inch, aluminum according to ASTM B 209, Alloy 3003, 3005, 3105 or 5005; Temper H-14.

2.13 ACOUSTIC LAG WRAPPING
A. Material: Loaded vinyl barrier, limp, unreinforced.
   3. Density: One pound per square foot.

2.14 REMOVABLE INSULATED EQUIPMENT COVER
A. Provide custom built removable insulating equipment cover for equipment indicated. Covers shall conform to the shape of the equipment.
   1. Construct covers using two layers of flexible vapor barrier materials with two parallel rows of lock stitching, stuffed with insulation, using belt and loops or velcro like material to hold cover in place.
   2. Construct covers using two layers of flexible heat resistant materials with two parallel rows of lock stitching, stuffed with insulation, using belt and loops or velcro like material to hold cover in place.
   3. Insulation thickness to provide cold face temperature of 100°F(38°C) at maximum operating temperature.
   4. Cover to overlap pipe insulation.

PART 3 - EXECUTION

3.1 PREPARATION
A. Surface Preparation: Clean and dry surfaces to receive insulation. Remove materials that will adversely affect insulation application.
B. Coordinate insulation installation with the trade installing heat tracing. Comply with requirements for heat tracing that apply to insulation.
C. Mix insulating cements with clean potable water; if insulating cements are to be in contact with stainless-steel surfaces, use demineralized water.
3.2 GENERAL INSTALLATION REQUIREMENTS

A. Provide removable insulation covers on fittings, pumps, balancing valves, control valves, etc. that may require access for maintenance for adjustment.

B. Provide removable insulation covers on fittings, control valves, etc. that may require access for maintenance for adjustment.

C. Provide molded PVC covers on fittings, tees, elbows, end caps, valves, etc.
   1. Alternatively, flexible unicellular insulation may be custom fit over low temperature pumps and valves provided that it is removable.

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

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

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

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

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

I. Do not weld brackets, clips, or other attachment devices to piping, fittings, and specialties.

J. Keep insulation materials dry during application and finishing.

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

L. Install insulation with least number of joints practical.

M. 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.
N. Apply adhesives, mastics, and sealants at manufacturer’s recommended coverage rate and wet and dry film thicknesses.

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

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

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

R. 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.

S. 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.
   5. Handholes.
   6. Cleanouts.

3.3 PENETRATIONS

A. Insulation Installation at Roof Penetrations: Install insulation continuously through roof penetrations.
   1. Seal penetrations with flashing sealant.
   2. For applications requiring only indoor insulation, terminate insulation above roof surface and seal with joint sealant.
3. For applications requiring indoor and outdoor insulation, install insulation for outdoor applications tightly joined to indoor insulation ends. Seal joint with joint sealant.
4. Extend jacket of outdoor insulation outside roof flashing at least 2 inches below top of roof flashing.
5. 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.
3. For applications requiring indoor and outdoor insulation, install insulation for outdoor applications tightly joined to indoor insulation ends. Seal joint with joint sealant.
4. Extend jacket of outdoor insulation outside wall flashing and overlap wall flashing at least 2 inches.
5. 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. 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 Division 07 Section "Penetration Firestopping" and fire-resistive joint sealers.

F. Insulation Installation at Floor Penetrations:
1. Duct: Install insulation continuously through floor penetrations that are not fire rated. 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. Pipe: Install insulation continuously through floor penetrations.
3. Seal penetrations through fire-rated assemblies. Comply with requirements in Division 07 Section "Penetration Firestopping."

3.4 EQUIPMENT, TANK, AND VESSEL INSULATION INSTALLATION

A. Mineral Fiber, Pipe and Tank Insulation Installation for Tanks and Vessels: Secure insulation with adhesive and anchor pins and speed washers.
1. Apply adhesives according to manufacturer's recommended coverage rates per unit area, for 50 percent coverage of tank and vessel surfaces.
2. Apply adhesives according to manufacturer's recommended coverage rates per unit area, for [100] [50] <insert percentage> percent coverage of tank and vessel surfaces.
3. Groove and score insulation materials to fit as closely as possible to equipment, including contours. Bevel insulation edges for cylindrical surfaces for tight joints. Stagger end joints.
4. Protect exposed corners with secured corner angles.
5. Install adhesively attached or self-sticking insulation hangers and speed washers on sides of tanks and vessels as follows:
   a. Do not weld anchor pins to ASME-labeled pressure vessels.
   b. Select insulation hangers and adhesive that are compatible with service temperature and with substrate.
   c. On tanks and vessels, maximum anchor-pin spacing is 3 inches from insulation end joints, and 16 inches o.c. in both directions.
   d. Do not overcompress insulation during installation.
   e. Cut and miter insulation segments to fit curved sides and domed heads of tanks and vessels.
   f. Impale insulation over anchor pins and attach speed washers.
   g. Cut excess portion of pins extending beyond speed washers or bend parallel with insulation surface. Cover exposed pins and washers with tape matching insulation facing.
6. Secure each layer of insulation with stainless-steel or aluminum bands. Select band material compatible with insulation materials.
7. Where insulation hangers on equipment and vessels are not permitted or practical and where insulation support rings are not provided, install a girdle network for securing insulation. Stretch prestressed aircraft cable around the diameter of vessel and make taut with clamps, turnbuckles, or breather springs. Place one circumferential girdle around equipment approximately 6 inches from each end. Install wire or cable between two circumferential girdles 12 inches o.c. Install a wire ring around each end and around outer periphery of center openings, and stretch prestressed aircraft cable radially from the wire ring to nearest circumferential girdle. Install additional circumferential girdles along the body of equipment or tank at a minimum spacing of 48 inches o.c. Use this network for securing insulation with tie wire or bands.
8. Stagger joints between insulation layers at least 3 inches.
9. Install insulation in removable segments on equipment access doors, manholes, handholes, and other elements that require frequent removal for service and inspection.
10. Bevel and seal insulation ends around manholes, handholes, ASME stamps, and nameplates.
11. For equipment with surface temperatures below ambient, apply mastic to open ends, joints, seams, breaks, and punctures in insulation.

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

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

C. Insulation Installation on Pumps:

1. Fabricate metal boxes lined with insulation. Fit boxes around pumps and coincide box joints with splits in pump casings. Fabricate joints with outward bolted flanges. Bolt flanges on 6-inch centers, starting at corners. Install 3/8-inch diameter fasteners with wing nuts. Alternatively, secure the box sections together using a latching mechanism.
2. Fabricate boxes from galvanized steel or aluminum, at least 0.050 inch thick.
3. Fabricate boxes from [galvanized steel] [aluminum] [stainless steel], at least [0.040 inch] [0.050 inch] [0.060 inch] thick.

4. For below ambient services, install a vapor barrier at seams, joints, and penetrations. Seal between flanges with replaceable gasket material to form a vapor barrier.

3.5 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 or plug can be easily removed and replaced without damaging the insulation and jacket. Provide a removable reusable insulation cover. For below ambient services, provide a design that maintains vapor barrier.

6. Insulate flanges and unions using a section of oversized preformed pipe insulation. Overlap adjoining pipe insulation by not less than two times the thickness of pipe insulation, or one pipe diameter, whichever is thicker.

7. Cover segmented insulated surfaces with a layer of finishing cement and coat with a mastic. Install vapor-barrier mastic for below ambient services and a breather mastic for above ambient services. Reinforce the mastic with fabric-reinforcing mesh. Trowel the mastic to a smooth and well-shaped contour.

8. For mineral fiber insulation, 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. For services not specified to receive a field-applied jacket except for flexible elastomeric, 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.
10. 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.

11. 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, vessels, and equipment. 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.

3.6 CELLULAR-GLASS INSULATION INSTALLATION

A. Insulation Installation on Straight Pipes and Tubes:

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

B. Insulation Installation on Pipe Flanges:

1. Install preformed pipe insulation to outer diameter of pipe flange.
2. Make width of insulation section same as overall width of flange and bolts, plus twice the thickness of pipe insulation.
3. Fill voids between inner circumference of flange insulation and outer circumference of adjacent straight pipe segments with cut sections of cellular-glass block insulation of same thickness as pipe insulation.
4. Install jacket material with manufacturer’s recommended adhesive, overlap seams at least 1 inch, and seal joints with flashing sealant.

C. Insulation Installation on Pipe Fittings and Elbows:

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

D. Insulation Installation on Valves and Pipe Specialties:

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

3.7 FLEXIBLE ELASTOMERIC INSULATION INSTALLATION

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

B. Provide center peak metal cap on top of new insulation to match existing construction.

1. Refinish worn-out portions of existing cap to match new.

C. 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 manufacturers recommended adhesive to eliminate openings in insulation that allow passage of air to surface being insulated.

D. 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.

E. Insulation Installation on Valves and Pipe Specialties:

1. Install preformed valve covers manufactured of same material as pipe insulation when available.
2. When preformed valve covers are not available, install cut sections of pipe and sheet insulation to valve body. Arrange insulation to permit access to packing and to allow valve operation without disturbing insulation.

3. Install insulation to flanges as specified for flange insulation application.

4. Secure insulation to valves and specialties and seal seams with manufacturer's recommended adhesive to eliminate openings in insulation that allow passage of air to surface being insulated.

3.8 MINERAL-FIBER INSULATION INSTALLATION

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 but 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.

E. Blanket Insulation Installation on Ducts and Plenums: Secure with adhesive and insulation pins.
1. Apply adhesives according to manufacturer's recommended coverage rates per unit area, for 50 percent coverage of duct and plenum surfaces.
2. Apply adhesive to entire circumference of ducts and to all surfaces of fittings and transitions.
3. Install either capacitor-discharge-weld pins and speed washers or cupped-head, capacitor-discharge-weld pins on sides and bottom of horizontal ducts and sides of vertical ducts as follows:
   a. On duct sides with dimensions 18 inches and smaller, place pins along longitudinal centerline of duct. Space 3 inches maximum from insulation end joints, and 16 inches o.c.
   b. On duct sides with dimensions larger than 18 inches, place pins 16 inches o.c. each way, and 3 inches maximum from insulation joints. Install additional pins to hold insulation tightly against surface at cross bracing.
   c. Pins may be omitted from top surface of horizontal, rectangular ducts and plenums.
   d. Do not overcompress insulation during installation.
   e. Impale insulation over pins and attach speed washers.
   f. Cut excess portion of pins extending beyond speed washers or bend parallel with insulation surface. Cover exposed pins and washers with tape matching insulation facing.
4. For ducts and plenums with surface temperatures below ambient, install a continuous unbroken vapor barrier. Create a facing lap for longitudinal seams and end joints with insulation by removing 2 inches from 1 edge and 1 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 2 times the insulation thickness but not less than 3 inches.
5. Overlap unfaced blankets a minimum of 2 inches on longitudinal seams and end joints. At end joints, secure with steel bands spaced a maximum of 18 inches o.c.
6. Install insulation on rectangular duct elbows and transitions with a full insulation section for each surface. Install insulation on round and flat-oval duct elbows with individually mitered gores cut to fit the elbow.
7. Insulate duct stiffeners, hangers, and flanges that protrude beyond insulation surface with 6-inch- wide strips of same material used to insulate duct. Secure on alternating sides of stiffener, hanger, and flange with pins spaced 6 inches o.c.

F. Board Insulation Installation on Ducts and Plenums: Secure with adhesive and insulation pins.
   1. Apply adhesives according to manufacturer's recommended coverage rates per unit area, for 50 percent coverage of duct and plenum surfaces.
   2. Apply adhesive to entire circumference of ducts and to all surfaces of fittings and transitions.
3. Install either capacitor-discharge-weld pins and speed washers or cupped-head, capacitor-discharge-weld pins on sides and bottom of horizontal ducts and sides of vertical ducts as follows:
   a. On duct sides with dimensions 18 inches and smaller, place pins along longitudinal centerline of duct. Space 3 inches maximum from insulation end joints, and 16 inches o.c.
   b. On duct sides with dimensions larger than 18 inches, space pins 16 inches o.c. each way, and 3 inches maximum from insulation joints. Install additional pins to hold insulation tightly against surface at cross bracing.
   c. Pins may be omitted from top surface of horizontal, rectangular ducts and plenums.
   d. Do not overcompress insulation during installation.
   e. Cut excess portion of pins extending beyond speed washers or bend parallel with insulation surface. Cover exposed pins and washers with tape matching insulation facing.

4. For ducts and plenums with surface temperatures below ambient, install a continuous unbroken vapor barrier. Create a facing lap for longitudinal seams and end joints with insulation by removing 2 inches from 1 edge and 1 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 2 times the insulation thickness but not less than 3 inches.

5. Install insulation on rectangular duct elbows and transitions with a full insulation section for each surface. Groove and score insulation to fit as closely as possible to outside and inside radius of elbows. Install insulation on round and flat-oval duct elbows with individually mitered gores cut to fit the elbow.

6. Insulate duct stiffeners, hangers, and flanges that protrude beyond insulation surface with 6-inch- wide strips of same material used to insulate duct. Secure on alternating sides of stiffener, hanger, and flange with pins spaced 6 inches o.c.

3.9 POLYOLEFIN INSULATION INSTALLATION

A. Insulation Installation on Straight Pipes and Tubes:
   1. Seal split-tube 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 polyolefin 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 polyolefin 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 cut sections of polyolefin pipe and sheet insulation to valve body.
2. Arrange insulation to permit access to packing and to allow valve operation without disturbing insulation.
3. Install insulation to flanges as specified for flange insulation application.
4. Secure insulation to valves and specialties, and seal seams with manufacturer's recommended adhesive to eliminate openings in insulation that allow passage of air to surface being insulated.

3.10 POLYISOCYANURATE INSULATION INSTALLATION

A. Insulation Installation on Inside of Horizontal Unit Ventilator Outside Air Intake Sleeve:
1. All insulation shall be tightly butted and free of voids and gaps at all joints.

3.11 POLYSTYRENE INSULATION INSTALLATION

3.12 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 fitting jackets are indicated, install with 1-inch overlap at longitudinal seams and end joints; for horizontal applications, install with longitudinal seams along top and bottom of tanks and vessels. Seal with manufacturers 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 selecting 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.

E. Install self-adhesive outdoor jacket over rigid mineral fiber duct insulation per jacket manufacturer’s recommendations.

F. Install acoustic lag wrapping over <Insert Location Here>. Attach and seal sound barrier material at all edges per manufacturer’s recommendations.

3.13 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 Division 07 Section “Penetration Firestopping.”

3.14 FINISHES

A. Paintable Jacket Material: Paint jacket with paint system identified in Division 09 painting Sections.

B. Flexible Elastomeric Thermal Insulation: After adhesive has fully cured, apply two coats of insulation manufacturer’s recommended protective coating.
1. Repair, clean, and refinish existing exterior flexible elastomeric thermal duct insulation.

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

D. Do not field paint aluminum jackets.

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

3.15 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 [one] <Insert number> location(s) for each duct system defined in the "Duct Insulation Schedule, General" Article.

2. Inspect field-insulated equipment, randomly selected by Architect, by removing field-applied jacket and insulation in layers in reverse order of their installation. Extent of inspection shall be limited to [one] <Insert number> location(s) for each type of equipment defined in the "Equipment Insulation Schedule" Article. For large equipment, remove only a portion adequate to determine compliance.

3. Inspect pipe, fittings, strainers, and valves, 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] <Insert number> locations of straight pipe, [three] <Insert number> locations of threaded fittings, [three] <Insert number> locations of welded fittings, [two] <Insert number> locations of threaded strainers, [two] <Insert number> locations of welded strainers, [three] <Insert number> locations of threaded valves, and [three] <Insert number> 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.

3.16 BOILER BREECHING INSULATION SCHEDULE

A. Round, Exposed Breeching and Connector: High-temperature mineral-fiber [blanket] [board], 3 inches thick and 3-lb/cu. ft. nominal density.

B. Round, Concealed Breeching and Connector Insulation: High-temperature mineral-fiber [blanket] [board], 3 inches thick and 3-lb/cu. ft. nominal density.

3.17 DUCT INSULATION SCHEDULE, GENERAL

A. Plenums and Ducts Requiring Insulation: Insulate the following in accordance with insulation schedule:
1. Supply air.
2. Outdoor air.
3. Return air.
4. Relief air plenum at louver.
5. Relief air.
6. Exhaust air to and from AHU.
7. Existing ductwork where indicated.
8. Outdoor supply air.
9. Outdoor return air.
10. Duct mounted reheat coils.
11. Slot and linear diffuser plenums.
12. Commercial, kitchen hood exhaust.
13. Oven and warewash exhaust.

B. Items Not Insulated:
1. Factory-insulated flexible ducts.
2. Factory-insulated plenums and casings, except as indicated.
3. Flexible connectors.
5. Factory-insulated access panels and doors.
6. Metal ducts with duct liner of sufficient thickness to comply with energy code and ASHRAE/IESNA 90.1.
7. Exposed metal ducts within rooms they are serving.

3.18 INDOOR DUCT AND PLENUM INSULATION SCHEDULE

A. Concealed supply and return air duct and plenum insulation shall be one of the following:

B. Concealed supply air duct and plenum insulation shall be one of the following:

   1. Mineral-Fiber Blanket: 1-1/2 inches (38 mm) thick and 0.75-lb/cu. ft. (12-kg/cu. m) nominal density.
   2. Semi-Rigid Mineral-Fiber Blanket: 1 inches (25 mm) thick and 2.5-lb/cu. ft. (32-kg/cu. m) nominal density.

C. Exposed, outside, supply and exhaust air duct insulation within mechanical room shall be the following:

D. Exposed, outside, relief, supply and return air duct insulation within mechanical rooms shall be the following:

   1. Mineral-Fiber Board (Rectangular Duct): 1-1/2 inches (38 mm) thick and 3-lb/cu. ft. (48-kg/cu. m) nominal density.
   2. Mineral-Fiber Blanket: 1-1/2 inches (38 mm) thick and 0.75-lb/cu. ft. (12-kg/cu. m) nominal density.
   3. Semi-Rigid Mineral-Fiber Board (Round Duct): 1 inches (25 mm) thick and 2.5-lb/cu. ft. (32-kg/cu. m) nominal density.
E. Existing concealed supply and exhaust air duct and plenum insulation where indicated shall be one of the following:
   1. Mineral-Fiber Blanket: 1-1/2 inches (38 mm) thick and 0.75-lb/cu. ft. (12-kg/cu. m) nominal density.

F. Exposed relief air duct insulation within mechanical room at louver plenum shall be the following:
   1. Mineral-Fiber Board: 1-1/2 inches (38 mm) thick and 3-lb/cu. ft. (48-kg/cu. m) nominal density.

G. Concealed exhaust air duct and plenum insulation from energy recovery unit to penetration of building exterior shall be the following:
   1. Mineral-Fiber Board (Rectangular Duct): 1-1/2 inches (38 mm) thick and 3-lb/cu. ft. (48-kg/cu. m) nominal density.
   2. Semi-Rigid Mineral-Fiber Board (Round Duct): 1 inches (25 mm) thick and 2.5-lb/cu. ft. (32-kg/cu. m) nominal density.

H. Concealed outside air duct and plenum insulation to and from energy recovery unit shall be the following:
   1. Mineral-Fiber Board (Rectangular Duct): 1-1/2 inches (38 mm) thick and 3-lb/cu. ft. (48-kg/cu. m) nominal density.
   2. Semi-Rigid Mineral-Fiber Board (Round Duct): 1 inches (25 mm) thick and 2.5-lb/cu. ft. (32-kg/cu. m) nominal density.

I. Vertical unit ventilator outdoor air duct and plenum insulation shall be the following:
   1. Flexible Elastomeric: 1 inches (25 mm) thick.

J. Concealed [outside, ][relief, ]supply and return air duct and plenum insulation shall be the following:
   1. Mineral-Fiber Blanket: 1-1/2 inches (38 mm) thick and 0.75-lb/cu. ft. (12-kg/cu. m) nominal density.

K. Concealed exhaust-air duct and plenum insulation between isolation damper and penetration of building exterior shall be the following:
   1. Mineral-Fiber Blanket: 1-1/2 inches (38 mm) thick and 0.75-lb/cu. ft. (12-kg/cu. m) nominal density.

L. Concealed, Type I, Commercial, Kitchen Hood Exhaust Duct and Plenum Insulation: Fire-rated [blanket] [board] [blanket or board]; thickness as required to achieve 2-hour fire rating.

M. Exposed, round and flat-oval, [outside, ][relief, ]supply and return air duct insulation within mechanical rooms shall be the following:
1. Mineral-Fiber Board: 1-1/2 inches (38 mm) thick and 3-lb/cu. ft. (48-kg/cu. m) nominal density.

N. Exposed, round [and flat-oval, ]exhaust-air duct insulation within mechanical rooms between isolation damper and penetration of building exterior [or becomes concealed ]shall be the following:

1. Mineral-Fiber Board: 1-1/2 inches (38 mm) thick and 3-lb/cu. ft. (48-kg/cu. m) nominal density.

O. Exposed, rectangular, [outside, ][relief, ]supply and return air duct and plenum insulation within mechanical rooms shall be the following:

1. Mineral-Fiber Board: 1-1/2 inches (38 mm) thick and 3-lb/cu. ft. (48-kg/cu. m) nominal density.

P. Exposed, rectangular, exhaust-air duct and plenum insulation within mechanical rooms between isolation damper and penetration of building exterior [or becomes concealed ]shall be the following:

1. Mineral-Fiber Board: 1-1/2 inches (38 mm) thick and 3-lb/cu. ft. (48-kg/cu. m) nominal density.

Q. Exposed, Type I, Commercial, Kitchen Hood Exhaust Duct and Plenum Insulation: Fire-rated [blanket] [board] [blanket or board]; thickness as required to achieve 2-hour fire rating.

R. Exposed [outside, ][relief, ]supply and return air duct insulation within mechanical rooms shall be the following:

1. Mineral-Fiber Board (For Rectangular Applications): 1-1/2 inches (38 mm) thick and 3-lb/cu. ft. (48-kg/cu. m) nominal density.
2. Mineral-Fiber Duct, Pipe and Tank (For Round or Flat Oval Duct Applications): 1-1/2 inches thick.

S. Exposed exhaust-air duct insulation within mechanical rooms between isolation damper and penetration of building exterior [or becomes concealed ]shall be the following:

1. Mineral-Fiber Board (For Rectangular Applications): 1-1/2 inches (38 mm) thick and 3-lb/cu. ft. (48-kg/cu. m) nominal density.

3.19 ABOVEGROUND, OUTDOOR DUCT AND PLENUM INSULATION SCHEDULE

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

B. Outdoor duct and plenum insulation shall be the following:

1. New Mineral-Fiber Board: 2 inches (50 mm) thick and 3-lb/cu. ft. (48-kg/cu. m) nominal density, with protective self-adhesive field applied jacket.
   a. Peak insulation on top of duct to shed water.
2. Existing Flexible Elastomeric: 2-1/2 inches (63 mm) thick, with protective field applied finish.
   a. Repair, clean, and refinish existing exterior flexible elastomeric thermal duct insulation.

3.20 EQUIPMENT INSULATION SCHEDULE

3.21 PIPING INSULATION SCHEDULE, GENERAL

A. Acceptable preformed pipe insulation materials and thicknesses are identified for each piping system and pipe size range.

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

C. Items Not Insulated: Unless otherwise indicated, do not install insulation on the following:
   1. Drainage piping located in crawl spaces.
   2. Underground piping.
   3. Chrome-plated pipes and fittings.

3.22 INDOOR PIPING INSULATION SCHEDULE

A. Condensate and Equipment Drain Water below 60 Deg F (16 Deg C) Located in Ceiling Space:
   1. All Pipe Sizes: Insulation shall be one of the following:
      a. Flexible Elastomeric: 1 inch (25 mm) thick.
      b. Mineral-Fiber, Preformed Pipe Insulation, Type I: 1 inch (25 mm) thick.

B. Chilled Water, above 40 Deg F: Insulation shall be the following:
   1. Flexible Elastomeric: 1 inch thick.
   2. Mineral-Fiber, Preformed Pipe, Type I: 1 inch thick, NPS 4 diameter and under; 1-1/2 inch thick, over NPS 4 diameter.

C. Heating-Hot-Water Supply and Return, 200 Deg F and below: Insulation shall be the following:
   1. Mineral-Fiber, Preformed Pipe, Type I: 2 inch thick, NPS 2 diameter and under; 2-1/2 inch thick, NPS 2-1/2 to NPS 4 diameter; 3 inch thick, NPS 5 diameter and larger.

D. Low Pressure Steam and Condensate (15 psi and less): Insulation shall be the following:
   1. Mineral-Fiber, Preformed Pipe, Type I: 2 inch thick, NPS 2 diameter and under; 2-1/2 inch thick, NPS 2-1/2 to NPS 4 diameter; 3 inch thick, NPS 5 diameter and larger.

E. Medium Pressure Steam and Condensate Piping (16-120 psi): Insulation shall be the following:
1. Mineral-Fiber, Preformed Pipe, Type I: 2 inch thick, NPS 2 diameter and under; 2-1/2 inch thick, NPS 2-1/2 to NPS 4 diameter; 3 inch thick, NPS 5 diameter and larger.

F. Chilled Water, above 40 Deg F: Insulation shall be one of the following:
   1. Flexible Elastomeric: 1 inch thick.
   2. Mineral-Fiber, Preformed Pipe, Type I: 1 inch thick.
   3. Polyolefin: 1 inch thick.

G. Heating-Hot-Water Supply and Return, 200 Deg F and below: Insulation shall be one of the following:
   1. Mineral-Fiber, Preformed Pipe, Type I: 1 inch thick, NPS 3 diameter and under; 1-1/2 inch thick, over NPS 3 diameter.

H. Refrigerant Suction and Hot-Gas Piping: Insulation shall be one of the following:
   1. Flexible Elastomeric: 1 inch thick.
   2. Mineral-Fiber, Preformed Pipe, Type I: 1 inch thick.
   3. Polyolefin: 1 inch thick.

I. Refrigerant Suction and Hot-Gas Flexible Tubing: Flexible elastomeric [Polyolefin], 1 inch <Insert thickness> thick.

J. Dual-Service Heating and Cooling, 40 to 200 Deg F: Insulation shall be the following:
   1. Mineral-Fiber, Preformed Pipe, Type I: 1 inch thick, NPS 3 diameter and under; 1-1/2 inch thick, over NPS 3 diameter.

K. Low Pressure Steam and Condensate (15 psi and less): Insulation shall be the following:
   1. Mineral-Fiber, Preformed Pipe, Type I: 1-1/2 inch thick, NPS 1-1/4 inches diameter and under; 2 inch thick, over NPS 1-1/4 inches diameter.

L. Medium Pressure Steam and Condensate Piping (16-120 psi): Insulation shall be the following:
   1. Mineral-Fiber, Preformed Pipe, Type I: 1-1/2 inch thick, NPS 3/4 inch diameter and under; 2-1/2 inch thick, NPS 1 inch diameter to NPS 1-1/4 inches diameter; 3 inch thick, over NPS 1-1/4 diameter.

3.23 OUTDOOR, ABOVEGROUND PIPING INSULATION SCHEDULE

A. Chilled Water: Insulation shall be one of the following:
   1. Flexible Elastomeric: 2 inches thick.
   2. Mineral-Fiber, Preformed Pipe Insulation, Type I: 2 inches thick.

B. Heating-Hot-Water Supply and Return, 200 Deg F and below: Insulation shall be the following:
   1. Mineral-Fiber, Preformed Pipe Insulation, Type I: 2-1/2 inches thick.

C. Refrigerant Suction and Hot-Gas Piping: Insulation shall be the following:
1. Flexible Elastomeric: 2 inches thick.
2. Mineral-Fiber, Preformed Pipe Insulation, Type I: 2 inches thick.

D. Refrigerant Suction and Hot-Gas Flexible Tubing: Insulation shall be [one of] the following:
   1. Flexible Elastomeric: [2 inches] <Insert thickness> thick.

E. Dual-Service Heating and Cooling: Insulation shall be one of the following:
   1. Mineral-Fiber, Preformed Pipe Insulation, Type I: 2-1/2 inches thick.

F. Low Pressure Steam and Condensate (15 psi and less): Insulation shall be the following:
   1. Mineral-Fiber, Preformed Pipe, Type I: 3 incehesthick.

G. Medium Pressure Steam and Condensate Piping (16-120 psi): Insulation shall be the following:
   1. Mineral-Fiber, Preformed Pipe, Type I: 4 incehesthick.

3.24 OUTDOOR, UNDERGROUND PIPING INSULATION SCHEDULE


C. Dual-Service Heating and Cooling, All Sizes, 40 to 200 Deg F: Cellular glass, [3 inches] <Insert thickness> thick.

3.25 INDOOR, FIELD-APPLIED JACKET SCHEDULE

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

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

C. Piping, Fittings:

D. Mineral Fiber Pipe Fittings Within Building:
   1. PVC Fitting Covers: 20 mils thick, white.

E. Pipe and Pipe Fittings Within Tunnels:
   1. Aluminum, Smooth or Stucco Embossed: 0.024 inch thick.

F. Piping, Vertical, Exposed, within 8 feet of Floor:
1. PVC: 30 mils thick, white.
2. Aluminum, Smooth or Stucco Embossed: 0.024 inch thick.

G. Ducts and Plenums, Concealed:

1. None.
2. [PVC] [PVC, Color-Coded by System]: [20 mils] [30 mils] thick.
3. Aluminum, [Smooth] [Corrugated] [Stucco Embossed]: [0.016 inch] [0.020 inch] [0.024 inch] [0.032 inch] [0.040 inch] thick.
4. <Insert jacket type.>

H. Ducts and Plenums, Exposed:

1. None.
2. [PVC] [PVC, Color-Coded by System]: [20 mils] [30 mils] thick.
3. Aluminum, [Smooth] [Corrugated] [Stucco Embossed]: [0.016 inch] [0.020 inch] [0.024 inch] [0.032 inch] [0.040 inch] thick.
4. <Insert jacket type.>

I. Equipment, Concealed:

1. None.
2. [PVC] [PVC, Color-Coded by System]: [20 mils] [30 mils] thick.
3. Aluminum, [Smooth] [Corrugated] [Stucco Embossed]: [0.016 inch] [0.020 inch] [0.024 inch] [0.032 inch] [0.040 inch] thick.
4. <Insert jacket type.>

J. Equipment, Exposed, up to 48 Inches in Diameter or with Flat Surfaces up to 72 Inches:

1. None.
2. [PVC] [PVC, Color-Coded by System]: [20 mils] [30 mils] thick.
3. Aluminum, [Smooth] [Corrugated] [Stucco Embossed]: [0.016 inch] [0.020 inch] [0.024 inch] [0.032 inch] [0.040 inch] thick.
4. <Insert jacket type.>

K. Equipment, Exposed, Larger Than 48 Inches in Diameter or with Flat Surfaces Larger Than 72 Inches:

1. None.
2. [Painted] Aluminum, [Smooth] [Stucco Embossed] with [1-1/4-Inch Deep Corrugations] [2-1/2-Inch Deep Corrugations] [4-by-1-Inch Box Ribs]: [0.032 inch] thick.
3. <Insert jacket type.>

L. Piping, Concealed:

1. None.
2. [PVC] [PVC, Color-Coded by System]: [20 mils] [30 mils] thick.
3. Aluminum, [Smooth] [Corrugated] [Stucco Embossed]: [0.016 inch] [0.020 inch] [0.024 inch] [0.032 inch] [0.040 inch] thick.
4. <Insert jacket type.>
M. Piping, Exposed:

1. None.
2. [PVC] [PVC, Color-Coded by System]: [20 mils] [30 mils] thick.
3. Aluminum, [Smooth] [Corrugated] [Stucco Embossed]: [0.016 inch] [0.020 inch] [0.024 inch] [0.032 inch] [0.040 inch] thick.
4. <Insert jacket type.>

3.26 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. Repaired Portions of Existing RTU Ducts and Plenums:

1. Cover flexible elastomeric insulation with the following:
   a. Finish with two coats of manufacturer’s recommended finish and cover with centered peaked metal cap.
   b. Adhere 10 x 10 woven mesh using insulation manufacturer’s recommended adhesive and finish with two coats of manufacturer’s recommended finish.

D. Existing RTU Ducts and Plenums:

1. Refinish existing flexible elastomeric insulation and metal cap to match existing

E. New RTU Ducts and Plenums:

1. Cover mineral fiber insulation with the following:
   a. Self-adhesive outdoor jacket with aluminum foil facing.

F. Piping:

1. Cover flexible elastomeric insulation with the following:
   a. Adhere 10 x 10 woven mesh using insulation manufacturer’s recommended adhesive and finish with two coats of manufacturer’s recommended finish.
   b. Aluminum, Smooth or Stucco Embossed: 0.024 inch thick with stainless steel bands.

2. Cover mineral fiber insulation with the following:
   a. Self-adhesive outdoor jacket with aluminum foil facing.
   b. Aluminum, Smooth or Stucco Embossed: 0.024 inch thick with stainless steel bands.
3.27 REMOVABLE INSULATED EQUIPMENT COVER SCHEDULE

A. Install removable flexible elastomeric insulation over chilled water pump volutes and suction diffusers.

B. Install removable insulating equipment cover over control valves at steam pressure reducing station.

C. Install removable insulating equipment cover over steam and condensate valves within vaults.

D. Install removable insulating equipment cover over chilled hinged marine water boxes.

E. Install removable insulating equipment cover over plate and frame heat exchangers.

F. Install removable insulating equipment cover over plate and frame heat exchangers.

G. Install removable insulating equipment cover over supply air duct mounted air valves.

3.28 UNDERGROUND, FIELD-INSTALLED INSULATION JACKET

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

3.29 BELOW SLAB, FIELD-INSTALLED INSULATION JACKET

A. For below slab direct-buried heating hot water piping applications with cellular glass insulation, install underground direct-buried waterproof jacket over insulation material.

END OF SECTION 23 0700
SECTION 23 0900 - INSTRUMENTATION AND CONTROL FOR HVAC

PART 1 - GENERAL

1.1 SUMMARY

A. This Section includes Tritium, Niagara N4 based control equipment for HVAC systems and components.

B. Direct digital control agency to be hired by WMU. **This section issued for reference only.**

C. Related Documents:
   1. Temperature control drawings showing control schematics and sequence of operations.

D. New Work shall communicate with and be integrated into Owner's existing campus energy management system.

E. New Work shall communicate with and be integrated into Owner's existing campus energy management system. **[Existing system is serviced by and new Work shall be performed by Havel Brothers, Kalamazoo, Michigan].**

F. Work shall include furnishing all labor, materials, equipment, and service necessary for a complete and operating Building Management System (BMS), utilizing Direct Digital Controls as shown on the drawings and as described herein. Control drawings are diagrammatic only. The BMS shall be capable of total integration of the facility infrastructure systems with user access to all system data either locally over a secure Intranet within the building or by remote access by a standard Web Browser over the Internet. This shall include HVAC control; electrical, gas and water metering for total building energy modeling; system and equipment alarm monitoring; and all trending, reporting and maintenance management functions related to normal building operations all as indicated on the drawings or elsewhere in this specification.

   1. All labor, material, equipment and software not specifically indicated required to meet the functional intent of the sequence of operations shall be provided without additional cost to the Owner. Point lists shall be a guide to the points required for control system. Final points required shall be determined by sequence of operation requirements.

G. Work shall include furnishing all labor, materials, equipment, and service necessary for a complete and operating Building Management System (BMS), utilizing Direct Digital Controls as shown on the drawings and as described herein. Control drawings are diagrammatic only. The BMS shall be capable of total integration of the facility infrastructure systems with user access to all system data either locally over a secure Intranet within the building or by remote access by a standard Web Browser over the Internet. This shall include HVAC control, **[electrical, gas**
and water metering, energy management, alarm monitoring, security and personnel access control, fire-life safety system monitoring, and all trending, reporting and maintenance management functions related to normal building operations all as indicated on the drawings or elsewhere in this specification.

H. Work required in this section shall include providing all interconnecting control wiring and power wiring to control components in conduit as required for a fully operational system as specified. Wiring and conduit shall be installed as per local codes or Division 26 whichever is more stringent.

I. WMU’s Energy Systems Specialist shall be given administrator level software access to all building automation system controllers installed on campus, including third party controllers supplied as packaged equipment controllers and purchased separately from the control system.

J. Work required in this section shall include providing all work required for this section. The system shall include all interconnecting pneumatic tubing, wiring and conduit as required for a fully operational system as specified. Wiring shall be installed as per local codes or Division 26 whichever is more stringent.

K. Work required in this section shall include relocating existing thermostats and temperature sensors as indicated.

L. Work required in this section shall include one new temperature sensor as indicated.

M. Work required in this section shall include providing all control components, control wiring, and services required for the connection and operation of the new fan coil units as indicated on drawings, and as specified in Section 23 8219 and Section 23 0993.

N. Work required in this section shall include providing all control components, control wiring, and services required for the connection and operation of the Air Handling Unit including related VAV terminal units as indicated on drawings, and as specified in [Sections 23 3600, 23 7313, 26 2923], and Section 23 0993.

O. Work required in this section shall include providing all control components, control wiring, and services required for the connection and operation of the new energy recovery units as indicated on drawings, and as specified in Section 23 7200, and Section 23 0993.

P. Work required in this section shall include providing all control components, control wiring, and services required for the connection and operation of the hydronic heating system and equipment as indicated on drawings and as specified in [Sections 23 2123, 23 5713], and Section 23 0993.

Q. Work required in this section shall include providing all control components, control wiring, and services required for the connection of the remaining equipment as indicated on drawings, as specified in various Division 23 sections, and as specified in Section 23 0993.

1.2 SUBMITTALS

A. Product Data: Include manufacturer’s technical literature for each control device. Indicate dimensions, capacities, performance characteristics, electrical characteristics, finishes for materials, and installation and startup instructions for each type of product indicated.
1. **DDC System Hardware:** Bill of materials of equipment indicating quantity, manufacturer, and model number. Include technical data for sensors and other required components.

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. Bill of materials of equipment indicating quantity, manufacturer, and model number.
2. Schematic flow diagrams showing fans, pumps, coils, dampers, valves, and control devices.
4. Written description of sequence of operation.
5. Schedule of valves including flow characteristics.
6. Schematic diagrams for control, communication, and power wiring, showing trunk data conductors and wiring.
7. Schematic diagrams of each controlled system with control points labeled and control elements graphically shown, with wiring.
8. A complete point list of all connected points to the DDC system.

C. **Project Record Documents:** Revise Shop Drawings to reflect actual installation and operating sequences.

1. As-built control drawings shall indicate the location of all control devices.
2. As-built control drawings shall indicate the proper device layout sequence of all control devices on a daisy chain communications bus.
3. Upon completion of the work, provide a complete set of ‘as-built’ drawings and application software on electronic media. Drawings shall be provided as AutoCAD™ compatible files. Electronic copies of the ‘as-built’ drawings shall be provided in addition to the documents on electronic media.

D. Field quality-control test reports.

1.3 **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.

1.4 **COORDINATION**

A. New Work shall be integrated into building management system (BMS). Integrate the following for new work into existing headend:

1. Incorporate graphic operator interface for accessing and displaying system data and commanding equipment and sensor operation.

B. Coordinate location of sensor with plans and room details before installation.

C. The TCS Contractor shall be responsible for all Interoperable Digital Controllers (IDC), Application Specific Controllers (ASC), Niagara N4 Network Area Controller(s) (NAC), control
devices, control panels, IDC, ASC, PCU & NAC controller programming, controller programming software, controller input/output wiring, power wiring, interlock and safety wiring, and controller network wiring. The TCS Contractor shall also be responsible for the Niagara N4 Supervisor (GUI) graphical user interface software, development of all graphical screens, setup of schedules, logs and alarms, LonWorks and/or BACnet network management, global supervisory control applications, system integration and coordination of all Niagara N4 NAC’s to the local and wide area network.

D. The following will be coordinated with WMU:

1. WMU shall be responsible for graphical standards and templates stored in the WMU Niagara N4 Network Supervisor.
2. The TCS Contractor will utilize WMU graphic standards and templates available on the WMU Network Supervisor.
3. The TCS Contractor will develop and submit for approval all non standard system graphics for all specified mechanical and electrical systems, using animated objects to display all system variables and process valves, according to WMU standards.
4. Provide supervisory control strategies for mechanical and electrical systems to permit the global sequence of operations specified herein.
5. Coordinate BACnet addresses for IBC devices to ensure that there are no duplicate addresses on the network per the WMU BACnet address guidelines.

1.5 SOFTWARE LICENSE AGREEMENT

A. The software licensing must have no restrictions on which brand of Niagara N4 NAC, Niagara N4 Supervisor or System Programming tools can interact with the system. Station Compatibility must = ALL and the Tool Compatibility must = ALL. (*brand* accept.station.in="*" accept.station.out="*" accept.wb.out="*" accept.wb.in="*")

B. The software and firmware licensing agreement shall grant use of all programs and application software to Owner as defined by the manufacturer's license agreement, but shall protect manufacturer's rights to disclosure of trade secrets contained within such software.

C. Software licensing for the Niagara N4 NAC shall give the Owner the capability to control their system and determine which contractors can bid and engineer their system.

D. It shall be possible to insure the Owner can prevent unauthorized partners from accessing the system for engineering changes.

E. Software licensing shall have the freedom to individually manage authorized parties and independent parties.

F. WMU shall be provided any software required to program, setup, override, or manipulate any BAS devices installed on campus.

1.6 NETWORK ACCESS

A. WMU WAN / LAN Access
1. TCS Contractor’s must adhere to WMU OIT policy and requirements to obtain WMU WAN access.

**DESIGNER NOTE:** Coordinate with project requirements.

B. Factory-Mounted Components: Arrange for shipping control devices to terminal unit manufacturer for factory mounting on equipment.

1.7 PROJECT COMMISSIONING

A. [WMU will be the commissioning agent](CX)](CxA). Contractors for this project shall meet CxA requirements and shall coordinate with and participate in commissioning activities.

B. Project is attempting to obtain LEED Certification and has an independent commissioning authority (CxA). Contractors for this project shall meet CxA requirements and shall coordinate with and participate in commissioning activities.

1. Refer to commissioning agent’s General Commissioning Requirements and Commissioning Plan documents.

PART 2 - PRODUCTS

2.1 INSTALLERS

A. Subject to compliance with requirements, provide installation, products, and services by the following:

1. ControlNet.
2. Havel Brothers.
3. Johnson Controls – Corporate.

B. The Temperature Control Contractor/System Integrator shall have a successful history in the design and installation of Niagara control systems with browser based wide area network connectivity and shall provide evidence of this history as a condition of acceptance of bid.

C. The Temperature Control Contractor/System Integrator shall have an office that is staffed with LONWORKS®, BACnet and Internet Protocol (IP) trained engineers and technicians fully capable of providing instruction and routine emergency maintenance service on all system components within 24 hours of notification.

2.2 GENERAL REQUIREMENTS

A. A campus Ethernet, modem, or other LAN connection must be installed early in the life of a project (if one does not already exist) so that the controls contractor and WMU personnel can remotely access the control system at the earliest possible time.
1. It is preferable that this is the permanent connection, rather than a temporary connection, so graphical access is possible.

B. The entire Temperature Control System (TCS) shall be comprised of a Niagara N4 Server, Niagara N4 Network Area Controller or Controllers (NAC), and a network of interoperable, stand-alone digital controllers communicating via the LonTalk and/or BACnet and/or Modbus communication protocols to the Niagara N4 Network Area Controllers (NAC).

C. The Niagara N4 NAC and Supervisor shall connect to the WMU wide area network (all NACs shall be connected to VLAN 260) and communicate to all WMU systems. This means that all monitoring and control points can be accessed from, and/or transferred to or from the existing Building Automation System (BAS). Access to the system, either locally in each building, or remotely from a central site or sites, shall be accomplished through standard Web browsers, via the Internet and/or local area network.

D. LonWorks is the preferred communication protocol for stand-alone digital controllers, VFDs, and other unitary controllers. It should always be considered first and not used only if it is not an option, or if a gateway is required for its use, or if there is significant additional cost associated with its use.

E. Electronic steam control valve actuators must have a labeled (“Test Trap *”) pushbutton switch located within 10 feet of the actuator that will fully open the valve for a period of 5 minutes (adjustable). If there is a 1/3 - 2/3 valve arrangement, it shall open only the 1/3 valve. This provision is to allow pipe fitters to test the associated steam traps without the assistance of others. The pushbutton switch shall be connected to the BAS and shall generate a BAS override alarm when pushed. The test mode shall also be displayed on the appropriate BAS graphics.

F. Cooling tower condenser supply 3-way valves shall have a labeled manual override control located within 10 feet of the actuator to allow chiller mechanics to control the valve during system startup and shutdown. This control shall generate a BAS alarm when in the override position, and shall display its value and status on the chiller graphic screen or screens.

G. A supply temperature sensor shall be installed downstream of any reheat coil.

H. A temperature sensor shall be installed in the cooling tower sump for any water cooled chiller plant for the purpose of resetting the condenser supply loop throttling range.

I. Temperature sensors shall be installed in any food service freezers or coolers that will alarm to the BAS when out of range. Each shall have a history trend, and all shall be displayed on a floor plan showing all related equipment.

J. A thermometer shall be installed adjacent to any BAS temperature sensor installed in a fluid pipe.

K. A pressure gauge shall be installed adjacent to any BAS pressure sensor installed in a fluid or gas pipe.

L. All monitoring and control points in a controller shall have the ability to be monitored from WMU’s existing HVAC graphical interface system. In addition, set points shall have change access from this system.
The control contractor shall provide WMU’s EMCS/Network Manager with all software needed to access and/or program any and all programmable devices installed on a project.

The control contractor shall provide WMU’s EMCS/Network Manager with all programming manuals relevant to any and all programmable devices installed on a project.

Keypad access and a display screen shall be provided on all devices available with such.

A Laptop PC access port must be a permanent part of all DDC control systems and/or devices available with such.

All thermostats shall be equipped with an override pushbutton. The controller connected to the thermostat must have a 2-hour override capability.

All thermostats shall be equipped with a space temperature display.

All thermostats shall be equipped with a space temperature setpoint adjustment. The device being controlled shall have the ability to use the setpoint from the thermostat, or a remote setpoint from the BAS.

Current sensors on the motor leads shall be used to confirm fan and pump status.

All LonWorks devices must be LonMark compliant. Documentation substantiating this fact must be submitted for approval.

The Temperature Control System (TCS) shall be comprised of a network of interoperable, stand-alone Niagara N4 NAC’s, servers, operator workstations, Niagara N4 graphical user interface software, network devices, digital controllers and other devices as specified herein.

The installed system shall provide secure password access to all features, functions and data contained in the overall TCS.

The following requirements apply to the Niagara N4 product selection:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following manufacturers specified.
   a. Tridium Vykon
   b. Schneider-Electric
   c. Honeywell
   d. Johnson Controls
   e. Or WMU approved alternate

The following requirements apply to the Interoperable Digital Controllers (IDC), Application Specific Controllers (ASC), and Programmable Control Units (PCU) product selection:
1. Manufacturers: Subject to compliance with requirements, provide products by one of the following manufacturers specified.
   a. Schneider-Electric I/A (MNL-800 Controllers are NOT acceptable)
   b. Others to be considered as part of RFQ process
   c. Or WMU approved alternate

2.4 OPEN, INTEROPERABLE, INTEGRATED ARCHITECTURES

A. The intent of this guideline is to provide a peer-to-peer networked, stand-alone, distributed control system based on ANSI/ASHRAE Standard 135-1995 BACnet and/or LonTalk communication protocols with the capability to integrate SNMP, LonWorks, BACnet IP, BACnet MSTP, Modbus TCP/IP or Modbus RTU communication protocols in one open interoperable system. Adherence to industry standards including ANSI / ASHRAE™ Standard 135-1995, BACnet and LonMark™ to assure interoperability between all system components is required. For each LonWorks device that does not have LonMark certification, the device supplier must provide an XIF file for the device. For each BACnet device, the device supplier must provide a PICS document showing the installed device’s compliance level. Minimum compliance is Level 3; with the ability to support data read and write functionality. Physical connection of BACnet devices shall be via Ethernet or MSTP. For each Modbus device supplier must provide a Registry of data points available on the system.

B. All components and controllers supplied under this contract shall be true “peer-to-peer” communicating devices. Components or controllers requiring “polling” by a host to pass data shall not be acceptable.

C. Use of gateway devices for communication at any level within the system shall not be acceptable without written permission from the Energy Systems Specialist.

2.5 Niagara N4 NETWORK AREA CONTROLLER (NAC)

A. The TCS contractor shall supply one or more Niagara N4 Network Area Controllers (NAC) as part of this contract. Number of area controllers required is dependent on the type and quantity of devices provided under this section.

B. The Niagara N4 Network Area Controller (NAC) shall provide the interface between the LAN or WAN and the field control devices, and provide global supervisory control functions over the control devices connected to the Niagara N4 NAC. It shall be capable of executing application control programs to provide:

1. Calendar functions
2. Scheduling
3. Trending
4. Alarm monitoring and routing
5. Time synchronization
6. Integration of LonWorks controller data, Modbus controller data and BACnet controller data
7. Network Management functions for all LonWorks, BACnet or Modbus based devices

C. All Niagara N4 Network Area Controllers (NAC) shall include embedded Workbench.
2.6 Programmable Control Units (PCU’S)

A. A LONWorks® or BACnet based DDC Programmable Control Unit (PCU) shall be provided where required to perform the sequence of operation. The PCU shall be fully configurable by configuration tool. The controller shall store all specific control sequences and program settings in non-volatile memory.

B. Each PCU shall perform all intended temperature control functions in a ‘standalone’ mode should the unit incur a loss of communications.

C. In the event of a power outage or controller reset, each PCU shall enter a preprogrammed state on power re-application. Upon application of power to the PCU, all control conditions will start from an ‘off’/’closed’ position or the default state. This state will be maintained for an automatically adjusted amount of time. Once this time delay has passed, the PCU control sequence shall resume according to current values.


E. All PCU’s shall be provided with a communications port to allow connection of any industry standard laptop PC and custom configuration tools. Program access via this communications port allows direct field modification of the configuration parameters.

2.7 INTEROPERABLE LONWORKS DIGITAL CONTROLLERS (ILC)

A. ILC controllers shall be microprocessor based Interoperable LonMark® or LonWorks Controllers. Where possible, all Interoperable Digital Controllers shall bear the applicable LonMark® interoperability logo on each product delivered.

B. Provide ILC’s and ancillary devices as herein specified, as indicated on the drawings, and as necessary to perform the sequences of operation.

C. Control shall be accomplished using LonMark® based devices where the application has a LonMark profile defined. Where LonMark devices are not available for a particular application, such as freely programmable controllers, the manufacturer must provide an XIF file for the device. Publicly available specifications for the Applications Programming Interface (API) must be provided. The TCS Contractor shall provide all programming and documentation necessary to set up and configure the supplied devices per the specified sequences of operation.

D. The TCS Contractor shall route the LonWorks network trunk to the Niagara N4 Network Area Controller (NAC) as indicated on the riser diagram in the bid documents. Coordinate locations of the Niagara N4 NAC to ensure that maximum network wiring distances, as specified by the LonWorks wiring guidelines, are not exceeded. All LonWorks and LonMark devices must be supplied using FTT-10A LonTalk communication transceivers.

E. All ILCs shall be fully application programmable and shall at all times maintain their LONMARK certification, if so certified. All control sequences within or programmed into the ILC shall be stored in non-volatile memory, which is not dependent upon the presence of a battery, to be retained.
F. The TCS Contractor shall provide two copies of the ILC programming tool and configuration tool, with documentation, to the owner. This tool shall NOT require IIS.

1. This tool shall allow the owner to fully program, configure, diagnose and otherwise manage the controller, without limitations.
2. The tool shall be of the latest revision currently in production release by the manufacturer.
3. The tool shall be licensed to the owner and shall not require annual license renewal fees.
4. The tool shall not be dependent on the LNS network management system in order to properly function and shall be capable of running as a stand-alone application on a Windows operating system. Use of LNS-based plug-ins for programming and configuration are not acceptable.

2.8 INTEROPERABLE BACnet CONTROLLER (IBC)

A. Controls shall be microprocessor based Interoperable BACnet Controllers (IBC) in accordance with the ANSI/ASHRAE Standard 135-1995. IBCs shall be provided for Unit Ventilators, Fan Coils, Heat Pumps, Variable Air Volume (VAV) Terminals and other applications as shown on the drawings. The application control program shall be resident within the same enclosure as the input/output circuitry, which translates the sensor signals. The system supplier must provide a PICS document showing the installed systems compliance level to the ANSI/ASHRAE Standard 135-1995. Each IBC shall have a connection port within 12 feet of the device. If the IBC has no port, use a sensor for connection. The IBC Sensor shall connect directly to the IBC and shall not utilize any of the I/O points of the controller. The IBC Sensor shall provide a two-wire connection to the controller that is polarity and wire type insensitive. The IBC Sensor shall provide a communications jack for connection to the BACnet communication trunk to which the IBC controller is connected. The IBC Sensor, the connected controller, and all other devices on the BACnet bus shall be accessible by the POT.

B. All IBCs shall be fully application programmable and shall at all times maintain their BACnet Level 3 compliance. All control sequences within or programmed into the IBC shall be stored in non-volatile memory, which is not dependent upon the presence of a battery, to be retained.

C. The Division 23 contractor supplying the IBC’s shall provide documentation for each device, with the following information at a minimum:

1. BACnet Device; MAC address, name, type and instance number
2. BACnet Objects; name, type and instance number

D. It is the responsibility of the Division 23 contractor to ensure that the proper BACnet objects are provided in each IBC and are exposed for connection to them as required by the point charts, and that BACnet instance numbers are not duplicated campus wide.

E. The TCS Contractor shall provide two copies of the IBC programming tool and configuration tool, with documentation, to the owner. This tool shall NOT require IIS.

1. This tool shall allow the owner to fully program, configure, diagnose and otherwise manage the controller, without limitations.
2. The tool shall be of the latest revision currently in production release by the manufacturer.
3. The tool shall be licensed to the owner and shall not require annual license renewal fees.
4. The tool shall not be dependent on the BACnet network management system in order to properly function and shall be capable of running as a stand-alone application on a Windows operating system.

2.9 SPACE TEMPERATURE SENSORS

A. Space temperature sensors shall display the temperature when used to directly control any terminal unit.

B. Space temperature sensors connected to VAV controllers shall include temperature adjustment, and the option for set-points to be set locally or remotely.

C. Space temperature sensors connected to fan-powered-boxes or other terminal units with fans shall include temperature adjustment, and the option for set-points to be set locally or remotely. They shall also include fan control, and the option for that fan control to be local, remote, or automatic.

2.10 TEMPERATURE CONTROL PANELS

2.11 GRAPHIC DISPLAY

A. Generate system graphics for all systems using programming software.

1. All temperature set points and all other setpoints identified as adjustable shall be adjustable from the appropriate graphic display(s). Setpoints given in the control sequences are for initial set-up and trial of system operations. Control system shop drawings shall utilize the written sequences with all setpoints, throttling range and differentials identified. As-built drawings shall include this same information with actual set points following start-up, testing and adjustment.

2. Monitored points and alarms for each system shall be shown on the displays with full color graphics and real-time data as listed below. All graphic displays shall be submitted to the Owner for review and approval prior to commencing any programming for the temperature controls.

3. All temperatures shall be displayed with zero decimal places.

4. All valve and damper positions shall be displayed as percent open and shall be displayed with zero decimal places.

5. All setpoints shall be adjustable via the associated graphic displays.

6. All dynamic displays shall depict motion (i.e. rotating fan wheel, rotating pump impeller, etc).

7. All set points adjustable from the graphic displays shall be programmed with the dead band on one side of the set point (not split evenly across the setpoint).

8. Zone Temperature Summary: Provide a summary screen, which indicates the current room temperature setpoint and current room temperature for each zone. The screen shall have a global room temperature setpoint capability that will override the current setpoint for all zones. Each zone shall be capable of being set to either the global setpoint or to a non-global or individual setpoint. By selecting any of the zones on the screen there shall be the capability to transfer to the selected zone’s equipment (VAV box, fan coil unit, etc.) control screen and back. The zone summary shall also include additional information such as discharge air temperature, valve position, fan status, etc.
9. Floor Plans: Provide a display showing the building floor plans, all space temperature sensors, and the equipment associated with each zone (with the zone borders depicted on the floor plans).

10. In addition to the color graphics screens previously defined, furnish “tabular” quick look-up screens to provide the operator with the maximum amount of status information possible on a screen at one time.

2.12 UNITARY CONTROLLERS (UCs)

A. Unitary DDC Controllers (UCs) shall be standalone configured to perform the sequences specified, and with I/O selected for the application. Each controller shall be designed with onboard jacks for quick commissioning and troubleshooting with a portable programming tool.

2.13 ELECTRONIC SENSORS

A. Digital Wall Sensor: Wall sensor shall provide temperature indication to the digital controller.
   1. Sensor make and model to match Owner’s existing standard.

2.14 ACTUATORS

A. Electric Motors: Size to operate with sufficient reserve power to provide smooth modulating action or two-position action.
   1. Comply with requirements in Division 23 Section "Common Motor Requirements for HVAC Equipment."
   2. Permanent Split-Capacitor or Shaded-Pole Type: Gear trains completely oil immersed and sealed. Equip spring-return motors with integral spiral-spring mechanism in housings designed for easy removal for service or adjustment of limit switches, auxiliary switches, or feedback potentiometer.
   3. Nonspring-Return Motors for Valves Larger Than NPS 2-1/2: Size for running torque of 150 in. x lbf and breakaway torque of 300 in. x lbf.
   4. Spring-Return Motors for Valves Larger Than NPS 2-1/2: Size for running and breakaway torque of 150 in. x lbf.
   5. Nonspring-Return Motors for Dampers Larger Than 25 Sq. Ft.: Size for running torque of 150 in. x lbf and breakaway torque of 300 in. x lbf.
   6. Spring-Return Motors for Dampers Larger Than 25 Sq. Ft.: Size for running and breakaway torque of 150 in. x lbf.

B. Electronic Actuators: Direct-coupled type designed for minimum 60,000 full-stroke cycles at rated torque.
   1. [Available] Manufacturers:
      a. Belimo Aircontrols (USA), Inc.
      b. <Insert manufacturer's name.>
   2. Valves: Size for torque required for valve close off at maximum pump differential pressure.
   3. Dampers: Size for torque required for damper operation at maximum face velocities.
4. **Dampers:** Size for running torque calculated as follows:
   a. **Parallel-Blade Damper with Edge Seals:** 7 inch-lb/sq. ft. of damper.
   b. **Opposed-Blade Damper with Edge Seals:** 5 inch-lb/sq. ft. of damper.
   c. **Parallel-Blade Damper without Edge Seals:** 4 inch-lb/sq. ft. of damper.
   d. **Opposed-Blade Damper without Edge Seals:** 3 inch-lb/sq. ft. of damper.
   e. **Dampers with 2- to 3-Inch wg of Pressure Drop or Face Velocities of 1000 to 2500 fpm:** Increase running torque by 1.5.
   f. **Dampers with 3- to 4-Inch wg of Pressure Drop or Face Velocities of 2500 to 3000 fpm:** Increase running torque by 2.0.

5. **Coupling:** V-bolt and V-shaped, toothed cradle.
6. **Overload Protection:** Electronic overload or digital rotation-sensing circuitry.
7. **Fail-Safe Operation:** Mechanical, spring-return mechanism. Provide external, manual gear release on nonspring-return actuators.
8. **Power Requirements (Two-Position Spring Return):** 24-V ac.
9. **Power Requirements (Modulating):** Maximum 10 VA at 24-V ac or 8 W at 24-V dc.
10. **Proportional Signal:** 2- to 10-V dc or 4 to 20 mA, and 2- to 10-V dc position feedback signal.
11. **Temperature Rating:** Minus 22 to plus 122 deg F.
12. **Temperature Rating (Smoke Dampers):** Minus 22 to plus 250 deg F.
13. **Run Time:** [12 seconds open, 5 seconds closed] [30 seconds] [60 seconds] [120 seconds].

2.15 **CONTROL VALVES**

A. **Control Valves:** Factory fabricated, of type, body material, and pressure class based on maximum pressure and temperature rating of piping system, unless otherwise indicated.

B. **Hydronic system globe valves** shall have the following characteristics:

1. **NPS 2 and Smaller:** Class 125 bronze body, bronze trim, rising stem, renewable composition disc, and screwed ends with backseating capacity repackable under pressure.
2. **NPS 2-1/2 and Larger:** Class 125 iron body, bronze trim, rising stem, plug-type disc, flanged ends, and renewable seat and disc.
3. **Internal Construction:** Replaceable plugs and stainless-steel or brass seats.
   a. **Single-Seated Valves:** Cage trim provides seating and guiding surfaces for plug on top and bottom.
   b. **Double-Seated Valves:** Balanced plug; cage trim provides seating and guiding surfaces for plugs on top and bottom.

4. **Sizing:** 3-psig <Insert value> maximum pressure drop at design flow rate or the following:
   a. **Two Position:** Line size.
   b. **Two-Way Modulating:** Either the value specified above or twice the load pressure drop, whichever is more.
   c. **Three-Way Modulating:** Twice the load pressure drop, but not more than value specified above.

5. **Flow Characteristics:** Two-way valves shall have equal percentage characteristics; three-way valves shall have linear characteristics.
6. Close-Off (Differential) Pressure Rating: Combination of actuator and trim shall provide minimum close-off pressure rating of 150 percent of total system (pump) head for two-way valves and 100 percent of pressure differential across valve or 100 percent of total system (pump) head.

C. Steam system globe valves shall have the following characteristics:

1. NPS 2 and Smaller: Class 125 bronze body, bronze trim, rising stem, renewable composition disc, and screwed ends with backseating capacity repackable under pressure.
2. NPS 2-1/2 and Larger: Class 125 iron body, bronze trim, rising stem, plug-type disc, flanged ends, and renewable seat and disc.
   a. Single-Seated Valves: Cage trim provides seating and guiding surfaces for plug on top and bottom of guided plugs.
   b. Double-Seated Valves: Balanced plug; cage trim provides seating and guiding surfaces for plugs on top and bottom of guided plugs.

4. Sizing: For pressure drop based on the following services:
   a. Two Position: 20 percent of inlet pressure.
   b. Modulating [15-psig Steam]: 80 percent of inlet steam pressure.
   c. Modulating [16- to 50-psig Steam]: 50 percent of inlet steam pressure.
   d. Modulating [More Than 50-psig Steam]: As indicated.

5. Flow Characteristics: Modified linear characteristics.
6. Close-Off (Differential) Pressure Rating: Combination of actuator and trim shall provide minimum close-off pressure rating of 150 percent of operating (inlet) pressure.

D. Butterfly Valves: 200-psig, 150-psig maximum pressure differential, ASTM A 126 cast-iron or ASTM A 536 ductile-iron body and bonnet, extended neck, stainless-steel stem, field-replaceable EPDM or Buna N sleeve and stem seals.

1. Body Style: [Wafer] [Lug] [Grooved].
2. Disc Type: [Nickel-plated ductile iron] [Aluminum bronze] [Elastomer-coated ductile iron] [Epoxy-coated ductile iron].
3. Sizing: 1-psig maximum pressure drop at design flow rate.

E. Terminal Unit Control Valves: Bronze body, bronze trim, two or three ports as indicated, replaceable plugs and seats, and union and threaded ends.

1. Rating: Class 125 for service at 125 psig and 250 deg F operating conditions.
2. Sizing: 3-psig maximum pressure drop at design flow rate, to close against pump shutoff head.
3. Flow Characteristics: Two-way valves shall have equal percentage characteristics; three-way valves shall have linear characteristics.

F. Self-Contained Control Valves: Bronze body, bronze trim, two or three ports as indicated, replaceable plugs and seats, and union and threaded ends.

1. Rating: Class 125 for service at 125 psig and 250 deg F operating conditions.
2. Thermostatic Operator: [Wax] [Liquid]-filled [integral] [remote] sensor with [integral] [remote] adjustable dial.
2.16 OTHER CONTROL SYSTEM HARDWARE

A. Airflow Measuring System (Duct Mounted Configuration): Provide where indicated, airflow measuring stations capable of continuously monitoring the duct airflow they serve. Airflow measuring stations shall consist of an airflow measuring station and a transmitter.

1. Each airflow traverse probe mounted within the station shall contain multiple total and static pressure sensors located along its exterior surface, and internally connected to their respective averaging manifolds.
2. The airflow measuring stations shall have a galvanized steel, 6” deep casing with 90º connecting flanges. Total and static pressure sensors shall be located at the centers of equal areas (for rectangular ducts) or at equal concentric area centers (for circular ducts) across the station's face area.
3. Stations shall be AMCA certified and be capable of measuring the airflow rates within an accuracy of ±2% without the use of correction factors. The maximum allowable unrecovered pressure drop caused by the station shall not exceed .025” w.c. at 2000 FPM, or .085” w.c. at 4000 FPM.
4. The Transmitter shall have an accuracy of ±0.5% of Natural Span and be furnished with a built-in 3-way zeroing valve, user selectable square root function, and integral 3-1/2 digit scalable LCD for display of measured process. The Transmitter shall be housed in a NEMA 1 aluminum enclosure with universal 1/8” FPT signal connection ports, and provide 0-5 volt, 0-10 volt, or 4-20ma output signals for use by the building control system.

B. Fan Airflow Probes:

1. Provide fan airflow probes on fans capable of continuously measuring the fan air volume.
   a. The airflow probes shall be factory calibrated to NIST traceable standards and use thermal dispersion technology.
   b. The airflow traverse probes shall not significantly impact fan performance or contribute to fan generated noise levels.
   c. The probes shall be capable of producing steady, non-pulsating signals of standard total and static pressure, without need for flow corrections or factors, with an accuracy of 2% of actual reading.

2. Include transmitter to communicate the CFM to the BMS.
3. The airflow probes shall be the Ebtron “Gold” Series.

C. Outside Airflow Probes:

1. Provide outside airflow probes on units capable of continuously measuring the outside air volume.
   a. The airflow probes shall be factory calibrated to NIST traceable standards and use thermal dispersion technology.
   b. The airflow traverse probes shall not significantly impact fan performance or contribute to fan generated noise levels.
   c. The probes shall be capable of producing steady, non-pulsating signals of standard total and static pressure, without need for flow corrections or factors, with an accuracy of 2% of actual reading.
2. Include transmitter to communicate the CFM to the BMS.

3. The airflow probes shall be the Ebtron “Gold” Series.

D. Duct Airflow Probes:

1. Provide duct airflow probes in ductwork capable of continuously measuring the duct air volume.
   a. The airflow probes shall be factory calibrated to NIST traceable standards and use thermal dispersion technology.
   b. The airflow traverse probes shall not significantly impact fan performance or contribute to fan generated noise levels.
   c. The probes shall be capable of producing steady, non-pulsating signals of standard total and static pressure, without need for flow corrections or factors, with an accuracy of 2% of actual reading.

2. Include transmitter to communicate the CFM to the BMS.

3. The airflow probes shall be the Ebtron “Gold” Series.

E. Natural Gas Flow Meters:

1. Provide an ONICON Model F-5000 series insertion thermal mass flow meter, complete with all installation hardware for insertion and removal of the meter without system shutdown. Materials of construction for metal components in contact with gas shall be 316 stainless steel. The flow meter shall provide SFPM flow readings from a pair of encapsulated platinum sensors and shall not require additional temperature or pressure compensation. In addition, the meter shall continuously display information that can be used to validate the calibration of the meter. Each flow meter shall be individually wet-calibrated against a standard that is directly traceable to NIST. Include certificate of calibration with each flow meter.

2. Accuracy shall be within ± 1% of rate from 500-7000 SFPM and ± 2% of rate from 100-7000 SFPM. Overall turndown shall exceed 1000:1. Output signals for communication to the BMS shall consist of one analog 4-20mA output and one scalable pulse output for totalization. The meter shall be equipped with an integrally mounted graphical display.

F. Thermally Isolated Dampers: Ruskin Model CDT150 or equivalent extruded aluminum thermally isolated control dampers with insulated air-foil shaped blades.

G. Venturi Flowmeters:

1. Manufacturers: Subject to compliance with requirements, provide products by the following:
   a. Gerand Engineering Co.
   b. Preso.

2. Description: Differential pressure type flowmeter with calibrated flow-measuring element, hoses or tubing, fittings, valves, indicator, and conversion chart.

3. Flow Range: Sensor and indicator shall cover operating range of equipment or system served.

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

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

7. Conversion Chart: Flow rate data compatible with sensor.
8. Operating Instructions: Include complete instructions with each flowmeter.
9. Transmitter: To communicate the GPM flow rate to the building DDC control system.

2.17 VARIABLE FREQUENCY CONTROLLERS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   2. Danfoss Inc.; Danfoss Electronic Drives Div.

B. VFC Description: Variable-frequency power converter (rectifier, dc bus, and IGBT, PWM inverter) factory packaged in an enclosure, with integral disconnecting means and overcurrent and overload protection; listed and labeled by an NRTL as a complete unit; arranged to provide self-protection, protection, and variable-speed control of one or more three-phase induction motors by adjusting output voltage and frequency.
   1. Units suitable for operation of NEMA MG 1, Design A and Design B motors as defined by NEMA MG 1, Section IV, Part 30, "Application Considerations for Constant Speed Motors Used on a Sinusoidal Bus with Harmonic Content and General Purpose Motors Used with Adjustable-Voltage or Adjustable-Frequency Controls or Both."
   2. Units suitable for operation of inverter-duty motors as defined by NEMA MG 1, Section IV, Part 31, "Definite-Purpose Inverter-Fed Polyphase Motors."
   3. Listed and labeled for integrated short-circuit current (withstand) rating by an NRTL acceptable to authorities having jurisdiction.

C. General Requirements for VFCs: Comply with NEMA ICS 7, NEMA ICS 61800-2, and UL 508C

D. Design and Rating: Match load type such as fans, blowers, and pumps; and type of connection used between motor and load such as direct or through a power-transmission connection.

E. Output Rating: 3-phase; 6 to 60 Hz, with voltage proportional to frequency throughout voltage range.

F. Unit Operating Requirements:
1. Input ac voltage tolerance of 208 V, plus or minus 5 percent or 380 to 500 V, plus or minus 10 percent.
2. Input AC Voltage Unbalance: Not exceeding 5 percent.
3. Input frequency tolerance of 50/60 Hz, plus or minus 6 percent.
4. Minimum Efficiency: 96 percent at 60 Hz, full load.
5. Minimum Displacement Primary-Side Power Factor: 96 percent at 60 Hz, full load.
6. Minimum Short-Circuit Current (Withstand) Rating: 22 kA.
7. Ambient Temperature Rating: Not less than 14 deg F and not exceeding 104 deg F.
8. Ambient Storage Temperature Rating: Not less than minus 4 deg F and not exceeding 140 deg F.
10. Overload Capability: 1.1 times the base load current for 60 seconds; 2.0 times the base load current for 3 seconds.
11. Starting Torque: 100 percent of rated torque from 3 to 60 Hz.
12. Speed Regulation: Plus or minus 1 percent.
13. The output carrier frequency of the AC Drive shall be programmable at 0.5, 1, 2, 4 or 8 kHz. In addition, the output carrier frequency shall be randomly modulated about the selected frequency. Field set the carrier frequency not to exceed 4 kHz.

G. Isolated control interface to allow controller to follow control signal over an 11:1 speed range.
1. Electrical Signal: 0 to 20 mA, 4 to 20 mA or 0 to 10V selectable.

H. Internal Adjustability Capabilities:
1. Minimum Speed: 5 to 25 percent of maximum rpm.
2. Maximum Speed: 80 to 100 percent of maximum rpm.
3. Acceleration: 2 to a minimum of 600 seconds.
4. Deceleration: 2 to a minimum of 600 seconds.
5. Current Limit: 50 to a minimum of 110 percent of maximum rating.

I. Self-Protection and Reliability Features:
1. Input transient protection by means of surge suppressors to provide three-phase protection against damage from supply voltage surges 10 percent or more above nominal line voltage.
2. Loss of Input Signal Protection: Selectable response strategy, including speed default to a percent of the most recent speed, a preset speed, or stop; with alarm.
4. Inverter overcurrent trips.
5. VFC and Motor Overload/Overtemperature Protection: Microprocessor-based thermal protection system for monitoring VFCs and motor thermal characteristics, and for providing VFC overtemperature and motor overload alarm and trip; settings selectable via the keypad; NRTL approved.
6. Critical frequency rejection, with three selectable, adjustable deadbands.
7. Instantaneous line-to-line and line-to-ground overcurrent trips.
10. Short-circuit protection.
11. Motor overtemperature fault.

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

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

L. Torque Boost: Automatically varies starting and continuous torque to at least 1.5 times the minimum torque to ensure high-starting torque and increased torque at slow speeds.

M. Motor Temperature Compensation at Slow Speeds: Adjustable current fall-back based on output frequency for temperature protection of self-cooled, fan-ventilated motors at slow speeds.

N. Input Line Conditioning: Provide a 5% line reactor located on the line side of the VFC.

O. VFC Output Filtering: Provide 3% output reactor on load side of VFC when circuit length from the VFC to the motor exceeds 200 feet

P. Non-NEMA MG31 Part 1 Motors: Provide 3% output reactor on load side of VFC when circuit length from the VFC to the motor exceeds 30 feet.

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

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


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

1. Output frequency (Hz).
5. Motor torque (percent).
6. Fault or alarming status (code).
7. PID feedback signal (percent).
8. DC-link voltage (VDC).
9. Set-point frequency (Hz).
10. Motor output voltage (V).

T. Control Signal Interface:

1. Electric Input Signal Interface: A minimum of 2 analog inputs (0 to 10 V or 0/4-20 mA) and 6 programmable digital inputs.
2. Remote Signal Inputs: Capability to accept any of the following speed-setting input signals from the BMS or other control systems:

   a. 0 to 10-V dc.
   b. 0-20 or 4-20 mA.
   c. Potentiometer using up/down digital inputs.
   d. Fixed frequencies using digital inputs.
   e. RS485.
   f. Keypad display for local hand operation.

3. Output Signal Interface:

   a. A minimum of 1 analog output signal (0/4-20 mA), which can be programmed to any of the following:

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

4. Remote Indication Interface: A minimum of 2 dry circuit relay outputs (120-V ac, 1 A) for remote indication of the following:

   a. Motor running.
   b. Set-point speed reached.
   c. Fault and warning indication (overtemperature or overcurrent).
   d. PID high- or low-speed limits reached.

U. Communications: Provide direct digital interface to building automation systems (BAS) using DDC protocols that accept on/off commands, time schedules and report status of all relays in all panels in real time. Interface cards shall “self populate” each individual relay and each group to the BAS. All BAS system programming required shall be the responsibility of the BAS system provider. Interface shall allow all parameter settings of VFC to be programmed via BMS control. Provide capability for VFC to retain these settings within the nonvolatile memory.

V. Contactor Rating: All contacts shall be NEMA ICS 2 rated for 100% of the VFC’s horsepower.

W. Integral Disconnecting Means: NEMA AB 1, molded-case switch or NEMA KS 1, nonfusible switch with lockable handle.

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

PART 3 - EXECUTION

3.1 GENERAL REQUIREMENTS

A. LonWorks installations shall be installed so that different subsystems (HVAC, fire, access, elevator, etc.) are each installed on separate segments of the LON network.
B. Routers can connect these segments to each other if control schemes or user interface require it.

C. All wiring in mechanical spaces, or areas with exposed ceilings shall be installed in conduit or electrical trays.

D. A duplex receptacle must be located within 6 feet of any control cabinet that contains a programmable device.

E. All sensor and bus wiring shall be labeled at each end to identify what device and/or contact point is at the other end of the wire.

3.2 INSTALLATION

A. Implement all features of programs to specified requirements and as appropriate to sequence of operation.

B. Connect and configure equipment and software to achieve sequence of operation specified.

C. Coordinate installation of hydronic control valves, and other accessories with Division 23 hydronic piping sections.

D. Coordinate installation of duct mounted control dampers, and other accessories with Division 23 Section "Metal Ducts."

E. Coordinate installation of steam control valves, and other accessories with Division 23 Section "Steam and Condensate Heating Piping."

F. All mechanical equipment shall have a control sheet attached to an accessible area of the equipment.

G. Install flow meter displays on walls or brackets in accessible and readable positions.

H. Install flow meter elements with at least minimum straight lengths of upstream and downstream from element as prescribed by manufacturer's written instructions.

I. For flow meter devices, perform the following field tests and inspections and prepare test reports:

   1. Operational Test: After substantial completion of system, test calibration and confirm proper operation and readings. Remove and replace malfunctioning units and retest.

J. Install VFCs with tops at uniform height and with disconnect operating handles not higher than 79 inches above finished floor unless otherwise indicated, and by bolting units to wall or mounting on freestanding lightweight racks bolted to wall or floor. Do not mount to vibrating equipment.
3.3 SEQUENCE OF OPERATIONS
   A. Integrate new space temperature sensor into area AHU controls to determine the AHU discharge temperature based on space temperature readings.

3.4 ELECTRICAL WIRING AND CONNECTION INSTALLATION
   A. Install raceways, boxes, and cabinets according to Division 26 Section "Raceway and Boxes for Electrical Systems."

3.5 FIELD QUALITY CONTROL
   A. Field Service: Engage a factory-authorized service representative to inspect, test, and adjust field-assembled components and equipment installation, including connections. Report results in writing.
   B. The controls contractor shall demonstrate to a WMU representative that all control points, sequences, and functions operate properly and as specified.
   C. As-Built or commissioning drawings shall be provided to WMU prior to the commissioning process for the purpose of commissioning.
   D. Software shall be provided to WMU prior to commissioning.

3.6 DEMONSTRATION
   A. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain HVAC instrumentation and controls.
      1. The control contractor shall provide training time on each project to fully familiarize WMU's controls trades, on site, with the complete control functionality of all controlled equipment.
      2. One week of school at the factory-training site shall be provided for every $200,000 in controls cost to a project.
      3. The control contractor shall provide training time on each project to fully familiarize WMU's controls trades, on site, with the complete control functionality of all controlled equipment. One hour of this training time shall be provided for every $50,000 in controls cost to a project.

END OF SECTION 23 0900
WMU Design Guidelines Instructions: These guidelines are to be used by the Design Professional to inform the design process and outline WMU-specific desires for all University projects. These guidelines have been edited to reflect WMU preferences, and the intent is for the Design Professional to use this information to guide their normal specifications-writing process. Straying from what is indicated in the guidelines is not prohibited, but shall be discussed with WMU during the development of the project.

SECTION 23 1123 - 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. Pressure regulators.
   6. Mechanical sleeve seals.

1.2 PERFORMANCE REQUIREMENTS

A. Minimum Operating-Pressure Ratings:
   1. Piping and Valves: 100 psig minimum unless otherwise indicated.
   2. Natural-Gas System Pressure within Buildings: 0.5 psig or less but not more than 5 psig.

1.3 ACTION SUBMITTALS

A. Product Data: For each type of the following:
   1. Valves. Include pressure rating, capacity, settings, and electrical connection data of selected models.
   2. Pressure regulators. Indicate pressure ratings and capacities.

1.4 INFORMATIONAL SUBMITTALS

A. Field quality-control reports.

1.5 CLOSEOUT SUBMITTALS

A. Operation and maintenance data.
1.6 DELIVERY, STORAGE, AND HANDLING

A. Handling Flammable Liquids: Remove and dispose of liquids from existing natural-gas piping according to requirements of authorities having jurisdiction.

B. Deliver pipes and tubes with factory-applied end caps. Maintain end caps through shipping, storage, and handling to prevent pipe end damage and to prevent entrance of dirt, debris, and moisture.

C. Store and handle pipes and tubes having factory-applied protective coatings to avoid damaging coating, and protect from direct sunlight.

D. Protect stored PE pipes and valves from direct sunlight.

1.7 PROJECT CONDITIONS

A. Interruption of Existing Natural-Gas Service: Do not interrupt natural-gas service to facilities occupied by Owner or others unless permitted under the following conditions and then only after arranging to provide purging and startup of natural-gas supply according to requirements indicated:

1. Notify [Architect] [Construction Manager] [Owner] no fewer than [two] <Insert number> days in advance of proposed interruption of natural-gas service.

2. Do not proceed with interruption of natural-gas service without [Architect's] [Construction Manager's] [Owner's] written permission.

1.8 COORDINATION

A. Refer to Bid Pack 1 for the installation of the natural gas service into the building.

B. Coordinate sizes and locations of concrete bases with actual equipment provided.

C. Coordinate requirements for access panels and doors for valves installed concealed behind finished surfaces. Comply with requirements in Division 08 Section "Access Doors and Frames."

PART 2 - PRODUCTS

2.1 PIPES, TUBES, AND FITTINGS

A. Steel Pipe: ASTM A 53/A 53M, black steel, Schedule 40, Type E or S, Grade B.


4. Forged-Steel Flanges and Flanged Fittings: ASME B16.5, minimum Class 150, including bolts, nuts, and gaskets of the following material group, end connections, and facings:
   b. End Connections: Threaded or butt welding to match pipe.
   c. Face: Lapped.
   e. Bolts and Nuts: ASME B18.2.1, carbon steel.

B. PE Pipe: ASTM D 2513, SDR 11.
   1. PE Fittings: ASTM D 2683, socket-fusion type or ASTM D 3261, butt-fusion type with dimensions matching PE pipe.
   2. 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.

2.2 PIPING SPECIALTIES

A. Appliance Flexible Connectors:
   3. Operating-Pressure Rating: 0.5 psig.
   5. Threaded Ends: Comply with ASME B1.20.1.

B. Y-Pattern Strainers:
   1. Body: ASTM A 126, Class B, cast iron with bolted cover and bottom drain connection.
   2. End Connections: Threaded ends for NPS 2 and smaller; flanged ends for NPS 2-1/2 and larger.
   3. Strainer Screen: 40-mesh startup strainer, and perforated stainless-steel basket with 50 percent free area.

C. 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.

2.3 JOINING MATERIALS

A. Joint Compound and Tape: Suitable for natural gas.

2.4 MANUAL GAS SHUTOFF VALVES

A. See "Manual Gas Shutoff Valve Schedules" below 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.
4. Listing: Listed and labeled by an NRTL acceptable to authorities having jurisdiction for valves 1 inch and smaller.
5. 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.
3. Flanged Ends: Comply with ASME B16.5.
5. 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.

2. Ball: Chrome-plated bronze.
3. Stem: Bronze; blowout proof.
4. Seats: Reinforced TFE; blowout proof.
5. Packing: Threaded-body packnut design with adjustable-stem packing.
7. CWP Rating: 600 psig.
8. Listing: Valves NPS 1 and smaller shall be listed and labeled by an NRTL acceptable to authorities having jurisdiction.

E. Bronze Plug Valves: MSS SP-78.

2. Plug: Bronze.
3. Ends: Threaded or flanged.
4. Operator: Square head or lug type with tamperproof feature where indicated.
5. Pressure Class: 125 psig.
6. Listing: Valves NPS 1 and smaller shall be listed and labeled by an NRTL acceptable to authorities having jurisdiction.
7. Service: Suitable for natural-gas service with "WOG" indicated on valve body.

F. Cast-Iron, Nonlubricated Plug Valves: MSS SP-78.

1. Body: Cast iron, complying with ASTM A 126, Class B.
2. Plug: Bronze or nickel-plated cast iron.
3. Seat: Coated with thermoplastic.
5. Ends: Threaded or flanged.
6. Operator: Square head or lug type with tamperproof feature where indicated.
7. Pressure Class: 125 psig.
8. Listing: Valves NPS 1 and smaller shall be listed and labeled by an NRTL acceptable to authorities having jurisdiction.

G. Cast-Iron, Lubricated Plug Valves: MSS SP-78.

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
2. Manufacturers: Subject to compliance with requirements, [provide products by one of the following] [available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following]:
   a. Flowserve.
   b. Homestead Valve; a division of Olson Technologies, Inc.
   d. Milliken Valve Company.
   e. Mueller Co.; Gas Products Div.
   g. <Insert manufacturer's name>.

3. Body: Cast iron, complying with ASTM A 126, Class B.
4. Plug: Bronze or nickel-plated cast iron.
5. Seat: Coated with thermoplastic.
10. Service: Suitable for natural-gas service with "WOG" indicated on valve body.

2.5 PRESSURE REGULATORS

A. General Requirements:

1. Single stage and suitable for natural gas.
2. Steel jacket and corrosion-resistant components.
3. Elevation compensator.
4. End Connections: Threaded for regulators NPS 2 and smaller; flanged for regulators NPS 2-1/2 and larger.


1. Body and Diaphragm Case: Cast iron or die-cast aluminum.
2. Springs: Zinc-plated steel; interchangeable.
4. Seat Disc: Nitrile rubber resistant to gas impurities, abrasion, and deformation at the valve port.
5. Orifice: Aluminum; interchangeable.
7. Single-port, self-contained regulator with orifice no larger than required at maximum pressure inlet, and no pressure sensing piping external to the regulator.
8. Pressure regulator shall maintain discharge pressure setting downstream, and not exceed 150 percent of design discharge pressure at shutoff.
9. Atmospheric Vent: Factory- or field-installed, stainless-steel screen in opening if not connected to vent piping.

C. Appliance Pressure Regulators: Comply with ANSI Z21.18.

2. Springs: Zinc-plated steel; interchangeable.
7. Regulator may include vent limiting device, instead of vent connection, if approved by authorities having jurisdiction.

2.6 VALVE WALL BOX (MASTER GAS VALVE)
A. Master gas valve wall boxes shall be recessed, constructed of painted steel or aluminum with turned out flange on all four sides. Box shall be large enough to enclose the shut-off valve in both the open and closed position.
B. The access door shall be hinged and have keyed lock. Provide three sets of keys for each lock.
C. The Installer shall provide the gas cock with lever handle and install it within the valve box.
D. A label shall be affixed to the valve in the box and the access door shall also be labeled identifying the valve as a master gas shutoff valve.

2.7 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:
2. Manufacturers: Subject to compliance with requirements, [provide products by one of the following] [available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following]:
3. Basis-of-Design Product: Subject to compliance with requirements, provide [product indicated on Drawings] <Insert manufacturer's name; product name or designation> or comparable product 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.
h. <Insert manufacturer's name>.

4. Pilot operated.
5. Body: Brass or aluminum.
7. Springs and Valve Trim: Stainless steel.
8. 120-V ac, 60 Hz, Class B, continuous-duty molded coil, and replaceable.
9. NEMA ICS 6, Type 4, coil enclosure.

2.8 SLEEVES

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

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

2.9 MECHANICAL SLEEVE SEALS

A. Description: Modular sealing element unit, designed for field assembly, to fill annular space between pipe and sleeve.

1. Sealing Elements: EPDM interlocking links shaped to fit surface of pipe. Include type and number required for pipe material and size of pipe and sleeve.
2. Pressure Plates: Plastic.
3. Pressure Plates: [Plastic] [Carbon steel] [Stainless steel].
4. Connecting Bolts and Nuts: Carbon steel with corrosion-resistant coating of length required to secure pressure plates to sealing elements. Include one nut and bolt for each sealing element.
5. Connecting Bolts and Nuts: [Carbon steel with corrosion-resistant coating] [Stainless steel] of length required to secure pressure plates to sealing elements. Include one nut and bolt for each sealing element.

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 GAS SERVICE

A. Refer to Bid Pack 1 for the installation of the natural gas service into the building.

B. Arrange and pay for the installation of the natural gas service piping by the local gas utility. The Contractor shall be responsible for all fees and charges required by the local gas utility for complete installation, inspection, and testing of the system.

3.2 [GAS SERVICE]

A. Arrange and pay for the [installation][relocation] of the natural gas service piping by the local gas utility. The Contractor shall be responsible for all fees and charges required by the local gas utility for complete installation, inspection, and testing of the system. [The Contractor shall provide for an allowance of $___________ for work performed by the local gas utility. This allowance does not include surface repair or replacement.]

3.3 PREPARATION

A. Close equipment shutoff valves before turning off natural gas to premises or piping section.

B. Inspect natural-gas piping according to the International Fuel Gas Code to determine that natural-gas utilization devices are turned off in piping section affected.

C. Inspect natural-gas piping according to [NFPA 54] [the International Fuel Gas Code] to determine that natural-gas utilization devices are turned off in piping section affected.

D. Comply with the International Fuel Gas Code requirements for prevention of accidental ignition.

E. Comply with [NFPA 54] [the International Fuel Gas Code] requirements for prevention of accidental ignition.

3.4 OUTDOOR PIPING INSTALLATION

A. Comply with the International Fuel Gas Code for installation and purging of natural-gas piping.

B. Comply with [NFPA 54] [the International Fuel Gas Code] for installation and purging of natural-gas piping.

C. Install underground, natural-gas piping buried at least 36 inches below finished grade. Comply with requirements in Division 31 Section "Earth Moving" for excavating, trenching, and backfilling.

1. If natural-gas piping is installed less than 36 inches below finished grade, install it in containment conduit.

D. Install underground, PE, natural-gas piping according to ASTM D 2774.
E. Install fittings for changes in direction and branch connections.

F. 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.

G. 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.

H. 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.

I. Install pressure gage downstream from each service regulator. Pressure gages are specified in Division 23 Section "Meters and Gages for HVAC Piping."

3.5 INDOOR PIPING INSTALLATION

A. Comply with the International Fuel Gas Code for installation and purging of natural-gas piping.

B. Comply with [NFPA 54] [the International Fuel Gas Code] for installation and purging of natural-gas piping.

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

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

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

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

G. 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.

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

I. Locate valves for easy access.

J. Install piping free of sags and bends.
K. Install fittings for changes in direction and branch connections.

L. Install escutcheons at penetrations of interior walls, ceilings, and floors. Comply with requirements in Division 23 Section "Common Work Results for HVAC."

M. 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 Section "Penetration Firestopping."

N. Verify final equipment locations for roughing-in.

O. Comply with requirements in Sections specifying gas-fired appliances and equipment for roughing-in requirements.

P. Drips and Sediment Traps: Install drips at points where condensate may collect. Locate where accessible to permit cleaning and emptying. Do not install where condensate is subject to freezing.

Q. 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.

R. Extend relief vent connections for pressure regulators to outdoors and terminate with weatherproof vent cap.

S. Conceal pipe installations in walls, pipe spaces, utility spaces, above ceilings, unless indicated to be exposed to view.

T. Conceal pipe installations in walls, pipe spaces, utility spaces, above ceilings, [and below grade or floors,] unless indicated to be exposed to view.

U. Concealed Location Installations: Except as specified below, install concealed natural-gas piping and piping installed under the building in containment conduit. 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. Underground Piping Beneath Buildings: Install underground piping beneath buildings encased in a code approved conduit designed to withstand superimposed loads and the same pressure as the pipe.

3. Prohibited Locations:
   a. Do not install natural-gas piping in or through circulating air ducts, clothes or trash chutes, chimneys or gas vents (flues), ventilating ducts, or dumbwaiter or elevator shafts.
   b. Do not install natural-gas piping in solid walls or partitions.
V. Use eccentric reducer fittings to make reductions in pipe sizes. Install fittings with level side down.

W. Connect branch piping from top or side of horizontal piping.

X. Install unions in pipes NPS 2 and smaller, adjacent to each valve, at final connection to each piece of equipment. Unions are not required at flanged connections.

Y. Do not use natural-gas piping as grounding electrode.

Z. Install strainer on inlet of each line-pressure regulator and automatic or electrically operated valve.

AA. Install pressure gage upstream and downstream from each line regulator. Pressure gages are specified in Division 23 Section "Meters and Gages for HVAC Piping."

BB. Install automatic gas shutoff valve furnished by food service equipment supplier.

CC. Make final connection to gas-fired kitchen equipment furnished by food service equipment supplier.

3.6 VALVE INSTALLATION

A. Install manual gas shutoff valve at each gas-fired piece of equipment.

B. Install regulators with maintenance access space adequate for servicing and testing.

C. Install motorized gas shutoff valve for classroom shut-off as indicated with switch at teacher’s demonstration table.

D. Install master gas shutoff valve for classroom in wall box outside classroom as indicated.

3.7 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:
   2. Bevel plain ends of steel pipe.

E. Flanged Joints: Install gasket material, size, type, and thickness appropriate for natural-gas service. Install gasket concentrically positioned.

F. PE Piping Heat-Fusion Joints: Clean and dry joining surfaces by wiping with clean cloth or paper towels. Join according to ASTM D 2657.
   1. Plain-End Pipe and Fittings: Use butt fusion.
   2. Plain-End Pipe and Socket Fittings: Use socket fusion.

3.8 HANGER AND SUPPORT INSTALLATION
A. Comply with requirements for pipe hangers and supports specified in Division 23 Section "Hangers and Supports for HVAC Piping and Equipment."
B. 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, 1/2 inch.
   5. NPS 4 and Larger: Maximum span, 10 feet; minimum rod size, 5/8 inch.

3.9 CONNECTIONS
A. Install piping adjacent to appliances to allow service and maintenance of appliances.
B. 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.
   1. Install pressure regulator at connection to gas-fired appliance and equipment as required to meet maximum gas pressure requirements of that particular device.
C. Sediment Traps: Install tee fitting with capped nipple in bottom to form drip, as close as practical to inlet of each appliance.

3.10 LABELING AND IDENTIFYING
A. Comply with requirements in Division 23 Section "Identification for HVAC Piping and Equipment" for above ground 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.

3.11 PAINTING

A. Comply with requirements in Division 09 painting Sections for painting interior and exterior natural-gas piping.

B. Paint exposed, exterior metal piping, valves, and piping specialties, except components with factory-applied paint or protective coating.
   2. Color to be [safety yellow] [gray] [color to match building background color].

C. Paint interior exposed metal piping, valves, and piping specialties in mechanical rooms, except components with factory-applied paint or protective coating.
   1. Color to be safety yellow for exposed piping in mechanical rooms.
   2. Color to match building wall/ceiling color for exposed piping in finished spaces.
   3. <Insert Special Locations or Colors Here>

3.12 FIELD QUALITY CONTROL

A. Perform tests and inspections.

B. Tests and Inspections:
   1. Test, inspect, and purge natural gas according to the International Fuel Gas Code and authorities having jurisdiction.
   2. Test, inspect, and purge natural gas according to [NFPA 54] [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.

3.13 OUTDOOR PIPING SCHEDULE

A. Underground natural-gas piping shall be the following:
   1. PE pipe and fittings joined by heat fusion; terminated in an accessible location.

B. Aboveground natural-gas piping shall be the following:
   1. For NPS 2 and smaller, use steel pipe with malleable-iron fittings and threaded joints.
   2. For NPS 2-1/2 and larger, use steel pipe with wrought-steel fittings and welded joints.
3.14 INDOOR PIPING SCHEDULE FOR SYSTEM PRESSURES MORE THAN 0.5 PSIG AND LESS THAN 5 PSIG

A. Aboveground, distribution piping shall be one of the following:
   1. For NPS 2 and smaller, use steel pipe with malleable-iron fittings and threaded joints.
   2. For NPS 2-1/2 and larger, use steel pipe with wrought-steel fittings and welded joints.

3.15 ABOVEGROUND MANUAL GAS SHUTOFF VALVE SCHEDULE

A. Distribution piping valves for pipe sizes NPS 2 and smaller shall be one of the following:
   1. Two-piece, full-port, bronze ball valves with bronze trim.
   2. Bronze plug valve.

B. Distribution piping valves for pipe sizes NPS 2-1/2 and larger shall be one of the following:
   1. Bronze plug valve.
   2. Cast-iron, lubricated plug valve.
   3. Cast-iron, nonlubricated 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 23 1123
SECTION 23 2113 - HYDRONIC PIPING

PART 1 - GENERAL

1.1 SUMMARY

A. This Section includes pipe and fitting materials, joining methods, special-duty valves, and specialties for the following:

1. Hot-water heating piping.
2. Chilled-water cooling piping.
3. Makeup-water piping.
4. Condensate-drain piping.
5. Air-vent piping.

B. Related Sections include the following:

1. Division 23 Section "Hydronic Pumps" for pumps, motors, and accessories for hydronic piping.
2. Division 23 Section "Common Work Results for HVAC" for general piping materials and installation requirements.
3. Division 23 Section "Expansion Fittings and Loops for HVAC Piping" for pipe expansion compensating devices for hydronic piping systems.
4. Division 23 Section "Meters and Gages for HVAC Piping" for flow meters, thermometers and pressure gages.
5. Division 23 Section "General Duty Valves for HVAC Piping" for general-duty valves.
6. Division 23 Section "Hangers and Supports for HVAC Equipment" for pipe supports, product descriptions, and installation requirements. Hanger and support spacing is specified in this Section.
7. Division 23 Section "Identification for HVAC Piping and Equipment" for labeling and identifying hydronic piping.
8. Division 23 Section "Instrumentation and Control for HVAC" for temperature-control valves and sensors.
9. Division 23 Section "HVAC Water Treatment" for glycol, pipe cleaning and water treatment for HVAC systems.
10. Division 23 Section "HVAC Water Treatment" for glycol, pipe cleaning and water treatment for HVAC systems.
11. Division 23 Section "Heat Transfer Package" for components and specialties included with package.
1.2 ACTION SUBMITTALS

A. Product Data: For each type of the following:

1. Pressure-seal fittings.
2. Calibrated Balancing Valves: Include flow and pressure drop curves based on manufacturer's testing for calibrated-orifice balancing valves.
3. Automatic Flow Control Valves: Include flow and pressure drop curves based on manufacturer's testing for automatic flow-control valves.
4. Air control devices.
5. Hydronic specialties.

B. LEED Submittal:

1. Product Data for Credit EQ 4.1: For adhesives and sealants, including printed statement of VOC content.

1.3 INFORMATIONAL SUBMITTALS

A. Field quality-control test reports.

1.4 CLOSEOUT SUBMITTALS

A. Operation and maintenance data.

1.5 QUALITY ASSURANCE

A. Installer Qualifications:

1. Installers of Pressure-Sealed Joints: Installers shall be certified by the pressure-seal joint manufacturer as having been trained and qualified to join piping with pressure-seal pipe couplings and fittings.

B. ASME Compliance: Comply with ASME B31.9, "Building Services Piping," for materials, products, and installation. Safety valves and pressure vessels shall bear the appropriate ASME label. Fabricate and stamp air separators and expansion tanks to comply with ASME Boiler and Pressure Vessel Code: Section VIII, Division 01.


D. Comply with the provisions of the following:

1. Michigan Mechanical Code
PART 2 - PRODUCTS

2.1 COPPER TUBE AND FITTINGS

A. Drawn-Temper Copper Tubing: ASTM B 88, Type L.
B. Annealed-Temper Copper Tubing: ASTM B 88, Type K.
C. Wrought-Copper Fittings: ASME B16.22.
D. Copper or Bronze Pressure-Seal Fittings:
   1. Manufacturers: Subject to compliance with requirements, provide products by the following:
      a. Stadler-Viega.
      b. NIPCO Press.
   2. Housing: Copper.
   3. O-Rings and Pipe Stops: EPDM.
   4. Tools: Manufacturer’s special tools.
   5. Minimum 200-psig working-pressure rating at 250 deg F.
E. Copper, Mechanically Formed Tee Option: For forming T-branch on copper water tube.
   1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
      a. T-DRILL Industries Inc.
F. Wrought-Copper Unions: ASME B16.22.

2.2 STEEL PIPE AND FITTINGS

A. Steel Pipe: ASTM A 53/A 53M, black steel with plain ends; type, grade, and wall thickness as indicated in Part 3 “Piping Applications” Article.
B. Cast-Iron Threaded Fittings: ASME B16.4; Classes 125.
E. Cast-Iron Pipe Flanges and Flanged Fittings: ASME B16.1, Classes 125, raised ground face, and bolt holes spot faced as indicated in Part 3 “Piping Applications” Article.
F. Wrought-Steel Fittings: ASTM A 234/A 234M, wall thickness to match adjoining pipe.
G. Wrought Cast- and Forged-Steel Flanges and Flanged Fittings: ASME B16.5, including bolts, nuts, and gaskets of the following material group, end connections, and facings:
H. Forged-Steel Weld Neck Flanges: ASME B16.5, including bolts, nuts, and gaskets of the following material group, end connections, and facings:

2. End Connections: Butt welded.
3. End Connections: Slip-on or butt welded.
4. Facings: Raised face.

I. 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. Victaulic Company of America.
   c. Tyco/Grinnell.

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.

4. Refer to Division 23 Section "Hydronic Pumps" for allowable mechanical joint pump accessories.

J. Steel Pressure-Seal Fittings:

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

2. Housing: Steel.

3. O-Rings and Pipe Stop: EPDM.

4. Tools: Manufacturer's special tool.

5. Minimum 300-psig working-pressure rating at 230 deg F.

K. Steel Pipe Nipples: ASTM A 733, made of same materials and wall thicknesses as pipe in which they are installed.

2.3 PLASTIC PIPE AND FITTINGS

A. PVC Plastic Pipe: ASTM D 1785, Schedules 40 and 80, plain ends as indicated in Part 3 "Piping Applications" Article.


C. PVC Solvent Cement: ASTM D 2564.
2.4 PEX TUBE AND FITTINGS

A. Tubing:
   1. Material Standard: Manufactured in accordance with ASTM F876 and ASTM F877.
      a. Tubing shall have an oxygen-diffusion barrier that does not exceed an oxygen diffusion rate of 0.10 grams per cubic meter per day at 104 degrees F (40 degrees C) water temperature.

B. Fittings:
   1. Insertion type as required by tubing manufacturer.

2.5 JOINING MATERIALS

A. Pipe-Flange Gasket Materials: Suitable for chemical and thermal conditions of piping system contents.
   1. ASME B16.21, flat, asbestos free, 1/16-inch minimum thickness unless thickness or specific material is indicated.
      a. Full-Face Type: For flat-face, Class 125, cast-iron and cast-bronze flanges.
      b. Narrow-Face Type: For raised-face, Class 250, cast-iron and steel flanges.
      c. Narrow-Face Type: For raised-face, Class 150, steel flanges.

B. Flange Bolts and Nuts: ASME B18.2.1, carbon steel, 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, copper-phosphorus alloys for joining copper with copper; or BAg-1, silver alloy for joining copper with bronze or steel.


G. Solvent Cements for Joining Plastic Piping:
   1. PVC Piping: ASTM D 2564. Include primer according to ASTM F 656.
      a. PVC solvent cement shall have a VOC content of 510 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
      b. Adhesive primer shall have a VOC content of 550 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
2.6 DIELECTRIC FITTINGS

A. Dielectric Connections: Ground joint, copper unions, ASME B16.18, cast-copper-alloy body, hexagonal stock, with ball-and-socket joint, metal-to-metal seating surfaces, and solder-joint, threaded, or solder-joint and threaded ends; and suitable system fluid, pressure and temperature.

B. Dielectric Flanges:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   b. Central Plastics Company.
   c. Watts Regulator Co.; a division of Watts Water Technologies, Inc.

2. Factory-fabricated companion-flange assembly, for 150-psig minimum working pressure.

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

D. Description: Combination fitting of copper-alloy and ferrous materials with threaded end connections that match piping system materials.

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

E. Dielectric Unions:

1. Factory-fabricated union assembly, for 250-psig minimum working pressure at 180 deg F.
2. Connections: Female iron pipe thread to female brass pipe thread connection.

F. Dielectric-Flange Kits:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   a. Advance Products & Systems, Inc.
   b. Calpico, Inc.
   c. Central Plastics Company.
   d. Pipeline Seal and Insulator, Inc.

2. Companion-flange assembly for field assembly. Include flanges, full-face- or ring-type neoprene or phenolic gasket, phenolic or polyethylene bolt sleeves, phenolic washers, and steel backing washers.
3. Separate companion flanges and steel bolts and nuts shall have 150-psig minimum working pressure.

G. Dielectric Couplings:

1. Galvanized-steel coupling with inert and noncorrosive thermoplastic lining; threaded ends; and 300-psig minimum working pressure at 225 deg F.

H. Dielectric Nipples:
1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   a. Perfection Corporation; a subsidiary of American Meter Company.
   b. Precision Plumbing Products, Inc.
   c. Sioux Chief Manufacturing Company, Inc.
   d. Victaulic Company of America.

2. Electroplated steel nipple with inert and noncorrosive, thermoplastic lining; threaded ends; and 300-psig minimum working pressure at 225 deg F.

2.7 VALVES

A. Butterfly, Check, and Ball Valves: Comply with requirements specified in Division 23 Section "General-Duty Valves for HVAC Piping."

B. Automatic Temperature-Control Valves, Actuators, and Sensors: Furnished by temperature controls provider. Refer to Division 23 Section "Instrumentation and Control for HVAC."

C. Calibrated-Orifice, Balancing Valves:
   1. Manufacturers: Subject to compliance with requirements, provide products by the following:
      a. Bell & Gossett – Sentry Flo-Setter, NPS 2 and Smaller.
      b. Tour Andersson, NPS 3 and Smaller.
   2. Body: Non-ferrous alloy
   5. Handle Style: Dial, with memory stop to retain set position.
   7. Maximum Operating Temperature: 230 deg F.

D. Bronze, Calibrated-Orifice, Balancing Valves:
   1. Manufacturers: Subject to compliance with requirements, provide products by the following:
   2. 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. Flow Design Inc.
      d. Gerard Engineering Co.
      e. Griswold Controls.
      f. Taco.
   4. Body: Bronze, ball or plug type with calibrated orifice or venturi.
   5. Ball: Stainless steel.
   6. Ball: Brass or stainless steel.
   7. Plug: Resin.
8. Seat: PTFE.
9. End Connections: Threaded or socket.
11. Handle Style: Dial, with memory stop to retain set position.
13. Maximum Operating Temperature: 250 deg F.

E. Cast-Iron or Steel, Calibrated-Orifice, Balancing Valves, Larger than NPS 3:

1. Manufacturers: Subject to compliance with requirements, provide products by the following:
   a. Bell & Gossett.
   b. Tour Andersson.

2. 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. Flow Design Inc.
   d. Gerard Engineering Co.
   e. Griswold Controls.
   f. Taco.
   g. Tour & Andersson; available through Victaulic Company of America.

3. Body: Cast-iron or steel body, ball, plug, or globe pattern with calibrated orifice or venturi.
4. Body: Cast-iron or steel body with calibrated orifice.
5. Ball: Stainless steel.
6. Ball: Brass or stainless steel.
7. Stem Seals: EPDM O-rings.
8. Disc: Glass and carbon-filled PTFE.
9. Seat: PTFE.
11. End Connections: Flanged or grooved.
13. Handle Style: Dial, with memory stop to retain set position.
14. Handle Style: Lever or dial, with memory stop to retain set position.
15. CWP Rating: Minimum 125 psig.
16. Maximum Operating Temperature: 250 deg F.

F. Diaphragm-Operated, Pressure-Reducing 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. Spence Engineering Company, Inc.

2. 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. Conbraco Industries, Inc.; Apollo Valves.
e. Spence Engineering Company, Inc.
f. Watts Regulator Co.; a division of Watts Water Technologies, Inc.

3. Body: Bronze or brass.
4. Disc: Glass and carbon-filled PTFE.
5. Seat: Brass.
7. Diaphragm: EPT.
8. Low inlet-pressure check valve.
9. Inlet Strainer: removable without system shutdown.
11. Valve Size, Capacity, and Operating Pressure: Selected to suit system in which installed, with operating pressure and capacity factory set and field adjustable.

G. Diaphragm-Operated Safety Valves:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
a. Bell & Gossett Domestic Pump; a division of ITT Industries.
b. Spence Engineering Company, Inc.
c. Watts Regulator Co.; a division of Watts Water Technologies, Inc.

2. 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. Conbraco Industries, Inc.; Apollo Valves.
e. Spence Engineering Company, Inc.
f. Watts Regulator Co.; a division of Watts Water Technologies, Inc.

3. Body: Bronze or brass.
4. Disc: Glass and carbon-filled PTFE.
5. Seat: Brass.
7. Diaphragm: EPT.
9. Inlet Strainer: removable without system shutdown.
11. 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.

H. Automatic Flow-Control Valves:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
a. Flow Design Inc.
b. Griswold Controls.
2. Body: Brass or ferrous metal.
3. Piston and Spring Assembly: Stainless steel, tamper proof, self cleaning, and removable.
4. Combination Assemblies: Include bronze or brass-alloy ball valve.
5. Identification Tag: Marked with zone identification, valve number, and flow rate.
6. Size: Same as pipe in which installed.
7. Performance: Maintain constant flow, plus or minus 5 percent over system pressure fluctuations.
9. Maximum Operating Temperature: 200 deg F.

I. Drain and Vent Valves:

1. Ball-Valve-Type, Hose-End Valves:
   a. Standard: MSS SP-110 for full-port, two-piece ball valves.
   b. Pressure Rating: 400-psig minimum CWP.
   d. Body: Copper alloy.
   e. Ball: Stainless steel.
   f. Ball: Chrome-plated brass.
   g. Seats and Seals: Replaceable.
   h. Handle: Vinyl-covered steel.
   i. Inlet: Threaded or solder joint.
   j. Outlet: Threaded, short nipple with garden-hose thread complying with ASME B1.20.7 and cap with brass chain.

2. Gate-Valve-Type, Hose-End Drain Valves:
   b. Pressure Rating: Class 125.
   e. Inlet: NPS 3/4 threaded or solder joint.
   f. Outlet: Garden-hose thread complying with ASME B1.20.7 and cap with brass chain.

2.8 AIR CONTROL DEVICES

A. Manufacturers: Subject to compliance with requirements, provide products by the following:
   1. Bell & Gossett Domestic Pump; a division of ITT Industries.

B. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   1. Amtrol, Inc.
   2. Armstrong Pumps, Inc.
   3. Bell & Gossett Domestic Pump; a division of ITT Industries.
   4. Taco.

C. Manual Air Vents:
1. Manufacturers: Subject to compliance with requirements, provide products by the following:
   a. Bell & Gossett.

2. Body: Bronze.
3. Internal Parts: Nonferrous.
4. Operator: Screwdriver or thumbscrew.
5. Inlet Connection: NPS 1/2.
7. CWP Rating: 150 psig.
8. Maximum Operating Temperature: 225 deg F.

2.9 Automatic Air Vents:

1. Manufacturers: Subject to compliance with requirements, provide products by the following:
   a. Bell & Gossett.

2. Body: Bronze or cast iron.
3. Internal Parts: Nonferrous.
5. Inlet Connection: NPS 1/2.
7. CWP Rating: 150 psig.
8. Maximum Operating Temperature: 240 deg F.

B. Expansion Tanks:

1. Manufacturers: Subject to compliance with requirements, provide products by the following:
   a. Amtrol, Inc.
   b. Armstrong Pumps, Inc.
   c. Bell & Gossett.

2. Tank: Welded steel, rated for 125-psig working pressure and 375 deg F maximum operating temperature, with taps in bottom of tank for tank fitting and taps in end of tank for gage glass. Tanks shall be factory tested with taps fabricated and labeled according to ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.
3. Air-Control Tank Fitting: Cast-iron body, copper-plated tube, brass vent tube plug, and stainless-steel ball check, 100-gal. unit only; sized for compression-tank diameter. Provide tank fittings for 125-psig working pressure and 250 deg F maximum operating temperature.
4. Tank Drain Fitting: Brass body, nonferrous internal parts; 125-psig working pressure and 240 deg F maximum operating temperature; constructed to admit air to compression tank, drain water, and close off system.

C. Diaphragm-Type Expansion Tanks:
1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   a. Amtrol, Inc.
   b. Armstrong Pumps, Inc.
   c. Bell & Gossett.

2. Tank: Welded steel, rated for 125-psig (860-kPa) working pressure and 240 deg F (115 deg C) design operating temperature. Factory test with taps fabricated and supports installed and labeled according to ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.

3. Tank: Welded steel, rated for 125-psig (860-kPa) working pressure and 375 deg F (191 deg C) maximum operating temperature. Factory test with taps fabricated and supports installed and labeled according to ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.

4. Diaphragm: Securely sealed into tank to separate air charge from system water to maintain required expansion capacity.

5. Air-Charge Fittings: Schrader valve, stainless steel with EPDM seats.

D. Bladder-Type Expansion Tanks:

1. Tank: Welded steel, rated for 125-psig (860-kPa) working pressure and 375 deg F (191 deg C) maximum operating temperature. Factory test with taps fabricated and supports installed and labeled according to ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.

2. Bladder: Securely sealed into tank to separate air charge from system water to maintain required expansion capacity.


E. Air Eliminators:

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

2. Description: Coalescing type air eliminator, steel fabricated, rated for 150 psig working pressure with internal coalescing bundle consisting of a copper core tube with continuous wound copper medium permanently affixed to the core. Eliminator shall have a separate venting chamber to prevent system contaminants from harming the float and venting valve operation. At the top of the venting chamber shall be an integral full port float actuated brass venting mechanism. Units shall include a valved side tap to flush floating dirt or liquids and for quick bleeding of large amounts of air during system fill or refill. Eliminator shall include a bottom connection for use as a blow down connection for periodic cleaning.

F. Air Eliminators:

1. Manufacturers: Subject to compliance with requirements, provide products by the following:
   a. Bell & Gossett.

2. Description: Coalescing type air eliminator, steel fabricated, rated for 125 psig working pressure with stainless steel medium and connections for air vent, blow-down valve, and skim valve.
G. Tangential-Type Air Separators:

1. Manufacturers: Subject to compliance with requirements, provide products by the following:
   a. Amtrol, Inc.
   b. Armstrong Pumps, Inc.
   c. Bell & Gossett Domestic Pump; a division of ITT Industries.
   d. Taco.

2. Tank: Welded steel; ASME constructed and labeled for 125-psig minimum working pressure and 375 deg F maximum operating temperature.

3. Air Collector Tube: Perforated stainless steel, constructed to direct released air into expansion tank.

4. Tangential Inlet and Outlet Connections: Threaded for NPS 2 and smaller; flanged or grooved connections for NPS 2-1/2 and larger.

5. Blowdown Connection: Threaded.


H. In-Line Air Separators:

1. Tank: One-piece cast iron with an integral weir constructed to decelerate system flow to maximize air separation.


3. Maximum Operating Temperature: Up to 300 deg F.

I. Air Purgers:

1. Body: Cast iron with internal baffles that slow the water velocity to separate the air from solution and divert it to the vent for quick removal.


3. Maximum Operating Temperature: 250 deg F.

J. Enhanced Air Separator:

1. Manufacturers: Subject to compliance with requirements, provide products by the following:
   a. Bell & Gossett.

2. Body: Cast iron body and cap with stainless steel internals.

3. Air Outlet: Large capacity automatic air vent with non-ferrous internals.


5. Maximum Operating Temperature: 250 deg F.
2.10 CHEMICAL TREATMENT

2.11 GLYCOL

2.12 HYDRONIC PIPING SPECIALTIES

A. Y-Pattern Strainers:
   1. Body: ASTM A 126, Class B, cast iron with bolted cover and bottom drain connection.
   2. End Connections: Threaded ends for NPS 2 and smaller; flanged ends for NPS 2-1/2(DN 65) and larger.
   3. Strainer Screen: 40-mesh startup strainer, and perforated stainless-steel basket with 50 percent free area.
   4. CWP Rating: minimum 125 psig.
   5. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
      a. Apollo.
      b. Spence
      c. Mueller.

B. Basket Strainers:
   1. Body: ASTM A 126, Class B, high-tensile 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.

C. T-Pattern Strainers:
   1. Body: Ductile or malleable iron with removable access coupling and end cap for strainer maintenance.
   2. End Connections: Grooved ends.
   3. Strainer Screen: 40-mesh startup strainer, and perforated stainless-steel basket with 57 percent free area.
   4. CWP Rating: 750 psig.

D. Stainless-Steel Bellow, Flexible Connectors:
   2. End Connections: Threaded or flanged to match equipment connected.
   4. CWP Rating: 150 psig.
   5. Maximum Operating Temperature: 250 deg F.
   6. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
a. Flex-Hose Co., Inc.
b. Flexicraft Industries.
c. Metraflex, Inc.

E. Spherical, Rubber, Flexible Connectors:
   2. End Connections: Steel flanges drilled to align with Classes 150 and 300 steel flanges.
   4. CWP Rating: 150 psig.
   5. Maximum Operating Temperature: 250 deg F.

F. Expansion fittings are specified in Division 23 Section "Expansion Fittings and Loops for HVAC Piping."

G. Pipe Cover System:
   1. Description: Factory-fabricated steel cover support system with concealed surface mounted attachment clamps for concealment of piping.
      a. Cover system shall incorporate a concealed snap-lock connection which, once assembled, renders the cover essentially irremovable with the use of ordinary tools.
   2. Cover: Smooth in appearance and made of 18-gauge G90 galvanized steel, with a paint-grip finish for field painting.
   3. Manufacturer: Grice Engineering, Interlock, or equivalent.

H. Sight Flow Indicators: Provide self-cleaning glass with wiper type flow indicator with brass body, threaded connections, and rotating impeller. John C. Ernst Co. Model 700 or equivalent.

2.13 BACKFLOW PREVENTERS

A. Reduced-Pressure-Principle Backflow Preventers:
   1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
      a. Ames Co.
      b. Conbraco Industries, Inc.; Apollo Valves.
      c. FEBCO; SPX Valves & Controls.
      e. Zurn Plumbing Products Group; Wilkins Div.
   3. Operation: Continuous-pressure applications.
   4. Pressure Loss: 12 psig maximum, through middle 1/3 of flow range.
   5. Body: Bronze for NPS 2 and smaller; cast iron with interior lining complying with AWWA C550 or that is FDA approved for NPS 2-1/2 and larger.
   7. End Connections: Threaded for NPS 2 and smaller; flanged for NPS 2-1/2 and larger.
   8. End Connections: Threaded for NPS 2 and smaller.
   9. Accessories:
WMU Design Guidelines

a. Valves: Ball type with threaded ends on inlet and outlet of NPS 2 and smaller.
b. Valves: Ball type with threaded ends on inlet and outlet of NPS 2 and smaller; outside screw and yoke gate-type with flanged ends on inlet and outlet of NPS 2-1/2 and larger.

PART 3 - EXECUTION

3.1 PIPING APPLICATIONS

A. Chilled water cooling piping, aboveground, NPS 2-1/2(DN 650) and smaller, shall be the following:

B. Hot-water heating and chilled water cooling piping, aboveground, NPS 2-1/2 and smaller, shall be any of the following:

1. Type L, 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 threaded fittings.
3. Schedule 5 steel pipe; steel, pressure-seal couplings and fittings; and pressure-seal joints.
4. Type L, drawn-temper copper tubing, wrought-copper fittings, and pressure-seal joints.

C. Hot-water heating piping, aboveground, NPS 2-1/2 and larger, shall be [any of ] the following:

D. Chilled water cooling piping, aboveground, NPS 2-1/2 and larger, shall be the following:

E. Hot-water heating and chilled water cooling piping, aboveground, NPS 2-1/2 and larger, shall be the following:

1. Schedule 40 steel pipe, wrought-steel fittings and wrought-cast or forged-steel flanges and flange fittings, and welded and flanged joints.
2. Schedule 40 steel pipe; grooved, mechanical joint coupling and fittings; and grooved, mechanical joints.

F. Hot-water heating piping installed below slabs, NPS 2(DN 50) and smaller, shall be the following:

1. Type K, annealed-temper copper tubing, wrought-copper fittings, and soldered or brazed joints. Use the fewest possible joints.

G. Hot-water heating piping installed below slabs, NPS 2-1/2(DN 65) and larger, shall be the following:

1. <INSERT PREINSULATED PIPING SYSTEMS BELOW SIMILAR TO PERMA-PIPE "POLY-THERM". SEE 95 MECH-GUIDESPEC 02551 OR 02555>

H. Makeup-water piping installed aboveground, NPS 2 and smaller, shall be the following:
1. Type L, drawn-temper copper tubing, wrought-copper fittings, and soldered or brazed joints.

I. Condensate-Drain Piping: Type L, drawn-temper copper tubing, wrought-copper fittings, and soldered joints[ or Schedule 40 PVC plastic pipe and fittings and solvent-welded joints].

J. AHU Condensate-Drain Piping: Type L, drawn-temper copper tubing, wrought-copper fittings, and soldered joints.

1. Use galvanized steel pipe and drainage fittings for outdoor air handling unit condensate drains.

K. Air-Vent Piping:

1. Inlet: Same as service where installed.
2. Outlet: Type L, annealed-temper copper tubing with soldered or flared joints.

L. Safety-Valve-Inlet and -Outlet Piping: Same materials and joining methods as for piping specified for the service in which safety valve is installed.

M. 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 mains, and at supply connection to each piece of equipment.

B. Install balancing valve (throttle-duty valve with memory stop) and flow meter in chilled water piping at entrance to Lee Honors building.

C. Install balancing valve (throttle-duty valve with memory stop) and flow meter in hydronic piping where indicated.

D. Install throttling-duty valve and calibrated-orifice balancing valve where indicated.

E. On NPS 2 and smaller, install throttling-duty valve and calibrated-orifice balancing valve at each branch connection to return main.

F. On NPS 2-1/2 and larger, install calibrated-orifice balancing valves at each branch connection to return main.

G. On NPS 2-1/2 and larger, install [balancing valve (throttle-duty valve with memory stop) and flow meter ]or ][calibrated-orifice balancing valves ]at each branch connection to return main.

H. Install calibrated-orifice, balancing valves in the return pipe of each heating or cooling terminal.

I. Install check valves at each pump discharge and elsewhere as required to control flow direction.
J. Install safety valves at hot-water generators and elsewhere as required by ASME Boiler and Pressure Vessel Code. Install drip-pan elbow on safety-valve outlet and pipe without valves to the outdoors; and pipe drain to nearest floor drain or as indicated on Drawings. Comply with ASME Boiler and Pressure Vessel Code: Section VIII, Division 01, for installation requirements.

K. Install pressure-reducing valves at makeup-water connection to regulate system fill 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 valve servicing.

F. Install piping at indicated slopes.

G. Install piping free of sags and bends.

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

I. Install piping to allow application of insulation.

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

K. Install groups of pipes parallel to each other, spaced to permit applying insulation and servicing of valves.

L. Install drains, consisting of a tee fitting, short NPS 3/4 threaded nipple, and NPS 3/4 drain valve with cap, at low points in piping system mains and elsewhere as required for system drainage.

M. Install drains, consisting of a tee fitting, NPS 3/4 drain valve and short NPS 3/4 threaded nipple with cap, at low points in piping system mains and elsewhere as required for system drainage.

N. Install air vents, consisting of a tee fitting, short NPS 3/4 threaded nipple, and NPS 3/4 valve with cap, at high points in piping system and at hydronic coils for manual venting.

O. Install air vents, consisting of a tee fitting, NPS 3/4 ball valve and NPS 3/4 turn-down with threaded cap at high points in piping system mains for manual venting.

P. Reduce pipe sizes using eccentric reducer fitting installed with level side up.
Q. Install branch connections to mains using tee fittings or where allowed, mechanically formed tee fittings in main pipe, with the branch connected to the bottom of the main pipe. For up-feed risers, connect the branch to the top of the main pipe.

R. For expansion compensation at risers and terminals, install connection between piping mains and risers with at least 5 pipe fittings including tee in main. Install connections between piping risers and terminal units with at least 4 pipe fittings including tee in riser.

S. Install valves according to Division 23 Section "General-Duty Valves for HVAC Piping."

T. Install unions in piping, NPS 2 and smaller, adjacent to valves, at final connections of equipment, and elsewhere as indicated.

U. Install flanges in piping, NPS 2-1/2 and larger, at final connections of equipment and elsewhere as indicated.

V. Install flanges in piping, NPS 2-1/2 and larger, at final connections of equipment and elsewhere as indicated [unless mechanical grooved connections allowed].

W. Install strainers on inlet side of each 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.

X. 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.

Y. Install expansion loops, expansion joints, anchors, and pipe alignment guides as specified in Division 23 Section "Expansion Fittings and Loops for HVAC Piping."

Z. Identify piping as specified in Division 23 Section "Identification for HVAC Piping and Equipment."

3.4 HANGERS AND SUPPORTS

A. Install structural steel members between building structure members as required for upper attachment of hangers and supports. Use members of size and strength required for span and load. The use of joist or truss bridging for hanging and supporting is prohibited.

B. Hanger, support, and anchor devices are specified in Division 23 Section "Hangers and Supports for HVAC Piping and Equipment." Comply with the following requirements for maximum spacing of supports.

C. Install the following pipe attachments:

1. Adjustable steel clevis hangers for individual horizontal piping less than 20 feet long.
2. Adjustable roller hangers and spring hangers for individual horizontal piping 20 feet or longer.
3. Pipe Roller: MSS SP-58, Type 44 for multiple horizontal piping 20 feet or longer, supported on a trapeze.
4. Spring hangers to support vertical runs.
5. Provide copper-clad hangers and supports for hangers and supports in direct contact with copper pipe.

D. Install hangers for steel piping with the following maximum spacing and minimum rod [sizes unless grooved or pressure sealed fitting manufacturer requires more frequent support]:

E. Install hangers for steel piping with the following maximum spacing and minimum rod:

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 5(DN 125): Maximum span, 14 feet(4.3 m); minimum rod size, 1/2 inch(13 mm).
9. NPS 6: Maximum span, 17 feet; minimum rod size, 1/2 inch.
10. NPS 8: Maximum span, 19 feet; minimum rod size, 5/8 inch.
11. NPS 10: Maximum span, 20 feet; minimum rod size, 3/4 inch.
12. NPS 12: Maximum span, 23 feet; minimum rod size, 7/8 inch.
13. NPS 14: Maximum span, 25 feet; minimum rod size, 1 inch.
14. NPS 16: Maximum span, 27 feet; minimum rod size, 1 inch.
15. NPS 18: Maximum span, 28 feet; minimum rod size, 1-1/4 inches.
16. NPS 20: Maximum span, 30 feet; minimum rod size, 1-1/4 inches.

F. Install hangers for 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.

G. Support vertical runs at each floor, and at 10-foot intervals between floors.

3.5 PIPE JOINT CONSTRUCTION

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

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

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

E. Threaded Joints: Thread pipe with tapered pipe threads according to ASME B1.20.1. Cut threads full and clean using sharp dies. Ream threaded pipe ends to remove burrs and restore full ID. Join pipe fittings and valves as follows:

1. Apply appropriate tape or thread compound to external pipe threads unless dry seal threading is specified.
2. Damaged Threads: Do not use pipe or pipe fittings with threads that are corroded or damaged. Do not use pipe sections that have cracked or open welds.


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

H. Plastic Piping Solvent-Cemented Joints: Clean and dry joining surfaces. Join pipe and fittings according to the following:

1. Comply with ASTM F 402 for safe-handling practice of cleaners, primers, and solvent cements.
2. PVC Nonpressure Piping: Join according to ASTM D 2855.

I. Grooved Joints: Assemble joints with coupling and gasket, lubricant, and bolts. Cut or roll grooves in ends of pipe based on pipe and coupling manufacturer's written instructions for pipe wall thickness. Use grooved-end fittings and rigid, grooved-end-pipe couplings.

J. Mechanically Formed, Copper-Tube-Outlet Joints: Use manufacturer-recommended tool and procedure, and brazed joints.

K. Pressure-Sealed Joints: Use manufacturer-recommended tool and procedure. Leave insertion marks on pipe after assembly.

3.6 HYDRONIC SPECIALTIES INSTALLATION

A. Install small manual air vents at high points in branch piping and at heat-transfer coils as required for system air venting.

B. Install manual air vents at high points in piping, at heat-transfer coils, and elsewhere as required for system air venting.

C. Install automatic air vents at high points of system piping in mechanical equipment rooms only.

D. Install piping to expansion tank with a 2 percent upward slope toward tank.

E. Install in-line air separators in pump suction. Install drain valve on air separators NPS 2 and larger.

F. Install tangential air separator in pump suction. Install ball valve in blowdown connection. [Install blowdown piping; extend full size to nearest floor drain.]
G. Install air eliminator in pump suction. Install ball valve in blowdown connection.
   1. Install piping from automatic air vent in top of air eliminator and extend full size to nearest floor drain.

H. Install tangential air separator in pump suction. Install ball valve in blowdown connection.

I. Install bypass chemical feeders in each hydronic system where indicated, in upright position with top of funnel not more than 48 inches (1200 mm) above the floor. Install feeder in minimum NPS 3/4 (DN 20) bypass line, from main with full-size, full-port, ball valve in the main between bypass connections. Install ball valve in drain connection. [Install drain piping; extend full size to nearest floor drain.]

J. Install expansion tanks above take-off connection. Install tank fitting in tank bottom and charge tank. Use manual vent for initial fill to establish proper water level in tank.

K. Install expansion tanks above the air separator. Install tank fitting in tank bottom and charge tank. Use manual vent for initial fill to establish proper water level in tank.
   1. Install tank fittings that are shipped loose.
   2. Support tank from floor or structure above with sufficient strength to carry weight of tank, piping connections, fittings, plus tank full of water. Do not overload building components and structural members.

L. Install expansion tanks where indicated. Vent and purge air from hydronic system, and ensure tank is properly charged with air to suit system project requirements.

M. Install expansion tanks on the floor. Vent and purge air from hydronic system, and ensure tank is properly charged with air to suit system Project requirements.

N. Install pipe cover system where indicated in accordance with manufacturer’s requirements. Paint cover to match surrounding area. Coordinate with Architect.

3.7 BACKFLOW PREVENTER INSTALLATION

A. Install backflow preventers in each water supply to mechanical equipment and systems. Comply with authorities having jurisdiction.
   1. Locate backflow preventers in same room as connected equipment or system.
   2. Install drain for backflow preventers with atmospheric-vent drain connection with air-gap fitting, fixed air-gap fitting, or equivalent positive pipe separation of at least two pipe diameters in drain piping and pipe to floor drain. Locate air-gap device attached to or under backflow preventer. Simple air breaks are not acceptable for this application.
   3. Do not install bypass piping around backflow preventers.

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 bypass piping with globe valve around control valve. If parallel control valves are installed, only one bypass is required.

D. Install ports for test plugs and pressure gages at pumps and elsewhere as indicated according to Division 23 Section "Meters and Gages for HVAC Piping."

E. Install ports for pressure gages and thermometers at coil inlet and outlet connections and elsewhere as indicated according to Division 23 Section "Meters and Gages for HVAC Piping."

3.9 CHEMICAL TREATMENT

A. Perform an analysis of makeup water to determine type and quantities of chemical treatment needed to keep system free of scale, corrosion, and fouling, and to sustain the water characteristics as required by water-treatment specialist.

B. Fill system with fresh water and add liquid alkaline compound with emulsifying agents and detergents to remove grease and petroleum products from piping. Circulate solution for a minimum of 24 hours, drain, clean strainer screens, and refill with fresh water.

C. Add initial chemical treatment and maintain water quality as required by water-treatment specialist for the first year of operation.

D. Fill systems indicated to have glycol solutions with the following concentrations:

2. Chilled-Water Piping: Minimum 40 percent propylene glycol.

3.10 FIELD QUALITY CONTROL

A. Prepare hydronic piping according to ASME B31.9 and as follows:

1. Leave joints, including welds, uninsulated and exposed for examination during test.
2. Provide temporary restraints for expansion joints that cannot sustain reactions due to test pressure. If temporary restraints are impractical, isolate expansion joints from testing.
3. Flush hydronic piping systems with clean water; then remove and clean or replace strainer screens.
4. Isolate equipment from piping. If a valve is used to isolate equipment, its closure shall be capable of sealing against test pressure without damage to valve. Install blinds in flanged joints to isolate equipment.
5. Install safety valve, set at a pressure no more than one-third higher than test pressure, to protect against damage by expanding liquid or other source of overpressure during test.

B. Perform the following tests on hydronic piping:
1. Use ambient temperature water as a testing medium unless there is risk of damage due to freezing. Another liquid that is safe for workers and compatible with piping may be used.
2. While filling system, use vents installed at high points of system to release air. Use drains installed at low points for complete draining of test liquid.
3. Isolate expansion tanks and determine that hydronic system is full of water.
4. Subject piping system to hydrostatic test pressure that is not less than 1.5 times the system's working pressure. Test pressure shall not exceed maximum pressure for any vessel, pump, valve, or other component in system under test. Verify that stress due to pressure at bottom of vertical runs does not exceed 90 percent of specified minimum yield strength or 1.7 times "SE" value in Appendix A in ASME B31.9, "Building Services Piping."
5. After hydrostatic test pressure has been applied for at least 10 minutes, examine piping, joints, and connections for leakage. Eliminate leaks by tightening, repairing, or replacing components, and repeat hydrostatic test until there are no leaks.
6. Prepare written report of testing.

C. Perform the following before operating the system:
   1. Open manual valves fully.
   2. Inspect pumps for proper rotation.
   3. Set makeup pressure-reducing valves for required system pressure.
   4. Inspect air vents at high points of system and determine if all are installed and bleed air completely.
   5. Set temperature controls so all coils are calling for full flow.
   6. Inspect and set operating temperatures of hydronic equipment to specified values.
   7. Verify lubrication of motors and bearings.

D. Test each backflow preventer according to authorities having jurisdiction and the device's reference standard.
   1. Remove and replace malfunctioning backflow preventer and retest as specified above.

END OF SECTION 23 2113
WMU Design Guidelines Instructions: These guidelines are to be used by the Design Professional to inform the design process and outline WMU-specific desires for all University projects. These guidelines have been edited to reflect WMU preferences, and the intent is for the Design Professional to use this information to guide their normal specifications-writing process. Straying from what is indicated in the guidelines is not prohibited, but shall be discussed with WMU during the development of the project.

SECTION 23 2114 - UNDERGROUND HYDRONIC PIPING

PART 1 - GENERAL

1.1 SUMMARY

   A. This Section includes underground piping outside the building for distribution of heating hot water, chilled water, cooling tower makeup water, and condenser water.

   B. This Section includes underground piping outside the building for distribution of chilled water.

   C. This Section includes underground piping outside the building for distribution of heating hot and chilled water.

1.2 PERFORMANCE REQUIREMENTS

   A. Provide components and installation capable of producing hydronic piping systems with the following minimum working-pressure ratings:

      1. Hot-Water Piping: 100 psig.
      2. Chilled-Water Piping: 100 psig.
      5. Hot-Water Piping: [100 psig] [150 psig] <Insert psig>.
      6. Chilled-Water Piping: [100 psig] [150 psig] <Insert psig>.
      7. Condenser-Water Piping: [100 psig] [150 psig] <Insert psig>.

1.3 SUBMITTALS

   A. Product Data: For the following:

      1. Underground piping system.

   B. Shop Drawings: Signed and sealed by a qualified professional engineer.

      1. Calculate requirements for expansion compensation for underground piping.
      2. Show expansion compensators, offsets, and loops with appropriate materials to allow piping movement in the required locations. Show anchors and guides that restrain piping movement with calculated loads, and show concrete thrust block dimensions.
      3. Show pipe sizes, locations, and elevations. Show piping in trench, conduit, and cased pipe with details showing clearances between piping, and show insulation thickness.
C. Qualification Data: For qualified Installer.

D. 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.

E. Source quality-control test reports.

F. Field quality-control test reports.

1.4 QUALITY ASSURANCE

A. Certify that each installer has been trained by the manufacturer’s representative for piping installation.


PART 2 - PRODUCTS

2.1 UNDERGROUND PLASTIC PIPING SYSTEM (CHILLED, MAKEUP, AND CONDENSER WATER DISTRIBUTION)

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

1. Aquatherm® Blue Pipe

B. Description:

1. Pipe and fittings shall be manufactured from a PP-R resin (Fusiolen) meeting the short-term properties and long-term strength requirements of ASTM F 2389. The pipe shall contain no rework or recycled materials except that generated in the manufacturer’s own plant from resin of the same specification from the same raw material. All pipe shall be made in an extrusion process. Piping shall contain a fiber layer (faser) to restrict thermal expansion. All pipe shall comply with the rated pressure requirements of ASTM F 2389. All pipe shall be certified by NSF International as complying with NSF 14, and ASTM F 2389 or CSA B137.11.

2. Polypropylene outlet fittings shall be used for fusion weld joints between pipe and fittings.

3. Mechanical fittings and transition fittings shall be used where transitions are made to other piping materials or to valves and appurtenances.

4. Polypropylene pipe shall not be threaded. Threaded transition fittings per ASTM F 2389 shall be used where a threaded connection is required.

5. Polypropylene pipe used for hot water distribution shall include a fiberglass-reinforced layer to reduce thermal expansion/contraction.

C. Plastic, Pipe-Flange Gasket, Bolts, and Nuts: Type and material recommended by piping system manufacturer unless otherwise indicated.
D. Plastic-to-Metal Transition Fittings shall be the following:

1. PP-R one-piece fitting with threaded stainless steel, brass, or copper insert and one PP-R fusion weld joint end.

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

1. Aquatherm® Blue Pipe.
2. NUPI.

B. Description:

1. Pipe and fittings shall be manufactured from a PP-R resin meeting the requirements of ASTM F 2389. The pipe shall contain no rework or recycled materials except that generated in the manufacturer's own plant from resin of the same specification from the same raw material. All pipe shall be made in an extrusion process. All pipe shall comply with the rated pressure requirements of ASTM F 2389. All pipe shall be certified by NSF International as complying with NSF 14, and ASTM F 2389 or CSA B137.11.

2. Polypropylene outlet fittings shall be used for fusion weld joints between pipe and fittings.

3. Mechanical fittings and transition fittings shall be used where transitions are made to other piping materials or to valves and appurtenances.

4. Polypropylene pipe shall not be threaded. Threaded transition fittings per ASTM F 2389 shall be used where a threaded connection is required.

[B]Polypropylene pipe used for hot water distribution shall include an integral reinforcing layer to reduce thermal expansion/contraction].

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

D. Plastic-to-Metal Transition Fittings shall be the following:

1. PP-R one-piece fitting with threaded stainless steel, brass, or copper insert and one PP-R fusion weld joint end.

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:

1. Centennial Plastics, Inc.
2. Chevron-Phillips Chemical Company; Performance Pipe Division.

B. Description:

1. HDPE Pipe: ASTM D 3035.

2. Molded PE Fittings: ASTM D 2683 or ASTM D 3261, ASTM F 1055 PE resin, socket, butt-fusion or electro-fusion type, made to match PE pipe dimensions and class.


5. Operating Temperature: Between 23 and 104 deg F.

6. Plastic, Pipe-Flange Gasket, Bolts, and Nuts: Type and material recommended by piping system manufacturer unless otherwise indicated.
7. Plastic-to-Metal Transition Fittings: One-piece fitting with threaded stainless steel, brass, or copper insert and fusion weld joint end.

2.2 UNDERGROUND PREINSULATED PIPING SYSTEM (HEATING WATER DISTRIBUTION)

A. Basis-of-Design Product: Subject to compliance with requirements, provide <Insert Product name Here> or a comparable product by the following:

B. Manufacturers:
   1. Insul-Tek Piping Systems, Inc.
   2. PERMA-PIPE, Inc.
   3. Rovanco Piping Systems, Inc.
   4. Thermacor Process, L.P.
   5. Tricon Piping Systems, Inc.

C. Description: Factory-fabricated carrier piping with insulation and exterior jacket.

D. Carrier Pipe:
   1. Schedule 80 PVC plastic pipe complying with ASTM D 1785 with plain ends for solvent cement joints.
   2. Steel Pipe: ASTM A 53/A 53M, black with plain ends; Schedule 40.
      a. Wrought-Steel Fittings: ASTM A 234/A 234M, wall thickness to match adjoining pipe.

E. Carrier Pipe Insulation:
      a. Thermal Conductivity (k-Value): 0.13 at 75 deg F.
      b. Dry Density: 2 lb/cu. ft. maximum.
   2. Insulation: Rigid cellular polyurethane.
      a. Thermal Conductivity (k-Value): 0.16 at 73 deg F.
      b. Dry Density: 2 lb/cu. ft. minimum.

F. Jacket:
   1. HDPE waterproof jacketing material.
   2. Manufacturers standard waterproof jacketing material.

G. Fittings: Factory-fabricated and insulated elbows equivalent to the pipe.

H. Accessories:
   1. Joint Kit: Half-shell, pourable or split insulation and shrink-wrap sleeve.
   2. Elbows, tees, reducers, anchors, end seals, anchors and anchor plates.
I. Source Quality Control: Factory test the carrier pipe to 150 percent of the operating pressure of system. Furnish test certificates.

2.3 FERROUS-ALLOY BUTTERFLY VALVES

A. Manufacturers:

1. Lug Type, Ferrous-Alloy Butterfly Valves:
   a. Apollo Valves.
   b. Crane.
   c. General Signal; DeZurik Unit.
   d. Tyco / Grinnell.
   e. Hammond Valve.
   f. Milwaukee Valve Company.
   g. NIBCO INC.
   h. Watts Industries, Inc.; Water Products Div.

B. Ferrous-Alloy Butterfly Valves, General: MSS SP-67, Type I, for tight shutoff.

C. Flangeless, 200-psig CWP Rating, Ferrous-Alloy Butterfly Valves: Lug type with one- or two-piece stainless steel stem, ASTM A 536 ductile iron body, extended neck, EPDM seat, aluminum bronze disc.

D. Valve Actuators:

1. Gear Drive: For quarter-turn valves NPS 5(DN 125) and larger.

2.4 COPPER-ALLOY BALL VALVES

A. Manufacturers:

1. Two-Piece, Copper-Alloy Ball Valves:
   b. Crane.
   c. Hammond Valve.
   d. Jamesbury, Inc.
   e. Jomar International, LTD.
   f. Milwaukee Valve Company.
   g. NIBCO INC.
   h. Watts Industries, Inc.; Water Products Div.

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

C. Two-Piece, Copper-Alloy Ball Valves: Cast bronze threaded two-piece body with full-port, stainless steel ball; PTFE or TFE seats; and 600-psig minimum CWP rating and blowout-proof stem.
2.5 PRECAST CONCRETE VAULT

A. Precast Sections: Reinforced precast concrete in accordance with ASTM C478.

2. Joints: Butyl rubber gaskets in accordance with ASTM C990.
3. Exterior shall be coated with a minimum of 60 mils asphaltic coating.
4. Vault shall be watertight design and installed per the precast concrete producer’s recommendations.

B. Frames and Covers:

1. Product Description: Grey cast iron ASTM A48/A48M, Class 30B; size and shape as indicated on Drawings. Live load rating of HS 20 in paved areas.

C. Configuration:

1. Provide size and shape as indicated on Drawings.
2. Foundation Slab: Cast-in-place or precast reinforced concrete integral with bottom section, level top surface.
3. All piping penetrations shall have modular sleeve sealing assemblies designed for field assembly, for filling annular space between piping and sleeve.

D. Accessories:

1. Steps: Conform to local agency requirements, minimum 12 inches wide spaced vertically 16 inches on center.
2. Strap Anchors: Stainless steel capable of supporting pipe or accessories indicated on Drawings, minimum 1 inch wide x 1/8 inch thick.

E. Bedding and Backfill Materials:

1. Bedding: Clean course aggregate.

2.6 SLEEVE-SEAL SYSTEMS

A. Description: Modular sealing-element unit, designed for field assembly, for filling annular space between piping and sleeve.

1. Sealing Elements: EPDM-rubber interlocking links shaped to fit surface of pipe. Include type and number required for pipe material and size of pipe.
2. Pressure Plates: Reinforced plastic.
3. Connecting Bolts and Nuts: Carbon steel, with corrosion-resistant coating, of length required to secure pressure plates to sealing elements.
PART 3 - EXECUTION

3.1 EARTHWORK
   A. Refer to Division 31 Section "Earth Moving" for excavating, trenching, and backfilling.

3.2 PIPING INSTALLATION
   A. General Locations and Arrangements: Drawings indicate general location and arrangement of piping. Indicated locations and arrangements were used to size pipe and calculate friction loss, expansion, pump sizing, and other design considerations. Install piping as indicated, unless deviations to layout are approved on Coordination Drawings.
   B. Install in strict accordance with manufacturers requirements, including excavating, trenching, and backfilling.
   C. Remove any standing water in the bottom of trench.
   D. Bed the pipe on a minimum 6-inch layer of granular fill material with a minimum 6-inch clearance between the pipes.
   E. Do not backfill piping trench until field quality-control testing has been completed and results approved.
   F. Do not insulate piping or backfill piping trench until field quality-control testing has been completed and results approved.
   G. Install piping at uniform grade of 0.2 percent upward in direction of flow or as indicated.
   H. Install components with pressure rating equal to or greater than system operating pressure.
   I. Install piping free of sags and bends.
   J. Install fittings for changes in direction and branch connections.
   K. Include blind flange at all underground piping terminations within buildings and vaults, and at above ground piping termination points at [cooling towers]. Blind flanges will be removed upon connection to continuation piping.
      1. Include threaded blind flanges as required for piping pressure testing.
   L. Include line size shut-off valves before blind flange at underground heating and chilled water piping terminations [within NADA building].
   M. Refer to Division 23 Section "Common Work Results for HVAC" for sleeves and mechanical sleeve seals through exterior building walls.
   N. Secure anchors with concrete thrust blocks. Concrete is specified in Division 03 "Cast-in-Place Concrete."
O. Connect to hydronic piping where it passes through the building wall. Hydronic piping inside the building is specified in Division 23 Section “Hydronic Piping.”

3.3 VALVE INSTALLATION
   A. Locate valves for easy access and provide separate support where necessary.
   B. Install valves in horizontal piping with stem at or above center of pipe.

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

3.5 CONCRETE VAULT INSTALLATION
   A. Preparation:
      1. Coordinate placement of piping.
      2. Do not install vaults where site conditions induce loads exceeding structural capacity of vaults.
      3. Inspect precast concrete vaults immediately prior to placement in excavation to verify structures are internally clean and free from damage. Remove and replace damaged units.
   B. Installation:
      1. Excavation and Backfill:
         a. Excavate and backfill for vaults and meter boxes in accordance with Division 31 Section "Earth Moving" for excavating, trenching, and backfilling and to depth shown. Provide clearance around sidewalls of structure for construction operations and backfill.
         b. When groundwater is encountered, prevent accumulation of water in excavations. Place structures in dry trench.
         c. Where possibility exists of watertight structure becoming buoyant in flooded excavation, anchor manhole or structure to avoid flotation.
      2. Place bedding and foundation slab.
      3. Install underground structures in accordance with ASTM C891.
      4. Lift precast vaults and structures at lifting points designated by manufacturer.
      5. When lowering vaults and structures into excavations and joining pipe to units, take precautions to ensure interior of pipeline and manhole or structure remains clean.
6. Set precast vaults bearing firmly and fully on stone bedding, 8-inch minimum thickness, compacted to 95 percent maximum density.

3.6 IDENTIFICATION

A. Install continuous plastic underground warning tapes during back filling of trenches for underground hydronic distribution piping. Locate 6 to 8 inches below finished grade, directly over piping. Refer to Division 31 Section "Earth Moving" for warning-tape materials and devices and their installation.

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. Prepare hydronic piping for testing according to ASME B31.9 and as follows:

1. Leave joints, including welds, uninsulated and exposed for examination during test.
2. Isolate equipment. Do not subject equipment to test pressure.
3. Install relief valve set at pressure no more than one-third higher than test pressure.
4. Fill system with water. Where there is risk of freezing, air or a safe, compatible liquid may be used.
5. Use vents installed at high points to release trapped air while filling system.

C. Test piping as follows:

1. Subject piping to hydrostatic test pressure that is not less than 1.5 times the design pressure.
2. After hydrostatic test pressure has been applied for 10 minutes, examine joints for leakage. Remake leaking joints using new materials and repeat hydrostatic test until no leaks exist.

D. Prepare a written report of testing.

END OF SECTION 23 2114
WMU Design Guidelines Instructions: These guidelines are to be used by the Design Professional to inform the design process and outline WMU-specific desires for all University projects. These guidelines have been edited to reflect WMU preferences, and the intent is for the Design Professional to use this information to guide their normal specifications-writing process. Straying from what is indicated in the guidelines is not prohibited, but shall be discussed with WMU during the development of the project.

SECTION 23 2115 - GROUND-LOOP HEAT-PUMP PIPING

PART 1 - GENERAL

1.1 SUMMARY

A. This Section includes ground-coupled heat exchanger and piping up to and including group distribution headers for HVAC heat-pump system.

B. This Section includes piping for horizontal and vertical, direct-buried, ground-loop, heat-pump systems that operate between 23 and 104 deg F.

C. Related Sections include the following:
   1. Division 23 Section “Hydronic Piping” for piping systems within building.
   2. Division 23 Section “HVAC Water Treatment” for glycol and water treatment for HVAC systems.

1.2 PERFORMANCE REQUIREMENTS

A. Components and installation shall be capable of withstanding the following minimum working pressure, unless otherwise indicated:

1.3 REFERENCE STANDARDS

A. ASTM D 2447 - Standard Specification for Polyethylene (PE) Plastic Pipe, Schedules 40 and 80, Based on Outside Diameter.

B. ASTM D 2683 - Standard Specification for Socket-Type Polyethylene Fittings for Outside Diameter-Controlled Polyethylene Pipe and Tubing.

C. ASTM D 2837 - Standard Test Method for Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials or Pressure Design Basis for Thermoplastic Pipe Products.


G. ASTM F 1055 - Standard Specification for Electrofusion Type Polyethylene Fittings for Outside Diameter Controlled Polyethylene Pipe and Tubing.


J. PPI TR4 - PPI Listing of Hydrostatic Design Basis (HDB), Strength Design Basis, Pressure Design Basis (PDB) and Minimum Required Strength (MRS) Ratings for Thermoplastic Piping Materials or Pipe; Plastics Pipe Institute

1.4 ACTION SUBMITTALS

A. Product Data: For the following:
   1. Polyethylene Piping: Provide manufacturer's data for piping and pipe fittings, showing compliance with specified requirements. Include manufacturer's name, schedule, type or class of pipe and fittings, and where optional materials are specified in the Pipe and Fitting Schedule, indicate the option selected.
   2. Product Data, Grout and Slurry: Provide information on thermal conductivity of proposed materials.
   3. Pipe and fittings.
   4. Joining method and equipment.
   5. Propylene glycol solution.

1.5 INFORMATIONAL SUBMITTALS

A. Test Reports, Piping: Provide data on test method and results of hydrostatic pressure tests.

B. Test Reports, Grout: Provide thermal conductivity value from test results of installed grout.

   1. A minimum of 3 grout samples shall be submitted during the installation process upon the 1st bore, last bore and half way thru the drilling process, and shall be tested by a third party.

C. As-Build Drawings: Provide as-built drawing indicating locations by dropping a 3-M Scotchmark Electronic Marking System Ball into the trenches each time the lateral pipe changes direction and the corners of the bore field. Identify the location of the markers on the as-built drawing.

D. Field quality-control test reports.

E. Documentation for Installers as required under Quality Assurance article.
1.6 QUALITY ASSURANCE

A. Installer Qualifications: Company specializing in performing the work of this section with minimum 3 years of documented experience and accredited by IGSHPA.

B. Geothermal System Contractor's Qualifications Data: Names and addresses of 3 geothermal projects of similar size and complexity that the Supplier has worked on during the past 5 years.

C. Heat Fusion Technician Certification: IGSHPA training and certification, certified within three years from the date of project commencement.

D. Installer shall provide documentation as a Michigan Licensed Mechanical Contractor for installation of hydronic piping.

E. Installer shall provide documentation of supervision by a Michigan Licensed Water Well installer.

1.7 SEQUENCING AND SCHEDULING

A. Transmit written notification of proposed date and time of operational tests to the Construction Manager Owner's representative at least 5 days in advance of such tests.

B. Perform cleaning and testing work in the presence of the Owner's representative.

1.8 WARRANTY

A. Manufacturer's Warranty: 50-year warranty for polyethylene piping.

PART 2 - PRODUCTS

2.1 SYSTEM DESIGN

A. Installer's responsibilities include designing and installing ground-coupled heat exchanger system and providing professional engineering services needed to assume engineering responsibility for field capacities and configuration.

2.2 SYSTEM DESCRIPTION

A. System includes vertical boreholes with vertical piping, pre-fabricated distribution headers and zone shut-off and balancing valves, interconnecting horizontal piping from wells to building.

1. Refer to geothermal system drawings for system design; civil drawings for location of well field and routing of piping from field to building; and mechanical drawings for connection to interior building HVAC piping.
B. System includes vertical boreholes with vertical piping, pre-cast concrete valve vault with prefabricated distribution headers and zone shut-off and balancing valves, interconnecting horizontal piping from wells to pre-cast concrete valve vault, and piping from valve vault to building.

1. Refer to [Midwest Geothermal] drawings for system design; civil drawings for location of well field and routing of piping from vault to building; and mechanical drawings for connection to interior building HVAC piping.

2.3 HEAT EXCHANGER

A. The ground-coupled heat exchanger has been designed; Contractor is responsible for execution as required in the Contract Documents.

B. Heat Exchanger Configuration: Closed system using polyethylene piping and vertical boreholes.

C. Heat Exchanger Configuration: Closed system using polyethylene piping and vertical boreholes:
   1. Total Pipe Length: [28,800] feet.
   6. Total Number of Boreholes: [96].
   7. Stable soil temperature: [52.8] deg. F.
   8. Grout thermal conductivity of [0.88] Btu/(hr*ft/deg. F).
   10. System Flow Rate:
        a. [640] GPM minimum.
        b. [1180] GPM maximum.

D. Voluntary Alternates: The geothermal system bidders are encouraged to submit Voluntary Alternates in addition to the Base Bid. Alternates may include items like different thermal conductivity grout and alternate pipe sizes. Voluntary alternates should perform equal or better than Base Bid and have comparable pressure drop to minimize changes to the remainder of the system.

E. Heat Exchanger Performance for Base Bid.

1. Building Monthly Heating/Cooling Loads:

2.4

1. Heat pump performance (water with [10]% propylene glycol)
   a. Heating @ [35]: COP of [2.8]
   b. Cooling @ [850]: EER of [14.9]
2.5 MATERIALS

A. Pipe: High density polyethylene pipe, SDR 11 for 2 inch and under and SDR 15.5 for over 2 inches.

1. Material:
   a. Tubing to be produced only with approved bimodal PE 3408/PE 100/PE 4710 listed resins.
   b. Minimum Cell Classification: 445574 as defined in ASTM D3350.
   c. Pressure Rating: Compounds shall have a PPI recommended Hydrostatic Design Basis (HDB) of 1600 psi at 68 degrees Fahrenheit (20 degrees Celsius).
   d. Pressure Rating at Elevated Temperatures: Compounds shall have a PPI recommended HDB of 1000 psi at 176 degrees Fahrenheit (80 degrees Celsius).
   e. Slow Crack Growth Resistance: Shall be measured in accordance with ASTM F1473 (PENT). The minimum required time to failure shall be a minimum of 4000 hours.
   f. Blue Tubing to have a 5 year Florida UV Rating

2. Joints and Fittings: Polyethylene of same type as pipe, of sizes and types suitable for the pipe being used; use only heat fusion or stab-type mechanical fittings that are quality controlled to provide a leak-free union between piping ends that is stronger than the piping itself. Do not use other barbed fittings or hose clamps.

B. Pipe: High density polyethylene pipe (DR-11), type PE3408, PE3608, or PE4710, with minimum ASTM D 3350 cell classification of PE345364C.

1. Pipe Used in Vertical Bore Applications: Comply with ASTM D 3035 with minimum working pressure rating of 160 psi.
2. Other Pipe of 3 Inches Diameter and Larger: Comply with ASTM D 3035 or ASTM F 714, with minimum working pressure rating of 160 psi, or ASTM D 2447 Schedule 40.
3. Other Pipe 1.25 Inches, but Less Than 3 Inches In Diameter (Nominal): Comply with ASTM D 3035 with minimum working pressure rating of 160 psi, or ASTM D 2447 Schedule 40.
4. Other Pipe Less Than 1.25 Inches in Diameter (Nominal): Comply with ASTM D 3035 with minimum working pressure rating of 160 psi.
5. Long Term Hydrostatic Design Basis: 1600 psi at 73 degrees F, when tested in accordance with ASTM D 2837; appropriate listing in current edition of PPI TR-4 will constitute evidence of compliance with this requirement; otherwise, submit independent test results.
6. Joints and Fittings: Polyethylene of same type as pipe, of sizes and types suitable for the pipe being used; use only heat fusion or stab-type mechanical fittings that are quality controlled to provide a leak-free union between piping ends that is stronger than the piping itself. Do not use other barbed fittings or hose clamps.
   a. Electrofusion Type Fittings: Comply with ASTM F 1055.
   c. Socket Type Fittings: Comply with ASTM D 2683.
   d. Where threaded fittings must be used for connection to equipment or dissimilar piping, use fittings and thread sealant compatible and effective with glycol used.
      1) Lake Chemical Company Slic-Tite or Loctite Corporation pipe sealant with teflon.
7. Resistance to environmental stress cracking is critical to long life expectancy. Therefore, as a more stringent requirement, the piping shall experience zero failures (FO) after 5,000 hours under condition “C” (100% reagent at 100°C) when tested in accordance with ASTM D1693, “Standard Test Method for Environmental Stress-Cracking of Ethylene Plastics”. A 25 year limited warranty (in writing) must be issued by the pipe manufacturer. U-type fittings shall be shop fabricated under quality controlled conditions of the same material designation.

8. Note that blow mold resin pipe is not acceptable.

9. Manufacturers:
   a. Lamson Vylon.
   b. A & D Technologies
   c. Philips Driscopipe.

C. Detectable Underground Tape: 5Mil overall thickness with not less than 0.35 Mil solid aluminum foil core backings. Construction is 0.8Mil clear polyethylene film, with 3.75Mil clear polyethylene. Detectable conductor marking tape in 2 inch wide rot-resistant plastic tape or mesh, brightly colored, imprinted with “Geothermal Line Buried Below” in large letters.

D. Wall Seals for Building Construction penetrations:
   1. Mechanical Modular Seals: Thunderline Corporation Link Seal wall and floor seals designed for the service of piping system in which installed.
   2. All piping passing through exterior walls shall have opening around pipe sealed with modular mechanical type seals, consisting of interlocking synthetic rubber links shaped to continuously fill the annular space between the pipe and wall opening.
   3. Links shall be loosely assembled with bolts to form a continuous rubber belt around the pipe with a pressure plate under each bolt head and nut. After the seal assembly is positioned in the sleeve, tightening of the bolts shall cause the rubber sealing elements to expand and provide a watertight seal between the pipe and wall.

E. Butterfly Valves:
   1. Butterfly valves shall be full-port flow with cast-iron body, EPDM liner and wafer type disc.
   2. The disc shall be ductile iron with electroless-nickel coating. The stem shall be one piece 316 stainless steel with “O” ring seals and self-lubricating corrosion resistant bearings.
   3. The disc shall be ductile iron with electroless-nickel coating. The stem shall be one piece 316 stainless steel with “O” ring seals and self-lubricating corrosion resistant bearings. The body shall be cast iron [with neck extended to provide for 2-inches of insulation over flange outside diameter] [THIS IMPLIES THAT THE PIPING IN VAULT IS TO BE INSULATED BUT NOT IF CONSULTANT SEE THE VAULT BEING FLOODED].
   4. Valves 2-inches to 8-inches shall have lever type handle with 10 degree notched throttling plate. Valves 10-inches and larger shall have enclosed heavy duty hand wheel, worm gear operation. All valves shall be suitable for installation between any type of 125 or 150 pounds ANSI flange.

F. Grout for Vertical Boreholes: Thermally enhanced bentonite.
   1. Manufacturer: Black Hills Bentonite for Thermal Grout Performance such as GeoPro, Inc., or approved equivalent.
   2. Thermal Conductivity: The thermal conductivity of the grouting compound must be 0.88 Btu/hr-ft-°F or greater as determined when tested in accordance to ASTM D-5334, “Standard Test Method for Determination of Thermal Conductivity of Soils and Soft Rock by Thermal Needle Probe Procedure” per International Ground Source Heat Pump
Association (IGSHPA) Standard 2B.1.2.1. The reported thermal conductivity value shall be verified by an independent company which has a minimum of 5 years experience in measuring thermal conductivity using this method. A minimum of six samples will be tested by the installing contractor and a copy of the verification reports shall be submitted to the Engineer. The samples shall be taken on the first bore, four bores evenly spaced through the project and on the last bore grouted.

3. Permeability: The grout mixture shall also have a maximum permeability rate of less than $8.0 \times 10^{-8}$ cm/sec as determined by using ASTM D-5084, "Measurement of Hydraulic Conductivity of Saturated Porous Materials using a Flexible Wall Permeameter, Method C - test with increasing tailwater level", per IGSHPA Standard 2B.1.2.2, with a 5 psi confinement pressure (to simulate an approximate sample depth of 5 foot). The report permeability shall be verified by an independent lab which has been certified by AMRL (American Association of State Highway & Transportation Officials, Materials Reference Laboratory) and validated by the US Army Corp of Engineers to perform ASTM D-5084 at the time of verification as found on the Internet at www.wes.army.mil/SL/MTC/ValidatedLabsList.htm per IGSHPA Standard 2B.1.2.3. A copy of the report shall be supplied upon request to the Engineer. Credentials of the independent laboratory shall also be supplied upon request to the Engineer.

4. Total Solids and Enhancement Compound Percentage: The thermally enhanced grout used shall have a minimum manufacturer's recommended mixture of 63% solids. The thermal enhancement compound (high-grade silica compound) shall constitute a minimum of 50% by weight of the total aqueous slurry (sand to total weight by mass).

5. Installed Material Set: The installed grouting material shall be fully set into a putty consistency within a minimum of hours after being pressure pumps in the vertical bore annulus.

G. Underground Pipe Vault:

1. Shall be a 5000psi precast concrete design with reinforcement suitable to concrete producer’s recommendations for green space areas. Walls shall be a minimum of 6” thick with suitable reinforcement and cored for each pipe penetration as required. Precast concrete lid shall be reinforced and supplied with a riser and 24” manhole cover equal to East Jordan 1040 frame with Type A solid cover. Any preformed joint shall have supplied and installed butyl rubber gasket such as Pro-Stik meeting all requirements of ASTM C-990 and AASHTO M-198. Exterior shall be coated with a minimum of 60 mils asphaltic coating. Vault shall be watertight design and installed per the precast concrete producer’s recommendations. All piping penetrations shall have Link Seal assemblies installed as described.

a. Vault shall be provided with recessed drainage sump 2” deep at a min area of 24” diameter.

H. Fittings:

1. P/T Plugs: Shall be constructed of solid brass and have a dual seal core of Nordel, good up to 3500 F for water. Plugs shall be rated zero leakage from vacuum to 1000 psi and are capable of receiving a pressure or temperature probe.

2. Butterfly Valve: Shall be full flow design constructed of a cast iron body, 316 stainless steel stem with a lever/lug type shut off system.

3. Circuit Balancing Valve: Shall be full flow design constructed of a cast iron body and globe design for precise balancing and reduced pressure drop, such as FloFab Valve
Series LGS, or approved equal. Valves should have acceptable pressure drop diagrams available and include two reading points.

4. 90 Degree Elbows: Shall be molded out of High Density Polyethylene resins in accordance with the requirements of ASTM 3261.

5. Branch and Service Saddles: Shall be molded out of High Density Polyethylene resins in accordance with the requirements of ASTM 3261.

2.6 PIPES AND FITTINGS

A. PE Pipe: ASTM D 2239, SIDR Numbers 5.3, 7, 9, or 11.5; with PE compound number required to achieve required system working pressure.

1. Molded PE Fittings: ASTM D 2683 or ASTM D 3261, PE resin, socket- or butt-fusion type, made to match PE pipe dimensions and class.

B. U-Bend Assembly: Factory fabricated with embossed depth stamp every 24 inches from U-bend.

C. U-Bend Assembly: Factory fabricated with embossed depth stamp every [24 inches] [36 inches] <insert dimension> from U-bend.

2.7 BOREHOLE BACKFILL

A. Surface Seal: Bentonite or cement with thermal conductivity greater than 1.2 Btu/h x sq. ft. x deg F.

B. Backfill below Surface Seal: Natural or manufactured sand specified in Division 31 Section "Earth Moving."

2.8 [ANTIFREEZE SOLUTION]

A. Propylene Glycol: Minimum [99 percent] propylene glycol with corrosion inhibitors and environmental stabilizer additives to be mixed with water to protect the piping circuit and connected equipment from physical damage from freezing or corrosion.

B. Quantity: Sufficient solution for initial system startup and for preventive maintenance for one year from date of Substantial Completion.

C. Dilution Water: Chloride content shall be less than 25 ppm, sulfate less than 25 ppm, and hardness less than 100 ppm.

PART 3 - EXECUTION

3.1 EARTHWORK

A. Excavating, trenching, warning tape, and backfilling are specified in Division 31 Section "Earth Moving."
3.2 EQUIPMENT

A. All equipment furnished to complete the work shall be in good operating condition and capable of safely and efficiently performing the work required in a timely fashion. The Contractor shall provide qualified operating personnel for the operation of this equipment.

B. The Installer shall provide at the Installer’s own expense, all fuel, oil, hydraulic fluid, grease, cable, repair parts, including worn or broken tools, and all other supplies, bits and parts or personnel necessary for the efficient operation of each piece of equipment.

3.3 EXCAVATION & GENERAL INSTALLATION

A. Prior to any excavation, trenching, or drilling, all buried utilities, drainage, and irrigation systems shall be located and flagged by the appropriate utility and Installer’s representatives.

B. Mobilization shall consist of furnishing at the project site, labor, power, supplies, tools, equipment and performing operations in connection with the completion of the borehole and required tests.

C. Prior to arrival on-site, the drilling rig, drill rods, tools and bits shall be clean and free from potential contaminants, such as leaks, excessive grease, oils, gasoline or other substances which could be construed as much.

D. Excavate in accordance with requirements of authorities having jurisdiction.

E. E. Remove rock as specified in Section zz, Rock Removal.

F. Vertical Boreholes: Drill to depths required.
   1. Minimize over-drilling.
   2. Piping: Test on-site each factory assembled u-bend for 30 minutes at a minimum of 80psi prior to inserting into the bore hole.

G. The Installer shall utilize potable water as necessary to perform the work. The required equipment will include pumps, water trucks or trailers, storage tanks and all other items necessary to provide an adequate supply of potable water. The source shall be subject to approval of the Construction Manager and Owner.

H. Materials:
   1. No drilling fluids other than potable water may be introduced into the borings. The boreholes shall be drilled and cleaned/purged to a depth as indicated.
   2. The Installer shall not deposit drilling waste and water within any existing stream, or in any manner which violates Local, State and Federal laws and regulations. The disposal method of all drilling waste and water must be acceptable to the Construction Manager and the Owner.
   3. If required, a temporary casing will be installed to keep the upper consolidated materials from caving and boring. The temporary casing should be of steel, Grade B, with a minimum wall thickness of 0.280 inches, with an outside diameter 5 ½ inches or 5 3/8 inches schedule 40 PVC and be of sufficient length. This temporary casing will be pulled at the time when grouting of the boring takes place.
4. Throughout the entire project, the driller must make all attempts to keep any material that could be construed as contaminants from entering the boreholes. In the event that borehole becomes contaminated due to the neglect of the Installer, he shall at his own expense, perform such work and supply materials as needed to eliminate the contamination.

I. Protection: During test work, protect controls, gages and accessories which are not designed to withstand test procedures. Do not utilize permanently installed gages for field testing of systems.

J. Provide submittal with a copy of a dimensioned site layout showing the location of the buried GSP piping relative to permanent on site structures and buried conduits and the location of the 3M Scotchmark units.

K. The Installer shall install metallized warning tape (with printed side up) 18” below finished grade directly over the horizontal geothermal piping and upper ends of each well.

L. Borings:
   1. If the Installer finds it necessary to change the location or depth of any proposed borings, the Construction Manager and Engineer shall be notified and a new location or depth shall be agreed upon.
   2. If unusual conditions are encountered, including but not limited to unanticipated materials which cannot be penetrated by standard equipment, the Installer shall immediately consult with the Construction Manager and Engineer.

M. Grout Installation:
   1. Thermally enhanced bentonite grouting material shall be mixed according to the manufacturer's instructions.
   2. Grout material shall be pressure pumped through tremie pipe and placed in the bore columns from the bottom to the top. Grouting process shall conform to the manufacturer's instructions and "Grouting for Vertical Geothermal Heat Pump Systems - Engineering Design and Field Procedures Manual", as published by the IGSHPA. Completed grouted surface shall be placed at the ground level to ensure complete fill of the bore column.
   3. Inspection: Since some settling may occur after initial placement of the grout material, the Installer shall monitor each borehole and continue adding grout as required to overcome settling.

N. Protection of Property: The Installer shall contact the Owner and all utility companies for information regarding buried utilities and structures, and shall take all reasonable precautions to prevent damage to property both visible and concealed.

O. Demobilization shall consist of the removal from the construction site of all plant, equipment, supplies and personnel after completion of the work including the cleanup of all rubbish, litter and waster materials generated by the Installer's activities. Drill cuttings are not to be utilized as part of borehole construction.

P. General Piping Installation:
   1. This Installer shall provide as shown on the drawings a complete system of piping, valves or other components as indicated or as necessary. The piping drawings are
diagrammatic and indicate the general location and connections. The piping may have to be offset, lowered or raised as required or as directed at the site.

2. Piping shall be properly supported and adequate provisions shall be made for expansion, contractions, slope and anchorage. All piping shall be cut accurately for fabrication to measurements established at the construction site. Pipe shall be placed without springing or forcing, properly clearing all interferences. All pipes shall have burr and cutting slag removed by reaming or other cleaning methods.

3. All piping shall be arranged so as not to interfere with removal of other equipment or devices nor to block access. All valves and specialties shall be placed to permit easy operation and access, and all valves shall be regulated, packed and glands adjusted at the completion of the work before final acceptance. Piping shall be installed so as to avoid liquid or air pockets throughout the work.

Q. Underground Horizontal Piping:

1. Install piping in pipe trenches after cushion material bedding has been placed and completed.
   a. Minimum Pipe Depth: 60” below finished grade. If ledge rock is encountered and less than 60” below finished grade is required, 2” insulation board may be placed over headers. This must be approved by the engineer prior to installation of insulation board.

2. Minimize the number of points where supply and return lines cross one another.

3. Install piping of such lengths to minimize the number of fusion joints required.

4. Avoid sharp bends in piping, use elbows where required.

5. Install bell reducing fittings or reducing tees at pipe reductions to eliminate trapped air.

6. Cap open end of pipe to prevent entry of contaminants until final connections are made.

7. Pressure test piping after connecting to vertical well piping. Test as specified in Pipe Cleaning and Testing article below.

R. Underground Vertical Piping:

1. The holes or bores shall be clean and of sufficient diameter to facilitate the installation of the u-bend assembly. Extreme care shall be taken not to crush, cut or kink the pipe. If damaged, it shall be repaired, at no additional cost to the Owner.

2. Remove all cutout material remaining in well from drilling process before installing u-bend piping.

3. Vertical Piping shall be factory assembled:
   a. Manufacturer shall construct down-hole closed-loop piping from two continuous lengths of pipe with U-bend joints at the bottom of the well.
   b. Manufacturer shall hydrostatically test the assembled vertical piping at 1-½ times the maximum working pressure, but not less than 125 psig, for four hours.
   c. Manufacturer shall cap piping assembly before shipment.

4. Provide fittings required for pressure testing.

5. Immediately before insertion into well, fill u-bend piping with water until it runs clear and pressure check the u-bend assembly for 30 minutes at a minimum of 80psi.

6. Cap upper ends of u-bend piping until connection to horizontal manifold is made.

7. Cap or fuse open end of pipe to prevent contaminants from entering until final connections are made.
8. Grouting: Materials to be utilized by the Installer shall be a thermally enhanced Bentonite grout. Grout shall have a minimum thermal conductivity of 0.88 BTU/hr-ft-deg F. The grout will be a slurry that will be tremie grouted from the bottom of the boring to the surface in accordance with the IGSHPA installation manual. The Contractor will work quickly to assure that there are not air voids forming as a result of the Grout placing.

9. Connect vertical piping to horizontal manifolds and pressure test entire underground system as specified in Pipe Cleaning and Testing article below before back filling trenches.

S. Underground Pipe Vault Installation:

1. The vault shall be lowered into a pit approximately 105" deep with a 6" bed of #57 gravel.

T. Pipe Joint Makeup:

1. Polyethylene Butt or Saddle (side wall) Fusion Pipe Joints: Follow the manufacturer's printed installation instructions.

2. Dissimilar Pipe Joints:
   a. Joining Dissimilar Threaded Piping: Make up connection with a threaded coupling or with companion flanges.
   b. Joining Dissimilar Non-Threaded Piping: Make up connection with adapters recommended by the manufacturer's of the piping to be joined.

3.4 POLYETHYLENE PIPING

A. Join piping and fittings using heat fusion or electrofusion; do not use solvents, adhesives, or mechanical fittings.

B. Provide flanges or unions to connect heat exchanger piping to equipment or piping of different type; locate all transitions between piping of different types inside the building, valve vault, or otherwise accessible (i.e. above grade).

C. Keep dirt, water, and debris out of pipe assemblies; cap or plug open ends until connected to adjacent piping.

D. Do not bend piping to shorter radius than recommended by pipe manufacturer; do not kink piping; use elbow or other fittings for sharp bends.

E. Partially backfill radius bends in narrow trenches by hand to ensure that piping is properly supported and to prevent kinking.

F. Test piping to be installed in boreholes after assembly but before installation in boreholes; re-cap tested assemblies before installation.

G. Where piping passes through foundation or vault walls, provide Link-Seal mechanical sleeve seals.

H. Terminate ground-loop heat-pump piping above building floor. Terminate piping with flanges with blind flange cap. Make connections to building ground-loop heat-pump piping systems when those systems are installed.
3.5 BACKFILLING

A. Install in compliance with local authorities having jurisdiction.

B. Vertical Boreholes: Backfill after pipe installation in accordance with IGSHPA Grouting Procedures for GSHP Systems.

C. Protect piping from displacement.

3.6 PIPE CLEANING AND TESTING

A. Preliminary Work: Thoroughly clean pipe and tubing prior to installation. During installation, prevent foreign matter from entering systems. Prevent if possible or remove obstructions from piping and systems.

B. Flushing, Purging, Pressure and Flow Testing:

1. All fusion joints and loops lengths shall be checked to verify that no leaks have occurred in shipping or in fusion joining.

2. All loops shall be pressure tested before installation, and all horizontal components of the ground heat exchanger will be pressure tested prior to back-filling.

3. Heat exchanger will be tested hydrostatically at the smaller of 150% of the pipe design rating or 300% of the new system operating pressure. Do not test until every joint has set and cooled at least 8 hours. Maintain test pressure for a minimum of 12 hours. Record the trench temperature at start and finish of pressure testing. There shall be no reduction in applied test pressure other than that due to a change in ambient temperature and normalizing of the PE pipe. Use test gage with one psi increment and readable to ½ psi.

4. Cleaning: Flush systems and apparatus, upon completion of pressure and miscellaneous tests. Completely open valves and flush each system with clean water. Follow IGSHPA procedures for flush and filling of the ground heat exchanger. Remove and clean strainer screens prior to operational test.

a. Refill system with clean potable water.

b. For glycol fill, refer to Division 23 Section 23 2500 - “HVAC Water Treatment”.

5. Flow rates and pressure drops will be compared to calculated values to assure that there is not blockage or kinking of any pipe.

6. A minimum velocity of 2 ft./sec in each piping section must be maintained for a minimum of 15 minutes to remove all air. A change of more than one inch in the level of fluid in the purge pump tank during pressurization indicates air still trapped in the system.

7. Prepare reports of testing activity.

3.7 BALANCING

A. Refer to Division 23 Section “Testing, Adjusting, and Balancing for HVAC” for testing, adjusting, and balancing of heat pump heat exchanger (well field) zone distribution.
3.8 SITE CONDITIONS

A. Clean up work on the site shall be a daily activity. The Installer shall not leave any type of trash or refuse of any sort on the site at any time.

B. Final clean-up must be completed prior to final inspection and acceptance of the work. No refuse of any variety shall be buried on the site. The Installer will dispose of all drill cuttings as directed by the Construction Manager.

END OF SECTION 23 2115
WMU Design Guidelines

WMU Design Guidelines Instructions: These guidelines are to be used by the Design Professional to inform the design process and outline WMU-specific desires for all University projects. These guidelines have been edited to reflect WMU preferences, and the intent is for the Design Professional to use this information to guide their normal specifications-writing process. Straying from what is indicated in the guidelines is not prohibited, but shall be discussed with WMU during the development of the project.

SECTION 23 2123 - HYDRONIC PUMPS

PART 1 - GENERAL

1.1 SUMMARY

A. This Section includes the following:

1. In-line centrifugal booster pumps.
2. In-line pumps with ECM.
4. Separately coupled, horizontal, in-line centrifugal pumps.
7. Close-coupled, end-suction centrifugal pumps.
8. Separately coupled, base-mounted, end-suction centrifugal pumps.
10. Automatic condensate pump units.
11. Pump specialty fittings.

B. Related Sections include the following:

1. Division 23 Section "Common Work Results for HVAC" for general installation requirements and concrete equipment bases.
2. Division 23 Section "Common Motor Requirements for HVAC Equipment" for general motor requirements [and shaft grounding rings].
3. Division 23 Section "Meters and Gages for HVAC Piping" for pressure gauges requirements at pumps.
4. [Division 23 Section "Instrumentation and Controls for HVAC" for field installed variable frequency drives for pump motors].
5. [Division 26 Section "Variable Frequency Motor Controllers" for variable frequency drives for pump motors].

1.2 DEFINITIONS

A. Buna-N: Nitrile rubber.

B. EPT: Ethylene propylene terpolymer.
1.3 ACTION SUBMITTALS

A. Product Data: Include certified performance curves and rated capacities, operating characteristics, furnished specialties, final impeller dimensions, and accessories for each type of product indicated. Indicate pump's operating point on curves.

1. No pump shall be submitted whose impeller diameter exceeds 90% of the maximum published impeller diameter for the pump, nor an impeller which is less than 15% larger than the smallest published impeller diameter for the pump.

B. Shop Drawings: Show pump layout and connections. Include setting drawings with templates for installing foundation and anchor bolts and other anchorages.


1.4 CLOSEOUT SUBMITTALS

A. Alignment Certificate: Include signed certificate verifying based mounted pump alignment procedures have been completed.

B. Operation and maintenance data.

1.5 QUALITY ASSURANCE

A. Source Limitations: Obtain hydronic pumps through one source from a single manufacturer.

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. UL Compliance: Comply with UL 778 for motor-operated water pumps.

1.6 DELIVERY, STORAGE, AND HANDLING

A. Manufacturer's Preparation for Shipping: Clean flanges and exposed machined metal surfaces and treat with anticorrosion compound after assembly and testing. Protect flanges, pipe openings, and nozzles with flange covers or with screwed-in plugs.

B. Store pumps in dry location.

C. Retain protective covers for flanges and protective coatings during storage.

D. Protect bearings and couplings against damage from sand, grit, and other foreign matter.

E. Comply with pump manufacturer's written rigging instructions.
1.7 COORDINATION

A. Coordinate size and location of concrete bases. Cast anchor-bolt inserts into bases. Concrete, reinforcement, and formwork requirements are specified in Division 03.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. Subject to compliance with requirements, provide products by one of the following:
   1. Bell & Gossett.

B. Subject to compliance with requirements, provide products by [one of ] the following:
   1. Bell & Gossett.
   2. Taco, Inc.
   3. Armstrong Pumps Inc.
   5. Wilo USA.

2.2 IN-LINE CENTRIFUGAL PUMPS

A. Basis of Design: Bell & Gossett Series NBF.

B. Description: Factory-assembled and -tested in-line horizontal system lubricated centrifugal pumps.
   1. Pump and Motor Assembly: Motor and impeller on common shaft and designed for installation with pump and motor shaft mounted horizontally.
   2. Casing: Lead-free bronze, with companion-flange connections for potable water applications.
   3. Casing: Cast iron, with companion-flange connections for hydronic heating applications.
   5. Face Plate: Stainless steel.
   6. Impeller: Corrosion-resistant material.
   7. Shaft: Ceramic.
   8. Motor: Multi-speed. Comply with requirements in Division 22 Section "Common Motor Requirements for HVAC Equipment."

2.3 INLINE PUMPS WITH ECM

A. Basis of Design: Bell & Gossett Model ecocirc 19-14.

B. Description: Factory-assembled and -tested, in-line pumps with ECM motor.
   1. Pump and Motor Assembly: Motor and impeller on common shaft and designed for
installation with pump and motor shaft mounted horizontally.

2. Casing: Cast iron, with companion-flange connections.
3. Impeller: Nylon/PPO.
4. Rotor: Permanent magnet.
5. Bearing: Carbon/Alumina ceramic.
6. O-Ring: EPDM.
7. All Other Wetted Parts: Stainless steel.
8. Motor Type: Electronically commutated motor /permanent magnet.
9. Control Modes:
   a. Auto: The ecocirc® auto has a proportional pressure control which automatically adjusts the pump performance continuously to the requirements of the heating system, based on the curve that is set on the adjustable dial. When the zone or thermostatic valve closes, the pump performance is reduced to save energy and to avoid velocity noise in the system.
   b. Vario: The ecocirc® vario allows for stepless speed control to set the pump performance to meet individual system requirements.
11. Maximum Working Temperature: 200°F.

2.4 IN-LINE CENTRIFUGAL BOOSTER PUMPS

A. Basis of Design: Bell & Gossett Series LR.

B. Description: Factory-assembled and -tested in-line horizontal system lubricated centrifugal pumps.

1. Pump and Motor Assembly: Motor and impeller on common shaft and designed for installation with pump and motor shaft mounted horizontally.
2. Casing: Lead-free bronze, with companion-flange connections.
4. Face Plate: Stainless steel.
5. Impeller: Corrosion-resistant material.
7. Motor: Multi-speed. Comply with requirements in Division 22 Section "Common Motor Requirements for HVAC Equipment."

2.5 CLOSE COUPLED, HORIZONTAL IN-LINE, CENTRIFUGAL BOOSTER PUMPS

A. Basis of Design: Bell & Gossett Model PL.

B. Description: Factory-assembled and -tested, single-stage, close-coupled, in-line, centrifugal pumps.

1. Pump and Motor Assembly: Motor and impeller on common shaft and designed for installation with pump and motor shaft mounted horizontally.
2. Casing: Cast iron, with companion-flange connections.
3. Face Plate: Stainless steel.
4. Impeller: Corrosion-resistant material.
5. Shaft: Solid, high strength alloy steel.
7. Motor: Single speed, ODP, unless otherwise indicated. Comply with requirements in Division 22 Section “Common Motor Requirements for Plumbing Equipment.”

2.6 SEPARATELY COUPLED, HORIZONTAL, IN-LINE CENTRIFUGAL PUMPS

A. Basis of Design: Bell & Gossett Series [PR][PD][Series 2].
B. Description: Factory-assembled and -tested, centrifugal, overhung-impeller, separately coupled, in-line pump as defined in HI 1.1-1.2 and HI 1.3; designed for installation with pump and motor shafts mounted horizontally. Rate pump for 125-psig minimum working pressure and a continuous water temperature of 225 deg F.
C. Pump Construction:
   1. Casing: Radially split, cast iron, with threaded gage tappings at inlet and outlet, and companion-flange connections.
   2. Impeller: ASTM B 584, cast bronze; statically and dynamically balanced, and keyed to shaft. Trim impeller to match specified performance.
   3. Pump Shaft: Steel, with copper-alloy shaft sleeve.
   4. Mechanical Seal: Carbon rotating ring against a ceramic seat held by a stainless-steel spring, and Buna-N bellows and gasket. Include water slinger on shaft between motor and seal.
   5. Mechanical Seal: Carbon rotating ring against a ceramic seat held by a stainless-steel spring, and [Buna-N] [EPT] bellows and gasket. Include water slinger on shaft between motor and seal.
D. Shaft Coupling: Flexible coupling capable of absorbing vibration.
E. Motor: Single speed and resiliently mounted through 1 HP or rigidly mounted over 1.5 HP to pump casing. Comply with requirements in Division 23 Section “Common Motor Requirements for HVAC Equipment.”

2.7 INLINE PUMPS WITH ECM

A. Basis of Design: Bell & Gossett Model ecocirc 19-14.
B. Description: Factory-assembled and -tested, in-line pumps with ECM motor.
   1. Pump and Motor Assembly: Motor and impeller on common shaft and designed for installation with pump and motor shaft mounted horizontally.
   2. Casing: Cast iron, with companion-flange connections.
   3. Casing: Lead-free bronze, with companion-flange connections.
   4. Impeller: Nylon/PPO.
   5. Rotor: Permanent magnet.
   7. O-Ring: EPDM.
8. All Other Wetted Parts: Stainless steel.
10. Control Modes:
   a. Auto: The ecocirc® auto has a proportional pressure control which automatically adjusts the pump performance continuously to the requirements of the heating system, based on the curve that is set on the adjustable dial. When the zone or thermostatic valve closes, the pump performance is reduced to save energy and to avoid velocity noise in the system.
   b. Vario: The ecocirc® vario allows for stepless speed control to set the pump performance to meet individual system requirements.
12. Maximum Working Temperature: 200°F.

2.8 WET ROTOR INLINE PUMPS

A. Basis of Design: Bell & Gossett Model ecocirc XL.

B. Description: Factory-assembled and -tested, wet rotor in-line pumps with ECM motor and integrated variable frequency drive.

1. Pump and Motor Assembly: Motor and impeller on common shaft and designed for installation with pump and motor shaft mounted horizontally.
2. Casing: Cast iron, with companion-flange connections.
3. Casing: Lead-free bronze, with companion-flange connections.
4. Impeller: Plastic or stainless steel.
5. Shaft: Stainless steel.
8. Gasket/O-Ring: EPDM.
9. All Other Wetted Parts: Stainless steel.
10. Motor Type: Electronically commutated motor /permanent magnet and includes:
   a. Class F motor insulation.
   b. Integrated motor protection against over/under voltage, over temperature of motor and/or electronics, over current, locked rotor and dry run (no load condition).

11. Integrated Variable Frequency Drive: Tested as one unit by the manufacturer and includes:
   a. MODBUS or BACnet connections built into the VFD as standard.
   b. Analog inputs, such as 0-10V and 4-20mA inputs built into the VFD.


2.9 SEPARATELY COUPLED, HORIZONTAL, IN-LINE CENTRIFUGAL PUMPS

A. Basis of Design: Bell & Gossett Series 60.
B. Description: Factory-assembled and -tested, centrifugal, overhung-impeller, separately coupled, in-line pump as defined in HI 1.1-1.2 and HI 1.3; designed for installation with pump and motor shafts mounted horizontally. Rate pump for 175-psig minimum working pressure and a continuous water temperature of 225 deg F.

C. Pump Construction:

1. Casing: Radially split, cast iron, with threaded gage tappings at inlet and outlet, and companion-flange connections.
2. Impeller: ASTM B 584, cast bronze; statically and dynamically balanced, and keyed to shaft. Trim impeller to match specified performance.
3. Pump Shaft: Steel, with copper-alloy shaft sleeve.
4. Mechanical Seal: Carbon rotating ring against a ceramic seat held by a stainless-steel spring, and Buna-N bellows and gasket. Include water slinger on shaft between motor and seal.
5. Mechanical Seal: Carbon rotating ring against a ceramic seat held by a stainless-steel spring, and [Buna-N] [EPT] bellows and gasket. Include water slinger on shaft between motor and seal.

D. Shaft Coupling: Flexible coupling capable of absorbing vibration.

E. Motor: Single speed, with permanently lubricated ball bearings and resiliently mounted through 1 HP or rigidly mounted over 1.5 HP to pump casing. Comply with requirements in Division 23 Section "Common Motor Requirements for HVAC Equipment."

2.1 CLOSE-COUPLING, IN-LINE CENTRIFUGAL PUMPS

A. Basis of Design: Bell & Gossett Series e80.

B. Description: Factory-assembled and -tested, centrifugal, overhung-impeller, close-coupled, in-line pump as defined in HI 1.1-1.2 and HI 1.3; designed for installation with pump and motor shafts mounted horizontally or vertically. Rate pump for 175-psig minimum working pressure and a continuous water temperature of 225 deg F.

C. Pump Construction:

1. Casing: Cast iron, with threaded gage tappings at inlet and outlet, and flange connections.
2. Impeller: Stainless steel; statically and dynamically balanced, keyed to shaft, and secured with a locking cap screw. Trim impeller to match specified performance.
4. Mechanical Seal: Carbon rotating ring against a ceramic seat held by a stainless-steel spring, and Buna-N bellows and gasket. Include water slinger on shaft between motor and seal.
5. Mechanical Seal: Carbon rotating ring against a ceramic seat held by a stainless-steel spring, and [Buna-N] [EPR] bellows and gasket. Include water slinger on shaft between motor and seal.
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D. Motor: Single speed, with grease-lubricated ball bearings; and rigidly mounted to pump casing. Comply with requirements in Division 23 Section "Common Motor Requirements for HVAC Equipment."

2.2 [CLOSE-COUPLED], IN-LINE CENTRIFUGAL PUMPS

A. Basis of Design: Bell & Gossett Series 80.

B. Description: Factory-assembled and -tested, centrifugal, overhung-impeller, close-coupled, in-line pump as defined in HI 1.1-1.2 and HI 1.3; designed for installation with pump and motor shafts mounted horizontally or vertically. Rate pump for 175-psig minimum working pressure and a continuous water temperature of 225 deg F.

C. Pump Construction:

1. Casing: Radially split, cast iron, with threaded gage tappings at inlet and outlet, and flange connections.
2. Impeller: ASTM B 584, cast bronze; statically and dynamically balanced, keyed to shaft, and secured with a locking cap screw. Trim impeller to match specified performance.
3. Pump Shaft: Steel, with aluminum bronze shaft sleeve.
4. Mechanical Seal: Carbon rotating ring against a ceramic seat held by a stainless-steel spring, and Buna-N bellows and gasket. Include water slinger on shaft between motor and seal.

D. Motor: Single speed, with grease-lubricated ball bearings; and rigidly mounted to pump casing. Comply with requirements in Division 23 Section "Common Motor Requirements for HVAC Equipment."

2.3 CLOSE-COUPLED, IN-LINE CENTRIFUGAL PUMPS

A. Basis of Design: Bell & Gossett Series e80.

B. Description: Factory-assembled and -tested, centrifugal, overhung-impeller, close-coupled, in-line pump as defined in HI 1.1-1.2 and HI 1.3; designed for installation with pump and motor shafts mounted horizontally or vertically. Rate pump for 175-psig minimum working pressure and a continuous water temperature of 225 deg F.

C. Pump Construction:

1. Casing: Cast iron, with threaded gage tappings at inlet and outlet, and flange connections.
2. Impeller: Stainless steel; statically and dynamically balanced, keyed to shaft, and secured with a locking cap screw. Trim impeller to match specified performance.
4. Mechanical Seal: Carbon rotating ring against a ceramic seat held by a stainless-steel spring, and Buna-N bellows and gasket. Include water slinger on shaft between motor and seal.
5. Mechanical Seal: Carbon rotating ring against a ceramic seat held by a stainless-steel spring, and [Buna-N] [EPR] bellows and gasket. Include water slinger on shaft between motor and seal.

D. Motor: Single speed, with grease-lubricated ball bearings; and rigidly mounted to pump casing. Comply with requirements in Division 23 Section "Common Motor Requirements for HVAC Equipment."

2.4 [CLOSE-COUPLED], IN-LINE CENTRIFUGAL PUMPS

A. Basis of Design: Bell & Gossett Series 80.

B. Description: Factory-assembled and -tested, centrifugal, overhung-impeller, close-coupled, in-line pump as defined in HI 1.1-1.2 and HI 1.3; designed for installation with pump and motor shafts mounted horizontally or vertically. Rate pump for 175-psig minimum working pressure and a continuous water temperature of 225 deg F.

C. Pump Construction:

1. Casing: Radially split, cast iron, with threaded gage tappings at inlet and outlet, and flange connections.
2. Impeller: ASTM B 584, cast bronze; statically and dynamically balanced, keyed to shaft, and secured with a locking cap screw. Trim impeller to match specified performance.
3. Pump Shaft: Steel, with aluminum bronze shaft sleeve.
4. Mechanical Seal: Carbon rotating ring against a ceramic seat held by a stainless-steel spring, and Buna-N bellows and gasket. Include water slinger on shaft between motor and seal.

D. Motor: Single speed, with grease-lubricated ball bearings; and rigidly mounted to pump casing. Comply with requirements in Division 23 Section "Common Motor Requirements for HVAC Equipment."

2.5 [SPLIT-COUPLED], VERTICAL IN-LINE CENTRIFUGAL PUMPS

A. Basis of Design: Bell & Gossett Series 80-SC[ with ITSC].

B. Description: Factory-assembled and -tested, centrifugal, split-coupled, in-line pump as defined in HI 1.1-1.2 and HI 1.3; designed for installation with pump and motor shafts mounted vertically. Rate pump for 175-psig minimum working pressure and a continuous water temperature of 250 deg F.

C. Pump Construction:

1. Casing: Ductile or cast iron, with threaded gage tappings at inlet and outlet, and flange connections.
2. Impeller: Cast iron or brass; statically and dynamically balanced, keyed to shaft, and secured with a lock. Trim impeller to match specified performance.
4. Mechanical Seal: Rotating unitized seal head design with EPR elastomer bellows and a positive metal to-metal drive system.

D. Motor: Single speed, NEMA premium efficient, with grease-lubricated ball bearings; and mounted to pump casing. Comply with requirements in Division 23 Section "Common Motor Requirements for HVAC Equipment."

E. [Integrated VFD with Sensorless Pump Speed Control]:

1. Integrated Pump Controller shall be factory mounted, wired, with a main disconnect switch and menu- driven graphical interface.
2. Controller shall provide near unity displacement power factor (cos 0) without need for external power factor correction capacitors at all loads and speeds using WC-PWM type integrated controls.
3. Controller shall include dual DC link reactors equivalent to 5% impedance line reactors, for reduction of main born harmonic currents and DC link ripple current to increase DC link capacitor lifetime.
4. Controller shall support direct communication with the building management system (BMS) with built-in support for the following protocols:
   a. [Modbus RTU]
   b. [BACnet™ MS/TP]
   c. [Metasys N2]
5. Controller shall be provided in an Enclosure rated to UL Type 12 suitable for indoor operation.
6. Controller shall support Programmable skip Frequencies and adjustable switching frequency for noise and vibration control.
7. Controller shall provide a temperature controlled Fan for cooling of the heat sink in the back panel.
8. Controller shall be rated to operate in ambient working conditions of 14°F to +113°F, up to 3300 feet above sea level.
9. Controller shall provide the following inputs and outputs:
   a. 2 Analog inputs (current or voltage) and 1 current output.
   b. 6 programmable Digital inputs with 2 configurable as outputs.
   c. 2 programmable pulse inputs
   d. 2 programmable relay outputs
   e. 1 RS485 communication port
10. Controller system software shall be capable of sensorless control in variable volume systems without need for pump mounted (internal/ external) or remotely mounted differential pressure sensor.
11. Controller Sensorless control shall operate under Quadratic Pressure Control (QPC) to ensure head reduction with reducing flow conforms to quadratic control curve.
12. Controller shall support a minimum head of 40% of design duty head.
13. Controller shall provide user adjustable control mode settings and minimum/maximum head set points using built-in programming interface.
14. Controller integrated control software shall be capable of controlling pump performance for non-overloading power at every point of operation.
15. Controller integrated control software shall be capable of maintaining flow rate data.
2.6 CLOSE-COUPLED, IN-LINE CENTRIFUGAL PUMPS

A. Basis of Design: Bell & Gossett Series e90.

B. Description: Factory-assembled and -tested, centrifugal, overhung-impeller, close-coupled, in-line pump as defined in HI 1.1-1.2 and HI 1.3; designed for installation with pump and motor shafts mounted horizontally or vertically. Rate pump for 175-psig minimum working pressure and a continuous water temperature of 250 deg F.

C. Pump Construction:
   1. Casing: Cast iron, with threaded gage tappings at inlet and outlet and companion flange connections.
   2. Impeller: ASTM B 584, brass; statically and dynamically balanced, keyed to shaft, and secured with a locking cap screw. Trim impeller to match specified performance.

D. Motor: Single speed, with doubled sealed ball bearings; and rigidly mounted to pump casing. Comply with requirements in Division 23 Section "Common Motor Requirements for HVAC Equipment."

2.7 CLOSE-COUPLED, IN-LINE CENTRIFUGAL PUMPS

A. Basis of Design: Bell & Gossett Series 90.

B. Description: Factory-assembled and -tested, centrifugal, overhung-impeller, close-coupled, in-line pump as defined in HI 1.1-1.2 and HI 1.3; designed for installation with pump and motor shafts mounted horizontally or vertically. Rate pump for 175-psig minimum working pressure and a continuous water temperature of 225 deg F.

C. Pump Construction:
   1. Casing: Radially split, cast iron, with threaded gage tappings at inlet and outlet, and companion flange connections.
   2. Impeller: ASTM B 584, brass; statically and dynamically balanced, keyed to shaft, and secured with a locking cap screw. Trim impeller to match specified performance.
   3. Pump Shaft: Steel shaft with copper alloy shaft sleeve with up to 5 HP motors and aluminum bronze shaft sleeve with over 5 HP motors.
   4. Mechanical Seal: Carbon rotating ring against a ceramic seat held by a stainless-steel spring, and Buna-N bellows and gasket. Include water slinger on shaft between motor and seal.
   5. Mechanical Seal: Carbon rotating ring against a ceramic seat held by a stainless-steel spring, and [Buna-N] [EPT] bellows and gasket. Include water slinger on shaft between motor and seal.

D. Motor: Single speed, with grease-lubricated ball bearings; and rigidly mounted to pump casing. Comply with requirements in Division 23 Section "Common Motor Requirements for HVAC Equipment."
2.8 CLOSE-COUpled, end-SuCTION CENTRIfUGAL PUMPS

A. Basis of Design: Bell & Gossett Series 1531.

B. Description: Factory-assembled and -tested, centrifugal, overhung-impeller, close-coupled, end-suction pump as defined in HI 1.1-1.2 and HI 1.3; designed for installation with pump and motor shafts mounted horizontally.

C. Pump Construction:

1. Casing: Radially split, cast iron, with drain plug at bottom and air vent at top of volute, threaded gage tappings at inlet and outlet, and threaded companion-flange or flanged connections.
2. Casing: Radially split, cast iron, with replaceable bronze wear rings, drain plug at bottom and air vent at top of volute, threaded gage tappings at inlet and outlet, and threaded companion-flange connections.
3. Impeller: ASTM B 584, cast bronze; statically and dynamically balanced, keyed to shaft, and secured with a locking cap screw. For constant-speed pumps, trim impeller to match specified performance.
4. Pump Shaft: Steel, with copper-alloy shaft sleeve.
6. Mechanical Seal: Carbon rotating ring against a ceramic seat held by a stainless-steel spring, and Buna-N bellows and gasket. Include water slinger on shaft between motor and seal.
7. Mechanical Seal: Carbon rotating ring against a ceramic seat held by a stainless-steel spring, and EPT bellows and gasket. Include water slinger on shaft between motor and seal.
8. Pump Bearings: Permanently lubricated ball bearings. Oil lubricated; bronze-journal or thrust type.

D. Motor: Single speed and rigidly mounted to pump casing with integral pump support. Comply with requirements in Division 23 Section “Common Motor Requirements for HVAC Equipment.”

2.9 SEPARATELY COUPLED, VERTICAL, IN-LINE CENTRIFUGAL PUMPS

2.10 SEPARATELY COUPLED, BASE-MOUNTED, END-SUCTION CENTRIFUGAL PUMPS

A. Basis of Design: Bell & Gossett Series e1510.

B. Description: Factory-assembled and -tested, centrifugal, single stage, separately coupled, end-suction pump; designed for base mounting, with pump and motor shafts horizontal. Rate pump for 175-psig minimum working pressure and a continuous water temperature of 225 deg F.

C. Pump Construction:

1. Casing: Cast iron, with threaded gage tappings at inlet and outlet, drain plug at bottom and air vent at top of volute, and threaded or flanged connections. Provide integral mount on volute to support the casing, and attached piping to allow removal and replacement of impeller without disconnecting piping or requiring the realignment of pump and motor shaft.
2. Impeller: ASTM B 584, cast bronze or cast stainless steel; statically and dynamically balanced, keyed to shaft, and secured with a locking cap screw. Trim impeller to match specified performance.

3. Pump Shaft: Steel, with stainless steel shaft sleeve.

4. Mechanical Seal: Carbon rotating ring against a ceramic seat held by a stainless-steel spring, and Buna-N bellows and gasket.

5. Mechanical Seal: Carbon rotating ring against a ceramic seat held by a stainless-steel spring, and [Buna-N] [EPT] bellows and gasket.

D. Shaft Coupling: Molded rubber insert and interlocking spider capable of absorbing vibration. Couplings shall be drop-out type to allow disassembly and removal without removing pump shaft or motor. EPDM coupling sleeve for variable-speed applications.

E. Coupling Guard: Dual rated; ANSI B15.1, Section 8; OSHA 1910.219 approved; steel; removable; attached to mounting frame.

F. Mounting Frame: Welded-steel frame and cross members, factory fabricated from ASTM A 36/A 36M channels and angles. Fabricate to mount pump casing, coupling guard, and motor.

G. Pump Condition Monitor: Battery powered pump condition monitoring system to be provided on the pump power end to continuously measure pump vibration and temperature at the outboard bearing. The system shall record the baseline vibration at start-up and have local alarm indication at the pump when the vibration levels are double the baseline values or when alarm limits are reached for vibration and temperature. Sensors and condition monitors’ electronics to be provided in a stainless steel enclosure potted in epoxy for protection from the environment.

H. Motor: Single speed, with permanently lubricated ball bearings for 5 HP and smaller motors or with grease-lubricated ball bearings for larger than 5 HP motors; secured to mounting frame, with adjustable alignment. Comply with requirements in Division 23 Section "Common Motor Requirements for HVAC Equipment."

1. Refer to Division 23 Section "Common Motor Requirements for HVAC Equipment" for special requirements for motors operated with variable frequency drives.

2.11 SEPARATELY COUPLED, BASE-MOUNTED, END-SUCTION CENTRIFUGAL PUMPS

A. Basis of Design: Bell & Gossett Series 1510.

B. Description: Factory-assembled and -tested, centrifugal, overhung-impeller, separately coupled, end-suction pump as defined in HI 1.1-1.2 and HI 1.3; designed for base mounting, with pump and motor shafts horizontal. Rate pump for 175-psig minimum working pressure and a continuous water temperature of 225 deg F.

C. Pump Construction:

1. Casing: Radially split, cast iron, with threaded gage tappings at inlet and outlet, drain plug at bottom and air vent at top of volute, and threaded or flanged connections. Provide integral mount on volute to support the casing, and attached piping to allow removal and replacement of impeller without disconnecting piping or requiring the realignment of pump and motor shaft.
2. Impeller: ASTM B 584, cast bronze[ or stainless steel]; statically and dynamically balanced, keyed to shaft, and secured with a locking cap screw. Trim impeller to match specified performance.

3. Pump Shaft: Steel, with aluminum bronze shaft sleeve.

4. Mechanical Seal: Carbon rotating ring against a ceramic seat held by a stainless-steel spring, and Buna-N bellows and gasket.

5. Mechanical Seal: Carbon rotating ring against a ceramic seat held by a stainless-steel spring, and [Buna-N][EPT] bellows and gasket.

D. Shaft Coupling: Molded rubber insert and interlocking spider capable of absorbing vibration. Couplings shall be drop-out type to allow disassembly and removal without removing pump shaft or motor. EPDM coupling sleeve for variable-speed applications.

E. Coupling Guard: Dual rated; ANSI B15.1, Section 8; OSHA 1910.219 approved; steel; removable; attached to mounting frame.

F. Mounting Frame: Welded-steel frame and cross members, factory fabricated from ASTM A 36/A 36M channels and angles. Fabricate to mount pump casing, coupling guard, and motor.

G. Motor: Single speed, with permanently lubricated ball bearings for 5 HP and smaller motors or with grease-lubricated ball bearings for larger than 5 HP motors; secured to mounting frame, with adjustable alignment. [Comply with requirements in Division 23 Section "Common Motor Requirements for HVAC Equipment."

1. [Refer to Division 23 Section "Common Motor Requirements for HVAC Equipment" for special requirements for motors operated with variable frequency drives.]

2.12 SEPARATELY COUPLED, BASE-MOUNTED, DOUBLE-SUCTION CENTRIFUGAL PUMPS

A. Basis of Design: Bell & Gossett Series VSX.

B. Description: Factory-assembled and -tested, centrifugal, impeller-between-bearings, separately coupled, double-suction pump as defined in HI 1.1-1.2 and HI 1.3; designed for base mounting, with pump and motor shafts horizontal. Rate pump for 175 psig minimum working pressure and a continuous water temperature of 300 deg F.

C. Pump Construction:

1. Casing: Vertical split, cast iron bronze fitted, with threaded gage tappings at inlet and outlet, drain plug at bottom and air vent at top of volute, and Class 125 flanges. Casing supports shall allow removal and replacement of impeller without disconnecting piping.

2. Impeller: Bronze; statically and dynamically balanced, and keyed to shaft. Trim impeller to match specified performance.


4. Mechanical Seal: Carbon rotating ring against a ceramic seat held by a stainless-steel spring, and EPR bellows and gasket.

5. Pump Bearings: Permanently-lubricated ball bearings contained in bearing housing.
D. Shaft Coupling: Molded rubber insert and interlocking spider capable of absorbing vibration. Couplings shall be drop-out type to allow disassembly and removal without removing pump shaft or motor. Include EPDM coupling sleeve for variable-speed applications.

E. Coupling Guard: Dual rated; ANSI B15.1, Section 8; OSHA 1910.219 approved; steel; removable; attached to mounting frame.

F. Mounting Frame: Welded-steel frame and cross members, factory fabricated. Fabricate to mount pump casing, coupling guard, and motor.

G. Motor: Single speed, with grease-lubricated ball bearings; secured to mounting frame, with adjustable alignment. Comply with requirements in Division 23 Section "Common Motor Requirements for HVAC Equipment."

2.13 SEPARATELY COUPLED, VERTICAL-MOUNTED, DOUBLE-SUCTION CENTRIFUGAL PUMPS

2.14 SEPARATELY COUPLED, VERTICAL-MOUNTED, TURBINE CENTRIFUGAL PUMPS

2.15 AUTOMATIC CONDENSATE PUMP UNITS

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

1. Little Giant Pump Co.
2. Beckett Corporation.
4. Sauermann.

B. Description: Packaged units with corrosion-resistant pump, plastic tank with cover, and automatic controls. Include factory- or field-installed check valve and the following electrical power connection:

1. For exposed applications, include a 72-inch minimum, electrical power cord with plug.
2. For concealed above ceiling applications, include a hard wired electrical power connection.

2.16 PUMP SPECIALTY FITTINGS

A. Suction Diffuser: Angle pattern, 175-psig pressure rating, ductile or 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; drain plug; and factory-fabricated support. Manufacturer shall be the same as the pump.

1. When grooved piping systems allowed, suction diffuser may be as described above except with ductile iron body and cap with grooved piping side connection.
B. **[Triple-Duty Valve]**: Angle or straight pattern, 175-psig pressure rating, ductile or cast-iron body, pump-discharge fitting; with drain plug and bronze-fitted shutoff, balancing, and check valve features. Brass gage ports with integral check valve, and orifice for flow measurement. Manufacturer shall be the same as the pump.

1. When grooved piping systems allowed, triple duty valve may be as described above except with ductile iron body with grooved piping connections and 300-psig pressure rating.
2. When grooved piping systems allowed, in lieu of triple duty valves, tri-service valves from mechanical grooved coupling system provider will be allowed.

**PART 3 - EXECUTION**

3.1 PUMP INSTALLATION

A. Comply with HI 1.4.

B. Comply with [HI 1.4] [HI 2.4].

C. Install pumps with access for periodic maintenance including removal of motors, impellers, couplings, and accessories.

D. Independently support pumps and piping so weight of piping is not supported by pumps and weight of pumps is not supported by piping.

E. Install continuous-thread hanger rods and [elastomeric hangers] [spring hangers] [spring hangers with vertical-limit stop] of sufficient size to support pump weight. Vibration isolation devices are specified in Division 23 Section “Vibration and Seismic Controls for HVAC Piping and Equipment.” Fabricate brackets or supports as required. Hanger and support materials are specified in Division 23 Section “Hangers and Supports for HVAC Piping and Equipment.”

F. Suspend vertically mounted, in-line centrifugal pumps independent of piping. Install pumps with motor and pump shafts vertical. Use continuous-thread hanger rods and [elastomeric hangers] [spring hangers] [spring hangers with vertical-limit stop] of sufficient size to support pump weight. Vibration isolation devices are specified in Division 21 Section “Vibration and Seismic Controls for Fire-Suppression Piping and Equipment.” Hanger and support materials are specified in Division 22 Section “Hangers and Supports for Plumbing Piping and Equipment/Hangers and Supports for HVAC Piping and Equipment.”

G. For foot-mounted pumps located on slab-on-grade type floors, set pumps on concrete equipment bases.

H. For base-mounted pumps located on slab-on-grade type floors, set pumps on concrete equipment bases. Disconnect coupling before setting. Do not reconnect couplings until alignment procedure is complete.

1. Support pump baseplate on rectangular metal blocks and shims, or on metal wedges with small taper, at points near foundation bolts to provide a gap of 3/4 to 1-1/2 inches between pump base and foundation for grouting.
2. Adjust metal supports or wedges until pump and driver shafts are level. Check coupling faces and suction and discharge flanges of pump to verify that they are level and plumb.

I. For base-mounted pumps located on elevated floors, set pumps on a concrete inertia base on top of a concrete equipment bases. Inertia base shall be fabricated from welded structural steel with the height of the base being 1/12th of the longest dimension. Inertia base shall be mounted on spring isolators, employing height saving clips. Disconnect coupling before setting. Do not reconnect couplings until alignment procedure is complete.

   1. Support pump baseplate on rectangular metal blocks and shims, or on metal wedges with small taper, at points near foundation bolts to provide a gap of 3/4 to 1-1/2 inches between pump base and foundation for grouting.
   2. Adjust metal supports or wedges until pump and driver shafts are level. Check coupling faces and suction and discharge flanges of pump to verify that they are level and plumb.

J. Trim pump impellers as required to have pump discharge balancing valves no more than 50% closed.

K. Automatic Condensate Pump Units: Install units for collecting condensate and extend to open drain.

3.2 ALIGNMENT

A. Align pump and motor shafts and piping connections after setting on foundation, grout has been set and foundation bolts have been tightened, and piping connections have been made.

   1. Alignment procedure to be witnessed by Engineer or Owner representative with witness signing the alignment certificate.

B. Comply with pump and coupling manufacturers' written instructions.

C. Adjust pump and motor shafts for angular and offset alignment by methods specified in HI 1.1-1.5, "Centrifugal Pumps for Nomenclature, Definitions, Application and Operation."

D. Adjust pump and motor shafts for angular and offset alignment by methods specified in [HI 1.1-1.5, "Centrifugal Pumps for Nomenclature, Definitions, Application and Operation] [HI 2.1-2.5, "Vertical Pumps for Nomenclature, Definitions, Application and Operation]."

E. After alignment is correct, tighten foundation bolts evenly but not too firmly. Completely fill baseplate with nonshrink, nonmetallic grout while metal blocks and shims or wedges are in place. After grout has cured, fully tighten foundation bolts.

3.3 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 machine to allow service and maintenance.
C. Connect piping to pumps. Install valves that are same size as piping connected to pumps.

D. Install suction and discharge pipe sizes equal to or greater than diameter of pump nozzles.

E. **[Install triple-duty valve]** on discharge side of base mounted pumps.

F. Install suction diffuser and shutoff valve on suction side of base mounted pumps.

   1. When grooved piping systems allowed, in lieu of flexible connectors, three flexible connectors from mechanical grooved coupling system provider will be allowed.

G. Install flexible connectors on suction and discharge sides of base-mounted pumps between pump casing and valves.

   1. When grooved piping systems allowed, in lieu of flexible connectors, three flexible connectors from mechanical grooved coupling system provider will be allowed.

H. Install flexible connectors on suction and discharge sides of foot-mounted pumps.

I. Install pressure gage across pump suction and discharge. Install single gage with metal tubing and multiple input selector valves.

J. Install check valve and gate or ball valve on each condensate pump unit discharge.

K. Install electrical connections for power, controls, and devices.

L. Ground equipment according to Division 26 Section "Grounding and Bonding for Electrical Systems."

M. Connect wiring according to Division 26 Section "Low-Voltage Electrical Power Conductors and Cables."

3.4 SHAFT GROUNDING RING INSTALLATION

A. Factory install at each three phase motor utilizing a variable frequency controller, a shaft grounding ring. Comply with requirements in Division 23 Section "Common Motor Requirements for HVAC Equipment."

3.5 STARTUP SERVICE

A. 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.


7. Open discharge valve slowly.

3.6 DEMONSTRATION

A. Train Owner's maintenance personnel to adjust, operate, and maintain hydronic pumps. Refer to Division 01 Section "Demonstration and Training."

B. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain hydronic pumps. Refer to Division 01 Section "Demonstration and Training."

END OF SECTION 23 2123
WMU Design Guidelines

WMU Design Guidelines Instructions: These guidelines are to be used by the Design Professional to inform the design process and outline WMU-specific desires for all University projects. These guidelines have been edited to reflect WMU preferences, and the intent is for the Design Professional to use this information to guide their normal specifications-writing process. Straying from what is indicated in the guidelines is not prohibited, but shall be discussed with WMU during the development of the project.

SECTION 23 2213 - STEAM AND CONDENSATE HEATING PIPING

PART 1 - GENERAL

1.1 SUMMARY

A. This Section includes the following HP steam and LP condensate piping:

B. Section includes pipe and fittings for LP [and] HP steam and condensate piping:

C. Section includes pipe and fittings for LP [and] HP steam and condensate piping:

D. Related Requirements:
   1. Section 23 2216 "Steam and Condensate Piping Specialties" for strainers, steam traps, and thermostatic air vents and vacuum breakers.
   2. Section 23 2216 "Steam and Condensate Piping Specialties" for strainers, flash tanks, special-duty valves, steam traps, steam and condensate meters, and thermostatic air vents and vacuum breakers.
   3. Section 23 2223 "Steam and Condensate Pumps" for condensate pumps.
   4. Section 33 6313 "Underground Steam and Condensate Distribution Piping" for underground piping.

1.2 DEFINITIONS

A. HP Systems: High-pressure piping operating at more than 15 psig as required by ASME B31.1.

B. LP Systems: Low-pressure piping operating at 15 psig or less as required by ASME B31.9.

1.3 ACTION SUBMITTALS

A. Product Data: For RTRP and RTRF and adhesive.

B. Delegated-Design Submittal:
   1. Design calculations and detailed fabrication and assembly of pipe anchors and alignment guides, hangers and supports for multiple pipes, expansion joints and loops, and attachments of the same to the building structure.
   2. Locations of pipe anchors and alignment guides and expansion joints and loops.
   3. Locations of and details for penetrations, including sleeves and sleeve seals for exterior walls, floors, basement, and foundation walls.
4. Locations of and details for penetration and firestopping for fire- and smoke-rated wall and floor and ceiling assemblies.

1.4 INFORMATIONAL SUBMITTALS

A. 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.

B. Qualification Data: For Installer.

C. Welding certificates.

D. Flexitallic gasket submittals.

E. Field quality-control reports.

1.5 QUALITY ASSURANCE

A. Installer Qualifications:
   1. Fiberglass Pipe and Fitting Installers: Installers of RTRF and RTRP shall be certified by the manufacturer of pipes and fittings as having been trained and qualified to join fiberglass piping with manufacturer-recommended adhesive.

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

C. Pipe Welding: Qualify procedures and operators according to the following:
   2. ASME Compliance: Comply with [ASME B31.1, "Power Piping,"] [and] [ASME B31.9, "Building Services Piping,"] for materials, products, and installation.
   3. 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. Components and installation shall be capable of withstanding the following minimum working pressures and temperatures unless otherwise indicated:
   1. HP Steam Piping: 150 psig.
2. HP Steam Piping: \(<\text{Insert psig}\>\).
3. LP Steam Piping: 125 psig.
4. LP Steam Piping: \(<\text{Insert psig}\>\).
5. Condensate Piping: 150 psig at 250 deg F.
6. Condensate Piping: \(<\text{Insert psig}\> \text{ at [250 deg F]}\) \(<\text{Insert temperature}\>\).
7. Makeup-Water Piping: \([80 \text{ psig}]\) \(<\text{Insert value}\> \text{ at [150 deg F]}\) \(<\text{Insert temperature}\>\).
8. Blowdown-Drain Piping: Equal to pressure of the piping system to which it is attached.
9. Air-Vent and Vacuum-Breaker Piping: Equal to pressure of the piping system to which it is attached.
10. Safety-Valve-Inlet and -Outlet Piping: Equal to pressure of the piping system to which it is attached.

2.2 STEEL PIPE AND FITTINGS

A. Steel Pipe: ASTM A 53/A 53M, black steel, plain ends, welded and seamless, Grade B, and Schedule as indicated in piping applications articles.

B. Cast-Iron Threaded Fittings: ASME B16.4; Classes 125, 150, and 300 as indicated in piping applications articles.

C. Malleable-Iron Threaded Fittings: ASME B16.3; Classes 150 and 300 as indicated in piping applications articles.

D. Malleable-Iron Unions: ASME B16.39; Classes 150, 250, and 300 as indicated in piping applications articles.

E. Cast-Iron Threaded Flanges and Flanged Fittings: ASME B16.1, Classes 125 and 250 as indicated in piping applications articles; raised ground face, and bolt holes spot faced.

F. Wrought-Steel Fittings: ASTM A 234/A 234M, wall thickness to match adjoining pipe.

G. Wrought-Steel Flanges and Flanged Fittings: ASME B16.5, including bolts, nuts, and gaskets of the following material group, end connections, and facings:

2. End Connections: Butt welding.
3. Facings: Raised face.

H. Steel Pipe Nipples: ASTM A 733, made of ASTM A 53/A 53M, black steel of same Type, Grade, and Schedule as pipe in which installed.

2.3 FIBERGLASS PIPE AND FITTINGS

A. RTRP: ASTM D 2996, Type 1, Grade 1, Class F, filament-wound pipe with tapered bell and spigot ends for adhesive joints.

B. RTRF: ASTM D 5685, Type 2 or Type 5, Grade 1, Class F, compression or spray-up/contact molded fittings of same material, pressure class, and joining method as pipe.
WMU Design Guidelines

C. Flanges: ASTM D 4024, Type 1, Grade 1, full-face gaskets suitable for the service, minimum 1/8 inch thick, 60-70 durometer. ASTM A 307, Grade B, hex head bolts with washers.

D. Bonding Adhesive for Fiberglass Piping: As recommended by fiberglass piping manufacturer.

2.4 JOINING MATERIALS

A. Pipe-Flange Gasket Materials: Suitable for chemical and thermal conditions of piping system contents.

1. ASME B16.21, nonmetallic, flat, asbestos free, 1/8-inch maximum thickness unless otherwise indicated. Steam and Condensate Gaskets shall be flexitallic spiral wound.

   a. Full-Face Type: For flat-face, Class 125, cast-iron and cast-bronze flanges.
   b. Narrow-Face Type: For raised-face, Class 250, cast-iron and steel flanges.

B. Flange Bolts and Nuts: ASME B18.2.1, carbon steel, unless otherwise indicated.

C. Welding Filler Metals: Comply with AWS D10.12M/D10.12 for welding materials appropriate for wall thickness and chemical analysis of steel pipe being welded.

D. Welding Materials: Comply with Section II, Part C, of ASME Boiler and Pressure Vessel Code for welding materials appropriate for wall thickness and for chemical analysis of pipe being welded.

PART 3 - EXECUTION

3.1 LP STEAM PIPING APPLICATIONS

A. LP Steam Piping, NPS 2 and Smaller: Schedule 40, Type S, Grade B, steel pipe; Class 125 cast-iron fittings; and threaded joints.

B. LP Steam Piping, [NPS 2 and Smaller] <Insert pipe size range>: [Schedule 40] [Schedule 80], Type S, Grade B, steel pipe; Class 125 cast-iron fittings; and threaded joints.

C. LP Steam Piping, NPS 2-1/2 through NPS 12: Schedule 40, Type E, Grade B, steel pipe; Class 150 wrought-steel fittings, flanges, and flange fittings; and welded and flanged joints.

D. LP Steam Piping, [NPS 2-1/2 through NPS 12] <Insert pipe size range>: [Schedule 40] [Schedule 80], Type E, Grade B, steel pipe; Class 150 wrought-steel fittings, flanges, and flange fittings; and welded and flanged joints.

E. LP Steam Piping, NPS 14 through NPS 18: Schedule 30, Type E, Grade B, steel pipe; Class 150 wrought-steel fittings, flanges, and flange fittings; and welded and flanged joints.

F. LP Steam Piping, [NPS 14 through NPS 18] <Insert pipe size range>: Schedule 30, Type E, Grade B, steel pipe; Class 150 wrought-steel fittings, flanges, and flange fittings; and welded and flanged joints.
G. LP Steam Piping, NPS 20 and Larger: Schedule 20, Type E, Grade B, steel pipe; Class 150 wrought-steel fittings, flanges, and flange fittings; and welded and flanged joints.

H. LP Steam Piping, [NPS 20 and Larger] <Insert pipe size range>: Schedule 20, Type E, Grade B, steel pipe; Class 150 wrought-steel fittings, flanges, and flange fittings; and welded and flanged joints.

I. LP Condensate piping above grade, NPS 2 and smaller, shall be the following:

J. Condensate piping above grade, [NPS 2] <Insert pipe size range> and smaller, shall be [either of] the following:
   1. Schedule 80, Type S, Grade B, steel pipe; Class 150 cast-iron fittings; and threaded joints.
   2. RTRP and RTRF with adhesive or flanged joints.

K. Condensate piping above grade, NPS 2-1/2 and larger, shall be the following:

L. Condensate piping above grade, [NPS 2-1/2] <Insert pipe size range> and larger, shall be [either of] the following:
   1. Schedule 80, Type E, Grade B, steel pipe; Class 150 wrought-steel fittings, flanges, and flange fittings; and welded and flanged joints.
   2. RTRP and RTRF with adhesive or flanged joints.

M. Condensate piping below grade, [NPS 2] <Insert pipe size range> and smaller, shall be [either of] the following:
   1. Schedule 80, Type S, Grade B, steel pipe; Class 125 cast-iron fittings; and threaded joints.
   2. RTRP and RTRF with adhesive or flanged joints.

N. Condensate piping below grade, [NPS 2-1/2] <Insert pipe size range> and larger, shall be [either of] the following:
   1. Schedule 80, Type E, Grade B, steel pipe; Class 150 wrought-steel fittings, flanges, and flange fittings; and welded and flanged joints.
   2. RTRP and RTRF with adhesive or flanged joints.

3.2 HP STEAM PIPING APPLICATIONS

A. HP Steam Piping, NPS 2 and Smaller: Schedule 40, Type S, Grade B, steel pipe; Class 125 cast-iron fittings; and threaded joints.

B. HP Steam Piping, [NPS 2 and Smaller] <Insert pipe size range>: [Schedule 40] [Schedule 80], Type S, Grade B, steel pipe; Class 125 cast-iron fittings; and threaded joints.

C. HP Steam Piping, NPS 2-1/2 through NPS 12: Schedule 40, Type E, Grade B, steel pipe; Class 150 wrought-steel fittings, flanges, and flange fittings; and welded and flanged joints.
D. HP Steam Piping, NPS 2-1/2 through NPS 12: Schedule 40, Type E, Grade B, steel pipe; Class 150 wrought-steel fittings, flanges, and flange fittings; and welded and flanged joints.

E. HP Steam Piping, NPS 14 through NPS 18: Schedule 30, Type E, Grade B, steel pipe; Class 150 wrought-steel fittings, flanges, and flange fittings; and welded and flanged joints.

F. HP Steam Piping, [NPS 14 through NPS 18] <Insert pipe size range>: Schedule 30, Type E, Grade B, steel pipe; Class 150 wrought-steel fittings, flanges, and flange fittings; and welded and flanged joints.

G. HP Steam Piping, NPS 20 and Larger: Schedule 20, Type E, Grade B, steel pipe; Class 150 wrought-steel fittings, flanges, and flange fittings; and welded and flanged joints.

H. HP Steam Piping, [NPS 20 and Larger] <Insert pipe size range>: Schedule 20, Type E, Grade B, steel pipe; Class 150 wrought-steel fittings, flanges, and flange fittings; and welded and flanged joints.

I. Condensate piping, NPS 2 and smaller, shall be the following:

J. Condensate piping above grade, [NPS 2] <Insert pipe size range> and smaller, shall be[ either of] the following:
   1. Schedule 80, Type S, Grade B, steel pipe; Class 125 cast-iron fittings; and threaded joints.
   2. RTRP and RTRF with adhesive or flanged joints.

K. Condensate piping, NPS 2-1/2 and larger, shall be the following:

L. Condensate piping above grade, [NPS 2-1/2] <Insert pipe size range> and larger, shall be[ either of] the following:
   1. Schedule 80, Type E, Grade B, steel pipe; Class 150 wrought-steel fittings, flanges, and flange fittings; and welded and flanged joints.
   2. RTRP and RTRF with adhesive or flanged joints.

M. Condensate piping below grade, [NPS 2] <Insert pipe size range> and smaller, shall be[ either of] the following:
   1. Schedule 80, Type S, Grade B, steel pipe; Class 125 cast-iron fittings; and threaded joints.
   2. RTRP and RTRF with adhesive or flanged joints.

N. Condensate piping below grade, [NPS 2-1/2] <Insert pipe size range> and larger, shall be[ either of] the following:
   1. Schedule 80, Type E, Grade B, steel pipe; Class 150 wrought-steel fittings, flanges, and flange fittings; and welded and flanged joints.
   2. RTRP and RTRF with adhesive or flanged joints.
3.3 ANCILLARY PIPING APPLICATIONS

A. Blowdown-Drain Piping: Same materials and joining methods as for piping specified for the service in which blowdown drain is installed.

B. Vacuum-Breaker Piping: Outlet, same as service where installed.

C. Hatch Drain Piping Within Tunnel: Galvanized steel pipe with threaded malleable iron fittings.

D. Safety-Valve-Inlet and -Outlet Piping: Same materials and joining methods as for piping specified for the service in which safety valve is installed.

3.4 PIPING INSTALLATION

A. Drawing plans, schematics, and diagrams indicate general location and arrangement of piping systems. Install piping as indicated unless deviations to layout are approved.

B. Drawing plans, schematics, and diagrams indicate general location and arrangement of piping systems. Install piping as indicated unless deviations to layout are approved [on Coordination Drawings].

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 walls. Diagonal runs are prohibited unless otherwise indicated.

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

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

G. Install piping to permit valve servicing.

H. Install piping free of sags and bends.

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

J. Install piping to allow application of insulation.

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

L. Install groups of pipes parallel to each other, spaced to permit applying insulation and servicing of valves.

M. Install drains, consisting of a tee fitting, NPS 3/4 full port-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.
N. Install steam supply piping at a minimum uniform grade of 0.2 percent downward in direction of steam flow.

O. Install condensate return piping at a minimum uniform grade of 0.4 percent downward in direction of condensate flow.

P. Reduce pipe sizes using eccentric reducer fitting installed with level side down.

Q. Install branch connections to mains using tee fittings in main pipe, with the branch connected to top of main pipe.

R. Install branch connections to mains using [mechanically formed] tee fittings in main pipe, with the branch connected to top of main pipe.

S. Install valves to comply with requirements specified in Division 23 Section "General-Duty Valves for HVAC Piping."


U. Install unions in piping, NPS 2 and smaller, adjacent to valves, at final connections of equipment, and elsewhere as indicated.

V. Install flanges in piping, NPS 2-1/2 and larger, at final connections of equipment and elsewhere as indicated.

W. Install shutoff valve immediately upstream of each dielectric fitting.

X. Install strainers on supply side of control valves, pressure-reducing valves, traps, and elsewhere as indicated. Install NPS 3/4 nipple and full port ball valve in blowdown connection of strainers NPS 2 and larger. Match size of strainer blowoff connection for strainers smaller than NPS 2.

Y. Install NPS 3/4 warm-up loop with high-performance ball valve and pressure gauges across steam valves NPS 6(DN 150) and larger.

Z. Comply with requirements in Section 23 0516 "Expansion Fittings and Loops for HVAC Piping" for installation of expansion loops, expansion joints, anchors, and pipe alignment guides.

AA. Comply with requirements in Section 23 0553 "Identification for HVAC Piping and Equipment" for identifying piping.

BB. Install drip legs at low points and natural drainage points such as ends of mains, bottoms of risers, and ahead of pressure regulators, and control valves.

1. On straight runs with no natural drainage points, install drip legs at intervals not exceeding 300 feet.
2. On straight runs with no natural drainage points, install drip legs at intervals not exceeding [300 feet] <Insert distance>.
3. Size drip legs same size as main. In steam mains NPS 6 and larger, drip leg size can be reduced, but to no less than NPS 4.
CC. Install sleeves, sleeve seals, and escutcheons for piping penetrations of walls, ceilings, and floors. Comply with requirements in Section 23 0500 "Common Work Results for HVAC."

DD. Install sleeves for piping penetrations of walls, ceilings, and floors. Comply with requirements for sleeves specified in Section 23 0517 "Sleeves and Sleeve Seals for HVAC Piping."

EE. Install sleeve seals for piping penetrations of concrete walls and slabs. Comply with requirements for sleeve seals specified in Section 23 0517 "Sleeves and Sleeve Seals for HVAC Piping."

FF. Install escutcheons for piping penetrations of walls, ceilings, and floors. Comply with requirements for escutcheons specified in Section 23 0518 "Escutcheons for HVAC Piping."

3.5 STEAM AND CONDENSATE PIPING SPECIALTIES INSTALLATION

A. Comply with requirements in Section 23 2216 "Steam and Condensate Piping Specialties" for installation requirements for steam and condensate specialties.

B. Comply with requirements in Section 23 2216 "Steam and Condensate Piping Specialties" for installation requirements for strainers, flash tanks, special-duty valves, steam traps, thermostatic air vents and vacuum breakers, and steam and condensate meters.

3.6 HANGERS AND SUPPORTS

A. Comply with requirements in Section 23 0529 "Hangers and Supports for HVAC Piping and Equipment" for installation of hangers and supports. Comply with requirements below for maximum spacing.

B. Comply with requirements in Section 23 0548 "Vibration and Seismic Controls for HVAC" for seismic restraints.

C. Install the following pipe attachments:

1. Adjustable steel clevis hangers for individual horizontal piping less than 20 feet long.
2. Adjustable roller hangers and spring hangers for individual horizontal piping 20 feet or longer.
3. Pipe Roller: MSS SP-58, Type 44 for multiple horizontal piping 20 feet or longer, supported on a trapeze.
4. Spring hangers to support vertical runs.

D. Install hangers and supports for steel steam supply and steam condensate piping in accordance Michigan Mechanical Code or MSS SP-69.

E. Install hangers for steel steam supply piping with the following maximum spacing:

1. NPS 3/4: Maximum span, 9 feet.
2. NPS 1: Maximum span, 9 feet.
3. NPS 1-1/2: Maximum span, 12 feet.
4. NPS 2: Maximum span, 13 feet.
5. NPS 2-1/2: Maximum span, 14 feet.
6. NPS 3 and Larger: Maximum span, 15 feet.

F. Install hangers for steel steam condensate piping with the following maximum spacing:

1. NPS 3/4: Maximum span, 7 feet.
2. NPS 1: Maximum span, 7 feet.
3. NPS 1-1/2: Maximum span, 9 feet.
4. NPS 2: Maximum span, 10 feet.
5. NPS 2-1/2: Maximum span, 11 feet.
6. NPS 3 and Larger: Maximum span, 12 feet

G. Support vertical runs at roof, at each floor, and at 10-foot intervals between floors.

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

3.7 PIPE JOINT CONSTRUCTION

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

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

C. 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.

D. Welded Joints: Construct joints according to AWS D10.12M/D10.12, using qualified processes and welding operators according to "Quality Assurance" Article.

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

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

3.8 TERMINAL EQUIPMENT CONNECTIONS

A. Size for supply and return piping connections shall be the same as or larger than equipment connections.

B. Install traps and control valves in accessible locations close to connected equipment.
C. Install bypass piping with globe valve around control valve. If parallel control valves are installed, only one bypass is required.

D. Install vacuum breakers downstream from control valve, close to coil inlet connection.

E. Install a drip leg at coil outlet.

3.9 FIELD QUALITY CONTROL

A. Prepare steam and condensate piping according to ASME B31.1, "Power Piping," and ASME B31.9, "Building Services Piping," and as follows:

B. Prepare steam and condensate piping according to [ASME B31.1, "Power Piping,"] [and] [ASME B31.9, "Building Services Piping,"] and as follows:

1. Leave joints, including welds, uninsulated and exposed for examination during test.
2. Provide temporary restraints for expansion joints that cannot sustain reactions due to test pressure. If temporary restraints are impractical, isolate expansion joints from testing.
3. Flush system with clean water. Clean strainers.
4. Isolate equipment from piping. If a valve is used to isolate equipment, its closure shall be capable of sealing against test pressure without damage to valve. Install blinds in flanged joints to isolate equipment.

C. Testing Agency: [Owner will engage] [Engage] a qualified testing agency to perform tests and inspections.

D. Manufacturer's Field Service: Engage a factory-authorized service representative to test and inspect components, assemblies, and equipment installations, including connections.

E. Perform the following tests and inspections:

F. Perform the following tests and inspections[with the assistance of a factory-authorized service representative]:

1. Use ambient temperature water as a testing medium unless there is risk of damage due to freezing. Another liquid that is safe for workers and compatible with piping may be used.
2. Subject piping system to hydrostatic test pressure that is not less than 1.5 times the working pressure. Test pressure shall not exceed maximum pressure for any vessel, pump, valve, or other component in system under test. Verify that stress due to pressure at bottom of vertical runs does not exceed 90 percent of specified minimum yield strength.
3. 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.

G. Prepare test and inspection reports.

END OF SECTION 23 2213
WMI Design Guidelines Instructions: These guidelines are to be used by the Design Professional to inform the design process and outline WMI-specific desires for all University projects. These guidelines have been edited to reflect WMI preferences, and the intent is for the Design Professional to use this information to guide their normal specifications-writing process. Straying from what is indicated in the guidelines is not prohibited, but shall be discussed with WMI during the development of the project.

SECTION 23 2216 - STEAM AND CONDENSATE PIPING SPECIALTIES

PART 1 - GENERAL

1.1 SUMMARY

A. Section includes the following piping specialties for LP and HP steam and condensate piping:

B. Section includes the following piping specialties for [LP] [and] [HP] steam and condensate piping:

   1. Strainers.
   2. Flash tanks.
   4. Pressure-reducing valves.
   5. Steam traps.
   6. Thermostatic air vents and vacuum breakers.
   8. Steam and condensate meters.

1.2 DEFINITIONS

A. HP Systems: High-pressure piping operating at more than 15 psig as required by ASME B31.1.

B. LP Systems: Low-pressure piping operating at 15 psig or less as required by ASME B31.9.

1.3 ACTION SUBMITTALS

A. Product Data: For each type of the following:

   1. Pressure-reducing and safety valve.
   2. Steam trap.
   3. Strainers
   4. Air vent and vacuum breaker.
   5. Balancing valves.
   6. Flash tank.
   7. Meter.
1.4 CLOSEOUT SUBMITTALS

A. Operation and maintenance data.

1.5 QUALITY ASSURANCE

A. Pipe Welding: Qualify procedures and operators according to the following:

1. ASME Compliance: [Safety valves and pressure vessels] shall bear the appropriate ASME label. [Fabricate and stamp flash tanks] to comply with ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.
2. ASME Compliance: [Safety valves and pressure vessels] shall bear the appropriate ASME label. [Fabricate and stamp flash tanks] to comply with ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

A. Components and installation shall be capable of withstanding the following minimum working pressures and temperatures unless otherwise indicated:

1. HP Systems: 150 psig.
2. HP Steam Piping: <Insert psig>.
4. LP Steam Piping: <Insert psig>.
5. Condensate Piping: 125 psig at 250 deg F.
7. Blowdown-Drain Piping: Equal to pressure of the piping system to which it is attached.
8. Air-Vent and Vacuum-Breaker Piping: Equal to pressure of the piping system to which it is attached.
9. Safety-Valve-Inlet and -Outlet Piping: Equal to pressure of the piping system to which it is attached.

2.2 VALVES

A. General Duty Valves: Comply with requirements specified in Division 23 Section "General-Duty Valves for HVAC Piping."


C. Stop-Check Valves:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
a. A.Y. McDonald Mfg. Co.
b. Cincinnati Valve Company.
c. Crane; Crane Energy Flow Solutions.
d. Jenkins Valves.
e. Lunkenheimer Valves.

2. Body and Bonnet: Malleable iron.
4. Disc: Cylindrical with removable liner and machined seat.
5. Stem: Brass alloy.
6. Operator: Outside screw and yoke with cast-iron handwheel.
8. Pressure Class: 250.

2.3 STRAINERS

A. Y-Pattern Strainers:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   b. Hoffman Specialty.
   c. Mueller Co.

2. Body: ASTM A 126, Class B cast iron, with bolted cover and bottom drain connection.
3. End Connections: Threaded ends for strainers NPS 2 and smaller; flanged ends for strainers NPS 2-1/2 and larger.
5. Strainer Screen: Stainless-steel, [20] [40] [60]-mesh strainer, or perforated stainless-steel basket.
6. Tapped blowoff plug.
7. CWP Rating: 250-psig working steam pressure.

B. Basket Strainers:

1. Body: ASTM A 126, Class B cast iron, with bolted cover and bottom drain connection.
2. End Connections: Threaded ends for strainers NPS 2 and smaller; flanged ends for strainers NPS 2-1/2 and larger.
3. Strainer Screen: Stainless-steel, 20 mesh strainer, and perforated stainless-steel basket with 50 percent free area.
4. Strainer Screen: Stainless-steel, [20] <Insert number> mesh strainer, and perforated stainless-steel basket with 50 percent free area.
5. CWP Rating: 250-psig working steam pressure.
2.4 FLASH TANKS

A. Shop or factory fabricated of welded steel according to ASME Boiler and Pressure Vessel Code, for 150-psig rating; and bearing ASME label. Fabricate with tappings for low-pressure steam and condensate outlets, high-pressure condensate inlet, air vent, safety valve, and legs.

2.5 SAFETY VALVES

A. **[Bronze] [or] [Brass]** Safety Valves: ASME labeled.

1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
   b. Kunkle Valve.
   c. Spirax Sarco, Inc.
   d. Watts; a Watts Water Technologies company.

2. Disc Material: Forged copper alloy.
3. End Connections: Threaded inlet and outlet.
4. Spring: Fully enclosed steel spring with adjustable pressure range and positive shutoff, factory set and sealed.
5. Pressure Class: 250.
6. Drip-Pan Elbow: Cast iron and having threaded inlet and outlet with threads complying with ASME B1.20.1.
7. Size and Capacity: As required for equipment according to ASME Boiler and Pressure Vessel Code.


1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
   b. Kunkle Valve.
   c. Spirax Sarco, Inc.
   d. Watts; a Watts Water Technologies company.

2. Disc Material: Forged copper alloy with bronze nozzle.
3. End Connections: Raised-face flanged inlet and threaded or flanged outlet connections.
4. Spring: Fully enclosed cadmium-plated steel spring with adjustable pressure range and positive shutoff, factory set and sealed.
5. Pressure Class: 250.
6. Drip-Pan Elbow: Cast iron and having threaded inlet, outlet, and drain, with threads complying with ASME B1.20.1.
7. Exhaust Head: Cast iron and having threaded inlet and drain, with threads complying with ASME B1.20.1.
2.6 PRESSURE-REDUCING VALVES

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

3. Leslie Controls, Inc.
5. Spirax Sarco, Inc.

B. ASME labeled.

C. Size, Capacity, and Pressure Rating: Factory set for inlet and outlet pressures indicated.

D. Description: Pilot-actuated, diaphragm type, with adjustable pressure range and positive shutoff.

E. Body: Cast iron.

F. End Connections: Threaded connections for valves NPS 2 and smaller and flanged connections for valves NPS 2-1/2 and larger.

G. Trim: Hardened stainless steel.

H. Head and Seat: Replaceable, main head stem guide fitted with flushing and pressure-arresting device cover over pilot diaphragm.


J. Capacities and Characteristics:

1. Steam Flow Rate: \(<\text{Insert lb/h}>\).
2. Inlet Pressure: \(<\text{Insert psig}>\).
3. Outlet Set Pressure: \(<\text{Insert psig}>\).
4. Pressure Loss (Wide Open): \(<\text{Insert psig}>\).

2.7 STEAM TRAPS

A. Thermostatic Traps:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   b. Barnes & Jones, Inc.
   c. Dunham-Bush, Inc.
   d. Hoffman Specialty.
   e. Spirax Sarco, Inc.
   f. Sterling.
   g. Tunstall Corporation.
2. Body: Bronze angle-pattern body with integral union tailpiece and screw-in cap.
3. Trap Type: Balanced-pressure.
4. Bellows: Stainless steel or monel.
5. Head and Seat: Replaceable, hardened stainless steel.
6. Pressure Class: 125.

B. Thermodynamic Traps:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   b. Barnes & Jones, Inc.
   c. Dunham-Bush, Inc.
   d. Hoffman Specialty.
   e. Spirax Sarco, Inc.
   f. Tunstall Corporation.

4. Disc and Seat: Stainless steel.
5. Maximum Operating Pressure: 600 psig.

C. Float and Thermostatic Traps:

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

2. Description: ASTM A 278, Class 30 cast iron body and bolted cap; renewable, stainless steel float mechanism, with renewable, hardened stainless steel head and seat; balanced pressure thermostatic air vent made of stainless steel or monel bellows with stainless steel head and seat.
3. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   b. Barnes & Jones, Inc.
   c. Dunham-Bush, Inc.
   d. Hoffman Specialty.
   e. Spirax Sarco, Inc.
   f. Sterling.
   g. Tunstall Corporation.

5. End Connections: Threaded.
8. Trap Type: Balanced pressure.
9. Thermostatic Bellows: Stainless steel or monel.
10. Thermostatic air vent capable of withstanding 45 deg F of superheat and resisting water hammer without sustaining damage.

D. Inverted Bucket Traps:

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

2. Description: ASTM A 278, Class 30 cast iron body and cap, pressure rated for 250 psi; stainless steel head and seat; stainless steel valve retainer, lever, guide pin assembly, brass or stainless steel bucket.
   a. Integral stainless steel inlet strainer within trap body.

3. Inverted Bucket Traps on HP Steam system shall be sized with a PMO greater than 80 psig.
4. Inverted Bucket Traps on LP Steam system shall be sized with a PMO greater than the safety relief valve.
5. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   b. Barnes & Jones, Inc.
   c. Dunham-Bush, Inc.
   d. Hoffman Specialty.
   e. Spirax Sarco, Inc.
   f. Sterling.
   g. Tunstall Corporation.

11. Strainer: Integral stainless-steel inlet strainer within the trap body.

2.8 THERMOSTATIC AIR VENTS AND VACUUM BREAKERS

A. Thermostatic Air Vents:

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

2. Body: Cast iron, bronze, or stainless steel.
5. Thermostatic Element: Phosphor bronze bellows in a stainless-steel cage.
7. Pressure Rating: \([125 \text{ psig}] [300 \text{ psig}] \) <Insert value>.
8. Maximum Temperature Rating: 350 deg F.

B. Vacuum Breakers:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   b. Hoffman Specialty.
2. Body: Cast iron, bronze, or stainless steel.
5. O-Ring Seal: EPR.
7. Pressure Rating: \([125 \text{ psig}] [300 \text{ psig}] \) <Insert value>.
8. Maximum Temperature Rating: 350 deg F.

2.9 BALANCING VALVES

A. Bronze, Calibrated-Orifice, Balancing Valves:

1. Manufacturers: Subject to compliance with requirements, provide products by the following:
   a. Bell & Gossett.
2. Body: Bronze, ball type with calibrated orifice or venturi.
4. Seat: TFE.
5. End Connections: Threaded.
7. Handle Style: Dial, with memory stop to retain set position.
8. Design Pressure/Temperature Rating: 400 psig at 250 deg F.

2.10 FLEXIBLE CONNECTORS

A. Stainless-Steel Bellows, Flexible Connectors:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   a. Duraflex, Inc.
   b. Flexcraft Industries.
   c. Hyspan Precision Products, Inc.
   d. Mason Industries, Inc.
   e. Metraflex Company (The).
   f. Twin City Hose, Inc.
3. End Connections: Threaded or flanged to match equipment connected.
5. CWP Rating: 150 psig.
6. Maximum Operating Temperature: 250 deg F.

2.11 STEAM METERS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   1. EMCO Flow Systems.
   2. ISTEC Corporation.
   4. Spirax Sarco, Inc.

B. Meters shall have a microprocessor to display totalizer flow, flow rate, temperature, pressure, time, and date; alarms for high and low flow rate and temperature.
   1. Computer shall have 4- to 20-mA or 2- to 10-V output for temperature, pressure, and contact closure for flow increments.
   2. Independent timers to store four peak flow rates and total flow.
   3. Interface compatible with central workstation described in Section 23 0923 "Direct Digital Control (DDC) System for HVAC."

C. Sensor: Venturi, of [stainless-steel] [carbon-steel] construction, for insertion in pipeline between flanges. At least 10:1 turndown with plus or minus 1 percent accuracy over full-flow range.

D. Sensor: Vortex type with stainless-steel wetted parts and [wafer] [flange] connections; and with a piezoelectric sensor removable and serviceable without shutting down the process. At least 10:1 turndown with plus or minus 1 percent accuracy over full-flow range.

E. Sensor: Spring-loaded, variable-area flowmeter type; density compensated with stainless-steel wetted parts and [wafer] [flange] connections. At least 10:1 turndown with plus or minus 2 percent accuracy over full-flow range.

2.12 CONDENSATE METERS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   1. Central Station Steam Co.
   2. Lincoln Meter Company.

B. Body: Cast iron, bronze, or brass.

C. Turbine: Copper, brass, or stainless steel.
D. Connections: Threaded for NPS 2 and smaller and flanged for NPS 2-1/2.

E. Totalizer: Meters shall have a microprocessor to display flow, flow rate, time, and date; alarms for high and low flow rate, pressure, and temperature.
   1. Computer shall have 4- to 20-mA or 2- to 10-V output for temperature, pressure, and contact closure for flow increments.
   2. Independent timers to store four peak flow rates and total flow.
   3. Interface compatible with central workstation specified in Section 23 0923 "Direct Digital Control (DDC) System for HVAC."

F. Pressure Rating: [Atmospheric] <Insert pressure>.

G. Maximum Temperature Rating: [250 deg F] <Insert temperature>.

PART 3 - EXECUTION

3.1 VALVE APPLICATIONS

A. Install shutoff duty valves at branch connections to steam supply mains, at steam supply connections to equipment, and at the outlet of steam traps.

B. Install safety valves on pressure-reducing stations and elsewhere as required by ASME Boiler and Pressure Vessel Code. Install safety-valve discharge piping, without valves, to nearest floor drain or as indicated on Drawings. Comply with ASME Boiler and Pressure Vessel Code: Section VIII, Division 1, for installation requirements.

3.2 PIPING INSTALLATION

A. Install piping, unions, and flanges adjacent to specialties to permit servicing of specialties.

B. Install piping to permit valve servicing.

C. Install drains, consisting of a tee fitting, NPS 3/4 full port-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.


E. Install unions in piping, [NPS 2] <Insert pipe size> and smaller, adjacent to valves, at final connections of equipment, and elsewhere as indicated.

F. Install flanges in piping, [NPS 2-1/2] <Insert pipe size> and larger, at final connections of equipment and elsewhere as indicated.
G. Install shutoff valve immediately upstream of each dielectric fitting.

H. Install strainers on supply side of control valves, pressure-reducing valves, traps, and elsewhere as indicated. Install NPS 3/4 nipple and full port ball valve in blowdown connection of strainers NPS 2 and larger. Match size of strainer blowoff connection for strainers smaller than NPS 2.

3.3 FLASH TANK INSTALLATION
A. Pitch condensate piping down toward flash tank.
B. If more than one condensate pipe discharges into flash tank, install a check valve in each line.
C. Install thermostatic air vent at tank top.
D. Install safety valve at tank top.
E. Install full-port ball valve, and swing check valve on condensate outlet.
F. Install inverted bucket or float and thermostatic trap at low-pressure condensate outlet, sized for three times the calculated heat load.
G. Install pressure gage on low-pressure steam outlet according to Section 23 0519 "Meters and Gages for HVAC Piping."

3.4 STEAM-TRAP INSTALLATION
A. Install steam traps in accessible locations as close as possible to connected equipment.
B. Install ball or globe valve, strainer, and union upstream from trap; install union, check valve, and ball or globe valve downstream from trap unless otherwise indicated.
C. Install full-port ball valve, strainer, and union upstream from trap; install union, check valve, and full-port ball valve downstream from trap unless otherwise indicated.

3.5 BALANCING VALVE INSTALLATION
A. Install calibrated-orifice balancing valves in the condensate return pipe from each pump at collection header.

3.6 PRESSURE-REDUCING VALVE INSTALLATION
A. Install pressure-reducing valves in accessible location for maintenance and inspection.
B. Install bypass piping around pressure-reducing valves, with globe valve equal in size to area of pressure-reducing valve seat ring, unless otherwise indicated.
C. Install gate valves on both sides of pressure-reducing valves.
D. Install unions or flanges on both sides of pressure-reducing valves having threaded- or flanged-end connections, respectively.

E. Install pressure gages on low-pressure side of pressure-reducing valves after the bypass connection according to Section 23 0519 “Meters and Gages for HVAC Piping.”

F. Install strainers upstream for pressure-reducing valve.

G. Install safety valve downstream from pressure-reducing valve station.

3.7 STEAM OR CONDENSATE METER INSTALLATION

A. Install meters with lengths of straight pipe upstream and downstream according to steam meter manufacturer’s written instructions.

B. Provide data acquisition wiring. See Section 23 0923 “Direct Digital Control (DDC) System for HVAC”

3.8 SAFETY VALVE INSTALLATION


B. Pipe safety-valve discharge without valves to atmosphere outside the building.

C. Install drip-pan elbow fitting adjacent to safety valve and pipe drain connection to nearest floor drain.

D. Install exhaust head with drain to waste, on vents equal to or larger than NPS 2-1/2.

3.9 TERMINAL EQUIPMENT CONNECTIONS

A. Install traps and control valves in accessible locations close to connected equipment.

B. Install bypass piping with globe valve around control valve. If parallel control valves are installed, only one bypass is required.

C. Install vacuum breakers downstream from control valve, close to coil inlet connection.

END OF SECTION 23 2216
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SECTION 23 2223 - STEAM CONDENSATE PUMPS

PART 1 - GENERAL

1.1 SUMMARY

A. Section includes steam condensate pumps.

1.2 ACTION SUBMITTALS

A. Product Data: For each type of product. Include certified performance curves and rated capacities, operating characteristics, furnished specialties, and accessories for each type of product indicated. Indicate pump's operating point on curves. Include receiver capacity and material.

B. Shop Drawings: For each pump.
   1. Show pump layout and connections.
   2. Include setting drawings with templates for installing foundation and anchor bolts and other anchorages.
   3. Include diagrams for power, signal, and control wiring.

1.3 CLOSEOUT SUBMITTALS

A. Operation and maintenance data.

PART 2 - PRODUCTS

DESIGNER NOTE: All Condensate Pumps shall be Duplex at minimum. Triplex may be used if additional redundancy is required.

The preference is to utilize electric driven condensate pumps over steam powered. Steam powered are included in this standard for reference.

2.1 SINGLE-STAGE, CENTRIFUGAL PUMPS WITH FLOOR-MOUNTED RECEIVER

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. **Xylem Inc, Bell and Gossett**
2. **Skidmore Pump.**
3. **Shippensburg Pump.**
4. **MEPCO.**

**B. Description:** Factory-fabricated, packaged, electric-driven pumps; with receiver, pumps, controls, and accessories suitable for operation with steam condensate.

1. **Electrical Components, Devices, and Accessories:** Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
2. **ASME Compliance:** Fabricate and label steam condensate receivers to comply with ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.

**C. Configuration:** Duplex floor-mounted pump with receiver and float switches; rated to pump 200 deg F steam condensate.

**D. Receiver:**

1. Floor mounted.
2. Close-grained cast iron.
3. Externally adjustable float switches.
4. Flanges for pump mounting.
5. Water-level gage and dial thermometer.
6. Pressure gage at pump discharge.
7. Bronze fitting isolation valve between pump and receiver.
8. Lifting eyebolts.
9. Inlet vent and an overflow.

**E. Pumps:**

1. Centrifugal, close coupled, vertical design.
2. Permanently aligned.
3. Bronze fitted.
4. Replaceable bronze case ring.
5. Mechanical seals rated at 250 deg F.
6. Mounted on receiver flange.

**F. Motor:**

1. Comply with NEMA designation, temperature rating, service factor, and efficiency requirements.
2. Enclosure: Open, dripproof Totally enclosed, fan cooled.
3. Comply with NEMA designation, temperature rating, service factor, and efficiency requirements for motors specified in Section 23 0513 "Common Motor Requirements for HVAC Equipment."
4. Enclosure: [Open, dripproof] [Totally enclosed, fan cooled] [Totally enclosed, air over] [Open, externally ventilated] [Totally enclosed, nonventilated] [Severe duty] [Explosion proof] [Dust-ignition-proof machine].
5. Enclosure Materials: [Cast iron] [Cast aluminum] [Rolled steel].
7. Unusual Service Conditions:
a. Ambient Temperature: <Insert deg C>.
b. Altitude: <Insert feet> above sea level.
c. High humidity.
d. <Insert conditions>.

9. NEMA Design: <Insert designation>.
10. Service Factor: <Insert value>.

G. Control Panel:

1. Factory wired between pumps and float switches, for single external electrical connection.
2. Provide fused, control-power transformer if voltage exceeds 230 V ac.
3. NEMA 250, Type 2 enclosure with hinged door and grounding lug, mounted on unit.
4. NEMA 250, [Type 1] [Type 3] [Type 12] <Insert type> enclosure with hinged door and grounding lug, mounted on pump.
5. Motor controller for each pump.
6. Electrical pump alternator to operate pumps in lead-lag sequence and allow both pumps to operate on receiver high level.
7. Manual lead-lag control to override electrical pump alternator and manually select the lead pump.
8. Momentary-contact "TEST" push button on cover for each pump.
10. Disconnect switch.

H. Capacities and Characteristics:

1. Unit Total Capacity: <Insert sq. ft. EDR>.
2. Capacity, Each Pump:
   b. Discharge Head: <Insert psig>.
   c. Discharge Size: <Insert NPS>.
   d. Speed: <Insert rpm>.
   e. Motor Horsepower: <Insert value>.
3. Receiver:
   b. Inlet Size: <Insert NPS>.
   c. Height to Inlet: <Insert inches>.
4. Electrical Characteristics:
   a. Volts: [120] [230] [240] <Insert value>.
   b. Phase: Single.
   c. Hertz: 60.
   d. Full-Load Amperes: <Insert value>.
   e. Minimum Circuit Ampacity: <Insert value>.
   f. Maximum Overcurrent Protection: <Insert amperage>.
2.2 REGENERATIVE TURBINE PUMPS WITH FLOOR-MOUNTED RECEIVER

2.3 TWO-STAGE, CENTRIFUGAL PUMPS WITH FLOOR-MOUNTED RECEIVER

2.4 SINGLE-STAGE, CENTRIFUGAL PUMPS WITH ELEVATED RECEIVER

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

      1. Xylem Inc, Bell and Gossett.
      2. Skidmore Pump.

   B. Description: Factory-fabricated, packaged, electric-driven pumps; with receiver, pumps, controls, and accessories suitable for operation with steam condensate.

      1. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
      2. ASME Compliance: Fabricate and label steam condensate receivers to comply with ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.

   C. Configuration: Duplex floor-mounted pump with elevated receiver, float switches, and connecting piping; rated to pump 212 deg F steam condensate.

   D. Receiver:

      1. Mounted on fabricated-steel supports.
      2. Welded steel.
      3. [Close-grained cast iron] [Welded steel].
      4. Externally adjustable float switches.
      5. Water-level gage and dial thermometer.
      6. Pressure gage at pump discharge.
      7. Bronze isolation valves between receiver and pumps.
      8. Lifting eyebolts.
      9. Inlet cascade baffle and convex heads.
     10. Cast-iron inlet strainer with self-cleaning bronze screen, dirt pocket, and cleanout plug on receiver inlet.

   E. Pumps:

      1. Centrifugal, close coupled.
      2. Permanently aligned.
      3. Bronze fitted with enclosed bronze impellers.
      4. Replaceable bronze case rings.
      5. Stainless-steel shafts.
      6. Mechanical seals rated at 250 deg F.
      7. Mounted on base below receiver.
      8. Rated to operate with a minimum of 2 feet of NPSH.
F. Motor:
   1. Comply with NEMA designation, temperature rating, service factor, and efficiency requirements.
   2. Enclosure: Open, dripproof Totally enclosed, fan cooled.
   3. Comply with NEMA designation, temperature rating, service factor, and efficiency requirements for motors specified in Section 23 0513 "Common Motor Requirements for HVAC Equipment."
   4. Enclosure: [Open, dripproof] [Totally enclosed, fan cooled] [Totally enclosed, air over]
        [Open, externally ventilated] [Totally enclosed, nonventilated] [Severe duty] [Explosion proof] [Dust-ignition-proof machine].
   5. Motor enclosure Materials: [Cast iron] [Cast aluminum] [Rolled steel].
   7. Unusual Service Conditions:
      a. Ambient Temperature: <Insert deg C>.
      b. Altitude: <Insert feet> above sea level.
      c. High humidity.
      d. <Insert conditions>.
   9. NEMA Design: <Insert designation>.
   10. Service Factor: <Insert value>.

G. Pipe: ASTM A 53/A 53M, Type S, Grade B or ASTM A 106/A 106M; Schedule 80; seamless steel.

H. Fittings NPS 2 and Smaller: ASME B16.1, Class 125 cast iron, threaded.

I. Fittings NPS 2-1/2 and Larger: ASTM A 234/A 234M, steel, for welded connections.

J. Control Panel:
   1. Factory wired between pumps and float switches, for single external electrical connection.
   2. Provide fused, control-power transformer if voltage exceeds 230 V ac.
   3. NEMA 250, Type 2 enclosure with hinged door and grounding lug, mounted on pump.
   4. NEMA 250, [Type 1] [Type 3] [Type 12] <Insert type> enclosure with hinged door and grounding lug, mounted on pump.
   5. Motor controller for each pump.
   6. Electrical pump alternator to operate pumps in lead-lag sequence and allow both pumps to operate on receiver high level.
   7. Manual lead-lag control to override electrical pump alternator and manually select the lead pump.
   8. Momentary-contact "TEST" push button on cover for each pump.
   10. Disconnect switch.

K. Capacities and Characteristics:
   1. Unit Total Capacity: <Insert sq. ft. EDR>.
   2. Capacity, Each Pump:
b. Discharge Head: <Insert psig>.
c. Discharge Size: <Insert NPS>.
d. Speed: <Insert rpm>.
e. Motor Horsepower: <Insert value>.

3. Receiver:
   b. Inlet Size: <Insert NPS>.
   c. Height to Inlet: <Insert inches>.

4. Electrical Characteristics:
   a. Volts: [120] [208] [230] [240] [480] <Insert value>.
   b. Phase: [Single] [Three].
   c. Hertz: 60.
   d. Full-Load Amperes: <Insert value>.
   e. Minimum Circuit Ampacity: <Insert value>.
   f. Maximum Overcurrent Protection: <Insert amperage>.

2.5 VERTICAL, WET-PIT-MOUNTED DUPLEX PUMPS

2.6 PRESSURE-POWERED PUMPING TRAPS

A. Manufacturers: Subject to compliance with requirements, provide products by the following:
   1. Armstrong International, Inc., PT Series
   2. Bell and Gossett, Domestic Pump, Series PCC

B. Description: Factory-fabricated, pressure-powered pumps with mechanical controls, valves, piping connections, and accessories suitable for pumping steam condensate using low pressure steam.

   1. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
   2. ASME Compliance: Fabricate and label steam condensate receivers to comply with ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.

C. Configuration: Simplex pump with float-operated valve control.

D. Configuration: [Simplex] [Duplex] pump with float-operated valve control.

   1. Pump Body: Cast iron or welded steel, ASME rated to 125 psig.
   2. Piping Connections: Threaded; for steam condensate, operating medium, vent, and indicated accessories.
   3. Level Gage: Armored glass site gage with shutoff cocks.
   4. Valves: Manufacturer's standard check valves on inlet and outlet.
   5. Internal Parts: Stainless-steel float, springs, and actuating mechanism.

E. Capacities and Characteristics:
1. Unit Total Capacity: <Insert sq. ft. EDR>.
2. Capacity, Each Pump:
   b. Discharge Head: <Insert psig>.
   c. Discharge Size: <Insert NPS>.
3. Operating Steam Pressure: <Insert psig>.
4. Steam Consumption Rate: <Insert lb/1000 lb> of steam condensate.
5. Operating Compressed-Air Pressure: <Insert psig>.
6. Compressed-Air Consumption Rate: <Insert cu. ft./1000 lb> of steam condensate.
7. Receiver:
   b. Inlet Size: <Insert NPS>.
   c. Height to Inlet: <Insert inches>.

2.7 PRESSURE-POWERED PUMP TRAP PACKAGES WITH RECEIVER

A. Manufacturers: Subject to compliance with requirements, provide products by the following:
   2. Bell and Gossett, Domestic Pump, Series PCC

B. Description: Factory-fabricated, pressure-powered pumps with mechanical controls, valves, piping connections, and accessories suitable for pumping steam condensate using low pressure steam.

   1. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
   2. ASME Compliance: Fabricate and label steam condensate receivers to comply with ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.

C. Configuration: Duplex pumping trap package with two traps, each with a float-operated switch.

D. Configuration: [Simplex] [Duplex] pump with float-operated valve control.

   1. Pump Body: Cast iron or welded steel, ASME rated to 125 psig.
   2. Piping Connections: Threaded; for steam condensate, operating medium, vent, and indicated accessories.
   3. Level Gage: Armored glass site gage with shutoff cocks.
   4. Valves: Manufacturer's standard check valves on inlet and outlet.
   5. Internal Parts: Stainless-steel float, springs, and actuating mechanism.

E. Receiver:

   1. Factory mounted on steel supports.
   2. Cast iron or welded steel.
   3. Threaded piping connections.
   4. Armored water-level gage and dial thermometer.
   5. Pressure gage at pump discharge.
6. Bronze fitting isolation valve between pump and receiver.
7. Lifting eyebolts.
8. Inlet vent and an overflow.
9. Cast-iron inlet strainer with vertical self-cleaning bronze screen, large dirt pocket, and cleanout on receiver inlet.

F. Pipe: ASTM A 53/A 53M, Type S, Grade B or ASTM A 106/A 106M; Schedule 80; seamless steel.

G. Fittings: ASME B16.1, Class 125 cast iron, threaded.

H. Capacities and Characteristics:

1. Unit Total Capacity: <Insert sq. ft. EDR>.
2. Capacity, Each Pump:
   b. Discharge Head: <Insert psig>.
   c. Discharge Size: <Insert NPS>.
3. Operating Steam Pressure: <Insert psig>.
4. Steam Consumption Rate: <Insert lb/1000 lb> of steam condensate.
5. Operating Compressed-Air Pressure: <Insert psig>.
6. Compressed-Air Consumption Rate: <Insert cu. ft./1000 lb> of steam condensate.
7. Receiver:
   b. Inlet Size: <Insert NPS>.
   c. Height to Inlet: <Insert inches>.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine equipment foundations and anchor-bolt locations for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.

B. Examine roughing-in for piping systems to verify actual locations of piping connections before pump installation.

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

3.2 INSTALLATION

A. Install centrifugal pumps according to HI 1.1-1.2, HI 1.3, and HI 1.4.

B. Install pumps to provide access for periodic maintenance.

C. Install pumps to provide access for periodic maintenance including removing motors, impellers, couplings, and accessories.
D. Support pumps and piping separately so piping is not supported by pumps.

E. Install thermometers and pressure gages.

F. Equipment Mounting:
   1. Install pumps on floor or where indicated, on cast-in-place concrete equipment base(s).
   2. Install pumps on cast-in-place concrete equipment base(s). Comply with requirements for equipment bases and foundations specified in [Section 03 3000 "Cast-in-Place Concrete.”] [Section 03 3053 "Miscellaneous Cast-in-Place Concrete.”]
   3. Comply with requirements for vibration isolation and seismic control devices specified in Section 23 0548 "Vibration and Seismic Controls for HVAC."
   4. Comply with requirements for vibration isolation devices specified in Section 23 0548.13 "Vibration Controls for HVAC.”

3.3 CONNECTIONS

A. Comply with requirements for piping specified in Section 23 2213 "Steam and Condensate Heating Piping" and Section 23 2216 "Steam and Condensate Piping Specialties."

B. Where installing piping adjacent to machine, allow space for service and maintenance.

C. Install compressed-air supply for pressure-powered pumps as required in Section 22 1513 "General-Service Compressed-Air Piping."

D. Install a globe and check valve and pressure gage before inlet of each pump and a gate and check valve at pump outlet.

E. Pipe drain to nearest floor drain for overflow and drain piping connections.

F. Install full-size vent piping to outdoors, terminating in 180-degree elbow at point above highest steam system connection or as indicated.

G. Ground equipment.

H. Connect wiring.

3.4 STARTUP SERVICE

A. Perform startup service.

   1. Complete installation and startup checks according to manufacturer's written instructions.
   2. Clean strainers.
   3. Set steam condensate pump controls.
   4. Set pump controls for automatic start, stop, and alarm operation.
   5. Perform the following preventive maintenance operations and checks before starting:

      a. Set float switches to operate at proper levels.
      b. Set throttling valves on pump discharge for specified flow.
c. Check motors for proper rotation.
d. Test pump controls and demonstrate compliance with requirements.
e. Replace damaged or malfunctioning pump controls and equipment.
f. Verify that pump controls are correct for required application.

6. Start steam condensate pumps according to manufacturer's written startup instructions.

3.5 DEMONSTRATION

A. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain steam condensate pumps.

END OF SECTION 23 2223
WMU Design Guidelines

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SECTION 23 2300 - REFRIGERANT PIPING

PART 1 - GENERAL

1.1 SUMMARY

A. This Section includes refrigerant piping used for air-conditioning applications.

B. Related Sections include the following:

1. Division 23 Sections for smaller equipment furnished with refrigerant line sets.

1.2 PERFORMANCE REQUIREMENTS

1.3 ACTION SUBMITTALS

A. Product Data: For each type of valve and refrigerant piping specialty indicated. Include pressure drop, based on manufacturer's test data, for the following:

1. Thermostatic expansion valves.
2. Solenoid valves.
3. Hot-gas bypass valves.
4. Filter dryers.
5. Strainers.
6. Pressure-regulating valves.

B. Shop Drawings: 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. Show interface and spatial relationships between piping and equipment.

1. Shop Drawing Scale: 1/4 inch equals 1 foot.
2. Refrigerant piping indicated on Drawings is schematic only. Size piping and design actual 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.
1.4 INFORMATIONAL SUBMITTALS
   A. Welding certificates.
   B. Field quality-control test reports.

1.5 CLOSEOUT SUBMITTALS
   A. Operation and maintenance data.

1.6 QUALITY ASSURANCE
   A. Welding: Qualify procedures and personnel according to ASME Boiler and Pressure Vessel Code: Section IX, "Welding and Brazing Qualifications."
   C. Comply with ASME B31.5, "Refrigeration Piping and Heat Transfer Components."

1.7 PRODUCT STORAGE AND HANDLING
   A. Store piping in a clean and protected area with end caps in place to ensure that piping interior and exterior are clean when installed.

1.8 COORDINATION
   A. Coordinate size and location of roof curbs, equipment supports, and roof or wall penetrations.
   B. Coordinate size and location of wall penetrations.
   C. Coordinate size and location of equipment supports, and wall penetrations.

PART 2 - PRODUCTS

2.1 COPPER TUBE AND FITTINGS
   A. Copper Tube: ASTM B 88, Type K or L or ASTM B 280, Type ACR.
   B. Wrought-Copper Fittings: ASME B16.22.
   C. Wrought-Copper Unions: ASME B16.22.
   D. Solder Filler Metals: ASTM B 32. Use 95-5 tin antimony or alloy HB solder to join copper socket fittings on copper pipe.
   E. Brazing Filler Metals: AWS A5.8.
F. Flexible Connectors:

2. End Connections: Socket ends.
3. Offset Performance: Capable of minimum 3/4-inch misalignment in minimum 7-inch-long assembly.
5. Maximum Operating Temperature: 250 deg F.

2.2 STEEL PIPE AND FITTINGS

A. Steel Pipe: ASTM A 53/A 53M, black steel with plain ends; Type, Grade, and wall thickness as selected in Part 3 piping applications articles.

B. Wrought-Steel Fittings: ASTM A 234/A 234M, for welded joints.

C. Steel Flanges and Flanged Fittings: ASME B16.5, steel, including bolts, nuts, and gaskets, bevel-welded end connection, and raised face.


E. Flanged Unions:

1. Body: Forged-steel flanges for NPS 1 to NPS 1-1/2 and ductile iron for NPS 2 to NPS 3. Apply rust-resistant finish at factory.
2. Gasket: Fiber asbestos free.
3. Fasteners: Four plated-steel bolts, with silicon bronze nuts. Apply rust-resistant finish at factory.
4. End Connections: Brass tailpiece adapters for solder-end connections to copper tubing.
5. Offset Performance: Capable of minimum 3/4-inch misalignment in minimum 7-inch-long assembly.
7. Maximum Operating Temperature: 330 deg F.

F. Flexible Connectors:

2. End Connections:
   a. NPS 2 and Smaller: With threaded-end connections.
   b. NPS 2-1/2 and Larger: With flanged-end connections.
3. Offset Performance: Capable of minimum 3/4-inch misalignment in minimum 7-inch-long assembly.
5. Maximum Operating Temperature: 250 deg F.
2.3 VALVES AND SPECIALTIES

A. Provide the following as required for proper system design and operation:

1. Shut-off and service valves.
2. Check valves.
3. Thermostatic expansion valves.
5. Strainers.
6. Moisture/Liquid Indicators.
7. Replaceable-Core Filter Dryers.

2.4 REFRIGERANTS

A. Provide refrigerant type and amount as required by equipment.

PART 3 - EXECUTION

3.1 PIPING APPLICATIONS

A. Suction, Hot-Gas, and Liquid Lines: Copper, Type ACR or Type L, tubing and wrought-copper fittings with brazed or soldered joints.

1. Provide drawn-temper copper tubing for NPS 1 and larger.
2. Provide drawn or annealed temper copper tubing for smaller than NPS 1.

B. Safety-Relief-Valve Discharge Piping: Schedule 40, black-steel and wrought-steel fittings with welded joints.

3.2 PIPING INSTALLATION

A. Drawing plans, schematics, and diagrams indicate general location and arrangement of piping systems. Install piping as indicated unless deviations to layout are approved on Shop Drawings.

B. Install refrigerant piping according to ASHRAE 15.

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

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

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

F. Install piping adjacent to machines to allow service and maintenance.
G. Install piping free of sags and bends.

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

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

J. Refer to Division 23 Sections "Instrumentation and Control for HVAC" and "Sequence of Operation" for solenoid valve controllers, control wiring, and sequence of operation.

K. Install piping as short and direct as possible, with a minimum number of joints, elbows, and fittings.

L. Arrange piping to allow inspection and service of refrigeration equipment. Install valves and specialties in accessible locations to allow for service and inspection. Install access doors or panels as specified in Division 08 Section "Access Doors and Frames" if valves or equipment requiring maintenance is concealed behind finished surfaces.

M. Install refrigerant piping in protective conduit where installed belowground.

N. Install refrigerant piping in rigid or flexible conduit in locations where exposed to mechanical injury.

O. When brazing or soldering, remove solenoid-valve coils and sight glasses; also remove valve stems, seats, and packing, and accessible internal parts of refrigerant specialties. Do not apply heat near expansion-valve bulb.

P. Install pipe sleeves at penetrations in exterior walls and floor assemblies.

Q. Seal penetrations through fire and smoke barriers according to Division 07 Section "Penetration Firestopping."

R. Install piping with adequate clearance between pipe and adjacent walls and hangers or between pipes for insulation installation.

S. Install sleeves through floors, walls, or ceilings, sized to permit installation of full-thickness insulation.

T. Seal pipe penetrations through exterior walls according to Division 07 Section "Joint Sealants" for materials and methods.

U. Identify refrigerant piping and valves according to Division 23 Section "Identification for HVAC Piping and Equipment."

3.3 PIPE 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. Fill steel pipe and fittings with an inert gas (nitrogen or carbon dioxide), during brazing or welding, to prevent scale formation.

D. Soldered Joints: Construct joints according to ASTM B 828 or CDA’s “Copper Tube Handbook.”

E. Brazed Joints: Construct joints according to AWS’s “Brazing Handbook,” Chapter “Pipe and Tube.”
   1. Use Type BcuP, copper-phosphorus alloy for joining copper socket fittings with copper pipe.
   2. Use Type BAg, cadmium-free silver alloy for joining copper with bronze or steel.

F. Threaded Joints: Thread steel pipe with tapered pipe threads according to ASME B1.20.1. Cut threads full and clean using sharp dies. Ream threaded pipe ends to remove burrs and restore full ID. Join pipe fittings and valves as follows:
   1. Apply appropriate tape or thread compound to external pipe threads unless dry-seal threading is specified.
   2. Damaged Threads: Do not use pipe or pipe fittings with threads that are corroded or damaged. Do not use pipe sections that have cracked or open welds.

G. Steel pipe can be threaded, but threaded joints must be seal brazed or seal welded.

H. Welded Joints: Construct joints according to AWS D10.12/D10.12M.

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

3.4 HANGERS AND SUPPORTS

A. Hanger, support, and anchor products are specified in Division 23 Section "Hangers and Supports for HVAC Piping and Equipment."

B. Install the following pipe attachments:
   1. Adjustable steel clevis hangers for individual horizontal runs less than 20 feet long.
   2. Roller hangers and spring hangers for individual horizontal runs 20 feet or longer.
   3. Pipe Roller: MSS SP-58, Type 44 for multiple horizontal piping 20 feet or longer, supported on a trapeze.
   4. Spring hangers to support vertical runs.
   5. Copper-clad hangers and supports for hangers and supports in direct contact with copper pipe.

C. Install hangers for copper tubing with the following maximum spacing and minimum rod sizes:
   1. NPS 1/2: Maximum span, 60 inches; minimum rod size, 1/4 inch.
   2. NPS 5/8: Maximum span, 60 inches; minimum rod size, 1/4 inch.
   3. NPS 1: Maximum span, 72 inches; minimum rod size, 1/4 inch.
   4. NPS 1-1/4: Maximum span, 96 inches; minimum rod size, 3/8 inch.
   5. NPS 1-1/2: Maximum span, 96 inches; minimum rod size, 3/8 inch.
   6. NPS 2: Maximum span, 96 inches; minimum rod size, 3/8 inch.
7. NPS 2-1/2: Maximum span, 108 inches; minimum rod size, 3/8 inch.
8. NPS 3: Maximum span, 10 feet; minimum rod size, 3/8 inch.
9. NPS 4: Maximum span, 12 feet; minimum rod size, 1/2 inch.

D. Install hangers for steel piping with maximum spacing and minimum rod in accordance Michigan Mechanical Code or MSS SP-69.

E. Install hangers for steel piping with the following maximum spacing and minimum rod sizes:
   1. NPS 2: Maximum span, 10 feet; minimum rod size, 3/8 inch.
   2. NPS 2-1/2: Maximum span, 11 feet; minimum rod size, 3/8 inch.
   3. NPS 3: Maximum span, 12 feet; minimum rod size, 3/8 inch.
   4. NPS 4: Maximum span, 14 feet; minimum rod size, 1/2 inch.

F. Support multifloor vertical runs at least at each floor.

3.5 FIELD QUALITY CONTROL

A. Perform tests and inspections and prepare test reports.

B. Tests and Inspections:
   1. Comply with ASME B31.5, Chapter VI.
   2. Test refrigerant piping, specialties, and receivers. Isolate compressor, condenser, evaporator, and safety devices from test pressure if they are not rated above the test pressure.
   3. Test high- and low-pressure side piping of each system separately.
      a. Fill system with nitrogen to the required test pressure.
      b. System shall maintain test pressure at the manifold gage throughout duration of test.
      c. Test joints and fittings with electronic leak detector or by brushing a small amount of soap and glycerin solution over joints.
      d. Remake leaking joints using new materials, and retest until satisfactory results are achieved.

3.6 SYSTEM CHARGING

A. Charge system using the following procedures:
   1. Install core in filter dryers after leak test but before evacuation.
   2. Evacuate entire refrigerant system with a vacuum pump to 500 micrometers. If vacuum holds for 12 hours, system is ready for charging.
   3. Break vacuum with refrigerant gas, allowing pressure to build up to 2 psig.
   4. Charge system with a new filter-dryer core in charging line.
3.7 ADJUSTING

A. Adjust thermostatic expansion valve to obtain proper evaporator superheat.

B. Adjust high- and low-pressure switch settings to avoid short cycling in response to fluctuating suction pressure.

C. Adjust set-point temperature of air-conditioning controllers to the system design temperature.

D. Perform the following adjustments before operating the refrigeration system, according to manufacturer's written instructions:
   1. Open shutoff valves in condenser water circuit.
   2. Verify that compressor oil level is correct.
   3. Open compressor suction and discharge valves.
   4. Open refrigerant valves except bypass valves that are used for other purposes.
   5. Check open compressor-motor alignment and verify lubrication for motors and bearings.

E. Replace core of replaceable filter dryer after system has been adjusted and after design flow rates and pressures are established.
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SECTION 23 2500 - HVAC WATER TREATMENT

PART 1 - GENERAL

1.1 SUMMARY

A. This Section includes HVAC water-treatment for the following systems:

1. Heating hot-water.
2. Chilled water.
3. Steam Boiler Feedwater.
4. Heat recovery water.
5. Condenser water (Open cooling tower).
   a. Evaporative cooler water (Closed cooling tower).
   b. Heat pump water.
6. Glycol Make-up Unit

1.2 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.

1.3 ACTION SUBMITTALS

A. Product Data: Include rated capacities, operating characteristics, furnished specialties, and accessories for the following products:

1. Bypass feeders.
2. Water meters.
3. Automatic chemical-feed equipment components.
4. Cartridge-type filters.
5. Glycol.
6. Glycol make-up unit.
B. Shop Drawings: Pretreatment and chemical treatment equipment showing tanks, maintenance space required, and piping connections to HVAC systems. Include plans, elevations, sections, details, and attachments to other work.


1.4 INFORMATIONAL SUBMITTALS

A. Field quality-control test reports.

B. Other Informational Submittals:

1. Water-Treatment Program: Written sequence of operation on an annual basis for the application equipment required to achieve water quality.

1.5 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For sensors, injection pumps, and controllers.

1.6 QUALITY ASSURANCE

A. HVAC Water-Treatment Service Provider Qualifications: An experienced HVAC water-treatment service provider capable of analyzing water qualities, installing water-treatment equipment, and applying water treatment as specified in this Section.

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.

1.7 MAINTENANCE SERVICE

A. Scope of Maintenance Service: Provide chemicals and service program to maintain water conditions required to inhibit corrosion, scale formation, and biological growth for piping and equipment. Services and chemicals shall be provided for a period of one year from date of Substantial Completion, and shall include the following:

1. Initial water analysis and HVAC water-treatment recommendations.
2. Startup assistance for Contractor to flush the systems, clean with detergents, and initially fill systems with required chemical treatment prior to operation.
3. Periodic field service and consultation.
5. Laboratory technical analysis.
6. Analyses and reports of all chemical items concerning safety and compliance with government regulations.
PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. Subject to compliance with requirements, HVAC water-treatment service provider shall be the following:

1. Enerco Corporation.

B. Available Service Providers: Subject to compliance with requirements, HVAC water-treatment service provider offering products and services that may be incorporated into the Work include, but are not limited to, the following:

1. Enerco Corporation.

2.2 MANUAL CHEMICAL-FEED EQUIPMENT

A. Bypass Feeders: Steel, with corrosion-resistant exterior coating, minimum 3-1/2-inch fill opening in the top, and NPS 3/4 bottom inlet and top side outlet. Quarter turn or threaded fill cap with gasket seal and diaphragm to lock the top on the feeder when exposed to system pressure in the vessel.

2. Capacity: 5 gal.
3. Capacity: 12 gal.
4. Capacity: [2 gal.][5 gal.][12 gal.].
6. Minimum Working Pressure: [125 psig][175 psig].

2.3 AUTOMATIC CHEMICAL-FEED EQUIPMENT FOR CONDENSER WATER SYSTEMS

A. Provide automatic chemical-feed system for condenser water systems including the following:

1. Water meter with the following:
   a. Registration in Gallons
   b. Controls.
2. Inhibitor injection timers with the following:
   a. Microprocessor-based controller with LCD display.
   b. Programmable timers with hand-off-auto switches and status lights.
   c. Test switch.
   d. Hand-off-auto switch for chemical pump.
   e. Illuminated legend to indicate feed when pump is activated.
   f. Programmable lockout timer with indicator light.
   g. LCD makeup totalizer.
3. **pH Controller with the following:**
   a. Microprocessor-based controller with digital LCD display.
   b. Digital display and touch pad for input.
   c. Sensor probe.
   d. High, low, and normal pH indication.
   e. High or low pH alarm light, trip points field adjustable; with silence switch.
   f. Hand-off-auto switch for acid pump.
   g. Internal adjustable hysteresis or deadband.

4. **TDS Controller with the following:**
   a. Microprocessor-based controller with digital LCD display.
   b. Digital display and touch pad for input.
   c. Sensor probe.
   d. High, low, and normal conductance indication.
   e. High or low conductance alarm light, trip points field adjustable; with silence switch.
   g. Bleed-off valve activated indication.
   h. Internal adjustable hysteresis or deadband.
   i. Bleed valves with forged-brass body, globe pattern, general-purpose solenoid with continuous-duty coil, or motorized valve.

5. **Biocide feeder timer with the following:**
   a. Microprocessor-based controller with digital LCD display.
   b. 24-hour timer with 14-day skip feature to permit activation any hour of day.
   c. Precision, solid-state, bleed-off lockout timer and clock-controlled biocide pump timer with lockout timers for prebleed and bleed.
   d. Solid-state alternator to enable use of two different formulations.
   e. 24-hour display of time of day.
   f. 14-day display of day of week.
   g. Battery backup so clock is not disturbed by power outages.
   h. Hand-off-auto switches for biocide pumps.
   i. Biocide A and Biocide B pump running indication.

6. **Chemical solution tanks with 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.

7. **Chemical solution injection pumps with the following:**
   a. Self-priming, positive-displacement; rated for intended chemical with minimum 25 percent safety factor for design pressure and temperature.
   b. Adjustable flow rate.
   c. Metal and thermoplastic construction.
   d. Built-in relief valve.
   e. Fully enclosed, continuous-duty, single-phase motor.

8. **Chemical solution tubing as follows:**
9. Injection assembly with the following:
   a. Quill: Minimum NPS 1/2 with insertion length sufficient to discharge into at least 25 percent of pipe diameter.
   b. Ball Valve: Stainless steel, selected to fit quill.
   c. Packing Gland: Mechanical seal on quill of sufficient length to allow quill removal during system operation.
   d. Assembly Pressure/Temperature Rating: Minimum 600 psig at 200 deg F.

2.4 AUTOMATIC CHEMICAL-FEED EQUIPMENT FOR STEAM BOILER AND STEAM CONDENSATE SYSTEMS

A. Provide automatic chemical-feed system for steam boiler and steam condensate systems including the following:

1. Water meter with the following:
   a. Registration in Gallons
   b. Controls.

2. Inhibitor injection timers with the following:
   a. Microprocessor-based controller with LCD display.
   b. Programmable timers with hand-off-auto switches and status lights.
   c. Test switch.
   d. Hand-off-auto switch for chemical pump.
   e. Illuminated legend to indicate feed when pump is activated.
   f. Programmable lockout timer with indicator light.
   g. LCD makeup totalizer.

3. pH Controller with the following:
   a. Microprocessor-based controller with digital LCD display.
   b. Digital display and touch pad for input.
   c. Sensor probe to sample stream manifold.
   d. High, low, and normal pH indication.
   e. High or low pH alarm light, trip points field adjustable; with silence switch.
   f. Hand-off-auto switch for acid pump.
   g. Internal adjustable hysteresis or deadband.

4. TDS Controller with the following:
   a. Microprocessor-based controller with digital LCD display.
   b. Digital display and touch pad for input.
   c. Sensor probe to sample stream manifold.
   d. High, low, and normal conductance indication.
   e. High or low conductance alarm light, trip points field adjustable; with silence switch.
g. Bleed-off valve activated indication.
h. Internal adjustable hysteresis or deadband.
i. Motorized bleeder ball valves with steel body, and TFE seats and seals.

5. Chemical solution tanks with 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.

6. Chemical solution injection pumps with the following:
   a. Self-priming, positive-displacement; rated for intended chemical with minimum 25 percent safety factor for design pressure and temperature.
   b. Adjustable flow rate.
   c. Metal and thermoplastic construction.
   d. Built-in relief valve.
   e. Fully enclosed, continuous-duty, single-phase motor.

7. Chemical solution tubing as follows:
   a. ASTM A 269, Type 304, stainless steel for steam boiler injection assemblies.

8. Injection assembly with the following:
   a. Quill: Minimum NPS 1/2 with insertion length sufficient to discharge into at least 25 percent of pipe diameter.
   b. Ball Valve: Stainless steel, selected to fit quill.
   c. Packing Gland: Mechanical seal on quill of sufficient length to allow quill removal during system operation.
   d. Assembly Pressure/Temperature Rating: Minimum 600 psig at 200 deg F.

2.5 CHEMICAL TREATMENT TEST EQUIPMENT

A. Test Kit: Manufacturer-recommended equipment and chemicals in a wall-mounting cabinet for testing solutions to maintain performance requirements for each required characteristic.

B. Sample Cooler:

1. Tube: Sample.
   a. Size: NPS 1/4 tubing.
   b. Material: ASTM A 666, Type 316 stainless steel.
   d. Temperature Rating: Minimum 850 deg F.

2. Shell: Cooling water.
   a. Material: ASTM A 666, Type 304 stainless steel.
   c. Temperature Rating: Minimum 450 deg F.
C. Corrosion Test-Coupon Assembly: Constructed of corrosive-resistant material, complete with piping, valves, and mild steel and copper coupons. Locate copper coupon downstream from mild steel coupon in the test-coupon assembly.

2.6 CHEMICALS

A. Chemicals shall be as recommended by water-treatment system manufacturer that are compatible with piping system components and connected equipment, and that can attain water quality requirements.

2.7 FILTRATION EQUIPMENT

A. Cartridge-Type Filters:

1. Description: Type 304 stainless steel housing with minimum 150 psig pressure rating and 275 degree F temperature rating. For 2 inch inlet and outlet connection units, include support legs, fail-safe removable cover, cover gasket, and drain outlet. For 1 inch inlet and outlet connection units, include support bracket, fail-safe removable cover, cover gasket, and drain outlet. Filter media and support to be 100% stainless steel. Filter media to be cleanable stainless steel cartridges rated at 40 microns. Provide two complete sets of stainless steel filter cartridges.

   a. Include cotton filters for system startup, one set of 150 micron and one set of 75 micron.

2. Description: Type 304 stainless steel housing with 150 psig pressure rating and 300 degree F temperature rating. Unit to include support legs, 2 inch inlet and outlet connections, fail-safe removable cover, cover gasket, and drain outlet. Filter capacity to be minimum [60 gpm at 5 psig maximum pressure drop]. Filter media and support to be 100% stainless steel. Filter media to be cleanable stainless steel cartridges rated at [40] [20] microns. Provide two complete sets of filter cartridges. Unit supplier must have a program in place to provide complete cleaning of cartridges at reasonable cost and turnaround time.

3. Unit pump to be close coupled type with Type 304 stainless steel casing, impeller, and diffuser. Shaft to be type 416 stainless steel with Buna/Ceramic mechanical seals. Pump motor to be [1-1/2 hp, 115/230 single phase motor]. Pump delivery to be [30 gpm at 30 psig pressure drop up to 60 gpm at 10 psig pressure drop].

4. Filter housing and pump to be mounted on structural steel frame. Include piping between pump and filter housing.

2.8 CONDENSER WATER SIDE-STREAM FILTER SYSTEM

A. Basis-of-Design Product: Subject to compliance with requirements, provide the product indicated on Drawings or an equivalent product.

B. Description: Factory-fabricated and -tested, condenser water side-stream filter system complete with filter tank, media, circulating pump, piping, and controls, all mounted on steel skid, for removing particles from water.
1. Filter Tank: Type 316 Stainless steel.
2. Filter: Type 316 Stainless steel.
3. Filter Range: 100 microns.
6. Controls: Automatic control of circulating pump and filter tank backwash; factory wired for single electrical connection.
7. Support: Skid mounted steel frame.

2.9 GLYCOL

A. Provide pre-mixed solution of clean water and [30%][40%] by weight industrially inhibited propylene glycol-based heat transfer fluid, designed to provide freeze and corrosion protection in water-based closed loop system. Fluid shall contain corrosion inhibitors that are specially formulated for HVAC service to keep pipes free of corrosion without fouling. Fluid shall be easily analyzed for glycol concentration and inhibitor level, and easily reinhibited using inhibitors readily available from fluid manufacturer. Fluid shall pass ASTM D 1384. Dow Chemical Dowfrost or equivalent.

2.10 GLYCOL MAKE-UP UNIT

A. Subject to compliance with requirements, provide products by [one of] the following:
   1. Bell & Gossett;
   2. Wessels
   3. <Insert Manuf. Here>

B. Description: Package shall consist of a base, polyethylene reservoir with removable lid and visible solution level scale in gallons and liters, y-strainer, isolation valve, pump, open drip-proof motor, pump isolation, check and balance valve, expansion tank, discharge pressure gage, motor contactor, pressure control and necessary interconnecting piping.

C. Operation: Pump shall start based on falling pressure.

D. System shall include:
   1. 115/1/60 single power connection.
   2. 3/4" NPT system piping connection
   3. Green light on control panel shall indicate power supplied to unit.
   4. Low level cutout, with red indicator light on control panel and 110V contact for alarm indication, to stop the pump during low level condition

E. [GMU shall provide (10 or 5) GPM and maintain a fill pressure of (30 or 60) PSI.]
PART 3 - EXECUTION

3.1 WATER ANALYSIS

A. Perform an analysis of supply water to determine quality of water available at Project site.

3.2 INSTALLATION - GENERAL

A. Install chemical application equipment [on concrete bases, ]level and plumb. Maintain manufacturer’s recommended clearances. Arrange units so controls and devices that require servicing are accessible. Anchor chemical tanks and floor-mounting accessories to substrate.

B. Install water testing equipment on wall near water chemical application equipment.

C. Provide piping and control connections between components. Coordinate power connections for components with Division 26.

3.3 INSTALLATION OF BYPASS FEEDERS

A. Install bypass feeders in closed hydronic systems, and equipped with the following:

   1. Install bypass feeder in a bypass circuit around circulating pumps, unless otherwise indicated on Drawings.
   2. Install an isolation valves on inlet, outlet, and drain below feeder inlet.
   3. Install a swing check on inlet after the isolation valve.

3.4 INSTALLATION OF STEAM BOILER AND STEAM CONDENSATE CHEMICAL-FEED EQUIPMENT

A. Install automatic chemical-feed equipment for steam boiler and steam condensate systems and include the following:

   1. Mount sensors and injectors in piping circuits.
   2. Install water meter in makeup water supply.
   3. Install interconnecting control wiring for chemical treatment controls and sensors.
   4. Install inhibitor injection pumps and solution tanks with injection timer sensing contacts in water meter.
      a. Pumps shall operate for timed interval when contacts close at water meter in makeup water supply connection. Injection pump shall discharge into boiler feedwater tank or feedwater supply connection at boiler.
   5. Install test equipment and furnish test-kit to Owner.
   6. Install TDS controller with sensor and bleed valves.
      a. Bleed valves shall cycle to maintain maximum TDS concentration.
7. Install inhibitor injection timer with injection pumps and solution tanks.
   a. Pumps shall operate for timed interval on contact closure at water meter in makeup water supply connection. Injection pump shall discharge into main steam supply header.

3.5 INSTALLATION OF CONDENSER WATER CHEMICAL-FEED EQUIPMENT
A. Install automatic chemical-feed equipment for condenser water and include the following:
   1. Provide passivation of new galvanized steel cooling towers 30 days before putting load on tower. Report results in writing.
   2. Install water meter in makeup water supply.
   3. Install interconnecting control wiring for chemical treatment controls and sensors.
   5. Install inhibitor injection pumps and solution tanks with injection timer sensing contacts in water meter.
      a. Pumps shall operate for timed interval on contact closure at water meter in makeup water supply connection.
   6. Install test equipment and provide test-kit to Owner. Install test-coupon assembly in bypass circuit around circulating pumps, unless otherwise indicated on Drawings.
   7. Install TDS controller with sensor and bleed valves.
      a. Bleed valves shall cycle to maintain maximum TDS concentration.
   8. Install pH sensor and controller with injection pumps and solution tanks.
      a. Injector pumps shall operate to maintain required pH.
   9. Install biocide feeder alternating timer with two sets of injection pumps and solution tanks.
      a. Injection pumps shall operate to feed biocide on an alternating basis.

3.6 INSTALLATION OF CARTRIDGE FILTERS
A. Install cartridge filter in hydronic system where indicated. Install throttling valves on each side of filter.
   1. Install 150 micron cotton filter during initial system start-up and use until loaded.
   2. Replace with 75 micron cotton filter and use until loaded.
   3. Replace with 40 micron stainless steel filters after system cleaning.
   4. Install first set of filters during initial system start-up.
   5. Install second set of filters after initial system cleaning and have first set cleaned.
   6. Re-install first set of filters at end of project and have second set cleaned and returned to Owner.
B. Install pressure gage across filter unit to show pressure drop through unit.
C. [Mount wall bracket mounted units] with top of filter at maximum 48 inches above floor.

3.7 INSTALLATION OF CONDENSER WATER SIDE-STREAM FILTERS

A. Install condenser water side-stream filter system in a bypass line diverting 10% of full pump flow through filter system. Provide balancing valve and P-T tapings across separator for balancing. Mount unit on concrete housekeeping pad and anchor.

3.8 INSTALLATION OF GLYCOL MAKE-UP UNIT

A. Install glycol make-up unit (GMU) [on concrete bases,] level and plumb. Maintain manufacturer’s recommended clearances. Arrange units so controls and devices that require servicing are accessible. Anchor to substrate.

B. Contractor shall furnish application specific pressure reducing valve between GMU and connection to the system piping.

3.9 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 equipment to allow service and maintenance.

C. Make piping connections between HVAC water-treatment equipment and dissimilar-metal piping with dielectric fittings. Dielectric fittings are specified in Division 23 Section "Common Work Results for HVAC."

D. Install shutoff valves on HVAC water-treatment equipment inlet and outlet. Metal general-duty valves are specified in Division 23 Section "General-Duty Valves for HVAC Piping."

E. Refer to Division 22 Section "Domestic Water Piping Specialties" for backflow preventers required in makeup water connections to potable-water systems.

F. Confirm applicable electrical requirements in Division 26 Sections for connecting electrical equipment.

G. Ground equipment according to Division 26 Section "Grounding and Bonding for Electrical Systems."

H. Connect wiring according to Division 26 Sections.

3.10 CLEANING AND TREATMENT OF HYDRONIC SYSTEMS

A. General: Isolate all new piping to be cleaned from existing piping and new equipment. Provide shut-off valves and temporary bypasses as required to maintain circulation through new piping.
After cleaning, remove temporary bypasses and open shutoff valves to established circulation through entire system for the water treatment application.

B. Pre-Cleaning: Thoroughly flush all [new piping with fresh water. Determine loop capacity in gallons using electric contact head type bronze constructed water meter. Fill system from completely dry to full, including air bleed out. Submit written report of system capacity in gallons taken from water meter. Drain system completely. Open drip legs and other non-flow piping to remove debris. Remove and clean all strainers.

C. Cleaning of Non-Glycol Systems: Refill system with fresh water along with alkaline detergent cleaner. Feed cleaner through bypass feeder at recommended use rates. Circulate 8 to 72 hours. Flush system. Open, clean, and inspect all strainers, drip legs, and non-flow areas. Refill with fresh water, bleed air from system, and allow system to make-up fresh water and bleed air until water leaving system is of same quality as make-up water.

D. Cleaning of Glycol Systems: Refill system with fresh water along with alkaline detergent cleaner. Feed cleaner through bypass feeder at recommended use rates. Circulate 8 to 72 hours. Flush system. Open, clean, and inspect all strainers, drip legs, and non-flow areas. Immediately refill with glycol as indicated, bleed air from system, and close valve to automatic make-up fresh water line. Introduce corrosion inhibitor through bypass feeder to protect the clean system as required.

E. Treatment of Non-Glycol Systems: Immediately introduce corrosion inhibitor through bypass feeder to protect the clean system.

F. Sectional Cleaning: If entire system is not cleaned and treated at one time, each untreated section shall be isolated from treated sections. Untreated sections to be cleaned and treated as described above before connection to a previously treated section. Provide written report for each individual section.

G. For glycol systems, perform tests determining strength of glycol and water solution and submit written test results.

H. For non-glycol systems, perform tests determining analysis of supply water solution and submit written test results.

3.11 CLEANING OF STEAM SYSTEMS WITH NEW BOILERS

A. Fill Boilers with water to the middle of the glass. Add to the boilers after dissolving in a separate container, soda, ash, and caustic soda at the rate of one pound of each for each 1000 lbs. of water, (120 gallons). Boil for five hours at 5 psi during which time dirt legs and strainers are to be blown down periodically. Empty boilers and flush with a solution to neutralize the caustic soda solution, drain, flush and fill with clean treated water.

B. The system shall not be used, except for chemical cleaning, until the Architect/Engineer has been assured that cleaning has been accomplished.

C. After Cleaning, operate system for five hours at system operating pressure during which time dirt legs and strainers are to be blown down periodically.
D. Sectional Cleaning: If entire system is not cleaned and treated at one time, each untreated section shall be isolated from treated sections. Untreated sections to be cleaned and treated as described above before connection to a previously treated section. Provide written report for each individual section.

3.12 CLEANING OF STEAM SYSTEMS WITH EXISTING BOILERS

A. Flush the system with clean water. Remove, clean, and replace strainer screens.

B. Operate system for five hours at system operating pressure during which time dirt legs and strainers are to be blown down periodically.

C. Sectional Cleaning: If entire system is not cleaned at one time, each uncleaned section shall be isolated from cleaned sections. Uncleaned sections to be cleaned as described above before connection to a previously cleaned section. Provide written report for each individual section.

3.13 FIELD QUALITY CONTROL

A. Manufacturer’s Field Service: Engage a factory-authorized service representative to inspect, test, and adjust components, assemblies, and equipment installations, including connections. Report results in writing.

B. Perform tests and inspections and prepare test reports.

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.

C. 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.

   a. Test equipment (coils, heat exchangers, control valves, strainers, etc.) to verify water flow through equipment is not reduced due to debris caused by flushing and cleaning activities.

3. Place HVAC water-treatment system into operation [and calibrate controls] during the preliminary phase of HVAC systems’ startup procedures.

4. Do not enclose, cover, or put piping into operation until it is tested and satisfactory test results are achieved.

5. Test for leaks and defects. If testing is performed in segments, submit separate report for each test, complete with diagram of portion of piping tested.

6. Leave uncovered and un concealed new, altered, extended, and replaced water piping until it has been tested and approved. Expose work that has been covered or concealed before it has been tested and approved.
7. Cap and subject piping to static water pressure of 50 psig above operating pressure, without exceeding pressure rating of piping system materials. Isolate test source and allow test pressure to stand for four hours. Leaks and loss in test pressure constitute defects.

8. Repair leaks and defects with new materials and retest piping until no leaks exist.

D. Remove and replace malfunctioning components and retest as specified above.

E. Sample boiler water at one-week intervals after boiler startup for a period of five weeks, and prepare test report advising Owner of changes necessary to maintain performance requirements for each required characteristic. Sample boiler water at [four] [six] [eight] -week intervals following the testing noted above to show that automatic chemical-feed systems are maintaining water quality within performance requirements specified in this Section.

F. At [four] [six] [eight] -week intervals following Substantial Completion, perform separate water analyses on hydronic systems to show that automatic chemical-feed systems are maintaining water quality within performance requirements specified in this Section. Submit written reports of water analysis advising Owner of changes necessary to maintain performance requirements for each required characteristic.

3.14 DEMONSTRATION

A. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain HVAC water-treatment systems and equipment. Refer to Division 01 Section "Demonstration and Training."

END OF SECTION 23 2500
WMU Design Guidelines Instructions: These guidelines are to be used by the Design Professional to inform the design process and outline WMU-specific desires for all University projects. These guidelines have been edited to reflect WMU preferences, and the intent is for the Design Professional to use this information to guide their normal specifications-writing process. Straying from what is indicated in the guidelines is not prohibited, but shall be discussed with WMU during the development of the project.

SECTION 23 3113 - METAL DUCTS

PART 1 - GENERAL

1.1 SUMMARY

A. This Section includes metal ducts for air-distribution systems.

B. Related Sections include the following:

1. Division 23 Section "Nonmetal Ducts" for fibrous-glass ducts, thermoset FRP ducts, thermoplastic ducts, PVC ducts, and concrete ducts.
2. Division 23 Section "HVAC Casings" for factory- and field-fabricated casings for mechanical equipment.
3. Division 23 Section "Air Duct Accessories" for dampers, duct-mounting access doors, turning vanes, flexible ducts, and flexible connectors.
4. Division 23 Section "Air Duct Accessories" for dampers, [sound-control devices, ] duct-mounting access doors, turning vanes, [flexible ducts, ] and flexible connectors.

1.2 SYSTEM DESCRIPTION

A. Duct system design, as indicated, has been used to select size and type of air-moving and distribution equipment and other air system components. Changes to layout or configuration of duct system must be specifically approved in writing by Architect/Engineer. Accompany requests for layout modifications with calculations showing that proposed layout will provide original design results without increasing system total pressure.

1.3 ACTION SUBMITTALS

A. Product data for the following items:

2. Duct Liner.
3. Under slab duct system.

B. Duct Leakage Reports: Submit duct leakage test reports. The reports shall be certified proof that the systems have been leak tested, in accordance with this specification section and the referenced standards and are an accurate representation of the system leakage.

C. LEED Submittals:
1. Product Data for Prerequisite IEQ 1: Documentation indicating that duct systems comply with ASHRAE 62.1, Section 5 - "Systems and Equipment."
2. Product Data for Prerequisite EA 2: Documentation indicating that duct systems comply with ASHRAE/IESNA 90.1, Section 6.4.4 - "HVAC System Construction and Insulation."
3. Leakage Test Report for Prerequisite EA 2: Documentation of work performed for compliance with ASHRAE/IESNA 90.1, Section 6.4.4.2.2 - "Duct Leakage Tests."
4. Duct-Cleaning Test Report for Prerequisite IEQ 1: Documentation of work performed for compliance with ASHRAE 62.1, Section 7.2.4 - "Ventilation System Start-up."
5. Product Data for Credit IEQ 4.1: For adhesives and sealants, documentation including printed statement of VOC content.
6. Laboratory Test Reports for Credit IEQ 4: For adhesives and sealants, documentation indicating that products comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."

D. Shop Drawings: [CAD-generated and drawn | Drawn] to [1/4 inch equals 1 foot | 1/8 inch equals 1 foot] <Insert scale> scale. Show fabrication and installation details for metal ducts.
   1. <Insert lists of areas or systems requiring Shop Drawings.>
   2. Fabrication, assembly, and installation, including plans, elevations, sections, components, and attachments to other work.
   3. Duct layout indicating sizes and pressure classes.
   4. Elevations of top and bottom of ducts.
   5. Dimensions of main duct runs from building grid lines.
   6. Fittings.
   7. Reinforcement and spacing.
   8. Seam and joint construction.
   9. Penetrations through fire-rated and other partitions.
   10. Equipment installation based on equipment being used on Project.
   11. Duct accessories, including access doors and panels.
   12. Hangers and supports, including methods for duct and building attachment, vibration isolation, and seismic restraints.
   13. <Insert additional items.>

1.4 INFORMATIONAL SUBMITTALS

A. Coordination Drawings: Reflected ceiling plans, drawn to scale, on which the following items are shown and coordinated with each other, based on input from installers of the items involved:
   1. Ceiling suspension assembly members.
   2. Other systems installed in same space as ducts.
   3. Ceiling- and wall-mounting access doors and panels required to provide access to dampers and other operating devices.
   4. Ceiling-mounting items, including lighting fixtures, diffusers, grilles, speakers, sprinklers, access panels, and special moldings.

B. Field quality-control test reports.

1.5 QUALITY ASSURANCE

A. NFPA Compliance:
1. NFPA 90A, "Installation of Air Conditioning and Ventilating Systems."
2. NFPA 90B, "Installation of Warm Air Heating and Air Conditioning Systems."


C. Mockups:

1. Before installing duct systems, build mockups representing pressure classes higher than [2-inch wg] <Insert pressure class>. Build mockups to comply with the following requirements, using materials indicated for the completed Work, and include each of the following features and fittings:
   a. [Five] <Insert number> transverse joints.
   b. [One] <Insert number> access door(s).
   c. [Two] <Insert number> typical branch connections, each with at least one elbow.
   d. [Two] <Insert number> typical flexible duct or flexible connector connections for each duct and apparatus.
   e. Perform tests specified in Part 3 "Field Quality Control" Article. Modify mockup construction and perform additional tests as required to achieve specified minimum acceptable results.

2. Approved mockups may become part of the completed Work if undisturbed at time of Substantial Completion.

1.6 DELIVERY, STORAGE, AND PROTECTION

A. Deliver sealant materials to site in original unopened containers or bundles with labels informing about manufacturer, product name and designation, color, expiration period for use, pot life, curing time, and mixing instructions for multi-component materials.

B. Store and handle sealant materials in compliance with manufacturers' recommendations to prevent their deterioration or damage due to moisture, high or low temperatures, contaminants, or other causes.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. In other Part 2 articles where titles below introduce lists, the following requirements apply to product selection:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the manufacturers specified.
2.2 SHEET METAL MATERIALS

A. Comply with SMACNA's "HVAC Duct Construction Standards--Metal and Flexible" for acceptable materials, material thicknesses, and duct construction methods, unless otherwise indicated. Sheet metal materials shall be free of pitting, seam marks, roller marks, stains, discolorations, and other imperfections.

B. Galvanized Sheet Steel: Lock-forming quality; complying with ASTM A 653/A 653M and having G90 coating designation; ducts shall have mill-phosphatized finish for surfaces exposed to view.

C. Galvanized Sheet Steel: Lock-forming quality; complying with ASTM A 653/A 653M and having [G60] [G90] coating designation; ducts shall have mill-phosphatized finish for surfaces exposed to view.


E. Carbon-Steel Sheets: ASTM A 366/A 366M, cold-rolled sheets; commercial quality; with oiled, matte finish for exposed ducts.

F. Stainless Steel: ASTM A 480/A 480M, Type [316] [304], and having a No. 2D finish for concealed ducts and No. 4 for exposed ducts.

G. Aluminum Sheets: ASTM B 209, alloy 3003, temper H14; with mill finish for concealed ducts and standard, 1-side bright finish for exposed ducts.

H. Reinforcement Shapes and Plates: Galvanized-steel reinforcement where installed on galvanized sheet metal ducts.
   1. For aluminum ducts, provide reinforcing of compatible materials.
   2. For stainless steel ducts, provide reinforcing of compatible materials.

I. 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.

J. Bird Screen: 1/2 inch mesh, 16 gage galvanized wire.

2.3 DUCT LINER

A. Fibrous-Glass Liner: Comply with NFPA 90A or NFPA 90B and with NAIMA AH124.
   1. Manufacturers:
      a. CertainTeed Corp.; Insulation Group.
      c. Knauf Fiber Glass GmbH.
      d. Owens Corning.
2. Materials: ASTM C 1071; surfaces exposed to airstream shall be coated to prevent erosion of glass fibers.
   a. Thickness: 1 inch.
   b. Thickness: [1 inch(25 mm)] [1/2 inch(13 mm)] [1-1/2 inches(38 mm)].
   c. Thermal Conductivity (k-Value): 0.26 at 75 deg F mean temperature.
   d. Fire-Hazard Classification: Maximum flame-spread index of 25 and smoke-developed index of 50 when tested according to ASTM E 84.
   e. Liner Adhesive: Comply with NFPA 90A or NFPA 90B and with ASTM C 916.
      1) For indoor applications, use adhesive that has a VOC content of 80 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
   f. Mechanical Fasteners: Galvanized steel suitable for mechanical attachment, or welding attachment to duct without damaging liner when applied as recommended by manufacturer and without causing leakage in duct.
      1) Mechanical Fasteners: Galvanized steel suitable for adhesive attachment, mechanical attachment, or welding attachment to duct without damaging liner when applied as recommended by manufacturer and without causing leakage in duct.
      2) Tensile Strength: Indefinitely sustain a 50-lb- tensile, dead-load test perpendicular to duct wall.
      3) Fastener Pin Length: As required for thickness of insulation and without projecting more than 1/8 inch into airstream.
      4) Adhesive for Attaching Mechanical Fasteners: Comply with fire-hazard classification of duct liner system.

B. Flexible Elastomeric Duct Liner: Comply with NFPA 90A or NFPA 90B.
   1. Manufacturers:
      a. Armstrong World Industries, Inc.
      a. Thickness: [3/8 inch] [1/2 inch] [3/4 inch] [1 inch].
      b. Thermal Conductivity (k-Value): 0.24 at 75 deg F mean temperature.
      c. Fire-Hazard Classification: Maximum flame-spread index of 25 and smoke-developed index of 50 when tested according to ASTM C 411.
      d. Liner Adhesive: As recommended by insulation manufacturer and complying with NFPA 90A or NFPA 90B.

2.4 SEALANT MATERIALS

A. Joint and Seam Sealants, General: The term "sealant" is not limited to materials of adhesive or mastic nature but includes tapes and combinations of open-weave fabric strips and mastics.

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C. Tape Sealing System: Woven-fiber tape impregnated with gypsum mineral compound and modified acrylic/silicone activator to react exothermically with tape to form hard, durable, airtight seal.

D. Water-Based Joint and Seam Sealant: Flexible, adhesive sealant, resistant to UV light when cured, UL 723 listed, and complying with NFPA requirements for Class 1 ducts.
   1. For indoor applications, use adhesive that has a VOC content of 250 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).

E. Solvent-Based Joint and Seam Sealant: One-part, nonsag, solvent-release-curing, polymerized butyl sealant formulated with a minimum of 75 percent solids.

F. Flanged Joint Mastic: One-part, acid-curing, silicone, elastomeric joint sealant complying with ASTM C 920, Type S, Grade NS, Class 25, Use O.

G. Flange Gaskets: Butyl rubber or EPDM polymer with polyisobutylene plasticizer.

2.5 HANGERS AND SUPPORTS

A. Building Attachments: Concrete inserts, powder-actuated fasteners, or structural-steel fasteners appropriate for construction materials to which hangers are being attached.
   1. Use powder-actuated concrete fasteners for standard-weight aggregate concretes or for slabs more than 4 inches thick.
   2. Exception: Do not use powder-actuated concrete fasteners for lightweight-aggregate concretes or for slabs less than 4 inches thick.

B. Install structural steel members between building structure members as required for upper attachment of hangers and supports. Use members of size and strength required for span and load. The use of joist or truss bridging for hanging and supporting is prohibited.

C. Hanger Materials: Galvanized sheet steel or threaded steel rod.
   1. Hangers Installed in Corrosive Atmospheres: Electrogalvanized, all-thread rods or galvanized rods with threads painted with zinc-chromate primer after installation.
   2. Strap and Rod Sizes: Comply with SMACNA's "HVAC Duct Construction Standards--Metal and Flexible" for steel sheet width and thickness and for steel rod diameters.
   3. Galvanized-steel straps attached to aluminum ducts shall have contact surfaces painted with zinc-chromate primer.
   4. For exposed stainless steel or aluminum ductwork, provide matching stainless steel or aluminum support materials.

D. Duct Attachments: Sheet metal screws, blind rivets, or self-tapping metal screws; compatible with duct materials.

E. Trapeze and Riser Supports: Steel shapes complying with ASTM A 36/A 36M.
3. Supports for Aluminum Ducts: Aluminum support materials unless materials are electrolytically separated from ducts.

F. [Duct Supports Above Roof]: Steel shapes complying with ASTM A 36/A 36M.

2.6 RECTANGULAR DUCT FABRICATION

A. Fabricate ducts, elbows, transitions, offsets, branch connections, and other construction according to SMACNA's "HVAC Duct Construction Standards--Metal and Flexible" and complying with requirements for metal thickness, reinforcing types and intervals, tie-rod applications, and joint types and intervals.
   1. Lengths: Fabricate rectangular ducts in lengths appropriate to reinforcement and rigidity class required for pressure class.
   2. Deflection: Duct systems shall not exceed deflection limits according to SMACNA's "HVAC Duct Construction Standards--Metal and Flexible."

B. Transverse Joints: Prefabricated slide-on joints and components constructed using manufacturer's guidelines for material thickness, reinforcement size and spacing, and joint reinforcement.
   1. Manufacturers:
      a. Ductmate Industries, Inc.
      b. Nexus Inc.
      c. Ward Industries, Inc.

C. Formed-On Flanges: Construct according to SMACNA's "HVAC Duct Construction Standards--Metal and Flexible," Figure 1-4, using corner, bolt, cleat, and gasket details.
   1. Manufacturers:
      a. Ductmate Industries, Inc.
      b. Lockformer.
   2. Duct Size: Maximum 30 inches wide and up to 2-inch wg pressure class.
   3. Longitudinal Seams: Pittsburgh lock sealed with noncuring polymer sealant.

D. Cross Breaking or Cross Beading: Cross break or cross bead duct sides 19 inches and larger and 0.0359 inch thick or less, with more than 10 sq. ft. of nonbraced panel area unless ducts are lined.

2.7 APPLICATION OF LINER IN RECTANGULAR DUCTS

A. All sizes shown on the drawings for ducts which require duct liner shall be sizes inside the liner.

B. Adhere a single layer of indicated thickness of duct liner with at least 90 percent adhesive coverage at liner contact surface area. Attaining indicated thickness with multiple layers of duct liner is prohibited.
C. Apply adhesive to transverse edges of liner facing upstream that do not receive metal nosing.

D. Butt transverse joints without gaps and coat joint with adhesive.

E. Fold and compress liner in corners of rectangular ducts or cut and fit to ensure butted-edge overlapping.

F. Do not apply liner in rectangular ducts with longitudinal joints, except at corners of ducts, unless duct size and standard liner product dimensions make longitudinal joints necessary.

G. Apply adhesive coating on longitudinal seams in ducts with air velocity of 2500 fpm.

H. Secure liner with mechanical fasteners 4 inches from corners and at intervals not exceeding 12 inches transversely; at 3 inches from transverse joints and at intervals not exceeding 18 inches longitudinally.

I. Secure transversely oriented liner edges facing the airstream with metal nosings that have either channel or “Z” profiles or are integrally formed from duct wall. Fabricate edge facings at the following locations:
   1. Fan discharges.
   2. Intervals of lined duct preceding unlined duct.
   3. Upstream edges of transverse joints in ducts where air velocities are greater than 2500 fpm (12.7 m/s) or where indicated.

J. Secure insulation between perforated sheet metal inner duct of same thickness as specified for outer shell. Use mechanical fasteners that maintain inner duct at uniform distance from outer shell without compressing insulation.
   1. Sheet Metal Inner Duct Perforations: 3/32-inch diameter, with an overall open area of 23 percent.

K. Terminate inner ducts with buildouts attached to fire-damper sleeves, dampers, turning vane assemblies, or other devices. Fabricated buildouts (metal hat sections) or other buildout means are optional; when used, secure buildouts to duct walls with bolts, screws, rivets, or welds.

2.8 FABRICATED PIPE COVERS

A. General: Provide as indicated carbon steel or stainless steel pipe covers for vertical pipe runs. Pipe covers shall be self supporting, securely attached to building structure with tamper resistant removable fasteners.

2.9 DRYER VENT DUCTWORK

A. Provide round dryer vent ducts in accordance with SMACNA Standards using snaplock seam ducts with die-formed elbows. Provide cleanouts for ease of duct cleaning.
   1. Provide flexible aluminum dryer venting for connection to dryer.
   2. Provide roof curb and gooseneck outlet for roof outlet installations.
   3. Provide plastic wall cap with flapper for wall outlet installations.
B. Provide flexible aluminum dryer venting and plastic wall cap with flapper.

2.10 KITCHEN HOOD VENT DUCTWORK

A. Provide ductwork constructed and installed in accordance with SMACNA minimum gauges and requirements. Provide 18 gauge galvanized steel make-up air ductwork and welded 16 gauge galvanized exhaust ductwork as per code requirements and conform to all building requirements and obstructions with all dimensions subject to verification in field. Provide all ductwork with cleanouts every 6'-0" of horizontal run (with pitch as per code) and at changes in direction, access panel, dampers, curbs, flashing, flanges, plenums, supports, insulation, etc. as required by code and to provide a leak proof system.

2.11 ROUND AND FLAT-OVAL DUCT AND FITTING FABRICATION

A. Spiral Duct Manufacturers:
   1. Eastern Sheet Metal.
   2. SET Duct.
   3. LaPine Metal Products.
   5. SEMCO Incorporated.
   6. Universal Spiral Air.

B. Round and Flat-Oval, Spiral Lock-Seam Ducts: Fabricate ducts of galvanized steel according to SMACNA’s “HVAC Duct Construction Standards--Metal and Flexible.” Fabricate ducts larger than 72 inches in diameter with butt-welded longitudinal seams.

C. Diameter as applied to flat-oval ducts in this Article is the diameter of a round duct with a circumference equal to the perimeter of a given size of flat-oval duct.

D. Round Ducts: Fabricate ducts of longitudinal-seam or spiral lock-seam galvanized steel according to SMACNA’s "HVAC Duct Construction Standards--Metal and Flexible."

E. Round, Longitudinal-Seam Ducts: Fabricate 12 inch and smaller ducts and drops to diffusers of galvanized steel according to SMACNA’s "HVAC Duct Construction Standards--Metal and Flexible."

F. Round, Longitudinal-Seam Ducts: For ductwork down stream of VAV terminal units, fabricate ducts and drops to diffusers of galvanized steel according to SMACNA’s "HVAC Duct Construction Standards--Metal and Flexible."

G. Round, Spiral Lock-Seam Ducts: Fabricate 13 inch and larger ducts of galvanized steel according to SMACNA’s "HVAC Duct Construction Standards--Metal and Flexible." [Fabricate ducts larger than 72 inches in diameter with butt-welded longitudinal seams.]

H. Round, Spiral Lock-Seam Ducts: For ductwork up stream of VAV terminal units, fabricate ducts of galvanized steel according to SMACNA’s "HVAC Duct Construction Standards--Metal and Flexible."
I. **Flat-Oval, [Longitudinal]** [Spiral Lock] [Longitudinal- and Spiral Lock]-Seam Ducts: Fabricate supply ducts according to SMACNA's "HVAC Duct Construction Standards--Metal and Flexible." [Fabricate ducts larger than 72 inches in diameter with butt-welded longitudinal seams.]

J. Duct Joints:

1. Ducts up to 20 Inches in Diameter: Interior, center-beaded slip coupling, sealed before and after fastening, attached with sheet metal screws.
2. Ducts 21 to 72 Inches in Diameter: Three-piece, gasketed, flanged joint consisting of two internal flanges with sealant and one external closure band with gasket.
3. Ducts Larger Than 72 Inches in Diameter: Companion angle flanged joints per SMACNA "HVAC Duct Construction Standards--Metal and Flexible," Figure 3-2.
4. Round Ducts: Prefabricated connection system consisting of double-lipped, EPDM rubber gasket. Manufacture ducts according to connection system manufacturer's tolerances.
   a. Manufacturers:
      1) Ductmate Industries, Inc.
      2) Lindab Inc.

5. Flat-Oval Ducts: Prefabricated connection system consisting of two flanges and one synthetic rubber gasket.
   a. Manufacturers:
      1) Ductmate Industries, Inc.
      3) SEMCO Incorporated.

K. 90-Degree Tees and Laterals and Conical Tees: Fabricate to comply with SMACNA's "HVAC Duct Construction Standards--Metal and Flexible," with metal thicknesses specified for longitudinal-seam straight ducts.

L. Diverging-Flow Fittings: Fabricate with reduced entrance to branch taps and with no excess material projecting from fitting onto branch tap entrance.

M. Fabricate elbows using die-formed, gored, pleated, or mitered construction. Bend radius of die-formed, gored, and pleated elbows shall be 1-1/2 times duct diameter. Unless elbow construction type is indicated, fabricate elbows as follows:

1. Mitered-Elbow Radius and Number of Pieces: Welded construction complying with SMACNA's "HVAC Duct Construction Standards--Metal and Flexible," unless otherwise indicated.
2. Round Mitered Elbows: Welded construction with metal thickness equal to or greater than that of ducts.
3. Flat-Oval Mitered Elbows: Welded construction with same metal thickness as longitudinal-seam flat-oval duct.
4. 90-Degree, 2-Piece, Mitered Elbows: Use only for supply systems or for material-handling Class A or B exhaust systems and only where space restrictions do not permit using radius elbows. Fabricate with single-thickness turning vanes.
5. Round Elbows 8 Inches and Less in Diameter: Fabricate die-formed elbows for 45- and 90-degree elbows and pleated elbows for 30 and 60 degrees only. Fabricate nonstandard bend-angle configurations or nonstandard diameter elbows with gored construction.
6. Round Elbows 9 through 14 Inches in Diameter: Fabricate with gored construction, unless space restrictions require mitered elbows. Fabricate nonstandard bend-angle configurations or nonstandard diameter elbows with gored construction.

7. Round Elbows Larger Than 14 Inches in Diameter: Fabricate gored elbows unless space restrictions require mitered elbows.

8. Die-Formed Elbows for Sizes through 8 Inches in Diameter and All Pressures 0.040 inch thick with 2-piece welded construction.

9. Round Gored-Elbow Metal Thickness: Same as metal thickness or greater than that of ducts.

10. Flat-Oval Elbow Metal Thickness: Same as metal thickness or greater than that of ducts.

N. PVC-Coated Elbows and Fittings: Fabricate elbows and fittings as follows:

1. Round Elbows 4 to 8 Inches in Diameter: Two piece, die stamped, with longitudinal seams spot welded, bonded, and painted with PVC aerosol spray.

2. Round Elbows 9 to 26 Inches in Diameter: Standing-seam construction.

3. Round Elbows 28 to 60 Inches in Diameter: Standard gored construction, riveted and bonded.

4. Other Fittings: Riveted and bonded joints.

5. Couplings: Slip-joint construction with a minimum 2-inch insertion length.

2.12 DOUBLE-WALL DUCT AND FITTING FABRICATION

A. Manufacturers:

1. Eastern Sheet Metal.
2. SET Duct.
3. LaPine Metal Products.
5. SEMCO Incorporated.
6. Universal Spiral Air.

B. Ducts: Fabricate double-wall insulated ducts with an outer shell and an inner duct. Dimensions indicated are for inner ducts.

1. Outer Shell: Base metal thickness on outer-shell dimensions. Fabricate outer-shell lengths 2 inches longer than inner duct and insulation and in metal thickness specified for single-wall duct.

2. Insulation: 1-inch- thick fibrous glass, unless otherwise indicated. Terminate insulation where double-wall duct connects to single-wall duct or uninsulated components, and reduce outer shell diameter to inner duct diameter.
   a. Thermal Conductivity (k-Value): 0.26 at 75 deg F mean temperature.

3. Inner Ducts: Solid wall sheet metal.
4. Solid Inner Ducts: Use the following sheet metal thicknesses and seam construction:
   a. Ducts 3 to 8 Inches in Diameter: 0.019 inch with standard spiral-seam construction.
   b. Ducts 9 to 42 Inches in Diameter: 0.019 inch with single-rib spiral-seam construction.
WMU Design Guidelines

2.13 UNDERSLAB DUCTWORK

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

1. Blue Duct by AQC Industries.

B. Duct Material And Sealants:

1. Provide elbows, pipe, plenums, clamps & gaskets, boots, saddles, caulk, water gauge test and adapters as required by design for underslab installation.
   a. Manufacturer’s parts warranty: 10 years.

2. Ductwork shall be HDPE, food grade, closed cell plastic material that is recyclable, does not emit volatile organic compounds, and conforms to ASTM2412.

3. Ductwork shall be resistant to mildew, mold (UL 181B), and radon gas (BSS 7239-88).

4. Ductwork shall have R-10 thermal insulation value without the use of external insulation.

5. All joints shall be gasketed and sealed. Clamps and gaskets shall be used on ductwork without flanges. Clamps shall be polyethylene with 410 stainless steel plates and stainless steel screws. Gaskets shall comprise of ¼” thick butyl rubber sealant tape with Tedlar facing that is water and UV resistant and shall not stain. Gaskets shall comply with ASTM-E84 for flame and smoke spread.

6. Joints shall use a co-polymer adhesive caulking sealant that is water and UV resistant.

7. Assembled ductwork shall be able to maintain +/- 10” static pressure with no leakage.

8. Duct system shall be installed by manufacture trained installer for air and water tight system.
PART 3 - EXECUTION

3.1 DUCTWORK CONSTRUCTION

A. Provide ductwork constructed in accordance with SMACNA Duct Construction Standards but no less than the static pressure classification as indicated below. Fabricate ductwork that will have less leakage than the percentage of system design air flow as indicated below. Test all ductwork for leakage, unless otherwise noted, in accordance with SMACNA HVAC Air Duct Leakage Test Manual and the following:

1. VAV Supply Air Ductwork (AHU to Terminal Units)
   a. Duct Construction Static Pressure Class: +3-inch wg.
   b. SMACNA Seal Class: A.
   c. Percent Leakage of System Design Air Flow: 1/2 percent.
   d. Testing Static Pressure: +3-inch wg.

2. VAV Supply Air Ductwork (Terminal Units to Diffusers or Fan Coils)
   b. SMACNA Seal Class: C.
   c. Percent Leakage of System Design Air Flow: 5 percent.
   d. Testing Static Pressure: No testing required.

3. Constant Volume Supply Air Ductwork (AHU to Diffusers)
   a. Duct Construction Static Pressure Class: +3-inch wg.
   b. SMACNA Seal Class: B.
   c. Percent Leakage of System Design Air Flow: 5 percent.
   d. Testing Static Pressure: +3-inch wg.

4. Return Air Ductwork (To AHU)
   a. Duct Construction Static Pressure Class: -3-inch wg.
   b. SMACNA Seal Class: B.
   c. Percent Leakage of System Design Air Flow: 5 percent.
   d. Testing Static Pressure: -3-inch wg.

5. Exhaust Air Ductwork (To ERU)
   a. Duct Construction Static Pressure Class: -3-inch wg.
   b. SMACNA Seal Class: B.
   c. Percent Leakage of System Design Air Flow: 5 percent.
   d. Testing Static Pressure: -3-inch wg.

6. Exhaust Air Ductwork (From ERU)
   a. Duct Construction Static Pressure Class: +3-inch wg.
   b. SMACNA Seal Class: B.
   c. Percent Leakage of System Design Air Flow: 5 percent.
   d. Testing Static Pressure: +3-inch wg.
7. Exhaust Air Ductwork (To roof fans)
   a. Duct Construction Static Pressure Class: -3-inch wg.
   b. SMACNA Seal Class: B.
   c. Percent Leakage of System Design Air Flow: 5 percent.
   d. Testing Static Pressure: -3-inch wg.

8. Exhaust Air Ductwork (To inline fans)
   a. Duct Construction Static Pressure Class: -1-inch wg.
   b. SMACNA Seal Class: C.
   c. Percent Leakage of System Design Air Flow: 5 percent.
   d. Testing Static Pressure: No testing required.

9. Exhaust Air Ductwork (From inline fans)
   b. SMACNA Seal Class: C.
   c. Percent Leakage of System Design Air Flow: 5 percent.
   d. Testing Static Pressure: No testing required.

10. Relief Air Ductwork
    b. SMACNA Seal Class: C.
    c. Percent Leakage of System Design Air Flow: 5 percent.
    d. Testing Static Pressure: No testing required.

11. Outside Air Ductwork
    a. Duct Construction Static Pressure Class: -1-inch wg.
    b. SMACNA Seal Class: C.
    c. Percent Leakage of System Design Air Flow: 5 percent.
    d. Testing Static Pressure: No testing required.

12. Transfer Air Ductwork
    a. Duct Construction Static Pressure Class: -1/2-inch wg.
    b. SMACNA Seal Class: C.
    c. Percent Leakage of System Design Air Flow: 5 percent.
    d. Testing Static Pressure: No testing required.

3.2 DUCT APPLICATIONS

A. All ducts shall be galvanized steel.

B. Ducts exposed in Lower Level requiring insulation shall be double wall insulated construction. Refer to Section 23 0700 "HVAC Insulation".

C. All ducts shall be galvanized steel except as follows:
2. Shower Room Exhaust Ducts:
   a. Aluminum, with seams and laps arranged on top of duct.

   b. Exposed: Type 304, stainless steel with finish to match kitchen equipment and range hood.
   c. Weld and flange seams and joints.

4. Dishwasher Hood Exhaust Ducts:
   a. Type 304, stainless steel with finish to match kitchen equipment and range hood.
   b. Aluminum, with seams and laps arranged on top of duct.

5. Acid-Resistant (Fume-Handling) Ducts: Type [316] [304], stainless-steel sheet with [No. 4] [No. 3] <Insert finish> finish.

6. Acid-Resistant (Fume-Handling) Ducts: PVC-coated galvanized steel with thicker coating on duct interior.

7. Underground Ducts: [Concrete-encased galvanized steel] [PVC-coated galvanized steel with thicker coating on duct exterior].

8. Dust Collector Ducts:

3.3 DUCT INSTALLATION

A. Construct and install ducts according to SMACNA's "HVAC Duct Construction Standards--Metal and Flexible," unless otherwise indicated.

B. Install round and flat-oval ducts in lengths not less than 12 feet unless interrupted by fittings.

C. Install ducts with fewest possible joints.

D. Install fabricated fittings for changes in directions, size, and shape and for connections.

E. Install couplings tight to duct wall surface with a minimum of projections into duct. Secure couplings with sheet metal screws. Install screws at intervals of 12 inches, with a minimum of 3 screws in each coupling.

F. Install ducts, unless otherwise indicated, vertically and horizontally and parallel and perpendicular to building lines; avoid diagonal runs.

G. Install ducts close to walls, overhead construction, columns, and other structural and permanent enclosure elements of building.

H. Install ducts with a clearance of 1 inch, plus allowance for insulation thickness.

I. Conceal ducts from view in finished spaces. Do not encase horizontal runs in solid partitions unless specifically indicated.

J. Coordinate layout with suspended ceiling, fire and smoke-control dampers, lighting layouts, and similar finished work.
K. Seal all joints and seams. Apply sealant to male end connectors before insertion, and afterward to cover entire joint and sheet metal screws.

L. Electrical Equipment Spaces: Route ducts to avoid passing through transformer vaults and electrical equipment spaces and enclosures.

M. Non-Fire-Rated Partition Penetrations: Where ducts pass through interior partitions and are exposed to view, conceal spaces between construction openings and ducts or duct insulation with sheet metal flanges of same metal thickness as ducts. Overlap openings on 4 sides by at least 1-1/2 inches.

N. Non-Fire-Rated Partition Penetrations: Where ducts pass through interior partitions and exterior walls and are exposed to view, conceal spaces between construction openings and ducts or duct insulation with sheet metal flanges of same metal thickness as ducts. Overlap openings on 4 sides by at least 1-1/2 inches.

O. Fire-Rated Partition Penetrations: Where ducts pass through interior partitions, install appropriately rated fire dampers, sleeves, and firestopping sealant. Fire and smoke dampers are specified in Division 23 Section "Air Duct Accessories." Firestopping materials and installation methods are specified in Division 07 Section "Penetration Firestopping."

P. Paint interiors of metal ducts, that do not have duct liner, for 24 inches upstream of registers and grilles. Apply one coat of flat, black, latex finish coat over a compatible galvanized-steel primer. Paint materials and application requirements are specified in Division 09 painting Sections.

Q. Coordinate duct installations with installation of accessories, dampers, coil frames, equipment, controls and other associated work of ductwork system. Install control dampers supplied by Temperature Control Installer.

R. At ends of ducts which are not connected to equipment or air distribution devices at time of ductwork installation, provide temporary closure of polyethylene film or other covering which will prevent entrance of dust and debris until time connections are to be completed.

S. Where indicated, install wire mesh bird screen grilles mounted in a removable frame.

3.4 UNDERSLAB DUCT INSTALLATION

A. Construct and install ducts according to manufacturer’s instructions.

B. Install ducts with fewest possible joints.

C. Install fabricated fittings for changes in directions, size, and shape and for connections.

D. Install ducts parallel and perpendicular to building lines; avoid diagonal runs.

E. Coordinate installation with other under slab installations.

F. Seal all joints and seams.
G. At ends of ducts which are not connected to equipment or air distribution devices at time of ductwork installation, provide temporary closure of polyethylene film or other covering which will prevent entrance of dust and debris until time connections are to be completed.

H. Verify undamaged condition of ducts before enclosure with fill or encasement.
   1. Repair damage with manufacturer’s recommended materials.

I. Protect ducts from damage by equipment used in placing fill materials and concrete on or around ducts.

J. Protect duct openings from damage and prevent entrance of foreign materials.

K. Excavating, trenching, and backfilling are specified in Division 31 Section “Earth Moving.”

3.5 DUCT CLEANLINESS REQUIREMENTS

A. Protect duct interiors from the elements and foreign materials in accordance with the following SMACNA’s “Duct Cleanliness for New Construction.” Guidelines:
   1. Basic Level.
   2. Intermediate Level.
   3. Advance Level.

3.6 PVC-COATED DUCT, SPECIAL INSTALLATION REQUIREMENTS

A. Repair damage to PVC coating with manufacturer’s recommended materials.

3.7 UNDERSLAB DUCTS, SPECIAL INSTALLATION REQUIREMENTS

A. Install ductwork in accordance with SMACNA Duct Construction Standards.

B. Verify undamaged condition of ducts before enclosure with fill or encasement.

C. Protect ducts from damage by equipment used in placing fill materials and concrete on or around ducts.

D. Protect duct openings from damage and prevent entrance of foreign materials.

E. Excavating, trenching, and backfilling are specified in Division 31 Section “Earth Moving.”

3.8 RANGE HOOD EXHAUST DUCTS, SPECIAL INSTALLATION REQUIREMENTS

A. Install ducts to allow for thermal expansion through 2000 deg F temperature range.

B. Install ducts without dips or traps that may collect residues unless traps have continuous or automatic residue removal.
C. Install access openings at each change in direction and at intervals defined by NFPA 96; locate on sides of duct a minimum of 1-1/2 inches from bottom; and fit with grease-tight covers of same material as duct.

D. Do not penetrate fire-rated assemblies except as permitted by applicable building codes.

3.9 DUST COLLECTOR DUCT, SPECIAL INSTALLATION REQUIREMENTS

A. Install without dips or traps that may collect residues.

B. Install access doors as indicated, located on bottom of duct, constructed of same material as duct. Access doors shall be rolled hinged plate with commercial latches. Ductwork outside of building shall be finished with rust inhibiting paint.

3.10 SEAM AND JOINT SEALING

A. All ductwork shall be suitably cleaned and prepared, and sealant applied in strict accordance with manufacturer’s instructions. Manufacturer’s recommendations for cure time shall be followed before pressure testing is begun. Any additional paint or coatings must conform to manufacturer’s specifications. Seal duct seams and joints as follows:

1. Pressure Classifications Greater Than 3 Inches Water Gage: All transverse joints, longitudinal seams, and duct penetrations (SMACNA Seal Class A).
2. Pressure Classification 2 and 3 Inches Water Gage: All transverse joints and longitudinal seams (SMACNA Seal Class B).
3. Pressure Classification Less than 2 Inches Water Gage: Transverse joints only (SMACNA Seal Class C).

B. Seal ducts and leak test where indicated before external insulation is applied.

3.11 HANGING AND SUPPORTING

A. Support ductwork with support systems indicated in SMACNA "HVAC Duct Construction Standards".

B. Support horizontal ducts within 24 inches of each elbow and within 48 inches of each branch intersection.

C. Support vertical ducts at maximum intervals of 16 feet and at each floor.

D. Install upper attachments to structures with an allowable load not exceeding one-fourth of failure (proof-test) load.

E. Install concrete inserts before placing concrete.

F. Install powder-actuated concrete fasteners after concrete is placed and completely cured.

1. Do not use powder-actuated concrete fasteners for lightweight-aggregate concretes or for slabs less than 4 inches thick.
G. Install galvanized angle iron or pipe supports for ductwork above roof. Supports shall be bolted to "Pate" or equivalent equipment curbs. Install equipment curbs in accordance with curb and roofing Manufacturer guidelines. Patch roofing following curb and/or roofing manufacturer guidelines.

3.12 CONNECTIONS

A. Make connections to equipment with flexible connectors according to Division 23 Section "Air Duct Accessories."

B. Comply with SMACNA's "HVAC Duct Construction Standards--Metal and Flexible" for branch, outlet and inlet, and terminal unit connections.

C. Louver Plenums: Fabricate of heavy gauge sheet metal material in compliance with SMACNA's "HVAC Duct Construction Standards--Metal and Flexible."
   1. Fabricate with sloped bottom surface.
   2. Apply two coats of fire retardant, bitumastic waterproofing material to interior surfaces of bottom and lower half of sides.

3.13 FIELD QUALITY CONTROL

A. Provide duct leakage testing in accordance with SMACNA HVAC Air/Duct Leakage Test Manual and prepare test reports.

B. Disassemble, reassemble, and seal segments of the systems as required to accommodate leakage testing, and as required for compliance with test requirements.

C. Conduct tests, in the presence of the Architect/Engineer, at static pressures equal to the maximum design pressure of the system or the section being tested. If pressure classifications are not indicated, test entire system at the maximum system design pressure. Do not pressurize systems above the maximum design operating pressure. Give 3 days’ advanced notice for testing.

D. Remake leaking joints as required and apply sealants to achieve specified maximum allowable leakage.

E. Seal and leak test externally insulated ducts prior to insulation installation.

F. Provide Leakage Testing on ductwork located in inaccessible locations (underslab, in walls and chases, etc.) before final covering is performed.

3.14 CLEANING NEW SYSTEMS

A. Mark position of dampers and air-directional mechanical devices before cleaning, and perform cleaning before air balancing.

B. Use service openings, as required, for physical and mechanical entry and for inspection.
1. Create other openings to comply with duct standards.
2. Disconnect flexible ducts as needed for cleaning and inspection.
3. Remove and reinstall ceiling sections to gain access during the cleaning process.

C. Vent vacuuming system to the outside. Include filtration to contain debris removed from HVAC systems, and locate exhaust down wind and away from air intakes and other points of entry into building.

D. Clean the following metal duct systems by removing surface contaminants and deposits:
   1. Air outlets and inlets (registers, grilles, and diffusers).
   2. Supply, return, and exhaust fans including fan housings, plenums (except ceiling supply and return plenums), scrolls, blades or vanes, shafts, baffles, dampers, and drive assemblies.
   3. Air-handling unit internal surfaces and components including mixing box, coil section, air wash systems, spray eliminators, condensate drain pans, humidifiers and dehumidifiers, filters and filter sections, and condensate collectors and drains.
   5. Return-air ducts, dampers, and actuators except in ceiling plenums and mechanical equipment rooms.

E. Mechanical Cleaning Methodology:
   1. Clean metal duct systems using mechanical cleaning methods that extract contaminants from within duct systems and remove contaminants from building.
   2. Use vacuum-collection devices that are operated continuously during cleaning. Connect vacuum device to downstream end of duct sections so areas being cleaned are under negative pressure.
   3. Use mechanical agitation to dislodge debris adhered to interior duct surfaces without damaging integrity of metal ducts, duct liner, or duct accessories.
   4. Clean fibrous-glass duct liner with HEPA vacuuming equipment; do not permit duct liner to get wet.
   5. Clean coils and coil drain pans according to NADCA 1992. Keep drain pan operational. Rinse coils with clean water to remove latent residues and cleaning materials; comb and straighten fins.

F. Cleanliness Verification:
   1. Visually inspect metal ducts for contaminants.
   2. Where contaminants are discovered, re-clean and reinspect ducts.

3.15 CLEANING EXISTING SYSTEMS

A. Use service openings, as required, for physical and mechanical entry and for inspection.
   1. Use existing service openings where possible.
   2. Create other openings to comply with duct standards.
   3. Disconnect flexible ducts as needed for cleaning and inspection.
   4. Reseal rigid fiberglass duct systems according to NAIMA recommended practices.
   5. Remove and reinstall ceiling sections to gain access during the cleaning process.
B. Mark position of dampers and air-directional mechanical devices before cleaning, and restore to their marked position on completion.

C. Particulate Collection and Odor Control:
   1. When venting vacuuming system inside the building, use HEPA filtration with 99.97 percent collection efficiency for 0.3-micron size (or larger) particles.
   2. When venting vacuuming system to the outside, use filtration to contain debris removed from HVAC system, and locate exhaust down wind and away from air intakes and other points of entry into building.

D. Clean the following metal duct systems by removing surface contaminants and deposits:
   1. Air outlets and inlets (registers, grilles, and diffusers).
   2. Supply, return, and exhaust fans including fan housings, plenums (except ceiling supply and return plenums), scrolls, blades or vanes, shafts, baffles, dampers, and drive assemblies.
   3. Air-handling unit internal surfaces and components including mixing box, coil section, air wash systems, spray eliminators, condensate drain pans, humidifiers and dehumidifiers, filters and filter sections, and condensate collectors and drains.
   5. Return-air ducts, dampers, and actuators except in ceiling plenums and mechanical equipment rooms.
   7. Dedicated exhaust and ventilation components and makeup air systems.

E. Mechanical Cleaning Methodology:
   1. Clean metal duct systems using mechanical cleaning methods that extract contaminants from within duct systems and remove contaminants from building.
   2. Use vacuum-collection devices that are operated continuously during cleaning. Connect vacuum device to downstream end of duct sections so areas being cleaned are under negative pressure.
   3. Use mechanical agitation to dislodge debris adhered to interior duct surfaces without damaging integrity of metal ducts, duct liner, or duct accessories.
   4. Clean fibrous-glass duct liner with HEPA vacuuming equipment; do not permit duct liner to get wet. Replace fibrous-glass duct liner that is damaged, deteriorated, or delaminated or that has friable material, mold, or fungus growth.
   5. Clean coils and coil drain pans according to NADCA 1992. Keep drain pan operational. Rinse coils with clean water to remove latent residues and cleaning materials; comb and straighten fins.
   6. Provide operative drainage system for washdown procedures.
   7. Biocidal Agents and Coatings: Apply biocidal agents if fungus is present. Apply biocidal agents according to manufacturer's written instructions after removal of surface deposits and debris.

F. Cleanliness Verification:
   1. Verify cleanliness after mechanical cleaning and before application of treatment, including biocidal agents and protective coatings.
   2. Visually inspect metal ducts for contaminants.
   3. Where contaminants are discovered, re-clean and reinspect ducts.
WMU Design Guidelines

G. **Gravimetric Analysis:** At discretion and expense of Owner, sections of metal duct system, chosen randomly by Owner, may be tested for cleanliness according to NADCA vacuum test gravimetric analysis.

1. If analysis determines that levels of debris are equal to or lower than suitable levels, system shall have passed cleanliness verification.
2. If analysis determines that levels of debris exceed suitable levels, system cleanliness verification will have failed and metal duct system shall be re-cleaned and re-verified.

H. **Verification of Coil Cleaning:** Cleaning must restore coil pressure drop to within 10 percent of pressure drop measured when coil was first installed. If original pressure drop is not known, coil will be considered clean only if it is free of foreign matter and chemical residue, based on thorough visual inspection.

END OF SECTION 23 3113
WMU Design Guidelines Instructions: These guidelines are to be used by the Design Professional to inform the design process and outline WMU-specific desires for all University projects. These guidelines have been edited to reflect WMU preferences, and the intent is for the Design Professional to use this information to guide their normal specifications-writing process. Straying from what is indicated in the guidelines is not prohibited, but shall be discussed with WMU during the development of the project.

SECTION 23 3115 - HVAC AIR-DISTRIBUTION SYSTEM CLEANING

PART 1 - GENERAL

1.1 SUMMARY

A. Section includes cleaning reused existing HVAC air-distribution equipment, ducts, plenums, and system components.

1.2 QUALITY ASSURANCE

A. UL Compliance: Comply with UL 181 and UL 181A for fibrous-glass ducts.

PART 2 - PRODUCTS (Not Used)

PART 3 - EXECUTION

3.1 PREPARATION

A. Use the existing service openings, as required for proper cleaning, at various points of the HVAC system for physical and mechanical entry and for inspection.


3.2 CLEANING

A. Comply with NADCA ACR 2006.

B. Remove visible surface contaminants and deposits from within the HVAC system.

C. Systems and Components to Be Cleaned:

1. Air devices for supply and return air.
2. Air-terminal units.
3. Ductwork:
   a. Supply-air ducts, including turning vanes and reheat coils, to the air-handling unit.
b. Return-air ducts to the air-handling unit.
c. Exhaust-air ducts.

4. Air-Handling Units:
   a. Interior surfaces of the unit casing.
   b. Coil surfaces compartment.
   c. Condensate drain pans.
   d. Fans, fan blades, and fan housings.

5. Filters and filter housings.

D. Collect debris removed during cleaning. Ensure that debris is not dispersed outside the HVAC system during the cleaning process.

E. Particulate Collection:
   1. For particulate collection equipment, include adequate filtration to contain debris removed. Locate equipment downwind and away from all air intakes and other points of entry into the building.
   2. HEPA filtration with 99.97 percent collection efficiency for particles sized 0.3 micrometer or larger shall be used where the particulate collection equipment is exhausting inside the building.

F. Control odors and mist vapors during the cleaning and restoration process.

G. Mark the position of manual volume dampers and air-directional mechanical devices inside the system prior to cleaning. Restore them to their marked position on completion of cleaning.

H. System components shall be cleaned so that all HVAC system components are visibly clean. On completion, all components must be returned to those settings recorded just prior to cleaning operations.

I. Clean all air-distribution devices, registers, grilles, and diffusers.

J. Clean visible surface contamination deposits according to NADCA ACR 2006 and the following:
   1. Clean air-handling units, airstream surfaces, components, condensate collectors, and drains.
   2. Ensure that a suitable operative drainage system is in place prior to beginning wash-down procedures.
   3. Clean evaporator coils, reheat coils, and other airstream components.

K. Duct Systems:
   1. Create service openings in the HVAC system as necessary to accommodate cleaning.
   2. Mechanically clean duct systems specified to remove all visible contaminants so that the systems are capable of passing the HVAC System Cleanliness Tests (see NADCA ACR 2006).

L. Debris removed from the HVAC system shall be disposed of according to applicable Federal, state, and local requirements.
M. Mechanical Cleaning Methodology:

1. Source-Removal Cleaning Methods: The HVAC system shall be cleaned using source-removal mechanical cleaning methods designed to extract contaminants from within the HVAC system and to safely remove these contaminants from the facility. No cleaning method, or combination of methods, shall be used that could potentially damage components of the HVAC system or negatively alter the integrity of the system.
   
a. Use continuously operating vacuum-collection devices to keep each section being cleaned under negative pressure.

b. Cleaning methods that require mechanical agitation devices to dislodge debris that is adhered to interior surfaces of HVAC system components shall be equipped to safely remove these devices. Cleaning methods shall not damage the integrity of HVAC system components or damage porous surface materials such as duct and plenum liners.

2. Cleaning Mineral-Fiber Insulation Components:
   
a. Fibrous-glass thermal or acoustical insulation elements present in equipment or ductwork shall be thoroughly cleaned with HEPA vacuuming equipment while the HVAC system is under constant negative pressure and shall not be permitted to get wet according to NADCA ACR 2006.

b. Cleaning methods used shall not cause damage to fibrous-glass components and will render the system capable of passing the HVAC System Cleanliness Tests (see NADCA ACR 2006).

c. Fibrous materials that become wet shall be discarded and replaced.

N. Coil Cleaning:

1. Measure static-pressure differential across each coil.

2. See NADCA ACR 2006, "Coil Surface Cleaning" Section. Type 1, or Type 1 and Type 2, cleaning methods shall be used to render the coil visibly clean and capable of passing Coil Cleaning Verification (see applicable NADCA ACR 2006).

3. Coil drain pans shall be subject to NADCA ACR 2006, "Non-Porous Surfaces Cleaning Verification." Ensure that condensate drain pans are operational.

4. Electric-resistance coils shall be de-energized, locked out, and tagged before cleaning.

5. Cleaning methods shall not cause any appreciable damage to, cause displacement of, inhibit heat transfer, or cause erosion of the coil surface or fins, and shall comply with coil manufacturer's written recommendations when available.

6. Rinse thoroughly with clean water to remove any latent residues.

3.3 RESTORATION

A. Restore and repair HVAC air-distribution equipment, ducts, plenums, and components according to NADCA ACR 2006, "Restoration and Repair of Mechanical Systems" Section.

B. Comply with Section 23 3113 "Metal Ducts" and Section 23 3300 "Air Duct Accessories" for duct materials, accessories, and hardware required for Work of this Section.

C. Ensure that closures do not hinder or alter airflow.
D. New closure materials, including insulation, shall match opened materials and shall have removable closure panels fitted with gaskets and fasteners.

E. Reseal fibrous-glass ducts. Comply with requirements in Section 23 3116 "Nonmetal Ducts."

END OF SECTION 23 3115
WMU Design Guidelines

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SECTION 23 3116 - NONMETAL DUCTS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

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

1.2 SUMMARY

A. Section Includes:

1. Fibrous-glass ducts and fittings.
2. Phenolic-foam ducts and fittings.
3. Thermoset FRP ducts and fittings.
4. PVC ducts and fittings.
5. CPVC ducts and fittings.

B. Related Requirements:

1. Section 23 0130.52 "Existing HVAC Air-Distribution System Cleaning" for cleaning of existing HVAC air-distribution equipment, ducts, plenums, and system components.
2. Section 23 0548 "Vibration and Seismic Controls for HVAC" for vibration-isolated and restrained ductwork hangers and supports.
3. Section 23 0548.13 "Vibration Controls for HVAC" for vibration-isolated ductwork and hangers.
4. Section 23 3113 "Metal Ducts" for single- and double-wall, rectangular and round ducts.
5. Section 23 3119 "HVAC Casings" for factory- and field-fabricated casings for mechanical equipment.

1.3 ACTION SUBMITTALS

A. Product Data: For each type of the following products:

1. Fibrous-glass duct materials.
2. Phenolic-foam duct materials.
3. Thermoset FRP duct materials.
4. PVC duct materials.
5. CPVC duct materials.
B. Sustainable Design Submittals:

1. <Double click to insert sustainable design text for HVAC units.>
2. <Double click to insert sustainable design text for adhesives.>
3. <Double click to insert sustainable design text for sealants.>

C. Shop Drawings:

1. Fabrication, assembly, and installation, including plans, elevations, sections, components, and attachments to other work.
2. Duct layout indicating sizes and pressure classes.
3. Elevation of top of ducts.
4. Dimensions of main duct runs from building grid lines.
5. Fittings.
6. Reinforcement and spacing.
7. Seam and joint construction.
8. Penetrations through fire-rated, smoke-rated, and other partitions.
9. Fire and smoke damper locations.
10. Equipment installation based on equipment being used on Project.
11. Hangers and supports, including methods for duct and building attachment[and seismic restraints.]

D. Delegated-Design Submittal: For nonmetal ducts, signed and sealed by a qualified professional engineer.

1. Duct materials and thicknesses.
2. Joint and seam construction and sealing.
3. Reinforcement details and spacing.
4. Materials, fabrication, assembly, and spacing of hangers and supports[and seismic restraints].
5. Design calculations for selecting hangers and supports[and seismic restraints]. Include analysis data signed and sealed by the qualified professional engineer responsible for their preparation.

1.4 INFORMATIONAL SUBMITTALS

A. Coordination Drawings: Plans, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:

1. Duct installation in congested spaces, indicating coordination with general construction, building components, including electrical, plumbing, fire protection, and other building services. Indicate proposed changes to duct layout.
2. Suspended ceiling components.
3. Structural members to which duct will be attached.
4. Size and location of initial access modules for acoustical tile.
5. Penetrations of smoke barriers and fire-rated construction.
6. Items provided by all trades mounted on or penetrating finished ceiling.

B. Seismic Qualification Data: Certificates, for nonmetal ducts, accessories, and components, from manufacturer.
1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.

C. Welding certificates.
D. Field quality-control reports.

1.5 QUALITY ASSURANCE

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

B. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1, Section 5 - "Systems and Equipment" and Section 7 - "Construction and System Start-up."

C. ASHRAE/IES Compliance: Applicable requirements in ASHRAE/IES 90.1, Section 6.4.4 - "HVAC System Construction and Insulation."

D. Mockups:
   1. Before installing duct systems, build mockups representing static-pressure classes [3-inch wg] <Insert value> and higher. Build mockups to comply with the following requirements, using materials indicated for the completed Work:
      a. [Five] <Insert number> transverse joints.
      b. [One] <Insert number> access door(s).
      c. [Two] <Insert number> typical branch connections, each with at least one elbow.
      d. [Two] <Insert number> typical flexible duct or flexible-connector connections for each duct and apparatus.
      e. [One] <Insert number> 90-degree turn(s) with turning vanes.
      f. [One] <Insert number> fire damper(s).
      g. [One] <Insert number> smoke damper(s).
      h. Perform leakage tests specified in "Field Quality Control" Article. Revise mockup construction and perform additional tests as required to achieve specified minimum acceptable results.

   2. Subject to compliance with requirements, approved mockups may become part of the completed Work if undisturbed at time of Substantial Completion.
PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

A. Delegated Duct Design: Duct construction, including duct closure, reinforcements, and hangers and supports, shall comply with the following and with the Works' performance requirements and design criteria:

1. SMACNA's "Fibrous Glass Duct Construction Standards."
2. SMACNA's "Phenolic Duct Construction Standards."
4. SMACNA's "Thermoset FRP Duct Construction Manual."
5. Static-Pressure Classes:
   b. Supply Ducts (Upstream from Air Terminal Units): [2-inch wg] <Insert value>.
   c. Supply Ducts (Downstream from Air Terminal Units): [1-inch wg] <Insert value>.
   e. Return Ducts (Negative Pressure): [1-inch wg] <Insert value>.
   g. <Insert duct systems and static-pressure class>.


1. Seismic Hazard Level: [A] [B] [C].

C. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1, Section 5.4 - "Airstream Surfaces."

D. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1, Section 5 - "Systems and Equipment" and Section 7 - "Construction and System Start-up."

E. ASHRAE/IES Compliance: Applicable requirements in ASHRAE/IES 90.1, Section 6.4.4 - "HVAC System Construction and Insulation."

F. NFPA Compliance:

1. NFPA 90A, "Installation of Air Conditioning and Ventilating Systems."
2. NFPA 90B, "Installation of Warm Air Heating and Air Conditioning Systems."

2.2 FIBROUS-GLASS DUCTS AND FITTINGS

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

B. Fibrous-Glass Duct Materials: Resin-bonded fiberglass, faced on the outside surface with fire-resistive FSK vapor retarder and with a smooth fiberglass mat finish on the air-side surface.
1. Duct Board: Factory molded into rectangular boards.
2. Temperature Limits: 40 to 250 deg F inside ducts; 150 deg F ambient temperature surrounding ducts.
3. Maximum Thermal Conductivity: \[0.24 \text{ Btu} \times \text{in./h} \times \text{sq. ft.} \times \text{deg F}\] at 75 deg F mean temperature.
4. Moisture Absorption: Not exceeding 5 percent by weight at 120 deg F and 95 percent relative humidity for 96 hours when tested according to ASTM C 1104/C 1104M.
6. Permeability: 0.02 perms maximum when tested according to ASTM E 96/E 96M, Procedure A.
7. Antimicrobial Agent: Compound shall be tested for efficacy by an NRTL, and registered by the EPA for use in HVAC systems.
8. Noise-Reduction Coefficient: 0.65 minimum when tested according to ASTM C 423, Mounting A.
9. Fire/Smoke Resistance: Duct material shall comply with UL 181, Class 1, maximum flame-spread index of 25 and maximum smoke-developed index of 50 when tested by an NRTL according to ASTM E 84.
10. Required Markings: EI stiffness rating, UL label, and other markings required by UL 181 on each full sheet of duct board.

C. Closure Materials:

1. Pressure-Sensitive Tape: Comply with UL 181A; imprinted by manufacturer with coding "181A-P," manufacturer's name, and a date code.
   a. Tape: Aluminum foil-scrim tape imprinted with listing information.
   b. Minimum Tape Width: 2-1/2 inches; 3 inches for duct board thicker than 1 inch.
   c. Staples: 1/2-inch outward clinching, 2 inches o.c. in tabs, one tab per joint.
   d. Water resistant.
   e. Mold and mildew resistant.

2. Heat-Activated Tape: Comply with UL 181A; imprinted by manufacturer with coding "181A-H," manufacturer's name, and a date code.
   a. Tape: Aluminum foil-scrim tape imprinted with listing information.
   b. Minimum Tape Width: 3 inches.
   c. Heat-Sensitive Imprint: Printed indicator on tape to show proper heating during application has been achieved.
   d. Water resistant.
   e. Mold and mildew resistant.

3. Two-Part Tape Sealing System: Comply with UL 181A; imprinted by manufacturer with coding "181A-M," manufacturer's name, and a date code.
   b. Minimum Tape Width: 3 inches.
   c. Sealant: Modified styrene acrylic.
   d. Water resistant.
   e. Mold and mildew resistant.
   f. \(<\text{Double click to insert sustainable design text for sealant}.>\)
g. <Double click to insert sustainable design text for sealant.>

D. Fabrication:

   a. Joints, seams, transitions, elbows, and branch connections.
   b. Reinforcements, including channel and tie rod reinforcement materials, spacing, and fabrications.

2. Fabricate 90-degree mitered elbows to include turning vanes.


2.3 PHENOLIC-FOAM DUCTS AND FITTINGS

NOTE:
AQC has duct insulated up to a R-12.
PTM has duct insulated up to a R-16.
Thermoduct has duct insulated up to a R-24.

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

1. AQC Industries, LLC.
2. PTM Manufacturing, LLC.
3. Thermoduct.

B. Duct Panel: CFC-free phenolic-foam bonded on both sides with factory-applied, 0.001-inch-thick, aluminum foil reinforced with fiberglass scrim.

1. Temperature Limits:
   a. Maximum 176 deg F.
   b. Minimum: Minus 4 deg F.

2. Maximum Thermal Conductivity: [0.15 Btu x in./h x sq. ft. x deg F] <Insert conductivity> at 75 deg F mean temperature.
3. Permeability: 0.0002 perms maximum when tested according to ASTM E 96/E 96M, Procedure A.
4. Antimicrobial Agent: Compound shall be tested for efficacy by an NRTL, and registered by the EPA for use in HVAC systems.
5. Noise-Reduction Coefficient: 0.65 minimum when tested according to ASTM C 423, Mounting A.

6. Fire/Smoke Resistance: Duct material shall comply with UL 181, Class 1, maximum flame-spread index of 25 and maximum smoke-developed index of 50 when tested by an NRTL according to ASTM E 84.

7. Required Markings: UL label and other markings required by UL 181 on each full sheet of duct panel; UL ratings for closure materials.

C. Closure Materials:

   a. <Double click to insert sustainable design text for sealant.>
   b. <Double click to insert sustainable design text for sealant.>

2. Pressure-Sensitive Tape: Comply with UL 181A; imprinted by manufacturer with coding “181A-P,” manufacturer's name, and a date code.
   a. Tape: Aluminum foil tape imprinted with listing information.
   b. Minimum Tape Width: 3 inches.
   c. Water resistant.
   d. Mold and mildew resistant.

3. Polymeric Sealing System:
   a. Structural Membrane: Woven glass fiber.
   b. Minimum Tape Width: 3 inches.
   c. Sealant: Water based.
   e. Water resistant.
   f. Mold and mildew resistant.
   g. <Double click to insert sustainable design text for sealant.>
   h. <Double click to insert sustainable design text for sealant.>

D. Fabrication:

1. Fabricate joints, seams, transitions, reinforcement, elbows, branch connections, access doors and panels, and damage repairs according manufacturer's written instructions.
2. Fabricate 90-degree mitered elbows to include turning vanes.

2.4 THERMOSET FRP DUCTS AND FITTINGS

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

B. Duct and Fittings:
1. Thermoset FRP Resin: Comply with UL 181, Class 1, maximum flame-spread index of 25 and maximum smoke-developed index of 50 when tested by an NRTL according to ASTM E 84.
2. Inner Liner: FSK liner rated by an NRTL to comply with UL 181, Class 1.
3. Round Duct: ASTM D 2996, Type I, Grade 2, Class E, filament-wound duct, minimum [0.125-inch] <Insert dimension> wall thickness, with tapered bell-and-spigot ends for adhesive joints or with plain ends with couplings.
4. Round Fittings: Compression or spray-up/contact, molded of same material, pressure class, and joining method as duct.
5. Rectangular Fittings: Minimum [0.125-inch-] <Insert dimension> thick, flat sheet with fiberglass roving and resin-reinforced joints and seams.
6. Double-Wall Insulated Duct: Inner and outer duct complying with requirements in "Round Duct" Subparagraph. Polyurethane foam or isocyanurate insulation with maximum thermal conductivity of [0.14 Btu x in./h x sq. ft. x deg F] <Insert conductivity> at 75 deg F mean temperature.

C. Joining Materials: Roving and polyester resin.

1. <Double click to insert sustainable design text for fiberglass pipe adhesive.>
2. <Double click to insert sustainable design text for low emitting adhesives.>

D. Fabrication:

1. Fabricate joints, seams, transitions, reinforcement, elbows, branch connections, and access doors and panels according to SMACNA's "Thermoset FRP Duct Construction Manual," Ch. 7, "Requirements."
2. Fabricate 90-degree rectangular mitered elbows to include turning vanes, and 90-degree round elbows with a minimum of three segments for 12 inches and smaller and a minimum of five segments for 14 inches and larger.

E. Drains: Formed drain pockets with a minimum of NPS 1 threaded pipe connections.

2.5 PVC DUCTS AND FITTINGS

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

B. Duct and Fittings:

1. Material: Rigid, virgin PVC compound complying with ASTM D 1784 Cell Classification 12454-B.
2. Flammability: Maximum flame-spread index of not more than 25 without evidence of continued progressive combustion.
4. Minimum Round Duct Wall Thickness: [0.187 inch for up to 18-inch] [0.219 inch for up to 20-inch] [0.25 inch for up to 24-inch] <Insert dimensions> duct.
5. Round Fittings: Socket end molded of same material, pressure class, and joining method as duct.
6. Rectangular Fittings: Minimum [0.125-inch-] <Insert dimension> thick, flat sheet with heat-formed corners and continuous welded butt joints.

C. Joining Materials: PVC solvent cement complying with ASTM D 2564.
1. <Double click to insert sustainable design text for adhesive primer.>
2. <Double click to insert sustainable design text for adhesive primer.>
3. <Double click to insert sustainable design text for solvent cement.>
4. <Double click to insert sustainable design text for low emitting adhesives.>

D. Fabrication:

2. Fabricate 90-degree rectangular mitered elbows to include turning vanes, and 90-degree round elbows with a minimum of three segments for 12 inches and smaller and a minimum of five segments for 14 inches and larger.

E. Drains: PVC drain pockets with a minimum of NPS 1 threaded PVC pipe connections.

2.6 CPVC DUCTS AND FITTINGS

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

B. Duct and Fittings:

1. Material: Rigid, virgin CPVC compound complying with ASTM D 1784 Cell Classification 23447.
2. Flammability: Maximum flame-spread index of not more than 25 without evidence of continued progressive combustion and a smoke-developed index of not more than 50.
3. Maximum Service Temperature: 200 deg F.
5. Round Fittings: Socket end molded of same material, pressure class, and joining method as duct.
6. Rectangular Fittings: Minimum [0.125-inch-] <Insert dimension> thick, flat sheet with heat-formed corners and continuous welded butt joints.


1. <Double click to insert sustainable design text for adhesive primer.>
2. <Double click to insert sustainable design text for adhesive primer.>
3. <Double click to insert sustainable design text for solvent cement.>
4. <Double click to insert sustainable design text for low emitting adhesives.>

D. Fabrication:

2. Fabricate 90-degree rectangular mitered elbows to include turning vanes, and 90-degree round elbows with a minimum of three segments for 12 inches and smaller and a minimum of five segments for 14 inches and larger.

E. Drains: CPVC drain pockets with a minimum of NPS 1 threaded CPVC pipe connections.
2.7 HANGERS AND SUPPORTS

A. Hanger Rods for Noncorrosive Environments: Zinc-plated steel rods and nuts.

B. Hanger Rods for Corrosive Environments: Electrogalvanized, all-thread rods or galvanized rods with threads painted with zinc-chromate primer after installation.

C. Strap and Rod Sizes: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Table 5-1, "Rectangular Duct Hangers Minimum Size," and Table 5-2, "Minimum Hanger Sizes for Round Duct."

D. Steel Cables: [ASTM A 603, galvanized] [ASTM A 492, stainless]-steel cables with end connections made of [zinc-plated ] [stainless]-steel assemblies with brackets, swivel, and bolts designed for duct hanger service; with an automatic-locking and clamping device.

E. Duct Attachments: Sheet metal screws, blind rivets, or self-tapping metal screws; compatible with duct materials.

F. Trapeze and Riser Supports: Steel shapes complying with ASTM A 36/A 36M.

2.8 SEISMIC-RESTRAINT DEVICES

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

B. General Requirements for Restraint Components: Rated strengths, features, and applications shall be as defined in reports by [an evaluation service member of ICC-ES] [the Office of Statewide Health Planning and Development for the State of California] [an agency acceptable to authorities having jurisdiction].

1. Structural Safety Factor: Allowable strength in tension, shear, and pullout force of components shall be at least [four] <Insert number> times the maximum seismic forces to which they will be subjected.

C. Channel Support System: Shop- or field-fabricated support assembly made of slotted steel channels with accessories for attachment to braced component at one end and to building structure at the other end. Include matching components and corrosion-resistant coating.

D. Restraint Cables: [ASTM A 603, galvanized] [ASTM A 492, stainless]-steel cables with end connections made of [zinc plated ] [stainless]-steel assemblies with brackets, swivel, and bolts designed for restraining cable service; with an automatic-locking and clamping device or double-cable clips.

E. Hanger Rod Stiffener: [Steel tube or steel slotted-support-system sleeve with internally bolted connections] [Reinforcing steel angle clamped] to hanger rod.

F. Mechanical Anchor Bolts: Drilled-in and stud-wedge or female-wedge type. Select anchor bolts with strength required for anchor and as tested according to ASTM E 488/E 488M.
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 duct sections in maximum practical lengths with fewest possible joints.

C. Install factory- or shop-fabricated fittings for changes in direction, size, and shape and for branch connections.

D. Unless otherwise indicated, install ducts vertically and horizontally, and parallel and perpendicular to building lines.

E. Install ducts close to walls, overhead construction, columns, and other structural and permanent enclosure elements of building.

F. Install ducts with a minimum clearance of 1 inch, plus allowance for insulation thickness.

G. Route ducts to avoid passing through transformer vaults and electrical equipment rooms and enclosures.

H. Where ducts pass through non-fire-rated interior partitions and exterior walls, and are exposed to view, cover the opening between the partition and duct or duct insulation with sheet metal flanges. Overlap openings on four sides by at least 1-1/2 inches.

I. Install fire[, combination fire/smoke,] and smoke dampers where indicated on Drawings and as required by code and by authorities having jurisdiction. Comply with requirements in Section 23 3300 "Air Duct Accessories" for fire and smoke dampers and specific installation requirements of the fire damper UL listing.

J. Install heating coils, cooling coils, air filters, dampers, and all other duct-mounted accessories in air ducts where indicated on Drawings.

K. Protect duct interiors from moisture, construction debris and dust, and other foreign materials both before and after installation. [Comply with SMACNA's "IAQ Guidelines for Occupied Buildings under Construction," Appendix G, "Duct Cleanliness for New Construction Guidelines."]

L. Elbows: Use long-radius elbows wherever they fit.

1. Fabricate 90-degree rectangular mitered elbows to include turning vanes, and 90-degree round elbows with a minimum of three segments for 12 inches and smaller and a minimum of five segments for 14 inches and larger.

M. Branch Connections: Use lateral or conical branch connections.
N. Install fibrous-glass ducts and fittings to comply with [NAIMA AH116, “Fibrous Glass Duct Construction Standards.”] [SMACNA’s “Fibrous Glass Duct Construction Standards.”]

O. Install phenolic-foam ducts and fittings to comply with SMACNA’s “Phenolic Duct Construction Standards.”

P. Install thermoset FRP ducts and fittings to comply with SMACNA’s “Thermoset FRP Duct Construction Manual.”

Q. Install PVC ducts and fittings to comply with SMACNA’s “Thermoplastic Duct (PVC) Construction Manual.”

R. Install CPVC ducts and fittings to comply with SMACNA’s “Thermoplastic Duct (PVC) Construction Manual.”

3.2 HANGER AND SUPPORT INSTALLATION


B. Install hangers and supports for phenolic-foam ducts and fittings to comply with SMACNA’s “Phenolic Duct Construction Standards” Ch. 6, “Hangers and Supports” and with manufacturer’s written instructions.

C. Install hangers and supports for thermoset FRP ducts and fittings to comply with SMACNA’s “Thermoset FRP Duct Construction Manual,” Ch. 7, “Requirements.”


F. Building Attachments: Concrete inserts, powder-actuated fasteners, or structural-steel fasteners appropriate for construction materials to which hangers are being attached.

1. 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.

G. 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 ducts with hangers and braces designed to support the duct and to restrain against seismic forces required by applicable building codes. Comply with [SMACNA’s "Seismic Restraint Manual: Guidelines for Mechanical Systems." ] [ASCE/SEI 7.]

1. Space lateral supports a maximum of [40 feet] <Insert dimension> o.c., and longitudinal supports a maximum of [80 feet] <Insert dimension> o.c.
2. Brace a change of direction longer than 12 feet.

B. Select sizes of components so strength will be adequate to carry present and future static and seismic loads within restraint device capacity.

C. Install cables so they do not bend across edges of adjacent equipment or building structure.

D. Install cable restraints where ducts are suspended with vibration isolators.

E. Install seismic-restraint devices using methods approved by [an evaluation service member of the ICC Evaluation Service] [the Office of Statewide Health Planning and Development for the State of California] [an agency acceptable to authorities having jurisdiction].

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

G. Drilling for and Setting Anchors:

1. Identify position of reinforcing steel and other embedded items prior to drilling holes for anchors. Do not damage existing reinforcement or embedded items during drilling. Notify Architect if reinforcing steel or other embedded items are encountered during drilling. Locate and avoid prestressed tendons, electrical and telecommunications conduit, and water 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 applications and stainless-steel anchors for applications exposed to weather.

3.4 PAINTING

A. Paint interior of [thermoset FRP] [PVC] [and] [CPVC] ducts that are visible through registers and grilles and that do not have duct liner. Apply one coat of flat, black, acrylic or latex paint that is chemically compatible with duct material. Confirm compatibility information with paint manufacturer. Oil-based paint is not recommended. Paint materials and application requirements are specified in Section 09 9123 "Interior Painting."
3.5 FIELD QUALITY CONTROL

A. Testing Agency: Owner will engage a qualified testing agency to perform tests and inspections.

B. Testing Agency: Engage a qualified testing agency to perform tests and inspections.

C. Manufacturer’s Field Service: Engage a factory-authorized service representative to test and inspect components, assemblies, and equipment installations, including connections.

D. Perform tests and inspections with the assistance of a factory-authorized service representative.

E. Leakage Tests:

2. Where static pressure and leakage values shown below differ from those in the SMACNA manual, the more stringent values shall apply.
3. Test the following systems:
   a. Ducts with a Pressure Class Higher Than 3-Inch wg: Test representative duct sections, selected by Architect from sections installed, totaling no less than 25 percent of total installed duct area for each designated pressure class.
   b. Supply Ducts with a Pressure Class of [2-Inch wg] [3-Inch wg] [4-Inch wg] <Insert value> or Higher: Test representative duct sections, selected by Architect from sections installed, totaling no less than [50] [100] <Insert number> percent of total installed duct area for each designated pressure class.
   c. Return Ducts with a Pressure Class of [2-Inch wg] [3-Inch wg] [4-Inch wg] <Insert value> or Higher: Test representative duct sections, selected by Architect from sections installed, totaling no less than [50] [100] <Insert number> percent of total installed duct area for each designated pressure class.
   d. Exhaust Ducts with a Pressure Class of [2-Inch wg] [3-Inch wg] [4-Inch wg] <Insert value> or Higher: Test representative duct sections, selected by Architect from sections installed, totaling no less than [50] [100] <Insert number> percent of total installed duct area for each designated pressure class.
   e. Outdoor Air Ducts with a Pressure Class of [2-Inch wg] [3-Inch wg] [4-Inch wg] <Insert value> or Higher: Test representative duct sections, selected by Architect from sections installed, totaling no less than [50] [100] <Insert number> percent of total installed duct area for each designated pressure class.

4. Disassemble, reassemble, and seal segments of systems to accommodate leakage testing and for compliance with test requirements.
5. Test for leaks before applying external insulation.
6. Conduct tests at static pressures equal to maximum design pressure of system or section being tested. If static-pressure classes are not indicated, test entire system at maximum system design pressure. Do not pressurize systems above maximum design operating pressure.
7. Give [seven] <Insert number> days’ advance notice for testing.

F. Duct System Cleanliness Tests:
1. Test protocols shall be performed according to NADCA ACR, "Assessment, Cleaning and Restoration of HVAC Systems," "Section 5 - Cleanliness Verification and Documentation."

2. Visually inspect duct system to ensure that no visible contaminants are present.

3. Test sections of fibrous-glass duct system chosen randomly by Owner for cleanliness according to "Method 2 Protocol."

4. Test sections of Phenolic-foam, Thermoset FRP, PVC, and CPVC duct systems chosen randomly by Owner, for cleanliness according to "Method 3 - NADCA Vacuum Test."

   a. Acceptable Cleanliness Level: Net weight of debris collected on the filter media shall not exceed 0.75 mg/100 sq. cm.

G. Duct system will be considered defective if it does not pass tests and inspections.

H. Prepare test and inspection reports.

3.6 DUCT CLEANING

A. Clean duct system(s) before testing, adjusting, and balancing.

B. Use service openings for entry and inspection.

   1. Create new openings and install access panels appropriate for duct static-pressure class if required for cleaning access. Provide insulated panels for insulated or lined duct. Patch duct as recommended by duct manufacturer. Comply with Section 23 3300 "Air Duct Accessories" for access panels and doors.

   2. Disconnect and reconnect flexible ducts as needed for cleaning and inspection.

   3. Remove and reinstall ceiling to gain access during the cleaning process.

C. Particulate Collection and Odor Control:

   1. When venting vacuuming system inside the building, use HEPA filtration with 99.97 percent collection efficiency for 0.3-micron (or larger) particles.

   2. When venting vacuuming system to outdoors, use filter to collect debris removed from HVAC system, and locate exhaust downwind and away from air intakes and other points of entry into building.

D. Clean the following components by removing surface contaminants and deposits:

   1. Air outlets and inlets (registers, grilles, and diffusers).

   2. Supply, return, and exhaust fans including fan housings, plenums (except ceiling supply and return plenums), scrolls, blades or vanes, shafts, baffles, dampers, and drive assemblies.

   3. Air-handling unit internal surfaces and components including mixing box, coil section, air wash systems, spray eliminators, condensate drain pans, humidifiers and dehumidifiers, filters and filter sections, and condensate collectors and drains.


   5. Return-air ducts, dampers, actuators, and turning vanes except in ceiling plenums and mechanical equipment rooms.


   7. Dedicated exhaust and ventilation components and makeup air systems.
E. Mechanical Cleaning Methodology:

1. All duct cleaning shall be performed according to NADCA ACR, "Assessment, Cleaning and Restoration of HVAC Systems."
2. Use vacuum-collection devices that are operated continuously during cleaning. Connect vacuum device to downstream end of duct sections so areas being cleaned are under negative pressure.
3. Use mechanical agitation to dislodge debris adhered to interior duct surfaces without damaging integrity of ducts or duct accessories.
4. Clean fibrous-glass duct with HEPA vacuuming equipment; do not permit duct to get wet. Replace fibrous-glass duct that is damaged, deteriorated, or delaminated or that has friable material, mold, or fungus growth.
5. Clean coils and coil drain pans according to NADCA 1992. Keep drain pan operational. Rinse coils with clean water to remove latent residues and cleaning materials; comb and straighten fins.
6. Provide drainage and cleanup for washdown procedures.
7. Antimicrobial Agents and Coatings: Apply EPA-registered antimicrobial agents if fungus is present. Apply antimicrobial agents according to manufacturer's written instructions after removing surface deposits and debris.

3.7 STARTUP SERVICE

A. Air Balance: Comply with requirements in Section 23 0593 “Testing, Adjusting, and Balancing for HVAC.”

3.8 DUCT SCHEDULE

A. Indoor Ducts and Fittings:

1. Fibrous-Glass Rectangular Ducts and Fittings:
   a. Minimum Flexural Rigidity: EI-[475] [800] [1400].
   b. Minimum Board Thickness: [1 inch] [1-1/2 inches] [2 inches].

2. Phenolic-Foam Rectangular Ducts and Fittings:
   a. Minimum Panel Thickness: [7/8 inch] [1-3/32 inches].
   b. Aluminum Cladding: Minimum 0.025 inch thick.
   c. Joints: Secure joints with adhesive or clips according to duct manufacturer's written instructions, then tape joints with aluminum vapor tape.
   d. Sealing: All joints shall be sealed with a generous and continuous bead of silicone sealant and pressed into corners using a smooth radius tool.

B. Outdoor Ducts and Fittings:

1. Provide suitable external surface protection as recommended by manufacturer.
2. Phenolic-Foam Rectangular Ducts and Fittings:
   a. Minimum Panel Thickness: [7/8 inch] [1-3/32 inches].
   b. Aluminum Cladding: Minimum 0.032 inch thick.
c. Joints: Secure joints with adhesive or clips according to duct manufacturer's written instructions, then tape joints with aluminum vapor tape.
d. Sealing: All joints shall be sealed with a generous and continuous bead of silicone sealant and pressed into corners using a smooth radius tool.

3. Thermoset FRP Round Ducts and Fittings:
   a. Double-Wall Insulated Ducts: Minimum \([5/8\text{-inch}]\) \([7/8\text{-inch}]\) \([1\text{-inch}]\) insulation thickness with \([k\text{-factor of 14}]\) \(<\text{Insert value}>\) insulation thickness.

C. Underground Ducts:
   1. Provide suitable external surface protection as recommended by manufacturer.
   2. Thermoset FRP Round Ducts and Fittings:
      a. Double wall.
      b. Insulation Thickness: [1 inch] \(<\text{Insert dimension}>\).
      c. Drain: Minimum NPS 1 PVC pipe with P-trap to air-gap drain.

3. PVC Round Ducts and Fittings:
   a. Drain: Minimum NPS 1 PVC pipe with P-trap to air-gap drain.

4. CPVC Round Ducts and Fittings:
   a. Drain: Minimum NPS 1 CPVC pipe with P-trap to air-gap drain.

D. Fume Exhaust:
   1. Thermoset FRP ducts and fittings.
   2. Install exhaust ducts without dips and traps that may hold condensate or other liquid, and sloped a minimum of 2 percent to drain. Where indicated on Drawings, install trapped drain piping.
   3. Connect duct to fume hood or other equipment where indicated on Drawings.

END OF SECTION 23 3116
WMU Design Guidelines Instructions: These guidelines are to be used by the Design Professional to inform the design process and outline WMU-specific desires for all University projects. These guidelines have been edited to reflect WMU preferences, and the intent is for the Design Professional to use this information to guide their normal specifications-writing process. Straying from what is indicated in the guidelines is not prohibited, but shall be discussed with WMU during the development of the project.

SECTION 23 3300 - AIR DUCT ACCESSORIES

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:

1. Backdraft and pressure relief dampers.
2. Barometric relief dampers.
4. Control dampers.
5. Fire dampers.
6. Ceiling dampers.
7. Smoke dampers.
8. Combination fire and smoke dampers.
9. Corridor dampers.
10. Flange connectors.
11. Duct silencers.
12. Turning vanes.
14. Duct-mounted access doors.
15. Flexible connectors.
16. Flexible ducts.
17. Duct security bars.

B. Related Sections:

1. Division 23 Section “Instrumentation and Control for HVAC” for motorized control dampers and damper actuators.
2. Division 23 Section “HVAC Gravity Ventilators” for roof-mounted ventilator caps.
3. Division 28 Section “Fire Detection and Alarm” for duct-mounted fire and smoke detectors.

1.2 ACTION SUBMITTALS

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

1. For duct silencers, include pressure drop and dynamic insertion loss data. Include breakout noise calculations for high transmission loss casings.

B. LEED Submittal:
1. Product Data for Prerequisite EQ 1: Documentation indicating that units comply with ASHRAE 62.1, Section 5 - "Systems and Equipment."

C. Shop Drawings: For duct accessories. Include plans, elevations, sections, details and attachments to other work.

   1. Detail duct accessories fabrication and installation in ducts and other construction. Include dimensions, weights, loads, and required clearances; and method of field assembly into duct systems and other construction. Include the following:
      a. Special fittings.
      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. Coordination Drawings: Reflected ceiling plans, drawn to scale, on which ceiling-mounted access panels and access doors required for access to duct accessories are shown and coordinated with each other, using input from Installers of the items involved.

   B. Source quality-control reports.

1.4 CLOSEOUT SUBMITTALS

   A. Operation and maintenance data.

1.5 MAINTENANCE MATERIAL SUBMITTALS

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

      1. Fusible Links: Furnish quantity equal to 10 percent of amount installed.

1.6 QUALITY ASSURANCE


   B. Comply with AMCA 500-D testing for damper rating.
PART 2 - PRODUCTS

2.1 MATERIALS

A. Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" for acceptable materials, material thicknesses, and duct construction methods unless otherwise indicated. Sheet metal materials shall be free of pitting, seam marks, roller marks, stains, discolorations, and other imperfections.

B. Galvanized Sheet Steel: Comply with ASTM A 653/A 653M.
   2. Galvanized Coating Designation: [G60] [G90].

C. Stainless-Steel Sheets: Comply with ASTM A 480/A 480M, Type 304, and having a No. 2D finish for concealed applications and No. 4 for exposed applications.

D. Aluminum Sheets: Comply with ASTM B 209, Alloy 3003, Temper H14; with mill finish for concealed ducts and standard, 1-side bright finish for exposed ducts.

E. Extruded Aluminum: Comply with ASTM B 221, Alloy 6063, Temper T6.

F. Reinforcement Shapes and Plates: Galvanized-steel reinforcement where installed on galvanized sheet metal ducts; compatible materials for aluminum and stainless-steel ducts.

G. Tie Rods: Galvanized steel, 1/4-inch minimum diameter for lengths 36 inches or less; 3/8-inch minimum diameter for lengths longer than 36 inches.

2.2 BACKDRAFT AND PRESSURE RELIEF DAMPERS

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

   1. Air Balance Inc., a division of Mestek, Inc.
   2. American Warming and Ventilating, a division of Mestek, Inc.
   3. Cesco Products, a division of Mestek, Inc.
   4. Duro Dyne Inc.
   5. Greenheck Fan Corporation.
   6. Nailor Industries Inc.
   7. NCA Manufacturing, Inc.
   8. Ruskin Company.
   9. SEMCO Incorporated.

B. Description: Gravity balanced.

C. Maximum Air Velocity: [2000 fpm] [3000 fpm] <Insert value>.
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D. Maximum System Pressure: [1-inch wg] [2-inch wg] <Insert value>.

E. Frame: Galvanized sheet steel, [stainless steel, ] or extruded aluminum with welded corners[ and mounting flange].

F. Blades: Multiple single-piece galvanized steel, [stainless steel, ] or aluminum blades, maximum 6-inch width, with sealed edges.

G. Blade Action: Parallel.

H. Blade Seals: Felt, vinyl, or neoprene, mechanically locked.

I. Blade Axles:
   1. Material: Nonferrous metal, galvanized steel, plated steel, stainless steel, or aluminum.
   2. Diameter: 0.20 inch.

J. Tie Bars and Brackets: Aluminum or galvanized steel.

K. Return Spring: Adjustable tension.

L. Bearings: Steel ball or synthetic pivot bushings.

M. Accessories:
   1. Adjustment device to permit setting for varying differential static pressure.
   2. Counterweights and spring-assist kits for vertical airflow installations.
   3. Electric actuators.
   4. Chain pulls.
   5. Screen Mounting: Front mounted in sleeve.
      a. Sleeve Thickness: 20-gage minimum.
      b. Sleeve Length: 6 inches minimum.
   6. Screen Mounting: Rear mounted.
   7. Screen Material: [Galvanized steel] [Aluminum].
   8. Screen Type: [Bird] [Insect].
   9. 90-degree stops.

2.3 BAROMETRIC RELIEF DAMPERS

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

   1. Air Balance Inc.; a division of Mestek, Inc.
   2. American Warming and Ventilating; a division of Mestek, Inc.
   3. Cesco Products; a division of Mestek, Inc.
   4. Duro Dyne Inc.
   5. Greenheck Fan Corporation.
   6. Nailor Industries Inc.
   7. NCA Manufacturing, Inc.
   8. Ruskin Company.
9. SEMCO Incorporated.

B. Suitable for horizontal or vertical mounting.

C. Maximum Air Velocity: \[2000 \text{ fpm}\] \[2500 \text{ fpm}\] <Insert value>.

D. Maximum System Pressure: 2-inch wg.

E. Frame: Galvanized steel or aluminum, with welded corners[ and mounting flange].

F. Blades:
   1. Multiple, roll-formed aluminum or aluminum sheet.
   3. Action: Parallel.
   5. Eccentrically pivoted.

G. Blade Seals: Vinyl or neoprene.

H. Blade Axles: Galvanized steel or nonferrous metal.

I. Tie Bars and Brackets:
   1. Material: Aluminum or galvanized steel.
   2. Rattle free with 90-degree stop.

J. Return Spring: Adjustable tension.

K. Bearings: Synthetic, stainless steel, or bronze.

L. Accessories:
   1. Flange on intake.
   2. Adjustment device to permit setting for varying differential static pressures.

2.4 MANUAL VOLUME DAMPERS

A. Standard, Steel, Manual Volume Dampers:
   1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
      a. Air Balance Inc.; a division of Mestek, Inc.
      b. American Warming and Ventilating; a division of Mestek, Inc.
      c. Flexmaster U.S.A., Inc.
      d. Greenheck.
      e. McGill AirFlow LLC.
      f. METALAIRE, Inc.
2. Standard leakage rating, with linkage outside airstream.
3. Standard leakage rating, with linkage outside airstream.
4. Suitable for horizontal or vertical applications.
5. Frames:
   a. Hat-shaped, galvanized-steel channels, 0.064-inch minimum thickness.
   b. Hat-shaped, galvanized-stainless-steel channels, 0.064-inch minimum thickness.
   c. Mitered and welded corners.
   d. Flanges for attaching to walls and flangeless frames for installing in ducts.
6. Blades:
   a. Multiple or single blade.
   b. Parallel- or opposed-blade design.
   c. Stiffen damper blades for stability.
   d. Galvanized-steel, 0.064 inch thick.
   e. Galvanized-stainless-steel, 0.064 inch thick.
8. Blade Axles: Galvanized steel [Stainless steel] [Nonferrous metal].
9. Bearings:
   a. Oil-impregnated bronze or molded synthetic.
   b. Oil-impregnated bronze [Molded synthetic] [Stainless-steel sleeve].
   c. Dampers in ducts with pressure classes of 3-inch wg or less shall have axles full length of damper blades and bearings at both ends of operating shaft.
10. Tie Bars and Brackets: Galvanized steel.

B. Standard, Aluminum, Manual Volume Dampers:
1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   a. Air Balance Inc.; a division of Mestek, Inc.
   b. American Warming and Ventilating; a division of Mestek, Inc.
   c. Flexmaster U.S.A., Inc.
   d. McGill AirFlow LLC.
   e. METALAIRE, Inc.
   f. Nailor Industries Inc.
   g. Ruskin Company.
   h. Vent Products Company, Inc.
2. Standard leakage rating, with linkage outside airstream.
3. Suitable for horizontal or vertical applications.
4. Frames: Hat-shaped, 0.10-inch thick, aluminum sheet channels; frames with flanges for attaching to walls and flangeless frames for installing in ducts.
5. **Blades:**
   a. Multiple or single blade.
   b. Parallel- or opposed-blade design.
   c. Stiffen damper blades for stability.
   d. Blades: Aluminum sheet or extruded aluminum.

6. **Blade Axles:** Galvanized steel.

7. **Bearings:**
   a. Oil-impregnated bronze or molded synthetic.
   b. Dampers in ducts with pressure classes of 3-inch wg or less shall have axles full length of damper blades and bearings at both ends of operating shaft.

8. **Tie Bars and Brackets:** Aluminum.

C. **Low-Leakage, Steel, Manual Volume Dampers:**

D. **Low-Leakage, Aluminum, Manual Volume Dampers:**

E. **Jackshaft:**

F. **Damper Hardware:**
   1. Locking manual quadrant calibrated to show damper position.
   3. Include center hole to suit damper operating-rod size.
   4. Include elevated platform for insulated duct mounting.

2.5 **CONTROL DAMPERS**

A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
   1. American Warming and Ventilating; a division of Mestek, Inc.
   2. Arrow United Industries; a division of Mestek, Inc.
   3. Cesco Products; a division of Mestek, Inc.
   4. Duro Dyne Inc.
   5. Flexmaster U.S.A., Inc.
   7. Lloyd Industries, Inc.
   8. M&I Air Systems Engineering; Division of M&I Heat Transfer Products Ltd.
   9. McGill AirFlow LLC.
   10. METALAIRE, Inc.
   11. Metal Form Manufacturing, Inc.
   12. Nailor Industries Inc.
   13. NCA Manufacturing, Inc.
   15. Vent Products Company, Inc.
   16. Young Regulator Company.
B. Low-leakage rating, with linkage outside airstream, and bearing AMCA’s Certified Ratings Seal for both air performance and air leakage.

C. Frames:
   1. [Hat] [U] [Angle] shaped.
   2. [Galvanized] [Stainless]-steel channels, 0.064 inch thick.
   3. Mitered and welded corners.

D. Blades:
   1. Multiple blade with maximum blade width of 8 inches.
   2. [Parallel] [Parallel- and opposed] [Opposed]-blade design.
   3. [Galvanized] [Stainless] steel.
   4. 0.064 inch thick.

E. Blade Axles: 1/2-inch- diameter; [galvanized steel] [stainless steel] [nonferrous metal]; blade-linkage hardware of zinc-plated steel and brass; ends sealed against blade bearings.
   1. Operating Temperature Range: From minus 40 to plus 200 deg F.

F. Bearings:
   1. [Oil-impregnated bronze] [Molded synthetic] [Stainless-steel sleeve].
   2. Dampers in ducts with pressure classes of 3-inch wg or less shall have axles full length of damper blades and bearings at both ends of operating shaft.
   3. Thrust bearings at each end of every blade.

2.6 FIRE DAMPERS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   1. Air Balance Inc.; a division of Mestek, Inc.
   2. Arrow United Industries; a division of Mestek, Inc.
   3. Cesco Products; a division of Mestek, Inc.
   5. McGill AirFlow LLC.
   6. METALAIRE, Inc.
   7. Nailor Industries Inc.
   8. NCA Manufacturing, Inc.
   10. Ruskin Company.

B. Type: Static; rated and labeled according to UL 555 by an NRTL.
C. Type: [Static] [Dynamic] [Static and dynamic]; rated and labeled according to UL 555 by an NRTL.

D. Closing rating in ducts up to [4-inch wg] <Insert value> static pressure class and minimum [4000-fpm] <Insert value> velocity.

E. Fire Rating: 1-1/2 hours.

F. Fire Rating: [1-1/2] [and] [3] hours.

G. Frame: Curtain type with blades outside airstream except when located behind grille where blades may be inside airstream; fabricated with roll-formed, 0.034-inch- thick galvanized steel; with mitered and interlocking corners.

H. Frame: [Curtain type with blades inside airstream] [Curtain type with blades outside airstream] [Multiple-blade type] [Curtain type with blades outside airstream except when located behind grille where blades may be inside airstream]; fabricated with roll-formed, 0.034-inch- thick galvanized steel; with mitered and interlocking corners.

I. Mounting Sleeve: Factory- or field-installed, galvanized sheet steel.
   1. Minimum Thickness: 0.052 or 0.138 inch thick, as indicated, and of length to suit application.
   2. Exception: Omit sleeve where damper-frame width permits direct attachment of perimeter mounting angles on each side of wall or floor; thickness of damper frame must comply with sleeve requirements.

J. Mounting Orientation: Vertical or horizontal as indicated.

K. 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.

L. Horizontal Dampers: Include blade lock and stainless-steel closure spring.

M. Heat-Responsive Device: Replaceable, 165 deg F rated, fusible links.

N. Heat-Responsive Device: Replaceable, [165 deg F] [212 deg F] <Insert temperature> rated, fusible links.

O. Heat-Responsive Device: [Electric] [Pneumatic] resettable link and switch package, factory installed, [165 deg F] [and] [212 deg F] <Insert temperature> rated.

2.7 CEILING DAMPERS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   1. Air Balance Inc.; a division of Mestek, Inc.
   2. Cesco Products; a division of Mestek, Inc.
   3. McGill AirFlow LLC.
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4. METALAIRE, Inc.
5. Nailor Industries Inc.
6. Pottorff.
7. Prefco; Perfect Air Control, Inc.
8. Ruskin Company.

B. General Requirements:

1. Labeled according to UL 555C by an NRTL.
2. 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.


F. Heat-Responsive Device: Replaceable, [165 deg F] [212 deg F] <Insert temperature> rated, fusible links.


2.8 SMOKE DAMPERS

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

1. Air Balance Inc.; a division of Mestek, Inc.
2. Cesco Products; a division of Mestek, Inc.
4. Nailor Industries Inc.
5. Pottorff.
6. Ruskin Company.

B. General Requirements: Label according to UL 555S by an NRTL.

C. Smoke Detector: Integral, factory wired for single-point connection.

D. Frame: Multiple-blade type; fabricated with roll-formed, 0.034-inch- thick galvanized steel; with mitered and interlocking corners.

E. Frame: [Curtain type with blades inside airstream] [Curtain type with blades outside airstream] [Multiple-blade type] [Curtain type with blades outside airstream except when located behind grille where blades may be inside airstream]; fabricated with roll-formed, 0.034-inch- thick galvanized steel; with mitered and interlocking corners.

F. Blades: Roll-formed, horizontal, interlocking, 0.034-inch- thick, galvanized sheet steel. In place of interlocking blades, use full-length, 0.034-inch- thick, galvanized-steel blade connectors.
G. Leakage: Class II.

H. Leakage: [Class I] [Class II] <Insert class>.

I. Rated pressure and velocity to exceed design airflow conditions.

J. Mounting Sleeve: Factory-installed, 0.052-inch-thick, galvanized sheet steel; length to suit wall or floor application.

K. Mounting Sleeve: Factory-installed, 0.052-inch-thick, galvanized sheet steel; length to suit wall or floor application [with factory-furnished silicone calking].

L. Damper Motors: Two-position action.

M. Damper Motors: [Modulating] [or] [two-position] action.

N. Comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements for motors specified in Division 23 Section "Common Motor Requirements for HVAC Equipment."

1. 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.
3. Controllers, Electrical Devices, and Wiring: Comply with requirements for electrical devices and connections specified in [Division 23 Section "Instrumentation and Control for HVAC"] [Division 26 Sections.]
4. Permanent-Split-Capacitor or Shaded-Pole Motors: With oil-immersed and sealed gear trains.
5. Spring-Return Motors: Equip with an integral spiral-spring mechanism where indicated. Enclose entire spring mechanism in a removable housing designed for service or adjustments. Size for running torque rating of 150 in. x lbf and breakaway torque rating of 150 in. x lbf.
6. Outdoor Motors and Motors in Outdoor-Air Intakes: Equip with O-ring gaskets designed to make motors weatherproof. Equip motors with internal heaters to permit normal operation at minus 40 deg F.
7. Nonspring-Return Motors: For dampers larger than 25 sq. ft., size motor for running torque rating of 150 in. x lbf and breakaway torque rating of 300 in. x lbf.
8. Electrical Connection: 115 V, single phase, 60 Hz.
9. Electrical Connection: [115 V, single phase, 60 Hz] <Insert values>.

O. Accessories:

1. Auxiliary switches for [signaling] [fan control] [or] [position indication].
2. [Momentary test switch] [Test and reset switches], [damper] [remote] mounted.

2.9 COMBINATION FIRE AND SMOKE DAMPERS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
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1. Air Balance Inc.; a division of Mestek, Inc.
2. Cesco Products; a division of Mestek, Inc.
4. Nailor Industries Inc.
5. Pottorff.
6. Ruskin Company.

B. Type: Static; rated and labeled according to UL 555 and UL 555S by an NRTL.

C. Type: [Static] [Dynamic] [Static and dynamic]; rated and labeled according to UL 555 and UL 555S by an NRTL.

D. Closing rating in ducts up to [4-inch wg] <Insert value> static pressure class and minimum [4000-fpm] <Insert value> velocity.

E. Fire Rating: 1-1/2 hours.

F. Fire Rating: [1-1/2] [and] [3] hours.

G. Frame: Multiple-blade type; fabricated with roll-formed, 0.034-inch- thick galvanized steel; with mitered and interlocking corners.

H. Frame: [Curtain type with blades inside airstream] [Curtain type with blades outside airstream] [Multiple-blade type] [Curtain type with blades outside airstream except when located behind grille where blades may be inside airstream]; fabricated with roll-formed, 0.034-inch- thick galvanized steel; with mitered and interlocking corners.


J. Heat-Responsive Device: Replaceable, [165 deg F] [212 deg F] rated, fusible links.

K. Heat-Responsive Device: [Electric] [Pneumatic] resettable link and switch package, factory installed, rated.

L. Smoke Detector: Integral, factory wired for single-point connection.

M. Blades: Roll-formed, horizontal, interlocking, 0.034-inch- thick, galvanized sheet steel. In place of interlocking blades, use full-length, 0.034-inch- thick, galvanized-steel blade connectors.

N. Leakage: Class II.

O. Leakage: [Class I] [Class II] <Insert class>.

P. Rated pressure and velocity to exceed design airflow conditions.

Q. Mounting Sleeve: Factory-installed, 0.052-inch- thick, galvanized sheet steel; length to suit wall or floor application.

R. Mounting Sleeve: Factory-installed, 0.052-inch- thick, galvanized sheet steel; length to suit wall or floor application[ with factory-furnished silicone calking].

S. Master control panel for use in dynamic smoke-management systems.
T. Damper Motors: Two-position action.

U. Damper Motors: [Modulating] [or] [two-position] action.

V. Comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements for motors specified in Division 23 Section “Common Motor Requirements for HVAC Equipment.”

1. 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.
3. Controllers, Electrical Devices, and Wiring: Comply with requirements for electrical devices and connections specified in [Division 23 Section “Instrumentation and Control for HVAC.”] [Division 26 Sections.]
4. Permanent-Split-Capacitor or Shaded-Pole Motors: With oil-immersed and sealed gear trains.
5. Spring-Return Motors: Equip with an integral spiral-spring mechanism where indicated. Enclose entire spring mechanism in a removable housing designed for service or adjustments. Size for running torque rating of 150 in. x lbf and breakaway torque rating of 150 in. x lbf.
6. Outdoor Motors and Motors in Outdoor-Air Intakes: Equip with O-ring gaskets designed to make motors weatherproof. Equip motors with internal heaters to permit normal operation at minus 40 deg F.
7. Nonspring-Return Motors: For dampers larger than 25 sq. ft., size motor for running torque rating of 150 in. x lbf and breakaway torque rating of 300 in. x lbf.
8. Electrical Connection: 115 V, single phase, 60 Hz.

W. Accessories:

1. Auxiliary switches for [signaling] [fan control] [or] [position indication].
2. [Momentary test switch] [Test and reset switches], [damper] [remote] mounted.

2.10 CORRIDOR DAMPERS

2.11 FLANGE CONNECTORS

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

1. Ductmate Industries, Inc.
2. Nexus PDQ; Division of Shilco Holdings Inc.

B. Description: Add-on or roll-formed, factory-fabricated, slide-on transverse flange connectors, gaskets, and components.

C. Description: [Add-on] [or] [roll-formed], factory-fabricated, slide-on transverse flange connectors, gaskets, and components.
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D. Material: Galvanized steel.

E. Gage and Shape: Match connecting ductwork.

2.12 DUCT SILENCERS

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

1. Industrial Noise Control, Inc.
2. McGill AirFlow LLC.
3. Ruskin.
5. Aerosonics
6. Commercial Acoustics
7. IAC
8. Dynasonics
9. Vibron
10. Semco
11. VAW
12. Price-HVAC

B. General Requirements:

1. Factory fabricated.
2. Fire-Performance Characteristics: Adhesives, sealants, packing materials, and accessory materials shall have flame-spread index not exceeding 25 and smoke-developed index not exceeding 50 when tested according to ASTM E 84.
3. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.
4. The dynamic insertion loss in dB for silencers shall not be less than that shown on the Duct Silencer Schedule at the face air velocity of +1,000 fpm (+ indicates airflow in the same direction as attenuation).
5. Duct silencers shall not produce self-noise power levels in dB re 10^{-12} watts that exceed those shown on the Duct Silencer Schedule.
6. Duct silencers static pressure drop shall not exceed those indicated on the duct silencer schedule for the scheduled airflow velocity and location shown.

C. Shape:

1. Rectangular straight with splitters or baffles.
2. Round straight with center bodies or pods.
3. Rectangular elbow with splitters or baffles.
4. Round elbow with center bodies or pods.
5. Rectangular transitional with splitters or baffles.

D. Rectangular Silencer Outer Casing: ASTM A 653/A 653M, G90, galvanized sheet steel, 0.034 inch thick.

E. Rectangular Silencer Outer Casing: ASTM A 653/A 653M, [G90] [G60], galvanized sheet steel, [0.034 inch] [0.040 inch] thick.

   1. Sheet Metal Thickness for Units up to 24 Inches in Diameter: 0.034 inch thick.
   2. Sheet Metal Thickness for Units 26 through 40 Inches in Diameter: 0.040 inch thick.
   3. Sheet Metal Thickness for Units 42 through 52 Inches in Diameter: 0.052 inch thick.
   4. Sheet Metal Thickness for Units 54 through 60 Inches in Diameter: 0.064 inch thick.

H. Inner Casing and Baffles: ASTM A 653/A 653M, G90 galvanized sheet metal, 0.034 inch thick, and with 1/8-inch- diameter perforations.

I. Inner Casing and Baffles: ASTM A 653/A 653M, [G90] [G60] galvanized sheet metal, 0.034 inch thick, and with 1/8-inch- diameter perforations.

J. Special Construction:
   1. Suitable for outdoor use.
   2. High transmission loss [to achieve STC 45].

K. Connection Sizes: Match connecting ductwork unless otherwise indicated.

L. Principal Sound-Absorbing Mechanism:
   1. Controlled impedance membranes and broadly tuned resonators without absorptive media.
   2. Dissipative type with fill material.
   3. [Dissipative] [Film-lined] type with fill material.
      a. Fill Material: Inert, mold-resistant, and vermin- and moisture-proof fibrous material.
      b. Fill Material: [Inert and vermin-proof fibrous material, packed under not less than 5 percent compression] [Inert and vermin-proof fibrous material, packed under not less than 15 percent compression] [Moisture-proof nonfibrous material].
      c. [Erosion Barrier]: Polymer bag enclosing fill, and heat sealed before assembly.
   4. [Lining]: Mylar.
   5. Lining: [None] [Mylar] [Tedlar] [Fiberglas cloth] <Insert material>.

M. Fabricate silencers to form rigid units that will not pulsate, vibrate, rattle, or otherwise react to system pressure variations. Do not use mechanical fasteners for unit assemblies.
   1. Lock form and seal or continuously weld joints.
   2. [Lock form and seal or continuously weld joints] [Flange connections].
   3. Suspended Units: Factory-installed suspension hooks or lugs attached to frame in quantities and spaced to prevent deflection or distortion.
   4. Reinforcement: Cross or trapeze angles for rigid suspension.

N. Accessories:
   1. Factory-installed end caps to prevent contamination during shipping.
   2. Integral [1-1/2] [3]-hour fire damper with access door.[ Access door to be high transmission loss to match silencer.]
3. Removable splitters.

O. Source Quality Control: Test according to ASTM E 477.
   1. Testing [of mockups] to be witnessed by [Architect] [Owner].
   2. Record acoustic ratings, including dynamic insertion loss and generated-noise power levels with an airflow of at least 2000-fpm face velocity.
   3. Leak Test: Test units for airtightness at 200 percent of associated fan static pressure or 6-inch wg static pressure, whichever is greater.

P. Capacities and Characteristics:

2.13 TURNING VANES

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   1. Ductmate Industries, Inc.
   2. Duro Dyne Inc.
   3. METALAIRE, Inc.
   4. SEMCO Incorporated.

B. Manufactured Turning Vanes for Metal Ducts: Curved blades of galvanized sheet steel; support with bars perpendicular to blades set; set into vane runners suitable for duct mounting.

C. General Requirements: Comply with SMACNA’s “HVAC Duct Construction Standards - Metal and Flexible”; Figures 2-3, "Van"es and Vane Runners,” and 2-4, "Vane Support in Elbows.”

D. Vane Construction: [Single] [Double] wall.

E. Vane Construction: Single wall for ducts up to 48 inches wide and double wall for larger dimensions.

F. Vane Construction: Single wall for ducts up to [48 inches] [Insert dimension] wide and double wall for larger dimensions.

2.14 REMOTE DAMPER OPERATORS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   1. Pottorf.
   2. Ventfabrics, Inc.
   3. Young Regulator Company.
B. Description: Cable system designed for remote manual damper adjustment.

C. Tubing: Brass.

D. Cable: Stainless steel.

E. Wall-Box Mounting: [Recessed, 3/4 inches deep] [Recessed, 2 inches deep] [Surface].

F. Wall-Box Cover-Plate Material: [Steel] [Stainless steel].

2.15 DUCT-MOUNTED ACCESS DOORS

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

1. American Warming and Ventilating; a division of Mestek, Inc.
2. Cesco Products; a division of Mestek, Inc.
3. Ductmate Industries, Inc.
5. Greenheck Fan Corporation.
6. McGill AirFlow LLC.
7. Nailor Industries Inc.
8. Potterff.
9. Ruskin.
10. Ventfabrics, Inc.


C. Rectangular Ductwork Applications:

1. Door:
   a. Double wall, rectangular.
   b. Galvanized sheet metal with insulation fill and thickness as indicated for duct pressure class.
   c. Vision panel.
   d. Hinges and Latches: 1-by-1-inch butt or piano hinge and cam latches.
   e. Fabricate doors airtight and suitable for duct pressure class.

2. Frame: Galvanized sheet steel, with bend-over tabs and foam gaskets.

3. Number of Hinges and Locks:
   a. Access Doors Less Than 12 Inches Square: No hinges and two sash locks.
   b. Access Doors up to 18 Inches Square: Two hinges and two sash locks.
   c. Access Doors up to 24 by 24 Inches: Three hinges and two compression latches with outside and inside handles.
   d. Access Doors up to 24 by 48 Inches: Three hinges and two compression latches [with outside and inside handles].
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e. Access Doors Larger Than 24 by 48 Inches: Four hinges and two compression latches with outside and inside handles.

D. Round Ductwork Applications:

1. Sandwich Type for Uninsulated Ductwork: Oval shaped inner and outer plates connected by bolt fasteners and compression springs with hand knobs for compression fit in duct sidewall.
   a. Provide doors with insulated inner plate for installation in pre-insulated double wall ductwork.

2. Rectangular Type for Insulated Ductwork: Same as specified for rectangular ductwork application with field or factory installed rectangular tap.

E. Pressure Relief Access Door:

1. Door and Frame Material: Galvanized sheet steel.
2. Door: Single wall for uninsulated duct applications and double wall with insulation fill for insulated duct applications with metal thickness applicable for duct pressure class.
3. Door: [Single wall] [Double wall with insulation fill] with metal thickness applicable for duct pressure class.
4. Operation: Open outward for positive-pressure ducts and inward for negative-pressure ducts.
5. Doors close when pressures are within set-point range.
6. Hinge: Continuous piano.
7. Latches: Cam.
8. Seal: Neoprene or foam rubber.
10. Factory set at pressure settings indicated below:

   a. Spring clips rated at 3-inch wg negative and 5-inch wg positive for VAV applications.
   b. Spring clips rated at 2-inch wgnegative and 3-inch wg positive for constant volume systems.

2.16 DUCT ACCESS PANEL ASSEMBLIES

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

   1. Ductmate Industries, Inc.
   2. Flame Gard, Inc.
   3. 3M.

B. Labeled according to UL 1978 by an NRTL.

C. Panel and Frame: Minimum thickness [0.0528-inch carbon] [0.0428-inch stainless] steel.

D. Fasteners: [Carbon] [Stainless] steel. Panel fasteners shall not penetrate duct wall.
E.        Gasket: Comply with NFPA 96; grease-tight, high-temperature ceramic fiber, rated for minimum 2000 deg F.

F.        Minimum Pressure Rating: 10-inch wg, positive or negative.

2.17 FLEXIBLE CONNECTORS

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

            1. Ductmate Industries, Inc.
            2. Duro Dyne Inc.
            3. Ventfabrics, Inc.

B.        Materials: Flame-retardant or noncombustible fabrics.

C.        Coatings and Adhesives: Comply with UL 181, Class 1.

D.        Metal-Edged Connectors: Factory fabricated with a fabric strip 3-1/2 inches wide attached to 2 strips of 2-3/4-inch wide, 0.028-inch thick, galvanized sheet steel or 0.032-inch thick aluminum sheets. Provide metal compatible with connected ducts.

E.        Metal-Edged Connectors: Factory fabricated with a fabric strip [3-1/2 inches] [5-3/4 inches] wide attached to 2 strips of 2-3/4-inch wide, 0.028-inch thick, galvanized sheet steel or 0.032-inch thick aluminum sheets. Provide metal compatible with connected ducts.


            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 deg F.

G.        Outdoor System, Flexible Connector Fabric: Glass fabric double coated with weatherproof, synthetic rubber resistant to UV rays and ozone.

            1. Minimum Weight: 24 oz./sq. yd..
            2. Tensile Strength: 530 lbf/inch in the warp and 440 lbf/inch in the filling.
            3. Service Temperature: Minus 50 to plus 250 deg F.


            1. Minimum Weight: 16 oz./sq. yd..
            2. Tensile Strength: 285 lbf/inch in the warp and 185 lbf/inch in the filling.
            3. Service Temperature: Minus 67 to plus 500 deg F.


            1. Minimum Weight: 14 oz./sq. yd..
2. Tensile Strength: 450 lbf/inch in the warp and 340 lbf/inch in the filling.
3. Service Temperature: Minus 67 to plus 500 deg F.

J. Thrust Limits: Combination coil spring and elastomeric insert with spring and insert in compression, and with a load stop. Include rod and angle-iron brackets for attaching to fan discharge and duct.

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. Outdoor Spring Diameter: Not less than 80 percent of the compressed height of the spring at rated load.
3. Minimum Additional Travel: 50 percent of the required deflection at rated load.
4. Lateral Stiffness: More than 80 percent of rated vertical stiffness.
5. Overload Capacity: Support 200 percent of rated load, fully compressed, without deformation or failure.
6. Elastomeric Element: Molded, oil-resistant rubber or neoprene.
7. Coil Spring: Factory set and field adjustable for a maximum of 1/4-inch movement at start and stop.

2.18 FLEXIBLE DUCTS

A. Insulated, Flexible Duct (Type F-1): UL 181, Class 1, acoustically rated, woven fiberglass fabric with flame resistant coated core supported by helically wound, spring-steel wire; fibrous-glass insulation (R-4.2); bi-directional reinforced metallized vapor-barrier film.

1. Basis-of-Design Product: Subject to compliance with requirements, provide Themaflex Model M-KC or comparable product by the following:
   a. Flexmaster U.S.A., Inc.
   b. McGill AirFlow LLC.
   c. Thermaflex.
   d. Ward Industries, Inc.; a division of Hart & Cooley, Inc.

2. Positive Pressure Rating: 16-inch wg positive for sizes 4 to 10 Inches, 10-inch wg positive for sizes 12 to 16 Inches.
3. Negative Pressure Rating: 2.0-inch wg negative for sizes 4 to 16 Inches.
5. Temperature Range: Minus 20 to plus 250 deg F.
6. Insulation R-value: R-4.2

B. Insulated, Flexible Duct (Type F-2): UL 181, Class 1, acoustically rated, self-extinguishing chlorinated polyethylene (CPE) core supported by helically wound, spring-steel wire; fibrous-glass insulation (R-4.2); polyethylene vapor-barrier film.

1. Basis-of-Design Product: Subject to compliance with requirements, provide Themaflex Model G-KM or comparable product by one of the following:
   a. Flexmaster U.S.A., Inc.
   b. McGill AirFlow LLC.
   c. Ward Industries, Inc.; a division of Hart & Cooley, Inc.

2. Positive Pressure Rating: 6-inch wg positive for sizes 3 to 16 Inches.
3. Negative Pressure Rating: 1.0-inch wg negative for sizes 3 to 12 Inches, 1/2-inch wg negative for sizes 14 to 16 Inches.
5. Temperature Range: Minus 20 to plus 200 deg F.
6. Insulation R-value: R-4.2

C. Noninsulated, Flexible Duct: UL 181, Class 1, 2-ply vinyl film supported by helically wound, spring-steel wire.
   1. Pressure Rating: 10-inch wg positive and 1.0-inch wg negative.
   3. Temperature Range: Minus 10 to plus 160 deg F.

D. Noninsulated, Flexible Duct: UL 181, Class 1, black polymer film supported by helically wound, spring-steel wire.
   1. Pressure Rating: 4-inch wg positive and 0.5-inch wg negative.
   3. Temperature Range: Minus 20 to plus 175 deg F.

E. Noninsulated, Flexible Duct: UL 181, Class 1, multiple layers of aluminum laminate supported by helically wound, spring-steel wire.
   1. Pressure Rating: 10-inch wg positive and 1.0-inch wg negative.
   3. Temperature Range: Minus 20 to plus 210 deg F.

F. Noninsulated, Flexible Duct: UL 181, Class 1, aluminum laminate and polyester film with latex adhesive supported by helically wound, spring-steel wire.
   1. Pressure Rating: 10-inch wg positive and 1.0-inch wg negative.
   3. Temperature Range: Minus 20 to plus 210 deg F.

G. Noninsulated, Flexible Duct: UL 181, Class 0, interlocking spiral of aluminum foil.
   1. Pressure Rating: 8-inch wg positive or negative.
   3. Temperature Range: Minus 100 to plus 435 deg F.

H. Insulated, Flexible Duct: UL 181, Class 1, 2-ply vinyl film supported by helically wound, spring-steel wire; fibrous-glass insulation; [polyethylene] [aluminized] vapor-barrier film.
   1. Pressure Rating: 10-inch wg positive and 1.0-inch wg negative.
   3. Temperature Range: Minus 10 to plus 160 deg F.

I. Insulated, Flexible Duct: UL 181, Class 1, black polymer film supported by helically wound, spring-steel wire; fibrous-glass insulation; [polyethylene] [aluminized] vapor-barrier film.
   1. Pressure Rating: 4-inch wg positive and 0.5-inch wg negative.
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3. Temperature Range: Minus 20 to plus 175 deg F.

J. Insulated, Flexible Duct: UL 181, Class 1, multiple layers of aluminum laminate supported by helically wound, spring-steel wire; fibrous-glass insulation; [polyethylene] [aluminized] vapor-barrier film.

1. Pressure Rating: 10-inch wg positive and 1.0-inch wg negative.
3. Temperature Range: Minus 20 to plus 210 deg F.

K. Insulated, Flexible Duct: UL 181, Class 1, aluminum laminate and polyester film with latex adhesive supported by helically wound, spring-steel wire; fibrous-glass insulation; [polyethylene] [aluminized] vapor-barrier film.

1. Pressure Rating: 10-inch wg positive and 1.0-inch wg negative.
3. Temperature Range: Minus 20 to plus 210 deg F.

L. Insulated, Flexible Duct: UL 181, Class 0, interlocking spiral of aluminum foil; fibrous-glass insulation; [polyethylene] [aluminized] vapor-barrier film.

1. Pressure Rating: 8-inch wg positive or negative.
3. Temperature Range: Minus 20 to plus 250 deg F.

M. Flexible Duct Connectors:

1. Clamps: Stainless-steel band with cadmium-plated hex screw to tighten band with a worm-gear action or nylon strap in sizes 3 through 18 inches, to suit duct size.
2. Clamps: [Stainless-steel band with cadmium-plated hex screw to tighten band with a worm-gear action] [Nylon strap] in sizes 3 through 18 inches, to suit duct size.
3. Non-Clamp Connectors: [Adhesive] [Liquid adhesive plus tape] [Adhesive plus sheet metal screws].

2.19 DUCT SECURITY BARS

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

1. Carnes.
2. KEES, Inc.
3. Lloyd Industries, Inc.
4. Metal Form Manufacturing, Inc.
5. Price Industries.
B. Description: [Field-fabricated] [Factory-fabricated and field-installed] [Field- or factory-fabricated and field-installed] duct security bars.

C. Configuration:

1. Frame: [10 gage by 2 inches] <Insert values>.
2. Sleeve: [3/16-inch] <Insert size>, [continuously welded] [bent] steel frames with [1-by-1-by-3/16-inch] <Insert size> angle frame [factory welded to 1 end] [furnished loose for field welding on other end]. To be poured in place or set with concrete block or welded or bolted to wall, one side only. Duct connections on both sides.
3. Horizontal Bars: [1/2 inch] [2 by 1/4 inch] <Insert values>.
4. Vertical Bars: [1/2 inch] [3/4 inch] [1 inch] <Insert value>.
5. Bar Spacing: [6 inches] <Insert value>.
6. Mounting: [Metal deck or roofing] [Bolted or welded] [Bolted or welded with masonry anchors] [Ductwork or other framing] [Poured in place or set with concrete block] [Welded or bolted to one wall (one side only)] [Bar extends 6 inches into wall].

PART 3 - EXECUTION

3.1 INSTALLATION

A. Install duct accessories according to applicable details in SMACNA’s “HVAC Duct Construction Standards - Metal and Flexible” for metal ducts.

B. Install duct accessories according to applicable details in SMACNA’s “HVAC Duct Construction Standards - Metal and Flexible” for metal ducts and in NAIMA AH116, “Fibrous Glass Duct Construction Standards,” for fibrous-glass ducts.

C. Install duct accessories of galvanized-steel materials in galvanized-steel ducts.

D. Install duct accessories of materials suited to duct materials; use galvanized-steel accessories in galvanized-steel and fibrous-glass ducts, stainless-steel accessories in stainless-steel ducts, and aluminum accessories in aluminum ducts.

E. Install turning vanes in all square or rectangular 90 degree elbows.

F. Install [backdraft] [control] dampers at inlet of exhaust fans or exhaust ducts as close as possible to exhaust fan unless otherwise indicated.

G. Install volume dampers at points on supply, return, and exhaust systems where branches extend from larger ducts. [Where dampers are installed in ducts having duct liner, install dampers with hat channels of same depth as liner, and terminate liner with nosing at hat channel.]

H. Install volume dampers at points on supply, return, and exhaust systems where branches extend from larger ducts. [Where dampers are installed in ducts having duct liner, install dampers with hat channels of same depth as liner, and terminate liner with nosing at hat channel.]

1. Install steel volume dampers in steel ducts.
2. Install aluminum volume dampers in aluminum ducts.

I. Set dampers to fully open position before testing, adjusting, and balancing.

J. Install fire[ and fire/smoke] dampers according to UL listing.

K. Install duct security bars. Construct duct security bars from 0.164-inch steel sleeve, continuously welded at all joints and 1/2-inch- diameter steel bars, 6 inches o.c. in each direction in center of sleeve. Weld each bar to steel sleeve and each crossing bar. Weld 2-1/2-by-2-1/2-by-1/4-inch steel angle to 4 sides and both ends of sleeve. Connect duct security bars to ducts with flexible connections. Provide 12-by-12-inch hinged access panel with cam lock in duct in each side of sleeve.

L. Connect ducts to duct silencers rigidly.

1. Do not locate duct silencers within one duct diameter from fan discharge/intake openings, elbows, or takeoffs.
2. When elbows precede duct silencer by less than 3 duct widths (as measured in the elbow plane), splitters should be parallel to the plane of the elbow turn.

M. Connect ducts to duct silencers [with flexible duct connectors] [rigidly].

N. Install duct access doors on sides of ducts to allow for inspecting, adjusting, and maintaining accessories and equipment at the following locations:

1. On both sides of duct coils.
2. Upstream[and downstream] from duct filters.
3. At outdoor-air intakes and mixed-air plenums.
4. At drain pans and seals.
5. Downstream from manual volume dampers, control dampers, backdraft dampers, and equipment.
6. Adjacent to and close enough to fire or smoke dampers, to reset or reinstall fusible links. Access doors for access to fire or smoke dampers having fusible links shall be pressure relief access doors and shall be outward operation for access doors installed upstream from dampers and inward operation for access doors installed downstream from dampers.
   a. For fire or smoke dampers located in ducts with [no other air path between AHU outlet and damper], install pressure relief access doors upstream of fire or smoke dampers.
   b. For fire or smoke dampers located in ducts [with high velocity and no other air path between AHU outlet and damper], install pressure relief access doors upstream and downstream of fire or smoke dampers.
   c. For fire or smoke dampers located in ducts [with high velocity and other air paths between AHU outlet and damper], install pressure relief access doors downstream of fire or smoke dampers.
7. At each change in direction and at maximum 50-foot spacing.
8. Upstream[and downstream] from turning vanes.
9. Upstream or downstream from duct silencers.
10. Upstream and downstream of duct mounted airflow monitor devices.
11. At duct mounted smoke detectors.
12. Control devices requiring inspection.
13. Elsewhere as indicated.

O. Install access doors with swing against duct static pressure.

P. Access Door Minimum Sizes:

1. Two-Hand or Inspection Access: 12 by 12 inches.
4. For ducts less than 12 by 12 inches
5. One-Hand or Inspection Access: 8 by 5 inches.

Q. Label access doors according to Division 23 Section "Identification for HVAC Piping and Equipment" to indicate the purpose of access door.

R. Install flexible connectors to connect ducts to equipment.

S. For fans developing static pressures of 5-inch wg and more, cover flexible connectors with loaded vinyl sheet held in place with metal straps.

T. Install flexible ducts as follows:

1. Install flexible ducts at accessible concealed locations only.
2. Connect terminal units to high velocity supply ducts with maximum 18-inch lengths of flexible duct Type F-1, clamped or strapped in place. Flexible ducts are for alignment purposes only. Do not use flexible ducts to change directions.
3. Connect diffusers to ducts directly or with maximum 60-inch lengths of flexible duct Type F-1, clamped or strapped in place. Flexible ducts are for alignment purposes only. Do not use flexible ducts to change directions.
4. Connect to split-system air conditioners directly or with maximum 60-inch lengths of flexible duct Type F-2, clamped or strapped in place.

U. Connect terminal units to supply ducts[**directly or**] with maximum [12-inch] [**Insert value**] lengths of flexible duct. Do not use flexible ducts to change directions.

V. Connect diffusers or light troffer boots to ducts[**directly or**] with maximum [60-inch] [**Insert value**] lengths of flexible duct clamped or strapped in place.

W. Connect flexible ducts to metal ducts with [adhesive] [liquid adhesive plus tape] [draw bands] [adhesive plus sheet metal screws].

X. Install thrust limits at centerline of thrust, symmetrical on both sides of equipment. Attach thrust limits at centerline of thrust and adjust to a maximum of 1/4-inch movement during start and stop of fans.
3.2 FIELD QUALITY CONTROL

A. Tests and Inspections:

1. Operate dampers to verify full range of movement.
2. Inspect locations of access doors and verify that purpose of access door can be performed.
3. Operate fire, smoke, and combination fire and smoke dampers to verify full range of movement and verify that proper heat-response device is installed.
4. Inspect turning vanes for proper and secure installation.
5. Operate remote damper operators to verify full range of movement of operator and damper.

END OF SECTION 23 3300
WMU Design Guidelines Instructions: These guidelines are to be used by the Design Professional to inform the design process and outline WMU-specific desires for all University projects. These guidelines have been edited to reflect WMU preferences, and the intent is for the Design Professional to use this information to guide their normal specifications-writing process. Straying from what is indicated in the guidelines is not prohibited, but shall be discussed with WMU during the development of the project.

SECTION 23 3423 - HVAC POWER VENTILATORS

PART 1 - GENERAL

1.1 SUMMARY

A. This Section includes the following:

1. Utility set fans.
2. Centrifugal roof ventilators.
3. Axial roof ventilators.
4. Upblast propeller roof exhaust fans.
5. Centrifugal wall ventilators.
6. Ceiling-mounting ventilators.
7. In-line centrifugal fans.
8. Propeller fans.
10. Laboratory exhaust system.
11. Kiln exhaust ventilation system.

1.2 PERFORMANCE REQUIREMENTS

A. Project Altitude: Base fan-performance ratings on [actual Project site elevations] [sea level].

B. Operating Limits: Classify according to AMCA 99.

1.3 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 thickness and finishes, including color charts.
5. Dampers, including housings, linkages, and operators.
6. Roof curbs.
7. Fan speed controllers.
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.

   2. Design Calculations: Calculate requirements for selecting vibration isolators and seismic restraints and for designing vibration isolation bases.
   3. Vibration Isolation Base Details: Detail fabrication, including anchorages and attachments to structure and to supported equipment. Include auxiliary motor slides and rails, and base weights.

1.4 INFORMATIONAL SUBMITTALS

A. Coordination Drawings: Reflected ceiling plans and other details, drawn to scale, on which the following items are shown and coordinated with each other, based on input from installers of the items involved:

   1. Roof framing and support members relative to duct penetrations.
   2. Ceiling suspension assembly members.
   3. Size and location of initial access modules for acoustical tile.
   4. Ceiling-mounted items including light fixtures, diffusers, grilles, speakers, sprinklers, access panels, and special moldings.

B. Field quality-control test reports.

1.5 CLOSEOUT SUBMITTALS

A. Operation and maintenance data.

1.6 MAINTENANCE MATERIAL SUBMITTALS

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

   1. Belts: [One] <Insert number> set(s) for each belt-driven unit.

1.7 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.
1.8 DELIVERY, STORAGE, AND HANDLING

A. Deliver fans as factory-assembled unit, to the extent allowable by shipping limitations, with protective crating and covering.

B. Disassemble and reassemble units, as required for moving to final location, according to manufacturer's written instructions.

C. Lift and support units with manufacturer’s designated lifting or supporting points.

1.9 COORDINATION

A. Coordinate size and location of structural-steel support members.

B. Coordinate size and location of concrete bases. Cast anchor-bolt inserts into bases. Concrete, reinforcement, and formwork requirements are specified in Division 03.

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

D. Coordinate installation of roof curbs, equipment supports, and roof penetrations. These items are specified in Division 07 Section “Roof Accessories.”

PART 2 - PRODUCTS

2.1 UTILITY SET FANS

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

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

C. Basis-of-Design Product: Subject to compliance with requirements, provide [the product indicated on Drawings] <Insert manufacturer’s name; product name or designation> or a comparable product by one of the following:

2. Aerovent; a Twin City Fan Company
4. Hartzell Fan, Inc.
5. Loren Cook Company.
6. Penn-Barry.
7. Trane.

D. Description: [Direct] [Belt]-driven centrifugal fans consisting of housing, wheel, fan shaft, bearings, motor and disconnect switch, drive assembly, and accessories.
E. Housing: Fabricated of steel with side sheets fastened with a deep lock seam or welded to scroll sheets.

F. Housing: Fabricated of [galvanized] steel with side sheets fastened with a deep lock seam or welded to scroll sheets.

1. Housing Discharge Arrangement: Adjustable to eight standard positions.

G. Fan Wheels: Single-width, single inlet; welded to cast-iron or cast-steel hub and spun-steel inlet cone, with hub keyed to shaft.

1. Blade Materials: [Steel] [Aluminum].
2. Blade Type: [Backward inclined] [Forward curved] [Airfoil].
3. Spark-Resistant Construction: AMCA 99, Type [A] [B] [C].

H. Fan Shaft: Turned, ground, and polished steel; keyed to wheel hub.

I. Shaft Bearings: Prelubricated and sealed, self-aligning, pillow-block-type ball bearings with ABMA 9, $L_{50}$ of 200,000 hours.

J. Shaft Bearings: Prelubricated and sealed, self-aligning, pillow-block-type ball bearings with ABMA 9, $[L_{50} \text{ of } 200,000 \text{ hours}] [L_{10} \text{ of } 80,000 \text{ hours}] <\text{Insert life}>$.

K. Belt Drives: Factory mounted, with final alignment and belt adjustment made after installation.

1. Service Factor Based on Fan Motor Size: 1.5.
2. Service Factor Based on Fan Motor Size: [1.5] [1.4] [1.3] [1.2].
3. Motor Pulleys: Adjustable pitch for use with motors through 5 hp; fixed pitch for use with larger motors. Select pulley so pitch adjustment is at the middle of adjustment range at fan design conditions.
4. Belts: Oil resistant, nonsparking, and nonstatic; matched sets for multiple belt drives.
5. Belt Guards: Fabricate of steel for motors mounted on outside of fan cabinet.

L. Accessories:

1. Inlet and Outlet: Flanged.
2. Companion Flanges: Rolled flanges for duct connections of same material as housing.
4. Access Door: Gasketed door in scroll with latch-type handles.
5. Scroll Dampers: Single-blade damper installed at fan scroll top with adjustable linkage.
6. Inlet Screens: Removable wire mesh.
9. Discharge Dampers: Assembly with [parallel] [opposed] blades constructed of two plates formed around and to shaft, channel frame, sealed ball bearings, with blades linked outside of airstream to single control lever of same material as housing.
10. Variable Inlet Vanes: With blades supported at both ends with two permanently lubricated bearings of same material as housing. Variable mechanism terminating in single control lever with control shaft for double-width fans.
11. Speed Controller: Solid-state control to reduce speed from 100 to less than 50 percent.
12. Coatings: [Thermoplastic vinyl] [Epoxy] [Zinc] [Synthetic resin] [Phenolic] [Color-match enamel] [Polytetrafluoroethylene] [Vinyl ester] [Hot-dip galvanized] [Powder-baked enamel]; <Insert manufacturer's name and trade name>.
13. Vibration Isolators:
   a. Type: Use the following:
      1) Indoor Application: Spring isolators.
      2) Outdoor Application: Restrained spring isolators.
   b. Static Deflection: 1 inch

2.2 CENTRIFUGAL ROOF VENTILATORS

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

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

C. Basis-of-Design Product: Subject to compliance with requirements, provide [the product indicated on Drawings] <Insert manufacturer's name; product name or designation> or a comparable product by one of the following:

2. Aerovent; a Twin City Fan Company
4. Hartzell Fan, Inc.
5. Loren Cook Company.
6. Penn-Barry.

D. Description: Direct- or belt-driven centrifugal fans consisting of housing, wheel, fan shaft, bearings, motor and disconnect switch, drive assembly, curb base, and accessories.

E. Housing: Removable, spun-aluminum, dome top and outlet baffle; square, one-piece, aluminum base with venturi inlet cone.

F. Housing: Removable, [spun-aluminum, dome top and outlet baffle] [extruded-aluminum, rectangular top] [galvanized steel, mushroom-domed top]; square, one-piece, aluminum base with venturi inlet cone.

1. Upblast Units: Provide spun-aluminum discharge baffle to direct discharge air upward, with rain and snow drains[ and grease collector].
2. Hinged Subbase: Galvanized-steel hinged arrangement permitting service and maintenance.

G. Fan Wheels: Aluminum hub and wheel with backward-inclined blades.

H. Drive Assembly: Resiliently mounted to housing, with the following features:
WMU Design Guidelines

2. Fan and motor isolated from exhaust airstream.

I. Belt-Driven Drive Assembly: Resiliently mounted to housing, with the following features:
   1. Fan Shaft: Turned, ground, and polished steel; keyed to wheel hub.
   4. Fan and motor isolated from exhaust airstream.

J. Accessories:
   1. Variable-Speed Controller (Direct Drive Only): Solid-state control to reduce speed from 100 to less than 50 percent.
   2. Disconnect Switch: Nonfusible type, with thermal-overload protection mounted [inside] [outside] fan housing, factory wired through an internal aluminum conduit.
   3. Bird Screens: Removable, 1/2-inch mesh, aluminum or brass wire.
   4. Dampers: Counterbalanced, parallel-blade, backdraft dampers mounted in curb base; factory set to close when fan stops.
   5. Motorized Dampers: [Parallel-blade] [Thermally isolated] dampers mounted in curb base with electric actuator and auxiliary end switch; wired to close when fan stops.

K. 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.

   2. Configuration: [Self-flashing without a cant strip, with mounting flange] [Built-in cant and mounting flange] [Built-in raised cant and mounting flange].
   3. Overall Height: As scheduled.
   4. Overall Height: [8 inches] [9-1/2 inches] [12 inches] [16 inches] [18 inches].
   5. Sound Curb: Curb with sound-absorbing insulation matrix.
   7. Metal Liner: Galvanized steel.
   9. Mounting Pedestal: Galvanized steel with removable access panel.

2.3 AXIAL ROOF VENTILATORS

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

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

C. Basis-of-Design Product: Subject to compliance with requirements, provide [the product indicated on Drawings] <Insert manufacturer's name; product name or designation> or a comparable product by one of the following:
2. Aerovent; a Twin City Fan Company.
3. American Coolair Corp.
4. Ammerman; General Resource Corp.
5. Bayley Fans; a division of Lau Industries, Inc.
8. Carnes Company HVAC.
10. Greenheck.
11. Hartzell Fan, Inc.
12. Industrial Air; a division of Lau Industries, Inc.
13. JencoFan; Div. of Breidert Air Products.
14. Loren Cook Company.
15. New York Blower Company (The).
17. Stanley Fans.
18. <Insert manufacturer's name.>

D. Description: Direct- or belt-driven axial fans consisting of housing, wheel, fan shaft, bearings, motor and disconnect switch, drive assembly, curb base, and accessories.

E. Housing: Heavy-gage, removable, spun-aluminum, dome top and outlet baffle; square, one-piece, hinged, aluminum base.

1. Hinged Subbase: Galvanized-steel hinged arrangement permitting service and maintenance.

F. Fan Wheel: [Aluminum] [Steel] hub and blades.

G. Belt-Driven Drive Assembly: Resiliently mounted to housing, with the following features:

1. Fan Shaft: Turned, ground, and polished steel; keyed to wheel hub.

H. Accessories:

1. Disconnect Switch: Nonfusible type, with thermal-overload protection mounted [inside] [outside] fan housing, factory wired through an internal aluminum 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: Parallel-blade dampers mounted in curb base with electric actuator; wired to close when fan stops.

I. 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.

2. Configuration: [Self-flashing without a cant strip, with mounting flange] [Built-in cant and mounting flange] [Built-in raised cant and mounting flange].
3. Overall Height: As scheduled.
4. Overall Height: [8 inches] [9-1/2 inches] [12 inches] [16 inches] [18 inches].
5. Sound Curb: Curb with sound-absorbing insulation matrix.
7. Metal Liner: Galvanized steel.
9. Mounting Pedestal: Galvanized steel with removable access panel.

2.4 UPBLAST PROPELLER ROOF EXHAUST FANS

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

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

C. Basis-of-Design Product: Subject to compliance with requirements, provide [the product indicated on Drawings] <Insert manufacturer's name; product name or designation> or a comparable product by one of the following:

2. Aerovent; a Twin City Fan Company.
3. American Coolair Corp.
4. Ammerman; General Resource Corp.
5. Breidert Air Products.
6. Carnes Company HVAC.
8. Greenheck.
9. Hartzell Fan, Inc.
10. Industrial Air; a division of Lau Industries, Inc.
11. JencoFan; Div. of Breidert Air Products.
12. Loren Cook Company.
15. Penn Ventilation.
16. Quietaire Corporation.
17. Stanley Fans.
18. <Insert manufacturer's name.>

D. Description: Direct- or belt-driven propeller fans consisting of housing, wheel, butterfly-type discharge damper, fan shaft, bearings, motor and disconnect switch, drive assembly, curb base, and accessories.

E. Wind Band, Fan Housing, and Base: Reinforced and braced [galvanized steel] [aluminum], containing [galvanized-steel] [aluminum] butterfly dampers and rain trough, motor and drive assembly, and fan wheel.

1. Damper Rods: Steel with [bronze] [nylon] bearings.
2. Hinged Subbase: Galvanized-steel hinged arrangement permitting service and maintenance.

F. Fan Wheel: Replaceable, [cast] [extruded]-aluminum, airfoil blades fastened to cast-aluminum hub; factory set pitch angle of blades.

G. Belt-Driven Drive Assembly: Resiliently mounted to housing; weatherproof housing of same material as fan housing with the following features:

1. Fan Shaft: Turned, ground, and polished steel; keyed to wheel hub.

H. 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.

2. Configuration: [Self-flashing without a cant strip, with mounting flange] [Built-in cant and mounting flange] [Built-in raised cant and mounting flange].
3. Overall Height: As scheduled.
4. Overall Height: [8 inches] [9-1/2 inches] [12 inches] [16 inches] [18 inches].
5. Sound Curb: Curb with sound-absorbing insulation matrix.
7. Metal Liner: Galvanized steel.
9. Mounting Pedestal: Galvanized steel with removable access panel.

2.5 CENTRIFUGAL WALL VENTILATORS

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

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

C. Basis-of-Design Product: Subject to compliance with requirements, provide [the product indicated on Drawings] <Insert manufacturer’s name; product name or designation> or a comparable product by one of the following:

2. Aerovent; a Twin City Fan Company
4. Loren Cook Company.
5. Penn-Barry.
6. S & P.

D. Description: Direct- or belt-driven centrifugal fans consisting of housing, wheel, fan shaft, bearings, motor and disconnect switch, drive assembly, and accessories.
WMU Design Guidelines

E. Housing: Heavy-gage, removable, spun-aluminum, dome top and outlet baffle; venturi inlet cone.

F. Fan Wheel: Aluminum hub and wheel with backward-inclined blades.

G. Belt-Driven Drive Assembly: Resiliently mounted to housing, with the following features:
   1. Fan Shaft: Turned, ground, and polished steel; keyed to wheel hub.
   4. Fan and motor isolated from exhaust airstream.

H. Accessories:
   1. Variable-Speed Controller: Solid-state control to reduce speed from 100 to less than 50 percent.
   2. Disconnect Switch: Nonfusible type, with thermal-overload protection mounted inside fan housing, factory wired through internal aluminum conduit.
   3. Bird Screens: Removable, 1/2-inch mesh, aluminum or brass wire.
   4. Wall Grille: Ring type for flush mounting.
   5. Dampers: Counterbalanced, parallel-blade, backdraft dampers mounted in wall sleeve; factory set to close when fan stops.
   6. Motorized Dampers: Parallel-blade dampers mounted in curb base with electric actuator; wired to close when fan stops.

2.6 CEILING-MOUNTING VENTILATORS

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

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

C. Basis-of-Design Product: Subject to compliance with requirements, provide [the product indicated on Drawings] <Insert manufacturer's name; product name or designation> or a comparable product by one of the following:
   2. American Coolair Corp.
   3. Ammerman; General Resource Corp.
   4. Breidert Air Products.
   6. Carnes Company HVAC.
   8. FloAire.
   10. JencoFan; Div. of Breidert Air Products.
   11. Loren Cook Company.
   12. NuTone Inc.
   13. Penn Ventilation.
D. Description: Centrifugal fans designed for installing in ceiling or wall or for concealed in-line applications.

E. Housing: Steel, lined with acoustical insulation.

F. Fan Wheel: Centrifugal wheels directly mounted on motor shaft. Fan shrouds, motor, and fan wheel shall be removable for service.

G. Grille: Louvered grille with flange on intake and thumbscrew attachment to fan housing.

H. Grille: [Plastic] [Stainless steel] [Aluminum] [Painted aluminum], louvered grille with flange on intake and thumbscrew attachment to fan housing.

I. Electrical Requirements: Junction box for electrical connection on housing and receptacle for motor plug-in.

J. Accessories:
   1. Variable-Speed Controller: Solid-state control to reduce speed from 100 to less than 50 percent.
   3. Time-Delay Switch: Assembly with single-pole rocker switch, timer, and cover plate.
   4. Motion Sensor: Motion detector with adjustable shutoff timer.
   5. Ceiling Radiation Damper: Fire-rated assembly with ceramic blanket, stainless-steel springs, and fusible link.
   6. Filter: Washable aluminum to fit between fan and grille.
   8. Manufacturer's standard roof jack or wall cap, and transition fittings.

2.7 CEILING-MOUNTING VENTILATORS

2.8 IN-LINE CENTRIFUGAL FANS

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

   2. Aerovent; a Twin City Fan Company
   4. Loren Cook Company.
   5. Penn-Barry.
   6. S & P.

B. Description: In-line, [direct] [belt]-driven centrifugal fans consisting of housing, wheel, fan shaft, bearings, motor and disconnect switch, drive assembly, mounting brackets, and accessories.

C. Housing: Square galvanized steel or aluminum with inlet and outlet flanges, removable access panels, and support brackets adaptable to floor, side wall, or ceiling mounting.
D. Direct-Driven Units: Motor mounted in airstream, factory wired to disconnect switch located on outside of fan housing.

E. 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.

F. Fan Wheels: Aluminum, welded to aluminum hub.

G. Accessories:

1. Variable-Speed Controller: Solid-state control to reduce speed from 100 to less than 50 percent.
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): Epoxy-coated steel.
4. Vibration Isolators:
   a. Type: Elastomeric hangers.
   b. Static Deflection: 1 inch.
5. Spark Arrestance Class: [A] [B] [C].

2.9 IN-LINE CENTRIFUGAL FANS

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

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

C. Basis-of-Design Product: Subject to compliance with requirements, provide [the product indicated on Drawings] <Insert manufacturer's name; product name or designation> or a comparable product by one of the following:

2. American Coolair Corp.
3. Ammerman; General Resource Corp.
4. Bayley Fans; a division of Lau Industries, Inc.
5. Breidert Air Products.
6. Carnes Company HVAC.
7. FloAire.
8. Greenheck.
9. Hartzell Fan, Inc.
10. JencoFan; Div. of Breidert Air Products.
11. Loren Cook Company.
13. Penn Ventilation.
15. <Insert manufacturer's name.>
D. Description: In-line, [direct] [belt]-driven centrifugal fans consisting of housing, wheel, outlet guide vanes, fan shaft, bearings, motor and disconnect switch, drive assembly, mounting brackets, and accessories.

E. Housing: Split, spun aluminum with aluminum straightening vanes, inlet and outlet flanges, and support bracket adaptable to floor, side wall, or ceiling mounting.

F. Direct-Driven Units: Motor mounted in airstream, factory wired to disconnect switch located on outside of fan housing[; with wheel, inlet cone, and motor on swing-out service door].

G. 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.

H. Fan Wheels: Aluminum, airfoil blades welded to aluminum hub.

I. Accessories:
   1. Variable-Speed Controller: Solid-state control to reduce speed from 100 to less than 50 percent.
   2. Volume-Control Damper: Manually operated with quadrant lock, located in fan outlet.
   3. Companion Flanges: For inlet and outlet duct connections.
   4. 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.
   5. Motor and Drive Cover (Belt Guard): Epoxy-coated steel.
   6. Vibration Isolators:
      a. Type: [Elastomeric hangers] <Insert type>.
      b. Static Deflection: [1 inch] <Insert value>.

   7. Spark Arrestance Class: [A] [B] [C].

2.10 PROPELLER FANS

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

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

C. Basis-of-Design Product: Subject to compliance with requirements, provide [the product indicated on Drawings] <Insert manufacturer's name; product name or designation> or a comparable product by one of the following:

   2. Aerovent; a Twin City Fan Company.
   3. Airmaster Fan Co.
   4. American Coolair Corp.
   5. Ammerman; General Resource Corp.
   6. Bayley Fans; a division of Lau Industries, Inc.
   7. Breidert Air Products.
   8. Carnes Company HVAC.
12. Hartzell Fan, Inc.
13. Howden Buffalo Inc.
15. JencoFan; Div. of Breidert Air Products.
16. King Co. (The); King Air Systems.
17. Loren Cook Company.
19. Moffitt Corporation, Inc.
21. NuTone Inc.
22. Penn Ventilation.
23. Quietaire Corporation.
25. <Insert manufacturer's name.>

D. Description: Direct- or belt-driven propeller fans consisting of fan blades, hub, housing, orifice ring, motor, drive assembly, and accessories.

E. Housing: Galvanized-steel sheet with flanged edges and integral orifice ring with baked-enamel finish coat applied after assembly.

F. Steel Fan Wheels: Formed-steel blades riveted to heavy-gage steel spider bolted to cast-iron hub.

G. Fan Wheel: Replaceable, [cast] [extruded]-aluminum, airfoil blades fastened to cast-aluminum hub; factory set pitch angle of blades.

H. Belt-Driven Drive Assembly: Resiliently mounted to housing, 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.

1. Service Factor Based on Fan Motor Size: 1.4.
2. Fan Shaft: Turned, ground, and polished steel; keyed to wheel hub.
   a. Ball-Bearing Rating Life: ABMA 9, \[L_{10} \text{ of } 100,000 \text{ hours}\] <Insert life>.
4. Pulleys: Cast iron with split, tapered bushing; dynamically balanced at factory.
5. Motor Pulleys: Adjustable pitch for use with motors through 5 hp; fixed pitch for use with larger motors. Select pulley so pitch adjustment is at the middle of adjustment range at fan design conditions.
6. Belts: Oil resistant, nonsparking, and nonstatic; matched sets for multiple belt drives.

I. Accessories:

1. Gravity Shutters: Aluminum blades in aluminum frame; interlocked blades with nylon bearings.
3. Wall Sleeve: Galvanized steel to match fan and accessory size.
4. Weathershield Hood: Galvanized steel to match fan and accessory size.
5. Weathershield Front Guard: Galvanized steel with expanded metal screen.
6. Variable-Speed Controller: Solid-state control to reduce speed from 100 to less than 50 percent.
7. Disconnect Switch: Nonfusible type, with thermal-overload protection mounted inside fan housing, factory wired through an internal aluminum conduit.
8. Vibration Isolators:
   a. Type: [Elastomeric hangers] [Spring isolators] [Restrained spring isolators] <Insert type>.
   b. Static Deflection: [1 inch] <Insert value>.
9. Spark Arrestance Class: [A] [B] [C].

2.11 HIGH VOLUME LOW SPEED CEILING FANS
A. Basis-of-Design Product: Subject to compliance with requirements, provide the product indicated on Drawings (SkyBlade) or a comparable product by one of the following:
   1. Big Ass Fan Company.
   2. MacroAir Technologies.
   3. Rite Hite.
B. Description: The fan shall be designed to move an effective amount of air for cooling and destratification in large industrial applications and be designed specifically for high volume, low speed to ensure lower noise operation.
C. Airfoils: The fan shall be equipped high volume, low speed airfoils blades.
D. Motor: The fan motor shall be suitable for variable frequency drive application.
E. Motor: The fan motor shall be an AC induction type inverter rated.
F. Gearbox: The fan gearbox shall include a high efficiency gear reducer with two stage gearing, output shaft, housing, seals, and high quality bearings.
   1. The fan gearbox shall be equipped with a passageway in which wiring can be routed below the fan. A non-rotating, standard junction box shall be provided at the base of the fan for installing optional features. An aluminum cover plate shall be provided for attachment to the junction box when these features are not installed.
G. Mounting Post: The fan shall be equipped with a mounting post that provides a structural connection between the fan assembly and upper mounting system.
H. Hub: The fan hub shall be high strength and light weight. The hub shall be secured to the output shaft of the gearbox by means of a steel interface and be precision machined to achieve a well balanced and solid rotating assembly. The hub shall incorporate safety retaining clips that shall restrain the hub/airfoil assembly in case of gearbox output shaft failure.
WMU Design Guidelines

I. Mounting System: The fan mounting system shall be designed for installation from a structural support beam.

J. Mounting System: The fan mounting system shall be designed for installation from a structural support beam. All components in the mounting system shall be of welded construction.

K. Safety Cable: The fan shall be equipped with a safety cable that provides an additional means of securing the fan assembly to the building structure.

L. Safety Cable: The fan shall be equipped with a safety cable that provides an additional means of securing the fan assembly to the building structure. The safety cable shall be fabricated out of stranded galvanized steel.

M. Controller: The fan controller shall be constructed using a Variable Speed Drive (VSD) factory programmed to minimize the starting and braking torques, for smooth and efficient operation. The controller shall be contained within a completely sealed enclosure.

N. Controller: The fan controller shall be constructed using a Variable Speed Drive (VSD) that is pre-wired to the motor and factory programmed to minimize the starting and braking torques, for smooth and efficient operation. The controller shall be prewired to the motor using a short run of flexible conduit with a dedicated ground conductor to minimize electromagnetic interference (EMI) and radio frequency interference (RFI). An incoming power cord shall also be pre-wired to the controller. The controller shall be contained within a completely sealed enclosure and be secured to the fan assembly mounting post.

O. Wall Controller: The fan shall be equipped with a remote wall controller which shall control the fan's direction, operation and speed.

2.12 LABORATORY EXHAUST SYSTEM

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

1. Greenheck.

B. General:

1. Fans shall be belt driven and be capable of accommodating static pressure and flow variations of +/-15% of scheduled values.
2. Fans to be equipped with stainless steel lifting lugs and fasteners exposed to corrosive exhaust shall be stainless steel.
3. Fan assembly shall be designed for a minimum of 125 MPH wind loading, without the use of guy wires.
4. Base fan performance at standard conditions (density 0.075 Lb/ft³).
5. Fans selected shall be capable of accommodating static pressure and flow variations of +/-15% of scheduled values.
6. Fans shall be belt driven.
7. Fans to be equipped with 316 stainless steel lifting lugs for corrosion resistance.
8. Fasteners exposed to corrosive exhaust shall be stainless steel.
9. Fan assembly shall be designed for a minimum of 125 MPH wind loading, without the use of guy wires.
C. Corrosion Resistant Coating:

1. All fan and system components (fan, nozzle, wind band, plenum) shall be corrosion resistant coated.
2. All fan and system components (fan, nozzle, wind band, plenum) shall be corrosion resistant coated with a two part electrostatically applied and baked, sustainable, corrosion resistant coating system; or Heresite P-413C. Standard finish color to be gray.
3. All parts shall be cleaned and chemically prepared for coating using a multi-stage wash system which includes acid pickling that removes oxide, increases surface area, and improves coating bond to the substrate.
4. The first powder coat applied over the prepared surface shall be a zinc rich epoxy primer (no less than 70% zinc) and heated to a gelatinous consistency (partial cure) at which the second powder coat of polyester resin shall be electrostatically applied and simultaneously be cured at a uniform temperature of 400°F.
5. The coating system, a total thickness of up to 6 mils, is not affected by the UV component of sunlight (does not chalk), and has superior corrosion resistance to acid, alkali, and solvents. Coating system shall exceed 4000 hour ASTM B117 Salt Spray Resistance and must have a 30% gloss retention and no more than a 5 Delta E change after 5 yrs to meet an AAMA 2604 specification.

D. Fan Housing And Outlet:

1. Fan housing shall be welded steel and have corrosion resistant coating.
2. A high velocity conical discharge nozzle shall be supplied by the fan manufacturer
3. Include a housing drain for removal of rain and condensation.
4. Include a bolted and gasketed access door on fan housing for internal inspection or removal of impeller, and shaft and bearings without removal of the fan housing.
5. Fan housing to be aerodynamically designed with high-efficiency inlet, engineered to reduce incoming air turbulence.
6. Fan housing shall be welded steel and meet specification section 2.15 for corrosion resistant coating. No uncoated metal fan parts shall be acceptable.
7. Fan housings that are fabricated of polypropylene or fiberglass that have lower mechanical properties than steel, have rough interior surfaces in which corrosive, hazardous compounds can collect, and / or which chalk and structurally degrade due to the UV component of the sunlight shall not be acceptable.
8. A high velocity conical discharge nozzle shall be supplied by the fan manufacturer and be designed to efficiently handle an outlet velocity of up to 6000 FPM. Discharge stack caps or hinged covers, impeding exhaust flow shall not be permitted.
10. A bolted and gasketed access door shall be supplied in the fan housing allowing for impeller inspection or removal of impeller, shaft and bearings without removal of the fan housing.
11. Standard finish color to be gray.

E. Fan Impeller:

1. Impeller shall be centrifugal, backward inclined type, with non-stall characteristics.
2. Impeller shall be electronically statically and dynamically balanced per AMCA Standard 204.
3. Impeller shall be manufactured of aluminum (AMCA type B spark resistant), fully welded and have corrosion resistant coating.
4. Fan impeller shall be centrifugal, backward inclined, with non-stall characteristics. The impeller shall be electronically balanced both statically and dynamically per AMCA Standard 204.

5. Fan impeller shall be manufactured of aluminum (AMCA type B spark resistant), fully welded and meet specification section 2.15 for corrosion resistant coating.

F. Fan Bypass Air Plenum:

1. A bypass air plenum shall be provided and equipped with a bypass air damper and intake air hood with bird screen for introducing outside air at roof level upstream of the fan.

2. Construct plenum of fully welded steel, with corrosion resistant coating, for mounting on roof curb.

3. Bypass air plenum shall mount on a factory fabricated roof curb provided by the fan manufacturer.

4. Bypass air dampers shall be opposed-blade design and shall include a corrosion resistant coating.

5. Fan isolation damper shall be two position motor actuated, fabricated of steel or aluminum and shall include a corrosion resistant coating.

6. Include Blower / Plenum assembly with vibration isolators.

7. For constant volume systems, the fan shall be connected directly to the exhaust duct without the need of a bypass air plenum.

8. For variable volume systems, a bypass air plenum shall be provided as shown on drawings. The plenum shall be equipped with a bypass air damper and intake air hood with bird screen for introducing outside air at roof level upstream of the fan.

9. The plenum shall be constructed of fully welded steel, meet specification section 2.15 for corrosion resistant coating, and mount on roof curb as shown on the project drawings. Plenums that are fabricated of plastics or resins that are combustible and have mechanical properties less than steel shall not be acceptable.

10. The bypass air plenum shall be mounted on factory fabricated roof curb provided by the fan manufacturer, as shown on the project drawings (see section 2.5)

11. Fan designs that use inlet flexible connectors that can leak causing loss of lab exhaust shall not be accepted.

12. Bypass air dampers shall be opposed-blade design, and coated with up to 4 mils of Hi-Pro Polyester resin, electrostatically applied and baked.

13. A fan isolation damper, either gravity back draft or two position actuated, fabricated of steel or aluminum and coated with minimum 4 mils of Hi-Pro Polyester resin, electrostatically applied and baked, shall be provided as shown on the project documents.

14. Blower / Plenum vibration isolation shall be limited to neoprene / cork vibration pads.

G. Bypass Air Plenum Curb:

1. System manufacturer shall supply an insulated support curb for the plenum, fabricated of a minimum 14 gauge corrosion resistant coated steel and be structurally reinforced.

2. When properly anchored to the roof structure, the standard curb / plenum / blower assembly shall withstand wind loads of up to 125 mph without additional structural support.

3. Exhaust system manufacturer shall supply a structural support curb for the plenum, of specified height, as shown on the drawings.

4. Curb shall be fabricated of a minimum of 14 gauge corrosion resistant coated steel and structurally reinforced.

5. Curbs shall be insulated.
6. When properly anchored to the roof structure, the standard curb / plenum / blower assembly shall withstand wind loads of up to 125 mph without additional structural support.

H. Fan Motors And Drive:

1. Motors shall be premium efficiency, standard NEMA frame, 1800 or 3600 RPM, TEFC with a 1.15 service factor.
2. Include a factory-mounted NEMA 3R disconnect switch shall be provided for each fan.
3. Motor maintenance shall be accomplished without fan impeller removal or requiring maintenance personnel to access the contaminated exhaust components.
4. Drive belts and sheaves shall be readily accessible for service and consist of a minimum of two belts.
5. Shaft to be polished and ground steel.
6. Fan shaft bearings shall be air handling quality, ball or roller pillow block type and be sized for an L-10 life of no less than 100,000 hours. Bearings shall be fixed to the fan shaft using concentric mounting locking collars, for reduce vibration, increase service life, and improve serviceability.
7. Provide extended lube lines with zerk fittings for all shaft bearings.
8. Motors shall be premium efficiency, standard NEMA frame, 1800 or 3600 RPM, TEFC with a 1.15 service factor. A factory-mounted NEMA 3R disconnect switch shall be provided for each fan. Motor maintenance shall be accomplished without fan impeller removal or requiring maintenance personnel to access the contaminated exhaust components.
9. Drive belts and sheaves shall be sized for 200% of the motor horsepower, and shall be readily and easily accessible for service, if required. Drive shall consist of a minimum of two belts under all circumstances.
10. Shaft to be polished and ground steel.
11. Fan shaft bearings shall be Air Handling Quality, ball or roller pillow block type and be sized for an L-10 life of no less than 100,000 hours. Bearings shall be fixed to the fan shaft using concentric mounting locking collars, which reduce vibration, increase service life, and improve serviceability. Bearings that use set screws shall not be allowed.
12. All shaft bearings shall have extended lube lines with zerk fittings.

2.13 KILN EXHAUST VENTILATION SYSTEM

A. Basis-of-Design Product: Subject to compliance with requirements, provide Vent-A Kiln or comparable product.

B. Description: Ventilation system for exhausting heat and fumes from over fume hoods shall include [54-inch diameter] (coordinate with actual kiln furnished by Owner) spun aluminum hood tapering to a [6-inch diameter] exit. Single speed blower fan mounted on top of hood shall propel exhaust using a flexible hose to the exiting ductwork. The placement of the hood and blower assembly shall be user adjustable using an overhead pulley and counterweight system.

1. Collection Hood: 0.063 gage aluminum, alloy 1100-0.
2. Blower: Non-explosion proof, 1/8 HP, 115/1/60.
3. Flexible Exhaust Hose: 6-inch diameter UL listed triply ply laminate hose that is corrosion, moisture, temperature (250 deg. F), and flame resistant.
4. Lift System:
WMU Design Guidelines

2.14 MOTORS
A. Comply with requirements in Division 23 Section "Common Motor Requirements for HVAC Equipment."

B. Enclosure Type: Totally enclosed, fan cooled.

2.15 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. Install floor-mounted utility set fans units on concrete bases with vibration isolators. Concrete, reinforcement, and formwork requirements are specified in Division 03 Section "Cast-in-Place Concrete."

C. Install floor-mounted utility set fans on a concrete filled inertia base on a concrete housekeeping pad as indicated on drawings. Inertia base shall be fabricated from welded structural steel with the height of the base being 1/12th of the longest dimension. Inertia base shall be mounted on spring isolators, employing height saving clips. Concrete, reinforcement, and formwork requirements are specified in Division 03 Section "Cast-in-Place Concrete."

D. Support suspended utility set fans from structure using threaded steel rods and vibration isolators.

E. Support suspended utility set fans from structure using steel angle iron frame. Mount to steel frame with vibration isolators.

F. Support roof-mounted utility set fans on Pate or equivalent equipment curb rails with restrained spring isolators.
G. Support suspended circulation fans from structure using structural steel framing. Install factory furnished field installed control components.

H. Secure roof-mounted ventilators to roof curbs with cadmium-plated hardware.

I. Secure wall-mounted ventilators to building structure with cadmium-plated fasteners.

J. Support suspended ceiling mounted units from structure using threaded steel rods and vibration isolators.

K. Support units using [elastomeric mounts] [restrained elastomeric mounts] [spring isolators] [restrained spring isolators] <Insert device> having a static deflection of [1 inch] <Insert deflection>. Vibration- and seismic-control devices are specified in Division 23 Section “Vibration and Seismic Controls for HVAC Piping and Equipment.”

1. Secure vibration and seismic controls to concrete bases using anchor bolts cast in concrete base.

L. Install floor-mounting units on concrete bases. Concrete, reinforcement, and formwork requirements are specified in Division 03 Section “Cast-in-Place Concrete.”

M. Install floor-mounting units on concrete bases designed to withstand, without damage to equipment, the seismic force required by code. Concrete, reinforcement, and formwork requirements are specified in Division 03 Section “Cast-in-Place Concrete.”

N. Secure roof-mounting fans to roof curbs with cadmium-plated hardware. Refer to Division 07 Section “Roof Accessories” for installation of roof curbs.

O. Ceiling Units: Suspend units from structure; use steel wire or metal straps.

P. Support suspended units from structure using threaded steel rods and [elastomeric hangers] [spring hangers] [spring hangers with vertical-limit stops] <Insert device> having a static deflection of [1 inch] <Insert deflection>. Vibration-control devices are specified in Division 23 Section “Vibration and Seismic Controls for HVAC Piping and Equipment.”

Q. Install units with clearances for service and maintenance.

R. Label units according to requirements specified in Division 23 Section “Identification for HVAC Piping and Equipment.”

3.2 KILN EXHAUST VENTILATION SYSTEM INSTALLATION

A. Install system components level and plumb in accordance with manufacturer’s instructions.

B. Install units with clearances for service and maintenance.

C. Field cut flexible hose to shortest length permissible.

D. Provide Type B double wall vent duct through roof with roof thimble and gooseneck end bird screen.
3.3 CONNECTIONS

A. Duct installation and connection requirements are specified in other Division 23 Sections. Drawings indicate general arrangement of ducts and duct accessories. Make final duct connections with flexible connectors. Flexible connectors are specified in Division 23 Section "Air Duct Accessories."

B. Install ducts adjacent to power ventilators to allow service and maintenance.

C. Ground equipment according to Division 26 Section "Grounding and Bonding for Electrical Systems."

D. Connect wiring according to Division 26 Section "Low-Voltage Electrical Power Conductors and Cables."

3.4 FIELD QUALITY CONTROL

A. Perform the following field tests and inspections and prepare test reports:
   1. Verify that shipping, blocking, and bracing are removed.
   2. Verify that unit is secure on mountings and supporting devices and that connections to ducts and electrical components are complete. Verify that proper thermal-overload protection is installed in motors, starters, and disconnect switches.
   3. Verify that cleaning and adjusting are complete.
   4. Disconnect fan drive from motor, verify proper motor rotation direction, and verify fan wheel free rotation and smooth bearing operation. Reconnect fan drive system, align and adjust belts, and install belt guards.
   5. Adjust belt tension.
   6. Adjust damper linkages for proper damper operation.
   7. Verify lubrication for bearings and other moving parts.
   8. Verify that manual and automatic volume control and fire and smoke dampers in connected ductwork systems are in fully open position.
   9. Disable automatic temperature-control operators, energize motor and adjust fan to indicated rpm, and measure and record motor voltage and amperage.
  10. Shut unit down and reconnect automatic temperature-control operators.
  11. Remove and replace malfunctioning units and retest as specified above.

B. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.

3.5 ADJUSTING

A. Adjust damper linkages for proper damper operation.

B. Adjust belt tension.

C. Refer to Division 23 Section "Testing, Adjusting, and Balancing for HVAC" for testing, adjusting, and balancing procedures.

D. Replace fan and motor pulleys as required to achieve design airflow.
E. Lubricate bearings.

END OF SECTION 23 3423
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SECTION 23 3600 - AIR TERMINAL UNITS

PART 1 - GENERAL

1.1 SUMMARY
   A. This Section includes shutoff single-duct air terminal units.

1.2 ACTION SUBMITTALS
   A. Product Data: For each type of product indicated, include rated capacities, furnished specialties, sound-power ratings, and accessories.
   B. LEED Submittal:
      1. Product Data for Prerequisite EQ 1: Documentation indicating that units comply with ASHRAE 62.1, Section 5 - "Systems and Equipment."

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. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1, Section 5 - "Systems and Equipment" and Section 7 - "Construction and Startup."
   C. NFPA Compliance: Install air terminal units according to NFPA 90A, "Standard for the Installation of Air Conditioning and Ventilating Systems."
PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. In other Part 2 articles where titles below introduce lists, the following requirements apply to product selection:

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

2.2 SHUTOFF SINGLE-DUCT AIR TERMINAL UNITS

A. Manufacturers:

1. Anemostat; a Mestek Company.
2. Johnson Controls
4. Nailor Industries of Texas Inc.
5. Price Industries.
6. Titus.
7. Trane.
8. Tuttle & Bailey.
11. METALAIRE, Inc.; Metal Industries Inc.
13. Trox USA, Inc.

B. Configuration: Volume-damper assembly inside unit casing with control components located inside a protective metal shroud.

C. Casing: Steel or aluminum.

1. Casing Lining: Minimum 1/2-inch thick, coated, fibrous-glass duct liner complying with ASTM C 1071; secured with adhesive. [Cover liner with nonporous foil and seal edges.]
2. Casing Lining: [1/2-inch] [3/4-inch] [1-inch] thick, coated, fibrous-glass duct liner complying with ASTM C 1071; secured with adhesive.[Cover liner with nonporous foil.[Cover liner with nonporous foil and perforated metal.]
3. Air Inlet: Round stub connection or S-slip and drive connections for duct attachment.
5. Access: Removable panels for access to dampers and other parts requiring service, adjustment, or maintenance; with airtight gasket.
6. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.

D. Velocity Sensors: Multipoint array with velocity sensors in air inlet.
E. Regulator Assembly: Extruded-aluminum or galvanized-steel components; key damper blades onto shaft with nylon-fitted pivot points located inside unit casing.
   1. Factory-calibrated and field-adjustable assembly with shaft extension for connection to externally mounted control actuator.

F. Volume Damper: Galvanized steel with peripheral gasket and self-lubricating bearings.
   1. Maximum Damper Leakage: ARI 880 rated, 2 percent of nominal airflow at 3-inch wg inlet static pressure.
   4. Damper Position: Normally [open] [closed].

G. Attenuator Section: Steel or aluminum sheet metal.
   1. Lining: Minimum 1/2-inch- thick, coated, fibrous-glass duct liner complying with ASTM C 1071; secured with adhesive. Cover liner with nonporous foil and seal edges.
   2. Lining: [1/2-inch-] [3/4-inch-] [1-inch-] thick, coated, fibrous-glass duct liner complying with ASTM C 1071; secured with adhesive.[ Cover liner with nonporous foil.][ Cover liner with nonporous foil and perforated metal.]

H. Multioutlet Attenuator Section: With quantity and size of diameter collars as indicated; each with locking butterfly balancing damper.

I. Multioutlet Attenuator Section: With [two] [three] [four] <Insert number> [6-inch-] [8-inch-] [10-inch-] diameter collars; each with locking butterfly balancing damper.

J. Hot-Water Heating Coil: Copper tube, mechanically expanded into aluminum-plate fins; leak tested underwater to 200 psig; and factory installed.

K. Electric Heating Coil: Slip-in-type, open-coil design with integral control box factory wired and installed. Include the following features:
   1. Primary and secondary overtemperature protection.
   2. Nickel chrome 80/20 heating elements.
   3. Airflow switch.
   5. Fuses (for coils more than 48 A).
   7. Magnetic contactor for each step of control (for three-phase coils).

L. Direct Digital Controls: Single-package unitary controller and actuator specified in Division 23 Section "Instrumentation and Control for HVAC."
   1. The terminal unit controller flow transducer and damper actuators shall be supplied by the controls contractor for factory installation on the terminal unit. All controls components shall be mounted and wired per the control contractor’s documentation. When required the control components shall be installed within a controls enclosure provided by the terminal manufacturer.
3.1 INSTALLATION

A. Install air terminal units level and plumb. Maintain sufficient clearance for normal 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 air terminal units to allow service and maintenance.

   1. Offset piping at coils to allow for coil removal.

D. Hot-Water Piping: In addition to requirements in Division 23 Section "Hydronic Piping," connect heating coils to supply with shutoff valve, strainer, control valve, and union or flange; and to return with balancing valve, shutoff valve, drain valve, and union or flange.

   1. Provide coil bypass during flushing activities.

E. Connect ducts to air terminal units according to Division 23 Section "Metal Ducts."

F. Ground units with electric heating coils according to Division 26 Section "Grounding and Bonding for Electrical Systems."

G. Connect wiring according to Division 26 Section "Low-Voltage Electrical Power Conductors and Cables."

H. Label each air terminal unit with plan number, nominal airflow, and maximum and minimum factory-set airflow. Comply with requirements in Division 23 Section "Identification for HVAC Piping and Equipment."

3.2 FIELD QUALITY CONTROL

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

   1. After installing air terminal units, test for compliance with requirements.
   2. After installing air terminal units and after electrical circuitry has been energized, test for compliance with requirements.
   3. Leak Test: After installation, fill water coils and test for leaks. Repair leaks and retest until no leaks exist.
   4. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.

B. Remove and replace malfunctioning units and retest as specified above.

END OF SECTION 23 3600
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SECTION 23 3713 - DIFFUSERS, REGISTERS, AND GRILLES

PART 1 - GENERAL

1.1 SUMMARY

A. Section includes diffusers, registers, and grilles.
B. Section includes [louvers], and diffusers, registers, and grilles.
C. Related Sections:
   1. [Division 08 Section "Louvers and Vents" for fixed and adjustable louvers and wall vents, whether or not they are connected to ducts.]
   2. Division 23 Section "Air Duct Accessories" for [fire and smoke dampers and ]volume-control dampers not integral to diffusers, registers, and grilles.

1.2 ACTION SUBMITTALS

A. Product Data: For each type of product indicated, include the following:
   1. Data Sheet: Indicate materials of construction, finish, and mounting details; and performance data including throw and drop, static-pressure drop, and noise ratings.
   2. Diffuser, Register, and Grille Schedule: Indicate drawing designation, room location, quantity, model number, size, and accessories furnished.
B. Samples for Initial Selection: For [louvers ]with factory-applied color finishes.
C. Samples for Initial Selection: For diffusers, registers, and grilles with factory-applied color finishes.
D. Samples for Verification: For diffusers, registers, and grilles, in manufacturer's standard sizes to verify color selected.

1.3 INFORMATIONAL SUBMITTALS

A. Coordination Drawings: Reflected ceiling plans, drawn to scale, on which the following items are shown and coordinated with each other, using input from Installers of the items involved:
   1. Ceiling suspension assembly members.
   2. Method of attaching hangers to building structure.
3. Size and location of initial access modules for acoustical tile.
4. Ceiling-mounted items including lighting fixtures, diffusers, grilles, speakers, sprinklers, access panels, and special moldings.
5. Duct access panels.

B. Source quality-control reports.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

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

1. Grilles, Registers and Diffusers:
   a. Anemostst.
   b. Krueger.
   c. Price.
   d. Tuttle and Bailey.
   e. Titus.
   f. Nailor.

2. Louver Manufacturers:
   a. Air Balance Inc.
   b. All-Lite Architectural Products.
   c. American Warming and Ventilating.
   d. Arrow United Industries.
   e. Construction Specialties.
   f. Dowco Products.
   g. Greenheck Fan Corp.
   h. Industrial Louvers.
   i. Louvers and Dampers.
   j. NCA Manufacturing.
   k. Ruskin Company.

2.2 DIFFUSERS

A. General: Provide manufacturer's standard diffusers where shown; of size, shape, capacity and type as listed on diffuser schedule, with accessories and finishes as indicated.

1. Diffuser Faces:
   a. Square: Square housing; core of square concentric louvers; square or round duct connection.
   b. Rectangular: Rectangular housing; core of rectangular concentric louvers; square or round duct connection.
   c. Panel: Square or rectangular housing extended to form panel to fit in ceiling system module; core of square or rectangular concentric louvers; square or round duct connection.
d. Slot: Aluminum continuous single or multiple slot with plenum and extended frame to fit in ceiling system module. Provide full coverage 1/2-inch thick coated erosion resistant insulation liner inside plenum.
e. Round: Round housing; core of round concentric louvers; round duct connection. On units larger then 12 inch diameter, provide safety chain for removable core.

2. Diffuser Mountings
a. Surface: Diffuser housing at duct, wall or ceiling surface with gasketed perimeter flange.
b. Lay-In: Diffuser housing sized to fit between ceiling exposed suspension tee bars and rest on top surface of tee bar.

2.3 GRILLES AND REGISTERS
A. General: Provide manufacturer's standard grilles and registers where shown; of size, shape, capacity and type as listed on schedule, with accessories and finishes as indicated.

1. Register and Grille Materials:
   a. Steel Construction: Manufacturer's standard stamped sheet steel frame and adjustable blades.
   b. Aluminum Construction: Manufacturer's standard extruded aluminum frame and adjustable blades.

2.4 SECURITY INLETS AND OUTLETS
A. General: Provide manufacturer's security inlets and outlets where shown; of size, shape, capacity and type as listed on schedule, with accessories and finishes as indicated.

1. Materials:
   a. Steel Construction: Manufacturer's standard steel face, frame and structure attachments.

2.5 LOUVERS
A. Horizontal, Sightproof, Drainable-Blade Louvers:

1. Louver Depth: 5 inches.
2. Frame and Blade Nominal Thickness: Not less than 0.080 inch.
3. Mullion Type: Exposed.
4. Louver Performance Ratings:
5. Free Area: Not less than 8.3 sq. ft. for 48-inch- wide by 48-inch- high louver.
6. Point of Beginning Water Penetration: Not less than 950 fpm.
7. Air Performance: Not more than 0.10-inch wg static pressure drop at 550-fpm free-area intake velocity.
8. Screen: Aluminum 1/2-inch- square mesh, 0.063-inch wire bird screen on interior face.
9. Fabrication: Fabricate frames, including integral sills, to fit in openings of sizes indicated, with allowances made for fabrication and installation tolerances, adjoining material tolerances, and perimeter sealant joints.

10. Finish: As selected by Architect. Refer to louver schedule on drawings.


2.6 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 DIFFUSER, REGISTER, AND GRILLE INSTALLATION

A. Install diffusers, registers, and grilles level and plumb.

B. Ceiling-Mounted Outlets and Inlets: Drawings indicate general arrangement of ducts, fittings, and accessories. Air outlet and inlet locations have been indicated to achieve design requirements for air volume, noise criteria, airflow pattern, throw, and pressure drop. Make final locations where indicated, as much as practical. For units installed in lay-in ceiling panels, locate units in the center of panel. Where architectural features or other items conflict with installation, notify Architect for a determination of final location.

1. Locate slot diffusers as indicated on general construction drawings. Locate units along one side of acoustical ceiling modules.

C. Install diffusers, registers, and grilles with airtight connections to ducts.

D. Install diffusers, registers, and grilles with airtight connections to ducts and to allow service and maintenance of dampers, air extractors, and fire dampers.

E. After installation, adjust diffusers, registers, and grilles to air patterns indicated, or as directed, before starting air balancing.

3.2 LOUVER INSTALLATION

A. Locate and place louvers level, plumb, and at indicated alignment with adjacent work.

B. Use concealed anchorages. Provide brass or lead washers fitted to screws where required to protect metal surfaces and to make a weathertight connection.

C. Form closely fitted joints with exposed connections accurately located and secured.

D. Provide perimeter reveals and openings of uniform width for sealants and joint fillers, as indicated.
E. Protect unpainted galvanized and nonferrous-metal surfaces that are in contact with concrete, masonry, or dissimilar metals from corrosion and galvanic action by applying a heavy coating of bituminous paint or by separating surfaces with waterproof gaskets or nonmetallic flashing.

F. Restore louvers damaged during installation and construction so no evidence remains of corrective work. If results of restoration are unsuccessful, as determined by Architect, remove damaged units and replace with new units.

END OF SECTION 23 3713
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SECTION 23 3723 - HVAC GRAVITY VENTILATORS

PART 1 - GENERAL

1.1 SUMMARY

A. This Section includes the following types of roof-mounting intake and relief ventilators:
   1. Louver penthouses.
   2. Roof hoods.

B. Related Sections include the following:
   1. Division 08 Section "Louvers and Vents" for ventilator assemblies provided as part of the general construction.
   2. Division 23 Section "HVAC Power Ventilators" for roof-mounting exhaust fans.

1.2 ACTION SUBMITTALS

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

B. LEED Submittals:
   1. Product Data for Prerequisite IEQ 1: Documentation indicating that units comply with ASHRAE 62.1, Section 5 - "Systems and Equipment."

PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. In other Part 2 articles where titles below introduce lists, the following requirements apply to product selection:
   1. Manufacturers: Subject to compliance with requirements, provide products by one of the manufacturers specified.
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.

E. Bituminous Paint: Cold-applied asphalt emulsion complying with ASTM D 1187.

2.3 LOUVER PENTHOUSES

A. Manufacturers:
   2. Aerovent; a Twin City Fan company.
   5. Loren Cook Company.
   6. Penn Ventilation.
   7. Ruskin.
   8. Vent Products.

B. Construction: All-welded assembly with 4-inch-deep louvers, mitered corners, and aluminum sheet roof.

C. Construction: All-welded assembly with [4-inch] [6-inch]-deep louvers, mitered corners, and aluminum sheet roof.

D. 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 0.080 inch for blades.

E. 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 [0.080 inch] [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] [mitered blades with concealed close-fitting splices] and with [fully recessed] [semirecessed] mullions at corners.

F. Roof Curbs: Galvanized-steel sheet; with mitered and welded corners; 1-1/2-inch-(40-mm-) thick, rigid fiberglass insulation adhered to inside walls; and 1-1/2-inch(40-mm) wood nailer.
Size as required to fit roof opening and ventilator base. Provide with level top and bottom to match roof slope.

2. Configuration: [Self-flashing without a cant strip, with] [Built-in cant and] [Built-in raised cant and] mounting flange.
3. Overall Height: Refer to drawing detail.
4. Overall Height: [8 inches] [9-1/2 inches] [12 inches] [16 inches] [18 inches].

G. Bird Screening: Galvanized-steel, 1/2-inch- square mesh, 0.041-inch wire; or aluminum, 1/2-inch- square mesh, 0.063-inch wire.

H. Bird Screening: [Galvanized-steel, 1/2-inch- square mesh, 0.041-inch wire] [Aluminum, 1/2-inch- square mesh, 0.063-inch wire] [Flattened, expanded aluminum, 3/4 by 0.050 inch thick].

I. Insect Screening: Aluminum, 18-by-16 mesh, 0.012-inch or stainless-steel, 18-by-18 mesh, 0.009-inch wire.

2.4 ROOF HOODS

A. Manufacturers:
2. Aerovent; a Twin City Fan company.
5. Loren Cook Company.
6. Penn Ventilation.
7. Ruskin.

B. Factory fabricate according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figures 5-6 and 5-7.

C. Factory or shop fabricate according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figures 5-6 and 5-7.

D. Materials: Galvanized-steel sheet, minimum 0.064-inch- thick base and 0.040-inch- thick hood; suitably reinforced.

E. Roof Curbs: Galvanized-steel sheet; with mitered and welded corners; 1-1/2-inch-(40-mm-) thick, rigid fiberglass insulation adhered to inside walls; and 1-1/2-inch(40-mm) wood nailer. Size as required to fit roof opening and ventilator base. Provide with level top and bottom to match roof slope.

2. Overall Height: Refer to drawing detail.
3. Overall Height: [8 inches] [9-1/2 inches] [12 inches] [16 inches] [18 inches].

F. Bird Screening: Galvanized-steel, 1/2-inch- square mesh, 0.041-inch wire.
G. Insect Screening: Aluminum, 18-by-16 mesh, 0.012-inch or stainless-steel, 18-by-18 mesh, 0.009-inch wire.

H. Insulation: Insulate inside bottom of ventilator roof.

2.5 GOOSENECKS

A. Factory or shop fabricate according to SMACNA’s “HVAC Duct Construction Standards - Metal and Flexible,” Figure 5-5; with a minimum of 0.052-inch- thick, galvanized-steel sheet.

B. Roof Curbs: Galvanized-steel sheet; with mitered and welded corners; 1-1/2-inch-(40-mm-) thick, rigid fiberglass insulation adhered to inside walls; and 1-1/2-inch(40-mm) wood nailer. Size as required to fit roof opening and ventilator base. Provide with level top and bottom to match roof slope.
   2. Configuration: [Self-flashing without a cant strip, with] [Built-in cant and] [Built-in raised cant and] mounting flange.
   3. Overall Height: Refer to drawing detail.
   4. Overall Height: [8 inches] [9-1/2 inches] [12 inches] [16 inches] [18 inches].

C. Bird Screening: Galvanized-steel, 1/2-inch- square mesh, 0.041-inch wire.

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.

C. Secure gravity ventilators to roof curbs with cadmium-plated hardware. Use concealed anchorages where possible.[Refer to Division 07 Section “Roof Accessories” for installation of roof curbs.]

D. Install goosenecks on curb base where throat size exceeds [9 by 9 inches] <Insert measurement>.

E. Install gravity ventilators with clearances for service and maintenance.

F. Install perimeter reveals and openings of uniform width for sealants and joint fillers, as indicated.

G. Install concealed gaskets, flashings, joint fillers, and insulation as installation progresses. Comply with Division 07 Section “Joint Sealants” for sealants applied during installation.

H. Label gravity ventilators according to requirements specified in Division 23 Section "Identification for HVAC Piping and Equipment."
I. 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.

J. 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.

K. Duct installation and connection requirements are specified in other Division 23 Sections. Drawings indicate general arrangement of ducts and duct accessories.

L. Adjust damper linkages for proper damper operation.

END OF SECTION 23 3723
WMU Design Guidelines Instructions: These guidelines are to be used by the Design Professional to inform the design process and outline WMU-specific desires for all University projects. These guidelines have been edited to reflect WMU preferences, and the intent is for the Design Professional to use this information to guide their normal specifications-writing process. Straying from what is indicated in the guidelines is not prohibited, but shall be discussed with WMU during the development of the project.

SECTION 23 5700 - HEAT EXCHANGERS FOR HVAC

PART 1 - GENERAL

1.1 SUMMARY

A. This Section includes shell-and-tube and plate type heat exchangers.
B. This Section includes shell-and-tube type heat exchangers.
C. This Section includes plate type heat exchangers.
D. This Section includes brazed plate type heat exchangers.

1.2 ACTION SUBMITTALS

A. Product Data: Include rated capacities, operating characteristics, furnished specialties, and accessories.

1.3 CLOSEOUT SUBMITTALS

A. Operation and maintenance data.

1.4 QUALITY ASSURANCE

A. Product Options: Drawings indicate size, profiles, performance, and dimensional requirements of heat exchangers and are based on the specific equipment indicated. Refer to Division 01 Section “Product Requirements.”
B. ASME Compliance: Fabricate and label heat exchangers to comply with ASME Boiler and Pressure Vessel Code: Section VIII, “Pressure Vessels,” Division 1.

PART 2 - PRODUCTS

2.1 SHELL-AND-TUBE HEAT EXCHANGERS

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

1. Bell & Gossett.
2. Taco, Inc.
3. Armstrong Pumps, Inc.
4. API Heat Transfer Inc.
5. Thrush Company, Inc.


D. Configuration: [U-tube with removable] [Straight tube with removable] [Straight tube with fixed] bundle.

E. Shell Materials: Steel.

F. Shell Materials: [Steel] [Stainless steel].

G. Head:

1. Materials: Cast iron.
2. Materials: [Cast iron] [Cast stainless steel] [Fabricated steel] [Fabricated steel with removable cover] [Fabricated stainless steel] [Fabricated stainless steel with removable cover].
3. Flanged and bolted to shell.

H. Tube:

1. Seamless copper tubes.
2. [Seamless copper] [Steel] [Stainless-steel] [Cupronickel] [Admiralty-metal] tubes.
3. Tube diameter is determined by manufacturer based on service.

I. Tubesheet Materials: Steel tubesheets.

J. Tubesheet Materials: [Steel] [Stainless-steel] tubesheets.

K. Baffles: Steel.

L. Baffles: [Steel] [Stainless steel].

M. Piping Connections:

1. Shell: Flanged or threaded inlet and outlet fluid connections, with threaded drain and vent connections.
2. Shell: [Flanged inlet and threaded] [Threaded inlet and] [Flanged inlet and] outlet fluid connections, threaded drain, and vent connections.
3. Head: Threaded[, grooved,] or flanged inlet and outlet fluid connections.

N. Support Saddles:

1. Fabricated of material similar to shell.
2. Foot mount with provision for anchoring to support.
2.2 GASKETED PLATE HEAT EXCHANGERS

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

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

1. Bell & Gossett.
2. Taco, Inc.
3. Armstrong Pumps, Inc.
4. Alfa Laval Thermal, Inc.
5. API Heat Transfer Inc.
6. Invensys APV, Inc.
9. Tranter PHE, Inc.

C. Configuration: Freestanding assembly consisting of frame support, top and bottom carrying and guide bars, fixed and movable end plates, tie rods, individually removable plates, and one-piece gaskets.

D. Frame:

1. Capacity to accommodate 20 percent additional plates.
2. Painted carbon steel with provisions for anchoring to support.

E. Top and Bottom Carrying and Guide Bars: Painted carbon steel, aluminum, or stainless steel.

F. End-Plate Material: Painted carbon steel.

G. Tie Rods and Nuts: Steel or stainless steel.

H. Plate Material: 0.024 inch thick before stamping; Type 304 stainless steel.

I. Plate Material: [0.024 inch] [0.031 inch] [0.039 inch] thick before stamping; Type [304] [304L] [316] [316L] stainless steel.

J. Gasket Material: Suitable for application.

K. Gasket Material: [Nitrile rubber] [EPDM] <Insert material>.

L. Piping Connections:

1. Threaded port for NPS 2 and smaller. For larger sizes, furnish end-plate port with threaded studs suitable for flanged connection.
2. End plate with welded carbon-steel nozzles. Threaded pipe connection for NPS 2 and smaller; carbon-steel flanged pipe connection for larger sizes.
3. Line wetted surfaces with same material as plates.

M. Enclose plates in a solid aluminum or stainless-steel removable shroud.
2.3 BRAZED PLATE HEAT EXCHANGERS

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

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

1. Bell & Gossett.
2. Taco, Inc.
3. Armstrong Pumps, Inc.
4. Alfa Laval Thermal, Inc.
5. API Heat Transfer Inc.
6. FlatPlate, Inc.
7. Invensys APV, Inc.
10. Tranter PHE, Inc.

C. Configuration: Brazed assembly consisting of two end plates, one with threaded nozzles and pattern-embossed plates.

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.

H. Brazing Material: [Copper] [Nickel] [Copper or nickel].

PART 3 - EXECUTION

3.1 HEAT-EXCHANGER INSTALLATION

A. Install shell-and-tube heat exchangers on saddle supports.

B. Install plate type heat exchangers on concrete base. Anchor heat exchanger to concrete base. Concrete base is specified in Division 23 Section "Common Work Results for HVAC," and concrete materials and installation requirements are specified in Division 03.

C. Support brazed plate type heat exchangers for piping racked on wall.

3.2 CONNECTIONS

A. Piping installation requirements are specified in other Division 23 Sections. Drawings indicate general arrangement of piping, fittings, and specialties.
B. Maintain manufacturer’s recommended clearances for service and maintenance. Install piping connections to allow service and maintenance of heat exchangers.

   1. For shell-and-tube heat exchangers, offset piping to allow tube pull.

C. Install shutoff valves at heat-exchanger inlet and outlet connections.

D. Install relief valves on heat-exchanger heated-fluid connection and pipe relief valves, full size of valve connection, to floor drain.

E. Install vacuum breaker at heat-exchanger steam inlet connection.

F. Install hose end valve to drain shell.

3.3 FIELD QUALITY CONTROL

A. Test units for leaks. Replace damaged equipment.

3.4 CLEANING

A. After completing system installation, including outlet fitting and devices, inspect exposed finish. Remove burrs, dirt, and construction debris and repair damaged finishes.

3.5 DEMONSTRATION

A. Train Owner’s maintenance personnel to adjust, operate, and maintain heat exchangers. Refer to Division 01 Section "Demonstration and Training."

B. [Engage a factory-authorized service representative to train] [Train] Owner’s maintenance personnel to adjust, operate, and maintain heat exchangers. Refer to Division 01 Section "Demonstration and Training."

END OF SECTION 23 5700
WMU Design Guidelines Instructions: These guidelines are to be used by the Design Professional to inform the design process and outline WMU-specific desires for all University projects. These guidelines have been edited to reflect WMU preferences, and the intent is for the Design Professional to use this information to guide their normal specifications-writing process. Straying from what is indicated in the guidelines is not prohibited, but shall be discussed with WMU during the development of the project.

SECTION 23 6200 - PACKAGED COMPRESSOR AND CONDENSER UNITS

PART 1 - GENERAL

1.1 SUMMARY

A. This Section includes air-cooled condensing units.

B. This Section includes air- and water-cooled condensing units.

1.2 ACTION SUBMITTALS

A. Product Data: For each condensing unit, include rated capacities, operating characteristics, furnished specialties, and accessories. Include equipment dimensions, weights and structural loads, required clearances, method of field assembly, components, and location and size of each field connection.


B. LEED Submittals:

1. Product Data for Prerequisite EA 2: Documentation indicating that units comply with applicable requirements in ASHRAE/IESNA 90.1.
2. Product Data for Credit EA 4: Documentation indicating that compressor and condenser units and refrigerants comply.

C. Shop Drawings: Signed and sealed by a qualified professional engineer showing the required refrigeration piping design and including the following:

1. Liquid and vapor pipe sizes.
2. Refrigerant specialties.
3. Piping including connections, oil traps, and double risers.

D. Shop Drawings: Signed and sealed by a qualified professional engineer.

1. Design Calculations: Calculate requirements for selecting vibration isolators and seismic restraints and for designing vibration isolation bases.
2. Vibration Isolation Base Details: Detail fabrication including anchorages and attachments to structure and to supported equipment.
1.3 INFORMATIONAL SUBMITTALS

A. Coordination Drawings: Plans, drawn to scale, on which the following items are shown and coordinated with each other, based on input from installers of the items involved:

1. Structural members to which condensing units will be attached.
2. Liquid and vapor pipe sizes.
3. Refrigerant specialties.
4. Piping including connections, oil traps, and double risers.
5. Evaporators.

B. Manufacturer Seismic Qualification Certification: Submit certification that condensing units, accessories, and components will withstand seismic forces defined in Division 23 Section "Vibration and Seismic Controls for HVAC Piping and Equipment." Include the following:

1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
   a. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified."
   b. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified and the unit will be fully operational after the seismic event."

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.

C. Field quality-control test reports.

D. Warranty: Special warranty specified in this Section.

1.4 CLOSEOUT SUBMITTALS

A. Operation and maintenance data.

1.5 QUALITY ASSURANCE

A. Product Options: Drawings indicate size, profiles, and dimensional requirements of condensing units and are based on the specific system indicated. Refer to Division 01 Section “Product Requirements."

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. Fabricate and label refrigeration system according to ASHRAE 15, "Safety Code for Mechanical Refrigeration."
D. ASHRAE/IESNA 90.1 Compliance: Applicable requirements in ASHRAE/IESNA 90.1, Section 6 - "Heating, Ventilating, and Air-Conditioning."

1.6 COORDINATION

A. Coordinate size and location of concrete bases. Cast anchor-bolt inserts into bases. Concrete, reinforcement, and formwork requirements are specified in Division 03.

B. Coordinate installation of roof curbs, equipment supports, and roof penetrations. These items are specified in Division 07 Section "Roof Accessories."

C. Coordinate installation of units with steel mounting frames and roof penetrations.

D. Coordinate location of piping and electrical rough-ins.

1.7 WARRANTY

A. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace components of condensing units that fail in materials or workmanship within specified warranty period.

1. Failures include, but are not limited to, the following:

   a. Compressor failure.
   b. Condenser coil leak.

2. Warranty Period: [Four] [Five] [10] <Insert number> years from date of Substantial Completion.

3. Warranty Period: [Four] <Insert number> years from date of Substantial Completion.

4. Warranty Period (Compressor Only): [Five] [10] <Insert number> years from date of Substantial Completion.

5. Warranty Period (Condenser Coil Only): [Five] <Insert number> years from date of Substantial Completion.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. In other Part 2 articles where titles below introduce lists, the following requirements apply to product selection:

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

2. Manufacturers: Subject to compliance with requirements, provide products by one of the manufacturers specified.
2.2 CONDENSING UNITS, AIR COOLED, 1 TO 5 TONS

A. Manufacturers:

B. **Available** Manufacturers:

1. Carrier.
2. Lennox Industries Inc.
4. Trane.
5. Weatherking Air Conditioning Div.
6. JCI/York.
7. <Insert manufacturer's name.>

C. Description: Factory assembled and tested, consisting of compressor, condenser coil, fan, motors, refrigerant reservoir, and operating controls.

D. Compressor: Scroll, hermetically sealed, with rubber vibration isolators.

1. Motor: **[Single]** **[Two]** speed, and includes thermal- and current-sensitive overload devices, start capacitor, relay, and contactor.
2. Two-Speed Compressor: Include manual-reset, high-pressure switch and automatic-reset, low-pressure switch.
5. Refrigerant: R-407C or R-410A.

E. Condenser Coil: Seamless copper-tube, aluminum-fin coil; circuited for integral liquid subcooler, with removable drain pan and brass service valves with service ports.

F. Condenser Fan: Direct-drive, aluminum propeller fan; with permanently lubricated, totally enclosed fan motor with thermal-overload protection[ and ball bearings].

G. Accessories:

1. Coastal Filter: Mesh screen to protect condenser coil from salt damage.
2. Crankcase heater.
3. Cycle Protector: Automatic-reset timer to prevent rapid compressor cycling.
4. **[Electronic programmable thermostat]** **[Low-voltage thermostat and subbase]** to control condensing unit and evaporator fan.
5. Evaporator Freeze Thermostat: Temperature-actuated switch that stops unit when evaporator reaches freezing temperature.
7. High-Pressure Switch: Automatic-reset switch cycles compressor off on high refrigerant pressure.
8. Liquid-line solenoid.
9. Low Ambient Controller: Cycles condenser fan to permit operation down to 0 deg F[ with time-delay relay to bypass low-pressure switch].
10. Low Ambient Controller: Controls condenser fan speed to permit operation down to minus 20 deg F[ with time-delay relay to bypass low-pressure switch].
11. Low-Pressure Switch: Automatic-reset switch cycles compressor off on low refrigerant pressure.
12. PE mounting base to provide a permanent foundation.
13. Precharged and insulated suction and liquid tubing.
15. Thermostatic expansion valve.
16. Time-Delay Relay: Continues operation of evaporator fan after compressor shuts off.
17. <Insert accessories.>

H. Unit Casing: Galvanized steel, finished with baked enamel; with removable panels for access to controls, weep holes for water drainage, and mounting holes in base. Mount service valves, fittings, and gage ports on exterior of casing.

2.3 CONDENSING UNITS, AIR COOLED, 6 TO 120 TONS

A. Manufacturers:
B. [Available] Manufacturers:

1. Carrier.
2. Continental Products.
3. Engineered Air.
4. Lennox Industries Inc.
5. Daikin/McQuay.
7. Trane.
8. JCI/York.
9. <Insert manufacturer's name.>

C. Description: Factory assembled and tested, air cooled; consisting of casing, compressors, condenser coils, condenser fans and motors, and unit controls.

D. Compressor: Hermetic or semihermetic compressor designed for service with crankcase sight glass, crankcase heater, and backseating service access valves on suction and discharge ports.

1. Capacity Control: [Cylinder unloading] [Hot-gas bypass].
2. Refrigerant Charge: [R-22] [R-407C] [R-410A] [HFC-134a] <Insert type>.
3. Refrigerant: R-134a, R-407C, or R-410A.

E. Condenser Coil: Seamless copper-tube, aluminum-fin coil, including subcooling circuit and backseating liquid-line service access valve. Factory pressure test coils, then dehydrate by drawing a vacuum and fill with a holding charge of nitrogen or refrigerant.

F. Condenser Fans: Propeller-type vertical discharge; either directly or belt driven. Include the following:

1. Permanently lubricated ball-bearing motors.
2. Separate motor for each fan.
3. Dynamically and statically balanced fan assemblies.

G. Operating and safety controls include the following:

1. Manual-reset, high-pressure cutout switches.
2. Automatic-reset, low-pressure cutout switches.
3. Low oil pressure cutout switch.
4. Compressor-winding thermostat cutout switch.
5. Three-leg, compressor-overload protection.
6. Control transformer.
7. Magnetic contactors for compressor and condenser fan motors.
8. Timer to prevent excessive compressor cycling.

H. Accessories:

1. [Electronic programmable thermostat] [Low-voltage thermostat and subbase] to control condensing unit and evaporator fan.
2. Low Ambient Controller: Cycles condenser fan to permit operation down to 0 deg F [with time-delay relay to bypass low-pressure switch].
3. Low Ambient Controller: Controls condenser fan speed to permit operation down to minus 20 deg F [with time-delay relay to bypass low-pressure switch].
5. Hot-gas bypass kit.
6. Part-winding-start timing relay, circuit breakers, and contactors.
7. <Insert accessories.>

I. Unit Casings: Designed for outdoor installation with weather protection for components and controls and with removable panels for required access to compressors, controls, condenser fans, motors, and drives. Additional features include the following:

1. Steel, galvanized or zinc coated, for exposed casing surfaces; treated and finished with manufacturer's standard paint coating.
2. Perimeter base rail with forklift slots and lifting holes to facilitate rigging.
3. Gasketed control panel door.
4. Nonfused disconnect switch, factory mounted and wired, for single external electrical power connection.
5. Condenser coil [hail guard] [grille] to protect coil from physical damage.

2.4 MOTORS

A. General requirements for motors are specified in Division 23 Section "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: Electrical devices and connections are specified in Division 26 Sections.

2.5 SOURCE QUALITY CONTROL

A. Verification of Performance: Rate condensing units according to ARI 210/240, ARI 340/360, or ARI 365.

B. Test and inspect shell and tube condensers according to ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.

C. Testing Requirements: Factory test sound-power-level ratings according to ARI 270.

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 condensing units.

B. Examine roughing-in for refrigerant piping systems to verify actual locations of piping connections before equipment installation.

C. Examine walls, floors, and roofs for suitable conditions where condensing units will be installed.

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

3.2 INSTALLATION

A. Install units level and plumb, firmly anchored in locations indicated; maintain manufacturer's recommended clearances.

B. Install condensing units on concrete base. Concrete base is specified in Division 23 Section "Common Work Results for HVAC," and concrete materials and installation requirements are specified in Division 03.

C. Concrete Bases:

   1. Install dowel rods to connect concrete base to concrete slab. 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. Install anchor bolts to elevations required for proper attachment to supported equipment.
   5. Install anchor bolts according to anchor-bolt manufacturer's written instructions.

D. Install roof-mounting units on equipment supports specified in Division 07.

E. Install roof-mounting condensing units on Pate or equivalent equipment curb rails with restrained spring isolators.

F. For 6-ton units and larger, install roof-mounting condensing units on Pate or equivalent equipment curb rails with restrained spring isolators.
G. For 5-ton units and smaller, install roof-mounting compressor-condenser components on polyethylene mounting base. Anchor units to base with removable, cadmium-plated fasteners.

H. Install roof-mounting units on structural steel supports.

I. Vibration Isolation: Mount condensing units on rubber pads with a minimum deflection of 1/4 inch. Vibration isolation devices and installation requirements are specified in Division 23 Section "Vibration and Seismic Controls for HVAC Piping and Equipment."

J. Vibration Isolation: Mount condensing units on restrained spring isolators with a minimum deflection of <Insert measurement>. Vibration isolation devices and installation requirements are specified in Division 23 Section "Vibration and Seismic Controls for HVAC Piping and Equipment."

K. Maintain manufacturer's recommended clearances for service and maintenance.

L. Loose Components: Install electrical components, devices, and accessories that are not factory mounted.

3.3 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 machine to allow service and maintenance.

C. Connect precharged refrigerant tubing to unit's quick-connect fittings. Install tubing so it does not interfere with access to unit. Install furnished accessories.

D. Connect refrigerant piping to air-cooled condensing units; maintain required access to unit. Install furnished field-mounted accessories. Refrigerant piping and specialties are specified in Division 23 Section "Refrigerant Piping."

3.4 FIELD QUALITY CONTROL

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

1. Perform electrical test and visual and mechanical inspection.
2. Leak Test: After installation, charge systems 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 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.

B. Verify that vibration isolation and flexible connections properly dampen vibration transmission to structure.
C. Remove and replace malfunctioning condensing units and retest as specified above.

3.5 STARTUP SERVICE

A. Complete installation and startup checks according to manufacturer's written instructions and perform the following:

1. Inspect for physical damage to unit casing.
2. Verify that access doors move freely and are weathertight.
3. Clean units and inspect for construction debris.
4. Verify that all bolts and screws are tight.
5. Adjust vibration isolation and flexible connections.
6. Verify that controls are connected and operational.

B. Lubricate bearings on fans.

C. Verify that fan wheel is rotating in the correct direction and is not vibrating or binding.

D. Adjust fan belts to proper alignment and tension.

E. Start unit according to manufacturer's written instructions and complete manufacturer's startup checklist.

F. Measure and record airflow over coils.

G. Verify proper operation of condenser capacity control device.

H. Verify that vibration isolation and flexible connections properly dampen vibration transmission to structure.

I. After startup and performance test, lubricate bearings[ and adjust belt tension].

3.6 DEMONSTRATION

A. [Engage a factory-authorized service representative to train] [Train] Owner's maintenance personnel to adjust, operate, and maintain condensing units.

END OF SECTION 23 6200
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SECTION 23 6416 - CENTRIFUGAL WATER CHILLERS

1.1 SUMMARY

A. Section includes the pre-ordering of a centrifugal water chiller. Owner is pre-ordering unit to obtain satisfactory delivery date. The successful installing contractor will be assigned the responsibility to receive, store, install, start-up, and carry warranty on the unit. Factory start-up, participation in Owner chiller commissioning activities, and Owner training shall be included.

B. Section Includes:
   1. Packaged, water-cooled, electric-motor-driven centrifugal chillers.
   2. Chiller Plant Optimization Software.
   3. Packaged, portable refrigerant recovery units.

C. Related Section:
   1. Section 28 3400 "Refrigerant Detection and Alarm" for refrigerant monitors, alarms, supplemental breathing apparatus, and ventilation equipment interlocks.

1.2 DEFINITIONS

A. BAS: Building automation system.

B. COP: Coefficient of performance. The ratio of the rate of heat removal to the rate of energy input using consistent units for any given set of rating conditions.

C. EER: Energy-efficiency ratio. The ratio of the cooling capacity given in terms of Btu/h to the total power input given in terms of watts at any given set of rating conditions.

D. IPLV: Integrated part-load value. A single-number part-load efficiency figure of merit calculated per the method defined by ARI 506/110 and referenced to ARI standard rating conditions.

E. kW/Ton: The ratio of total power input of the chiller in kilowatts to the net refrigerating capacity in tons at any given set of rating conditions.

F. NPLV: Nonstandard part-load value. A single-number part-load efficiency figure of merit calculated per the method defined by ARI 506/110 and intended for operating conditions other than the ARI standard rating conditions.
1.3 PERFORMANCE REQUIREMENTS

A. Seismic Performance: Centrifugal chillers shall withstand the effects of earthquake motions determined according to [ASCE/SEI 7] \(<\text{Insert requirement}>\).

1. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified\(\text{ and the unit will be fully operational after the seismic event}.\)"

B. Condenser-Fluid Temperature Performance:

1. Startup Condenser-Fluid Temperature: Chiller shall be capable of starting with an entering condenser-fluid temperature of \([60 \text{ deg F}] [55 \text{ deg F}] [40 \text{ deg F}] <\text{Insert temperature}>\) and providing stable operation until the system temperature is elevated to the minimum operating entering condenser-fluid temperature.
2. Minimum Operating Condenser-Fluid Temperature: Chiller shall be capable of continuous operation over the entire capacity range indicated with an entering condenser-fluid temperature of \([65 \text{ deg F}] [60 \text{ deg F}] [55 \text{ deg F}]\).
3. Make factory modifications to standard chiller design if necessary to comply with performance indicated.

C. Site Altitude: Chiller shall be suitable for altitude at which installed without affecting performance indicated. Make adjustments to affected chiller components to account for site altitude.

D. Performance Tolerance: Comply with the following in lieu of ARI 506/110:

1. Allowable Capacity Tolerance: \([\text{Zero}] <\text{Insert number}>\) percent.
2. Allowable IPLV/NPLV Performance Tolerance: \([\text{Zero}] <\text{Insert number}>\) percent.

1.4 ACTION SUBMITTALS

A. Product Data: For each type of product indicated. Include refrigerant, rated capacities, operating characteristics, furnished specialties, and accessories.

1. Performance at ARI standard conditions and at conditions indicated.
2. Performance at ARI standard unloading conditions.
3. Minimum evaporator flow rate.
4. Minimum condenser flow rate.
5. Refrigerant capacity of chiller.
6. Oil capacity of chiller.
7. Fluid capacity of evaporator.
10. Minimum entering condenser-fluid temperature.
11. 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.

B. LEED Submittals:
1. Product Data for Credit EA 4: Documentation indicating that equipment and refrigerants comply.

C. 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.

1.5 INFORMATIONAL SUBMITTALS
   A. Coordination Drawings: Floor plans, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:
      1. Structural supports.
      2. Piping roughing-in requirements.
      3. Wiring roughing-in requirements, including spaces reserved for electrical equipment.
      4. Access requirements, including working clearances for mechanical controls and electrical equipment, and tube pull and service clearances.
   B. Certificates: For certification required in "Quality Assurance" Article.
   C. Seismic Qualification Certificates: For chillers, accessories, and components, from manufacturer.
      1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
      2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
      3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.
   D. Source quality-control reports.
   E. Startup service reports.
   F. Warranty: Sample of special warranty.

1.6 CLOSEOUT SUBMITTALS
   A. Operation and maintenance data.

1.7 QUALITY ASSURANCE
   A. ARI Certification: Certify chiller according to ARI 550 certification program.
   B. ARI Rating: Rate chiller performance according to requirements in ARI 506/110.
C. AHRI Rating: Rate chiller performance according to requirements in AHRI 550/590.

D. ASHRAE Compliance:
   1. ASHRAE 15 for safety code for mechanical refrigeration.
   2. ASHRAE 147 for refrigerant leaks, recovery, and handling and storage requirements.

E. ASHRAE/IESNA Compliance: Applicable requirements in ASHRAE/IESNA 90.1.

F. 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.

G. Comply with NFPA 70.

H. Comply with requirements of UL and UL Canada, and include label by a qualified testing agency showing compliance.


1.8 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] [in containers separate from chiller].

D. Package chiller for export shipping in totally enclosed [bagging] [crate] [crate with bagging].

1.9 COORDINATION

A. Coordinate sizes and locations of concrete bases with actual equipment provided. Cast anchor-bolt inserts into bases.

B. Coordinate sizes, locations, and anchoring attachments of structural-steel support structures.

1.10 WARRANTY

A. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace components of chillers that fail in materials or workmanship within specified warranty period.

   1. The chiller manufacturer’s warranty shall cover parts and labor costs for the repair or replacement of defects in material or workmanship for a period of one year from
equipment startup or 18 months from shipment, whichever occurs first and shall also include an additional extended warranty for two years on entire unit including refrigerant coverage.

2. Extended warranties include, but are not limited to, the following:
   a. Refrigerant charge.
   b. Complete chiller including refrigerant and oil charge.
   c. Complete compressor and drive assembly including refrigerant and oil charge.
   d. Parts [only] [and labor].
   e. Loss of refrigerant charge for any reason.

3. Warranty Period: Five 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] [available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following]:

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

1. Daikin/McQuay.
2. JCI/YORK.
3. Carrier.
4. Daikin/McQuay.
5. Trane.
6. JCI/YORK.

C. Basis-of-Design Product: Subject to compliance with requirements, provide the product indicated on Drawings or a comparable product by one of the following:

1. Carrier Corporation.
3. Trane.
5. <Insert manufacturer's name>.

2.2 MANUFACTURED UNIT

A. Description: Factory-assembled and -tested chiller complete with centrifugal compressor(s), direct drive electric motor, compressor motor controller, evaporator, condenser, controls, interconnecting unit piping and wiring, and indicated accessories.

1. Disassemble chiller into major assemblies as required by the installation after factory testing and before packaging for shipment.
2. For chillers with dual compressors, provide each compressor with a dedicated motor and motor controller, and provide for continued operation when either compressor-drive assembly fails or is being serviced.

B. Fabricate chiller mounting base with reinforcement strong enough to resist chiller movement during a seismic event when chiller is anchored to field support structure.

2.3 COMPRESSOR-DRIVE ASSEMBLY

A. Description: Multistage, variable-displacement, centrifugal-type compressor driven by an electric motor with magnetic bearings.

B. Description: Single-stage or multistage, variable-displacement, centrifugal-type compressor driven by an electric motor.

1. Where indicated, provide oil-free compressor technology using a permanent magnet synchronous motor, magnetic bearings, integral variable frequency controller, and digital electronic controls.

C. Compressor:

1. Casing: Cast iron, precision ground.
2. Impeller: High-strength cast aluminum or cast-aluminum alloy on carbon- or alloy-steel shaft.

D. Drive: Direct hermetic design using an electric motor with magnetic bearings as the driver.

1. Gear Drives: For chillers with gear drives, provide single- or double-helical gear design continuously coated with oil while chiller is operating. Gears shall comply with American Gear Manufacturer Association standards.
2. Drive Coupling: For chillers with open drives, provide flexible disc with all-metal construction and no wearing parts to ensure long life without the need for lubrication.
3. Seals: Seal drive assembly to prevent refrigerant leakage.

E. Magnetic Bearings: The motor shaft shall be supported on active magnetic radial and thrust bearings. Magnetic bearing control shall be equipped with auto vibration reduction and balancing systems. During a power failure event, the magnetic bearings shall remain active throughout the compressor coast down. Rolling element bearings shall be provided as a backup to the magnetic bearings designed for emergency touch down situations.

F. Compressor Motor:

1. Hermetically sealed permanent magnet synchronous motor with energy efficiency required to suit chiller energy efficiency indicated.
2. Factory mounted, aligned, and balanced as part of compressor assembly before shipping.
3. Motor shall be of sufficient capacity to drive compressor throughout entire operating range without overload and with sufficient capacity to start and accelerate compressor without damage.
4. For chillers with open drives, provide motor with open-drip-proof enclosure.
5. Provide motor with thermistor or RTD in each of three-phase motor windings to monitor temperature and report information to chiller control panel.
6. Provide motor with thermistor or RTD to monitor bearing temperature and report information to chiller control panel.
7. The motor shall be designed for variable frequency drive operation
8. Provide open-drive motor with internal electric heater, internally powered from chiller power supply.

G. Vibration Balance: Balance chiller compressor and drive assembly to provide a precision balance that is free of noticeable vibration over the entire operating range.
   1. Overspeed Test: 25 percent above design operating speed.

H. Service: Easily accessible for inspection and service.
   1. Compressor's internal components shall be accessible without having to remove compressor-drive assembly from chiller.
   2. Provide lifting lugs or eyebolts attached to casing.

I. Economizers: For multistage chillers, provide inter-stage economizers.

J. Capacity Control: Modulating, variable-inlet, guide-vane assembly combined with hot-gas bypass, if necessary, to achieve performance indicated.
   1. Maintain stable operation that is free of surge, cavitation, and vibration throughout range of operation. Configure to achieve most energy-efficient operation possible.
   2. Operating Range: From 100 to [15] [10] [5] [zero] <Insert number> percent of design capacity.
   3. Condenser-Fluid Unloading Requirements over Operating Range: [Constant-design entering condenser-fluid temperature] [Drop-in entering condenser-fluid temperature of 2.5 deg F for each 10 percent in capacity reduction] <Insert conditions>.
   4. Chillers with variable frequency controllers shall modulate compressor speed with variable-inlet, guide-vane control to achieve optimum energy efficiency.

K. Oil Lubrication System: Consisting of pump, filtration, cooler, factory-wired power connection, and controls.
   1. Provide lubrication to bearings, gears, and other rotating surfaces at all operating, startup, coast down, and standby conditions including power failure.
   2. Manufacturer's standard method to remove refrigerant from oil.
   3. Oil filter shall be the easily replaceable cartridge type, minimum 0.5-micron efficiency, with means of positive isolation while servicing.
   4. Refrigerant- or water-cooled oil cooler.
   5. Factory-installed and pressure-tested piping with isolation valves and accessories.
   6. Oil compatible with refrigerant and chiller components.
   7. Positive visual indication of oil level.

2.4 REFRIGERATION

A. Refrigerant:
WMU Design Guidelines

1. Type: R-134a.
2. Compatibility: Chiller parts exposed to refrigerants shall be fully compatible with refrigerants, and pressure components shall be rated for refrigerant pressures.

B. Refrigerant Flow Control: Manufacturer's standard refrigerant flow-control device satisfying performance requirements indicated.

C. Pressure Relief Device:
   1. Comply with requirements in ASHRAE 15 and in applicable portions of ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.
   2. For Chillers Using R-123: Rupture disc constructed of frangible carbon.
   3. 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.

D. 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.

E. Refrigerant Isolation for Chillers Using R-134a: Factory install positive shutoff 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.

F. Purge System:
   1. For chillers operating at sub-atmospheric pressures (using R-123 refrigerant), factory install an automatic purge system for collection and return of refrigerant and lubricating oil and for removal of non-condensables including, but not limited to, water, water vapor, and non-condensable gases.
   2. System shall be a thermal purge design, refrigerant or air cooled, 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.
   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 ARI 580.
   7. Operation independent of chiller per ASHRAE 147.

G. Positive-Pressure System:
   1. For chillers operating at sub-atmospheric 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.
2.5 EVAPORATOR

A. Description: Shell-and-tube design with water in tubes and refrigerant surrounding tubes within shell. Shell is separate from condenser.

B. Shell Material: Carbon-steel rolled plates with continuously welded seams or seamless pipe.

C. Designed to prevent liquid refrigerant carryover from entering compressor.

D. Provide evaporator with sight glass or other form of positive visual verification of liquid-refrigerant level.

E. Tubes:
   1. Individually replaceable from either end and without damage to tube sheets and other tubes.
   2. Mechanically expanded into end sheets and physically attached to intermediate tube sheets.
   3. Material: Copper.
   5. Minimum Wall Thickness: Manufacturer's choice.
   7. Internal Finish: Enhanced or smooth.

F. End Tube Sheets: Continuously welded to each end of shell; drilled and reamed to accommodate tubes with positive seal between fluid in tubes and refrigerant in shell.

G. Intermediate Tube Sheets: Installed in shell and spaced along length of tube at intervals required to eliminate vibration and to avoid contact of tubes resulting in abrasion and wear.

H. Water Box:
   1. Cast-iron or carbon-steel construction; arranged to provide visual inspection and cleaning of tubes from either end without disturbing refrigerant in shell.
   2. Standard type for water box with piping connections. Standard type for water box without piping connections.
   3. Provide water boxes with lifting lugs or eyebolts.
   4. Hinged or davited water boxes.
   7. Thermistor or RTD temperature sensor factory installed in each nozzle.
   8. Fit each water box with 3/4-inch drain connection at low point and vent connection at high point, each with threaded plug.

I. Additional Corrosion Protection:
   1. Electrolytic corrosion-inhibitor anode.
   2. Coat wetted surfaces with a corrosion-resistant finish.
   3. Using same material as tubes, clad surfaces of end tube sheets in contact with fluid. Coat other wetted surfaces, including water boxes, with a corrosion-resistant finish.
2.6 CONDENSER

A. Description: Shell-and-tube design with water in tubes and refrigerant surrounding tubes within shell. Shell is separate from evaporator.

B. Shell Material: Carbon-steel rolled plates with continuously welded seams or seamless pipe.

C. Designed to prevent direct impingement of high-velocity hot gas from compressor discharge on tubes.

D. Provide condenser with sight glass or other form of positive visual verification of refrigerant charge and condition.

E. Tubes:
   1. Individually replaceable from either end and without damage to tube sheets and other tubes.
   2. Mechanically expanded into end sheets and physically attached to intermediate tube sheets.
   3. Material: Copper.
   4. Nominal OD: Manufacturer’s choice.
   5. Minimum Wall Thickness: Manufacturer’s choice.
   7. Internal Finish: Enhanced or smooth.

F. End Tube Sheets: Continuously welded to each end of shell; drilled and reamed to accommodate tubes with positive seal between fluid in tubes and refrigerant in shell.

G. Intermediate Tube Sheets: Installed in shell and spaced along length of tube at intervals required to eliminate vibration and to avoid contact of tubes resulting in abrasion and wear.

H. Water Box:
   1. Cast-iron or carbon-steel construction; arranged to provide visual inspection and cleaning of tubes from either end without disturbing refrigerant in shell.
   2. Standard type for water box with piping connections. Standard type for water box without piping connections.
   3. Provide water boxes with lifting lugs or eyebolts.
   4. Hinged or davited water boxes.
   7. Thermistor or RTD temperature sensor factory installed in each nozzle.
   8. Fit each water box with 3/4-inch drain connection at low point and vent connection at high point, each with threaded plug.

I. Additional Corrosion Protection:
   1. Electrolytic corrosion-inhibitor anode.
   2. Coat wetted surfaces with a corrosion-resistant finish.
   3. Using same material as tubes, clad surfaces of end tube sheets in contact with fluid. Coat other wetted surfaces, including water boxes, with a corrosion-resistant finish.
2.7 HEAT-RECLAIM CONDENSER

A. Description: Shell-and-tube design with water in tubes and refrigerant surrounding tubes within shell. Shell is separate from evaporator and condenser.

B. Shell Material: Carbon-steel rolled plates with continuously welded seams or seamless pipe.

C. Designed to prevent direct impingement of high-velocity hot gas from compressor discharge on tubes.

D. Tubes:
   1. Individually replaceable from either end and without damage to tube sheets and other tubes.
   2. Mechanically expanded into end sheets and physically attached to intermediate tube sheets.
   3. Material: [Copper] [Copper-nickel alloy] [Stainless steel] [Titanium] [Copper, copper-nickel alloy, stainless steel, or titanium] <Insert material>.
   4. Nominal OD: [Manufacturer's choice] [3/4 inch] [1 inch] [3/4 or 1 inch].
   5. Minimum Wall Thickness: [Manufacturer's choice] [0.025 inch] [0.028 inch] [0.035 inch] <Insert value>.
   7. Internal Finish: [Enhanced] [Smooth] [Enhanced or smooth].

E. End Tube Sheets: Continuously welded to each end of shell; drilled and reamed to accommodate tubes with positive seal between fluid in tubes and refrigerant in shell.

F. Intermediate Tube Sheets: Installed in shell and spaced along length of tube at intervals required to eliminate vibration and to avoid contact of tubes resulting in abrasion and wear.

G. Water Box:
   1. Cast-iron or carbon-steel construction; arranged to provide visual inspection and cleaning of tubes from either end without disturbing refrigerant in shell.
   2. [Standard] [Marine] type for water box with piping connections. Standard type for water box without piping connections.
   4. [Hinged] [Davited] [Hinged or davited] water boxes.
   5. [Hinged] [Davited] [Hinged or davited] marine water-box covers.
   7. Thermistor or RTD temperature sensor factory installed in each nozzle.
   8. Fit each water box with [3/4-inch] [1-inch] [3/4- or 1-inch] <Insert size> drain connection at low point and vent connection at high point, each with threaded plug.

H. Additional Corrosion Protection:
   1. Electrolytic corrosion-inhibitor anode.
   2. Coat wetted surfaces with a corrosion-resistant finish.
   3. Using same material as tubes, clad surfaces of end tube sheets in contact with fluid. Coat other wetted surfaces, including water boxes, with a corrosion-resistant finish.
2.8 INSULATION

A. Closed-cell, flexible elastomeric thermal insulation complying with ASTM C 534, Type I for tubular materials and Type II for sheet materials.

1. Thickness: 3/4 inch.

B. Adhesive: As recommended by insulation manufacturer.

C. Factory-applied insulation over all cold surfaces of chiller capable of forming condensation. Components shall include, but not be limited to, evaporator shell and end tube sheets, evaporator water boxes including nozzles, refrigerant suction pipe from evaporator to compressor, cold surfaces of compressor, refrigerant-cooled motor, and auxiliary piping.

1. Apply adhesive to 100 percent of insulation contact surface.
2. Before insulating steel surfaces, prepare surfaces for paint, and prime and paint as indicated for other painted components. Do not insulate unpainted steel surfaces.
3. Seal seams and joints to provide a vapor barrier.
4. After adhesive has fully cured, paint exposed surfaces of insulation to match other painted parts.

2.9 ELECTRICAL

A. Factory installed and wired, and functionally tested at factory before shipment.

B. Single-point, field-power connection to fused disconnect switch. Minimum withstand rating shall be as required by electrical power distribution system.

1. Branch power circuit to each motor, electric heater, dedicated electrical load, and controls with disconnect switch or circuit breaker.

   a. NEMA KS 1, heavy-duty, fusible switch with rejection-type fuse clips rated for fuses. Select and size fuses to provide Type 2 protection according to IEC 60947-4-1.

   b. NEMA AB 1, motor-circuit protector (circuit breaker) with field-adjustable, short-circuit-trip set point.

2. NEMA ICS 2-rated motor controller for auxiliary motors, hand-off-auto switch, and overcurrent protection for each motor. Provide variable frequency controller for each variable-speed motor furnished.

3. Control-circuit transformer with primary and secondary side fuses.

C. Terminal blocks with numbered wiring to match wiring diagram. Spare wiring terminal block for connection to external controls or equipment.

D. Factory-installed wiring outside of enclosures shall be in metal raceway except make terminal connections with not more than a 24-inch length of flexible metallic conduit.

E. Factory-installed wiring outside of enclosures shall be in metal raceway except make terminal connections with not more than a 24-inch length of [liquidtight] [flexible metallic] [liquidtight or flexible metallic] conduit.
F. Factory install and wire capacitor bank for the purpose of power factor correction to 0.95 at all operating conditions.

1. If capacitors are mounted in a dedicated enclosure, use same NEMA enclosure type as motor controller. Provide enclosure with service entrance knockouts and bushings for conduit.

2. Capacitors shall be non-PCB dielectric fluid, metallized electrode design, low loss with low-temperature rise. The kVAR ratings shall be indicated and shall not exceed the maximum limitations set by NFPA 70. Provide individual cells as required.

3. Provide each cell with current-limiting replaceable fuses and carbon-film discharge resistors to reduce residual voltage to less than 50 V within one minute after de-energizing.

4. Provide a ground terminal and a terminal block or individual connectors for phase connection.

2.10 MOTOR CONTROLLER

A. Enclosure: [Factory installed, unit mounted] [Factory furnished, field mounted], [NEMA 250] [NEMA ICS 6], [Type 1] [Type 4] [Type 4X] [Type 12] <Insert type>, with hinged full-front access door[ with lock and key or padlock and key].

B. Control Circuit: Obtained from [integral control power transformer] <Insert source of control power> with a control power [transformer] [source] of enough capacity to operate connected control devices.

C. Overload Relay: Shall be sized according to UL 1995 or shall be an integral component of chiller control microprocessor.

D. Across-the-Line Controller: NEMA ICS 2, Class A, full voltage, nonreversing; include isolation switch and current-limiting fuses.

E. Star-Delta, Reduced-Voltage Controller: NEMA ICS 2, closed transition.

F. Autotransformer Reduced-Voltage Controller: NEMA ICS 2, closed transition; include isolation switch and current-limiting fuses.

G. Solid-State, Reduced-Voltage Controller: NEMA ICS 2.

1. Surge suppressor in solid-state power circuits providing three-phase protection against damage from supply voltage surges 10 percent or more above nominal line voltage.

2. Visual indication of motor and control status, including the following conditions:
   a. Controller on.
   b. Overload trip.
   c. Loss of phase.
   d. Starter fault.

H. Accessories: Devices shall be factory installed in controller enclosure unless otherwise indicated.

1. Externally Operated[, Door-Interlocked] Disconnect: [Fused disconnect switch] [Nonfused disconnect switch] [Circuit breaker]. Minimum withstand rating shall be as
required by electrical power distribution system, but not less than [42,000] [65,000]


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


5. Elapsed-Time Meters: Numerical readout in hours on face of enclosure.


7. Meters: Panel type, [2-1/2 inches] [4-1/4 inches] with [90] [120] [270]-degree scale and [1] [2] percent accuracy. Where indicated, provide transfer device with an off position. Meters shall indicate the following:
   a. Ammeter: Output current for each phase, with current sensors rated to suit application.
   b. Voltmeter: Output voltage for each phase.
   c. Frequency Meter: Output frequency.
   d. Real-time clock with current time and date.
   e. Total run time.
   f. <Insert features>.

8. Multifunction Digital-Metering Monitor: Microprocessor-based unit suitable for three- or four-wire systems and with the following features:
   a. Selectable, digital display of the following:
      1) Phase Currents, Each Phase: Plus or minus 1 percent.
      2) Phase-to-Phase Voltages, Three Phase: Plus or minus 1 percent.
      3) Phase-to-Neutral Voltages, Three Phase: Plus or minus 1 percent.
      4) Three-Phase Real Power: Plus or minus 2 percent.
      5) Three-Phase Reactive Power: Plus or minus 2 percent.
      6) Power Factor: Plus or minus 2 percent.
      7) Frequency: Plus or minus 0.5 percent.
      8) Integrated Demand with Demand Interval Selectable from Five to 60 Minutes: Plus or minus 2 percent.
      9) Accumulated energy, in megawatt hours (joules), plus or minus 2 percent; stored values unaffected by power outages for up to 72 hours.
   b. Mounting: Display and control unit flush or semirecessed in instrument compartment door.


2.11 VARIABLE FREQUENCY CONTROLLER

A. Motor controller shall be factory mounted and wired on the chiller to provide a single-point, field-power termination to the chiller and its auxiliaries.

B. Description: NEMA ICS 2; listed and labeled as a complete unit and arranged to provide variable speed by adjusting output voltage and frequency.

C. Enclosure: Unit mounted, NEMA 250, Type 1, with hinged full-front access door with lock and key.
D. Enclosure: Unit mounted, NEMA 250, [Type 1][Type 4][Type 4x][Type 12], with hinged full-front access door with lock and key.

E. Integral Disconnecting Means: Door-interlocked, NEMA AB 1, instantaneous-trip circuit breaker with lockable handle.

F. Integral Disconnecting Means: [Door-interlocked,] NEMA AB 1, instantaneous-trip circuit breaker with lockable handle. Minimum withstand rating shall be as required by electrical power distribution system, but not less than [42,000] [65,000] "Insert value" A.

G. Technology: Pulse width modulated (PWM) output with insulated gate bipolar transistors (IGBT); suitable for variable torque loads.

H. Controller shall consist of a rectifier converter section, a digital/analog driver regulator section, and an inverter output section.

1. Rectifier section shall be a full-wave diode bridge that changes fixed-voltage, fixed-frequency, ac line power to a fixed dc voltage. Silicon controller rectifiers, current source inverters, and paralleling of devices are unacceptable. Rectifier shall be insensitive to phase rotation of the ac line.
2. Regulator shall provide full digital control of frequency and voltage.
3. Inverter section shall change fixed dc voltage to variable-frequency, variable ac voltage, for application to a squirrel-cage motor. Inverter shall produce a sine-coded, pulse width modulated (PWM) output wave form and shall conduct no radio-frequency interference back to the input power supply.

I. Output Rating: Three phase; with voltage proportional to frequency throughout voltage range.

J. Operating Requirements:

1. Input AC Voltage Tolerance: 460-V ac, plus 10 percent or 506 V maximum.
2. Input frequency tolerance of 60 Hz, plus or minus 2 Hz.
3. Capable of driving full load, without derating, under the following conditions:
   a. Ambient Temperature: 0 to 40 deg C.
   b. Relative Humidity: Up to 95 percent (noncondensing).
   c. Altitude: 3300 feet.
   d. Ambient Temperature: 0 to 50 deg C.
   e. Relative Humidity: Up to [90][95] percent (noncondensing).
   f. Altitude: [3300 feet][6600 feet].
4. Minimum Efficiency: 96 percent at 60 Hz, full load.
5. Minimum Displacement Primary-Side Power Factor: 95 percent without harmonic filter, 98 percent with harmonic filter.
6. Overload Capability: 1.05 times the full-load current for 7 seconds.
7. Starting Torque: As required by compressor-drive assembly.
8. Speed Regulation: Plus or minus 1 percent.
9. Isolated control interface to allow controller to follow control signal over a 10:1 speed range.
10. To avoid equipment resonant vibrations, provide critical speed lockout circuitry to allow bands of operating frequency at which controller shall not operate continuously.
11. Capable of being restarted into a motor coasting in either the forward or reverse direction without tripping.

K. Internal Adjustability Capabilities:

1. Minimum Output Frequency: 6 Hz.
2. Maximum Output Frequency: 60 Hz.
3. Acceleration: 2 seconds to a minimum of 60 seconds.
4. Deceleration: 2 seconds to a minimum of 60 seconds.
5. Current Limit: 30 percent to a minimum of 100 percent of maximum rating.

L. Self-Protection and Reliability Features: Subjecting the controller to any of the following conditions shall not result in component failure or the need for replacement:

1. Overtemperature.
2. Short circuit at controller output.
3. Ground fault at controller output. Variable frequency controller shall be able to start a grounded motor.
4. Open circuit at controller output.
5. Input undervoltage.
6. Input overvoltage.
7. Loss of input phase.
8. Reverse phase.
9. AC line switching transients.
10. Instantaneous overload, line to line or line to ground.
11. Sustained overload exceeding 100 percent of controller rated current.
12. Starting a rotating motor.

M. Motor Protection: Controller shall protect motor against overvoltage and undervoltage, phase loss, reverse phase, overcurrent, overtemperature, and ground fault.

N. Automatic Reset and Restart: Capable of three restarts after controller fault or on return of power after an interruption and before shutting down for manual reset or fault correction. Controller shall be capable of automatic restart on phase-loss and overvoltage and undervoltage trips.

O. Visual Indication: On face of controller enclosure or chiller control enclosure; indicating the following conditions:

1. Power on.
2. Run.
3. Overvoltage.
4. Line fault.
5. Overcurrent.
7. Motor speed (percent).
8. Fault or alarm status (code).
9. DC-link voltage.
11. Input kilovolt amperes.
12. Total power factor.
13. Input kilowatts.
15. Three-phase input voltage.
16. Three-phase output voltage.
17. Three-phase input current.
18. Three-phase output current.
19. Three-phase input voltage total harmonic distortion.
20. Three-phase input current total harmonic distortion.
21. Output frequency (Hertz).
22. Elapsed operating time (hours).
23. Diagnostic and service parameters.

P. Operator Interface: At controller or chiller control panel; with start-stop and auto-manual selector with manual-speed-control potentiometer.

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

R. Active Harmonic Distortion Filter: Factory mounted and wired to limit total voltage and current distortion to 5 percent or less. Filter to meet IEEE519-1992. Chiller Efficiency ratings to include filter losses.

S. Input Line Conditioning: <Insert requirements>.

T. Cooling: Air, refrigerant, or water cooled.

U. Cooling: [Air] [Refrigerant] [Water] [Air, refrigerant, or water] cooled.

V. Accessories: Devices shall be factory installed in controller enclosure unless otherwise indicated.
1. Control Relays: Auxiliary and adjustable time-delay relays.

W. Chiller Capacity Control Interface: Equip chiller with adaptive control logic to automatically adjust the compressor motor speed and the compressor pre-rotation inlet vane position independently to achieve maximum part-load efficiency in response to sensor inputs that are integral to the chiller controls.

2.12 CONTROLS

A. Control: Standalone and microprocessor based, with all memory stored in nonvolatile memory so that reprogramming is not required on loss of electrical power.

B. Enclosure: Unit mounted, NEMA 250, Type 1, hinged or lockable; factory wired with a single-point, field-power connection and a separate control circuit.

C. Enclosure: Unit mounted, NEMA 250, <Type 1> [Type 4] [Type 4x] [Type 12] <Insert type>, hinged or lockable; factory wired with a single-point, field-power connection and a separate control circuit.
D. Operator Interface: Multiple-character digital or graphic display with dynamic update of information and with keypad or touch-sensitive display located on front of control enclosure. In either imperial or metric units selectable through the interface, display the following information:

1. Date and time.
2. Operating or alarm status.
3. Fault history with not less than last 10 faults displayed.
4. Set points of controllable parameters.
5. Trend data.
6. Operating hours.
7. Number of chiller starts.
8. Outdoor-air temperature or space temperature if required for chilled-water reset.
10. Difference in fluid temperatures of evaporator and condenser.
11. Fluid flow of evaporator and condenser.
12. Fluid pressure drop of evaporator and condenser.
13. Refrigerant pressures in evaporator and condenser.
14. Refrigerant saturation temperature in evaporator and condenser shell.
15. Compressor refrigerant suction and discharge temperature.
16. Compressor bearing temperature.
17. Motor bearing temperature.
18. Motor winding temperature.
19. Oil temperature.
20. Oil discharge pressure.
22. Percent of motor rated load amperage.
23. Phase voltage.
24. Demand power (kilowatts).
25. Energy use (kilowatt-hours).
27. For chillers equipped with variable frequency controllers and harmonic filters, include the following:
   a. Output voltage and frequency.
   b. Voltage total harmonic distortion for each phase.
   c. Supply current total demand distortion for each phase.
   d. Inlet vane position.
   e. Controller internal ambient temperature.
   f. Heatsink temperature.
28. Purge suction temperature if purge system is provided.
29. Purge elapsed time if purge system is provided.
30. <Insert status display items>.

E. Control Functions:

1. Manual or automatic startup and shutdown time schedule.
2. Entering and leaving chilled-water temperatures, control set points, and motor load limits. Evaporator fluid temperature shall be reset based on return-water temperature.
3. Entering and leaving chilled-water temperatures, control set points, and motor load limits. Evaporator fluid temperature shall be reset based on [return-water] [outdoor-air] [space] temperature.
5. Condenser-fluid temperature.
6. External chiller emergency stop.
7. Variable evaporator flow.
8. Thermal storage.
10. <Insert control functions>.

F. Manually Reset Safety Controls: The following conditions shall shut down chiller and require manual reset:

1. Low evaporator pressure or temperature; high condenser pressure.
2. Low evaporator fluid temperature.
3. Low oil differential pressure.
4. High or low oil pressure.
5. High oil temperature.
6. High compressor-discharge temperature.
7. Loss of condenser-fluid flow.
8. Loss of evaporator fluid flow.
10. Motor overvoltage.
12. Motor phase reversal.
15. Processor communication loss.
17. Extended compressor surge.
18. Excessive air-leakage detection for chillers using R-123 refrigerant.
19. <Insert manually reset safety controls>.

G. Trending: Capability to trend analog data of up to five parameters simultaneously over an adjustable period and frequency of polling.

H. Security Access: Provide electronic security access to controls through identification and password with at least three levels of access: view only; view and operate; and view, operate, and service.

I. Control Authority: At least four conditions: Off, local manual control at chiller, local automatic control at chiller, and automatic control through a remote source.

J. Communication Port: RS-232 port, USB 2.0 port, or equivalent connection capable of connecting a printer and a notebook computer.

K. BAS Interface: Factory-installed hardware and software to enable the BMS to monitor, control, and display chiller status and alarms.

1. [Hardwired Points]:
   a. Monitoring: On-off status, [common trouble alarm] [electrical power demand (kilowatts)] [electrical power consumption (kilowatt-hours)] [power factor] <Insert monitoring point>.
   b. Control: On-off operation, [chilled-water, discharge temperature set-point adjustment] [electrical power demand limit] <Insert control point>. 
2. LonTalk communication interface with the BMS which shall enable the BMS operator to remotely adjust and monitor the chiller from an operator workstation. Control features and monitoring points displayed locally at chiller control panel shall be available through the BMS.
   a. Coordinate BMS interface with Chiller Plant Optimization Controller interface.
   b. ASHRAE 135 (BACnet) communication interface with the BMS which shall enable the BMS operator to remotely adjust and monitor the chiller from an operator workstation. Control features and monitoring points displayed locally at chiller control panel shall be available through the BMS.

2.13 FINISH

A. Paint chiller, using manufacturer's standard color and procedures:
   1. Provide at least one coat of primer with a total dry film thickness of at least 2 mils.
   2. Provide at least two coats of [alkyd-modified, vinyl enamel] [epoxy] [polyurethane] finish with a total dry film thickness of at least 4 mils.
   3. Paint surfaces that are to be insulated before applying the insulation.
   4. Paint installed insulation to match adjacent uninsulated surfaces.
   5. Color of finish coat to be [manufacturer's standard] [custom color selected by Architect] <Insert color description>.

B. Provide Owner with quart container of paint used in application of topcoat to use in touchup applications after Project Closeout.

2.14 ACCESSORIES

A. Flow Switches:
   1. Chiller manufacturer shall furnish a switch for each evaporator and condenser and verify field-mounting location before installation.
   2. Paddle Flow Switches:
      a. Vane operated to actuate a double-pole, double-throw switch with one pole field wired to the chiller control panel and the other pole field wired to the BAS.
      b. Contacts: Platinum alloy, silver alloy, or gold-plated switch contacts with a rating of 10 A at 120-V ac.
      c. Pressure rating equal to pressure rating of heat exchanger.
      d. Construct body and wetted parts of Type 316 stainless steel.
      e. House switch in a NEMA 250, [Type 4] <Insert type> enclosure constructed of die-cast aluminum.
      f. Vane length to suit installation.
   3. Pressure Differential Switches:
      a. Construction: Wetted parts of body and trim constructed of Type 316 stainless steel.
b. Performance: Switch shall withstand, without damage, the full-pressure rating of the heat exchanger applied to either port and exhibit zero set-point shift due to variation in working pressure.

c. Set Point: Screw type, field adjustable.

d. Electrical Connections: Internally mounted screw-type terminal blocks.

e. Switch Enclosure: NEMA 250, [Type 4] <Insert type>.

f. Switch Action: Double-pole, double-throw switch with one pole field wired to the chiller control panel and the other pole field wired to the BAS.

B. Vibration Isolation:

1. Chiller manufacturer shall furnish vibration isolation for each chiller.

2. Neoprene Pad:

   a. Two layers of 0.375-inch- thick, ribbed- or waffle-pattern neoprene pads separated by a 16-gage, stainless-steel plate.
   
   b. Fabricate pads from 40- to 50-durometer neoprene.
   
   c. Provide stainless-steel square bearing plate to load the pad uniformly between 20 and 40 psig with a 0.12- to 0.16-inch deflection.

3. Spring Isolator:

   a. Stable in operation and designed for not less than 30 percent reserve deflection beyond actual operating conditions. Isolators shall be designed so that the Kx/Ky ratio shall be 1.0 or more for stability.
   
   b. Provide PVC or neoprene-coated springs and hot-dip, galvanized-steel components. Aluminum components shall be etched and painted. Nuts, bolts, and washers shall be zinc electroplated.
   
   c. Isolators shall be adjustable and with an open spring, having one or more coil springs attached to a top compression plate and a baseplate. An elastomeric pad with a minimum thickness of 0.25 inch shall be bonded to the baseplate.
   
   d. Spring assembly shall be removable and shall fit within a welded steel enclosure consisting of a top plate and rigid lower housing, which serves as a blocking device during installation. Isolated restraining bolts shall not be engaged during normal operation and shall connect the top plate and lower housing to prevent the isolated equipment from rising when drained of fluid.
   
   e. Isolators shall be selected for a nominal [1-inch] [2-inch] <Insert dimension> deflection.

C. [Sound Barrier]:

1. Furnish removable and reusable sound-barrier covers over the compressor housing, hermetic motor, compressor suction and discharge piping, and condenser shell.

2. Provide for repeated installation and removal without use of tape or caulk.

3. Inner and outer cover shall consist of a PTFE-impregnated fiberglass cloth enclosing heavy-density, needled fiberglass insulation material with a mass-loaded vinyl acoustic barrier.

4. Covers shall be double sewn and lock stitched with edges folded and sewn so no raw cut edges are exposed.

5. Form covers around control devices, gages, conduit, piping, and supports without degrading sound-barrier performance.

6. Continuously lap all exposed seams at least 2 inches for better sound containment.
7. Permanently label each section of cover to indicate its location, description, size, and number sequence.
8. Randomly place stainless-steel quilting pins to prevent covers from shifting and sagging.

D. Tool Kit: Chiller manufacturer shall assemble a tool kit specially designed for use in serving the chiller(s) furnished. Include special tools required to service chiller components not readily available to Owner service personnel in performing routine maintenance. Place tools in a lockable case with hinged cover. Provide a list of each tool furnished and attach the list to underside of case cover.

2.15 CHILLER PLANT OPTIMIZATION CONTROLS

A. Chiller manufacturer shall provide all engineering, hardware, software, sensors, actuators, associated equipment, installation and commissioning required for an operational chiller plant optimization system. The system shall work to select the most efficient and effective combination of chillers, pumps, and cooling tower needed to match building load. It shall command the selected devices to the appropriate state and speed, and provide the necessary sequencing of pump, isolation valves, and main equipment while observing all required timing delays for a safe and stable operation of the chiller plant. The system shall contain standardized algorithms configured for control of the chiller plant as designed and be capable of being reprogrammed to accommodate changes in future plant configuration.

1. Provide ASHRAE 135 (BACnet) communication interface with the BMS which shall enable the BMS operator to remotely adjust and monitor the chiller plant operation from an operator workstation. Control features and monitoring points displayed locally shall be available through the BMS.

B. The chiller plant includes the following:

1. Two (2) variable speed chillers piped in parallel.
2. Two (2) manifolded variable speed chilled water system pumps with one as standby.
   a. Refer to and coordinate with chilled water system pump operation as described in sequence of operations Section 23 0993.
3. One (1) induced draft counter flow cooling tower with variable speed fan.
4. Two (2) manifolded variable speed tower water pumps with one as standby.
5. [One (1) modulating cooling tower bypass valve].

2.16 CAPACITIES AND CHARACTERISTICS

A. Capacity: <Insert tons>.

B. Full-Load Efficiency:

1. COP: <Insert value>.
2. EER: <Insert value>.
5. Comply with FEMP.
C. Part-Load Efficiency:
   1. IPLV: <Insert value>.
   2. NPLV: <Insert value>.
   4. Comply with FEMP.

D. Evaporator:
   1. Pressure Rating: <Insert psig>.
   2. Number of Passes: [One] [Two] [Three].
   3. Fluid Type: [Water] <Insert fluid type>.
   7. Leaving-Fluid Temperature: <Insert deg F>.
   10. Fouling Factor: [0.0001 sq. ft. x h x deg F/Btu] [0.00025 sq. ft. x h x deg F/Btu] [0.0005 sq. ft. x h x deg F/Btu] <Insert value>.

E. Condenser:
   1. Pressure Rating: <Insert psig>.
   2. Number of Passes: [One] [Two] [Three].
   3. Fluid Type: [Water] <Insert fluid type>.
   5. Entering-Fluid Temperature: <Insert deg F>.
   7. Fluid Pressure Drop: <Insert feet of head>.
   9. Fouling Factor: [0.00025 sq. ft. x h x deg F/Btu] [0.0005 sq. ft. x h x deg F/Btu] [0.001 sq. ft. x h x deg F/Btu] <Insert value>.

F. Heat-Reclaim Condenser:
   1. Pressure Rating: <Insert psig>.
   2. Number of Passes: [One] [Two] [Three].
   3. Fluid Type: [Water] <Insert fluid type>.
   5. Entering-Fluid Temperature: <Insert deg F>.
   7. Fluid Pressure Drop: <Insert feet of head>.
   9. Fouling Factor: [0.0001 sq. ft. x h x deg F/Btu] [0.00025 sq. ft. x h x deg F/Btu] [0.0005 sq. ft. x h x deg F/Btu] <Insert value>.

G. Compressor:
   1. Number of Compressors: [One] [Two].
   2. First Compressor Rated Load Amperes: <Insert value>.
   3. First Compressor Locked-Rotor Amperes: <Insert value>.
4. Second Compressor Rated Load Amperes: <Insert value>.
5. Second Compressor Locked-Rotor Amperes: <Insert value>.

H. Chiller Control Electrical Requirements:

1. Power Connections: [Integral] [Field].
5. Volts: [120] <Insert value>-V ac.
6. Phase: [Single] [Three].

I. Chiller Electrical Requirements:

2. Power Factor: [0.90] [0.95] <Insert value>.
5. Volts: [208] [240] [480] [600] [2300] [4160] <Insert value>-V ac.
6. Phase: Three.

J. Noise Rating: [85] <Insert dBA> sound power level when measured according to ARI 575. Provide factory-installed sound treatment if necessary to achieve the performance indicated.

2.17 PACKAGED REFRIGERANT RECOVERY UNITS

A. Packaged portable unit consisting of compressor, air-cooled condenser, recovery system, tank pressure gages, filter-dryer, and valving that allows for switching between liquid and vapor recovery mode. Refrigerant recovery unit shall be factory mounted on an ASME-constructed and-stamped refrigerant storage vessel that is sized to hold the full refrigerant charge of the largest chiller furnished.

2.18 HEAT-EXCHANGER, BRUSH-CLEANING SYSTEM

A. Furnish for field installation a brush-cleaning system on each chiller [condenser] <Insert heat exchanger> for tube cleaning and improved heat transfer.

B. System shall maintain tube fouling at or below design conditions without interrupting normal equipment operation.

C. System shall consist of a brush inserted in each tube and a catch basket attached to each end of the tube. A four-way valve shall operate to reverse the direction of water flow to push the brush through the tube while removing tube deposits. Four-way reversing valve’s actuator shall be controlled by a preset time cycle that provides regular tube brushing during equipment operation. Frequency of the brushing cycle shall be set up to match Project requirements.

D. Components:
1. **Brush**: Each brush shall have nylon bristles, titanium wires, and polypropylene tips. Brush interference fit with the ID of the tube shall not exceed 0.025 inch.

2. **Basket**: Single-piece polypropylene basket with neck OD to press fit inner diameter of tube. Design shall provide for insertion of eddy current probe or removal of brushes without removing baskets from the valve.

3. **Four-Way Valve**:
   a. Construct valve body of carbon steel with internal sealing parts of hard rubber and Type 304 stainless steel.
   b. Configure valve with parallel flow connections to minimize field installation piping.
   c. Construct to comply with ASME Boiler and Pressure Vessel Code: Section VIII, Division 1, at a system working pressure equal to condenser.
   d. Pipe connections shall be flanged.
   e. Valve manufacturer to test and certify a maximum leakage rate of less than 0.05 percent of the design flow rate at operation conditions of maximum differential pressure.
   f. Hydrostatically test to 1.5 times the design working pressure.
   g. Design the valve to cause no more than 0.5-psig pressure drop at design flow conditions.
   h. Provide valve with valve-mounted indicating/warning light, which shall light before the valve begins rotation.
   i. Valve Actuator: Mount electric actuator to operate valve.
   j. Valve Actuator: Mount pneumatic piston-type actuator to operate valve. Actuator shall be suitable for operation using field-supplied air pressure.
   k. Position Switches: Factory mount microswitches on the valve to indicate the complete turn of valve in both normal and reverse flow.

4. **Control Panel**: Factory or field mount a control panel on chiller. Control panel shall include the following features:
   a. NEMA 250, [Type 1] [Type 4] [Type 4x] [Type 12] enclosure.
   b. Timer to automatically initiate the cleaning cycle over a 24-hour period.
   e. For pneumatic actuators, mount four-way solenoid valve for actuator operation in the control panel.
   f. Flow switch bypass.
   g. Unloading signal to chiller.

### 2.19 SOURCE QUALITY CONTROL

**A.** Perform functional [run] tests of chillers before shipping.

**B.** Factory performance test chillers, before shipping, according to ARI 506/110.

1. Test the following conditions:
   a. Design conditions indicated.
   b. Reduction in capacity from design to minimum load in steps of [10] [25] [33] <Insert number> with condenser fluid at design conditions.
   c. Reduction in capacity from design to minimum load in steps of [10] [25] [33] <Insert number> with varying entering condenser-fluid temperature from design to minimum conditions in [5 deg F] <Insert temperature> increments.
d. At [one] [two] [three] [four] [five] [10] <Insert number> point(s) of varying part-load performance to be selected by Owner at time of test.

2. Allow [Owner] <Insert entity> access to place where chillers are being tested. Notify Architect [14] <Insert number> days in advance of testing.
3. Prepare test report indicating test procedures, instrumentation, test conditions, and results. Submit copy of results within one week of test date.

C. Factory sound test chillers, before shipping, according to ARI 575.

1. Test the following conditions:
   a. Design conditions indicated.
   b. Chiller operating at calculated worst-case sound condition.
   c. At [one] [two] [three] [four] [five] <Insert number> point(s) of varying part-load performance to be selected by Owner at time of test.

2. Allow [Owner] <Insert entity> access to place where chillers are being tested. Notify Architect [14] <Insert number> days in advance of testing.
3. Prepare test report indicating test procedures, instrumentation, test conditions, and results. Submit copy of results within one week of test date.

D. For chillers using R-134a refrigerant, factory test and inspect evaporator and condenser according to ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.

E. For chillers using R-123 refrigerant, factory test and inspect evaporator and condenser according to ASME Boiler and Pressure Vessel Code: Section VIII, Division 1. Pressure test fluid side of heat exchangers, including water boxes, to 1.5 times the rated pressure. Pressure proof test refrigerant side of heat exchangers to a minimum of 45 psig. Vacuum and pressure test for leaks.

F. For chillers located indoors, rate sound power level according to ARI 575.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine chillers before installation. Reject chillers that are damaged.

B. Examine roughing-in for equipment support, anchor-bolt sizes and locations, piping, and electrical connections to verify actual locations, sizes, and other conditions affecting chiller performance, maintenance, and operations before equipment installation.
   1. Final chiller locations indicated on Drawings are approximate. Determine exact locations before roughing-in for piping and electrical connections.

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

A. Install chillers on support structure indicated.

B. Equipment Mounting:
   1. Install chillers on cast-in-place concrete equipment bases. Comply with requirements for equipment bases and foundations specified in Section 03 3000 "Cast-in-Place Concrete."
   2. Comply with requirements for vibration isolation and seismic control devices specified in Section 23 0548 "Vibration and Seismic Controls for HVAC."
   3. Comply with requirements for vibration isolation devices specified in Section 23 0548.13 "Vibration Controls for HVAC."

C. Maintain manufacturer's recommended clearances for service and maintenance.

D. Charge chiller with refrigerant and fill with oil if not factory installed.

E. Install separate devices furnished by manufacturer and not factory installed.

3.3 HEAT-EXCHANGER, BRUSH-CLEANING SYSTEM INSTALLATION

A. Install brush-cleaning system control panel adjacent to chiller control panel.

B. Arrange piping to provide service access to four-way valve assembly without affecting access to chiller. Secure valve to prevent lateral movement and vibration during operation.

C. Provide field electric power, as required, to each system control panel and electric actuated valve.

D. Provide pneumatic piping with pressure regulator and isolation valve to each pneumatic supply connection. Coordinate field source of air with manufacturer to ensure that requirements are satisfied for proper valve operation.

E. Interconnect brush-cleaning system controls with chiller controls. Coordinate requirements to ensure safe, trouble-free operation.

F. Functionally test the entire brush-cleaning system, including the valve, actuator, position indicator, and control panel, with chiller in operation.

3.4 CONNECTIONS

A. Comply with requirements for piping specified in Section 23 2113 "Hydronic Piping," Section 23 2116 "Hydronic Piping Specialties," and Section 23 2300 "Refrigerant Piping." Drawings indicate general arrangement of piping, fittings, and specialties.

B. Install piping adjacent to chiller to allow service and maintenance.

C. Evaporator Fluid Connections: Connect to evaporator inlet with shutoff valve, flexible connector, flow switch, thermometer, and P-T tapping. Connect to evaporator outlet with shutoff
valve, control valve, flexible connector, thermometer, P-T tapping, and drain connection with valve. Make connections to chiller with a flange.

D. Evaporator Fluid Connections: Connect to evaporator inlet with shutoff valve, strainer, flexible connector, thermometer, and plugged tee with pressure gage. Connect to evaporator outlet with shutoff valve, balancing valve, flexible connector, flow switch, thermometer, plugged tee with shutoff valve and pressure gage, and drain connection with valve. Make connections to chiller with a flange.

E. Condenser-Fluid Connections: Connect to condenser inlet with shutoff valve, flexible connector, thermometer, and P-T tapping. Connect to condenser outlet with shutoff valve, control valve, flexible connector, thermometer, P-T tapping, and drain connection with valve. Make connections to chiller with a flange.

F. Condenser-Fluid Connections: Connect to condenser inlet with shutoff valve, strainer, flexible connector, thermometer, and plugged tee with pressure gage. Connect to condenser outlet with shutoff valve, balancing valve, flexible connector, flow switch, thermometer, plugged tee with shutoff valve and pressure gage, and drain connection with valve. Make connections to chiller with a flange.

G. Heat-Reclaim Condenser-Fluid Connections: Connect to condenser inlet with shutoff valve, [strainer,] [flexible connector,] thermometer, and plugged tee with pressure gage. Connect to condenser outlet with shutoff valve, balancing valve,[ flexible connector,] flow switch, thermometer, plugged tee with shutoff valve and pressure gage,[ flow meter,] and drain connection with valve. Make connections to chiller with a [flange] [mechanical coupling] [flange or mechanical coupling].

H. Refrigerant Pressure Relief Device Connections: For chillers installed indoors, extend separate vent piping for each chiller to the outdoors without valves or restrictions. Comply with ASHRAE 15. Connect to chiller pressure relief device with flexible connector and dirt leg with drain valve.

I. For chillers equipped with a purge system, extend separate purge vent piping for each chiller to the outdoors. Comply with ASHRAE 15 and ASHRAE 147.

J. Connect each chiller drain connection with a union and drain pipe, and extend pipe, full size of connection, to floor drain. Provide a shutoff valve at each connection.

3.5 STARTUP SERVICE

A. As part of the pre-order package, a factory-authorized service representative to perform startup service.

1. Complete installation and startup checks according to manufacturer's written instructions.
2. Prepare test and inspection startup reports.

B. As part of the pre-order package, a factory-authorized service representative to participation in Owner chiller commissioning activities.

C. Engage a factory-authorized service representative to perform startup service.
1. Complete installation and startup checks according to manufacturer's written instructions.
2. Verify that refrigerant charge is sufficient and chiller has been leak tested.
3. Verify that pumps are installed and functional.
4. Verify that thermometers and gages are installed.
5. Operate chiller for run-in period.
6. Check bearing lubrication and oil levels.
7. Verify that refrigerant pressure relief device is vented outside.
8. Verify proper motor rotation.
9. Verify static deflection of vibration isolators, including deflection during chiller startup and shutdown.
12. Test and adjust controls and safeties. Replace damaged or malfunctioning controls and equipment.

D. Inspect field-assembled components, equipment installation, and piping and electrical connections for proper assembly, installation, and connection.

E. Prepare test and inspection startup reports.

3.6 DEMONSTRATION

A. As part of the pre-order package, a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain chillers.

B. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain chillers.

C. Engage a factory-authorized service representative to train Owner's building automation system operators to adjust, operate, and maintain chiller plant optimization system. Provide three sessions of not less than eight hours each at a time and location approved by the Owner.

END OF SECTION 23 6416
WMU Design Guidelines Instructions: These guidelines are to be used by the Design Professional to inform the design process and outline WMU-specific desires for all University projects. These guidelines have been edited to reflect WMU preferences, and the intent is for the Design Professional to use this information to guide their normal specifications-writing process. Straying from what is indicated in the guidelines is not prohibited, but shall be discussed with WMU during the development of the project.

SECTION 23 6426 - ROTARY-SCREW WATER CHILLERS

PART 1 - GENERAL

1.1 SUMMARY

A. Section includes the pre-ordering of an air-cooled rotary screw chiller. Owner is pre-ordering unit to obtain satisfactory delivery date. The successful installing contractor will be assigned the responsibility to receive, store, install, start-up, and carry warranty on the unit. Factory start-up, participation in Owner chiller commissioning activities, and Owner training shall be included.

B. Section Includes:

1. Packaged, water-cooled, single-compressor chillers.
2. Packaged, water-cooled, multiple-compressor chillers.
3. Packaged, air-cooled chillers.
4. Packaged, portable refrigerant recovery units.
5. Heat-exchanger, brush-cleaning system.

C. Related Section:

1. Section 28 3500 "Refrigerant Detection and Alarm" for refrigerant monitors, alarms, supplemental breathing apparatus, and ventilation equipment interlocks.

1.2 DEFINITIONS

A. BAS: Building automation system.

B. COP: Coefficient of performance. The ratio of the rate of heat removal to the rate of energy input using consistent units for any given set of rating conditions.

C. EER: Energy-efficiency ratio. The ratio of the cooling capacity given in terms of Btu/h to the total power input given in terms of watts at any given set of rating conditions.

D. IPLV: Integrated part-load value. A single-number part-load efficiency figure of merit calculated per the method defined by ARI 506/110 and referenced to ARI standard rating conditions.

E. kW/Ton: The ratio of total power input of the chiller in kilowatts to the net refrigerating capacity in tons at any given set of rating conditions.
F. NPLV: Nonstandard part-load value. A single-number part-load efficiency figure of merit calculated per the method defined by ARI 506/110 and intended for operating conditions other than ARI standard rating conditions.

1.3 PERFORMANCE REQUIREMENTS

A. Seismic Performance: Chillers shall withstand the effects of earthquake motions determined according to [ASCE/SEI 7] <Insert requirement>.
   1. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified and the unit will be fully operational after the seismic event."

B. Condenser-Fluid Temperature Performance:
   1. Startup Condenser-Fluid Temperature: Chiller shall be capable of starting with an entering condenser-fluid temperature of [60 deg F] [55 deg F] [40 deg F] and providing stable operation until the system temperature is elevated to the minimum operating entering condenser-fluid temperature.
   2. Minimum Operating Condenser-Fluid Temperature: Chiller shall be capable of continuous operation over the entire capacity range indicated with an entering condenser-fluid temperature of [65 deg F] [60 deg F] [55 deg F].
   3. Make factory modifications to standard chiller design if necessary to comply with performance indicated.

C. Site Altitude: Chiller shall be suitable for altitude in which installed without affecting performance indicated. Make adjustments to affected chiller components to account for site altitude.

D. Performance Tolerance: Comply with the following in lieu of ARI 506/110:
   1. Allowable Capacity Tolerance: [Zero] <Insert number> percent.

1.4 ACTION SUBMITTALS

A. Product Data: For each type of product indicated. Include refrigerant, rated capacities, operating characteristics, furnished specialties, and accessories.
   1. Performance at ARI standard conditions and at conditions indicated.
   2. Performance at ARI standard unloading conditions (100, 75, 50, and 25%).
   3. Minimum evaporator flow rate.
   4. Refrigerant capacity of chiller.
   5. Oil capacity of chiller.
   6. Fluid capacity of evaporator.
   7. Characteristics of safety relief valves.
   9. Fluid capacity of condenser[ and heat-reclaim condenser].
   10. Minimum entering condenser-fluid temperature.
11. Performance at varying capacities with constant-design entering condenser-fluid temperature. Repeat performance at varying capacities for different condenser-fluid temperatures from design to minimum in 5 deg F increments.
12. Minimum entering condenser-air temperature.
14. Performance at varying capacities with constant-design entering condenser-air temperature. Repeat performance at varying capacities for different entering condenser-air temperatures from design to minimum in 10 deg F increments.
15. Sound power and sound pressure data in decibels. Sound pressure data per ARI 370 in 8 octave band format at full load. In addition, A-weighted sound pressure at 30 feet should be provided at 100%, 75%, 50% and 25% load points to identify the full operational noise envelope. Sound power must be provided in 1/3 octave band format to highlight any tonal quality issues.

1.5 INFORMATIONAL SUBMITTALS

A. Coordination Drawings: Floor plans, drawn to scale, on which the following items are shown and coordinated with each other, using input from Installers of the items involved:

1. Structural supports.
2. Piping roughing-in requirements.
3. Wiring roughing-in requirements, including spaces reserved for electrical equipment.
4. Access requirements, including working clearances for mechanical controls and electrical equipment, and tube pull and service clearances.

B. Certificates: For certification required in "Quality Assurance" Article.

C. Seismic Qualification Certificates: For chillers, accessories, and components, from manufacturer.

1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.

D. Source quality-control reports.

E. Startup service reports.

F. Warranty: Sample of special warranty.

1.6 CLOSEOUT SUBMITTALS

A. Operation and maintenance data.
1.7 QUALITY ASSURANCE

A. ARI Certification: Certify chiller according to ARI 550 and ARI 590 certification program(s).

B. ARI Rating: Rate chiller performance according to requirements in ARI 506/110.

C. ASHRAE Compliance:
   1. ASHRAE 15 for safety code for mechanical refrigeration.
   2. ASHRAE 147 for refrigerant leaks, recovery, and handling and storage requirements.

D. ASHRAE/IESNA Compliance: Applicable requirements in ASHRAE/IESNA 90.1.

E. ASME Compliance: Fabricate and label chiller to comply with ASME Boiler and Pressure Vessel Code: Section VIII, Division 1, and include an ASME U-stamp and nameplate certifying compliance.

F. Comply with NFPA 70.

G. Comply with requirements of UL and UL Canada and include label by a qualified testing agency showing compliance.

1.8 DELIVERY, STORAGE, AND HANDLING

A. The outdoor condensing unit shall be delivered to the job site completely assembled and charged with refrigerant and oil by the manufacturer. The evaporator shall have a nitrogen holding charge and be shipped loose for field mounting and charging.

B. Ship chillers from the factory fully charged with refrigerant.

C. [Ship each chiller with a full charge of refrigerant. Charge each chiller with nitrogen if refrigerant is shipped in containers separate from chiller.]

D. Ship each oil-lubricated chiller with a full charge of oil.
   1. Ship oil [factory installed in chiller] [in containers separate from chiller].

E. Package chiller for export shipping in totally enclosed [crate] [and] [bagging].

1.9 COORDINATION

A. Coordinate sizes and locations of concrete bases with actual equipment provided. Cast anchor-bolt inserts into bases.

B. Coordinate sizes, locations, and anchoring attachments of structural-steel support structures.

C. Coordinate sizes and locations of roof curbs, equipment supports, and roof penetrations with actual equipment provided.
1.10 **WARRANTY**

A. Special Warranty: Manufacturer’s standard form in which manufacturer agrees to repair or replace components of chillers that fail in materials or workmanship within specified warranty period.

1. Extended warranties include, but are not limited to, the following:
   a. Standard Warranty: The refrigeration equipment manufacturer’s warranty shall be for a period of one (1) year from date of equipment start up, but not more than 18 months from shipment. It shall cover replacement parts (and the labor to replace them) having proven defective within the above period.
   b. Extended Unit Warranty: 4 years extended warranty, entire unit, parts and labor.
   c. Refrigerant Warranty: 5 years.
   d. Complete chiller including refrigerant and oil charge.
   e. Complete compressor and drive assembly including refrigerant and oil charge.
   g. Parts [only] [and labor].
   h. Loss of refrigerant charge for any reason.

2. Warranty Period: Five years from date of Substantial Completion.

**PART 2 - PRODUCTS**

2.1 **PACKAGED, WATER-COOLED, SINGLE-COMPRESSOR CHILLERS**

2.2 **PACKAGED, WATER-COOLED, MULTIPLE-COMPRESSOR CHILLERS**

2.3 **PACKAGED, AIR-COOLED CHILLERS**

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

1. JCI/York.
2. Daikin
3. Carrier
4. Trane

B. Manufacturers: Subject to compliance with requirements, [provide products by one of the following] [available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following]:

C. Basis-of-Design Product: Subject to compliance with requirements, provide [product indicated on Drawings] [Insert manufacturer’s name; product name or designation] or comparable product by one of the following:
1. Carrier Corporation.
2. Dunham-Bush.
4. Trane.
6. <Insert manufacturer's name>.

D. Description: Standard efficient with VFD, factory-assembled, factory charged with refrigerant, air-cooled, screw compressor outdoor condensing unit. Condensing unit shall consist of multiple semi-hermetic screw compressors, evaporator, air-cooled condenser section, control panel and all components necessary for protected and controlled unit operation.

E. Description: Factory-assembled and run-tested chiller complete with base and frame, condenser casing, compressors, compressor motors and motor controllers, evaporator, condenser coils, condenser fans and motors, electrical power, controls, and accessories.

F. Fabricate base, frame, and attachment to chiller components strong enough to resist chiller movement during a seismic event when chiller base is anchored to field support structure.

G. Cabinet:
1. Base: Galvanized-steel base extending the perimeter of chiller. Secure frame, compressors, and evaporator to base to provide a single-piece unit.
2. Frame: Rigid galvanized-steel frame secured to base and designed to support cabinet, condenser, control panel, and other chiller components not directly supported by base.
4. Finish: Coat base, frame, and casing with a corrosion-resistant coating capable of withstanding a 500-hour salt-spray test according to ASTM B 117.
5. Finish: Coat base, frame, and casing with a corrosion-resistant coating capable of withstanding a [500] [1000] <Insert number>-hour salt-spray test according to ASTM B 117.
6. [Sound-reduction package] designed to reduce sound level without affecting performance and consisting of the following:
   a. Acoustic enclosure around compressors.
   b. Reduced-speed fans with acoustic treatment.
7. Louver Panels: Provide removable louvered panels with fasteners for additional protection of compressors, evaporator, and condenser coils without inhibiting service access. Finish to match cabinet.
8. Grille Panels: Provide removable grilles with fasteners for additional protection of compressors, evaporator, and condenser coils without inhibiting service access. Finish to match cabinet.
9. [Security Package]: Provide removable [grilles] [louvered panels] with fasteners for additional protection of compressors, evaporator, and condenser coils without inhibiting service access. Finish to match cabinet.

H. Compressors:
1. Description: Positive displacement, semi-hermetically sealed.
2. Casing: Cast iron, precision machined for minimum clearance about periphery of rotors.
3. Rotors: Manufacturer's standard one- or two-rotor design.
4. Each compressor provided with suction and discharge shutoff valves, crankcase oil heater, and suction strainer.
5. Compressors used in VFD controlled units must have electrically insulated, coated bearings to mitigate bearing and/or lubricant damage from stray electric current passage.

I. Service: Easily accessible for inspection and service.

J. Capacity Control: The chiller shall be capable of stable operation to a minimum of 20% percent of full load without hot gas bypass. Configure to achieve most energy-efficient operation possible.

1. The unit shall have factory mounted, low ambient head pressure control providing operation to 35°F.

K. Capacity Control: On-off compressor cycling and modulating slide-valve assembly or port unloaders combined with hot-gas bypass, if necessary, to achieve performance indicated.

1. Maintain stable operation throughout range of operation. Configure to achieve most energy-efficient operation possible.
2. Operating Range: From 100 to 20 percent of design capacity with two compressors and from 100 to 13 percent of design capacity with three compressors.
3. Operating Range: From 100 to 10 percent of design capacity.
4. Operating Range: From 100 to \[20\] \[15\] \[10\] \[5\] \[0\] \[\text{zero}\] <Insert number> percent of design capacity.
5. Condenser-Air Unloading Requirements over Operating Range: \[\text{Constant-design entering condenser-air temperature}\] \[\text{Drop-in entering condenser-air temperature of 5 deg F drop for each 10 percent in capacity reduction}\] <Insert conditions>.
6. For units equipped with a variable frequency controller, capacity control shall be both "valveless" and "stepless," requiring no slide valve or capacity-control valve(s) to operate at reduced capacity.

L. Oil Lubrication System: Consisting of pump if required, filtration, heater, cooler, factory-wired power connection, and controls.

1. Provide lubrication to bearings, gears, and other rotating surfaces at all operating, startup, shutdown, and standby conditions including power failure.
2. Thermostatically controlled oil heater properly sized to remove refrigerant from oil.
3. Factory-installed and pressure-tested piping with isolation valves and accessories.
4. Oil compatible with refrigerant and chiller components.
5. Positive visual indication of oil level.

M. Vibration Control:

1. Vibration Balance: Balance chiller compressors and drive assemblies to provide a precision balance that is free of noticeable vibration over the entire operating range.
   a. Overspeed Test: 25 percent above design operating speed.
2. Isolation: Mount individual compressors on vibration isolators.

N. Compressor Motors:

1. Semi-hermetically sealed and cooled by refrigerant suction gas.
a. Include additional liquid injection for motor cooling.

2. High-torque, induction type with inherent thermal-overload protection on each phase.

O. Compressor Motor Controllers:

1. Across the Line: NEMA ICS 2, Class A, full voltage, nonreversing[, or solid state].
2. Wye-Delta, Reduced-Voltage Controller: NEMA ICS 2, closed transition.
3. Star-Delta, Reduced-Voltage Controller: NEMA ICS 2, closed transition[, or solid state].
4. Variable Frequency Controller:
   a. Motor controller shall be factory mounted and wired on the chiller to provide a single-point, field-power termination to the chiller and its auxiliaries.
   b. Description: NEMA ICS 2; listed and labeled as a complete unit and arranged to provide variable speed by adjusting output voltage and frequency.
      1) Include EMI filters with drives.
   c. Enclosure: Unit mounted, NEMA 250, Type 3R, with hinged full-front access door.
   d. Integral Disconnecting Means: Door-interlocked, NEMA AB 1, instantaneous-trip circuit breaker with lockable handle.
   e. Integral Disconnecting Means: Door-interlocked, NEMA AB 1, instantaneous-trip circuit breaker with lockable handle. Minimum withstand rating shall be as required by electrical power distribution system, but not less than [42,000] [65,000] [100,000] <Insert value> A.
   f. Technology: Pulse width modulated (PWM) output suitable for constant or variable torque loads.
   g. Motor current at start shall not exceed the rated load amperes, providing no electrical inrush.

P. Refrigerant Circuits:

1. Refrigerant: Type as indicated on Drawings.
2. Refrigerant Type: R-134a. Classified as Safety Group A1 according to ASHRAE 34.
3. Refrigerant Type: [R-22] [R-134a] [R-407c] [or] [any HFC] <Insert type>. Classified as Safety Group A1 according to ASHRAE 34.
4. Refrigerant Compatibility: Chiller parts exposed to refrigerants shall be fully compatible with refrigerants, and pressure components shall be rated for refrigerant pressures.
5. Refrigerant Circuit: Each shall include a thermal- or electronic-expansion valve, refrigerant charging connections, a hot-gas muffler, compressor suction and discharge shutoff valves, a liquid-line shutoff valve, a replaceable-corefilter-dryer, a sight glass with moisture indicator, a liquid-line solenoid valve, and an insulated suction line.
6. Pressure Relief Device:
   a. Comply with requirements in ASHRAE 15 and in applicable portions of ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.
   b. ASME-rated, spring-loaded pressure relief valve; single- or multiple-reseating type.

Q. Evaporator:

1. Description: Shell-and-tube design.
a. Direct-expansion (DX) type with fluid flowing through the shell, and refrigerant flowing through the tubes within the shell or flooded type with fluid flowing through tubes and refrigerant flowing around tubes within the shell.

b. Direct-expansion (DX) type with fluid flowing through the shell, and refrigerant flowing through the tubes within the shell.

c. Flooded type with fluid flowing through tubes and refrigerant flowing around tubes within the shell.

2. Code Compliance: Tested and stamped according to ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.
4. Shell Heads: Removable carbon-steel heads located at each end of the tube bundle.
5. Fluid Nozzles: Terminated with mechanical-coupling or flanged end connections for connection to field piping.
6. Tube Construction: Individually replaceable copper tubes with enhanced fin design, expanded into tube sheets.
7. Heater: Factory-installed and -wired electric heater with integral controls designed to protect the evaporator to minus 20 deg F.

R. Air-Cooled Condenser: Plate-fin or micro-channel type coils as described below:

1. Condenser coils shall use Micro-Channel coil technology. Coil shall have a series of flat tubes containing a series of multiple, parallel flow micro-channels layered between the refrigerant manifolds. Micro-channel coils shall consist of a two-pass arrangement. Coils shall be factory leak and pressure tested.

2. Plate-fin coil with integral subcooling on each circuit, rated at 450 psig.

a. Construct coil casing of galvanized steel.

b. Construct coil casing of [galvanized] [or] [stainless] steel.

c. Construct coils of copper tubes mechanically bonded to aluminum fins.

d. Construct coils of copper tubes mechanically bonded to [aluminum] [aluminum with precoated epoxy-phenolic] [copper] fins.

e. Coat coils with a baked-epoxy, corrosion-resistant coating after fabrication.

f. [Hail Protection]: Provide condenser coils with louvers, baffles, or hoods to protect against hail damage.

3. Fans: Direct-drive propeller type with statically and dynamically balanced fan blades, arranged for vertical air discharge.
4. Fan Motors: Totally enclosed air over (TEAO) enclosure, with permanently lubricated bearings. Equip each motor with overload protection integral to either the motor or chiller controls.
5. Fan Motors: Totally enclosed nonventilating (TENV) or totally enclosed air over (TEAO) enclosure, with permanently lubricated bearings. Equip each motor with overload protection integral to either the motor or chiller controls.
6. Fan Guards: Steel safety guards with corrosion-resistant coating.

S. Electrical Power:

1. Factory-installed and -wired switches, motor controllers, transformers, and other electrical devices necessary shall provide a single-point, field-power connection to chiller.
2. Factory-installed and -wired switches, motor controllers, transformers, and other electrical devices necessary shall provide a [multipoint] [single-point], field-power connection to chiller.

3. House in a unit-mounted, NEMA 250, Type 3R enclosure with hinged access door.

4. House in a unit-mounted, NEMA 250, Type 3R enclosure with hinged access door[ with lock and key or padlock and key].

5. Wiring shall be numbered to match wiring diagram.

6. Install factory wiring outside of an enclosure in a raceway.

7. Field-power interface shall be to NEMA KS 1, heavy-duty, nonfused disconnect switch.

8. Field-power interface shall be to [wire lugs] [NEMA KS 1, heavy-duty, nonfused disconnect switch] [NEMA AB 1, instantaneous-trip circuit breaker with lockable handle].

   a. Disconnect means shall be interlocked with door operation.
   b. Minimum withstand rating shall be as required by electrical power distribution system, but not less than [42,000] [65,000] [100,000] <Insert value> A.

9. Provide branch power circuit to each motor and to controls with one of the following disconnecting means:

   a. NEMA KS 1, heavy-duty, fusible switch with rejection-type fuse clips rated for fuses. Select and size fuses to provide Type 2 protection according to IEC 60947-4-1.
   b. NEMA AB 1, motor-circuit protector (circuit breaker) with field-adjustable, short-circuit-trip set point.

10. Provide each motor with overcurrent protection.

11. Overload relay sized according to UL 1995 or an integral component of chiller control microprocessor.


13. Provide power factor correction capacitors to correct power factor to [0.90] [0.95] <Insert value> at full load.

14. Control Transformer: Unit-mounted transformer with primary and secondary fuses and sized with enough capacity to operate electrical load plus spare capacity.

   a. Power unit-mounted controls where indicated.
   b. Power unit-mounted, ground fault interrupt (GFI) duplex receptacle.

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

16. For chiller electrical power supply, indicate the following:

   a. Current and phase to phase for all three phases.
   b. Voltage, phase to phase, and phase to neutral for all three phases.
   c. Three-phase real power (kilowatts).
   d. Three-phase reactive power (kilovolt amperes reactive).
   e. Power factor.
   f. Running log of total power versus time (kilowatt-hours).
   g. Fault log, with time and date of each.
   h. <Insert features>.

T. Controls:

1. Standalone and microprocessor based.
2. Enclosure: Share enclosure with electrical power devices or provide a separate enclosure.

3. Operator Interface: Multiple-character digital or graphic display with dynamic update of information and with keypad or touch-sensitive display located on front of control enclosure. In either imperial or metric units, display the following information:

   a. Date and time.
   b. Operating or alarm status.
   c. Operating hours.
   d. Outdoor-air temperature if required for chilled-water reset.
   e. Temperature and pressure of operating set points.
   f. Entering and leaving temperatures of chilled water.
   g. Refrigerant pressures in evaporator and condenser.
   h. Saturation temperature in evaporator and condenser.
   i. No cooling load condition.
   j. Elapsed time meter (compressor run status).
   k. Pump status.
   l. Antirecycling timer status.
   m. Percent of maximum motor amperage.
   n. Current-limit set point.
   o. Number of compressor starts.
   p. <Insert items>.

4. Control Functions:

   a. Manual or automatic startup and shutdown time schedule.
   b. Entering and leaving chilled-water temperatures, control set points, and motor load limits. Chilled-water leaving temperature shall be reset based on return-water temperature.
   c. Entering and leaving chilled-water temperatures, control set points, and motor load limits. Chilled-water leaving temperature shall be reset based on [return-water]
   [outdoor-air] [space] temperature.
   d. Current limit and demand limit.
   e. External chiller emergency stop.
   f. Antirecycling timer.
   g. Automatic lead-lag switching.
   h. Variable evaporator flow.
   i. Thermal storage.
   j. <Insert control functions>.

5. Manually Reset Safety Controls: The following conditions shall shut down chiller and require manual reset:

   a. Low evaporator pressure or high condenser pressure.
   b. Low chilled-water temperature.
   c. Refrigerant high pressure.
   d. High or low oil pressure.
   e. High oil temperature.
   f. Loss of chilled-water flow.
   g. Control device failure.
   h. <Insert manually reset safety controls>.
6. Trending: Capability to trend analog data of up to five parameters simultaneously over an adjustable period and frequency of polling.

7. Security Access: Provide electronic security access to controls through identification and password with at least three levels of access: view only; view and operate; and view, operate, and service.

8. Control Authority: At least four conditions: Off, local manual control at chiller, local automatic control at chiller, and automatic control through a remote source.

9. BAS Interface: Factory-installed hardware and software to enable the BAS to monitor, control, and display chiller status and alarms.
   a. Hardwired Points:
      1) Monitoring: On-off status, [common trouble alarm] [electrical power demand (kilowatts)] [electrical power consumption (kilowatt-hours)] <Insert monitoring point>.
      2) Control: On-off operation, [chilled-water, discharge temperature set-point adjustment] [electrical power demand limit] <Insert control point>.

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

   c. [ASHRAE 135 (BACnet)] [LonTalk] [Modbus] communication interface with the BAS shall enable the BAS operator to remotely control and monitor the chiller from an operator workstation. Control features and monitoring points displayed locally at chiller control panel shall be available through the BAS.

U. Insulation:

1. Material: Closed-cell, flexible elastomeric, thermal insulation complying with ASTM C 534, Type I for tubular materials and Type II for sheet materials.

2. Thickness: 1-1/2 inch.


4. Factory-applied insulation over cold surfaces of chiller components.
   a. Adhesive: As recommended by insulation manufacturer and applied to 100 percent of insulation contact surface. Seal seams and joints.

5. Apply protective coating to exposed surfaces of insulation to protect insulation from weather.

V. Accessories:

1. Factory-furnished, chilled-water flow switches for field installation.

2. Individual compressor suction and discharge pressure gages with shutoff valves for each refrigerant circuit.

3. Factory-furnished spring isolators for field installation.

4. Factory-furnished [neoprene] [or] [spring] isolators for field installation.

5. [Tool Kit]: Chiller manufacturer shall assemble a tool kit specially designed for use in serving the chiller(s) furnished. Include special tools required to service chiller components not readily available to Owner service personnel in performing routine maintenance. Place tools in a lockable case with hinged cover. Provide a list of each tool furnished and attach the list to underside of case cover.

6. Control Panel High Ambient Kit: The kit includes a thermostat controlled, panel ventilation fan and inlet grille with filter. The option can be ordered with any unit.
7. Ground Fault Protection: Provide ground fault protection for the entire unit.

W. Capacities and Characteristics:

2. Full-Load Efficiency (COP): <Insert value>.
3. Full-Load Efficiency (EER): <Insert value>.
5. Part-Load Efficiency (IPLV): 17.3.
7. Low Ambient Operation: Chiller designed for operation to 0 deg F.
8. High Ambient Operation: Chiller designed for operation to 115 deg F.
9. Evaporator:
   a. Configuration: Shipped loose for field installation.
   b. Configuration: Integral to chiller.
   c. Pressure Rating: 150 psig.
   d. Fluid Type: 30% propylene glycol.
   e. Fluid Type: 30% [ethylene][propylene] glycol.
   f. Design Fluid Flow Rate: 395 gpm.
   g. Minimum Fluid Flow Rate: 205 gpm.
   h. Entering-Fluid Temperature: 54 deg F.
   i. Leaving-Fluid Temperature: 44 deg F.
   j. Fluid Pressure Drop: 11.5 feet of head.
   k. Fluid Velocity: <Insert fps>.
   l. Fouling Factor: 0.0001 sq. ft. x h x deg F/Btu.
   m. Fouling Factor: [0.0001 sq. ft. x h x deg F/Btu] [0.00025 sq. ft. x h x deg F/Btu] [0.0005 sq. ft. x h x deg F/Btu] <Insert value>.
10. Condenser Entering-Air Temperature: 95 deg F.
12. Site Altitude: <Insert feet>.
13. Number of Refrigerant Circuits: Each compressor on an independent circuit.
14. Number of Refrigerant Circuits: [Two] [Each compressor on an independent circuit] <Insert requirement>.
15. Compressor:
   a. Number of Compressors: <Insert number>.
   b. Rated Load Amperes: <Insert value>.
   c. Locked-Rotor Amperes: <Insert value>.
16. Control Electrical Requirements:
   b. Power Connection: [Fed through integral transformer] [Separate field-power connection].
   c. Power Input: <Insert kilowatts>.
   d. Minimum Circuit Ampacity: <Insert value>.
   e. Maximum Overcurrent Protection Device: <Insert amperage>.
   f. Volts: 120V ac.
   g. Phase: Single.
   h. Hertz: 60.
17. Chiller Electrical Requirements:
   b. Power Factor: <Insert value>.
   c. Minimum Circuit Ampacity: <Insert value>.
   d. Maximum Overcurrent Protection Device: <Insert amperage>.
   e. Volts: 480.
   f. Phase: Three.
   g. Hertz: 60.

18. Noise Rating: <Insert dBA> sound power level when measured according to ARI 370. Provide factory-installed sound treatment if necessary to achieve the performance indicated.

2.4 PACKAGED REFRIGERANT RECOVERY UNITS

2.5 HEAT-EXCHANGER, BRUSH-CLEANING SYSTEM

2.6 SOURCE QUALITY CONTROL

A. Perform functional tests of chillers before shipping.
   1. Submit factory test reports for Owner record.

B. Factory run test each air-cooled chiller with water flowing through evaporator.

C. Factory performance test water-cooled chillers, before shipping, according to ARI 506/110.
   1. Test the following conditions:
      a. Design conditions indicated.
      b. Reduction in capacity from design to minimum load in steps of [10] [25] [33] <Insert number> with condenser fluid at design conditions.
      c. Reduction in capacity from design to minimum load in steps of [10] [25] [33] <Insert number> with varying entering condenser-fluid temperature from design to minimum conditions in [5 deg F] <Insert temperature> increments.
      d. At [one] [two] [three] [four] [five] [10] <Insert number> point(s) of varying part-load performance to be selected by Owner at time of test.

2. Allow [Owner] <Insert entity> access to place where chillers are being tested. Notify Architect [14] <Insert number> days in advance of testing.

3. Prepare test report indicating test procedures, instrumentation, test conditions, and results. Submit copy of results within one week of test date.

D. Factory performance test air-cooled chillers, before shipping, according to ARI 506/110.
   1. Test the following conditions:
      a. Design conditions indicated.
      b. Reduction in capacity from design to minimum load in steps of [10] [25] [33] <Insert number> with condenser air at design conditions.
c. At [one] [two] [three] [four] [five] <Insert number> point(s) of varying part-load performance to be selected by Owner at time of test.

2. Allow [Owner] <Insert entity> access to place where chillers are being tested. Notify Architect [14] <Insert number> days in advance of testing.
3. Prepare test report indicating test procedures, instrumentation, test conditions, and results. Submit copy of results within one week of test date.

E. Factory sound test air-cooled chillers, before shipping, according to ARI 370.

F. Factory sound test [water-cooled chillers, before shipping, according to ARI 575] [air-cooled chillers, before shipping, according to ARI 370].

1. Test the following conditions:
   a. Design conditions indicated.
   b. Chiller operating at calculated worst-case sound condition.
   c. At [one] [two] [three] [four] [five] <Insert number> point(s) of varying part-load performance to be selected by Owner at time of test.

2. Allow [Owner] <Insert entity> access to place where chillers are being tested. Notify Architect [14] <Insert number> days in advance of testing.
3. Prepare test report indicating test procedures, instrumentation, test conditions, and results. Submit copy of results within one week of test date.

G. Factory test and inspect evaporator[ and condenser] [condenser, and heat-reclaim condenser] according to ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.

H. For chillers located indoors, rate sound power level according to ARI 575.

I. For chillers located outdoors, rate sound power level according to ARI 370.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine chillers before installation. Reject chillers that are damaged.

B. Examine roughing-in for equipment support, anchor-bolt sizes and locations, piping, and electrical connections to verify actual locations, sizes, and other conditions affecting chiller performance, maintenance, and operations before equipment installation.

1. Final chiller locations indicated on Drawings are approximate. Determine exact locations before roughing-in for piping and electrical connections.

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

A. Install chillers on support structure indicated.

B. Equipment Mounting:
   1. Install chillers on cast-in-place concrete equipment bases. Comply with requirements for equipment bases and foundations specified in [Section 03 3000 "Cast-in-Place Concrete."],[Section 03 3053 "Miscellaneous Cast-in-Place Concrete."]
   2. Comply with requirements for vibration isolation and seismic control devices specified in Section 23 0548 "Vibration and Seismic Controls for HVAC."
   3. Comply with requirements for vibration isolation devices specified in Section 23 0548.13 "Vibration Controls for HVAC."

C. Maintain manufacturer's recommended clearances for service and maintenance.

D. Charge chiller with refrigerant and fill with oil if not factory installed.

E. Install separate devices furnished by manufacturer and not factory installed.

3.3 HEAT-EXCHANGER, BRUSH-CLEANING SYSTEM INSTALLATION

3.4 CONNECTIONS

A. Comply with requirements for piping specified in Section 23 2113 "Hydronic Piping," Section 23 2116 Hydronic Piping Specialties," [and] [Section 23 2300 "Refrigerant Piping"]. Drawings indicate general arrangement of piping, fittings, and specialties.

B. Install piping adjacent to chiller to allow service and maintenance.

C. Evaporator Fluid Connections: Connect to evaporator inlet with shutoff valve, [strainer,] [flexible connector,] thermometer, and plugged tee with pressure gage. Connect to evaporator outlet with shutoff valve, balancing valve,[ flexible connector,] flow switch, thermometer, plugged tee with shutoff valve and pressure gage,[ flow meter,] and drain connection with valve. Make connections to chiller with a [flange] [or] [mechanical coupling].

D. Condenser Fluid Connections: Connect to condenser inlet with shutoff valve, [strainer,] [flexible connector,] thermometer, and plugged tee with pressure gage. Connect to condenser outlet with shutoff valve, balancing valve,[ flexible connector,] flow switch, thermometer, plugged tee with shutoff valve and pressure gage,[ flow meter,] and drain connection with valve. Make connections to chiller with a [flange] [or] [mechanical coupling].

E. Heat-Reclaim Condenser Fluid Connections: Connect to condenser inlet with shutoff valve, [strainer,] [flexible connector,] thermometer, and plugged tee with pressure gage. Connect to condenser outlet with shutoff valve, balancing valve,[ flexible connector,] flow switch, thermometer, plugged tee with shutoff valve and pressure gage,[ flow meter,] and drain connection with valve. Make connections to chiller with a [flange] [or] [mechanical coupling].

F. Refrigerant Pressure Relief Device Connections: For chillers installed indoors, extend [vent piping] [separate vent piping for each chiller] to the outdoors without valves or restrictions.
Comply with ASHRAE 15. Connect vent to chiller pressure relief device with flexible connector and dirt leg with drain valve.

G. Connect each chiller drain connection with a union and drain pipe, and extend pipe, full size of connection, to floor drain. Provide a shutoff valve at each connection.

3.5 STARTUP SERVICE

A. As part of the pre-order package, a factory-authorized service representative to perform startup service.

1. Complete installation and startup checks according to manufacturer's written instructions.
2. Prepare test and inspection startup reports.

B. As part of the pre-order package, a factory-authorized service representative to participation in Owner chiller commissioning activities.

C. Engage a factory-authorized service representative to perform startup service.

1. Complete installation and startup checks according to manufacturer's written instructions.
2. Verify that refrigerant charge is sufficient and chiller has been leak tested.
3. Verify that pumps are installed and functional.
4. Verify that thermometers and gages are installed.
5. Operate chiller for run-in period.
6. Check bearing lubrication and oil levels.
7. For chillers installed indoors, verify that refrigerant pressure relief device is vented outdoors.
8. Verify proper motor rotation.
9. Verify static deflection of vibration isolators, including deflection during chiller startup and shutdown.
10. Verify and record performance of fluid flow and low-temperature interlocks for evaporator[ and condenser] [ condenser, and heat-reclaim condenser].
12. Test and adjust controls and safeties. Replace damaged or malfunctioning controls and equipment.

D. Inspect field-assembled components, equipment installation, and piping and electrical connections for proper assembly, installation, and connection.

E. Prepare test and inspection startup reports.

3.6 DEMONSTRATION

A. As part of the pre-order package, a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain chillers.

B. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain chillers. [ Video record the training sessions.]
WMU Design Guidelines

WMU Design Guidelines Instructions: These guidelines are to be used by the Design Professional to inform the design process and outline WMU-specific desires for all University projects. These guidelines have been edited to reflect WMU preferences, and the intent is for the Design Professional to use this information to guide their normal specifications-writing process. Straying from what is indicated in the guidelines is not prohibited, but shall be discussed with WMU during the development of the project.

SECTION 23 6500 - COOLING TOWERS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

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

1.2 SUMMARY

A. Section Includes:

1. Closed-circuit, forced-draft, counterflow cooling towers.
2. Closed-circuit, induced-draft, combined-flow cooling towers.
3. Closed-circuit, induced-draft, counterflow cooling towers.
4. Open-circuit, forced-draft, counterflow cooling towers.
5. Open-circuit, induced-draft, counterflow cooling towers.

1.3 DEFINITIONS

A. BMS: Building management system.
B. FRP: Fiber-reinforced polyester.

1.4 PERFORMANCE REQUIREMENTS

A. Delegated Design: Design cooling tower support structure[ and seismic restraints] [ and wind restraints], including comprehensive engineering analysis by a qualified professional engineer, using performance requirements and design criteria indicated.

B. Structural Performance: Cooling tower support structure shall withstand the effects of gravity loads and the following loads and stresses within limits and under conditions indicated according to [SEI/ASCE 7] <Insert requirement>.

1. Dead Loads: <Insert loads>.
7. <Insert loads or load combinations>.
8. Deflection Limits: Design system to withstand design loads without deflections greater than the following:
   a. <Insert deflection limits>.

C. Seismic Performance: Cooling towers shall withstand the effects of earthquake motions determined according to [SEI/ASCE 7] <Insert requirement>.

   1. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified[ and the unit will be fully operational after the seismic event]."

1.5 ACTION SUBMITTALS

A. Product Data: For each type of product indicated. Include rated capacities, pressure drop, fan performance data, rating curves with selected points indicated, furnished specialties, and accessories.

   1. Maximum flow rate.
   3. Drift loss as percent of design flow rate.
   4. Volume of water in suspension for purposes of sizing a remote storage tank.
   5. Sound power levels in eight octave bands for operation with fans off, fans at minimum, and design speed.
   6. Performance curves for the following:
      a. Varying entering-water temperatures from design to minimum.
      b. Varying ambient wet-bulb temperatures from design to minimum.
      c. Varying water flow rates from design to minimum.
      d. Varying fan operation (off, minimum, and design speed).

   7. Fan airflow, brake horsepower, and drive losses.
   8. Pump flow rate, head, brake horsepower, and efficiency.
   9. Motor amperage, efficiency, and power factor at 100, 75, 50, and 25 percent of nameplate horsepower.
   10. Electrical power requirements for each cooling tower component requiring power.

B. Shop Drawings: Complete set of manufacturer's prints of cooling tower assemblies, control panels, sections and elevations, and unit isolation. Include the following:

   1. Assembled unit dimensions.
   2. Weight and load distribution.
   3. Required clearances for maintenance and operation.
   4. Sizes and locations of piping and wiring connections.
   5. Wiring Diagrams: For power, signal, and control wiring.
C. Delegated-Design Submittal: For cooling tower support structure indicated to comply with performance requirements and design criteria, including analysis data signed and sealed by the qualified professional engineer responsible for their preparation.

1. Detail fabrication and assembly of support structure.
2. Vibration Isolation Base Details: Detail fabrication including anchorages and attachments to structure and to supported equipment. Include adjustable motor bases, rails, and frames for equipment mounting.
3. Design Calculations: Calculate requirements for selecting vibration isolators and seismic restraints and wind restraints and for designing vibration isolation bases.

1.6 INFORMATIONAL SUBMITTALS

A. Coordination Drawings: Floor plans, drawn to scale, on which the following items are shown and coordinated with each other, using input from Installers of the items involved:

1. Structural supports.
2. Piping roughing-in requirements.
3. Wiring roughing-in requirements, including spaces reserved for electrical equipment.
4. Access requirements, including working clearances for mechanical controls and electrical equipment, and tube pull and service clearances.

B. Certificates: For certification required in “Quality Assurance” Article.

C. 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.

D. Source quality-control reports.

E. Field quality-control reports.

F. Startup service reports.

G. Warranty: Sample of special warranty.

1.7 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For each cooling tower to include in emergency, operation, and maintenance manuals.
1.8 QUALITY ASSURANCE

A. Testing Agency Qualifications: [Certified by CTI] [An NRTL].

B. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

C. ASHRAE/IESNA 90.1 Compliance: Applicable requirements in ASHRAE/IESNA 90.1, Section 6 - "Heating, Ventilating, and Air-Conditioning."

D. ASME Compliance: Fabricate and label heat-exchanger coils to comply with ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.

E. CTI Certification: Cooling tower thermal performance according to CTI STD 201, "Certification Standard for Commercial Water-Cooling Towers Thermal Performance."

F. FMG approval and listing in the latest edition of FMG's "Approval Guide."

1.9 COORDINATION

A. Coordinate sizes and locations of concrete bases with actual equipment provided.

B. Coordinate sizes, locations, and anchoring attachments of structural-steel support structures.

C. Coordinate sizes and locations of roof curbs, equipment supports, and roof penetrations with actual equipment provided.

1.10 WARRANTY

A. Special Warranty: Manufacturer's standard form 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 fan, drive, and motor.
2. All components of cooling tower.
3. <Insert components requiring extended warranty>.
4. Warranty Period: [Five] <Insert number> years from date of Substantial Completion.

PART 2 - PRODUCTS

2.1 CLOSED-CIRCUIT, FORCED-DRAFT, COUNTERFLOW COOLING TOWERS

A. Products: Subject to compliance with requirements, [provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:

1. Baltimore Aircoil Company; Models VFL and VF1.
3. Evapco Inc.; Models LSWA and LRW.
4. Recold; Models JM and JW.
5. <Insert manufacturer's name; product name or designation>.

B. Basis-of-Design Product: Subject to compliance with requirements, provide [product indicated on Drawings] <Insert manufacturer's name; product name or designation> or comparable product by one of the following:
2. Delta Cooling Towers, Inc.
3. Evapco Inc.
4. Recold.
5. <Insert manufacturer's name>.

C. 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.

D. Cooling tower designed to resist wind load of [30 lbf/sq. ft.] <Insert value>.

E. Casing and Frame:
2. Frame Material: [FRP with UV inhibitors] [Galvanized steel, ASTM A 653/A 653M, G210 coating] [Galvanized steel, ASTM A 653/A 653M, G235 coating] [Polymer-coated galvanized steel] [Stainless steel].
5. Welded Connections: Continuous and watertight.

F. Collection Basin: Configure tower for installation with a field-constructed collection basin.

G. Collection Basin:
1. Material: [FRP with UV inhibitors] [Galvanized steel, ASTM A 653/A 653M, G210 coating] [Galvanized steel, ASTM A 653/A 653M, G235 coating] [Polymer-coated galvanized steel] [Stainless steel].
3. Overflow and drain connections.
5. Basin Sweeper Distribution Piping and Nozzles:
   a. Pipe Material: [PVC] <Insert material>.
   c. Configure piping and nozzles to minimize sediment from collecting in the collection basin.

H. Mechanically Operated, Collection Basin Water-Level Control: Manufacturer's standard adjustable, mechanical float assembly and valve.
I. Electric/Electronic, Collection Basin Water-Level Controller with Solenoid Valve:

1. Enclosure: NEMA 250, [Type 4] [Type 4X] <Insert type>.
2. Sensor: Solid-state controls with multiple electrode probes and relays factory wired to a terminal strip to provide [control of water makeup valve] [control of water makeup valve and low-level alarm] [control of water makeup valve and low- and high-level alarms] [control of water makeup valve, low- and high-level alarms, and output for shutoff of pump on low level].
4. Water Stilling Chamber: [Corrosion-resistant material] [FRP] [Galvanized steel] [PVC pipe] [Stainless steel].
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.

J. Electric Basin Heater:

2. Heater Control Panel: Mounted on the side of each cooling tower cell.
3. Enclosure: NEMA 250, [Type 3R] [Type 4] [Type 4X].
4. Magnetic contactors controlled by a temperature sensor/controller to maintain collection basin water-temperature set point. Water-level probe shall monitor cooling tower water level and de-energize the heater when the water reaches low-level set point.
5. Control-circuit transformer with primary and secondary side fuses.
6. Terminal blocks with numbered and color-coded wiring to match wiring diagram.
7. Single-point, field-power connection to a [fused disconnect switch] [nonfused disconnect switch] [circuit breaker] and heater branch circuiting complying with NFPA 70.
8. Factory Wiring Method: Metal raceway for factory-installed wiring outside of enclosures, except make connections to each electric basin heater with liquidtight conduit.

K. Hot-Water-Coil Basin Heater: Manufacturer’s standard offering to provide capacity indicated.

L. Steam-Coil Basin Heater: Manufacturer’s standard offering to provide capacity indicated.

M. Steam-Injector Basin Heater: Manufacturer’s standard offering to provide capacity indicated.

N. Water Distribution Piping: Main header and lateral branch piping designed for even distribution over fill throughout the flow range without the need for balancing valves and for connecting individual, removable, nonclogging spray nozzles.

1. Pipe Material: [Fiberglass] [PVC] [Galvanized steel] <Insert material>.
2. Spray Nozzle Material: [Plastic] [Polypropylene] [PVC] <Insert material>.
3. Piping Supports: Corrosion-resistant hangers and supports designed to resist movement during operation and shipment.

O. Recirculating Piping: [PVC] <Insert pipe material>, with connections for separately provided, remote spray pump.

P. Spray Pump: Close-coupled, end-suction, single-stage, bronze-fitted centrifugal pump; with suction strainer and flow balancing valve, and mechanical seal suitable for outdoor service.
1. General Requirements for Spray Pump Motor: Comply with NEMA designation and temperature-rating requirements specified in Division 23 Section "Common Motor Requirements for HVAC Equipment" and not indicated below.

2. Motor Enclosure: [Totally enclosed] [Totally enclosed nonventilated (TENV)] [Totally enclosed fan cooled (TEFC)] [with epoxy or polyurethane finish].

3. Energy Efficiency: [Comply with ASHRAE/IESNA 90.1] [NEMA Premium Efficient].

4. Service Factor: [1.0] [1.15] <Insert value>.

Q. Heat-Exchanger Coils:

1. Tube and Tube Sheet Materials: [Copper tube with stainless-steel sheet] [Stainless-steel tube and sheet] [Prime-coated steel tube and sheet with outer surface of tube and sheet hot-dip galvanized after fabrication].

2. Heat-Exchanger Arrangement: [Serpentine tubes] [Serpentine tubes with removable cover plate on inlet and outlet headers] [Straight tubes with removable header cover plate on both ends of heat exchanger for straight-through access to each tube]; and sloped for complete drainage of fluid by gravity.

3. ASME Compliance: Designed, manufactured, and tested according to ASME Boiler and Pressure Vessel Code: Section VIII, Division 1, and bearing ASME "U" stamp; and sloped for complete drainage of fluid by gravity.

4. Field Piping Connections: Vent, supply, and return [suitable for mating to ASME B16.5, Class 150 flange].

R. [Removable] Drift Eliminator:

1. Material: [FRP] [PVC] [FRP or PVC] <Insert material>; with maximum flame-spread index of [5] [25] <Insert value> 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.

S. [Removable] Air-Intake Screens: [Galvanized] [Polymer-coated, galvanized] [Stainless]-steel wire mesh.

T. Centrifugal Fan: Double-width, double-inlet, forward-curved blades, and statically and dynamically balanced at the factory after assembly.

1. Number of Fans: Each cooling tower cell shall have a single fan or multiple fans connected to a common shaft.

2. Fan Wheel and Housing Materials: Galvanized steel.

3. Fan Shaft: Steel, coated to resist corrosion.


5. Fan Shaft Bearings: Self-aligning, grease-lubricated 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 [40,000] [50,000] <Insert value> hours.

6. Bearings Grease Fittings: Extended lubrication lines to an easily accessible location.

U. Belt Drive:

1. Belt-Drive Service Factor: [1.5] <Insert value> based on motor nameplate horsepower.
2. Sheaves: Fan and motor shafts shall have taper-lock sheaves fabricated from corrosion-resistant materials.
5. Belt Material: Oil resistant, nonstatic conducting, and constructed of neoprene polyester cord.
6. Belt-Drive Guard: Comply with OSHA regulations.
7. Two-Motor, Single-Fan Drive:
   a. Two single-speed motors per fan, one sized for full speed and load, and the other sized for [67] <Insert value> percent of full-load speed.
   b. Belt Drives: Each motor shall have belt drive complying with requirements for belt drives and configured for operation when other motor fails.
   c. Motor controller and wiring same as two-speed, two-winding motor.

V. Fan Motor:
1. General Requirements for Fan Motors: Comply with NEMA designation and temperature-rating requirements specified in Division 23 Section “Common Motor Requirements for HVAC Equipment” and not indicated below.
2. Motor Enclosure: [Totally enclosed] [Totally enclosed air over (TEAO)] [Totally enclosed fan cooled (TEFC)] [with epoxy or polyurethane finish].
3. Energy Efficiency: [Comply with ASHRAE/IESNA 90.1] [NEMA Premium Efficient].
5. Insulation: [Class F] [Class H] <Insert class>.
7. Severe-duty rating with the following features:
   a. Rotor and stator protected with corrosion-inhibiting epoxy resin.
   b. Double-shielded, vacuum-degassed bearings lubricated with premium moisture-resistant grease suitable for temperatures between minus 20 and plus 300 deg F.
   c. Internal heater automatically energized when motor is de-energized.

8. Motor Base: Adjustable, or other suitable provision for adjusting belt tension.

W. Discharge Hoods:
1. Hood Configuration: [Tapered] [Straight]; totally surrounding drift eliminators and constructed of same material as casing; and having factory-installed [insulation and ] access doors.
2. Discharge Dampers: Positive-closure, automatic, isolation dampers with electric actuators.
   a. Provide field power and controls to open dampers when pump is energized and close dampers when pump is de-energized.

X. Capacity-Control Dampers: [Galvanized-steel] [Stainless-steel] <Insert material> dampers, with linkages, electric operator, controller, limit switches, transformer, and weatherproof enclosure.

Y. Vibration Switch: For each fan drive.
1. Enclosure: NEMA 250, [Type 4] [Type 4X] <[Insert type].
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.

Z. Controls: Comply with requirements in Division 23 Section "Instrumentation and Control for HVAC."

AA. Control Package: Factory installed and wired, and functionally tested at factory before shipment.

1. NEMA 250, [Type 3R] [Type 4] [Type 4X] enclosure with removable internally mount backplate.
2. Control-circuit transformer with primary and secondary side fuses.
3. Terminal blocks with numbered and color-coded wiring to match wiring diagram. Spare wiring terminal block for connection to external controls or equipment.
4. Microprocessor-based controller for automatic control of fan and spray pump based on cooling tower leaving-water temperature with control features to improve operating efficiency based on outdoor ambient wet-bulb temperature by using adaptive logic.
5. Fan motor sequencer for multiple-cell and two-speed applications with automatic lead stage rotation.
7. Electric basin heaters with temperature control and low-water-level safety switch for each cell, complying with requirements in "Electric Basin Heater" Paragraph.
8. Vibration switch for each fan, complying with requirements in "Vibration Switch" Paragraph.
9. Controls and wiring for "two-motor, single-fan drives" shall be same as two-speed, two-winding motor.
10. Power and controls to open discharge hood dampers when pump is energized and close dampers when pump is de-energized.
11. Single-point, field-power connection to a [fused disconnect switch] [nonfused disconnect switch] [circuit breaker] [for each cooling tower cell].
   a. Branch power circuit to each motor and electric basin heater and to controls with a disconnect switch or circuit breaker.
   b. NEMA-rated motor controller, hand-off-auto switch, and overcurrent protection for each motor. Provide variable frequency controller with manual bypass and line reactors for each variable-speed motor indicated.

12. Factory-installed wiring outside of enclosures shall be in metal raceway, except make connections to each motor and electric basin heater with liquidtight conduit.
13. Visual indication of status and alarm with momentary test push button for each motor.
15. Visual indication of elapsed run time, graduated in hours for each motor.
16. Cooling tower shall have hardware to enable BMS to remotely monitor and display the following:
   a. Operational status of each motor.
   b. Position of dampers.
   c. Cooling tower leaving-fluid temperature.
   d. Fan vibration alarm.
   e. Collection basin [high] [low] [high- and low]-water-level alarms.
   f. <Insert conditions to be monitored>.

BB. 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, 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. External Platforms with Handrails: Aluminum, FRP, or galvanized-steel bar grating at cooling tower access doors when cooling towers are elevated and not accessible from grade.
5. Internal Platforms: Aluminum, FRP, or galvanized-steel 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 all parts are above the high water level of the collection basin.

CC. Capacities and Characteristics:

1. Number of Cells: <Insert quantity>.
2. Maximum Drift Loss: [0.005] <Insert number> percent of design water flow.
3. Heat-Exchanger Coil:
   a. Fluid Type: [Water] <Insert type>.
   d. Fluid Pressure Drop: <Insert psig>.
   e. Entering-Fluid Temperature: <Insert deg F>.
   f. Leaving-Fluid Temperature: <Insert deg F>.
   g. Entering-Air Wet-Bulb Temperature: <Insert deg F>.
4. Economizer Mode:
   b. Entering-Fluid Temperature: <Insert deg F>.
   c. Leaving-Fluid Temperature: <Insert deg F>.
   d. Entering-Air Wet-Bulb Temperature: <Insert deg F>.

5. Fan Location: [Bottom] [Side].
6. Fan Motor:
a. Type: [Single speed] [Two speed, single winding] [Two speed, two winding] [Variable speed].
c. Full-Load Ampacity: <Insert value>.  
d. Minimum Circuit Ampacity: <Insert value>.  
e. Maximum Overcurrent Protection Device: <Insert amperage>.  
f. Electrical Characteristics: [208] [240] [480] <Insert value>-V ac, 3 phase, 60 Hz.

7. Spray Pump and Motor:

c. Full-Load Ampacity: <Insert value>.  
d. Minimum Circuit Ampacity: <Insert value>.  
e. Maximum Overcurrent Protection Device: <Insert amperage>.  
f. Electrical Characteristics: [120] [208] [240] [277] [480] <Insert value>-V ac, [single] [3] phase, 60 Hz.

8. Sound Pressure Level: <Insert dBA> at <Insert distance in feet> [when measured according to CTI ATC 128].

9. Basin Heater:

a. Basin Water Temperature: [40 deg F] <Insert deg F>.  
b. Outdoor Ambient Temperature: [0 deg F] [Minus 20 deg F] <Insert deg F>.  
c. Capacity/Cell: <Insert kilowatts>.  
d. Full-Load Ampacity: <Insert value>.  
e. Minimum Circuit Ampacity: <Insert value>.  
g. Electrical Characteristics: [208] [240] [480] <Insert value>-V ac, 3 phase, 60 Hz.  
h. Capacity/Cell: <Insert MBtu/h>.  
i. Entering-Fluid Temperature: <Insert deg F>.  
j. Fluid Flow Rate: <Insert gpm>.  
k. Fluid Pressure Drop: <Insert psig>.  
l. Capacity/Cell: <Insert MBtu/h>.  
m. Steam Flow: <Insert lb/h>.  
n. Steam Pressure: <Insert psig>.

2.2 CLOSED-CIRCUIT, INDUCED-DRAFT, COMBINED-FLOW COOLING TOWERS

A. Products: Subject to compliance with requirements, [provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:

1. Baltimore Aircoil Company; Model FXV.  
2. Marley Cooling Technologies, an SPX Corporation; Model MH.  
3. <Insert manufacturer's name; product name or designation>.

B. Basis-of-Design Product: Subject to compliance with requirements, provide [product indicated on Drawings] <Insert manufacturer's name; product name or designation> or comparable product by one of the following:
3. <Insert manufacturer's name>.

C. 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.

D. Cooling tower designed to resist wind load of [30 lbf/sq. ft.] <Insert value>.

E. Casing and Frame:
   1. Casing and Frame Material: [FRP with UV inhibitors] [Galvanized steel, ASTM A 653/A 653M, G235 coating] [Polymer-coated galvanized steel] [Stainless steel].
   2. Frame Material: [FRP with UV inhibitors] [Galvanized steel, ASTM A 653/A 653M, G235 coating] [Polymer-coated galvanized steel] [Stainless steel].
   5. Welded Connections: Continuous and watertight.

F. Collection Basin: Configure tower for installation with a field-constructed collection basin.

G. Collection Basin:
   1. Material: [FRP with UV inhibitors] [Galvanized steel, ASTM A 653/A 653M, G235 coating] [Polymer-coated galvanized steel] [Stainless steel].
   2. Strainer: Removable stainless-steel strainer with openings smaller than nozzle orifices.
   3. Overflow and drain connections.
   5. Basin Sweeper Distribution Piping and Nozzles:
      a. Pipe Material: [PVC] <Insert material>.
      c. Configure piping and nozzles to minimize sediment from collecting in the collection basin.

H. Mechanically Operated, Collection Basin Water-Level Control: Manufacturer's standard adjustable, mechanical float assembly and valve.

I. Electric/Electronic, Collection Basin Water-Level Controller with Solenoid Valve:
   1. Enclosure: NEMA 250, [Type 4] [Type 4X] <Insert type>.
   2. Sensor: Solid-state controls with multiple electrode probes and relays factory wired to a terminal strip to provide [control of water makeup valve] [control of water makeup valve and low-level alarm] [control of water makeup valve and low- and high-level alarms] [control of water makeup valve, low- and high-level alarms, and output for shutoff of pump on low level].
   4. Water Stilling Chamber: [Corrosion-resistant material] [FRP] [Galvanized steel] [PVC pipe] [Stainless steel].
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.

J. Ultrasonic Collection Basin Water-Level Controller with Solenoid Valve:
1. Enclosure: NEMA 250, [Type 4] [Type 4X] <Insert type>.
2. Controller: Ultrasonic level sensor/transmitter and relays factory wired to a terminal strip to control water makeup valve and signal a level alarm. Controller shall provide continuous level indication through a 4- to 20-mA signal [for connection to BMS].
3. Water Stilling Chamber: [Corrosion-resistant material] [FRP] [Galvanized steel] [PVC pipe] [Stainless steel].
4. Solenoid Valve: Slow closing with stainless-steel body, controlled and powered through level controller in response to water-level set point.
5. Electrical Connection Requirements: 120 V, single phase, 60 Hz.

K. Electric Basin Heater:
2. Heater Control Panel: Mounted on the side of each cooling tower cell.
3. Enclosure: NEMA 250, [Type 3R] [Type 4] [Type 4X].
4. Magnetic contactors controlled by a temperature sensor/controller to maintain collection basin water-temperature set point. Water-level probe shall monitor cooling tower water level and de-energize the heater when the water reaches low-level set point.
5. Control-circuit transformer with primary and secondary side fuses.
6. Terminal blocks with numbered and color-coded wiring to match wiring diagram.
7. Single-point, field-power connection to a [fused disconnect switch] [nonfused disconnect switch] [circuit breaker] and heater branch circuiting complying with NFPA 70.
8. Factory Wiring Method: Metal raceway for factory-installed wiring outside of enclosures, except make connections to each electric basin heater with liquidtight conduit.

L. Hot-Water-Coil Basin Heater: Manufacturer's standard offering to provide capacity indicated.

M. Steam-Coil Basin Heater: Manufacturer's standard offering to provide capacity indicated.

N. Steam-Injector Basin Heater: Manufacturer's standard offering to provide capacity indicated.

O. Gravity Water Distribution Basin: Nonpressurized design with head of water level in basin adequate to overcome spray nozzle losses and designed to evenly distribute water over fill throughout the flow range indicated.
1. Material: [FRP with UV inhibitors] [Galvanized steel, ASTM A 653/A 653M, G210 coating] [Galvanized steel, ASTM A 653/A 653M, G235 coating] [Polymer-coated galvanized steel] [Stainless steel].
2. Location: Over each bank of fill with easily replaceable [plastic] <Insert material> spray nozzles mounted in bottom of basin.
4. Partitioning Dams: Same material as basin to distribute water over the fill to minimize icing while operating throughout the flow range indicated.
5. Removable Panels: Same material as basin to completely cover top of basin. Secure panels to basin with removable [corrosion-resistant] [stainless-steel] hardware.

6. Valves: Manufacturer's standard valve installed at each inlet connection and arranged to balance or shut off flow to each gravity water distribution basin.

P. Pressurized Water Distribution Piping: Main header and lateral branch piping designed for even distribution over heat-exchanger coil or fill throughout the flow range without the need for balancing valves and for connecting individual, removable, nonclogging spray nozzles.

1. Pipe Material: [PVC] [Galvanized steel] [Insert material].
2. Spray Nozzle Material: [Plastic] [Polypropylene] [Insert material].
3. Piping Supports: Corrosion-resistant hangers and supports to resist movement during operation and shipment.

Q. Recirculating Piping: [PVC] [Insert pipe material], with connections for separately provided, remote spray pump.

R. Spray Pump: Close-coupled, end-suction, single-stage, bronze-fitted centrifugal pump; with suction strainer and flow balancing valve, and mechanical seal suitable for outdoor service.

1. General Requirements for Spray Pump Motor: Comply with NEMA designation and temperature-rating requirements specified in Division 23 Section "Common Motor Requirements for HVAC Equipment" and not indicated below.
2. Motor Enclosure: [Totally enclosed] [Totally enclosed nonventilated (TENV)] [Totally enclosed fan cooled (TEFC)] [with epoxy or polyurethane finish].
3. Energy Efficiency: [Comply with ASHRAE/IESNA 90.1] [NEMA Premium Efficient].
4. Service Factor: [1.0] [1.15] [Insert value].

S. Fill:

1. Materials: [PVC] [Insert material], with maximum flame-spread index of [5] [25] [Insert value] according to ASTM E 84.
2. Minimum Thickness: [15 mils] [20 mils] [Insert value], before forming.
3. Fabrication: Fill-type sheets fabricated, formed, and bonded together after forming into removable assemblies that are factory installed by manufacturer.
4. Fill Material Operating Temperature: Suitable for entering-water temperatures up through [120 deg F] [Insert temperature]..

T. Heat-Exchanger Coils:

1. Tube and Tube Sheet Materials: [Copper tube with stainless-steel sheet] [Stainless-steel tube and sheet] [Prime-coated steel tube and sheet with outer surface of tube and sheet hot-dip galvanized after fabrication].
2. Heat-Exchanger Arrangement: [Serpentine tubes] [Serpentine tubes with removable cover plate on inlet and outlet headers] [Straight tubes with removable header cover plate on both ends of heat exchanger for straight-through access to each tube]; and sloped for complete drainage of fluid by gravity.
3. ASME Compliance: Designed, manufactured, and tested according to ASME Boiler and Pressure Vessel Code: Section VIII, Division 1 and bearing ASME "U" stamp; and sloped for complete drainage of fluid by gravity.
4. Field Piping Connections: Vent, supply, and return [suitable for mating to ASME B16.5, Class 150 flange].
U. Drift Eliminator:

1. Material: [FRP] [PVC] [FRP or PVC] <Insert material>; with maximum flame-spread index of [5] <Insert value> 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.
4. Fill Drift Eliminators: [Integral to] [Separate and removable from] fill.

V. Air-Intake Louvers:

1. Material: [FRP] [PVC] [Matching casing].
2. UV Treatment: Inhibitors to protect against damage caused by UV radiation.
3. Louver Blades: Arranged to uniformly direct air into cooling tower, to minimize air resistance, and to prevent water from splashing out of tower during all modes of operation including operation with fans off.
4. Location: [Integral to] [Separate from] fill.

W. Air-Intake Screens: [Galvanized] [Polymer-coated, galvanized] [Stainless]-steel wire mesh.

X. Axial Fan: Balanced at the factory after assembly.

1. Blade Material: [Aluminum] [FRP].
2. Hub Material: [Aluminum] [FRP].
5. 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 [40,000] [50,000] <Insert value> hours.
6. Bearings Grease Fittings: Extended lubrication lines to an easily accessible location.

Y. Belt Drive:

1. Service Factor: [1.5] <Insert value> based on motor nameplate horsepower.
2. Sheaves: Fan and motor shafts shall have taper-lock sheaves fabricated from corrosion-resistant materials.
5. Belt Material: Oil resistant, nonstatic conducting, and constructed of neoprene polyester cord.
6. Belt-Drive Guard: Comply with OSHA regulations.
7. Two-Motor, Single-Fan Drive:
   a. Two single-speed motors per fan, one sized for full speed and load and the other sized for [67] <Insert value> percent of full-load speed.
   b. Each motor with belt drive and configured for operation when other motor fails.
   c. Controls and wiring same as two-speed, two-winding motor.
Z. Gear Drive: 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] <Insert value> 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 all 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-to-Motor Connection: [Close coupled to motor using a flexible coupling] [Connected to motor located outside of cooling tower casing by a full-floating drive shaft].
6. Drive Shaft Material: [Corrosion resistant] [Stainless steel], and fitted with flexible couplings on both ends. Provide exposed shaft and couplings with guards according to OSHA regulations.
7. Extend oil fill, drain, and vent to outside of cooling tower casing using galvanized-steel piping. Provide installation with oil-level sight glass.

AA. Fan Motor:

1. General Requirements for Fan Motors: Comply with NEMA designation and temperature-rating requirements specified in Division 23 Section "Common Motor Requirements for HVAC Equipment" and not indicated below.
2. Motor Enclosure: [Totally enclosed] [Totally enclosed air over (TEAO)] [Totally enclosed fan cooled (TEFC)] [with epoxy or polyurethane finish].
3. Energy Efficiency: [Comply with ASHRAE/IESNA 90.1] [NEMA Premium Efficient].
5. Insulation: [Class F] [Class H] <Insert class>.
7. Motor Location: Mounted outside of cooling tower casing and cooling tower discharge airstream.
8. Severe-duty rating with the following features:
   a. Rotor and stator protected with corrosion-inhibiting epoxy resin.
   b. Double-shielded, vacuum-degassed bearings lubricated with premium, moisture-resistant grease suitable for temperatures between minus 20 and plus 300 deg F.
   c. Internal heater automatically energized when motor is de-energized.
9. Motor Base: Adjustable, or other suitable provision for adjusting belt tension.

BB. Fan Discharge Stack: Material shall match casing, [manufacturer's standard] [velocity recovery] design.

1. Stack Extension: Fabricated to extend above fan deck <Insert distance> unless otherwise indicated.
2. Stack Termination: Wire-mesh, galvanized-steel screens; complying with OSHA regulations.

CC. Vibration Switch: For each fan drive.
1. Enclosure: NEMA 250, [Type 4] [Type 4X] <Insert type>.
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.
4. Switch shall, on sensing excessive vibration,[ signal an alarm through the BMS and] shut down the fan.

DD. Gear-Drive, Oil-Level Switch: Low-oil-level warning switch[ for connection to a BMS].
1. Switch shall, on reaching a low-oil-level set point recommended by cooling tower manufacturer, signal an alarm[ through the BMS].

EE. Controls: Comply with requirements in Division 23 Section “Instrumentation and Control for HVAC.”

FF. Control Package: Factory installed and wired, and functionally tested at factory before shipment.
1. NEMA 250, [Type 3R] [Type 4] [Type 4X] enclosure with removable internally mount backplate.
2. Control-circuit transformer with primary and secondary side fuses.
3. Terminal blocks with numbered and color-coded wiring to match wiring diagram. Spare wiring terminal block for connection to external controls or equipment.
4. Microprocessor-based controller for automatic control of fan[ and spray pump] based on cooling tower leaving-water temperature with control features to improve operating efficiency based on outdoor ambient wet-bulb temperature by using adaptive logic.
5. Fan motor sequencer for multiple-cell and two-speed applications with automatic lead stage rotation.
7. Electric basin heaters with temperature control and low-water-level safety switch for each cell, complying with requirements in “Electric Basin Heater” Paragraph.
8. Vibration switch for each fan, complying with requirements in “Vibration Switch” Paragraph.
9. Oil-level switch for each fan with a gear drive, complying with requirement in “Gear-Drive, Oil-Level Switch” Paragraph.
10. Single-point, field-power connection to a [fused disconnect switch] [nontfused disconnect switch] [circuit breaker] [for each cooling tower cell].
   a. Branch power circuit to each motor and electric basin heater and to controls[ with a disconnect switch or circuit breaker].
   b. NEMA-rated motor controller, hand-off-auto switch, and overcurrent protection for each motor. Provide variable frequency controller with manual bypass and line reactors for each variable-speed motor indicated.
11. Factory-installed wiring outside of enclosures shall be in metal raceway, except make connections to each motor and electric basin heater with liquidtight conduit.
13. Audible alarm and silence switch.
14. Visual indication of elapsed run time, graduated in hours for each motor.
15. Cooling tower shall have hardware to enable BMS to remotely monitor and display the following:
   a. Operational status of each motor.
   b. Position of dampers.
   c. Cooling tower leaving-fluid temperature.
   d. Fan vibration alarm.
   e. Oil-level alarm.
   f. Collection basin [high] [low] [high-and low]-water-level alarms.
   g. <Insert conditions to be monitored>.

GG. 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, 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. External Platforms with Handrails: Aluminum, FRP, or galvanized-steel bar grating at cooling tower access doors when cooling towers are elevated and not accessible from grade.
   5. Internal Platforms: Aluminum, FRP, or galvanized-steel 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 all 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.

HH. Capacities and Characteristics:
   1. Number of Cells: <Insert quantity>.
   2. Air-Inlet Arrangement: [Single side] [Two sides] [Sides and top].
   3. Maximum Drift Loss: [0.005] <Insert number> percent of design water flow.
   4. Heat-Exchanger Coil:
      a. Fluid Type: [Water] <Insert type>.
      d. Fluid Pressure Drop: <Insert psig>.
      e. Entering-Fluid Temperature: <Insert deg F>.
      f. Leaving-Fluid Temperature: <Insert deg F>.
      g. Entering-Air Wet-Bulb Temperature: <Insert deg F>.
   5. Economizer Mode:
      b. Entering-Fluid Temperature: <Insert deg F>.
      c. Leaving-Fluid Temperature: <Insert deg F>.
d. Entering-Air Wet-Bulb Temperature: <Insert deg F>.

6. Fan Drive: Belt or gear.

7. Fan Motor:
   a. Type: [Single speed] [Two speed, single winding] [Two speed, two winding] [Variable speed].
   c. Full-Load Ampacity: <Insert value>.
   d. Minimum Circuit Ampacity: <Insert value>.
   e. Maximum Overcurrent Protection Device: <Insert amperage>.
   f. Electrical Characteristics: [208] [240] [480] <Insert value>-V ac, 3 phase, 60 Hz.

8. Spray Pump and Motor:
   c. Full-Load Ampacity: <Insert value>.
   d. Minimum Circuit Ampacity: <Insert value>.
   e. Maximum Overcurrent Protection Device: <Insert amperage>.
   f. Electrical Characteristics: [120] [208] [240] [277] [480] <Insert value>-V ac, [single] [3] phase, 60 Hz.

9. Sound Pressure Level: <Insert dBA> at <Insert distance in feet> [when measured according to CTI ATC 128].

10. Basin Heater:
    a. Basin Water Temperature: [40 deg F] <Insert deg F>.
    b. Outdoor Ambient Temperature: [0 deg F] [Minus 20 deg F] <Insert deg F>.
    c. Capacity/Cell: <Insert kilowatts>.
    d. Full-Load Ampacity: <Insert value>.
    e. Minimum Circuit Ampacity: <Insert value>.
    g. Electrical Characteristics: [208] [240] [480] <Insert value>-V ac, 3 phase, 60 Hz.
    h. Capacity/Cell: <Insert MBtu/h>.
    i. Entering-Fluid Temperature: <Insert deg F>.
    j. Fluid Flow Rate: <Insert gpm>.
    k. Fluid Pressure Drop: <Insert psig>.
    l. Capacity/Cell: <Insert MBtu/h>.
    m. Steam Flow: <Insert lb/h>.
    n. Steam Pressure: <Insert psig>.

2.3 CLOSED-CIRCUIT, INDUCED-DRAFT, COUNTERFLOW COOLING TOWERS

A. Products: Subject to compliance with requirements, [provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:

1. Evapco Inc.; Models ATW, ESW, and UBW.
2. Recold; Model MW.
3. <Insert manufacturer's name; product name or designation>.
B. Basis-of-Design Product: Subject to compliance with requirements, provide [product indicated on Drawings] <Insert manufacturer's name; product name or designation> or comparable product by one of the following:

1. Evapco Inc.
2. Recold.
3. <Insert manufacturer's name>.

C. 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.

D. Cooling tower designed to resist wind load of [30 lbf/sq. ft.] <Insert value>.

E. Casing and Frame:

2. Frame Material: [FRP with UV inhibitors] [Galvanized steel, ASTM A 653/A 653M, G210 coating] [Galvanized steel, ASTM A 653/A 653M, G235 coating] [Polymer-coated galvanized steel] [Stainless steel].
5. Welded Connections: Continuous and watertight.

F. Collection Basin: Configure tower for installation with a field-constructed collection basin.

G. Collection Basin:

2. Overflow and drain connections.

H. Mechanically Operated, Collection Basin Water-Level Control: Manufacturer's standard adjustable, mechanical float assembly and valve.

I. Electric/Electronic, Collection Basin Water-Level Controller with Solenoid Valve:

1. Enclosure: NEMA 250, [Type 4] [Type 4X] <Insert type>.
2. Sensor: Solid-state controls with multiple electrode probes and relays factory wired to a terminal strip to provide [control of water makeup valve] [control of water makeup valve and low-level alarm] [control of water makeup valve and low- and high-level alarms] [control of water makeup valve, low- and high-level alarms, and output for shutoff of pump on low level].
4. Water Stilling Chamber: [Corrosion-resistant material] [FRP] [Galvanized steel] [PVC pipe] [Stainless steel].
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.
J. Electric Basin Heater:

2. Heater Control Panel: Mounted on the side of each cooling tower cell.
3. Enclosure: NEMA 250, [Type 3R] [Type 4] [Type 4X].
4. Magnetic contactors controlled by a temperature sensor/controller to maintain collection basin water-temperature set point. Water-level probe shall monitor cooling tower water level and de-energize the heater when the water reaches low-level set point.
5. Control-circuit transformer with primary and secondary side fuses.
6. Terminal blocks with numbered and color-coded wiring to match wiring diagram.
7. Single-point, field-power connection to a [fused disconnect switch] [nonfused disconnect switch] [circuit breaker] and heater branch circuiting complying with NFPA 70.
8. Factory Wiring Method: Metal raceway for factory-installed wiring outside of enclosures, except make connections to each electric basin heater with liquidtight conduit.

K. Hot-Water-Coil Basin Heater: Manufacturer's standard offering to provide capacity indicated.

L. Steam-Coil Basin Heater: Manufacturer's standard offering to provide capacity indicated.

M. Steam-Injector Basin Heater: Manufacturer's standard offering to provide capacity indicated.

N. Pressurized Water Distribution Piping: Main header and lateral branch piping designed for even distribution over heat-exchanger coil or fill throughout the flow range without the need for balancing valves and for connecting individual, removable, nonclogging spray nozzles.

1. Pipe Material: [Fiberglass] [PVC] [Galvanized steel] <Insert material>.
2. Spray Nozzle Material: [Plastic] [Polypropylene] [PVC] <Insert material>.
3. Piping Supports: Corrosion-resistant hangers and supports to resist movement during operation and shipment.

O. Recirculating Piping: [PVC] <Insert pipe material>[, with connections for separately provided, remote spray pump].

P. Spray Pump: Close-coupled, end-suction, single-stage, bronze-fitted centrifugal pump; with suction strainer and flow balancing valve, and mechanical seal suitable for outdoor service.

Q. General Requirements for Spray Pump Motor: Comply with NEMA designation and temperature-rating requirements specified in Division 23 Section “Common Motor Requirements for HVAC Equipment” and not indicated below.

1. Motor Enclosure: [Totally enclosed] [Totally enclosed nonventilated (TENV)] [Totally enclosed fan cooled (TEFC)] [with epoxy or polyurethane finish].
2. Energy Efficiency: [Comply with ASHRAE/IESNA 90.1] [NEMA Premium Efficient].
3. Service Factor: [1.0] [1.15] <Insert value>.

R. Heat-Exchanger Coils:

1. Tube and Tube Sheet Materials: [Copper tube with stainless-steel sheet] [Stainless-steel tube and sheet] [Prime-coated steel tube and sheet with outer surface of tube and sheet hot-dip galvanized after fabrication].
2. Heat-Exchanger Arrangement: [Serpentine tubes] [Serpentine tubes with removable cover plate on inlet and outlet headers] [Straight tubes with removable header cover plate on both ends of heat exchanger for straight-through access to each tube]; and sloped for complete drainage of fluid by gravity.

3. ASME Compliance: Designed, manufactured, and tested according to ASME Boiler and Pressure Vessel Code: Section VIII, Division 1 and bearing ASME "U" stamp; and sloped for complete drainage of fluid by gravity.

4. Field Piping Connections: Vent, supply, and return[ suitable for mating to ASME B16.5, Class 150 flange].

S. [Removable] Drift Eliminator:

1. Material: [FRP] [PVC] [FRP or PVC] <Insert material>; with maximum flame-spread index of [5] [25] <Insert value> 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.

T. Air-Intake Louvers:

1. Material: [FRP] [PVC] [Matching casing].

2. UV Treatment: Treat louvers with inhibitors to protect against damage caused by UV radiation.

3. Louver Blades: Arranged to uniformly direct air into cooling tower, to minimize air resistance, and to prevent water from splashing out during all modes of operation including operation with fans off.

U. Axial Fan: Balanced at the factory after assembly.

1. Blade Material: [Aluminum] [FRP] [Galvanized steel].

2. Hub Material: [Aluminum] [FRP] [Galvanized steel].


5. 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 [40,000] [50,000] <Insert value> hours.

6. Bearings Grease Fittings: Extended lubrication lines to an easily accessible location.

V. Belt Drive:

1. Service Factor: [1.5] <Insert value> based on motor nameplate horsepower.

2. Sheaves: Fan and motor shafts shall have taper-lock sheaves fabricated from corrosion-resistant materials.


5. Belt Material: Oil resistant, nonstatic conducting, and constructed of neoprene polyester cord.

6. Belt-Drive Guard: Comply with OSHA regulations.

7. Two-Motor, Single-Fan Drive:

   a. Two single-speed motors per fan, one sized for full speed and load and the other sized for [67] <Insert value> percent of full-load speed.
b. Each motor with belt drive and configured for operation when other motor fails.
c. Controls and wiring same as two-speed, two-winding motor.

W. Fan Motor:
1. General Requirements for Fan Motors: Comply with NEMA designation and temperature-rating requirements specified in Division 23 Section “Common Motor Requirements for HVAC Equipment” and not indicated below.
2. Motor Enclosure: [Totally enclosed] [Totally enclosed air over (TEAO)] [Totally enclosed fan cooled (TEFC)] [with epoxy or polyurethane finish].
3. Energy Efficiency: [Comply with ASHRAE/IESNA 90.1] [NEMA Premium Efficient].
5. Insulation: [Class F] [Class H] <Insert class>.
7. Severe-duty rating with the following features:
   a. Rotor and stator protected with corrosion-inhibiting epoxy resin.
   b. Double-shielded, vacuum-degassed bearings lubricated with premium, moisture-resistant grease suitable for temperatures between minus 20 and plus 300 deg F.
   c. Internal heater automatically energized when motor is de-energized.
8. Motor Base: Adjustable, or other suitable provision for adjusting belt tension.

X. Fan Discharge Stack: Material shall match casing, [manufacturer's standard] [velocity recovery] design.
1. Stack Extension: Fabricated to extend above fan deck <Insert distance> unless otherwise indicated.
2. Stack Termination: Wire-mesh, galvanized-steel screens; complying with OSHA regulations.

Y. Vibration Switch: For each fan drive.
1. Enclosure: NEMA 250, [Type 4] [Type 4X] <Insert type>.
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.

Z. Controls: Comply with requirements in Division 23 Section “Instrumentation and Control for HVAC.”

AA. Control Package: Factory installed and wired, and functionally tested at factory before shipment.
1. NEMA 250, [Type 3R] [Type 4] [Type 4X] enclosure with removable internally mount backplate.
2. Control-circuit transformer with primary and secondary side fuses.
3. Terminal blocks with numbered and color-coded wiring to match wiring diagram. Spare wiring terminal block for connection to external controls or equipment.
4. Microprocessor-based controller for automatic control of fan[ and spray pump] based on cooling tower leaving-water temperature with control features to improve operating efficiency based on outdoor ambient wet-bulb temperature by using adaptive logic.
5. Fan motor sequencer for multiple-cell and two-speed applications with automatic lead stage rotation.
7. Electric basin heaters with temperature control and low-water-level safety switch for each cell, complying with requirements in "Electric Basin Heater" Paragraph.
8. Vibration switch for each fan, complying with requirements in "Vibration Switch" Paragraph.
9. Single-point, field-power connection to a [fused disconnect switch] [nonfused disconnect switch] [circuit breaker] [for each cooling tower cell].
   a. Branch power circuit to each motor and electric basin heater and to controls[ with a disconnect switch or circuit breaker].
   b. NEMA-rated motor controller, hand-off-auto switch, and overcurrent protection for each motor. Provide variable frequency controller with manual bypass and line reactors for each variable-speed motor indicated.
10. Factory-installed wiring outside of enclosures shall be in metal raceway, except make connections to each motor and electric basin heater with liquidtight conduit.
12. Audible alarm and silence switch.
13. Visual indication of elapsed run time, graduated in hours for each motor.
14. Cooling tower shall have hardware to enable BMS to remotely monitor and display the following:
   a. Operational status of each motor.
   b. Cooling tower leaving-fluid temperature.
   c. Fan vibration alarm.
   d. Collection basin [high] [low] [high- and low]-water-level alarms.
   e. <Insert conditions to be monitored>.

BB. 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, 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. External Platforms with Handrails: Aluminum, FRP, or galvanized-steel bar grating at cooling tower access doors when cooling towers are elevated and not accessible from grade.
5. Internal Platforms: Aluminum, FRP, or galvanized-steel 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 all 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.

**CC. Capacities and Characteristics:**

1. Number of Cells: \(<\text{Insert quantity}>\).
2. Maximum Drift Loss: \([0.005] <\text{Insert number}>\) percent of design water flow.
3. Heat-Exchanger Coil:
   
a. Fluid Type: \([\text{Water}] <\text{Insert type}>\).
   b. Fluid Flow/Cell: \(<\text{Insert gpm}>\).
   c. Minimum Fluid Flow/Cell: \(<\text{Insert gpm}>\).
   d. Fluid Pressure Drop: \(<\text{Insert psig}>\).
   e. Entering-Fluid Temperature: \(<\text{Insert deg F}>\).
   f. Leaving-Fluid Temperature: \(<\text{Insert deg F}>\).
   g. Entering-Air Wet-Bulb Temperature: \(<\text{Insert deg F}>\).

4. Economizer Mode:
   
a. Fluid Flow/Cell: \(<\text{Insert gpm}>\).
   b. Entering-Fluid Temperature: \(<\text{Insert deg F}>\).
   c. Leaving-Fluid Temperature: \(<\text{Insert deg F}>\).
   d. Entering-Air Wet-Bulb Temperature: \(<\text{Insert deg F}>\).

5. Fan Motor:
   
a. Type: \([\text{Single speed}] [\text{Two speed, single winding}] [\text{Two speed, two winding}] [\text{Variable speed}]\).
   b. Horsepower/Cell: \(<\text{Insert horsepower}>\).
   c. Full-Load Ampacity: \(<\text{Insert value}>\).
   d. Minimum Circuit Ampacity: \(<\text{Insert value}>\).
   e. Maximum Overcurrent Protection Device: \(<\text{Insert amperage}>\).
   f. Electrical Characteristics: \([208] [240] [480] <\text{Insert value}>-\text{V ac}, 3 \text{ phase}, 60 \text{ Hz}.\)

6. Spray Pump and Motor:
   
a. Water Flow/Cell: \(<\text{Insert gpm}>\).
   b. Horsepower/Cell: \(<\text{Insert horsepower}>\).
   c. Full-Load Ampacity: \(<\text{Insert value}>\).
   d. Minimum Circuit Ampacity: \(<\text{Insert value}>\).
   e. Maximum Overcurrent Protection Device: \(<\text{Insert amperage}>\).
   f. Electrical Characteristics: \([120] [208] [240] [277] [480] <\text{Insert value}>-\text{V ac}, [\text{single}] [3] \text{ phase}, 60 \text{ Hz}.\)

7. Sound Pressure Level: \(<\text{Insert dBA}>\) at \(<\text{Insert distance in feet}>\) [when measured according to CTI ATC 128].

8. Basin Heater:
   
a. Basin Water Temperature: \([40 \text{ deg F}] <\text{Insert deg F}>\).
b. Outdoor Ambient Temperature: [0 deg F] [Minus 20 deg F] <Insert deg F>.
c. Capacity/Cell: <Insert kilowatts>.
d. Full-Load Ampacity: <Insert value>.
e. Minimum Circuit Ampacity: <Insert value>.
g. Electrical Characteristics: [208] [240] [480] <Insert value> V ac, 3 phase, 60 Hz.
h. Capacity/Cell: <Insert MBtu/h>.
i. Fluid Flow Rate: <Insert gpm>.
j. Fluid Pressure Drop: <Insert psig>.
k. Capacity/Cell: <Insert MBtu/h>.
l. Steam Flow: <Insert lb/h>.
m. Steam Pressure: <Insert psig>.

2.4 OPEN-CIRCUIT, FORCED-DRAFT, COUNTERFLOW COOLING TOWERS

A. Products: Subject to compliance with requirements, [provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:

1. Baltimore Aircoil Company; Models VTL, VTO, and VT1.
3. Evapco Inc.; Models LRT and LSTA.
4. Tower Tech, Inc.; Model TTXE.
5. <Insert manufacturer's name; product name or designation>.

B. Basis-of-Design Product: Subject to compliance with requirements, provide [product indicated on Drawings] <Insert manufacturer's name; product name or designation> or comparable product by one of the following:

2. Delta Cooling Towers, Inc.
3. Evapco Inc.
4. Tower Tech, Inc.
5. <Insert manufacturer's name>.

C. 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.

D. Cooling tower designed to resist wind load of [30 lbf/sq. ft.] <Insert value>.

E. Casing and Frame:

2. Frame Material: [FRP with UV inhibitors] [Galvanized steel, ASTM A 653/A 653M, G210 coating] [Galvanized steel, ASTM A 653/A 653M, G235 coating] [Polymer-coated galvanized steel] [Stainless steel].
5. Welded Connections: Continuous and watertight.
F. Collection Basin: Configure tower for installation with a field-constructed collection basin.

G. Collection Basin:

1. Material: [FRP with UV inhibitors] [Galvanized steel, ASTM A 653/A 653M, G210 coating] [Galvanized steel, ASTM A 653/A 653M, G235 coating] [Polymer-coated galvanized steel] [Stainless steel].
3. Overflow and drain connections.
5. Basin Sweeper Distribution Piping and Nozzles:
   a. Pipe Material: [PVC] <Insert material>.
   c. Configure piping and nozzles to minimize sediment from collecting in the collection basin.

H. Mechanically Operated, Collection Basin Water-Level Control: Manufacturer’s standard adjustable, mechanical float assembly and valve.

I. Electric/Electronic, Collection Basin Water-Level Controller with Solenoid Valve:

1. Enclosure: NEMA 250, [Type 4] [Type 4X] <Insert type>.
2. Sensor: Solid-state controls with multiple electrode probes and relays factory wired to a terminal strip to provide [control of water makeup valve] [control of water makeup valve and low-level alarm] [control of water makeup valve and low- and high-level alarms] [control of water makeup valve, low- and high-level alarms, and output for shutoff of pump on low level].
4. Water Stilling Chamber: [Corrosion-resistant material] [FRP] [Galvanized steel] [PVC pipe] [Stainless steel].
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.

J. Electric Basin Heater:

2. Heater Control Panel: Mounted on the side of each cooling tower cell.
3. Enclosure: NEMA 250, [Type 3R] [Type 4] [Type 4X].
4. Magnetic contactors controlled by a temperature sensor/controller to maintain collection basin water-temperature set point. Water-level probe shall monitor cooling tower water level and de-energize the heater when the water reaches low-level set point.
5. Control-circuit transformer with primary and secondary side fuses.
6. Terminal blocks with numbered and color-coded wiring to match wiring diagram.
7. Single-point, field-power connection to a [fused disconnect switch] [nonfused disconnect switch] [circuit breaker] and heater branch circuiting complying with NFPA 70.
8. Factory Wiring Method: Metal raceway for factory-installed wiring outside of enclosures, except make connections to each electric basin heater with liquidtight conduit.
K. Hot-Water-Coil Basin Heater: Manufacturer’s standard offering to provide capacity indicated.

L. Steam-Coil Basin Heater: Manufacturer’s standard offering to provide capacity indicated.

M. Steam-Injector Basin Heater: Manufacturer’s standard offering to provide capacity indicated.

N. Pressurized Water Distribution Piping: Main header and lateral branch piping designed for even distribution over heat-exchanger coil or fill throughout the flow range without the need for balancing valves and for connecting individual, removable, nonclogging spray nozzles.

1. Pipe Material: [Fiberglass] [PVC] [Galvanized steel] <Insert material>.
2. Spray Nozzle Material: [Plastic] [Polypropylene] [PVC] <Insert material>.
3. Piping Supports: Corrosion-resistant hangers and supports to resist movement during operation and shipment.

O. Fill:

1. Materials: [PVC] <Insert material>, with maximum flame-spread index of 5 according to ASTM E 84.
2. Minimum Thickness: [15 mils] [20 mils] <Insert value>, before forming.
3. Fabrication: Fill-type sheets, fabricated, formed, and bonded together after forming into removable assemblies that are factory installed by manufacturer.
4. Fill Material Operating Temperature: Suitable for entering-water temperatures up through [120 deg F] <Insert temperature>.

P. [Removable ]Drift Eliminator:

1. Material: [FRP] [PVC] [FRP or PVC] <Insert material>; with maximum flame-spread index of [5] [25] <Insert value> 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.

Q. [Removable ]Air-Intake Screens: [Galvanized] [Polymer-coated, galvanized] [Stainless]-steel wire mesh.

R. Centrifugal Fan: Double-width, double-inlet, forward-curved blades, and statically and dynamically balanced at the factory after assembly.

1. Number of Fans: Each cooling tower cell shall have a single fan or multiple fans connected to a common shaft.
2. Fan Wheel and Housing Materials: Galvanized steel.
3. Fan Shaft: Steel, coated to resist corrosion.
5. Fan Shaft Bearings: Self-aligning, grease-lubricated 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 [40,000] [50,000] <Insert value> hours.
6. Bearings Grease Fittings: Extended lubrication lines to an easily accessible location.

S. Axial Fan: Balanced at the factory after assembly.
1. Blade Material: [FRP] <Insert material>.
2. Hub Material: [Aluminum] [FRP] <Insert material>.
5. 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 [40,000] [50,000] <Insert value> hours.
6. Bearings Grease Fittings: Extended lubrication lines to an easily accessible location.

T. Belt Drive:
1. Service Factor: [1.5] <Insert value> based on motor nameplate horsepower.
2. Sheaves: Fan and motor shafts shall have taper-lock sheaves fabricated from corrosion-resistant materials.
5. Belt Material: Oil resistant, nonstatic conducting, and constructed of neoprene polyester cord.
6. Belt-Drive Guard: Comply with OSHA regulations.
7. Two-Motor, Single-Fan Drive:
   a. Two single-speed motors per fan, one sized for full speed and load and the other sized for [67] <Insert value> percent of full-load speed.
   b. Each motor with belt drive and configured for operation when other motor fails.
   c. Controls and wiring same as two-speed, two-winding motor.

U. Direct Drive: Fan hub directly connected, and properly secured, to motor shaft.

V. Fan Motor:
1. General Requirements for Fan Motors: Comply with NEMA designation and temperature-rating requirements specified in Division 23 Section "Common Motor Requirements for HVAC Equipment" and not indicated below.
2. Motor Enclosure: [Totally enclosed] [Totally enclosed air over (TEAO)] [Totally enclosed fan cooled (TEFC)] [with epoxy or polyurethane finish].
3. Energy Efficiency: [Comply with ASHRAE/IESNA 90.1] [NEMA Premium Efficient].
5. Insulation: [Class F] [Class H] <Insert class>.
7. Severe-duty rating with the following features:
   a. Rotor and stator protected with corrosion-inhibiting epoxy resin.
   b. Double-shielded, vacuum-degassed bearings lubricated with premium, moisture-resistant grease suitable for temperatures between minus 20 and 300 deg F.
   c. Internal heater automatically energized when motor is de-energized.
8. Motor Base: Adjustable, or other suitable provision for adjusting belt tension.

W. Discharge Hoods:
1. Hood Configuration: [Tapered] [Straight]; totally surrounding drift eliminators and constructed of same material as casing; and having factory-installed [insulation and ] access doors.

2. Discharge Dampers: Positive-closure, automatic, isolation dampers with electric actuators.
   a. Provide field power and controls to open dampers when pump is energized and close dampers when pump is de-energized.

X. Capacity-Control Dampers: [Galvanized-steel] [Stainless-steel] <Insert material> dampers, with linkages, electric operator, controller, limit switches, transformer, and weatherproof enclosure.

Y. Vibration Switch: For each fan drive.
   1. Enclosure: NEMA 250, [Type 4] [Type 4X] <Insert type>.
   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.
   4. Switch shall, on sensing excessive vibration,[ signal an alarm through the BMS and ] shut down the fan.

Z. Controls: Comply with requirements in Division 23 Section "Instrumentation and Control for HVAC."

AA. Control Package: Factory installed and wired, and functionally tested at factory before shipment.
   1. NEMA 250, [Type 3R] [Type 4] [Type 4X] enclosure with removable internally mount backplate.
   2. Control-circuit transformer with primary and secondary side fuses.
   3. Terminal blocks with numbered and color-coded wiring to match wiring diagram. Spare wiring terminal block for connection to external controls or equipment.
   4. Microprocessor-based controller for automatic control of fan based on cooling tower leaving-water temperature with control features to improve operating efficiency based on outdoor ambient wet-bulb temperature by using adaptive logic.
   5. Fan motor sequencer for multiple-cell and two-speed applications with automatic lead stage rotation.
   6. Factory-installed and -wired, collection basin electric/electronic level controller.
   8. Electric basin heaters with temperature control and low-water-level safety switch for each cell, complying with requirements in "Electric Basin Heater" Paragraph.
   9. Vibration switch for each fan, complying with requirements in "Vibration Switch" Paragraph.
   10. Controls and wiring for "two-motor, single-fan drives" shall be same as two-speed, two-winding motor.
   11. Single-point, field-power connection to a [fused disconnect switch] [nonfused disconnect switch] [circuit breaker] [for each cooling tower cell].
a. Branch power circuit to each motor and electric basin heater and to controls [with a disconnect switch or circuit breaker].
b. NEMA-rated motor controller, hand-off-auto switch, and overcurrent protection for each motor. Provide variable frequency controller with manual bypass and line reactors for each variable-speed motor indicated.

12. Factory-installed wiring outside of enclosures shall be in metal raceway, except make connections to each motor and electric basin heater with liquidtight conduit.
15. Visual indication of elapsed run time, graduated in hours for each motor.
16. Cooling tower shall have hardware to enable BMS to remotely monitor and display the following:
   a. Operational status of each motor.
   b. Position of dampers.
   c. Cooling tower leaving-fluid temperature.
   d. Fan vibration alarm.
   e. Collection basin [high] [low] [high- and low]-water-level alarms.
   f. <Insert conditions to be monitored>.

BB. 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, 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. External Platforms with Handrails: Aluminum, FRP, or galvanized-steel bar grating at cooling tower access doors when cooling towers are elevated and not accessible from grade.
5. Internal Platforms: Aluminum, FRP, or galvanized-steel 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 all 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.

CC. Capacities and Characteristics:

1. Number of Cells: <Insert quantity>.
2. Air-Inlet Arrangement: [Single side] [Four sides].
3. Maximum Drift Loss: [0.005] <Insert number> percent of design water flow.
8. Leaving-Water Temperature: <Insert deg F>.
10. Economizer Mode:
   b. Entering-Water Temperature: <Insert deg F>.
   c. Leaving-Water Temperature: <Insert deg F>.
   d. Entering-Air Wet-Bulb Temperature: <Insert deg F>.

11. Fan Location: [Bottom] [Side] [Bottom or side].
12. Fan and Drive Type: Axial with direct drive or centrifugal with belt drive.
13. Fan Motor:
   a. Type: [Single speed] [Two speed, single winding] [Two speed, two winding] [Variable speed].
   c. Full-Load Ampacity: <Insert value>.
   d. Minimum Circuit Ampacity: <Insert value>.
   e. Maximum Overcurrent Protection Device: <Insert amperage>.
   f. Electrical Characteristics: [208] [240] [480] <Insert value>-V ac, 3 phase, 60 Hz.

14. Sound Pressure Level: <Insert dBA> at <Insert distance in feet> [when measured according to CTI ATC 128].
15. Basin Heater:
   a. Basin Water Temperature: [40 deg F] <Insert deg F>.
   b. Outdoor Ambient Temperature: [0 deg F] [Minus 20 deg F] <Insert deg F>.
   c. Capacity/Cell: <Insert kilowatts>.
   d. Full-Load Ampacity: <Insert value>.
   e. Minimum Circuit Ampacity: <Insert value>.
   g. Electrical Characteristics: [208] [240] [480] <Insert value>-V ac, 3 phase, 60 Hz.
   h. Capacity/Cell: <Insert MBtu/h>.
   i. Entering-Fluid Temperature: <Insert deg F>.
   j. Fluid Flow Rate: <Insert gpm>.
   k. Fluid Pressure Drop: <Insert psig>.
   l. Capacity/Cell: <Insert MBtu/h>.
   m. Steam Flow: <Insert lb/h>.
   n. Steam Pressure: <Insert psig>.

2.5 OPEN-CIRCUIT, INDUCED-DRAFT, COUNTERFLOW COOLING TOWERS

A. Products: Subject to compliance with requirements, [provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:

1. Amcot Cooling Tower Corp.; Model ST.
3. Evapco Inc.; Models AT, ICT, REP, UBT, and USS.
4. Protec Cooling Towers, Inc.; Model PTC.
5. Recold; Model MT.
6. Thermal Care, Inc., a division of MFRI, Inc.; Models FC and FT.
7. <Insert manufacturer's name; product name or designation>.
B. Basis-of-Design Product: Subject to compliance with requirements, provide [product indicated on Drawings] <Insert manufacturer's name; product name or designation> or comparable product by one of the following:

1. Amcot Cooling Tower Corp.
2. Delta Cooling Towers, Inc.
3. Evapco Inc.
4. Protec Cooling Towers, Inc.
5. Recold.
6. Thermal Care, Inc., a division of MFRI, Inc.
7. <Insert manufacturer's name>.

C. 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.

D. Cooling tower designed to resist wind load of [30 lbf/sq. ft.] <Insert value>.

E. Casing and Frame:

5. Welded Connections: Continuous and watertight.

F. Collection Basin: Configure tower for installation with a field-constructed collection basin.

G. Collection Basin:

1. Material: [FRP with UV inhibitors] [Galvanized steel, ASTM A 653/A 653M, G210 coating] [Galvanized steel, ASTM A 653/A 653M, G235 coating] [Polymer-coated galvanized steel] [Stainless steel].
3. Overflow and drain connections.
6. Removable equalization flume plate between adjacent cells of multiple-cell towers.
7. Equalizer connection for field-installed equalizer piping.
8. Basin Sweeper Distribution Piping and Nozzles:
   a. Pipe Material: [PVC] <Insert material>.
   c. Configure piping and nozzles to minimize sediment from collecting in the collection basin.

H. Mechanically Operated, Collection Basin Water-Level Control: Manufacturer's standard adjustable, mechanical float assembly and valve.
I. Electric/Electronic, Collection Basin Water-Level Controller with Solenoid Valve:

1. Enclosure: NEMA 250, [Type 4] [Type 4X] <Insert type>.
2. Sensor: Solid-state controls with multiple electrode probes and relays factory wired to a terminal strip to provide [control of water makeup valve] [control of water makeup valve and low-level alarm] [control of water makeup valve and low- and high-level alarms] [control of water makeup valve, low- and high-level alarms, and output for shutoff of pump on low level].
4. Water Stilling Chamber: [Corrosion-resistant material] [FRP] [Galvanized steel] [PVC pipe] [Stainless steel].
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.

J. Ultrasonic Collection Basin Water-Level Controller with Solenoid Valve:

1. Enclosure: NEMA 250, [Type 4] [Type 4X] <Insert type>.
2. Controller: Ultrasonic level sensor/transmitter and relays factory wired to a terminal strip to control water makeup valve and signal a level alarm. Controller shall provide continuous level indication through a 4- to 20-mA signal[ for connection to BMS].
3. Water Stilling Chamber: [Corrosion-resistant material] [FRP] [Galvanized steel] [PVC pipe] [Stainless steel].
4. Solenoid Valve: Slow closing[ with stainless-steel body]; controlled and powered through level controller in response to water-level set point.
5. Electrical Connection Requirements: 120 V, single phase, 60 Hz.

K. Electric Basin Heater:

2. Heater Control Panel: Mounted on the side of each cooling tower cell.
3. Enclosure: NEMA 250, [Type 3R] [Type 4] [Type 4X].
4. Magnetic contactors controlled by a temperature sensor/controller to maintain collection basin water-temperature set point. Water-level probe shall monitor cooling tower water level and de-energize the heater when the water reaches low-level set point.
5. Control-circuit transformer with primary and secondary side fuses.
6. Terminal blocks with numbered and color-coded wiring to match wiring diagram.
7. Single-point, field-power connection to a [fused disconnect switch] [nonfused disconnect switch] [circuit breaker] and heater branch circuiting complying with NFPA 70.
8. Factory Wiring Method: Metal raceway for factory-installed wiring outside of enclosures, except make connections to each electric basin heater with liquidtight conduit.

L. Hot-Water-Coil Basin Heater: Manufacturer’s standard offering to provide capacity indicated.

M. Steam-Coil Basin Heater: Manufacturer’s standard offering to provide capacity indicated.

N. Steam-Injector Basin Heater: Manufacturer’s standard offering to provide capacity indicated.

O. Pressurized Water Distribution Piping: Main header and lateral branch piping designed for even distribution over heat-exchanger coil or fill throughout the flow range without the need for balancing valves and for connecting individual, removable, nonclogging spray nozzles.
1. Pipe Material: [Fiberglass] [PVC] [Galvanized steel]<Insert material>.  
2. Spray Nozzle Material: [Plastic] [Polypropylene] [PVC]<Insert material>.  
3. Piping Supports: Corrosion-resistant hangers and supports to resist movement during operation and shipment.  

P. Fill:  
1. Materials: [CPVC] [PVC]<Insert material>, resistant to rot, decay, and biological attack; with maximum flame-spread index of [5] [25]<Insert value> according to ASTM E 84.  
2. Minimum Thickness: [15 mils] [20 mils]<Insert value> before forming.  
3. Fabrication: Fill-type sheets, fabricated, formed, and bonded together after forming into removable assemblies that are factory installed by manufacturer.  
4. Fill Material Operating Temperature: Suitable for entering-water temperatures up through [120 deg F]<Insert temperature>.  

Q. [Removable]Drift Eliminator:  
1. Material: [FRP] [PVC] [FRP or PVC]<Insert material>; resistant to rot, decay, and biological attack; with maximum flame-spread index of [5] [25]<Insert value> 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.  

R. Air-Intake Louvers:  
1. Material: [FRP] [PVC] [Matching casing].  
2. UV Treatment: Inhibitors to protect against damage caused by UV radiation.  
3. Louver Blades: Arranged to uniformly direct air into cooling tower, to minimize air resistance, and to prevent water from splashing out of tower during all modes of operation including operation with fans off.  

S. [Removable]Air-Intake Screens: [Galvanized] [Polymer-coated, galvanized] [Stainless]-steel wire mesh.  

T. Axial Fan: Balanced at the factory after assembly.  
1. Blade Material: [Aluminum] [FRP] [Galvanized steel].  
2. Hub Material: [Aluminum] [FRP] [Galvanized steel].  
5. 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 [40,000] [50,000]<Insert value> hours.  
6. Bearings Grease Fittings: Extended lubrication lines to an easily accessible location.  

U. Belt Drive:  
1. Service Factor: [1.5]<Insert value> based on motor nameplate horsepower.  
2. Sheaves: Fan and motor shafts shall have taper-lock sheaves fabricated from corrosion-resistant materials.
WMU Design Guidelines

a. Belt: Multiple V-belt design with a matched set of cogged belts.
b. Belt: One-piece, multigrooved, solid-back belt.
c. Belt Material: Oil resistant, nonstatic conducting, and constructed of neoprene polyester cord.
d. Belt-Drive Guard: Comply with OSHA regulations.

V. Direct Drive: Fan hub directly connected, and properly secured, to motor shaft.

W. Gear Drive: 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] <Insert value> 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 all 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-to-Motor Connection: [Close coupled to motor using a flexible coupling] [Connected to motor located outside of cooling tower casing by a full-floating drive shaft].
6. Drive Shaft Material: [Corrosion resistant] [Stainless steel], and fitted with flexible couplings on both ends. Provide exposed shaft and couplings with guards according to OSHA regulations.
7. Extend oil fill, drain, and vent to outside of cooling tower casing using galvanized-steel piping. Provide installation with oil-level sight glass.

X. Fan Motor:

1. General Requirements for Fan Motors: Comply with NEMA designation and temperature-rating requirements specified in Division 23 Section "Common Motor Requirements for HVAC Equipment" and not indicated below.
2. Motor Enclosure: [Totally enclosed] [Totally enclosed air over (TEAO)] [Totally enclosed fan cooled (TEFC)] [with epoxy or polyurethane finish].
3. Energy Efficiency: [Comply with ASHRAE/IESNA 90.1] [NEMA Premium Efficient].
5. Insulation: [Class F] [Class H] <Insert class>.
7. Motor Location: Mounted outside of cooling tower casing and cooling tower discharge airstream.
8. Severe-duty rating with the following features:
   a. Rotor and stator protected with corrosion-inhibiting epoxy resin.
   b. Double-shielded, vacuum-degassed bearings lubricated with premium, moisture-resistant grease suitable for temperatures between minus 20 and plus 300 deg F.
   c. Internal heater automatically energized when motor is de-energized.
9. Motor Base: Adjustable, or other suitable provision for adjusting belt tension.
Y. Fan Discharge Stack: Material shall match casing, [manufacturer's standard] [velocity recovery] design.

1. Stack Extension: Fabricated to extend above fan deck <Insert distance> unless otherwise indicated.
2. Stack Termination: Wire-mesh, galvanized-steel screens; complying with OSHA regulations.

Z. Vibration Switch: For each fan drive.

1. Enclosure: NEMA 250, [Type 4] [Type 4X] <Insert type>.
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.
4. Switch shall, on sensing excessive vibration,[ signal an alarm through the BMS and] shut down the fan.

AA. Gear-Drive, Oil-Level Switch: Low-oil-level warning switch[ for connection to a BMS].

1. Switch shall, on reaching a low-oil-level set point recommended by cooling tower manufacturer, signal an alarm[ through the BMS].

BB. Controls: Comply with requirements in Division 23 Section “Instrumentation and Control for HVAC.”

CC. Control Package: Factory installed and wired, and functionally tested at factory before shipment.

1. NEMA 250, [Type 3R] [Type 4] [Type 4X] enclosure with removable internally mount backplate.
2. Control-circuit transformer with primary and secondary side fuses.
3. Terminal blocks with numbered and color-coded wiring to match wiring diagram. Spare wiring terminal block for connection to external controls or equipment.
4. Microprocessor-based controller for automatic control of fan based on cooling tower leaving-water temperature with control features to improve operating efficiency based on outdoor ambient wet-bulb temperature by using adaptive logic.
5. Fan motor sequencer for multiple-cell and two-speed applications with automatic lead stage rotation.
7. Electric basin heaters with temperature control and low-water-level safety switch for each cell, complying with requirements in “Electric Basin Heater” Paragraph.
8. Vibration switch for each fan, complying with requirements in “Vibration Switch” Paragraph.
9. Oil-level switch for each fan with a gear drive, complying with requirement in “Gear-Drive, Oil-Level Switch” Paragraph.
10. Single-point, field-power connection to a [fused disconnect switch] [nonfused disconnect switch] [circuit breaker] [for each cooling tower cell].
a. Branch power circuit to each motor and electric basin heater and to controls with a disconnect switch or circuit breaker.

b. NEMA-rated motor controller, hand-off-auto switch, and overcurrent protection for each motor. Provide variable frequency controller with manual bypass and line reactors for each variable-speed motor indicated.

11. Factory-installed wiring outside of enclosures shall be in metal raceway, except make connections to each motor and electric basin heater with liquidtight conduit.

12. Visual indication of status and alarm with momentary test push button for each motor.

13. Audible alarm and silence switch.

14. Visual indication of elapsed run time, graduated in hours for each motor.

15. Cooling tower shall have hardware to enable BMS to remotely monitor and display the following:

   a. Operational status of each motor.
   b. Position of dampers.
   c. Cooling tower leaving-fluid temperature.
   d. Fan vibration alarm.
   e. Oil-level alarm.
   f. Collection basin [high] [low] [high- and low]-water-level alarms.
   g. <Insert conditions to be monitored>.

DD. 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, 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. External Platforms with Handrails: Aluminum, FRP, or galvanized-steel bar grating at cooling tower access doors when cooling towers are elevated and not accessible from grade.


5. Internal Platforms: Aluminum, FRP, or galvanized-steel 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 all 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.

EE. Capacities and Characteristics:

1. Number of Cells: <Insert quantity>.

2. Air-Inlet Arrangement: All sides.

3. Maximum Drift Loss: [0.005] <Insert number> percent of design water flow.


8. Leaving-Water Temperature: <Insert deg F>.
9. Entering-Air Wet-Bulb Temperature: \textless \text{Insert deg F}\textgreater.

10. Economizer Mode:
   a. Water Flow/Cell: \textless \text{Insert gpm}\textgreater.
   b. Entering-Water Temperature: \textless \text{Insert deg F}\textgreater.
   c. Leaving-Water Temperature: \textless \text{Insert deg F}\textgreater.
   d. Entering-Air Wet-Bulb Temperature: \textless \text{Insert deg F}\textgreater.

11. Fan Drive: Belt, direct, or gear.

12. Fan Motor:
   a. Type: [Single speed] [Two speed, single winding] [Two speed, two winding] [Variable speed].
   b. Horsepower/Cell: \textless \text{Insert horsepower}\textgreater.
   c. Full-Load Ampacity: \textless \text{Insert value}\textgreater.
   d. Minimum Circuit Ampacity: \textless \text{Insert value}\textgreater.
   e. Maximum Overcurrent Protection Device: \textless \text{Insert amperage}\textgreater.
   f. Electrical Characteristics: \textless 208\textgreater [240] [480] \textless \text{Insert value}\textgreater-V ac, 3 phase, 60 Hz.

13. Sound Pressure Level: \textless \text{Insert dBA}\textgreater at \textless \text{Insert distance in feet}\textgreater [when measured according to CTI ATC 128].

14. Basin Heater:
   a. Basin Water Temperature: [40 deg F] \textless \text{Insert deg F}\textgreater.
   b. Outdoor Ambient Temperature: [0 deg F] [Minus 20 deg F] \textless \text{Insert deg F}\textgreater.
   c. Capacity/Cell: \textless \text{Insert kilowatts}\textgreater.
   d. Full-Load Ampacity: \textless \text{Insert value}\textgreater.
   e. Minimum Circuit Ampacity: \textless \text{Insert value}\textgreater.
   f. Maximum Overcurrent Protection Device: \textless \text{Insert amperage}\textgreater.
   g. Electrical Characteristics: \textless 208\textgreater [240] [480] \textless \text{Insert value}\textgreater-V ac, 3 phase, 60 Hz.
   h. Capacity/Cell: \textless \text{Insert MBtu/h}\textgreater.
   i. Entering-Fluid Temperature: \textless \text{Insert deg F}\textgreater.
   j. Fluid Flow Rate: \textless \text{Insert gpm}\textgreater.
   k. Fluid Pressure Drop: \textless \text{Insert psig}\textgreater.
   l. Capacity/Cell: \textless \text{Insert MBtu/h}\textgreater.
   m. Steam Flow: \textless \text{Insert lb/h}\textgreater.
   n. Steam Pressure: \textless \text{Insert psig}\textgreater.

2.6 OPEN-CIRCUIT, INDUCED-DRAFT, CROSSFLOW COOLING TOWERS

A. Products: Subject to compliance with requirements, [provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:

2. Baltimore Aircoil Company; Series 1500 and 3000.
3. Marley Cooling Technologies, an SPX Corporation; Models Aquatower, AV series, NC Class, Primus.
4. \textless \text{Insert manufacturer's name; product name or designation}\textgreater.
B. Basis-of-Design Product: Subject to compliance with requirements, provide [product indicated on Drawings] <Insert manufacturer's name; product name or designation> or comparable product by one of the following:

1. Amcot Cooling Tower Corp.
2. Baltimore Aircoil Company.
4. <Insert manufacturer's name>.

C. 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.

D. Cooling tower designed to resist wind load of [30 lbf/sq. ft.] <Insert value>.

E. Casing and Frame:

2. Frame Material: FRP with UV inhibitors [Galvanized steel, ASTM A 653/A 653M, G235 coating] [Polymer-coated galvanized steel] [Stainless steel].
5. Welded Connections: Continuous and watertight.

F. Collection Basin: Configure tower for installation with a field-constructed collection basin.

G. Collection Basin:

1. Material: FRP with UV inhibitors [Galvanized steel, ASTM A 653/A 653M, G235 coating] [Polymer-coated galvanized steel] [Stainless steel].
2. Removable stainless-steel strainer with openings smaller than nozzle orifices.
3. Overflow and drain connections.
6. Removable equalization flume plate between adjacent cells of multiple-cell towers.
7. Equalizer connection for field-installed equalizer piping.
8. Basin Sweeper Distribution Piping and Nozzles:
   a. Pipe Material: PVC <Insert material>.
   c. Configure piping and nozzles to minimize sediment from collecting in the collection basin.

H. Mechanically Operated, Collection Basin Water-Level Control: Manufacturer's standard adjustable, mechanical float assembly and valve.

I. Electric/Electronic, Collection Basin Water-Level Controller with Solenoid Valve:

1. Enclosures: NEMA 250, [Type 4] [Type 4X] <Insert type>.
2. Sensor: Solid-state controls with multiple electrode probes and relays factory wired to a terminal strip to provide control of water makeup valve control of water makeup
valve and low-level alarm] [control of water makeup valve and low- and high-level alarms] [control of water makeup valve, low- and high-level alarms, and output for shutoff of pump on low level].

4. Water Stilling Chamber: [Corrosion-resistant material] [FRP] [Galvanized steel] [PVC pipe] [Stainless steel].
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.

J. Ultrasonic Collection Basin Water-Level Controller with Solenoid Valve:

1. Enclosure: NEMA 250, [Type 4] [Type 4X] <Insert type>.
2. Controller: Ultrasonic level sensor/transmitter and relays factory wired to a terminal strip to control water makeup valve and signal a level alarm. Controller shall provide continuous level indication through a 4- to 20-mA signal [for connection to BMS].
3. Water Stilling Chamber: [Corrosion-resistant material] [FRP] [Galvanized steel] [PVC pipe] [Stainless steel].
4. Solenoid Valve: Slow closing [with stainless-steel body]; controlled and powered through level controller in response to water-level set point.
5. Electrical Connection Requirements: 120 V, single phase, 60 Hz.

K. Electric Basin Heater:

2. Heater Control Panel: Mounted on the side of each cooling tower cell.
3. Enclosure: NEMA 250, [Type 3R] [Type 4] [Type 4X].
4. Magnetic contactors controlled by a temperature sensor/controller to maintain collection basin water-temperature set point. Water-level probe shall monitor cooling tower water level and de-energize the heater when the water reaches low-level set point.
5. Control-circuit transformer with primary and secondary side fuses.
6. Terminal blocks with numbered and color-coded wiring to match wiring diagram.
7. Single-point, field-power connection to a [fused disconnect switch] [nonfused disconnect switch] [circuit breaker] and heater branch circuiting complying with NFPA 70.
8. Factory Wiring Method: Metal raceway for factory-installed wiring outside of enclosures, except make connections to each electric basin heater with liquidtight conduit.

L. Hot-Water-Coil Basin Heater: Manufacturer's standard offering to provide capacity indicated.

M. Steam-Coil Basin Heater: Manufacturer's standard offering to provide capacity indicated.

N. Steam-Injector Basin Heater: Manufacturer's standard offering to provide capacity indicated.

O. Gravity Water Distribution Basin: Nonpressurized design with head of water level in basin adequate to overcome spray nozzle losses and designed to evenly distribute water over fill throughout the flow range indicated.

1. Material: [FRP with UV inhibitors] [Galvanized steel, ASTM A 653/A 653M, G235 coating] [Polymer-coated galvanized steel] [Stainless steel].
WMU Design Guidelines

2. Location: Over each bank of fill with easily replaceable [plastic] <Insert material> spray nozzles mounted in bottom of basin.
5. Partitioning Dams: Same material as basin to distribute water over the fill to minimize icing while operating throughout the flow range indicated.
6. Removable Panels: Same material as basin to completely cover top of basin. Secure panels to basin with removable [corrosion-resistant] [stainless-steel] hardware.
7. Valves: Manufacturer's standard valve installed at each inlet connection and arranged to balance or shut off flow to each gravity distribution basin.
8. Single-Inlet, Field Pipe Connection: [Galvanized-steel] [PVC] pipe arranged to provide balancing of flow within cooling tower cell without the need for additional balancing valves. Pipe each cooling tower cell internally to a single, field connection suitable for mating to ASME B16.5, Class 150 flange and located on the [bottom] [side] unless otherwise indicated.

P. Fill:

2. Minimum Thickness: [15 mils] [20 mils] <Insert value>, before forming.
3. Fabrication: Fill-type sheets, fabricated, formed, and bonded together after forming into removable assemblies that are factory installed by manufacturer.
4. Fill Material Operating Temperature: Suitable for entering-water temperatures up through [120 deg F] <Insert temperature>.

Q. Drift Eliminator:

1. Material: [FRP] [PVC] [FRP or PVC] <Insert material>; with maximum flame-spread index of [5] [25] <Insert value> 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.
4. Location: [Integral to] [Separate and removable from] fill.

R. Air-Intake Louvers:

1. Material: [FRP] [PVC] [Matching casing].
2. UV Treatment: Inhibitors to protect against damage caused by UV radiation.
3. Louver Blades: Arranged to uniformly direct air into cooling tower, to minimize air resistance, and to prevent water from splashing out of tower during all modes of operation including operation with fans off.
4. Location: [Integral to] [Separate from] fill.

S. Air-Intake Screens: [Galvanized] [Polymer-coated, galvanized] [Stainless]-steel wire mesh.

T. Axial Fan: Balanced at the factory after assembly.

1. Blade Material: [Aluminum] [FRP] [Galvanized steel].
2. Hub Material: [Aluminum] [FRP] [Galvanized steel].
5. 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 \[40,000\] \[50,000\] <Insert value> hours.
6. Bearings Grease Fittings: Extended lubrication lines to an easily accessible location.

U. Belt Drive:
   1. Service Factor: \[1.5\] <Insert value> based on motor nameplate horsepower.
   2. Sheaves: Fan and motor shafts shall have taper-lock sheaves fabricated from corrosion-resistant materials.
   3. Belt: Multiple V-belt design with a matched set of cogged belts.
   5. Belt Material: Oil resistant, nonstatic conducting, and constructed of neoprene polyester cord.
   6. Belt-Drive Guard: Comply with OSHA regulations.
   7. Two-Motor, Single-Fan Drive:
      a. Two single-speed motors per fan, one sized for full speed and load and the other sized for \[67\] <Insert value> percent of full-load speed.
      b. Each motor with belt drive and configured for operation when other motor fails.
      c. Controls and wiring same as two-speed, two-winding motor.

V. Gear Drive: 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: \[2.0\] <Insert value> 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 all 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-to-Motor Connection: [Close coupled to motor using a flexible coupling] [Connected to motor located outside of cooling tower casing by a full-floating drive shaft].
   6. Drive Shaft Material: [Corrosion resistant] [Stainless steel], and fitted with flexible couplings on both ends. Provide exposed shaft and couplings with guards according to OSHA regulations.
   7. Extend oil fill, drain, and vent to outside of cooling tower casing using galvanized-steel piping. Provide installation with oil-level sight glass.

W. Fan Motor:
   1. General Requirements for Fan Motors: Comply with NEMA designation and temperature-rating requirements specified in Division 23 Section "Common Motor Requirements for HVAC Equipment" and not indicated below.
   2. Motor Enclosure: [Totally enclosed] [Totally enclosed air over (TEAO)] [Totally enclosed fan cooled (TEFC)] [with epoxy or polyurethane finish].
   3. Energy Efficiency: [Comply with ASHRAE/IESNA 90.1] [NEMA Premium Efficient].
5. Insulation: [Class F] [Class H] <Insert class>.
7. Motor Location: Mounted outside of cooling tower casing and cooling tower discharge airstream.
8. Severe-duty rating with the following features:
   a. Rotor and stator protected with corrosion-inhibiting epoxy resin.
   b. Double-shielded, vacuum-degassed bearings lubricated with premium, moisture-resistant grease suitable for temperatures between minus 20 and plus 300 deg F.
   c. Internal heater automatically energized when motor is de-energized.
9. Motor Base: Adjustable, or other suitable provision for adjusting belt tension.

X. Fan Discharge Stack: Material shall match casing, [manufacturer's standard] [velocity recovery] design.
   1. Stack Extension: Fabricated to extend above fan deck <Insert distance> unless otherwise indicated.
   2. Stack Termination: Wire-mesh, galvanized-steel screens; complying with OSHA regulations.

Y. Vibration Switch: For each fan drive.
   1. Enclosure: NEMA 250, [Type 4] [Type 4X] <Insert type>.
   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.
   4. Switch shall, on sensing excessive vibration,[ signal an alarm through the BMS and] shut down the fan.

Z. Gear-Drive, Oil-Level Switch: Low-oil-level warning switch[ for connection to a BMS].
   1. Switch shall, on reaching a low-oil-level set point recommended by cooling tower manufacturer, signal an alarm[ through the BMS].

AA. Capacity-Control Dampers: [Galvanized-steel] [Stainless-steel] <Insert material> dampers, with linkages, electric operator, controller, limit switches, transformer, and weatherproof enclosure.

BB. Controls: Comply with requirements in Division 23 Section "Instrumentation and Control for HVAC."

CC. Control Package: Factory installed and wired, and functionally tested at factory before shipment.
   1. NEMA 250, [Type 3R] [Type 4] [Type 4X] enclosure with removable internally mount backplate.
2. Control-circuit transformer with primary and secondary side fuses.
3. Terminal blocks with numbered and color-coded wiring to match wiring diagram. Spare wiring terminal block for connection to external controls or equipment.
4. Microprocessor-based controller for automatic control of fan based on cooling tower leaving-water temperature with control features to improve operating efficiency based on outdoor ambient wet-bulb temperature by using adaptive logic.
5. Fan motor sequencer for multiple-cell and two-speed applications with automatic lead stage rotation.
7. Electric basin heaters with temperature control and low-water-level safety switch for each cell, complying with requirements in "Electric Basin Heater" Paragraph.
8. Vibration switch for each fan, complying with requirements in "Vibration Switch" Paragraph.
9. Oil-level switch for each fan with a gear drive, complying with requirement in "Gear-Drive, Oil-Level Switch" Paragraph.
10. Single-point, field-power connection to a [fused disconnect switch] [nonfused disconnect switch] [circuit breaker] [for each cooling tower cell].
   a. Branch power circuit to each motor and electric basin heater and to controls with a disconnect switch or circuit breaker.
   b. NEMA-rated motor controller, hand-off-auto switch, and overcurrent protection for each motor. Provide variable frequency controller with manual bypass and line reactors for each variable-speed motor indicated.
11. Factory-installed wiring outside of enclosures shall be in metal raceway, except make connections to each motor and electric basin heater with liquidtight conduit.
12. Visual indication of status and alarm with momentary test push button for each motor.
13. Audible alarm and silence switch.
14. Visual indication of elapsed run time, graduated in hours for each motor.
15. Cooling tower shall have hardware to enable BMS to remotely monitor and display the following:
   a. Operational status of each motor.
   b. Position of dampers.
   c. Cooling tower leaving-fluid temperature.
   d. Fan vibration alarm.
   e. Oil-level alarm.
   f. Collection basin [high] [low] [high- and low]-water-level alarms.
   g. <Insert conditions to be monitored>.

DD. 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, 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. External Platforms with Handrails: Aluminum, FRP, or galvanized-steel bar grating at cooling tower access doors when cooling towers are elevated and not accessible from grade.


5. Internal Platforms: Aluminum, FRP, or galvanized-steel 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 all 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.

EE. Capacities and Characteristics:

1. Number of Cells: <Insert quantity>.
2. Air-Inlet Arrangement: [Single side] [Two sides].
3. Maximum Drift Loss: [0.005] <Insert number> percent of design water flow.
8. Leaving-Water Temperature: <Insert deg F>.
10. Economizer Mode:
   b. Entering-Water Temperature: <Insert deg F>.
   c. Leaving-Water Temperature: <Insert deg F>.
   d. Entering-Air Wet-Bulb Temperature: <Insert deg F>.
11. Fan Drive: Belt or gear.
12. Fan Motor:
   a. Type: [Single speed] [Two speed, single winding] [Two speed, two winding] [Variable speed].
   c. Full-Load Ampacity: <Insert value>.
   d. Minimum Circuit Ampacity: <Insert value>.
   e. Maximum Overcurrent Protection Device: <Insert amperage>.
   f. Electrical Characteristics: [208] [240] [480] <Insert value>-V ac, 3 phase, 60 Hz.
13. Sound Pressure Level: <Insert dBA> at <Insert distance in feet> [when measured according to CTI ATC 128].
14. Basin Heater:
   a. Basin Water Temperature: [40 deg F] <Insert deg F>.
   b. Outdoor Ambient Temperature: [0 deg F] [Minus 20 deg F] <Insert deg F>.
   c. Capacity/Cell: <Insert kilowatts>.
   d. Full-Load Ampacity: <Insert value>.
   e. Minimum Circuit Ampacity: <Insert value>.
   g. Electrical Characteristics: [208] [240] [480] <Insert value>-V ac, 3 phase, 60 Hz.
h. Capacity/Cell: <Insert MBtu/h>.
i. Entering-Fluid Temperature: <Insert deg F>.
j. Fluid Flow Rate: <Insert gpm>.
k. Fluid Pressure Drop: <Insert psig>.
l. Capacity/Cell: <Insert MBtu/h>.
m. Steam Flow: <Insert lb/h>.
n. Steam Pressure: <Insert psig>.

2.7 SOURCE QUALITY CONTROL

A. Verification of Performance: Test and certify cooling tower performance according to CTI STD 201, “Certification Standard for Commercial Water-Cooling Towers Thermal Performance.”

B. Factory pressure test heat exchangers after fabrication and prove to be free of leaks.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Before cooling tower installation, examine roughing-in for tower support, anchor-bolt sizes and locations, piping, and electrical connections to verify actual locations, sizes, and other conditions affecting tower performance, maintenance, and operation.

1. Cooling tower locations indicated on Drawings are approximate. Determine exact locations before roughing-in for piping and electrical connections.

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

3.2 INSTALLATION

A. Install cooling towers on support structure indicated.

B. Equipment Mounting: Install cooling tower on concrete bases using [elastomeric pads] [elastomeric mounts] [restrained spring isolators] <Insert device>. Comply with requirements in Division 03 Section “[Cast-in-Place Concrete] [Miscellaneous Cast-in-Place Concrete].” Comply with requirements for vibration isolation devices specified in Division 23 Section “Vibration and Seismic Controls for HVAC Piping and Equipment.”

1. Minimum Deflection: [1/2 inch] [1 inch] [2 inches] [3 inches] <Insert dimension>.
2. Provide [galvanized] [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. Equipment Mounting: Install cooling tower using [elastomeric pads] [elastomeric mounts] [restrained spring isolators] <Insert device>. Comply with requirements for vibration isolation devices specified in Division 23 Section "Vibration and Seismic Controls for HVAC Piping and Equipment."

1. Minimum Deflection: [1/2 inch] [1 inch] [2 inches] [3 inches] <Insert dimension>.
2. Provide [galvanized] [stainless]-steel plate to equally distribute weight over elastomeric pad.

D. Equipment Mounting: Install cooling tower on concrete bases. Comply with requirements in Division 03 Section "[Cast-in-Place Concrete] [Miscellaneous Cast-in-Place Concrete]."

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.

E. Install anchor bolts to elevations required for proper attachment to supported equipment.

F. Maintain manufacturer's recommended clearances for service and maintenance.

G. Loose Components: Install electrical components, devices, and accessories that are not factory mounted.

3.3 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 sanitary sewage system.

F. Domestic Water Piping: Comply with applicable requirements in Division 22 Section "Domestic Water Piping." Connect to water-level control with shutoff valve and union, flange, or mechanical coupling at each connection.

G. Supply and Return Piping: Comply with applicable requirements in Division 23 Section "Hydronic Piping." Connect to entering cooling tower connections with shutoff valve, balancing 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, flange, mechanical coupling, or mechanical coupling.

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. Hot-Water Piping: Comply with applicable requirements in Division 23 Section "Hydronic Piping." Connect to supply and return basin heater with shutoff valve, strainer, control valve, and union or flange on supply connection and union or flange and balancing valve on return connection. Provide supply and return piping with pressure gage and thermometer.

J. Steam and Condensate Piping: Comply with applicable requirements in Division 23 Section "Steam and Condensate Heating Piping." Connect steam supply to basin heater with shutoff valve, strainer, control valve, and union or flange and condensate piping with union or flange, shutoff valve, strainer, and an appropriate steam trap.

3.4 FIELD QUALITY CONTROL

A. Testing Agency: Owner will engage Engage a qualified testing agency to perform tests and inspections.

B. Manufacturer’s Field Service: Engage a factory-authorized service representative to perform field tests and inspections.

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.


E. Cooling towers will be considered defective if they do not pass tests and inspections.

F. Prepare test and inspection reports.

3.5 STARTUP SERVICE

A. [Engage a factory-authorized service representative to perform] Perform startup service.

B. Inspect field-assembled components, equipment installation, and piping and electrical connections for proper assemblies, installations, and connections.

C. 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. 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.

D. Start cooling tower and associated water pumps. Follow manufacturer's written starting procedures.

E. Prepare a written startup report that records the results of tests and inspections.

3.6 ADJUSTING

A. Set and balance water flow to each tower inlet.

B. Adjust water-level control for proper operating level.

3.7 DEMONSTRATION

A. [Engage a factory-authorized service representative to train] [Train] Owner's maintenance personnel to adjust, operate, and maintain cooling towers.

END OF SECTION 23 6500
WMU Design Guidelines Instructions: These guidelines are to be used by the Design Professional to inform the design process and outline WMU-specific desires for all University projects. These guidelines have been edited to reflect WMU preferences, and the intent is for the Design Professional to use this information to guide their normal specifications-writing process. Straying from what is indicated in the guidelines is not prohibited, but shall be discussed with WMU during the development of the project.

SECTION 23 7313 - MODULAR INDOOR CENTRAL-STATION AIR-HANDLING UNITS

PART 1 - GENERAL

1.1 SUMMARY

A. Section includes modular indoor air handling units.

1.2 ACTION SUBMITTALS

A. Product Data: For each air-handling unit indicated.
   1. Unit dimensions and weight.
   2. Cabinet material, metal thickness, finishes, insulation, and accessories.
   3. Fans:
      a. Certified fan-performance curves with system operating conditions indicated.
      b. Certified fan-sound power ratings.
      c. Fan construction and accessories.
      d. Motor ratings, electrical characteristics, and motor accessories.
   4. Certified coil-performance ratings with system operating conditions indicated.
   5. Dampers, including housings and linkages.
   6. Filters with performance characteristics.
   7. Wiring diagrams.
   8. Variable frequency controllers.

1.3 [LEED Submittals]:

A. Product Data for Prerequisite IEQ 1: Documentation indicating that units comply with ASHRAE 62.1, Section 5 - "Systems and Equipment."

B. Shop Drawings for factory controls containing the following information:
   1. Schematic flow diagram showing fans, pumps, coils, dampers, valves, and control devices. One system per drawing.
   2. Each control device labeled with setting or adjustable range of control.
   3. Diagrams for all required electrical wiring. Clearly differentiate between factory-installed and field-installed wiring.
   4. Details of control panel faces, including controls, instruments, and labeling.
   5. Written description of sequence of operation.
6. Trunk cable schematic showing programmable control unit locations and trunk data conductors.
7. Listing of connected data points, including connected control unit and input device.
8. System graphics indicating monitored systems, data (connected and calculated) point addresses, and operator notations.
9. System configuration showing peripheral devices, batteries, power supplies, diagrams, modems, and interconnections.
10. Software description.

1.4 INFORMATIONAL SUBMITTALS
A. Source quality-control reports.
B. Field quality-control reports.

1.5 CLOSEOUT SUBMITTALS
A. Operation and maintenance data.

1.6 MAINTENANCE MATERIAL SUBMITTALS
A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
   1. Filters: One set for each air-handling unit.
   2. Gaskets: [One] <Insert number> set(s) for each access door.
   3. Fan Belts: [One] <Insert number> set(s) for each air-handling unit fan.

1.7 QUALITY ASSURANCE
A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
B. NFPA Compliance: Comply with NFPA 90A for design, fabrication, and installation of air-handling units and components.
C. ARI Certification: Air-handling units and their components shall be factory tested according to ARI 430, "Central-Station Air-Handling Units," and shall be listed and labeled by ARI.
D. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1, Section 5 - "Systems and Equipment" and Section 7 - "Construction and Startup."
E. ASHRAE/IESNA 90.1 Compliance: Applicable requirements in ASHRAE/IESNA 90.1, Section 6 - "Heating, Ventilating, and Air-Conditioning."
1.8 DELIVERY, STORAGE, AND HANDLING

A. Deliver air-handling units as a factory-assembled unit to the extent allowable by shipping limitations, with protective covering.

B. Lift and support units with the manufacturer's designated lifting or supporting points.

C. Disassemble and reassemble units as required for movement into the final location following manufacturer's written instructions.

1.9 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.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

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

1. Carrier.
2. Trane.
3. JCI.
4. Daikin

2.2 MANUFACTURED UNITS

A. General Description: Provide factory assembled modular air-handling units comprised of dimensionally compatible casing modules which house all system components; including fans, motor and drive assembly, access sections, coils, plenums, filters, drain pans, and dampers.

1. Minimum Static-Pressure Construction for Constant Volume Units: [2-inch wg] [3-inch wg] [4-inch wg] [6-inch wg] [8-inch wg] [9-inch wg] [10-inch wg].
2. Minimum Static-Pressure Construction for Variable Volume Units: [2-inch wg] [3-inch wg] [4-inch wg] [6-inch wg] [8-inch wg] [9-inch wg] [10-inch wg] <Insert value>.

2.3 UNIT CASINGS

A. General Fabrication Requirements for Casings: Construct of structural steel framing with removable 2" thick double-wall insulated panels; all galvanized steel materials.

1. Forming: Form walls, roofs, and floors with at least two breaks at each joint.
2. Casing Joints: Sheet metal screws or pop rivets.
3. Sealing: Seal all joints with water-resistant sealant.
5. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.

B. Casing Walls: Galvanized solid sheet steel with integral seals at all framing element contact surfaces, and secured to frame with corrosion resistant fastening system configured to minimized thermal bridging to air side of unit.
   1. Provide perforated material for interior surfaces of sections indicated in equipment schedules.

C. Casing Insulation and Adhesive:
   2. Location and Application: Encased between outside and inside casing.

D. Inspection and Access Panels and Access Doors:
   1. Panel and Door Fabrication: Formed and reinforced, double-wall insulated panels of same materials and thicknesses as casing.
   2. Inspection and Access Panels:
      a. Fasteners: Two or more camlock type for panel lift-out operation. Arrangement shall allow panels to be opened against air-pressure differential.
      b. Gasket: Neoprene, applied around entire perimeters of panel frames.
      c. Size: Large enough to allow inspection and maintenance of air-handling unit's internal components.
   3. Access Doors:
      a. Hinges: A minimum of two ball-bearing hinges or stainless-steel piano hinge and two wedge-lever-type latches, operable from inside and outside. Arrange doors to be opened against air-pressure differential.
      b. Gasket: Neoprene, applied around entire perimeters of panel frames.
         a. Fabricate windows in doors where indicated of safety glass with rubber seals.
         b. Door Size: Minimum 18 inches wide by full height of unit casing up to a maximum height of 72 inches.
   4. Locations and Applications:
      a. Fan Section: Doors and inspection and access panels.
      b. Access Section: Doors.
      c. Coil Section: Doors and inspection and access panels.
      d. Damper Section: Doors.
      e. Filter Section: Doors large enough to allow periodic removal and installation of filters.
      f. Air Blender Section: Doors.
      g. Mixing Section: Doors.
      h. Humidifier Section: Doors.
5. Service Light: Factory wired 100-W equivalent LED in a vaporproof fixture with switched junction box located outside of unit.
   a. Locations: As indicated on schedule.

E. Condensate Drain Pans:
   1. Fabricated with minimum one percent slope in at least two planes to collect condensate from cooling coils (including coil piping connections, coil headers, and return bends) and to direct water toward drain connection.
   2. Fabricated with minimum one percent slope in at least two planes to collect condensate from cooling coils (including coil piping connections, coil headers, and return bends) and from humidifiers and to direct water toward drain connection.
      a. Length: Extend drain pan downstream from leaving face to comply with ASHRAE 62.1.
      b. Depth: A minimum of 2 inches deep.
   4. Double-wall, stainless-steel sheet with space between walls filled with foam insulation and moisture-tight seal.
   5. Double-wall, [galvanized] [stainless]-steel sheet with space between walls filled with foam insulation and moisture-tight seal.
   6. Drain Connection: Located at lowest point of pan and sized to prevent overflow. Terminate outside of unit with threaded nipple and cap on one end of pan.
   7. Drain Connection: Located at lowest point of pan and sized to prevent overflow. Terminate outside of unit with threaded nipple and cap on [one end] [both ends] of pan.
   9. Units with stacked coils shall have an intermediate drain pan to collect condensate from top coil.
   10. Locations:
      a. Cooling Coil Sections.
      b. Outdoor Air Damper Sections.
      c. Humidifier Sections.

F. Air-Handling-Unit Mounting Frame: Formed galvanized-steel channel or structural channel supports, designed for low deflection, welded with integral lifting lugs.

G. [Floor Openings]: All duct connections or control dampers in the floor of the units shall be covered with painted heavy gauge steel bar grating bolted in place, to prevent people and large objects from passing through the unit floor into the ductwork.

2.4 FAN, DRIVE, AND MOTOR SECTION

A. Fan Mounting: Mount fan and motor on a structural steel frame mounted on manufacturer's standard restrained vibration isolation mounting devices having a minimum static deflection of 1 inch sized to eliminate fan vibration and noise. Provide flexible duct connecting between unit casing and fan outlet.

B. Fan Shaft Bearings:
1. Grease-Lubricated, Bearings: Self-aligning, pillow-block type with 2-piece, cast-iron housing with grease lines extended to outside unit and a rated life of 200,000 hours according to ABMA.

C. [Plenum Fans]:

1. Housings: Steel frame and panel; fabricated without fan scroll and volute housing.
3. Drives: Direct drive.
4. Guards: Comply with requirements specified by OSHA and fabricate according to SMACNA's "HVAC Duct Construction Standards"; 0.1046-inch- thick, 3/4-inch diamond-mesh wire screen, welded to steel angle frame; prime coated.

D. [Centrifugal Fans]:

1. Fan and Drive Assemblies: Statically and dynamically balanced and designed for continuous operation at maximum-rated fan speed and motor horsepower.
   a. Shafts: Designed for continuous operation at maximum-rated fan speed and motor horsepower, and with field-adjustable alignment.
      1) Turned, ground, and polished hot-rolled steel with keyway. Ship with a protective coating of lubricating oil.
      2) Designed to operate at no more than 70 percent of first critical speed at top of fan's speed range.

2. [Centrifugal Fan Housings]: Formed- and reinforced-steel panels to form curved scroll housings with shaped cutoff and spun-metal inlet bell.
   a. Bracing: Steel angle or channel supports for mounting and supporting fan scroll, wheel, motor, and accessories.
   b. Horizontal-Flanged, Split Housing: Bolted construction.
   c. Housing for Supply Fan: Attach housing to fan-section casing with metal-edged flexible duct connector.

3. [Backward-Inclined, Centrifugal Fan Wheels]: Double-width-double-inlet construction with curved inlet flange, backplate, backward-inclined blades welded or riveted to flange and backplate; cast-iron or cast-steel hub riveted to backplate and fastened to shaft with set screws.

4. [Forward-Curved, Centrifugal Fan Wheels]: Double-width-double-inlet construction with inlet flange, backplate, and shallow blades with inlet and tip curved forward in direction of airflow and mechanically fastened to flange and backplate; cast-steel hub swaged to backplate and fastened to shaft with set screws.

5. [Airfoil, Centrifugal Fan Wheels]: Double-width-double-inlet construction with smooth-curved inlet flange, backplate, and hollow die-formed airfoil-shaped blades continuously welded at tip flange and backplate; cast-iron or cast-steel hub riveted to backplate and fastened to shaft with set screws.

6. Belt Drives: Factory mounted, with adjustable alignment and belt tensioning, and with manufacturer's standard service factor based on fan motor.
   a. Pulleys: Cast iron or cast steel with split, tapered bushing; dynamically balanced at factory.
b. Motor Pulleys: Adjustable pitch for use with 5-hp motors and smaller; fixed pitch for use with motors larger than 5 hp. Select pulley size so pitch adjustment is at the middle of adjustment range at fan design conditions.

c. Belts: Oil resistant, nonsparking, and nonstatic; in matched sets for multiple-belt drives.

7. Belt Guards: Comply with requirements specified by OSHA and fabricate according to SMACNA's "HVAC Duct Construction Standards"; 0.1046-inch thick, 3/4-inch diamond-mesh wire screen, welded to steel angle frame; prime coated.

E. Axial Fans: Fan wheel and housing, straightening-vane section, factory-mounted motor with belt drive or direct drive, an inlet cone section, and accessories.

1. Variable-Pitch Fans: Internally mounted [pneumatic] [electric] [electronic] actuator, externally mounted positive positioner, and mechanical-blade-pitch indicator.

2. Housings: [Steel] [Galvanized steel] [Aluminum].

   a. Inlet and Outlet Connections: Flanges.

   b. Guide Vane Section: Integral guide vanes downstream from fan wheel designed to straighten airflow.

F. Variable-Inlet Vanes: Steel, with blades supported at both ends with permanently lubricated bearings. Variable mechanism terminating in single lever for connection to control actuator with connecting shaft for second set of variable inlet vanes on double-width fans.

G. Discharge Dampers: Heavy-duty steel assembly with channel frame and sealed ball bearings, and [opposed] [parallel] blades constructed of two plates formed around and welded to shaft, with blades linked out of air stream to single control lever.

H. Motor: Comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements for motors specified in Division 23 Section "Common Motor Requirements for HVAC Equipment."

   1. Enclosure Type: Totally enclosed, fan cooled.

   2. NEMA Premium (TM) efficient motors as defined in NEMA MG 1.

   3. NEMA energy efficient motors as defined in NEMA MG 1.

   4. 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.

   5. Controllers, Electrical Devices, and Wiring: Comply with requirements for electrical devices and connections specified in Division 26 Sections.

I. [Variable Frequency Drives]: Provided by Temperature Controls Installer. Refer to Division 23 Section "Instrumentation and Controls for HVAC."

J. [Variable Frequency Drives]: Provided with unit.

   1. The variable frequency drives (VFD) shall be designed specifically for use in Heating, Ventilation, and Air Conditioning (HVAC) applications in which speed control of the motor can be applied. The VFD, including all factory installed options, shall have UL & CSA approval.

   2. VFD’s shall include communications capability with DDC BMS via built-in interface card. Coordinate communications type with BMS.

   3. Unit manufacturer shall furnish variable frequency drive (VFD) for each fan motor.
4. Built-in VFD Protection:
   1) 5% DC Choke for harmonic protection.
   2) Standard RFI Filter: Ensures that EMC/RFI requirements are met.
   3) Fire Mode for safe operation.
   4) Enclosure Class: NEMA 1, NEMA 12 or NEMA 3R as required by application.
   5) Motor switch ride-through for easy, fault-free maintenance.
   6) Overvoltage trip and undervoltage trip protection.
   7) Ground fault protection.
   8) Mains and motor phase supervisions.
   9) Overcurrent and unit overtemperature protection.
   10) Motor overload, motor stall and motor underload protection.

b. Bypass Options:
   1) Fused disconnect with no bypass.
   3) Automatic bypass.
   4) Contactor.

K. Variable Frequency Controllers: Provided with units:
   1. Description: NEMA ICS 2, IGBT, PWM, VFC; listed and labeled as a complete unit and arranged to provide variable speed of an NEMA MG 1, Design B, 3-phase induction motor by adjusting output voltage and frequency.
   2. Output Rating: 3-phase; 6 to 60 Hz, with voltage proportional to frequency throughout voltage range.
   3. Unit Operating Requirements:
      a. Input ac voltage tolerance:
         1) 208 V, plus or minus 5 percent.
         2) 380 to 500 V, plus or minus 10 percent.
      b. Input frequency tolerance of 50/60 Hz, plus or minus 6 percent.
      c. Minimum Efficiency: 96 percent at 60 Hz, full load.
      d. Minimum Displacement Primary-Side Power Factor: 96 percent.
      e. Overload Capability: 1.1 times the base load current for 60 seconds; 2.0 times the base load current for 3 seconds.
      f. Starting Torque: 100 percent of rated torque or as indicated.
      g. Speed Regulation: Plus or minus 1 percent.
   4. Isolated control interface to allow controller to follow control signal over an 11:1 speed range.
   5. Internal Adjustability Capabilities:
      a. Minimum Speed: 5 to 25 percent of maximum rpm.
      b. Maximum Speed: 80 to 100 percent of maximum rpm.
      c. Acceleration: 2 to a minimum of 22 seconds.
      d. Deceleration: 2 to a minimum of 22 seconds.
      e. Current Limit: 50 to a minimum of 110 percent of maximum rating.
   6. Self-Protection and Reliability Features:
      a. Input transient protection by means of surge suppressors.
b. Undervoltage and overvoltage trips; inverter overtemperature, overload, and overcurrent trips.
c. Adjustable motor overload relays.
d. Notch filter to prevent operation of the controller-motor-load combination at a natural frequency of the combination.
e. Instantaneous line-to-line and line-to-ground overcurrent trips.
f. Loss-of-phase protection.
g. Reverse-phase protection.
h. Short-circuit protection.
i. Motor overtemperature fault.

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

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

9. Torque Boost: Automatically varies starting and continuous torque to at least 1.5 times the minimum torque to ensure high-starting torque and increased torque at slow speeds.


11. Door-mounted LED status lights shall indicate the following conditions:
   a. Power on.
   b. Run.
   c. Overvoltage.
   d. Line fault.
   e. Overcurrent.
   f. External fault.


13. Meters or digital readout devices and selector switch, mounted flush in controller door and connected to indicate the following controller parameters:
   a. Output frequency (Hertz).
   b. Motor speed (rpm).
   c. Motor status (running, stop, fault).
   d. Motor current (amperes).
   e. Motor torque (percent).
   f. Fault or alarming status (code).
   g. Proportional-integral-derivative (PID) feedback signal (percent).
   h. DC-link voltage (volts direct current).
   i. Set-point frequency (Hertz).
   j. Motor output voltage (volts).

14. Control Signal Interface:
   a. Electric Input Signal Interface: A minimum of 2 analog inputs (0 to 10 V or 0/4-20 mA) and 6 programmable digital inputs.
   b. Remote signal inputs capable of accepting any of the following speed-setting input signals from the control system:
      1) 0 to 10-V dc.
2) 0-20 or 4-20 mA.
3) Potentiometer using up/down digital inputs.
4) Fixed frequencies using digital inputs.
5) RS485.
6) Keypad display for local hand operation.

c. Output signal interface with a minimum of 1 analog output signal (0/4-20 mA), which can be programmed to any of the following:
   1) Output frequency (Hertz).
   2) Output current (load).
   3) DC-link voltage (volts direct current).
   4) Motor torque (percent).
   5) Motor speed (rpm).
   6) Set-point frequency (Hertz).

d. Remote indication interface with a minimum of 2 dry circuit relay outputs (120-V ac, 1 A) for remote indication of the following:
   1) Motor running.
   2) Set-point speed reached.
   3) Fault and warning indication (overtemperature or overcurrent).
   4) High- or low-speed limits reached.

15. Communications: RS485 interface allows VFC to be used with an external system within a multidrop LAN configuration. Interface shall allow all parameter settings of VFC to be programmed via BMS control. Provide capability for VFC to retain these settings within the nonvolatile memory.

16. Integral Disconnecting Means: NEMA KS 1, nonfusible switch with lockable handle.

17. Accessories:
   a. Devices shall be factory installed in controller enclosure unless otherwise indicated.
   c. Standard Displays:
      1) Output frequency (Hertz).
      2) Set-point frequency (Hertz).
      3) Motor current (amperes).
      4) DC-link voltage (volts direct current).
      5) Motor torque (percent).
      6) Motor speed (rpm).
      7) Motor output voltage (volts).

2.5 COIL SECTION

A. General Requirements for Coil Section:

1. Comply with ARI 410.
2. Fabricate coil section to allow removal and replacement of coil for maintenance and to allow in-place access for service and maintenance of coil(s).
3. Coils shall not act as structural component of unit.

B. Connections: Provide factory installed piping connection points outside of unit casing and ready for field connections; with casing penetration points sealed against leakage for unit’s rated pressure.
C. Water Coils: Drainable, rigidly supported across the full face of the coil, and pitched to allow drainage.

1. Fins: Aluminum, constructed from flat plate with belled collars for tubes. Fins shall be bonded to tubes by mechanically expanding copper tubes.
2. Tubes: Seamless copper.
4. Headers: Steel or cast iron, with connections for drain valve and air vent and threaded piping connections.
5. Rows: Cooling water coils shall be 6 row minimum.
6. Ultra-Violet Lights: Include UV Germicidal System to kill bacteria, fungi, and mold growing on cooling coils and in drain pans. Components to be constructed to withstand typical HVAC environments and be ETL listed under UL Standard 1598. Lights shall be wired to a manual reset door interlock safety switch to shut off lights when access door is open.

D. Steam Coils: Steam-distributing type comprised of copper distributing tube concentrically supported inside copper condensing tube with corrosion-resistant clips; with aluminum fins and seamless copper header having both steam and condensate chambers. Pitch coil in frame such that condensate drains properly when coil is installed level.

E. Steam Coils: Integral face and bypass (IFB) type comprised of alternate finned heating elements and bypass openings with interlocked dampers. Construct coils comprised of copper distributing tube concentrically supported inside copper condensing tube with corrosion-resistant clips; with aluminum fins and seamless copper header having both steam and condensate chambers. Pitch coil in frame such that condensate drains properly when coil is installed level. Fabricate dampers of extruded aluminum with heat reflective anodized finish; complete with edge seals and mounted on aluminum damper rods housed in oil impregnated bronze bearings.

F. Direct-Expansion Refrigerant Coils: Designed and fabricated in compliance with ASHRAE Standard 15, "Safety Code for Mechanical Refrigeration." Coils shall have the following features:

1. Suction Headers and Distributor Tubes: Seamless copper.
2. Venturi-type refrigerant distributor, designed for low pressure drop, arranged for down feed with solder connections, and having a maximum of 12 circuits for each distributor.
   a. Coils with more than 12 circuits shall have two distributors.
   b. Split circuit coils shall have two distributors.
   c. Coils with two distributors shall be interlaced or row controlled.
3. Ultra-Violet Lights: Include UV Germicidal System to kill bacteria, fungi, and mold growing on cooling coils and in drain pans. Components to be constructed to withstand typical HVAC environments and be ETL listed under UL Standard 1598. Lights shall be wired to a manual reset door interlock safety switch to shut off lights when access door is open.

2.6 AIR FILTRATION SECTION

A. General Requirements for Air Filtration Section:

1. Comply with NFPA 90A.
2. Provide minimum arrestance according to ASHRAE 52.1, and a minimum efficiency reporting value (MERV) according to ASHRAE 52.2.
3. Provide filter holding frames arranged for flat or angular orientation, with access doors. Filters shall be removable from one side or lifted out from access plenum.

B. **[Prefilters][Filters]**: Extended-surface, disposable panel filters:

1. Factory-fabricated, dry, extended-surface type.
2. Thickness: 2 inches.
3. Thickness: [2 inches] [4 inches].
6. Media: Fibrous material formed into deep-V-shaped pleats and held by self-supporting wire grid.
8. Mounting Frames: Galvanized steel, with gaskets and fasteners.

C. **[Filters]**: Extended-surface, non-supported media filters:

1. Factory-fabricated, dry, extended-surface, self-supporting type.
4. Length: [X inches].
7. Length: [X inches].
10. Length: [X inches].
13. Length: [X inches].
14. Media: Fibrous material constructed so individual pleats are maintained in tapered form by flexible internal supports under rated-airflow conditions.
16. Mounting Frames: Galvanized steel, with gaskets and fasteners[, with space for prefilter].

D. **[Filters][Final Filters]**: Extended-surface, rigid media filters:

1. Factory-fabricated, dry, deep pleated, rigid type.
10. Length: 12 inches.
11. Media: High density fibrous material with support grid and contour stabilizers.
13. Mounting Frames: Welded, galvanized steel, with gaskets and fasteners, suitable for bolting together into built-up filter banks [with space for prefilter].

E. Activated-Carbon Panel Filters:

1. Factory-fabricated unit with activated-carbon media.
2. Flat-Panel Media: Multilayer filter with inlet layer of polyester fibers, layer of activated-carbon granules bonded to fibers, layer of polyurethane foam, and housed in cardboard frame.
3. Pleated Media: Multilayer filter with inlet layer of cotton and synthetic fibers and layer of activated-carbon granules bonded to synthetic fibers, formed into deep-V-shaped pleats and held by self-wire grid, and housed in nonflammable cardboard frame.
4. Mounting Frames: Welded galvanized steel, with polyurethane gaskets and fasteners, capable of holding media and media frame in place and suitable for bolting together into built-up filter banks.

F. Activated-Carbon Filters:

1. Factory-fabricated unit in deep-V arrangement with disposable panel prefilter.
4. Housing: 0.064-inch-thick, galvanized steel, for side servicing through gasketed access doors on both sides. Equip housings with metal slide channel tracks to hold activated-carbon trays.

G. HEPA Filters:

1. Factory-fabricated unit.
2. Dust-Holding Capacity: <Insert lb>.
5. Arrestance (ASHRAE 52.1): [95 percent on 0.3-micrometer D.O.P. particles] [99.97 percent on 0.3-micrometer D.O.P. particles] [99.9995 percent on 0.1- and 0.2-micrometer D.O.P. particles] [99.99995 percent on 0.1- and 0.2-micrometer D.O.P. particles] <Insert value>.
6. Media: UL 586, fibrous glass, constructed of continuous sheets with closely spaced pleats with [aluminum separators] [vinyl-coated aluminum separators] [separators of ribbons of filter media].
7. Frame Material: [3/4-inch-thick, fire-retardant plywood] [3/4-inch-thick, fire-retardant particleboard] [3/4-inch-thick plywood] [3/4-inch-thick particleboard] [Galvanized steel] [Aluminized steel] [Cadmium-plated steel] [Stainless steel] [Aluminum].
8. Media to Frame Side Bond: [Polyurethane foam] [Silicone] [Neoprene adhesive] [Fiberglass-mat packing] [Thermosetting sealant] [Knife edge in fluid-filled channel].
9. Face Gasket: [Neoprene expanded rubber] [Ceramic fiber] [Silicone].
10. Mounting Frames: Downstream corners of holding device shall have cushion pads to protect media. Bolted filter-sealing mechanism shall mount and continuously seal each individual filter.

H. Filter Gage:

I. Filter Gage (One for prefilter and one for final filter bank):
1. 3-1/2-inch-diameter, diaphragm-actuated dial in metal case.
2. Vent valves.
3. Black figures on white background.
4. Front recalibration adjustment.
5. 2 percent of full-scale accuracy.
6. **[Range]**: 0- to 2.0-inch wg.
7. **[Prefilter Range]**: 0- to 0.5-inch wg.
8. **[Final Filter Range]**: 0- to 1.0-inch wg.
9. Range: [0- to 0.5-inch wg] [0- to 1.0-inch wg] [0- to 2.0-inch wg] [0- to 3.0-inch wg] [0- to 4.0-inch wg].
10. Accessories: Static-pressure tips with integral compression fittings, 1/4-inch tubing, and 2- or 3-way vent valves.

### 2.7 DAMPERS

A. General Requirements for Dampers: Leakage rate, according to AMCA 500, "Laboratory Methods for Testing Dampers for Rating," shall not exceed 2 percent of air quantity at 2000-fpm face velocity through damper and 4-inch wg pressure differential.

B. Face-and-Bypass Dampers: Opposed-blade, [galvanized-steel] [aluminum] [extruded-aluminum] dampers with [cadmium-plated] steel operating rods rotating in sintered bronze or nylon bearings mounted in a single [galvanized-steel] [aluminum] [extruded-aluminum] frame and with operating rods connected with a common linkage. Provide blade gaskets and edge seals, and mechanically fasten blades to operating rod.

C. Mixing Box Outdoor- and Return-Air Dampers: Galvanized-steel or aluminum dampers mechanically fastened to cadmium-plated steel operating rod in reinforced cabinet. [Connect operating rods with common linkage and interconnect linkages so dampers operate simultaneously.]

1. For combination filter and mixing box section, include cabinet support members to hold 2-inch-thick, pleated, flat, throwaway filters.

D. Economizer Outdoor, Relief and Return Air Dampers: Low-leakage, galvanized-steel or aluminum dampers with compressible jamb seals and extruded-vinyl blade edge seals with cadmium-plated steel operating rod. Leakage rate shall not exceed 5 cfm/sq. ft. at 1-inch wg and 9 cfm/sq. ft. at 4-inch wg.

1. For variable air volume units, divide outside air damper into two sections. One for minimum outside air and one for economizing air.
   a. Size damper sections for each AHU based on the ratio of scheduled minimum outside air volume divided by the scheduled supply air volume.

### 2.8 AIR BLENDER

A. Provide air blenders with integral blender blades arranged within the module to provide uniform velocity and temperature profile. Provide side access door in casing down stream of blender.
2.9 HUMIDIFIERS

A. Steam Grid Humidifier:

1. Manifold:
   a. ASTM A 666, Type 304 stainless steel.
   b. Steam jacketed.
   c. Insulated with 1/2-inch fiberglass and stainless-steel jacket.
   d. Manifold shall extend the full width of unit with mounting brackets at ends.

2. Steam Separator: [Cast iron, [ASTM A 666, Type 304 stainless steel,] with [separate] humidifier control valve.


4. Humidifier Control Valve: Actuator: As specified in Division 23 Section “Instrumentation and Control for HVAC.”

5. Steam Trap: Inverted-bucket type, sized for a minimum of three times the maximum rated condensate flow of humidifier at 1/2-psig inlet pressure.

6. Aquastat: For separate mounting on steam condensate, return piping to prevent cold operation of humidifier.

7. Strainer: In-line type.

8. Airflow Switch: To prevent humidifier operation in the absence of airflow.

2.10 AIR-TO-AIR ENERGY RECOVERY

A. Heat Wheels:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   a. Airxchange.
   c. Loren Cook Company.
   d. SEMCO Incorporated.
   e. Trane; American Standard Inc.

2. Casing:
   a. Steel, with manufacturer’s standard paint coating.
   b. Integral purge section limiting carryover of exhaust air to between 0.05 percent at 1.6-inch wg and 0.20 percent at 4-inch wg differential pressure.
   c. Casing seals on periphery of rotor, on duct divider, and on purge section.
   d. Support rotor on grease-lubricated ball bearings with extended grease fittings. Mount horizontal wheels on tapered roller bearing.

3. Rotor: Aluminum, segmented wheel, strengthened with radial spokes, with nontoxic, noncorrosive, silica-gel desiccant coating. Construct media for passing maximum [500] [800] [1200]-micrometer solids.


5. Drive: Fractional horsepower motor and gear reducer, with speed changed by variable frequency controller, and self-adjusting multilink belt around outside of rotor.
6. Controls:
   a. Starting relay, factory mounted and wired, and manual motor starter for field wiring.
   b. Variable frequency controller, factory mounted and wired, permitting input of field connected 4-20 mA or 1-10-V control signal.
   c. Variable frequency controller, factory mounted and wired, with exhaust-air sensor to vary rotor speed and maintain exhaust temperature above freezing.
   d. Variable frequency controller, factory mounted and wired, with exhaust- and outdoor-air sensors, automatic changeover thermostat and set-point adjuster, to vary rotor speed and maintain [exhaust temperature above freezing and] air differential temperature above set point. Provide maximum rotor speed when exhaust-air temperature is less than outdoor-air temperature.
   e. Pilot-Light Indicator: Display rotor rotation and speed.
   f. Speed Settings: Adjustable settings for maximum and minimum rotor speed limits.

B. Fixed-Plate Sensible Heat Exchangers:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   b. Des Champs Technologies.
   c. Exothermics Inc.; a brand of Eclipse, Inc.
   d. Nutech Brands Inc.
   e. RenewAire LLC.

2. Casing: [Aluminum] [Galvanized steel] [Enameled steel, with galvanized-steel liner] [Enamed steel].
3. Plates: Evenly spaced and sealed and arranged for counter airflow.
4. Plate Material: [Embossed aluminum] [Stainless steel] [Polypropylene copolymer (high-density plastic)].
   a. Plate Coating: [Epoxy] [Air-dried phenolic].

5. Bypass: Plenum within casing, with gasketed face-and-bypass dampers that have operating rods extended outside casing.
6. Water Wash: Automatic system, with spray manifold to individual spray tubes or traversing type with stainless-steel-screw operating mechanism and electric motor drive; activated by time clock[, with detergent injection].
7. Heat-Exchanger Prefilters: [1 inch thick, disposable] [2 inches thick, disposable] [Medium efficiency] [Electrostatic].

2.11 CONTROLS

A. Provide stand-alone DDC control system for air handling unit, complete with operator interface, remote field installed outdoor air sensor and room mounted field installed space sensor.

1. Refer to[ Section 23 0993][ controls drawing] for unit sequence of operations.

2.12 AIRFLOW MEASURING DEVICES

A. Outside Air Airflow Stations:
1. Provide airflow monitors on outside air dampers capable of continuously measuring the outside air volume. Airflow monitors shall provide a 2 to 10 Vdc signal which corresponds to cfm for controlling and documenting airflow.

B. Fan Air Airflow Stations:

1. Provide airflow monitors on each fan capable of continuously measuring the air volume. Airflow monitors shall provide a 2 to 10 Vdc signal which corresponds to cfm for controlling and documenting airflow.

C. Fan Inlet Airflow Probes:

1. Provide on supply and exhaust fans, airflow probes mounted in the fan inlets capable of continuously measuring the air handling capacity (air volume) of the respective plenum fans.
   a. The fan inlet airflow traverse probes shall be factory calibrated to NIST traceable standards and use “bead in glass” thermistor thermal dispersion technology.
   b. The fan inlet airflow traverse probes shall not significantly impact fan performance or contribute to fan generated noise levels.
   c. The probes shall be capable of producing steady, non-pulsating signals of standard total and static pressure, without need for flow corrections or factors, with an accuracy of 3% of actual reading.

2. Include a transmitter for each probe to communicate the fans CFM to the building DDC control system.
3. The fan inlet airflow probes shall be the Ebtron “Gold Series”.

D. Outside Air Inlet Airflow Probes:

1. Provide on outside air dampers airflow probes capable of continuously measuring the outside air volume.
   a. The airflow probes shall be factory calibrated to NIST traceable standards and use thermal dispersion technology.
   b. The airflow traverse probes shall not significantly impact fan performance or contribute to fan generated noise levels.
   c. The probes shall be capable of producing steady, non-pulsating signals of standard total and static pressure, without need for flow corrections or factors, with an accuracy of 3% of actual reading.

2. Include a transmitter for each probe to communicate the CFM to the building DDC control system.
3. The airflow probes shall be the Ebtron “Gold Series”.

2.13 SOURCE QUALITY CONTROL

A. Fan Sound-Power Level Ratings: Comply with AMCA 301, "Methods for Calculating Fan Sound Ratings from Laboratory Test Data." Test fans according to AMCA 300, "Reverberant Room Method for Sound Testing of Fans." Fans shall bear AMCA-certified sound ratings seal.
B. Fan Performance Rating: Factory test fan performance for airflow, pressure, power, air density, rotation speed, and efficiency. Rate performance according to AMCA 210, "Laboratory Methods of Testing Fans for Aerodynamic Performance Rating."

C. Water Coils: Factory tested to 300 psig according to ARI 410 and ASHRAE 33.

D. Steam Coils: Factory tested to 300 psig and to 200 psig underwater according to ARI 410 and ASHRAE 33.

E. Refrigerant Coils: Factory tested to 450 psig according to ARI 410 and ASHRAE 33.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Equipment Mounting: Install air-handling units on concrete bases. Secure units to anchor bolts installed in concrete bases. Comply with requirements for concrete bases specified in Division 23 “Common Work Results for HVAC”.

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. 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.

B. Add structure steel between unit and pad to provide adequate height at steam coil condensate outlet for drip leg, trap, and connection to existing steam condensate line.

C. [Equipment Mounting]: Install air-handling units on structural-steel support frame. Secure frame to floor and unit to frame.

D. [Suspended Units]: Suspend and brace units from structural-steel support frame using threaded steel rods and spring hangers. Comply with requirements for vibration isolation devices specified in Division 23 Section "Vibration and Seismic Controls for HVAC Piping and Equipment."

E. Arrange installation of units to provide access space around air-handling units for service and maintenance.

F. Do not operate fan system until filters (temporary or permanent) are in place. Replace temporary filters used during construction and testing, with new, clean filters.

G. Install filter-gage, static-pressure taps upstream and downstream of each filter bank. Mount filter gages on outside of filter housing or filter plenum in accessible position.
3.2 MOTOR GROUNDING

A. Provide factory installed shaft grounding ring at each three phase motor utilizing a variable frequency controller. Comply with requirements in Division 23 Section "Common Motor Requirements for HVAC Equipment."

B. Provide copper braided grounding strap between motor and metallic conduit for motors controlled by variable frequency motor controllers.

3.3 CONNECTIONS

A. Comply with requirements for piping specified in other Division 23 Sections. Drawings indicate general arrangement of piping, fittings, and specialties.

B. Install piping adjacent to air-handling unit to allow service and maintenance.

C. Connect piping to air-handling units mounted on vibration isolators with flexible connectors.

D. Connect to condensate drain pans and extend to [nearest floor drain]. Construct deep trap at connection to drain pan and install cleanouts at changes in direction.

E. Hydronic Water Piping: Comply with applicable requirements in Division 23 Section "Hydronic Piping." Install shutoff valve and union or flange at each coil supply connection. Install calibrated balancing valve and union or flange at each coil return connection.

F. Steam and Condensate Piping: Comply with applicable requirements in Division 23 Section "Steam and Condensate Heating Piping." Install shutoff valve at steam supply connections, trap, and union or flange at each coil return connection.

1. Install gate valve and inlet strainer at supply connection of steam humidifiers, and steam trap to condensate return connection.

G. Refrigerant Piping: Comply with applicable requirements in Division 23 Section "Refrigerant Piping." Install shutoff valve and union or flange at each supply and return connection.

H. Connect duct to air-handling units with flexible connections. Comply with requirements in Division 23 Section "Air Duct Accessories."

3.4 FIELD QUALITY CONTROL

A. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect, test, and adjust components, assemblies, and equipment installations, including connections.

B. 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.
Tests and Inspections:

1. Leak Test: After installation, test coils and connections for leaks.
2. Charge refrigerant coils with refrigerant and test for leaks.
3. Fan Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.
4. HEPA-Filter Operational Test: Pressurize housing to a minimum of 3-inch wg or to designed operating pressure, whichever is higher; test housing joints, door seals, and sealing edges of filter with soapy water to check for air leaks.
5. HEPA-Filter Operational Test: Pressurize housing to a minimum of 3-inch wg or to designed operating pressure, whichever is higher; test housing joints, door seals, and sealing edges of filter for air leaks according to ASME N510, pressure-decay method.
6. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.

Air-handling unit or components will be considered defective if unit or components do not pass tests and inspections.

Prepare test and inspection reports.

STARTUP SERVICE

A. Engage a factory-authorized service representative to perform startup service.

1. Complete installation and startup checks according to manufacturer's written instructions.
2. Verify that shipping, blocking, and bracing are removed.
3. Verify that unit is secure on mountings and supporting devices and that connections to piping, ducts, and electrical systems are complete. Verify that proper thermal-overload protection is installed in motors, controllers, and switches.
4. Verify proper motor rotation direction, free fan wheel rotation, and smooth bearing operations.
5. Verify that bearings and other moving parts are lubricated with factory-recommended lubricants.
6. Verify that face-and-bypass dampers provide full face flow.
7. Verify that dampers open and close, and maintain minimum outdoor-air setting.
9. Verify that manual and automatic volume control and fire and smoke dampers in connected duct systems are in fully open position.

B. Starting procedures for air-handling units include the following:

1. Energize motor; verify proper operation of motor, drive system, and fan wheel.
2. For belt driven units, replace fan and motor pulleys as required to achieve design conditions.
3. Measure and record motor electrical values for voltage and amperage.
4. Manually operate dampers from fully closed to fully open position and record fan performance.
3.6 ADJUSTING

A. Adjust damper linkages for proper damper operation.

B. Comply with requirements in Division 23 Section "Testing, Adjusting, and Balancing for HVAC" for air-handling system testing, adjusting, and balancing.

3.7 CLEANING

A. After completing system installation and testing, adjusting, and balancing air-handling unit and air-distribution systems and after completing startup service, clean air-handling units internally to remove foreign material and construction dirt and dust. Clean fan wheels, cabinets, dampers, coils, and filter housings, and install new clean filters.

3.8 DEMONSTRATION

A. [Engage a factory-authorized service representative to train] [Train] Owner's maintenance personnel to adjust, operate, and maintain air-handling units.

END OF SECTION 23 7313
WMU Design Guidelines Instructions: These guidelines are to be used by the Design Professional to inform the design process and outline WMU-specific desires for all University projects. These guidelines have been edited to reflect WMU preferences, and the intent is for the Design Professional to use this information to guide their normal specifications-writing process. Straying from what is indicated in the guidelines is not prohibited, but shall be discussed with WMU during the development of the project.

SECTION 23 7315 - MODULAR OUTDOOR CENTRAL STATION AIR HANDLING UNITS

PART 1 - GENERAL

1.1 SUMMARY

A. Section includes modular outdoor air handling units.

1.2 ACTION SUBMITTALS

A. Product Data: For each air-handling unit indicated.

1. Unit dimensions and weight.
2. Cabinet material, metal thickness, finishes, insulation, and accessories.
3. Fans:
   a. Certified fan-performance curves with system operating conditions indicated.
   b. Certified fan-sound power ratings.
   c. Fan construction and accessories.
   d. Motor ratings, electrical characteristics, and motor accessories.
4. Certified coil-performance ratings with system operating conditions indicated.
5. Dampers, including housings and linkages.
6. Filters with performance characteristics.
7. Wiring diagrams.
8. Roof curb.
9. Variable frequency controllers.

B. [LEED Submittals]:

1. Product Data for Prerequisite IEQ 1: Documentation indicating that units comply with ASHRAE 62.1, Section 5 - “Systems and Equipment.”

C. Shop Drawings for factory controls containing the following information:

1. Schematic flow diagram showing fans, pumps, coils, dampers, valves, and control devices. One system per drawing.
2. Each control device labeled with setting or adjustable range of control.
3. Diagrams for all required electrical wiring. Clearly differentiate between factory-installed and field-installed wiring.
4. Details of control panel faces, including controls, instruments, and labeling.
5. Written description of sequence of operation.
6. Trunk cable schematic showing programmable control unit locations and trunk data conductors.
7. Listing of connected data points, including connected control unit and input device.
8. System graphics indicating monitored systems, data (connected and calculated) point addresses, and operator notations.
9. System configuration showing peripheral devices, batteries, power supplies, diagrams, modems, and interconnections.
10. Software description.

1.3 INFORMATIONAL SUBMITTALS

A. Source quality-control reports.
B. Field quality-control reports.

1.4 CLOSEOUT SUBMITTALS

A. Operation and maintenance data.

1.5 MAINTENANCE MATERIAL SUBMITTALS

A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
   1. Filters: One set for each air-handling unit.
   2. Gaskets: [One] <Insert number> set(s) for each access door.
   3. Fan Belts: [One] <Insert number> set(s) for each air-handling unit fan.

1.6 QUALITY ASSURANCE

A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
B. NFPA Compliance: Comply with NFPA 90A for design, fabrication, and installation of air-handling units and components.
C. ARI Certification: Air-handling units and their components shall be factory tested according to ARI 430, "Central-Station Air-Handling Units," and shall be listed and labeled by ARI.
D. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1, Section 5 - "Systems and Equipment" and Section 7 - "Construction and Startup."
E. ASHRAE/IESNA 90.1 Compliance: Applicable requirements in ASHRAE/IESNA 90.1, Section 6 - "Heating, Ventilating, and Air-Conditioning."
1.7 DELIVERY, STORAGE, AND HANDLING

A. Deliver air-handling units as a factory-assembled unit to the extent allowable by shipping limitations, with protective crating and covering.

B. Lift and support units with the manufacturer's designated lifting or supporting points.

C. Disassemble and reassemble units as required for movement into the final location following manufacturer’s written instructions.

1.8 COORDINATION

A. Coordinate the installation of the unit and roof curb with roofing and structural steel.

B. Coordinate sizes and locations of concrete bases with actual equipment provided.

C. Coordinate sizes and locations of structural-steel support members, if any, with actual equipment provided.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

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

1. Carrier.
2. Trane.
3. JCI.
4. Daikin

2.2 MANUFACTURED UNITS

A. General Description: Provide factory assembled rooftop modular air-handling units comprised of dimensionally compatible casing modules which house all system components; including fans, motor and drive assembly, access sections, coils, plenums, filters, drain pans, and dampers.

1. Minimum Static-Pressure Construction for Constant Volume Units: [2-inch wg] [3-inch wg] [4-inch wg] [6-inch wg] [8-inch wg] [9-inch wg] [10-inch wg].
2. Minimum Static-Pressure Construction for Variable Volume Units: [2-inch wg] [3-inch wg] [4-inch wg] [6-inch wg] [8-inch wg] [9-inch wg] [10-inch wg] <Insert value>.
UNIT CASINGS

A. General Fabrication Requirements for Casings: Construct of structural steel framing with removable double-wall insulated panels suitable for outdoor installation; all galvanized steel materials.

1. Forming: Form walls, roofs, and floors with at least two breaks at each joint.
2. Casing Joints: Sheet metal screws or pop rivets.
3. Sealing: Seal all joints with water-resistant sealant.
5. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.

B. Casing Walls: Galvanized solid sheet steel, with integral seals at all framing element contact surfaces, and secured to frame with corrosion resistant fastening system configured to minimized thermal bridging to air side of unit.

1. Provide perforated material for interior surfaces of sections indicated in equipment schedules.

C. Casing Roof: Sloped, to promote drainage of precipitation and prevent standing water.

D. Casing Insulation and Adhesive:

2. Location and Application: Encased between outside and inside casing.

E. Hoods and Louvers:

1. Outside Air Hoods:
   a. Outside air hoods shall be constructed of galvanized G-90 steel and sized for 100% of unit nominal cfm.
   b. Hoods shall include easily accessible 1-in. moisture eliminators with a maximum velocity of no more than 500 fpm.

2. Exhaust Air Hoods:
   a. Exhaust air hoods shall be constructed of galvanized G-90 steel, include a metal bird screen, and be sized for 100% of unit nominal cfm.

3. Side Intake Louvers:
   a. Frames and blades shall be 6063 alloy, 0.081 in. thick, mechanically fastened with stainless steel fasteners. Frame depth shall be 6 inches.
   b. Vertical blades shall be designed to collect and drain water to exterior at sill by means of a center rain hook and channels in jambs and mullions.
   c. Louvers shall have ½ inch mesh removable aluminum bird screen.
   d. Louvers shall be designed to withstand a wind load of 25 lb per sq ft.
   e. Water penetration shall be no more than 0.01 oz per sq ft of free area at 1250 fpm.

F. Inspection and Access Panels and Access Doors:
1. Panel and Door Fabrication: Formed and reinforced, double-wall insulated panels of same materials and thicknesses as casing.

2. Inspection and Access Panels:
   a. Fasteners: Two or more camlock type for panel lift-out operation. Arrangement shall allow panels to be opened against air-pressure differential.
   b. Gasket: Neoprene, applied around entire perimeters of panel frames.
   c. Size: Large enough to allow inspection and maintenance of air-handling unit’s internal components.

3. Access Doors:
   a. Hinges: A minimum of two ball-bearing hinges or stainless-steel piano hinge and two wedge-lever-type latches, operable from inside and outside. Arrange doors to be opened against air-pressure differential.
   b. Gasket: Neoprene, applied around entire perimeters of panel frames.
   c. Fabricate windows in doors where indicated of safety glass with rubber seals.
   d. Door Size: Minimum 18 inches wide by full height of unit casing up to a maximum height of 72 inches.

4. Locations and Applications:
   a. Fan Section: Doors and inspection and access panels.
   b. Access Section: Doors.
   c. Coil Section: Doors and inspection and access panels.
   d. Damper Section: Doors.
   e. Filter Section: Doors large enough to allow periodic removal and installation of filters.
   f. Air Blender Section: Doors.
   g. Mixing Section: Doors.
   h. Humidifier Section: Doors.

5. Service Light: Factory wired 100-W equivalent LED in a vaporproof fixture with switched junction box located outside of unit.
   a. Locations: As indicated on schedule.

G. Condensate Drain Pans:

1. Fabricated with minimum one percent slope in at least two planes to collect condensate from cooling coils (including coil piping connections, coil headers, and return bends) and to direct water toward drain connection.

2. Fabricated with minimum one percent slope in at least two planes to collect condensate from cooling coils (including coil piping connections, coil headers, and return bends) and to direct water toward drain connection.
   a. Length: Extend drain pan downstream from leaving face to comply with ASHRAE 62.1.
   b. Depth: A minimum of 2 inches deep.

4. Double-wall, stainless-steel sheet with space between walls filled with foam insulation and moisture-tight seal.

5. Double-wall, [galvanized] [stainless]-steel sheet with space between walls filled with foam insulation and moisture-tight seal.

6. Drain Connection: Located at lowest point of pan and sized to prevent overflow. Terminate outside of unit with threaded nipple and cap on one end of pan.

7. Drain Connection: Located at lowest point of pan and sized to prevent overflow. Terminate outside of unit with threaded nipple and cap on [one end] [both ends] of pan.


9. Units with stacked coils shall have an intermediate drain pan to collect condensate from top coil.

10. Locations:
    a. Cooling Coil Sections.
    b. Outdoor Air Damper Sections.
    c. Humidifier Sections.

   H. Pipe Cabinet: Factory furnished enclosure of same construction as unit casing with access.

       1. Include extension of roof curb to support piping enclosure.

   I. [Floor Openings]: All duct connections or control dampers in the floor of the units shall be covered with painted heavy gauge steel bar grating bolted in place, to prevent people and large objects from passing through the unit floor into the ductwork.

   J. Air-Handling-Unit Mounting Frame: Formed galvanized-steel channel or structural channel supports, designed for low deflection, welded with integral lifting lugs.

   K. Roof Curb: Provide insulated prefabricated galvanized steel mounting curb, perimeter type, [minimum of 14 inches high]. Gasketing shall be provided for field mounting between the unit base and the roof curb. The roof curb shall be sloped to accommodate installation on a sloped surface.

       1. Provide extended height curb as indicated.

2.4 FAN, DRIVE, AND MOTOR SECTION

A. Fan Mounting: Mount fan and motor on a structural steel frame mounted on manufacturer's standard restrained vibration isolation mounting devices having a minimum static deflection of 1 inch sized to eliminate fan vibration and noise. Provide flexible duct connecting between unit casing and fan outlet.

B. Fan Shaft Bearings:

   1. Grease-Lubricated, Bearings: Self-aligning, pillow-block type with 2-piece, cast-iron housing with grease lines extended to outside unit and a rated life of 200,000 hours according to ABMA.

C. [Plenum Fans]:

   1. Housings: Steel frame and panel; fabricated without fan scroll and volute housing.
3. Drives: Direct drive.
4. Guards: Comply with requirements specified by OSHA and fabricate according to SMACNA's "HVAC Duct Construction Standards"; 0.1046-inch thick, 3/4-inch diamond-mesh wire screen, welded to steel angle frame; prime coated.

D. [Centrifugal Fans]:

1. Fan and Drive Assemblies: Statically and dynamically balanced and designed for continuous operation at maximum-rated fan speed and motor horsepower.
   a. Shafts: Designed for continuous operation at maximum-rated fan speed and motor horsepower, and with field-adjustable alignment.
      1) Turned, ground, and polished hot-rolled steel with keyway. Ship with a protective coating of lubricating oil.
      2) Designed to operate at no more than 70 percent of first critical speed at top of fan's speed range.

2. [Centrifugal Fan Housings]: Formed- and reinforced-steel panels to form curved scroll housings with shaped cutoff and spun-metal inlet bell.
   a. Bracing: Steel angle or channel supports for mounting and supporting fan scroll, wheel, motor, and accessories.
   b. Horizontal-Flanged, Split Housing: Bolted construction.
   c. Housing for Supply Fan: Attach housing to fan-section casing with metal-edged flexible duct connector.

3. [Backward-Inclined, Centrifugal Fan Wheels]: Double-width-double-inlet construction with curved inlet flange, backplate, backward-inclined blades welded or riveted to flange and backplate; cast-iron or cast-steel hub riveted to backplate and fastened to shaft with set screws.

4. [Forward-Curved, Centrifugal Fan Wheels]: Double-width-double-inlet construction with inlet flange, backplate, and shallow blades with inlet and tip curved forward in direction of airflow and mechanically fastened to flange and backplate; cast-steel hub swaged to backplate and fastened to shaft with set screws.

5. [Airfoil, Centrifugal Fan Wheels]: Double-width-double-inlet construction with smooth-curved inlet flange, backplate, and hollow die-formed airfoil-shaped blades continuously welded at tip flange and backplate; cast-iron or cast-steel hub riveted to backplate and fastened to shaft with set screws.

6. Belt Drives: Factory mounted, with adjustable alignment and belt tensioning, and with manufacturer's standard service factor based on fan motor.
   a. Pulleys: Cast iron or cast steel with split, tapered bushing; dynamically balanced at factory.
   b. Motor Pulleys: Adjustable pitch for use with 5-hp motors and smaller; fixed pitch for use with motors larger than 5 hp. Select pulley size so pitch adjustment is at the middle of adjustment range at fan design conditions.
   c. Belts: Oil resistant, nonsparking, and nonstatic; in matched sets for multiple-belt drives.
7. Belt Guards: Comply with requirements specified by OSHA and fabricate according to SMACNA's "HVAC Duct Construction Standards"; 0.1046-inch-thick, 3/4-inch diamond-mesh wire screen, welded to steel angle frame; prime coated.

E. Axial Fans: Fan wheel and housing, straightening-vane section, factory-mounted motor with belt drive or direct drive, an inlet cone section, and accessories.
   1. Variable-Pitch Fans: Internally mounted [pneumatic] [electric] [electronic] actuator, externally mounted positive positioner, and mechanical-blade-pitch indicator.
   2. Housings: [Steel] [Galvanized steel] [Aluminum].
      a. Inlet and Outlet Connections: Flanges.
      b. Guide Vane Section: Integral guide vanes downstream from fan wheel designed to straighten airflow.

F. Variable-Inlet Vanes: Steel, with blades supported at both ends with permanently lubricated bearings. Variable mechanism terminating in single lever for connection to control actuator with connecting shaft for second set of variable inlet vanes on double-width fans.

G. Discharge Dampers: Heavy-duty steel assembly with channel frame and sealed ball bearings, and [opposed] [parallel] blades constructed of two plates formed around and welded to shaft, with blades linked out of air stream to single control lever.

H. Motor: Comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements for motors specified in Division 23 Section "Common Motor Requirements for HVAC Equipment."
   1. Enclosure Type: Totally enclosed, fan cooled.
   2. NEMA Premium (TM) efficient motors as defined in NEMA MG 1.
   3. NEMA energy efficient motors as defined in NEMA MG 1.
   4. 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.
   5. Controllers, Electrical Devices, and Wiring: Comply with requirements for electrical devices and connections specified in Division 26 Sections.

I. [Variable Frequency Drives]: Provided by Temperature Controls Installer. Refer to Division 23 Section "Instrumentation and Controls for HVAC."

J. [Variable Frequency Drives]: Provided with unit.
   1. The variable frequency drives (VFD) shall be designed specifically for use in Heating, Ventilation, and Air Conditioning (HVAC) applications in which speed control of the motor can be applied. The VFD, including all factory installed options, shall have UL & CSA approval.
   2. VFD’s shall include communications capability with DDC BMS via built-in interface card. Coordinate communications type with BMS.
   3. Unit manufacturer shall furnish variable frequency drive (VFD) for each fan motor.
   4. Built-in VFD Protection:
      1) 5% DC Choke for harmonic protection.
      2) Standard RFI Filter: Ensures that EMC/RFI requirements are met.
      3) Fire Mode for safe operation.
      4) Enclosure Class: NEMA 1, NEMA 12 or NEMA 3R as required by application.
5) Motor switch ride-through for easy, fault-free maintenance.
6) Overvoltage trip and undervoltage trip protection.
7) Ground fault protection.
8) Mains and motor phase supervisions.
9) Overcurrent and unit overtemperature protection.
10) Motor overload, motor stall and motor underload protection.

b. Bypass Options:
   1) Fused disconnect with no bypass.
   3) Automatic bypass.
   4) Contactor.

K. Variable Frequency Controllers: Provided with units:

1. Description: NEMA ICS 2, IGBT, PWM, VFC; listed and labeled as a complete unit and arranged to provide variable speed of an NEMA MG 1, Design B, 3-phase induction motor by adjusting output voltage and frequency.
2. Output Rating: 3-phase; 6 to 60 Hz, with voltage proportional to frequency throughout voltage range.
3. Unit Operating Requirements:
   a. Input ac voltage tolerance:
      1) 208 V, plus or minus 5 percent.
      2) 380 to 500 V, plus or minus 10 percent.
   b. Input frequency tolerance of 50/60 Hz, plus or minus 6 percent.
   c. Minimum Efficiency: 96 percent at 60 Hz, full load.
   d. Minimum Displacement Primary-Side Power Factor: 96 percent.
   e. Overload Capability: 1.1 times the base load current for 60 seconds; 2.0 times the base load current for 3 seconds.
   f. Starting Torque: 100 percent of rated torque or as indicated.
   g. Speed Regulation: Plus or minus 1 percent.

4. Isolated control interface to allow controller to follow control signal over an 11:1 speed range.
5. Internal Adjustability Capabilities:
   a. Minimum Speed: 5 to 25 percent of maximum rpm.
   b. Maximum Speed: 80 to 100 percent of maximum rpm.
   c. Acceleration: 2 to a minimum of 22 seconds.
   d. Deceleration: 2 to a minimum of 22 seconds.
   e. Current Limit: 50 to a minimum of 110 percent of maximum rating.

6. Self-Protection and Reliability Features:
   a. Input transient protection by means of surge suppressors.
   b. Undervoltage and overvoltage trips; inverter overtemperature, overload, and overcurrent trips.
   c. Adjustable motor overload relays.
   d. Notch filter to prevent operation of the controller-motor-load combination at a natural frequency of the combination.
   e. Instantaneous line-to-line and line-to-ground overcurrent trips.
   f. Loss-of-phase protection.
g. Reverse-phase protection.

h. Short-circuit protection.

i. Motor overtemperature fault.

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

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

9. Torque Boost: Automatically varies starting and continuous torque to at least 1.5 times the minimum torque to ensure high-starting torque and increased torque at slow speeds.


11. Door-mounted LED status lights shall indicate the following conditions:
   a. Power on.
   b. Run.
   c. Overvoltage.
   d. Line fault.
   e. Overcurrent.
   f. External fault.


13. Meters or digital readout devices and selector switch, mounted flush in controller door and connected to indicate the following controller parameters:
   a. Output frequency (Hertz).
   b. Motor speed (rpm).
   c. Motor status (running, stop, fault).
   d. Motor current (amperes).
   e. Motor torque (percent).
   f. Fault or alarming status (code).
   g. Proportional-integral-derivative (PID) feedback signal (percent).
   h. DC-link voltage (volts direct current).
   i. Set-point frequency (Hertz).
   j. Motor output voltage (volts).

14. Control Signal Interface:
   a. Electric Input Signal Interface: A minimum of 2 analog inputs (0 to 10 V or 0/4-20 mA) and 6 programmable digital inputs.
   b. Remote signal inputs capable of accepting any of the following speed-setting input signals from the control system:
      1) 0 to 10-V dc.
      2) 0-20 or 4-20 mA.
      3) Potentiometer using up/down digital inputs.
      4) Fixed frequencies using digital inputs.
      5) RS485.
      6) Keypad display for local hand operation.
   c. Output signal interface with a minimum of 1 analog output signal (0/4-20 mA), which can be programmed to any of the following:
      1) Output frequency (Hertz).
2) Output current (load).
3) DC-link voltage (volts direct current).
4) Motor torque (percent).
5) Motor speed (rpm).
6) Set-point frequency (Hertz).

d. Remote indication interface with a minimum of 2 dry circuit relay outputs (120-V ac, 1 A) for remote indication of the following:
   1) Motor running.
   2) Set-point speed reached.
   3) Fault and warning indication (overtemperature or overcurrent).
   4) High- or low-speed limits reached.

15. Communications: RS485 interface allows VFC to be used with an external system within a multidrop LAN configuration. Interface shall allow all parameter settings of VFC to be programmed via BMS control. Provide capability for VFC to retain these settings within the nonvolatile memory.

16. Integral Disconnecting Means: NEMA KS 1, nonfusible switch with lockable handle.

17. Accessories:
   a. Devices shall be factory installed in controller enclosure unless otherwise indicated.
   c. Standard Displays:
      1) Output frequency (Hertz).
      2) Set-point frequency (Hertz).
      3) Motor current (amperes).
      4) DC-link voltage (volts direct current).
      5) Motor torque (percent).
      6) Motor speed (rpm).
      7) Motor output voltage (volts).

2.5 COIL SECTION

A. General Requirements for Coil Section:
   1. Comply with ARI 410.
   2. Fabricate coil section to allow removal and replacement of coil for maintenance and to allow in-place access for service and maintenance of coil(s).
   3. Coils shall not act as structural component of unit.

B. Connections: Provide factory installed piping connection points outside of unit casing and ready for field connections; with casing penetration points sealed against leakage for unit's rated pressure.

C. Water Coils: Drainable, rigidly supported across the full face of the coil, and pitched to allow drainage.
   1. Fins: Aluminum, constructed from flat plate with belled collars for tubes. Fins shall be bonded to tubes by mechanically expanding copper tubes.
   2. Tubes: Seamless copper.
4. Headers: Steel or cast iron, with connections for drain valve and air vent and threaded piping connections.
5. Rows: Cooling water coils shall be 6 row minimum.

D. Steam Coils: Steam-distributing type comprised of copper distributing tube concentrically supported inside copper condensing tube with corrosion-resistant clips; with aluminum fins and seamless copper header having both steam and condensate chambers. Pitch coil in frame such that condensate drains properly when coil is installed level.

E. Steam Coils: Integral face and bypass (IFB) type comprised of alternate finned heating elements and bypass openings with interlocked dampers. Construct coils comprised of copper distributing tube concentrically supported inside copper condensing tube with corrosion-resistant clips; with aluminum fins and seamless copper header having both steam and condensate chambers. Pitch coil in frame such that condensate drains properly when coil is installed level. Fabricate dampers of extruded aluminum with heat reflective anodized finish; complete with edge seals and mounted on aluminum damper rods housed in oil impregnated bronze bearings.

F. Direct-Expansion Refrigerant Coils: Designed and fabricated in compliance with ASHRAE Standard 15, "Safety Code for Mechanical Refrigeration." Coils shall have the following features:
   1. Suction Headers and Distributor Tubes: Seamless copper.
   2. Venturi-type refrigerant distributor, designed for low pressure drop, arranged for down feed with solder connections, and having a maximum of 12 circuits for each distributor.
      a. Coils with more than 12 circuits shall have two distributors.
      b. Split circuit coils shall have two distributors.
      c. Coils with two distributors shall be interlaced or row controlled.

2.6 AIR FILTRATION SECTION

A. General Requirements for Air Filtration Section:
   1. Comply with NFPA 90A.
   2. Provide minimum arrestance according to ASHRAE 52.1, and a minimum efficiency reporting value (MERV) according to ASHRAE 52.2.
   3. Provide filter holding frames arranged for flat or angular orientation, with access doors. Filters shall be removable from one side or lifted out from access plenum.

B. Prefilters/ [Filters]: Extended-surface, disposable panel filters:
   1. Factory-fabricated, dry, extended-surface type.
   2. Thickness: 2 inches.
   3. Thickness: [2 inches] [4 inches].
   6. Media: Fibrous material formed into deep-V-shaped pleats and held by self-supporting wire grid.
   8. Mounting Frames: Galvanized steel, with gaskets and fasteners.
C. **[Filters]**: Extended-surface, non-supported media filters:

1. Factory-fabricated, dry, extended-surface, self-supporting type.
4. Length: [X inches].
7. Length: [X inches].
10. Length: [X inches].
13. Length: [X inches].
14. Media: Fibrous material constructed so individual pleats are maintained in tapered form by flexible internal supports under rated-airflow conditions.
16. Mounting Frames: Galvanized steel, with gaskets and fasteners, with space for prefILTER.

D. **[Filters][Final Filters]**: Extended-surface, rigid media filters:

1. Factory-fabricated, dry, deep pleated, rigid type.
10. Length: 12 inches.
11. Media: High density fibrous material with support grid and contour stabilizers.
13. Mounting Frames: Welded, galvanized steel, with gaskets and fasteners, suitable for bolting together into built-up filter banks, with space for prefILTER.

E. **Activated-Carbon Panel Filters**:

1. Factory-fabricated unit with activated-carbon media.
2. Flat-Panel Media: Multilayer filter with inlet layer of polyester fibers, layer of activated-carbon granules bonded to fibers, layer of polyurethane foam, and housed in cardboard frame.
3. Pleated Media: Multilayer filter with inlet layer of cotton and synthetic fibers and layer of activated-carbon granules bonded to synthetic fibers, formed into deep-V-shaped pleats and held by self-wire grid, and housed in nonflammable cardboard frame.
4. Mounting Frames: Welded galvanized steel, with polyurethane gaskets and fasteners, capable of holding media and media frame in place and suitable for bolting together into built-up filter banks.

F. **Activated-Carbon Filters**:
1. Factory-fabricated unit in deep-V arrangement with disposable panel prefilter.
3. Activated-Carbon Capacity: \[12 \text{ lb of activated carbon per 500 cfm}\] \[8.8 \text{ lb of activated carbon per 2000 cfm}\] of airflow.
4. Housing: 0.064-inch-thick, galvanized steel, for side servicing through gasketed access doors on both sides. Equip housings with metal slide channel tracks to hold activated-carbon trays.

G. HEPA Filters:

1. Factory-fabricated unit.
2. Dust-Holding Capacity: \(<\text{Insert lb}>\).
3. Initial Resistance: \(<\text{Insert inches wg}>\).
4. Recommended Final Resistance: \(<\text{Insert inches wg}>\).
5. Arrestance (ASHRAE 52.1): \[95 \text{ percent on 0.3-micrometer D.O.P. particles}\] \[99.97 \text{ percent on 0.3-micrometer D.O.P. particles}\] \[99.9995 \text{ percent on 0.1- and 0.2-micrometer D.O.P. particles}\] \[99.99995 \text{ percent on 0.1- and 0.2-micrometer D.O.P. particles}\] \[<\text{Insert value}>\].
6. Media: UL 586, fibrous glass, constructed of continuous sheets with closely spaced pleats with \[\text{aluminum separators}\] \[\text{vinyl-coated aluminum separators}\] \[\text{separators of ribbons of filter media}\].
7. Frame Material: \[3/4\text{-inch-thick, fire-retardant plywood}\] \[3/4\text{-inch-thick, fire-retardant particleboard}\] \[3/4\text{-inch-thick plywood}\] \[3/4\text{-inch-thick particleboard}\] \[\text{Galvanized steel}\] \[\text{Aluminized steel}\] \[\text{Cadmium-plated steel}\] \[\text{Stainless steel}\] \[\text{Aluminum}\].
8. Media to Frame Side Bond: \[\text{Polyurethane foam}\] \[\text{Silicone}\] \[\text{Neoprene adhesive}\] \[\text{Fiberglass-mat packing}\] \[\text{Thermosetting sealant}\] \[\text{Knife edge in fluid-filled channel}\].
9. Face Gasket: \[\text{Neoprene expanded rubber}\] \[\text{Ceramic fiber}\] \[\text{Silicone}\].
10. Mounting Frames: Downstream corners of holding device shall have cushion pads to protect media. Bolted filter-sealing mechanism shall mount and continuously seal each individual filter.

H. Filter Gage:

I. Filter Gage: One for prefilter and one for final filter bank:

1. 3-1/2-inch-diameter, diaphragm-actuated dial in metal case suitable for outdoor application.
2. Vent valves.
3. Black figures on white background.
4. Front recalibration adjustment.
5. 2 percent of full-scale accuracy.
6. \[\text{Range}: \text{0- to 2.0-inch wg}\].
7. \[\text{Prefilter Range}: \text{0- to 0.5-inch wg}\].
8. \[\text{Final Filter Range}: \text{0- to 1.0-inch wg}\].
9. Range: \[\text{0- to 0.5-inch wg}\] \[\text{0- to 1.0-inch wg}\] \[\text{0- to 2.0-inch wg}\] \[\text{0- to 3.0-inch wg}\] \[\text{0- to 4.0-inch wg}\].
10. Accessories: Static-pressure tips with integral compression fittings, 1/4-inch tubing, and 2- or 3-way vent valves.
2.7 DAMPERS

A. General Requirements for Dampers: Leakage rate, according to AMCA 500, "Laboratory Methods for Testing Dampers for Rating," shall not exceed 2 percent of air quantity at 2000-fpm face velocity through damper and 4-inch wg pressure differential.

B. Face-and-Bypass Dampers: Opposed-blade, [galvanized-steel] [aluminum] [extruded-aluminum] dampers with [cadmium-plated] steel operating rods rotating in sintered bronze or nylon bearings mounted in a single [galvanized-steel] [aluminum] [extruded-aluminum] frame and with operating rods connected with a common linkage. Provide blade gaskets and edge seals, and mechanically fasten blades to operating rod.

C. Mixing Box Outdoor- and Return-Air Dampers: Galvanized-steel or aluminum dampers mechanically fastened to cadmium-plated steel operating rod in reinforced cabinet. [Connect operating rods with common linkage and interconnect linkages so dampers operate simultaneously.]

1. For combination filter and mixing box section, include cabinet support members to hold 2-inch- thick, pleated, flat, throwaway filters.

D. Economizer Outdoor, Relief and Return Air Dampers: Low-leakage, galvanized-steel or aluminum dampers with compressible jamb seals and extruded-vinyl blade edge seals with cadmium-plated steel operating rod. Leakage rate shall not exceed 5 cfm/sq. ft. at 1-inch wg and 9 cfm/sq. ft. at 4-inch wg.

1. For variable air volume units, divide outside air damper into two sections. One for minimum outside air and one for economizing air.
   a. Size damper sections for each AHU based on the ratio of scheduled minimum outside air volume divided by the scheduled supply air volume.

E. Economizer Outdoor, Exhaust and Return Air Dampers: Low-leakage, galvanized-steel or aluminum dampers with compressible jamb seals and extruded-vinyl blade edge seals with cadmium-plated steel operating rod. Leakage rate shall not exceed 5 cfm/sq. ft. at 1-inch wg and 9 cfm/sq. ft. at 4-inch wg.

2.8 AIR BLENDER

A. Provide air blenders with integral blender blades arranged within the module to provide uniform velocity and temperature profile. Provide side access door in casing down stream of blender.

2.9 HUMIDIFIERS

A. Steam Grid Humidifier:

1. Manifold:
   a. ASTM A 666, Type 304 stainless steel.
   b. Steam jacketed.
   c. Insulated with 1/2-inch fiberglass and stainless-steel jacket.
   d. Manifold shall extend the full width of unit with mounting brackets at ends.
2. Steam Separator: [Cast iron, ASTM A 666, Type 304 stainless steel,] with separate humidifier control valve.
4. Humidifier Control Valve: Actuator: As specified in Division 23 Section "Instrumentation and Control for HVAC."
5. Steam Trap: Inverted-bucket type, sized for a minimum of three times the maximum rated condensate flow of humidifier at 1/2-psig inlet pressure.
6. Aquastat: For separate mounting on steam condensate, return piping to prevent cold operation of humidifier.
7. Strainer: In-line type.
8. Airflow Switch: To prevent humidifier operation in the absence of airflow.

2.10 AIR-TO-AIR ENERGY RECOVERY

A. Heat Wheels:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   a. Airxchange.
   c. Loren Cook Company.
   d. SEMCO Incorporated.
   e. Trane; American Standard Inc.

2. Casing:
   a. Steel, with manufacturer's standard paint coating.
   b. Integral purge section limiting carryover of exhaust air to between 0.05 percent at 1.6-inch wg and 0.20 percent at 4-inch wg differential pressure.
   c. Casing seals on periphery of rotor, on duct divider, and on purge section.
   d. Support rotor on grease-lubricated ball bearings with extended grease fittings. Mount horizontal wheels on tapered roller bearing.

3. Rotor: Aluminum, segmented wheel, strengthened with radial spokes, with nontoxic, noncorrosive, silica-gel desiccant coating. Construct media for passing maximum [500] [800] [1200]-micrometer solids.


5. Drive: Fractional horsepower motor and gear reducer, with speed changed by variable frequency controller, and self-adjusting multilink belt around outside of rotor.

6. Controls:

7. Starting relay, factory mounted and wired, and manual motor starter for field wiring.
   a. Variable frequency controller, factory mounted and wired, permitting input of field connected 4-20 mA or 1-10-V control signal.
   b. Variable frequency controller, factory mounted and wired, with exhaust-air sensor to vary rotor speed and maintain exhaust temperature above freezing.
   c. Variable frequency controller, factory mounted and wired, with exhaust- and outdoor-air sensors, automatic changeover thermostat and set-point adjuster, to vary rotor speed and maintain exhaust temperature above freezing and air differential temperature above set point. Provide maximum rotor speed when exhaust-air temperature is less than outdoor-air temperature.
d. Pilot-Light Indicator: Display rotor rotation and speed.
e. Speed Settings: Adjustable settings for maximum and minimum rotor speed limits.

B. Fixed-Plate Sensible Heat Exchangers:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   b. Des Champs Technologies.
   c. Exothermics Inc.; a brand of Eclipse, Inc.
   d. Nutech Brands Inc.
   e. RenewAire LLC.

2. Casing: [Aluminum] [Galvanized steel] [Enamed steel, with galvanized-steel liner] [Enamed steel].
3. Plates: Evenly spaced and sealed and arranged for counter airflow.
4. Plate Material: [Embossed aluminum] [Stainless steel] [Polypropylene copolymer (high-density plastic)].
   a. Plate Coating: [Epoxy] [Air-dried phenolic].

5. Bypass: Plenum within casing, with gasketed face-and-bypass dampers that have operating rods extended outside casing.
6. Water Wash: Automatic system, with spray manifold to individual spray tubes or traversing type with stainless-steel-screw operating mechanism and electric motor drive; activated by time clock, with detergent injection.
7. Heat-Exchanger Prefilters: [1 inch thick, disposable] [2 inches thick, disposable] [Medium efficiency] [Electrostatic].

2.11 CONTROLS

A. Provide stand-alone DDC control system for air handling unit, complete with operator interface, remote field installed outdoor air sensor and room mounted field installed space sensor.

1. Refer to [Section 23 0993][controls drawing] for unit sequence of operations.

2.12 AIRFLOW MEASURING DEVICES

A. Outside Air Airflow Stations:

1. Provide airflow monitors on outside air dampers capable of continuously measuring the outside air volume. Airflow monitors shall provide a 2 to 10 Vdc signal which corresponds to cfm for controlling and documenting airflow.

B. Fan Air Airflow Stations:

1. Provide airflow monitors on each fan capable of continuously measuring the air volume. Airflow monitors shall provide a 2 to 10 Vdc signal which corresponds to cfm for controlling and documenting airflow.

C. Fan Inlet Airflow Probes:
1. Provide on supply and exhaust fans, airflow probes mounted in the fan inlets capable of continuously measuring the air handling capacity (air volume) of the respective plenum fans.
   a. The fan inlet airflow traverse probes shall be factory calibrated to NIST traceable standards and use "bead in glass" thermistor thermal dispersion technology.
   b. The fan inlet airflow traverse probes shall not significantly impact fan performance or contribute to fan generated noise levels.
   c. The probes shall be capable of producing steady, non-pulsating signals of standard total and static pressure, without need for flow corrections or factors, with an accuracy of 3% of actual reading.

2. Include a transmitter for each probe to communicate the fans CFM to the building DDC control system.

3. The fan inlet airflow probes shall be the Ebtron “Gold Series”.

D. Outside Air Inlet Airflow Probes:

1. Provide on outside air dampers airflow probes capable of continuously measuring the outside air volume.
   a. The airflow probes shall be factory calibrated to NIST traceable standards and use thermal dispersion technology.
   b. The airflow traverse probes shall not significantly impact fan performance or contribute to fan generated noise levels.
   c. The probes shall be capable of producing steady, non-pulsating signals of standard total and static pressure, without need for flow corrections or factors, with an accuracy of 3% of actual reading.

2. Include a transmitter for each probe to communicate the CFM to the building DDC control system.

3. The airflow probes shall be the Ebtron “Gold Series”.

2.13 SOURCE QUALITY CONTROL

A. Fan Sound-Power Level Ratings: Comply with AMCA 301, "Methods for Calculating Fan Sound Ratings from Laboratory Test Data." Test fans according to AMCA 300, "Reverberant Room Method for Sound Testing of Fans." Fans shall bear AMCA-certified sound ratings seal.


C. Water Coils: Factory tested to 300 psig according to ARI 410 and ASHRAE 33.

D. Steam Coils: Factory tested to 300 psig and to 200 psig underwater according to ARI 410 and ASHRAE 33.

E. Refrigerant Coils: Factory tested to 450 psig according to ARI 410 and ASHRAE 33.
PART 3 - EXECUTION

3.1 INSTALLATION

A. Install air-handling units' level and plumb, in accordance with manufacturer’s written instructions.

B. Support roof-mounted unit on roof curb. Secure units to curb.

C. Equipment Mounting: Install air-handling units on concrete bases. Secure units to anchor bolts installed in concrete bases. Comply with requirements for concrete bases specified in Division 03 concrete section.
   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. Install epoxy-coated anchor bolts that extend through concrete base and anchor into structural concrete floor.
   3. Place and secure anchorage devices. Use setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
   4. Install anchor bolts to elevations required for proper attachment to supported equipment.

D. Equipment Mounting: Install air-handling units on structural-steel support frame. Secure frame to floor and unit to frame.

E. Suspended Units: Suspend and brace units from structural-steel support frame using threaded steel rods and spring hangers.

F. Arrange installation of units to provide access space around air-handling units for service and maintenance.

G. Do not operate fan system until filters (temporary or permanent) are in place. Replace temporary filters used during construction and testing, with new, clean filters.

H. Install filter-gage, static-pressure taps upstream and downstream of each filter bank. Mount filter gages on outside of filter housing or filter plenum in accessible position.

3.2 MOTOR GROUNDING

A. Provide factory installed shaft grounding ring at each three phase motor utilizing a variable frequency controller. Comply with requirements in Division 23 Section "Common Motor Requirements for HVAC Equipment."

B. Provide copper braided grounding strap between motor and metallic conduit for motors controlled by variable frequency motor controllers.
3.3 CONNECTIONS

A. Comply with requirements for piping specified in other Division 23 Sections. Drawings indicate general arrangement of piping, fittings, and specialties.

B. Install piping adjacent to air-handling unit to allow service and maintenance.

C. Connect piping to air-handling units mounted on vibration isolators with flexible connectors.

D. Connect to condensate drain pans and extend to down to roof/grade. Construct deep trap at connection to drain pan and install cleanouts at changes in direction.

E. Hydronic Water Piping: Comply with applicable requirements in Division 23 Section "Hydronic Piping." Install shutoff valve and union or flange at each coil supply connection. Install calibrated balancing valve and union or flange at each coil return connection.

F. Steam and Condensate Piping: Comply with applicable requirements in Division 23 Section "Steam and Condensate Heating Piping." Install shutoff valve at steam supply connections, trap, and union or flange at each coil return connection.
   1. Install gate valve and inlet strainer at supply connection of steam humidifiers, and steam trap to condensate return connection.

G. Refrigerant Piping: Comply with applicable requirements in Division 23 Section "Refrigerant Piping." Install shutoff valve and union or flange at each supply and return connection.

H. 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 and pipes. Do not cut out decking under entire roof curb.
   3. Connect ducts to units with flexible duct connectors specified in Division 23 Section "Air Duct Accessories."
   4. Install drywall and rigid fiberglass insulation inside roof curb as indicated.

3.4 FIELD QUALITY CONTROL

A. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect, test, and adjust components, assemblies, and equipment installations, including connections.

B. 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.

C. Tests and Inspections:
   1. Leak Test: After installation, test coils and connections for leaks.
   2. Charge refrigerant coils with refrigerant and test for leaks.
3. Fan Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.

4. HEPA-Filter Operational Test: Pressurize housing to a minimum of 3-inch wg or to designed operating pressure, whichever is higher; test housing joints, door seals, and sealing edges of filter with soapy water to check for air leaks.

5. HEPA-Filter Operational Test: Pressurize housing to a minimum of 3-inch wg or to designed operating pressure, whichever is higher; test housing joints, door seals, and sealing edges of filter for air leaks according to ASME N510, pressure-decay method.

6. [Test and adjust controls and safeties]. Replace damaged and malfunctioning controls and equipment.

D. Air-handling unit or components will be considered defective if unit or components do not pass tests and inspections.

E. Prepare test and inspection reports.

3.5 STARTUP SERVICE

A. [Engage a factory-authorized service representative to perform] [Perform] startup service.

1. Complete installation and startup checks according to manufacturer’s written instructions.
2. Verify that shipping, blocking, and bracing are removed.
3. Verify that unit is secure on mountings and supporting devices and that connections to piping, ducts, and electrical systems are complete. Verify that proper thermal-overload protection is installed in motors, controllers, and switches.
4. Verify proper motor rotation direction, free fan wheel rotation, and smooth bearing operations.
5. Verify proper motor rotation direction, free fan wheel rotation, and smooth bearing operations. Reconnect fan drive system, align belts, and install belt guards.
6. Verify that bearings, pulleys, belts, and other moving parts are lubricated with factory-recommended lubricants.
7. Verify that face-and-bypass dampers provide full face flow.
8. Verify that dampers open and close.
9. Verify that dampers open and close, and maintain minimum outdoor-air setting.
11. Verify that manual and automatic volume control and fire and smoke dampers in connected duct systems are in fully open position.

B. Starting procedures for air-handling units include the following:

1. Energize motor; verify proper operation of motor, drive system, and fan wheel.
   a. Replace fan and motor pulleys as required to achieve design conditions.
2. Measure and record motor electrical values for voltage and amperage.
3. Manually operate dampers from fully closed to fully open position and record fan performance.
3.6 ADJUSTING

A. Adjust damper linkages for proper damper operation.

B. Comply with requirements in Division 23 Section “Testing, Adjusting, and Balancing for HVAC” for air-handling system testing, adjusting, and balancing.

3.7 CLEANING

A. After completing system installation and testing, adjusting, and balancing air-handling unit and air-distribution systems and after completing startup service, clean air-handling units internally to remove foreign material and construction dirt and dust. Clean fan wheels, cabinets, dampers, coils, and filter housings, and install new clean filters.

3.8 DEMONSTRATION

A. Train Owner's maintenance personnel to adjust, operate, and maintain air-handling units.

B. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain air-handling units.

END OF SECTION 23 7315
WMU Design Guidelines Instructions: These guidelines are to be used by the Design Professional to inform the design process and outline WMU-specific desires for all University projects. These guidelines have been edited to reflect WMU preferences, and the intent is for the Design Professional to use this information to guide their normal specifications-writing process. Straying from what is indicated in the guidelines is not prohibited, but shall be discussed with WMU during the development of the project.

SECTION 23 7413 - PACKAGED, OUTDOOR, CENTRAL-STATION AIR-HANDLING UNITS

PART 1 - GENERAL

1.1 SUMMARY

A. This Section includes packaged, outdoor, central-station air-handling units (rooftop units) with the following components and accessories:

1. Direct-expansion cooling.
3. [Hot-gas reheat].
4. Electric-heating coils.
5. Gas furnace.
6. Economizer outdoor- and return-air damper section.
7. [Integral, space temperature controls].
8. Roof curbs.

B. Related Sections include the following:

1. Division 23 Section "Indoor Indirect-Fuel-Fired Heating and Ventilating Units" for outdoor units providing 100 percent tempered outdoor air with heat exchangers.
2. Division 23 Section "Indoor, Direct Gas-Fired Heating and Ventilating Units" for outdoor units providing 100 percent tempered outdoor air without heat exchangers.
3. Division 23 Section "Packaged, Outdoor, Heating and Cooling Makeup Air-Conditioners" for outdoor equipment air conditioning 100 percent outdoor air to replace air exhausted from a building.

1.2 DEFINITIONS

A. DDC: Direct-digital controls.

B. ECM: Electrically commutated motor.

C. 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.

D. 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.
E. 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.

F. 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.

G. 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.

H. VVT: Variable-air volume and temperature.

1.3 PERFORMANCE REQUIREMENTS

A. Delegated Design: Design RTU supports to comply with wind and seismic performance requirements, including comprehensive engineering analysis by a qualified professional engineer, using performance requirements and design criteria indicated.

B. Wind-Restraint Performance:

1. Basic Wind Speed: <Insert value>.
2. Building Classification Category: [I] [II] [III] [IV].
3. Minimum 10 lb/sq. ft multiplied by the maximum area of the mechanical component projected on a vertical plane that is normal to the wind direction, and 45 degrees either side of normal.

C. Seismic Performance: RTUs shall withstand the effects of earthquake motions determined according to SEI/ASCE 7 <Insert requirement>.

1. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified."

1.4 ACTION SUBMITTALS

A. Product Data: Include manufacturer's technical data for each RTU, including rated capacities, dimensions, required clearances, characteristics, furnished specialties, and accessories.

B. LEED Submittals:

1. Product Data for Credit EA 4: Documentation indicating that equipment and refrigerants comply.
2. Product Data for Prerequisite EQ 1: Documentation indicating that units comply with ASHRAE 62.1, Section 5 - "Systems and Equipment."

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.

D. Delegated-Design Submittal: For RTU supports indicated to comply with performance requirements and design criteria, including analysis data signed and sealed by the qualified professional engineer responsible for their preparation.

   1. Design Calculations: Calculate requirements for selecting vibration isolators and seismic restraints and for designing vibration isolation bases.
   2. Detail mounting, securing, and flashing of roof curb to roof structure. Indicate coordinating requirements with roof membrane system.
   3. Wind- and Seismic Restraint Details: Detail fabrication and attachment of wind and seismic restraints and snubbers. Show anchorage details and indicate quantity, diameter, and depth of penetration of anchors.

E. Manufacturer Wind Loading Qualification Certification: Submit certification that specified equipment will withstand wind forces identified in "Performance Requirements" Article and in Division 23 Section "Vibration and Seismic Controls for HVAC Piping and Equipment."

   1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculations.
   2. Dimensioned Outline Drawings of Equipment Unit: Identify center of wind force and locate and describe mounting and anchorage provisions.
   3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.

F. Manufacturer Seismic Qualification Certification: Submit certification that RTUs, accessories, and components will withstand seismic forces defined in "Performance Requirements" Article and in Division 23 Section "Vibration and Seismic Controls for HVAC Piping and Equipment."

   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.

1.5 INFORMATIONAL SUBMITTALS

A. Coordination Drawings: Plans and other 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. Structural members to which RTUs will be attached.
   2. Roof openings
   3. Roof curbs and flashing.

B. Field quality-control test reports.

C. Warranty: Special warranty specified in this Section.
1.6 CLOSEOUT SUBMITTALS
   A. Operation and maintenance data.

1.7 MAINTENANCE MATERIAL SUBMITTALS
   A. Furnish extra materials described below that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
      1. Fan Belts: [One set] [<Insert number> sets] for each belt-driven fan.
      2. Filters: One set of filters for each unit.

1.8 QUALITY ASSURANCE
   A. ARI Compliance:
      1. Comply with ARI 210/240 and ARI 340/360 for testing and rating energy efficiencies for RTUs.
      2. Comply with ARI 270 for testing and rating sound performance for RTUs.
   B. ASHRAE Compliance:
      1. Comply with ASHRAE 15 for refrigeration 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."
   C. ASHRAE/IESNA 90.1 Compliance: Applicable requirements in ASHRAE/IESNA 90.1, Section 6 - "Heating, Ventilating, and Air-Conditioning."
   D. NFPA Compliance: Comply with NFPA 90A and NFPA 90B.
   E. UL Compliance: Comply with UL 1995.
   F. 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.

1.9 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: Manufacturer's standard, but not less than [five] [10] years from date of Substantial Completion.
      2. Warranty Period for Gas Furnace Heat Exchangers: Manufacturer's standard, but not less than [five] [10] [15] [20] years from date of Substantial Completion.
      3. Warranty Period for Solid-State Ignition Modules: Manufacturer's standard, but not less than [three] [<Insert number>] years from date of Substantial Completion.
4. 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. Available Manufacturers: Subject to compliance with requirements, manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:

B. [Manufacturers]: Subject to compliance with requirements, provide products by the following:

1. JCI/York.

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

D. Basis-of-Design Product: Subject to compliance with requirements, provide [the product indicated on Drawings] <Insert manufacturer's name; product name or designation> or a comparable product by one of the following:

1. AAON, Inc.
2. Addison Products Company.
3. Carrier.
4. Engineered Air.
5. Lennox Industries Inc.
6. Daikin/McQuay.
7. Trane.
8. JCI/York.
9. <Insert manufacturer's name>.

2.2 CASING

A. General Fabrication Requirements for Casings: Formed and reinforced insulated panels, fabricated to allow removal for access to internal parts and components, with joints between sections sealed.

B. 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.

C. 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: [0.052 inch] [0.0626 inch] [0.079 inch] <Insert thickness> thick.

D. Inner Casing Fabrication Requirements:
1. Inside Casing: Galvanized steel.
2. Inside Casing: Galvanized steel, [0.034 inch] [0.028 inch] <Insert thickness> thick, perforated 40 percent free area.

E. Casing Insulation and Adhesive: Comply with NFPA 90A or NFPA 90B.
   1. Materials: ASTM C 1071, Type I.
   2. Thickness: 1/2 inch.
   3. Thickness: [1/2 inch] [1 inch].
   4. 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.
   5. Liner Adhesive: Comply with ASTM C 916, Type I.

F. Condensate Drain Pans: Non-corrosive material complying with ASHRAE 62.1.
   1. Drain Connections: Threaded nipple.

G. Condensate Drain Pans: Formed sections of [galvanized] [stainless]-steel sheet, a minimum of 2 inches deep, and complying with ASHRAE 62.1-2004.
   1. Double-Wall Construction: Fill space between walls with foam insulation and seal moisture tight.
   2. Drain Connections: Threaded nipple both sides of drain pan.
   3. Drain Connections: Threaded nipple [both sides of drain pan].
   4. Pan-Top Surface Coating: Corrosion-resistant compound.

H. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.

2.3 FANS

A. [Direct-Driven Supply-Air Fans]: Double width, [forward curved] [backward inclined], centrifugal; with permanently lubricated, [multispeed] [ECM] 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] [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 Division 23 Section "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 Division 23 Section “Common Motor Requirements for HVAC Equipment.”

2.4 COILS

A. Condenser Coils:

1. Condenser coils shall use Micro-Channel coil technology. Coil shall have a series of flat tubes containing a series of multiple, parallel flow micro-channels layered between the refrigerant manifolds. Micro-channel coils shall consist of a two-pass arrangement. Coils shall be factory leak and pressure tested.

2. Condenser coils shall use Micro-Channel coil technology. Coil shall have a series of flat tubes containing a series of multiple, parallel flow micro-channels layered between the refrigerant manifolds. Micro-channel coils shall consist of a two-pass arrangement. Coils shall be factory leak and pressure tested.

a. Coil construction shall consist of aluminum alloys for the fins, tubes and manifolds in combination with a corrosion resistant coating on the tubes.

b. 0.3 fins/inch
c. 18 louvers per fin
d. 32 ports per tube
e. Double wall thickness on exposed tube edges
f. Epoxy-lined shrink wrap protection of Al to Cu tube joint

B. Supply-Air Refrigerant Coil:

1. Aluminum-plate fin and seamless internally grooved copper tube in steel casing with equalizing-type vertical distributor.

2. Aluminum [Copper]-plate fin and seamless internally grooved copper tube in steel casing with equalizing-type vertical distributor.

3. Polymer strip shall prevent all copper coil from contacting steel coil frame or condensate pan.


5. [Baked phenolic] [Cathodic epoxy] coating.

6. Condensate Drain Pan: Galvanized steel with corrosion-resistant coating or stainless steel formed with pitch and drain connections complying with ASHRAE 62.1.

7. Condensate Drain Pan: [Galvanized steel with corrosion-resistant coating] [Stainless steel] formed with pitch and drain connections [complying with ASHRAE 62.1-2004].

C. Outdoor-Air Refrigerant Coil:

1. Aluminum-plate fin and seamless internally grooved copper tube in steel casing with equalizing-type vertical distributor.

2. Aluminum [Copper]-plate fin and seamless internally grooved copper tube in steel casing with equalizing-type vertical distributor.

3. Polymer strip shall prevent all copper coil from contacting steel coil frame or condensate pan.

4. [Baked phenolic] [Cathodic epoxy] coating.

D. Hot-Gas Reheat Refrigerant Coil:

2. [Aluminum] [Copper]-plate fin and seamless[internally grooved] copper tube in steel casing with equalizing-type vertical distributor.

3. Polymer strip shall prevent all copper coil from contacting steel coil frame or condensate pan.

4. [Baked phenolic] [Cathodic epoxy] coating.

E. 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. Over-temperature 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. Magnetic contactors.
   b. [Magnetic] [Mercury] contactors.
   c. Step Controller: Pilot lights and override toggle switch for each step.
   d. SCR Controller: Pilot lights operate on load ratio, a minimum of five steps.
   e. Time-delay relay.
   f. Airflow proving switch.

2.5 REFRIGERANT CIRCUIT COMPONENTS

A. [Number of Refrigerant Stages]:

1. One for 7 tons and smaller.
2. Two for 7.5 tons and larger.

B. Number of Refrigerant Circuits: [One] [Two] <Insert number>.

C. Compressor: [Hermetic, scroll], mounted on vibration isolators; with internal overcurrent and high-temperature protection, internal pressure relief[, and crankcase heater].

D. Compressor: [Hermetic, reciprocating] [Semihermetic, reciprocating] [Hermetic, scroll], mounted on vibration isolators; with internal overcurrent and high-temperature protection, internal pressure relief[, and crankcase heater].

E. Refrigeration Specialties:

1. Refrigerant: [R-22] [R-407C] [R-410A] <Insert type>.
2. Refrigerant: R-410A.
3. Expansion valve with replaceable thermostatic element.
4. Refrigerant filter/dryer.
7. Minimum off-time relay.
10. Low-ambient kit high-pressure sensor.
11. Hot-gas reheat solenoid valve with a replaceable magnetic coil.
12. Hot-gas bypass solenoid valve with a replaceable magnetic coil.
13. Four-way reversing valve with a replaceable magnetic coil, thermostatic expansion valves with bypass check valves, and a suction line accumulator.

2.6 AIR FILTRATION

A. Minimum arrestance according to ASHRAE 52.1, and a minimum efficiency reporting value (MERV) according to ASHRAE 52.2.

2. Pleated: Minimum 90 percent arrestance, and MERV 8.

2.7 GAS FURNACE

A. Description: Factory assembled, piped, and wired; complying with ANSI Z21.47 and NFPA 54.

1. CSA Approval: Designed and certified by and bearing label of CSA.

B. Burners: Stainless steel.

1. Fuel: Natural gas.
2. Ignition: Electronically controlled electric spark or hot-surface igniter with flame sensor.
3. High-Altitude [Model] [Kit]: For Project elevations more than 2000 feet above sea level.

C. Heat-Exchanger and Drain Pan: Stainless steel.

D. Venting: Gravity vented[ with vertical extension].

E. Power Vent: Integral, motorized centrifugal fan interlocked with gas valve[ with vertical extension].

F. Safety Controls:

1. Gas Control Valve: [Single stage] [Two stage] [Modulating].

2.8 DAMPERS

A. Outdoor-Air Damper: Linked damper blades, for 0 to 25 percent outdoor air, with [manual] [motorized] damper filter.
B. 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 Damper: Gravity actuated or motorized, as required by ASHRAE/IESNA 90.1, with bird screen and hood.

2.9 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 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.

2.10 CONTROLS

A. [Control equipment and sequence of operation] are specified in Division 23 Section "Instrumentation and Control for HVAC."

B. [Basic Unit Controls]:

1. Control-voltage transformer.
2. Wall-mounted thermostat or sensor with the following features:
   b. Fan on-auto switch.
   c. Fan-speed switch.
   e. Adjustable deadband.
   f. [Concealed] [Exposed] set point.
   g. [Concealed] [Exposed] indication.
   h. [Degree F] [Degree C] indication.
   i. Unoccupied-period-override push button.
   j. Data entry and access port to input temperature[ and humidity] set points, occupied and unoccupied periods, and output room temperature[ and humidity], supply-air temperature, operating mode, and status.

3. Wall-mounted humidistat or sensor with the following features:
   a. [Concealed] [Exposed] set point.
   b. [Concealed] [Exposed] indication.

4. [Remote Wall] [Unit]-Mounted Annunciator Panel for Each Unit:
   a. Lights to indicate power on, cooling, heating, fan running, filter dirty, and unit alarm or failure.
b. DDC controller or programmable timer and interface with HVAC instrumentation and control system.
c. Digital display of outdoor-air temperature, supply-air temperature, return-air temperature, economizer damper position, indoor-air quality, and control parameters.

C. [Electronic] [DDC] 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] <Insert temperature> 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 Section “Fire Detection and Alarm.”
   d. Low-Discharge Temperature: Stop fan and close outdoor-air damper if supply air temperature is less than [40 deg F] <Insert temperature>.
   e. Defrost Control for Condenser Coil: Pressure differential switch to initiate defrost sequence.

3. Scheduled Operation: Occupied and unoccupied periods on [seven] [365]-day clock with a minimum of [two] [four] programmable periods per day.
4. Unoccupied Period:
   c. Override Operation: [Two] <Insert number> hours.

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[, and operate hot-gas bypass] to match compressor output to cooling load to maintain [room] [discharge] temperature[ and humidity]. Cycle condenser fans to maintain maximum hot-gas pressure. Operate low-ambient control kit to maintain minimum hot-gas pressure.
   b. Unoccupied Periods: [Compressors off] [Cycle compressors and condenser fans for heating to maintain setback temperature].
   c. Switch reversing valve for heating or cooling mode on air-to-air heat pump.

7. Hot-Gas Reheat-Coil Operation:
   a. Occupied Periods: Humidistat opens hot-gas valve to provide hot-gas reheat, and cycles compressor.
   b. Unoccupied Periods: Reheat not required.

8. Gas Furnace Operation:
a. Occupied Periods: [Cycle] [Stage] [Modulate] burner to maintain [room] [discharge] temperature.
b. Unoccupied Periods: Cycle burner to maintain setback temperature.

9. Electric-Heating-Coil Operation:
   a. Occupied Periods: [Cycle] [Stage] [Modulate] coil to maintain [room] [discharge] temperature.
   b. Unoccupied Periods: Energize coil to maintain setback temperature.
   c. Operate supplemental electric heating coil with compressor for heating with outdoor temperature below [25 deg F] <Insert temperature>.

10. Fixed Minimum Outdoor-Air Damper Operation:
   a. Occupied Periods: Open to [25] <Insert percent> percent.
   b. Unoccupied Periods: Close the outdoor-air damper.

11. Economizer Outdoor-Air Damper Operation:
   a. Occupied Periods: Open to [10] [25] <Insert percent> percent fixed minimum intake, and maximum 100 percent of the fan capacity to comply with ASHRAE Cycle II. Controller shall permit air-side economizer operation when outdoor air is less than [60 deg F] <Insert temperature>. Use [outdoor-air temperature] [mixed-air and outdoor-air temperature] [outdoor-air enthalpy] [mixed-air temperature and select between outdoor-air and return-air enthalpy] to adjust mixing dampers. [Start relief-air fan with end switch on outdoor-air damper.] During economizer cycle operation, lock out cooling.
   b. Unoccupied Periods: Close outdoor-air damper and open return-air damper.
   c. Outdoor-Airflow Monitor: Accuracy maximum plus or minus 5 percent within 15 and 100 percent of total outdoor air. Monitor microprocessor shall adjust for temperature, and output shall range from [2- to 10-V dc] [4 to 20 mA] <Insert value>.

12. Carbon Dioxide Sensor Operation:
   a. Occupied Periods: Reset minimum outdoor-air ratio down to minimum [10] <Insert percent> percent to maintain maximum [1000-ppm] <Insert concentration> concentration.
   b. Unoccupied Periods: Close outdoor-air damper and open return-air damper.

13. VVT Relays:
   a. Provide heating- and cooling-mode changeover relays compatible with VVT terminal control system required in Division 23 Sections "Air Terminal Units" and "Instrumentation and Control for HVAC."

D. [Interface Requirements for HVAC Instrumentation and Control Syst]em:
   1. Interface relay for scheduled operation.
   2. Interface relay to provide indication of fault at the central workstation and diagnostic code storage.
   3. Provide [BACnet] [or] [LonWorks] compatible interface for central HVAC control workstation for the following:
      a. Adjusting set points.
      b. Monitoring supply fan start, stop, and operation.
c. Inquiring data to include [outdoor-air damper position], supply- and room-air temperature [and humidity].

d. Monitoring occupied and unoccupied operations.

e. Monitoring constant and variable motor loads.

f. Monitoring variable-frequency drive operation.

g. Monitoring cooling load.

h. Monitoring economizer cycles.

i. Monitoring air-distribution static pressure and ventilation air volume.

2.11 ACCESSORIES

A. Electric heater with integral thermostat maintains minimum 50 deg F temperature in gas burner compartment.

B. Duplex, 115-V, ground-fault-interrupter outlet with 15-A overcurrent protection. Include transformer if required. Outlet shall be energized even if the unit main disconnect is open.

C. Duplex, 115-V, ground-fault-interrupter outlet with 15-A overcurrent protection. Include transformer if required. [Outlet shall be energized even if the unit main disconnect is open.]

D. Low-ambient kit using [staged] [damper on] [variable-speed] condenser fans for operation down to [35 deg F] <Insert temperature>.

E. Filter differential pressure switch with sensor tubing on either side of filter. Set for final filter pressure loss.

F. Coil guards of painted, galvanized-steel wire.

G. Hail guards of galvanized steel, painted to match casing.

H. Concentric diffuser with white louvers and polished aluminum return grilles, insulated diffuser box with mounting flanges, and interior transition.

2.12 ROOF CURBS

A. Roof curbs with vibration isolators and wind or seismic restraints are specified in Division 23 Section "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. Thickness: [1 inch] [1-1/2 inches] [2 inches] <Insert thickness>.
2. Application: Factory applied with adhesive and mechanical fasteners to the internal surface of curb.
   a. Liner Adhesive: Comply with ASTM C 916, Type I.
   b. Mechanical Fasteners: Galvanized steel, suitable for adhesive attachment, mechanical attachment, or welding attachment to duct without damaging liner when applied as recommended by manufacturer and without causing leakage in cabinet.
   c. Liner materials applied in this location shall have air-stream surface coated with a temperature-resistant coating or faced with a plain or coated fibrous mat or fabric depending on service air velocity.
   d. Liner Adhesive: Comply with ASTM C 916, Type I.

C. Curb Height: 14 inches.

D. Curb Height: [14 inches] [24 inches] [36 inches] <Insert height>.

E. Curb Height: [14 inches] [24 inches] [36 inches] <Insert height>.

F. 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 Division 23 Section "Vibration and Seismic Controls for HVAC Piping and Equipment" for wind-load requirements.

2.13 CAPACITIES AND CHARACTERISTICS

A. Supply-Air Fan:
   1. Airflow: <Insert cfm>.
   2. External Static Pressure: <Insert inches wg>.
   3. Fan Speed: <Insert rpm>.
   5. Motor Speed: <Insert rpm>.

B. Relief-Air Fan:
   1. Airflow: <Insert cfm>.
   2. External Static Pressure: <Insert inches wg>.
   3. Fan Speed: <Insert rpm>.
   5. Motor Speed: <Insert rpm>.

C. Outdoor-Air-Intake Relief-Air Fan:
   1. Airflow: <Insert cfm>.
   2. Static Pressure: <Insert inches wg>.
   3. Fan Speed: <Insert rpm>.
   5. Motor Speed: <Insert rpm>.

D. Supply-Air Refrigerant Coil:
1. Total Cooling Capacity: <Insert Btu/h>.
2. Sensible Cooling Capacity: <Insert Btu/h>.
5. Coating: [Baked phenolic] [Cathodic epoxy].

E. Outdoor Air Refrigerant Coil:
1. Ambient Air Temperature: <Insert deg F>.
2. Coating: [Baked phenolic] [Cathodic epoxy].
3. Fan Motor: <Insert value>.
4. Number of Fans: <Insert number>.

F. Hot-Gas Reheat Coil:
1. Heating Capacity: <Insert Btu/h>.
2. Entering-Air Temperature: <Insert deg F>.
4. Coating: [Baked phenolic] [Cathodic epoxy].

G. Electric-Resistance Heating Coil:
2. Number of Steps: <Insert number>.

H. Compressors:
5. Coefficient of Performance (COP): <Insert value>.

I. Gas Furnace:
1. Airflow: <Insert cfm>.
2. Minimum AFUE: <Insert value> percent.
5. Input: <Insert Btu/h>.
6. Output: <Insert Btu/h>.

J. Recirculating-Air Filters:
1. Minimum Face Area: <Insert sq. ft.>.
2. Thickness: [1 inch] [2 inches] <Insert thickness>.

K. Outdoor Air Filters:
1. Minimum Face Area: \(<\text{Insert sq. ft.}>\).
2. Thickness: \([1 \text{ inch}] [2 \text{ inches}] <\text{Insert thickness}>\).
3. Initial Resistance: \(<\text{Insert inches wg}>\).
4. Final Resistance: \(<\text{Insert inches wg}>\).

L. Electrical Characteristics for Single-Point Connection:
1. Voltage: \(<\text{Insert value}>\).
2. Phase: \(<\text{Insert value}>\).
3. Hertz: \(<\text{Insert value}>\).
4. Full-Load Amperes: \(<\text{Insert value}>\).
5. Minimum Circuit Ampacity: \(<\text{Insert value}>\).
6. Maximum Overcurrent Protection: \(<\text{Insert amperage}>\).

M. Sound Power: Radiated from condenser casing.
1. 1st Octave: \(<\text{Insert value}>\) dB.
2. 2nd Octave: \(<\text{Insert value}>\) dB.
3. 3rd Octave: \(<\text{Insert value}>\) dB.
4. 4th Octave: \(<\text{Insert value}>\) dB.
5. 5th Octave: \(<\text{Insert value}>\) dB.
6. 6th Octave: \(<\text{Insert value}>\) dB.
7. 7th Octave: \(<\text{Insert value}>\) dB.
8. 8th Octave: \(<\text{Insert value}>\) dB.

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 RTUs.
B. Examine roughing-in for RTUs to verify actual locations of piping and duct connections before equipment installation.
C. Examine roofs for suitable conditions where RTUs will be installed.
D. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION
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 4 inches larger than supported equipment and minimum 6 inches above finished ground elevation.
2. Place and secure anchorage devices. Use supported equipment manufacturer's setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
3. Install anchor bolts to elevations required for proper attachment to supported equipment. 
4. Install anchor bolts according to anchor-bolt manufacturer's written instructions. 
5. Use 3000-psi, 28-day compressive-strength concrete and reinforcement as specified in Division 03 concrete section. 
6. Use [3000-psi] <insert value>, 28-day compressive-strength concrete and reinforcement as specified in Division 03 Section "[Cast-in-Place Concrete] [Miscellaneous Cast-in-Place Concrete]."

B. Equipment Mounting: Install RTUs on concrete base using [elastomeric pads] [elastomeric mounts] [restrained spring isolators] <insert device>. Comply with requirements for concrete base specified in Division 03 Section "[Cast-in-Place Concrete] [Miscellaneous Cast-in-Place Concrete]."

   1. Minimum Deflection: [1/4 inch] [1 inch] <insert dimension>.

C. Roof Curb: Install on roof structure, level and secure. Install RTUs on curbs and coordinate roof penetrations and flashing with roof construction.

D. Roof Curb: Install on roof structure or concrete base, level and secure, according to [NRCA's "Low-Slope Membrane Roofing Construction Details Manual," Illustration "Raised Curb Detail for Rooftop Air Handling Units and Ducts."] [ARI Guideline B.] Install RTUs on curbs and coordinate roof penetrations and flashing with roof construction specified in Division 07 Section "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] [pilings]. 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. [Wind and seismically restrained vibration isolation roof-curb rails are specified in Division 23 Section "Vibration and Seismic Controls for HVAC Piping and Equipment."]

3.3 CONNECTIONS

A. Install condensate drain, minimum connection size, with trap and route down to roof.

B. Install condensate drain, minimum connection size, with trap and indirect connection to nearest roof drain or area drain.

C. Install piping adjacent to RTUs to allow service and maintenance.

   1. Gas Piping: Comply with applicable requirements in Division 23 Section "Facility Natural-Gas Piping." Connect gas piping to burner, full size of gas train inlet, and connect with union and shutoff valve with sufficient clearance for burner removal and service.

D. 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 RTUs with flexible duct connectors specified in Division 23 Section "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] <Insert thickness> thick. Concrete, formwork, and reinforcement are specified in Division 03.
6. Install <Insert type of insulation for sound attenuation > inside roof curb, <Insert thickness> thick.

3.4 FIELD QUALITY CONTROL

A. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect, test, and adjust components, assemblies, and equipment installations, including connections. Report results in writing.

B. Perform tests and inspections and prepare test reports.

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. Report results in writing.

C. Tests and Inspections:

1. After installing RTUs 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.

D. Remove and replace malfunctioning units and retest as specified above.

3.5 STARTUP SERVICE

A. Engage a factory-authorized service representative to perform startup service.

B. Complete installation and startup checks according to manufacturer's written instructions and do the following:

1. Inspect for visible damage to unit casing.
2. Inspect for visible damage to furnace combustion chamber.
3. Inspect for visible damage to compressor, coils, and fans.
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. Verify that filters are installed.
9. Clean condenser coil and inspect for construction debris.
10. Clean furnace flue and inspect for construction debris.
11. Connect and purge gas line.
12. Remove packing from vibration isolators.
13. Inspect operation of barometric relief dampers.
14. Verify lubrication on fan and motor bearings.
15. Inspect fan-wheel rotation for movement in correct direction without vibration and binding.
16. Adjust fan belts to proper alignment and tension.
17. Start unit according to manufacturer's written instructions.
   a. Start refrigeration system.
   b. Do not operate below recommended low-ambient temperature.
   c. Complete startup sheets and attach copy with Contractor's startup report.
18. Inspect and record performance of interlocks and protective devices; verify sequences.
19. Operate unit for an initial period as recommended or required by manufacturer.
20. Perform the following operations for both minimum and maximum firing. Adjust burner for peak efficiency.
   a. Measure gas pressure on manifold.
   b. Inspect operation of power vents.
   c. Measure combustion-air temperature at inlet to combustion chamber.
   d. Measure flue-gas temperature at furnace discharge.
   e. Perform flue-gas analysis. Measure and record flue-gas carbon dioxide and oxygen concentration.
   f. Measure supply-air temperature and volume when burner is at maximum firing rate and when burner is off. Calculate useful heat to supply air.
22. Adjust and inspect high-temperature limits.
23. Inspect outdoor-air dampers for proper stroke and interlock with return-air dampers.
24. Start refrigeration system and measure and record the following when ambient is a minimum of 15 deg F above return-air temperature:
   a. Coil leaving-air, dry- and wet-bulb temperatures.
   b. Coil entering-air, dry- and wet-bulb temperatures.
   c. Outdoor-air, dry-bulb temperature.
   d. Outdoor-air-coil, discharge-air, dry-bulb temperature.
25. Inspect controls for correct sequencing of heating, mixing dampers, refrigeration, and normal and emergency shutdown.
26. Measure and record the following minimum and maximum airflows. Plot fan volumes on fan curve.
   a. Supply-air volume.
   b. Return-air volume.
   c. Relief-air volume.
   d. Outdoor-air intake volume.
27. Simulate maximum cooling demand and inspect the following:
   a. Compressor refrigerant suction and hot-gas pressures.
   b. Short circuiting of air through condenser coil or from condenser fans to outdoor-air intake.
28. Verify operation of remote panel including pilot-light operation and failure modes. Inspect the following:
   b. Low-temperature safety operation.
   c. Filter high-pressure differential alarm.
   d. Economizer to minimum outdoor-air changeover.
   e. Relief-air fan operation.
   f. Smoke and firestat alarms.

29. After startup and performance testing and prior to Substantial Completion, replace existing filters with new filters.

3.6 CLEANING AND ADJUSTING

A. 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 during other-than-normal occupancy hours for this purpose.

B. After completing system installation and testing, adjusting, and balancing RTU and air-distribution systems, clean filter housings and install new filters.

3.7 DEMONSTRATION

A. Train Owner's maintenance personnel to adjust, operate, and maintain RTUs. Refer to Division 01 Section "Demonstration and Training."

END OF SECTION 23 7413
WMU Design Guidelines Instructions: These guidelines are to be used by the Design Professional to inform the design process and outline WMU-specific desires for all University projects. These guidelines have been edited to reflect WMU preferences, and the intent is for the Design Professional to use this information to guide their normal specifications-writing process. Straying from what is indicated in the guidelines is not prohibited, but shall be discussed with WMU during the development of the project.

SECTION 23 8123 - COMPUTER-ROOM AIR-CONDITIONERS

PART 1 - GENERAL

1.1 SUMMARY
A. Section Includes:
1. Floor-mounted computer-room air conditioners, 6 tons and larger.
2. Floor-mounted computer-room air conditioners, 5 tons and smaller.
3. Ceiling-mounted computer-room air conditioners.
4. Console computer-room air conditioners.

1.2 DEFINITION
A. BAS: Building automation system.

1.3 PERFORMANCE REQUIREMENTS
A. Seismic Performance: Computer-room air conditioners shall withstand the effects of earthquake motions determined according to [ASCE/SEI 7] <Insert requirement>.
   1. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified and the unit will be fully operational after the seismic event."

1.4 ACTION SUBMITTALS
A. Product Data: For each type of product indicated. Include rated capacities, operating characteristics, electrical characteristics, and furnished specialties and accessories.
B. LEED Submittals:
   1. Product Data for Credit EA 4: Documentation indicating that equipment and refrigerants comply.
   2. Product Data for Prerequisite IEQ 1: Documentation indicating that units comply with ASHRAE 62.1, Section 5 - "Systems and Equipment."
C. Shop Drawings: For computer-room air conditioners. 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.

D. Color Samples: For unit cabinet, discharge grille, and exterior louver and for each color and texture specified.

1.5 INFORMATIONAL SUBMITTALS

A. Coordination Drawings: Plans, elevations, and other details, drawn to scale, using input from Installers of the items involved.

B. Seismic Qualification Certificates: For computer-room air conditioners, accessories, and components, from manufacturer.
   1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
   2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
   3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.

C. Field quality-control reports.

D. Warranty: Sample of special warranty.

1.6 CLOSEOUT SUBMITTALS

A. Operation and maintenance data.

1.7 MAINTENANCE MATERIAL SUBMITTALS

A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
   1. Fan Belts: [One] <Insert number> set(s) for each belt-driven fan.
   2. Filters: One set of filters for each unit.

1.8 QUALITY ASSURANCE

A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

B. ASHRAE Compliance:
   1. Fabricate and label refrigeration system to comply with ASHRAE 15, "Safety Standard for Refrigeration Systems."
2. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1, Section 4 - "Outdoor Air Quality," Section 5 - "Systems and Equipment," Section 6 - "Ventilation Rate Procedures," and Section 7 - "Construction and Startup."

C. ASHRAE/IESNA Compliance: Applicable requirements in ASHRAE/IESNA 90.1.

D. ASME Compliance: Fabricate and label water-cooled condenser shell to comply with ASME Boiler and Pressure Vessel Code: Section VIII, "Pressure Vessels," Division 1.

1.9 COORDINATION

A. Coordinate layout and installation of computer-room air conditioners and suspension system with other construction that penetrates ceilings or is supported by them, including light fixtures, HVAC equipment, fire-suppression system, and partition assemblies.

B. Coordinate installation of computer-room air conditioners with computer-room access flooring Installer.

C. Coordinate sizes and locations of concrete bases with actual equipment provided.

D. Coordinate sizes and locations of equipment supports and roof penetrations with actual equipment provided.

1.10 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 FLOOR-MOUNTED UNITS 6 TONS AND LARGER

2.2 FLOOR-MOUNTED UNITS 5 TONS AND SMALLER

2.3 CEILING-MOUNTED UNITS

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

B. Manufacturers: Subject to compliance with requirements, [provide products by one of the following] [available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following):

C. Basis-of-Design Product: Subject to compliance with requirements, provide [product indicated on Drawings] <Insert manufacturer’s name; product name or designation> or comparable product by one of the following:

1. Airflow Company; a division of The McClain Company, Inc.
2. Carrier Corporation; a United Technologies company.
3. Compu-Aire, Inc.
4. Data Aire Inc.
5. Koldwave, Inc.; a Mestek company.
7. Daikin/McQuay.
8. Stulz-ATS.
10. <Insert manufacturer’s name>.

D. Description: Self-contained, factory assembled, prewired, and prepiped; consisting of cabinet, fan, filters, and controls; for horizontal above ceiling mounting with duct connections.

E. Description: Self-contained, factory assembled, prewired, and prepiped; consisting of cabinet, fan, filters, and controls; for horizontal ceiling mounting to fit T-bar ceiling opening of 24 by 48 inches.

F. Cabinet: Galvanized steel with baked-enamel finish, insulated with 1/2-inch-thick duct liner.

1. Integral factory-supplied supply and return grille to fit ceiling grid kit of 24 by 48 inches, with filter.
2. Finish of Interior Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.

G. Supply-Air Fan: Forward curved, centrifugal, and directly driven by two-speed motor.

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-22] [R-407C] [R-410A] <Insert type>.
4. Refrigerant: R-407C or R-410A.
5. Refrigerant Evaporator Coil: 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.
   a. Cooling Medium: [Water] [Glycol solution].

9. Split system shall have suction- and liquid-line compatible fittings and refrigerant piping for field interconnection.

I. Hydronic Cooling Coil: Seamless copper tubes expanded into aluminum fins with two-way control valve.
   1. Cooling Medium: [Water] [Glycol solution].
   2. 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].

J. Remote, Air-Cooled, Glycol-Solution Cooler: Corrosion-resistant cabinet, copper-tube aluminum-fin coil, direct-drive propeller fan with fan guards, and single-phase motors with internal overload protection.

K. Glycol-Solution Pump Package: Weatherproof and vented enclosure of enameled, galvanized steel on structural base frame containing centrifugal pump with mechanical seal.
   1. Piping: Interconnecting piping, to and from remote, air-cooled glycol-solution cooler, with shutoff valves, flow switches, unions, and pressurized expansion tank with air purge vent and system-charging connection.
   2. Glycol: Inhibited ethylene glycol and water solution mixed 50:50, suitable for operating temperature of minus 40 deg F.

L. Electric-Resistance Heating Coil: Finned-tube electric elements with contactor, dehumidification relay, and high-temperature-limit switches.

M. Filter: 1-inch- thick, disposable, glass-fiber media.
   1. Initial Resistance: <Insert inches wg>.
   3. Arrestance (ASHRAE 52.1): [90] <Insert number> percent.

N. Atomizing Humidifier: Centrifugal atomizer with stainless-steel pan, demister pad, and solenoid valve.

O. Electrode Steam Humidifier: Self-contained, microprocessor-controlled unit with disposable, polypropylene-plastic cylinders, and having field-adjustable steel electrodes and stainless-steel steam dispersion tube.
1. Plumbing Components and Valve Bodies: Plastic, linked by flexible rubber hosing, with water fill with air gap and solenoid valve incorporating built-in strainer, pressure-reducing and flow-regulating orifice, and drain with integral air gap.

2. Control: Fully modulating to provide gradual 0 to 100 percent capacity with field-adjustable maximum capacity; with high-water probe.

3. Drain Cycle: Field-adjustable drain duration and drain interval.

P. Disconnect Switch: Nonautomatic, molded-case circuit breaker with handle accessible when panel is closed and capable of preventing access until switched to off position.

Q. Control System: Unit-mounted panel with main fan contactor, compressor contactor, compressor start capacitor, control transformer with circuit breaker, solid-state temperature-control modules, time-delay relay, heating contactor, and high-temperature thermostat. Provide solid-state, wall-mounted control panel with start-stop switch and adjustable temperature set point.

R. Control System: Unit-mounted panel with main fan contactor, compressor contactor, compressor start capacitor, control transformer with circuit breaker, solid-state temperature-[and humidity]-control modules, humidity contactor, time-delay relay, heating contactor, and high-temperature thermostat. Provide solid-state, wall-mounted control panel with start-stop switch, adjustable humidity set point, and adjustable temperature set point.

2.4 CONSOLE UNITS

2.5 FAN MOTORS

A. Comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements for motors specified in Section 23 0513 "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 electrical Sections.

B. <Insert unique motor characteristics>.

2.6 CAPACITIES AND CHARACTERISTICS

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 hydronic piping systems to verify actual locations of piping connections before equipment installation.

C. Examine ceilings and roofs for suitable conditions where computer-room air conditioners will be installed.

D. Examine walls, floors, and roofs for suitable conditions where computer-room air conditioners will be installed.

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

3.2 INSTALLATION

A. Install computer-room air conditioners level and plumb, maintaining manufacturer's recommended clearances.

B. Computer-Room Air-Conditioner Mounting: Install using [elastomeric pads] [elastomeric mounts] [restrained spring isolators] <Insert device>. Comply with requirements for vibration isolation devices specified in [Section 23 0548 "Vibration and Seismic Controls for HVAC."].

   1. Minimum Deflection: [1/4 inch] [1 inch] <Insert dimension>.

C. Suspended Computer-Room Air Conditioners: Install using continuous-thread hanger rods and elastomeric hangers of size required to support weight of computer-room air conditioner.

   1. Comply with requirements for vibration isolation devices specified in [Section 23 0548 "Vibration and Seismic Controls for HVAC."].

   2. Comply with requirements for hangers and supports specified in Section 23 0529 "Hangers and Supports for HVAC Piping and Equipment."


E. Air-Cooled Refrigerant Condenser Mounting: Install roof-mounting condensers on equipment roof curb with bottom slope to match roof slope. Anchor units to curb with removable, cadmium-plated fasteners.

F. Install and connect precharged refrigerant tubing to component's quick-connect fittings. Install tubing to allow access to unit.

G. Air-Cooled Refrigerant Condenser Mounting: Install using [elastomeric pads] [elastomeric mounts] [restrained spring isolators] <Insert device>. Comply with requirements for vibration isolation devices specified in [Section 23 0548 "Vibration and Seismic Controls for HVAC."].

   1. Minimum Deflection: [1/4 inch] [1 inch] <Insert dimension>.
H. Remote, Air-Cooled, Glycol-Solution Cooler Mounting: Install using [elastomeric pads] [elastomeric mounts] [restrained spring isolators] <Insert device>. Comply with requirements for vibration isolation devices specified in [Section 23 0548 "Vibration and Seismic Controls for HVAC."] [Section 23 0548.13 "Vibration Controls for HVAC."]

1. Minimum Deflection: [1/4 inch] [1 inch] <Insert dimension>.

I. Glycol-Solution Pump Package Mounting: Install using [elastomeric pads] [elastomeric mounts] <Insert device>. Comply with requirements for vibration isolation devices specified in [Section 23 0548 "Vibration and Seismic Controls for HVAC."] [Section 23 0548.13 "Vibration Controls for HVAC."]

3.3 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 1116 "Domestic Water Piping." Provide adequate connections for water-cooled units, condensate drain, and humidifier flushing system.

D. Hot-Water Heating Piping: Comply with applicable requirements in Section 23 2113 "Hydronic Piping" and Section 23 2116 Hydronic Piping Specialties." Provide shutoff valves in inlet and outlet piping to heating coils.

E. Steam and Condensate Piping: Comply with applicable requirements in Section 23 2213 "Steam and Condensate Heating Piping" and Section 23 2216 Steam and Condensate Piping Specialties." Provide shutoff valves in steam inlet and steam trap in condensate outlet piping to heating coils.

F. Condenser-Water Piping: Comply with applicable requirements in Section 23 2113 "Hydronic Piping" and Section 23 2116 Hydronic Piping Specialties." Provide shutoff valves in water inlet and outlet piping on water-cooled units.

G. Connect to condensate pump and extend to indicate disposal point. Install cleanouts at changes in direction.

H. Connect duct to units with flexible connections. Comply with requirements in Division 23 Section "Air Duct Accessories."

I. Refrigerant Piping: Comply with applicable requirements in Section 23 2300 "Refrigerant Piping." Provide shutoff valves and piping.

3.4 FIELD QUALITY CONTROL

A. Manufacturer’s Field Service: Engage a factory-authorized service representative to inspect, test, and adjust components, assemblies, and equipment installations, including connections.
B. 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.

C. 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.

D. Computer-room air conditioners will be considered defective if they do not pass tests and inspections.

E. Prepare test and inspection reports.

F. After startup service and performance test, change filters and flush humidifier.

3.5 ADJUSTING

A. Adjust initial temperature set points.

B. Set field-adjustable switches and circuit-breaker trip ranges as indicated.

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

3.6 DEMONSTRATION

A. Train Owner's maintenance personnel to adjust, operate, and maintain computer-room air conditioners.

END OF SECTION 23 8123
WMU Design Guidelines Instructions: These guidelines are to be used by the Design Professional to inform the design process and outline WMU-specific desires for all University projects. These guidelines have been edited to reflect WMU preferences, and the intent is for the Design Professional to use this information to guide their normal specifications-writing process. Straying from what is indicated in the guidelines is not prohibited, but shall be discussed with WMU during the development of the project.

SECTION 23 8126 – SPLIT SYSTEM AIR CONDITIONERS

PART 1 - GENERAL

1.1 SUMMARY

A. This Section includes split-system air-conditioning [and heat pump] units consisting of separate evaporator-fan and compressor-condenser components. Units are designed for exposed or concealed mounting, and may be connected to ducts.

1.2 ACTION SUBMITTALS

A. Product Data: Include rated capacities, furnished specialties, and accessories for each type of product indicated. Include performance data in terms of capacities, outlet velocities, static pressures, sound power characteristics, motor requirements, and electrical characteristics.

B. LEED Submittals:
   1. Product Data for Credit EA 4: Documentation indicating that equipment and refrigerants comply.

C. Shop Drawings: Diagram power, signal, and control wiring.

D. Samples for Initial Selection: For units with factory-applied color finishes.

1.3 INFORMATIONAL SUBMITTALS

A. Field quality-control test reports.

B. Warranty: Special warranty specified in this Section.

1.4 CLOSEOUT SUBMITTALS

A. Operation and maintenance data.

1.5 MAINTENANCE MATERIAL SUBMITTALS

A. Furnish extra materials described below that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
1. Filters: One set of filters for each unit.
2. Fan Belts: One set of belts for each unit.

1.6 QUALITY ASSURANCE

A. Product Options: Drawings indicate size, profiles, and dimensional requirements of split-system units and are based on the specific system indicated. Refer to Division 01 Section “Product Requirements.”

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. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1, Section 5 - “Systems and Equipment” and Section 7 - “Construction and Startup.”

D. ASHRAE/IESNA 90.1 Compliance: Applicable requirements in ASHRAE/IESNA 90.1, Section 6 - “Heating, Ventilating, and Air-Conditioning.”

1.7 COORDINATION

A. Coordinate size and location of concrete bases for units. Cast anchor-bolt inserts into bases. Concrete, reinforcement, and formwork are specified in Division 03 Section “Cast-in-Place Concrete.”

B. Coordinate size, location, and connection details with roof curbs, equipment supports, and roof penetrations.

1.8 WARRANTY

A. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace components of split-system air-conditioning units that fail in materials or workmanship within specified warranty period.

1. Warranty Period: Five years from date of Substantial Completion.
2. Warranty Period: [Five] <Insert other number> 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. Enviromaster International.
2. Carrier Air Conditioning; Div. of Carrier Corporation.
3. Friedrich Air Conditioning Company.
4. Modine.
5. Mitsubishi Electronics America, Inc.; HVAC Division.
7. Trane.
8. JCI/York.
10. Evcon Industries, Inc.
11. First Co.
12. Koldwave, Inc.
13. Lennox Industries Inc.
14. Mitsubishi Electric Sales Canada, Inc.
15. Mitsubishi Heavy Industries America, Inc.; Air-Conditioning & Refrigeration Division, Inc.
16. Tadiran Electronic Industries Inc.; Appliance Division.

2.2 CONCEALED EVAPORATOR-FAN COMPONENTS

A. Chassis: Galvanized steel with flanged edges, removable panels for servicing, and insulation on back of panel.
   1. Insulation: Faced, glass-fiber duct liner.
   2. Drain Pans: Galvanized steel, with connection for drain; insulated[ and complying with ASHRAE 62.1].
   3. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.

B. Refrigerant Coil: Copper tube, with mechanically bonded aluminum fins, complying with ARI 210/240, and with thermal-expansion valve.

C. [Water] [Steam] Coil: Copper tube, with mechanically bonded aluminum fins spaced no closer than 0.1 inch; leak tested to 300 psig underwater; and having a two-position control valve.

D. 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.

E. Fan: Forward-curved, double-width wheel of galvanized steel; directly connected to motor.

F. Fan Motors: Comply with requirements in Division 23 Section "Common Motor Requirements for HVAC Equipment."
   1. Special Motor Features: Multitapped, multispeed with internal thermal protection and permanent lubrication.

G. Disposable Filters: 1 inch thick, in fiberboard frames[ with ASHRAE 52.2 MERV rating of 6 or higher].

H. Wiring Terminations: Connect motor to chassis wiring with plug connection.
2.3 FLOOR-MOUNTING, EVAPORATOR-FAN COMPONENTS

A. Cabinet: Enameled steel with removable panels on front and ends in color selected by Architect.

1. Discharge Grille: [Steel with surface-mounted frame] [Welded steel bars forming a linear grille and welded into supporting panel].
2. Insulation: Faced, glass-fiber, duct liner.
3. Drain Pans: Galvanized steel, with connection for drain; insulated and complying with ASHRAE 62.1.
4. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.

B. Refrigerant Coil: Copper tube, with mechanically bonded aluminum fins, complying with ARI 210/240, and with thermal-expansion valve.

C. [Water] [Steam] Coil: Copper tube, with mechanically bonded aluminum fins spaced no closer than 0.1 inch; leak tested to 300 psig underwater; and having a 2-position control valve.

D. 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.

E. Fan: Direct drive, centrifugal, with power-induced outside air.

F. Fan Motors: Comply with requirements in Division 23 Section "Common Motor Requirements for HVAC Equipment."

1. Special Motor Features: Multitapped, multispeed with internal thermal protection and permanent lubrication.

G. Filters: [Permanent, cleanable] [Disposable, with ASHRAE 52.2 MERV rating of 6 or higher].

2.4 WALL-MOUNTING, EVAPORATOR-FAN COMPONENTS

A. Cabinet: Enameled steel with removable panels on front and ends in color selected by Architect, and discharge drain pans with drain connection.

1. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.
2. Drain Pan and Drain Connection: Comply with ASHRAE 62.1.

B. Refrigerant Coil: Copper tube, with mechanically bonded aluminum fins, complying with ARI 210/240, and with thermal-expansion valve.

C. 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.
D. Fan: Direct drive, centrifugal fan.

E. Fan Motors: Comply with requirements in Division 23 Section "Common Motor Requirements for HVAC Equipment."
   1. Special Motor Features: Multitapped, multispeed with internal thermal protection and permanent lubrication.

F. Filters: [Permanent, cleanable] [Disposable, with ASHRAE 52.2 MERV rating of 6 or higher].

2.5 CEILING-MOUNTING, EVAPORATOR-FAN COMPONENTS

A. Cabinet: Enamelled steel with removable panels on front and ends [in color selected by Architect], and discharge drain pans with drain connection.
   1. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.
   2. Drain Pan and Drain Connection: Comply with ASHRAE 62.1.

B. Refrigerant Coil: Copper tube, with mechanically bonded aluminum fins, complying with ARI 210/240, and with thermal-expansion valve.

C. 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.

D. **Water** [Steam] Coil: Copper tube, with mechanically bonded aluminum fins spaced no closer than 0.1 inch; leak tested to 300 psig underwater; and having a two-position control valve.

E. Fan: Direct drive, centrifugal fan, with power-induced outside air, and integral condensate pump.

F. Fan Motors: Comply with requirements in Division 23 Section "Common Motor Requirements for HVAC Equipment."
   1. Special Motor Features: Multitapped, multispeed with internal thermal protection and permanent lubrication.

G. Filters: Permanent, cleanable.

H. Filters: [Permanent, cleanable] [Disposable, with ASHRAE 52.2 MERV rating of 6 or higher].

2.6 AIR-COOLED, COMPRESSOR-CONDENSER COMPONENTS

A. 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.
WMU Design Guidelines

SPLIT SYSTEM AIR CONDITIONERS

2.7 WATER-COOLED, COMPRESSOR-CONDENSER COMPONENTS

A. Casing: Steel, with baked-enamel finish in color selected by Architect, removable panels for access to controls, and mounting holes in base. Provide brass service valves, fittings, and gage ports on exterior of casing.

B. Compressor: Hermetically sealed with crankcase heater and mounted on vibration isolation. Compressor motor shall have thermal- and current-sensitive overload devices, start capacitor, relay, and contactor.

1. Compressor Type: [Reciprocating] [Scroll].
2. Two-speed compressor motor with manual-reset high-pressure switch and automatic-reset low-pressure switch.
3. Refrigerant: [R-22] [R-407C] [R-410A] <Insert type>.
4. Refrigerant: R-407C or R-410A.

C. Refrigerant Coil: Copper tube, with mechanically bonded aluminum fins, complying with ARI 210/240, and with liquid subcooler.

D. [Heat Pump Components]: Reversing valve and low-temperature air cut-off thermostat.

E. Fan: Aluminum-propeller type, directly connected to motor.

F. Motor: Permanently lubricated, with integral thermal-overload protection.

G. Low Ambient Kit: Permits operation down to 45 deg F.

H. Mounting Base: Polyethylene.

2.8 ACCESSORIES

A. Control equipment and sequence of operation are specified in Division 23 Sections "Instrumentation and Control for HVAC" and "Sequence of Operations for HVAC Controls."

B. Thermostat: Low voltage with subbase to control compressor and evaporator fan.

C. Thermostat: Wireless infrared functioning to remotely control compressor and evaporator fan, with the following features:

D. Thermostat: Wall mounted hard wired, functioning to remotely control compressor and evaporator fan, with the following features:
   1. Compressor time delay.
   2. 24-hour time control of system stop and start.
   3. Liquid-crystal display indicating temperature, set-point temperature, time setting, operating mode, and fan speed.
   4. Fan-speed selection, including auto setting.

E. Automatic-reset timer to prevent rapid cycling of compressor.

F. Condensate Pump: Provide condensate mini-pump for condensate disposal.

G. Safety: High condensate pan water level shutdown.

H. Refrigerant Line Kits: Soft-annealed copper suction and liquid lines factory cleaned, dried, pressurized, and sealed; factory-insulated suction line with flared fittings at both ends.
   1. Minimum Insulation Thickness: 1/2 inch thick.
   2. Minimum Insulation Thickness: [1/2 inch] [1 inch] <Insert thickness> thick.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Install units level and plumb.

B. Install evaporator-fan components using manufacturer’s standard mounting devices securely fastened to building structure.

C. Install ground-mounting, compressor-condenser components on 4-inch- thick, reinforced concrete base; 4 inches larger on each side than unit. Concrete, reinforcement, and formwork are specified in Division 03 Section “Cast-in-Place Concrete.” Coordinate anchor installation with concrete base.

D. Install ground-mounting, compressor-condenser components on polyethylene mounting base. Anchor units to base with removable, cadmium-plated fasteners.
E. Install roof-mounting compressor-condenser components on polyethylene mounting base. Anchor units to base with removable, cadmium-plated fasteners.

F. Install seismic restraints.

G. Install compressor-condenser components on restrained, spring isolators with a minimum static deflection of [1 inch] <Insert other static deflection>. Refer to Division 23 Section “Vibration and Seismic Controls for HVAC Piping and Equipment.”

H. Install and connect precharged refrigerant tubing to component's quick-connect fittings. Install tubing to allow access to unit.

3.2 CONNECTIONS

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

1. Water Coil Connections: Comply with requirements in Division 23 Section "Hydronic Piping." Connect to supply and return coil with shutoff-duty valve and union or flange on the supply connection and with throttling-duty valve and union or flange on the return connection.

2. Remote Water-Cooled Condenser Connections: Comply with requirements in Division 23 Section "Hydronic Piping." Connect to supply and return with shutoff-duty valve and union or flange on the supply connection and with throttling-duty valve and union or flange on the return connection.

3. Steam Coil Connections: Comply with requirements in Division 23 Section "Steam and Condensate Heating Piping." Connect to steam piping with shutoff valve and union or flange; for condensate piping, starting from the coil connection, connect with union or flange, strainer, trap, and shutoff valve.

4. Connect to condensate drain pans and extend to [condensate pump and then to roof][nearest floor drain]. Construct deep trap at connection to drain pan and install cleanouts at changes in direction.

B. Install piping adjacent to unit to allow service and maintenance.

C. Duct Connections: Duct installation requirements are specified in Division 23 Section "Metal Ducts." Drawings indicate the general arrangement of ducts. Connect supply[ and return] ducts to split-system air-conditioning units with flexible duct connectors. Flexible duct connectors are specified in Division 23 Section "Air Duct Accessories."

D. Ground equipment according to Division 26 Section "Grounding and Bonding for Electrical Systems."

E. Electrical Connections: Comply with requirements in Division 26 Sections for power wiring, switches, and motor controls.
3.3 FIELD QUALITY CONTROL

A. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect field-assembled components and equipment installation, including connections, and to assist in field testing. Report results in writing.

B. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect, test, and adjust field-assembled components and equipment installation, including connections, and to assist in field testing. Report results in writing.

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

1. Leak Test: After installation, charge system and test for leaks. Repair leaks and retest until no leaks exist.
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.

D. Remove and replace malfunctioning units and retest as specified above.

3.4 STARTUP SERVICE

A. Engage a factory-authorized service representative to perform startup service.

B. Perform startup service.

1. Complete installation and startup checks according to manufacturer's written instructions.
2. <Insert startup steps if any.>

3.5 DEMONSTRATION

A. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain units. Refer to Division 01 Section "Demonstration and Training."

B. Train Owner's maintenance personnel to adjust, operate, and maintain units. Refer to Division 01 Section "Demonstration and Training."

END OF SECTION 23 8126
WMU Design Guidelines Instructions:  These guidelines are to be used by the Design Professional to inform the design process and outline WMU-specific desires for all University projects. These guidelines have been edited to reflect WMU preferences, and the intent is for the Design Professional to use this information to guide their normal specifications-writing process. Straying from what is indicated in the guidelines is not prohibited, but shall be discussed with WMU during the development of the project.

SECTION 23 8216 - AIR COILS

PART 1 - GENERAL

1.1 SUMMARY

A. This Section includes the following types of air coils that are not an integral part of air-handling units:

1. Hot-water.
2. Chilled-water.
3. Steam.
4. Refrigerant.
5. Electric.

B. Related Sections include the following:

1. Division 23 Sections for air coils that are integral to air-handling units.

1.2 ACTION SUBMITTALS

A. Product Data: For each type of product indicated. Include construction details, material descriptions, dimensions of individual components and profiles, and finishes for each air coil. Include rated capacity and pressure drop for each air coil.

B. LEED Submittals:

1. Product Data for Credit EA 4: Documentation indicating that equipment and refrigerants comply.

C. Shop Drawings: Diagram power, signal, and control wiring.

1.3 INFORMATIONAL SUBMITTALS

A. Field quality-control test 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:
   1. Comply with ASHRAE 15 for refrigeration 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."

PART 2 - PRODUCTS

2.1 WATER COILS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   1. Aerofin Corporation.
   2. Carrier Corporation.
   3. Coil Company, LLC.
   4. Dunham-Bush, Inc.
   7. Trane.
   8. USA Coil & Air.

B. Performance Ratings: Tested and rated according to ARI 410 and ASHRAE 33.

C. Minimum Working-Pressure/Temperature Ratings: 200 psig, 325 deg F.

D. Source Quality Control: Factory tested to 300 psig.

E. Tubes: ASTM B 743 copper, minimum 0.020 inch thick.

F. Fins: Aluminum, minimum 0.006 inch thick.

G. Headers: Cast iron with drain and air vent tapings; seamless copper tube with brazed joints, prime coated; or steel with brazed joints, prime coated.

H. Frames: Galvanized-steel channel frame, for flanged mounting.

I. Hot-Water Coil and Steam Coil, Face-and-Bypass Dampers: Alternating arrangement of coil segments and dampers.
   1. Coil Configuration: [Horizontal] [Vertical] tubes.
   2. Dampers: [Extruded-aluminum] [Galvanized-steel] blades with edge and end seals; full-length drive rod and mount for actuator [in] [outside] the airstream.
2.2 STEAM COILS

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

1. Aerofin Corporation.
2. Carrier Corporation.
3. Coil Company, LLC.
4. Dunham-Bush, Inc.
7. Trane.
8. USA Coil & Air.

B. Performance Ratings: Tested and rated according to ARI 410 and ASHRAE 33.

C. Minimum Working-Pressure/Temperature Ratings: 100 psig, 400 deg F.

D. Source Quality Control: Factory tested to 300 psig.

E. Tubes: ASTM B 743 copper, minimum 0.035 inch thick.

F. Fins: Aluminum, minimum 0.006 inch thick.

G. Headers: Cast iron with drain and air vent tapings; cast iron with cleaning plugs, and drain and air vent tapings; seamless copper tube with brazed joints, prime coated; or steel with brazed joints, prime coated.

H. Tube Type: Distributing.

I. Frames: Galvanized-steel channel frame, for flanged mounting.

J. Face-and-Bypass Dampers: Alternating arrangement of coil segments and dampers.

1. Coil Configuration: [Horizontal] [Vertical] tubes.
2. Dampers: [Extruded-aluminum] [Galvanized-steel] blades with edge and end seals; full-length drive rod and mount for actuator [in] [outside] the airstream.

2.3 REFRIGERANT COILS

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

1. Aerofin Corporation.
2. Carrier Corporation.
3. Coil Company, LLC.
4. Dunham-Bush, Inc.
6. Lennox Industries Inc.
7. Super Radiator Coils.
8. Trane.
9. USA Coil & Air.

B. Performance Ratings: Tested and rated according to ARI 410 and ASHRAE 33.

C. Minimum Working-Pressure Rating: 300 psig.

D. Source Quality Control: Factory tested to 450 psig.

E. Tubes: ASTM B 743 copper, minimum 0.035 inch thick.

F. Fins: Aluminum, minimum 0.006 inch thick.

G. Suction and Distributor Piping: ASTM B 88, Type L copper tube with brazed joints.

1. Coil Split: [Row] [Face] [Interlaced].

H. Frames: Galvanized-steel channel frame, for flanged mounting.

I. Refrigerant Type: <Insert type.>

2.4 ELECTRIC COILS

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

   1. Brasch Manufacturing Co., Inc.
   2. Chromalox, Inc., Wiegand Industrial Division; Emerson Electric Company.
   3. Dunham-Bush, Inc.
   4. INDEECO.
   5. Trane.

B. Coil Assembly: Comply with UL 1995.

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, and fastened to supporting brackets.

E. High-Temperature Coil Protection: Disk-type, automatically reset, thermal-cutout, safety device; serviceable through terminal box without removing heater from duct or casing.

1. Secondary Protection: Load-carrying, manually reset or manually replaceable, thermal cutouts; factory wired in series with each heater stage.

F. Frames: Galvanized-steel channel frame, for [slip-in] [flanged] mounting.
G. Control Panel: [Unit] [Remote] mounted with disconnecting means and overcurrent protection. Include the following controls:

1. Magnetic contactor.
3. Toggle switches; one per step.
4. Step controller.
5. Time-delay relay.
6. Pilot lights; one per step.
7. Airflow proving switch.

H. Refer to Division 23 Section “Instrumentation and Control for HVAC” for thermostat.

I. Thermostats: Wall-mounted thermostats, with temperature range from 50 to 90 deg F, and 2.5 deg F throttling range.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Install coils level and plumb.

B. Install coils in metal ducts and casings constructed according to SMACNA’s “HVAC Duct Construction Standards, Metal and Flexible.”

C. Install [galvanized] [stainless]-steel drain pan under each cooling coil.

1. Construct drain pans with connection for drain; insulated and complying with ASHRAE 62.1.
2. Construct drain pans to extend beyond coil length and width and to connect to condensate trap and drainage.
3. Extend drain pan upstream and downstream from coil face.
4. Extend drain pan under coil headers and exposed supply piping.

D. Install moisture eliminators for cooling coils. Extend drain pan under moisture eliminator.

E. Straighten bent fins on air coils.

F. Clean coils using materials and methods recommended in writing by manufacturers, and clean inside of casings and enclosures to remove dust and debris.

G. Encase smaller than 12 x 12 inch water coils within ductwork in accordance with SMACNA Duct Construction Standards.

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 coils to allow service and maintenance.

C. Connect water piping with unions and shutoff valves to allow coils to be disconnected without draining piping. Control valves are specified in Division 23 Section "Instrumentation and Control for HVAC," and other piping specialties are specified in Division 23 Section "Hydronic Piping."

D. Connect steam piping with gate valve and union and steam condensate piping with union, strainer, trap, and gate valve to allow coils to be disconnected without draining piping. Control valves are specified in Division 23 Section "Instrumentation and Control for HVAC," and other piping specialties are specified in Division 23 Section "Steam and Condensate Heating Piping."

E. Connect refrigerant piping according to Division 23 Section "Refrigerant Piping."

F. Connect to condensate drain pans and extend to [nearest floor drain]. Construct deep trap at connection to drain pan and install cleanouts at changes in direction.

G. Ground equipment according to Division 26 Section "Grounding and Bonding for Electrical Systems."

H. Connect wiring according to Division 26 Section "Low-Voltage Electrical Power Conductors and Cables."

3.3 FIELD QUALITY CONTROL

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

1. Leak Test: After installation and test for leaks. Repair leaks and retest until no leaks exist.
2. Operational Test: After electrical circuitry has been energized, operate electric coils to confirm proper unit operation.
3. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.

END OF SECTION 23 8216
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SECTION 23 8219 - FAN COIL UNITS

PART 1 - GENERAL

1.1 SUMMARY
   A. This Section includes fan-coil units and accessories.

1.2 ACTION SUBMITTALS
   A. Product Data: Include rated capacities, operating characteristics, furnished specialties, and accessories.
   B. LEED Submittals:
      1. Product Data for Credit EA 4: Documentation indicating that equipment and refrigerants comply.
      2. Product Data for Prerequisite IEQ 1: Documentation indicating that units comply with ASHRAE 62.1, Section 5 - “Systems and Equipment.”
   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.

1.3 INFORMATIONAL SUBMITTALS
   A. Field quality-control test reports.

1.4 CLOSEOUT SUBMITTALS
   A. Operation and maintenance data.

1.5 MAINTENANCE MATERIAL SUBMITTALS
   A. Furnish extra materials described below that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
1. Fan-Coil-Unit Filters: Furnish one spare filter for each filter installed.

B. Fan Belts: Furnish <Insert number> spare fan belts for each unit installed.

1.6 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/IESNA 90.1 Compliance: Applicable requirements in ASHRAE/IESNA 90.1, Section 6 - "Heating, Ventilating, and Air-Conditioning."

PART 2 - PRODUCTS

2.1 MANUFACTURERS

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

1. Airtherm; a Mestek Company.
2. Carrier Corporation.
3. Engineered Air Ltd.
4. Environmental Technologies, Inc.
7. Marshall Engineered Products Co., LLC (MEPCO); Dunham-Bush, Inc.
8. Daikin/McQuay.
9. Rittling.
10. Rosemex.
11. Titus.
12. Trane.
13. USA Coil & Air.
14. JCI/York.

2.2 NON-DUCTED FAN-COIL UNITS

A. Description: Factory-packaged and -tested units rated according to ARI 440, ASHRAE 33, and UL 1995.

B. Coil Section Insulation: Minimum 1/2-inch thick, 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.

2. **Airstream Surfaces**: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.

C. **Main and Auxiliary Drain Pans**: Fabricate pans and drain connections to comply with ASHRAE 62.1.

D. **Main and Auxiliary Drain Pans**: [Plastic] [Stainless steel] [Insulated galvanized steel with plastic liner]. Fabricate pans and drain connections to comply with ASHRAE 62.1-2004.[ Drain pans shall be removable].

E. **Chassis**: Galvanized steel where exposed to moisture. Floor-mounting units shall have leveling screws.

F. **Cabinet**: Steel with baked-enamel finish in manufacturer's standard paint color as selected by Architect.

G. **Cabinet**: Steel with [factory prime coating, ready for field painting] [baked-enamel finish in manufacturer's standard paint color as selected by Architect] [baked-enamel finish in manufacturer's custom paint color as selected by Architect].

1. **Vertical Unit Front Panels**: Removable, steel, with [integral stamped] [steel] discharge grille and channel-formed edges, cam fasteners, and insulation on back of panel.

2. **Horizontal Unit Bottom Panels**: Fastened to unit with cam fasteners and hinge and attached with safety chain; with [integral stamped] [cast-aluminum] discharge grilles.

3. **Steel recessing flanges for recessing fan-coil units into ceiling or wall.**

H. **Filters**: Minimum arrestance according to ASHRAE 52.1, and a minimum efficiency reporting value (MERV) according to ASHRAE 52.2.

1. **Washable Foam**: 70 percent arrestance and 3 MERV.

2. **Glass Fiber Treated with Adhesive**: 80 percent arrestance and 5 MERV.

3. **Pleated Cotton-Polyester Media**: 90 percent arrestance and 7 MERV.

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 220 deg F. Include manual air vent and drain valve.

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. Terminate elements in stainless-steel machine-staked terminals secured with stainless-steel hardware.

K. **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.

3. Wiring Termination: Connect motor to chassis wiring with plug connection.

L. 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. [Two] [Three]-way, [two-position] [modulating] control valve for dual-temperature coil.
2. [Two] [Three]-way, [two-position] [modulating] control valve for chilled-water coil.
3. [Two] [Three]-way, [two-position] [modulating] control valve for heating coil.

4. Hose Kits: Minimum 400-psig working pressure, and operating temperatures from 33 to 211 deg F. Tag hose kits to equipment designations.
   a. Length: [24 inches] [36 inches] <Insert dimension>.
   b. Minimum Diameter: Equal to fan-coil-unit connection size.

5. 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.

6. 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.

7. Automatic Flow-Control Valve: Brass or ferrous-metal body; 300-psig working pressure at 250 deg F, with removable, corrosion-resistant, tamperproof, self-cleaning piston spring; factory set to maintain constant indicated flow with plus or minus 10 percent over differential pressure range of 2 to 80 psig.

8. 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.


M. Control devices and operational sequences are specified in Division 23 Sections “Instrumentation and Control for HVAC” and “Sequence of Operations for HVAC Controls.”

N. Basic Unit Controls:

1. Control voltage transformer.
2. [Wall-mounting] [Unit-mounted] thermostat with the following features:
   b. Fan on-auto switch.
   c. Fan-speed switch.
   e. Adjustable deadband.
   f. [Concealed] [Exposed] set point.
   g. [Concealed] [Exposed] indication.
   h. [Degree F] [Degree C] indication.

3. [Wall-mounting] [Unit-mounted] temperature sensor.
4. Unoccupied-period-override push button.
5. 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.

O. [DDC] Terminal Controller:

1. Scheduled Operation: Occupied and unoccupied periods on seven-day clock with a minimum of four programmable periods per day.
2. Unoccupied Period Override Operation: [Two] <Insert number> hours.
3. Unit Supply-Air Fan Operation:
   a. Occupied Periods: Fan runs continuously.
   b. Unoccupied Periods: Fan cycles to maintain room setback temperature.

4. Hydronic-Cooling-Coil Operation:
   a. Occupied Periods: [Open] [Modulate] control valve to maintain room temperature.
   b. Unoccupied Periods: Close control valve.

5. Heating-Coil Operation:
   a. Occupied Periods: [Open control valve] [Modulate control valve] [Energize electric-resistance coil] to provide heating if room temperature falls below thermostat set point.
   b. Unoccupied Periods: Start fan and [open control valve] [modulate control valve] [energize electric-resistance coil] if room temperature falls below setback temperature.

6. Dual-Temperature Hydronic-Coil Operation:
   a. Occupied Periods: When chilled water is available, [open] [modulate] control valve if room temperature exceeds thermostat set point. When hot water is available, open control valve if temperature falls below thermostat set point.
   b. Unoccupied Periods: When chilled water is available, close control valve. When hot water is available, [open] [modulate] control valve if room temperature falls below thermostat setback temperature.

7. Controller shall have volatile-memory backup.

P. Electrical Connection: Factory wire motors and controls for a single electrical connection.

2.3 DUCTED FAN-COIL UNITS

A. Description: Factory-packaged and -tested units rated according to ARI 440, ASHRAE 33, and UL 1995.

B. Coil Section Insulation: Minimum 1/2-inch thick 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.
2. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.

C. Drain Pans: Fabricate pans and drain connections to comply with ASHRAE 62.1.
D. Drain Pans: [Plastic] [Stainless steel] [Insulated galvanized steel with plastic liner]. Fabricate pans and drain connections to comply with ASHRAE 62.1.

E. Chassis: Galvanized steel where exposed to moisture, with baked-enamel finish and removable access panels.

F. Cabinets: Steel with baked-enamel finish in manufacturer's standard paint color.

1. Supply-Air Plenum: Sheet metal plenum finished and insulated to match the chassis [with mill-finish, aluminum, double-deflection grille].
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.
4. Dampers: Galvanized steel with extruded-vinyl blade seals, flexible-metal jamb seals, and interlocking linkage.

G. Filters: Minimum arrestance according to ASHRAE 52.1, and a minimum efficiency reporting value (MERV) according to ASHRAE 52.2.

1. Washable Foam: 70 percent arrestance and 3 MERV.
2. Glass Fiber Treated with Adhesive: 80 percent arrestance and 5 MERV.
3. Pleated Cotton-Polyester Media: 90 percent arrestance and 7 MERV.

H. 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 220 deg F. Include manual air vent and drain.

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 of heaters. Terminate elements in stainless-steel machine-staked terminals secured with stainless-steel hardware.

J. Direct-Driven Fans: Double width, forward curved, centrifugal; with permanently lubricated, multispeed motor resiliently mounted in the fan inlet. Aluminum or painted-steel or galvanized-steel fan scrolls.

K. 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.

1. Motors: Comply with requirements in Division 23 Section "Common Motor Requirements for HVAC Equipment."

L. 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. [Two] [Three]-way, [two-position] [modulating] control valve for chilled-water coil.
2. [Two] [Three]-way, [two-position] [modulating] control valve for heating coil.
3. [Two] [Three]-way, [two-position] [modulating] control valve for dual-temperature coil.
4. Hose Kits: Minimum 400-psig working pressure, and operating temperatures from 33 to 211 deg F. Tag hose kits to equipment designations.
a. Length: [24 inches] [36 inches] <Insert dimension>.
b. Minimum Diameter: Equal to fan-coil-unit connection size.

5. 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.

6. 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.

7. Automatic Flow-Control Valve: Brass or ferrous-metal body; 300-psig working pressure at 250 deg F; with removable, corrosion-resistant, tamperproof, self-cleaning piston spring; factory set to maintain constant indicated flow with plus or minus 10 percent over differential pressure range of 2 to 80 psig.

8. 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.


M. Control devices and operational sequence are specified in Division 23 Sections “Instrumentation and Control for HVAC” and “Sequence of Operations for HVAC Controls.”

N. Basic Unit Controls:

1. Control voltage transformer.
2. [Wall-mounting] [Unit-mounted] thermostat with the following features.
   b. Fan on-auto switch.
   c. Fan-speed switch.
   e. Adjustable deadband.
   f. [Concealed] [Exposed] set point.
   g. [Concealed] [Exposed] indication.
   h. [Degree F] [Degree C] indication.

3. [Wall-mounting] [Unit-mounted] temperature sensor.

4. Unoccupied-period-override push button.

5. 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.

O. [DDC] Terminal Controller:

1. Scheduled Operation: Occupied and unoccupied periods on seven-day clock with a minimum of four programmable periods per day.
2. Unoccupied Period Override Operation: [Two] <Insert number> hours.
3. Unit Supply-Air Fan Operation:
   a. Occupied Periods: Fan runs continuously.
   b. Unoccupied Periods: Fan cycles to maintain room setback temperature.
4. Hydronic-Cooling-Coil Operation:
   a. Occupied Periods: [Open] [Modulate] control valve to maintain room temperature.
   b. Unoccupied Periods: Close control valve.

5. Heating-Coil Operation:
   a. Occupied Periods: [Open control valve] [Modulate control valve] [Energize electric-resistance coil] to provide heating if room temperature falls below thermostat set point.
   b. Unoccupied Periods: Start fan and [open control valve] [modulate control valve] [energize electric-resistance coil] if room temperature falls below setback temperature.

6. Dual-Temperature Hydronic-Coil Operation:
   a. Occupied Periods: When chilled water is available, [open] [modulate] control valve if room temperature exceeds thermostat set point. When hot water is available, [open] [modulate] control valve if temperature falls below thermostat set point.
   b. Unoccupied Periods: When chilled water is available, close valve. When hot water is available, [open] [modulate] control valve if room temperature falls below thermostat setback temperature.

7. Outdoor-Air Damper Operation:
   a. Occupied Periods: Open damper to fixed position for [25] <Insert percent> percent outdoor air.
   b. Unoccupied Periods: Close damper.

8. Outdoor-Air Damper Operation:
   a. Occupied Periods:
      1) Outdoor-Air Temperature below Room Temperature: If room temperature is above room-temperature set point, modulate outdoor- and return-air dampers to maintain room-temperature set point (outdoor-air economizer). If room temperature is below set point, position damper to fixed minimum setting.
      2) Outdoor-Air Temperature above Room Temperature: Position damper to fixed minimum position for [25] <Insert percent> percent outdoor air.
   b. Unoccupied Periods: Close outdoor-air damper and open return-air damper.

9. Outdoor-Air Damper Operation:
   a. Occupied Periods:
      1) Outdoor-Air Enthalpy below Room Enthalpy: If room temperature is above room-temperature set point, modulate outdoor-air damper to maintain room temperature (outdoor-air economizer). If room temperature is below set point, position damper to fixed minimum position for [25] <Insert percent> percent outdoor air.
      2) Outdoor-Air Enthalpy above Room Enthalpy: Position damper to fixed minimum position for [25] <Insert percent> percent outdoor air.
   b. Unoccupied Periods: Close outdoor-air damper and open return-air damper.

10. Controller shall have volatile-memory backup.

P. Electrical Connection: Factory wire motors for a single electrical connection.

Q. Electrical Connection: Factory wire motors and controls for a single electrical connection.
PART 3 - EXECUTION

3.1 INSTALLATION

A. Install fan-coil units to comply with NFPA 90A.

B. Suspend fan-coil units from structure with elastomeric hangers. Vibration isolators are specified in Division 23 Section "Vibration and Seismic Controls for HVAC Piping and Equipment."

C. Verify locations of thermostats and other exposed control sensors with Drawings and room details before installation. Install devices 48 inches above finished floor.

D. Install new filters in each fan-coil unit within two weeks after Substantial Completion.

E. 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 to condensate drain pans and extend to [nearest floor drain]. Construct deep trap at connection to drain pan and install cleanouts at changes in direction.

   a. Install condensate trap of adequate depth to seal against the pressure of fan. Install cleanouts in piping at changes of direction.

F. Connect supply and return ducts to fan-coil units with flexible duct connectors specified in Division 23 Section "Air Duct Accessories." Comply with safety requirements in UL 1995 for duct connections.

3.2 FIELD QUALITY CONTROL

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

1. Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.
2. Operate electric heating elements through each stage to verify proper operation and electrical connections.
3. Test and adjust controls and safety devices. Replace damaged and malfunctioning controls and equipment.

B. Remove and replace malfunctioning units and retest as specified above.

END OF SECTION 23 8219
WMU Design Guidelines

WMU Design Guidelines Instructions: These guidelines are to be used by the Design Professional to inform the design process and outline WMU-specific desires for all University projects. These guidelines have been edited to reflect WMU preferences, and the intent is for the Design Professional to use this information to guide their normal specifications-writing process. Straying from what is indicated in the guidelines is not prohibited, but shall be discussed with WMU during the development of the project.

SECTION 23 8233 - CONVECTORS

PART 1 - GENERAL

1.1 SUMMARY

A. This Section includes the following:

1. [Hydronic] [Steam] finned-tube radiators.
2. [Hydronic] [Steam] [Electric] convectors.
3. Flat-pipe steel radiators.

1.2 ACTION SUBMITTALS

A. Product Data: Include rated capacities, operating characteristics, furnished specialties, and accessories for each type of product indicated.

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.


C. Color Samples for Initial Selection: For units with factory-applied color finishes.

D. Color Samples for Verification: For each type of exposed finish required.

1.3 INFORMATIONAL SUBMITTALS

A. Field quality-control test 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.

PART 2 - PRODUCTS

2.1 HOT-WATER FINNED-TUBE RADIATORS

2.2 HOT-WATER OR STEAM FINNED-TUBE RADIATORS

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

1. Modine.
2. Rittling, a div. of Hydro-Air Components.
3. Sigma.
4. Sterling.
5. Trane.
7. Embassy Industries, Inc.
8. Engineered Air.
9. Rosemex.
10. Slant/Fin.

B. Performance Ratings: Rate finned-tube radiators according to Hydronics Institute’s "I=B=R Testing and Rating Standard for Finned-Tube (Commercial) Radiation."

C. Heating Elements: Copper tubing mechanically expanded into flanged collars of evenly spaced aluminum fins resting on element supports. One tube end shall be belled.

D. Heating Elements: Steel tubing mechanically expanded into flanged collars of evenly spaced steel fins resting on element supports. Tube ends shall be threaded.

E. Element Supports: Ball-bearing cradle type to permit longitudinal movement on enclosure brackets.

F. Front Panel: Minimum 0.0781-inch-thick steel.

G. Front Panel: Minimum \[0.0428\text{-inch}\] [0.0528\text{-inch}] \(<\text{Insert thickness}>\) thick steel.

H. Wall-Mounting Back Panel: Minimum 0.0329-inch-thick steel, full height, with full-length channel support for front panel without exposed fasteners.

I. Floor-Mounting Pedestals: Conceal insulated piping at maximum 36-inch spacing. Pedestal-mounding back panel shall be solid panel matching front panel. Provide stainless-steel escutcheon for floor openings at pedestals.
J. Support Brackets: Locate at maximum 36-inch spacing to support front panel and element.

K. Finish: Baked finish in manufacturer's [standard] [custom] color as selected by Architect.

L. Damper: Knob-operated internal damper at enclosure outlet.

M. Access Doors: Factory made, permanently hinged with tamper-resistant fastener, minimum size 6 by 7 inches, integral with enclosure.

N. Enclosure Style: Sloped top.
   1. Bottom Inlet: Open bottom.
   2. Top Outlet Grille: Punched louver; painted to match enclosure.

O. Enclosure Style: [Sloped] [Flat] top.
   1. Front Inlet Grille: Punched louver; painted to match enclosure.
   2. Front Inlet Grille: Extruded-aluminum linear bar grille; pencil-proof bar spacing.
      b. Anodized finish, color as selected by Architect from manufacturer's [standard] [custom] colors.
      c. Painted to match enclosure.
   3. [Top] [Front] Outlet Grille: Punched louver; painted to match enclosure.
   4. [Top] [Front] Outlet Grille: Extruded-aluminum linear bar grille; pencil-proof bar spacing.
      b. Anodized finish, color as selected by Architect from manufacturer's [standard] [custom] colors.
      c. Painted to match enclosure.

P. Accessories:
   1. Filler sections, corners, relay sections, and splice plates all matching the enclosure and grille finishes.
   2. All required expansion controls located within enclosures for long sections of elements.

2.3 ELECTRIC CONVECTORS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   1. Berko Electric Heating; a division of Marley Engineered Products.
   2. Chromalox; a division of Emerson Electric Company.
   3. Indeeco.
   4. Markel Products; a division of TPI Corporation.
   5. Marley Electric Heating; a division of Marley Engineered Products.
   6. Ouellet Canada Inc.
   7. Qmark Electric Heating; a division of Marley Engineered Products.

B. Description: Factory-packaged units constructed according to UL 499, UL 1030, and UL 2021.
C. Heating Elements: Nickel-chromium-wire heating element enclosed in metallic sheath mechanically bonded into fins, with high-temperature cutout and sensor running the full length of element. Element supports shall eliminate thermal expansion noise.

D. Front and Top Panel: Minimum 0.0677-inch- thick steel with exposed corners rounded; removable front panels with tamper-resistant fasteners braced and reinforced for stiffness.

E. Wall-Mounting Back and End Panels: Minimum 0.0428-inch- thick steel.

F. Floor-Mounting Pedestals: Conceal conduit for power and control wiring at maximum 36-inch spacing. Pedestal-mounting back panel shall be solid panel matching front panel.

G. Support Brackets: Locate at maximum 36-inch spacing to support front panel and element.

H. Insulation: 1/2-inch- thick, fibrous glass on inside of the back of the enclosure.

I. Finish: Baked-enamel finish in manufacturer's [standard] [custom] color as selected by Architect.

J. Damper: Knob-operated internal damper.

K. Access Doors: Factory made, permanently hinged with tamper-resistant fastener, minimum size 6 by 7 inches, integral with enclosure.

L. Enclosure Style: [Sloped] [Flat] top.
   1. Front Inlet Grille: Punched louver; painted to match enclosure.
   2. Front Inlet Grille: Extruded-aluminum linear bar grille; pencil-proof bar spacing.
      b. Anodized finish, color as selected by Architect from manufacturer's [standard] [custom] colors.
      c. Painted to match enclosure.
   3. [Top] [Front] Outlet Grille: Punched louver; painted to match enclosure.
   4. [Top] [Front] Outlet Grille: Extruded-aluminum linear bar grille; pencil-proof bar spacing.
      b. Anodized finish, color as selected by Architect from manufacturer's [standard] [custom] colors.
      c. Painted to match enclosure.

M. Unit Controls: Integral [line-voltage thermostat with minimum range of 60 to 90 deg F] [low-voltage relay and control transformer for remote thermostat].

N. Accessories: Integral disconnect switch, recessing flanges finished to match enclosure or overlapping front cover for fully recessed units, and rubber gaskets to seal cabinet at wall.
2.4 HOT-WATER CONVECTORS

2.5 HOT-WATER OR STEAM CONVECTORS

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

1. Modine.
2. Rittling, a div. of Hydro-Air Components.
3. Sigma.
4. Sterling.
5. Trane.
7. Slant/Fin.
8. Rosemex.
9. Engineered Air.

B. Convector Elements: Seamless copper tubing mechanically expanded into evenly spaced aluminum fins and rolled into cast-iron or brass headers with inlet/outlet and air vent; steel side plates and supports. Factory-pressure-test element at minimum 100 psig.

C. Front and Top Panel: Minimum 0.0677-inch-thick steel with exposed corners rounded; removable front panels with tamper-resistant fasteners braced and reinforced for stiffness.

   1. Recessed Cabinets: One-piece front panel, with 4-side gasketed overlap.

D. Wall-Mounting Back and End Panels: Minimum 0.0428-inch-thick steel.

E. Floor-Mounting Pedestals: Conceal conduit for power and control wiring at maximum 36-inch spacing. Pedestal-mounting back panel shall be solid panel matching front panel.

F. Support Brackets: Locate at maximum 36-inch spacing to support front panel and element.

G. Insulation: 1/2-inch-thick, fibrous glass on inside of the back of the enclosure.

H. Finish: Baked-enamel finish in manufacturer's [standard] [custom] color as selected by Architect.

I. Damper: Knob-operated internal damper.

J. Access Doors: Factory made, permanently hinged with tamper-resistant fastener, minimum size 6 by 7 inches, integral with enclosure.

K. Enclosure Style: [Sloped] [Flat] top.

   1. Front Inlet Grille: Punched louver; painted to match enclosure.
   2. Front Inlet Grille: Extruded-aluminum linear bar grille; pencil-proof bar spacing.

b. Anodized finish, color as selected by Architect from manufacturer's [standard] [custom] colors.
c. Painted to match enclosure.

3. [Top] [Front] Outlet Grille: Punched louver; painted to match enclosure.
4. [Top] [Front] Outlet Grille: Extruded-aluminum linear bar grille; pencil-proof bar spacing.
b. Anodized finish, color as selected by Architect from manufacturer's [standard] [custom] colors.
c. Painted to match enclosure.

2.6 FLAT-PIPE STEEL RADIATORS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   1. Myson Inc.
   2. Rittling, a div. of Hydro-Air Components.
   3. Runtal North America, Inc.
   4. Sterling.

B. Heating Elements: Steel, welded and formed into flat, square, steel header with minimum thickness of 0.109 inches. Include threaded piping and air vent connections.
   1. Working Pressure 56 psig: 0.048 inch.
   2. Working Pressure 85 psig: 0.058 inch.
   3. Working Pressure 128 psig: 0.078 inch.

C. Mounting: [Wall brackets] [Floor pedestals] on maximum spacing of 36 inches.

D. Finish: Baked-enamel finish in manufacturer's [standard] [custom] color as selected by Architect.

E. Accessories:
   1. Steel piping covers finished to match radiator finish.
   2. Flexible Expansion Compensation Hoses: Minimum 400-psig (2758-kPa) working pressure, and operating temperatures from 33 to 211 deg F (0.5 to 99.5 deg C).

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine areas to receive convection heating units for compliance with requirements for installation tolerances and other conditions affecting performance.
B. Examine roughing-in for [hydronic-piping] [steam-piping] [electrical] connections to verify actual locations before convection heating unit installation.

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

3.2 FINNED-TUBE RADIATOR INSTALLATION

A. Install units level and plumb.

B. Install enclosure continuously around corners, using outside and inside corner fittings.

C. Join sections with splice plates and filler pieces to provide continuous enclosure.

D. Install access doors for access to valves.

E. Install enclosure continuously from wall to wall.

F. Terminate enclosures with manufacturer’s end caps, except where enclosures are indicated to extend to adjoining walls.

G. Install valves within reach of access door provided in enclosure.

H. Install expansion compensator with fin tube guides and anchors within enclosures on long runs where expansion is excessive.

I. Install air-seal gasket between wall and recessing flanges or front cover of fully recessed unit.

J. Install piping within pedestals for freestanding units.

3.3 CONVECTOR INSTALLATION

A. Install units level and plumb.

B. Install valves within reach of access door provided in enclosure.

C. Install air-seal gasketing between wall and recessing flanges or front cover of fully recessed unit.

3.4 FLAT-PIPE STEEL RADIATOR INSTALLATION

A. Install units level and plumb.

B. Install expansion compensation hoses.

C. Install piping covers.

D. Install coin or screw driver operated manual air vent on each panel section at factory provided vent connection.
3.5 CONNECTIONS

A. Piping installation requirements are specified in Division 23 Section "[Hydronic Piping] [Steam and Condensate Heating Piping]." Drawings indicate general arrangement of piping, fittings, and specialties.

B. Connect hot-water units and components to piping according to Division 23 Section "Hydronic Piping."
   1. Install shutoff valves on inlet and outlet, and balancing valve on outlet.

C. Connect steam units and components to piping according to Division 23 Section "Steam and Condensate Heating Piping."
   1. Install shutoff valve on inlet; install strainer, steam trap, and shutoff valve on outlet.

D. Install control valves as required by Division 23 Section "Instrumentation and Control for HVAC."

E. Install piping adjacent to convection heating units to allow service and maintenance.

F. Ground electric convection heating units according to Division 26 Section "Grounding and Bonding for Electrical Systems."

G. Connect wiring according to Division 26 Section "Low-Voltage Electrical Power Conductors and Cables."

3.6 FIELD QUALITY CONTROL

A. Retouch any marred or scratched surfaces of factory-finished cabinets, using finish materials furnished by manufacturer.

B. Perform the following field tests and inspections and prepare test reports:
   1. Leak Test: After installation, charge system and test for leaks. Repair leaks and retest until no leaks exist.
   2. Operational Test: After electrical circuitry has been energized, start units to confirm proper convection heating unit operation.
   3. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.

C. Remove and replace convection heating units that do not pass tests and inspections and retest as specified above.

END OF SECTION 23 8233
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SECTION 23 8239 - UNIT HEATERS

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:

1. Cabinet unit heaters with centrifugal fans and hot-water coils.
2. Cabinet unit heaters with centrifugal fans and [hot-water] [steam] [electric-resistance heating] coils.
3. Propeller unit heaters with hot-water coils.
4. Propeller unit heaters with [steam] [electric-resistance heating] coils.
5. Wall and ceiling heaters with propeller fans and electric-resistance heating coils.

1.2 ACTION SUBMITTALS

A. Product Data: Include rated capacities, operating characteristics, furnished specialties, and accessories for each product indicated.

B. LEED Submittal:

1. Product Data for Prerequisite EQ 1: Documentation indicating that units comply with ASHRAE 62.1, Section 5 - "Systems and Equipment."

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. Location and size of each field connection.
2. Details of anchorages and attachments to structure and to supported equipment.
3. Location and arrangement of piping valves and specialties.
4. Location and arrangement of integral controls.

D. Samples for Color Selection: Finish colors for cabinet unit heater units with factory-applied color finishes.

E. Manufacturer Seismic Qualification Certification:
1.3 INFORMATIONAL SUBMITTALS
   A. Field quality-control test reports.
   B. Coordination Drawings

1.4 CLOSEOUT SUBMITTALS
   A. Operation and maintenance data.

1.5 MAINTENANCE MATERIAL SUBMITTALS
   A. Furnish extra materials described below that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
      1. Cabinet Unit Heater Filters: Furnish one spare filter for each filter installed.

1.6 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/IESNA 90.1 Compliance: Applicable requirements in ASHRAE/IESNA 90.1, Section 6 - "Heating, Ventilating, and Air-Conditioning."

PART 2 - PRODUCTS

2.1 CABINET UNIT HEATERS
   A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
      1. Modine.
      2. Rittling.
      3. Sigma.
      4. Sterling.
      5. Trane.
   B. Description: A factory-assembled and -tested unit complying with ARI 440.
   C. Coil Section Insulation: Surfaces exposed to airstream shall be coated to prevent erosion of insulation.
1. **Fire-Hazard Classification:** Maximum flame-spread index of 25 and smoke-developed index of 50 when tested according to ASTM E 84.

D. **Cabinet:** Steel with baked-enamel finish with manufacturer's standard paint, in color selected by Architect. Include removable panels with tamperproof fasteners and the following:
   1. Steel recessing flanges with finish to match cabinet.
   2. Key operated control access door.
   3. Safety chains on horizontal units.

E. **Filters:** Pleated, 90 percent arrestance and 7 MERV.

F. **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 "Common Motor Requirements for HVAC Equipment."
   3. Wiring Terminations: Connect motor to chassis wiring with plug connection.

G. **Electrical Connection:** Factory wire unit for a single field connection with disconnect switch.

H. **Outdoor-Air Wall Box:** Aluminum, rain-resistant louver and box with integral eliminators and bird screen. Provide louver with anodized or baked-enamel finish in color selected by Architect from manufacturer's [standard] [custom] colors.
   1. Outdoor-Air Damper: Galvanized-steel blades with edge and end seals and nylon bearings; with [manual] [electronic] [pneumatic], two-position actuators.

I. **Hot-Water Coil:** Copper tube, with mechanically bonded aluminum fins spaced no closer than 0.1 inch and rated for a minimum working pressure of 200 psig and a maximum entering-water temperature of 220 deg F. Include manual air vent and drain.

J. **Basic Unit Controls:**
   1. Provide unit "DDC controls ready" for field furnished and installed controls by controls Installer.
   2. Unit-mounted with the following features:
      a. Control voltage transformer.
      b. Fan on-auto switch.

K. **Basic Unit Controls:** Unit-mounted with the following features.
   1. Control voltage transformer.
   2. Return air thermostat.
   3. Heat-off switch.
6. Adjustable deadband.
7. Concealed set point.

L. Basic Unit Controls: Unit-mounted with the following features.

1. Control voltage transformer.
2. 24v wall mounted thermostat with concealed set point.
3. Heat-off switch.
6. Adjustable deadband.

M. Unit Operations:

1. Energize fan and open control valve to provide heating if temperature falls below thermostat set point.
2. Energize fan and electric-resistance coil to provide heating if temperature falls below thermostat set point.
3. Outdoor-Air Damper Operation:
   a. Fan On: Damper is open.
   b. Fan Off: Damper is closed.

N. Basic Unit Controls: Unit-mounted with the following features.

1. Control voltage transformer.
2. Return air thermostat for wall mounted heaters] and wall mounted for [ceiling mounted heaters] provided by temperature controls installer.
3. Heat-off switch.

O. Control devices and operational sequences are specified in Division 23 Sections "Instrumentation and Control for HVAC" and "Sequence of Operations for HVAC Controls."

2.2 STEAM CABINET UNIT HEATERS

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

1. Modine
2. Rittling, a div. of Hydro-Air Components.
3. Sigma.
4. Sterling.
5. Trane.

B. Description: A factory-assembled and -tested unit complying with ARI 440.

C. Coil Section Insulation: Surfaces exposed to airstream shall be coated to prevent erosion of insulation.
1. Fire-Hazard Classification: Maximum flame-spread index of 25 and smoke-developed index of 50 when tested according to ASTM E 84.

D. Cabinet: Steel with baked-enamel finish with manufacturer's standard paint, in color selected by Architect. Include removable panels with tamperproof fasteners and the following:

1. Steel recessing flanges with finish to match cabinet.
2. Key operated control access door.
3. Safety chains on horizontal units.

E. Filters: Pleated, 90 percent arrestance and 7 MERV.

F. 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 "Common Motor Requirements for HVAC Equipment."

G. Electrical Connection: Factory wire unit for a single field connection with disconnect switch.

H. Outdoor-Air Wall Box: Aluminum, rain-resistant louver and box with integral eliminators and bird screen. Provide louver with anodized or baked-enamel finish in color selected by Architect from manufacturer's [standard] [custom] colors.

1. Outdoor-Air Damper: Galvanized-steel blades with edge and end seals and nylon bearings; with [manual] [electronic] [pneumatic], two-position actuators.

I. Steam Coil: Copper tube, with mechanically bonded aluminum fins spaced no closer than 0.1 inch and rated for a minimum working pressure of 75 psig.

J. Basic Unit Controls: Unit-mounted with the following features.

1. Control voltage transformer.
2. Return air thermostat.
3. Heat-off switch.
6. Adjustable deadband.
7. Concealed set point.

K. Basic Unit Controls: Unit-mounted with the following features.

1. Control voltage transformer.
2. 24v wall mounted thermostat with concealed set point.
3. Heat-off switch.
6. Adjustable deadband.
L. Unit Operations:
   1. Energize fan and open control valve to provide heating if temperature falls below thermostat set point.
   2. Energize fan and electric-resistance coil to provide heating if temperature falls below thermostat set point.
   3. Outdoor-Air Damper Operation:
      a. Fan On: Damper is open.
      b. Fan Off: Damper is closed.

M. Control devices and operational sequences are specified in Division 23 Sections "Instrumentation and Control for HVAC" and "Sequence of Operations for HVAC Controls."

2.3 ELECTRIC CABINET UNIT HEATERS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   1. Berko Electric Heating; a division of Marley Engineered Products.
   2. Markel Products; a division of TPI Corporation.
   3. QMark Electric Heating; a division of Marley Engineered Products.
   4. Trane.

B. Description: A factory-assembled and -tested unit complying with ARI 440.

C. Coil Section Insulation: Surfaces exposed to airstream shall be coated to prevent erosion of insulation.
   1. Fire-Hazard Classification: Maximum flame-spread index of 25 and smoke-developed index of 50 when tested according to ASTM E 84.

D. Cabinet: Steel with baked-enamel finish with manufacturer's standard paint, in color selected by Architect. Include removable panels with tamperproof fasteners and the following:
   1. Steel recessing flanges with finish to match cabinet.
   2. Key operated control access door.
   3. Safety chains on horizontal units.

E. Filters: Pleated, 90 percent arrestance and 7 MERV.

F. 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 "Common Motor Requirements for HVAC Equipment."
G. Electrical Connection: Factory wire unit for a single field connection with disconnect switch.

H. Outdoor-Air Wall Box: Aluminum, rain-resistant louver and box with integral eliminators and bird screen. Provide louver with anodized or baked-enamel finish in color selected by Architect from manufacturer's [standard] [custom] colors.

1. Outdoor-Air Damper: Galvanized-steel blades with edge and end seals and nylon bearings; with [manual] [electronic] [pneumatic], two-position actuators.

I. Electric-Resistance Heating Coil: Nickel-chromium heating wire, free from 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. Terminate elements in stainless-steel machine-staked terminals secured with stainless-steel hardware.

J. Basic Unit Controls: Unit-mounted with the following features.

1. Control voltage transformer.
2. Return air thermostat.
3. Heat-off switch.
6. Adjustable deadband.
7. Concealed set point.

K. Basic Unit Controls: Unit-mounted with the following features.

1. Control voltage transformer.
2. 24v wall mounted thermostat with concealed set point.
3. Heat-off switch.
6. Adjustable deadband.

L. Unit Operations:

1. Energize fan and electric-resistance coil to provide heating if temperature falls below thermostat set point.
2. Outdoor-Air Damper Operation:
   a. Fan On: Damper is open.
   b. Fan Off: Damper is closed.

M. Control devices and operational sequences are specified in Division 23 Sections "Instrumentation and Control for HVAC" and "Sequence of Operations for HVAC Controls."

2.4 CABINET UNIT HEATERS

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

1. Berko Electric Heating; a division of Marley Engineered Products.
2. Markel Products; a division of TPI Corporation.
3. Marley Electric Heating; a division of Marley Engineered Products.
4. Modine.
5. QMark Electric Heating; a division of Marley Engineered Products.
6. Rosemex Products.
7. Trane.

B. Description: A factory-assembled and -tested unit complying with ARI 440.


C. Coil Section Insulation: ASTM C 1071; surfaces exposed to airstream shall be [aluminum-foil facing] [erosion-resistant coating] to prevent erosion of glass fibers.

1. Thickness: [1/2 inch] [1 inch] [1-1/2 inches].
2. Thermal Conductivity (k-Value): 0.26 Btu x in./h x sq. ft. at 75 deg F mean temperature.
3. Fire-Hazard Classification: Maximum flame-spread index of 25 and smoke-developed index of 50 when tested according to ASTM E 84.
4. Adhesive: Comply with ASTM C 916 and with NFPA 90A or NFPA 90B.
5. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.

D. Coil Section Insulation: Comply with NFPA 90A or NFPA 90B. Unicellular polyethylene thermal plastic, preformed sheet insulation complying with ASTM C 534, Type II, except for density.

1. Thickness: [3/8 inch] [1/2 inch] [3/4 inch] [1 inch].
2. Thermal Conductivity (k-Value): 0.24 Btu x in./h x sq. ft. at 75 deg F mean temperature.
3. Fire-Hazard Classification: Maximum flame-spread index of 25 and smoke-developed index of 50 when tested according to ASTM C 411.
4. Adhesive: As recommended by insulation manufacturer and complying with NFPA 90A or NFPA 90B.
5. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.

E. Cabinet: Steel with [factory prime coating, ready for field painting] [baked-enamel finish with manufacturer's standard paint, in color selected by Architect] [baked-enamel finish with manufacturer's custom paint, in color selected by Architect].

1. Vertical Unit, Exposed Front Panels: Minimum [0.0528-inch-] [0.0677-inch-] thick, [galvanized,] sheet steel, removable panels with channel-formed edges secured with tamperproof cam fasteners.
2. Horizontal Unit, Exposed Bottom Panels: Minimum [0.0528-inch-] [0.0677-inch-] thick, [galvanized,] sheet steel, removable panels secured with tamperproof cam fasteners and safety chain.
3. Recessing Flanges: Steel, finished to match cabinet.
4. Control Access Door: Key operated.
5. Base: Minimum 0.0528-inch-thick steel, finished to match cabinet, [4 inches] [6 inches] <Insert dimension> high with leveling bolts.
6. Extended Piping Compartment: [8-inch-] <Insert dimension> wide piping end pocket.
7. False Back: Minimum 0.0428-inch-thick steel, finished to match cabinet.
8. Outdoor-Air Wall Box: Minimum 0.1265-inch-thick, aluminum, rain-resistant louver and box with integral eliminators and bird screen. Aluminum louver with [anodized] [baked-enamel] finish in color selected by Architect from manufacturer's [standard] [custom] colors.
a. Outdoor-Air Damper: Galvanized-steel blades with edge and end seals and nylon bearings; with [manual] [electronic] [pneumatic], two-position actuators.

F. Filters: Minimum arrestance according to ASHRAE 52.1 and a minimum efficiency reporting value (MERV) according to ASHRAE 52.2.
   1. Washable Foam: 70 percent arrestance and 3 MERV.
   2. Glass Fiber Treated with Adhesive: 80 percent arrestance and 5 MERV.
   3. Pleated: 90 percent arrestance and 7 MERV.

G. Hot-Water Coil: Copper tube, with mechanically bonded aluminum fins spaced no closer than 0.1 inch and rated for a minimum working pressure of 200 psig and a maximum entering-water temperature of 220 deg F. Include manual air vent and drain.

H. Steam Coil: Copper distributing tube, with mechanically bonded aluminum fins spaced no closer than 0.1 inch and rated for a minimum working pressure of 75 psig.

I. Electric-Resistance Heating Coil: Nickel-chromium heating wire, free from 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. Terminate elements in stainless-steel machine-staked terminals secured with stainless-steel hardware.

J. Fan and Motor Board: Removable.
   1. Fan: Forward curved, [high static, 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 "Common Motor Requirements for HVAC Equipment."
   3. Wiring Terminations: Connect motor to chassis wiring with plug connection.

K. Factory, Hot-Water Piping Package: [ASTM B 88, Type L] [ASTM B 88, Type M] copper tube with wrought-copper fittings and brazed joints. Label piping to indicate service, inlet and outlet.
   1. [Two] [Three]-way, [two-position] [modulating] control valve.[ Three-way valve packages shall include bypass line with manually adjustable balance device.]
   2. Hose Kits: Minimum 400-psig working pressure, and operating temperatures from 33 to 211 deg F. Tag hose kits to equipment designations.
   3. Length: [24 inches] [36 inches] <Insert dimension>.
   5. 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.
   6. Calibrated-Orifice Balancing Valves: Bronze body, ball type, 125-psig working pressure, 250 deg F maximum operating temperature; with calibrated orifice or venture, connection for portable differential pressure meter with integral seals, threaded ends, and equipped with a memory stop to retain set position.
   7. Automatic Flow-Control Valve: Brass or ferrous-metal body, 300-psig working pressure at 250 deg F, with removable, corrosion-resistant, tamperproof, self-cleaning, piston-spring; factory set to maintain constant indicated flow with plus or minus 10 percent over differential pressure range of 2 to 80 psig.
8. Y-Pattern, Hot-Water Strainers: Cast-iron body (ASTM A 126, Class B); 125-psig minimum working pressure; with threaded connections, bolted cover, perforated stainless-steel basket, and bottom drain connection. Include minimum NPS 1/2 threaded pipe and full-port ball valve in strainer drain connection.


L. Control devices and operational sequences are specified in Division 23 Sections “Instrumentation and Control for HVAC” and “Sequence of Operations for HVAC Controls.”

M. Basic Unit Controls:

1. Control voltage transformer.
2. [Wall-mounting] [Unit-mounted] thermostat with the following features.
   b. Fan on-auto switch.
   d. Adjustable deadband.
   e. [Concealed] [Exposed] set point.
   f. [Concealed] [Exposed] indication.
   g. Deg F indication.

3. [Wall-mounting] [Unit-mounted] temperature sensor.
4. Unoccupied period override push button.
5. Data entry and access port.
   a. Input data includes room temperature, and occupied and unoccupied periods.
   b. Output data includes room temperature, supply-air temperature, entering-water temperature, operating mode, and status.

N. [DDC] Terminal Controller:

1. Scheduled Operation: Occupied and unoccupied periods on seven-day clock with a minimum of four programmable periods per day.
2. Unoccupied Period Override: [Two] <Insert number> hours.
3. Unit Supply-Air Fan Operations:
   a. Occupied Periods: Fan runs continuously.
   b. Unoccupied Periods: Fan cycles to maintain setback room temperature.

4. Heating Coil Operations:
   a. Occupied Periods: [Open control valve] [Modulate control valve] [Energize electric-resistance coil] to provide heating if room temperature falls below thermostat set point.
   b. Unoccupied Periods: Start fan and [open control valve] [modulate control valve] [energize electric-resistance coil] if room temperature falls below setback temperature.

5. Outdoor-Air Damper Operation:
   a. Occupied Periods: Open dampers. Delay damper opening if room temperature is more than three degrees below set point.
   b. Unoccupied Periods: Close damper.

6. Controller shall have volatile-memory backup.

O. BAS Interface Requirements:
1. Interface relay for scheduled operation.
2. Interface relay to provide indication of fault at central workstation.
3. Interface shall be [BAC-net] [or] [LonWorks] compatible for central BAS workstation and include the following functions:
   a. Adjust set points.
   b. Cabinet unit heater start, stop, and operating status.
   c. Data inquiry, including [outdoor-air damper position, ]supply-air and room-air temperature.
   d. Occupied and unoccupied schedules.

P. Electrical Connection: Factory wire motors and controls for a single field connection.

2.5 HOT WATER PROPELLER UNIT HEATERS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   1. Modine
   2. Rittling, a div. of Hydro-Air Components.
   3. Sigma.
   4. Sterling.
   5. Trane.

B. Description: An assembly including casing, coil, fan, and motor in [vertical] [and] [horizontal] discharge configuration with adjustable discharge louvers.

C. Cabinet: Removable panels for maintenance access to controls.

D. Cabinet Finish: Manufacturer's standard baked enamel applied to factory-assembled and -tested propeller unit heater before shipping.

E. Cabinet Finish: Manufacturer's [standard] [custom] baked enamel applied to factory-assembled and -tested propeller unit heater before shipping.

F. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.

G. Discharge Louver: Adjustable fin diffuser for horizontal units and conical diffuser for vertical units.

H. Electrical Connection: Factory wire unit for a single field connection.

   1. Include control voltage transformer[ for wall mounted thermostat].

I. General Coil Requirements: Test and rate hot-water propeller unit heater coils according to ASHRAE 33.

J. Hot-Water Coil: Copper tube, minimum 0.025-inch wall thickness, with mechanically bonded aluminum fins spaced no closer than 0.1 inch and rated for a minimum working pressure of 200 psig and a maximum entering-water temperature of 325 deg F, with manual air vent. Test for leaks to 350 psig underwater.
K. Fan: Propeller type with aluminum wheel directly mounted on motor shaft in the fan venturi.

L. Fan Motors: Comply with requirements in Division 23 Section "Common Motor Requirements for HVAC Equipment."
   1. Motor Type: Permanently lubricated.
   2. Motor Type: Permanently lubricated, explosion proof, multispeed, variable speed.

M. Control Devices:
   1. Unit-mounted Wall-mounting 24V thermostat.

N. Control devices and operational sequences are specified in Division 23 Sections "Instrumentation and Control for HVAC" and "Sequence of Operations for HVAC Controls."

2.6 STEAM PROPELLE UNIT HEATERS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   1. Airtherm; a Mestek Company.
   2. Carrier Corporation.
   3. Dunham-Bush, Inc.
   4. Engineered Air Ltd.
   5. Daikin/McQuay.
   7. Rittling, a div. of Hydro-Air Components.
   8. Sigma.
   10. Trane.
   11. Vulcan.

B. Description: An assembly including casing, coil, fan, and motor in [vertical] [and] [horizontal] discharge configuration with adjustable discharge louvers.

C. Cabinet: Removable panels for maintenance access to controls.

D. Cabinet Finish: Manufacturer's standard baked enamel applied to factory-assembled and tested propeller unit heater before shipping.

E. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.

F. Discharge Louver: Adjustable fin diffuser for horizontal units and conical diffuser for vertical units.

G. Electrical Connection: Factory wire unit for a single field connection.
   1. Include control voltage transformer [for wall mounted thermostat].
H. General Coil Requirements: Test and rate steam propeller unit heater coils according to ASHRAE 33.

I. Steam Coil: Copper tube, minimum 0.025-inch wall thickness, with mechanically bonded aluminum fins spaced no closer than 0.1 inch and rated for a minimum working pressure of 75 psig.

J. Fan: Propeller type with aluminum wheel directly mounted on motor shaft in the fan venturi.

K. Fan Motors: Comply with requirements in Division 23 Section "Common Motor Requirements for HVAC Equipment."
   1. Motor Type: Permanently lubricated.
   2. Motor Type: Permanently lubricated, [explosion proof] [multispeed] [variable speed].

L. Control Devices:
   1. [Unit-mounted] [Wall-mounting 24V] thermostat.
   2. [Unit-mounted] [Wall-mounting], [variable] fan-speed switch.

M. Control devices and operational sequences are specified in Division 23 Sections "Instrumentation and Control for HVAC" and "Sequence of Operations for HVAC Controls."

2.7 ELECTRIC PROPELLER UNIT HEATERS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   1. Berko Electric Heating; a division of Marley Engineered Products.
   2. Marley Electric Heating; a division of Marley Engineered Products.
   3. QMark Electric Heating; a division of Marley Engineered Products.
   4. Trane.

B. Description: An assembly including casing, coil, fan, and motor in [vertical] [and] [horizontal] discharge configuration with adjustable discharge louvers.

C. Comply with UL 2021.

D. Comply with UL 823.

E. Cabinet: Removable panels for maintenance access to controls.

F. Cabinet Finish: Manufacturer's standard baked enamel applied to factory-assembled and -tested propeller unit heater before shipping.

G. Cabinet Finish: Manufacturer's [standard] [custom] baked enamel applied to factory-assembled and -tested propeller unit heater before shipping.

H. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.
I. Discharge Louver: Adjustable fin diffuser for horizontal units and conical diffuser for vertical units.

J. Electrical Connection: Factory wire unit for a single field connection.
   1. Include control voltage transformer [for wall mounted thermostat].

K. Electric-Resistance Heating Elements: Nickel-chromium heating wire, free from expansion noise and 60-Hz hum, embedded in magnesium oxide refractory and sealed in steel or corrosion-resistant metallic sheath with fins no closer than 0.16 inch. Element ends shall be enclosed in terminal box. Fin surface temperature shall not exceed 550 deg F at any point during normal operation.
   2. Wiring Terminations: Stainless-steel or corrosion-resistant material.

L. Fan: Propeller type with aluminum wheel directly mounted on motor shaft in the fan venturi.

M. Fan Motors: Comply with requirements in Division 23 Section "Common Motor Requirements for HVAC Equipment."
   1. Motor Type: Permanently lubricated.
   2. Motor Type: Permanently lubricated, [explosion proof] [multispeed] [variable speed].

N. Control Devices:
   1. [Unit-mounted] [Wall-mounting 24V] thermostat.
   2. [Unit-mounted] [Wall-mounting], [variable] fan-speed switch.

2.8 WALL AND CEILING HEATERS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   1. Berko Electric Heating; a division of Marley Engineered Products.
   2. Chromalox, Inc.; a division of Emerson Electric Company.
   3. Indeeco.
   4. Markel Products; a division of TPI Corporation.
   5. Marley Electric Heating; a division of Marley Engineered Products.
   6. QMark Electric Heating; a division of Marley Engineered Products.
   7. Trane.

B. Description: An assembly including chassis, electric heating coil, fan, motor, and controls. Comply with UL 2021.

C. Cabinet:
   1. Front Panel: [Stamped-steel louver] [Extruded-aluminum bar grille], with removable panels fastened with tamperproof fasteners.
2. Finish: Baked enamel over baked-on primer with manufacturer’s standard color selected by Architect, applied to factory-assembled and -tested wall and ceiling heaters before shipping.

3. Finish: Baked enamel over baked-on primer with manufacturer’s [standard] [custom] color selected by Architect, applied to factory-assembled and -tested wall and ceiling heaters before shipping.

D. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.

E. Surface-Mounting Cabinet Enclosure: Steel with finish to match cabinet.

F. Electric-Resistance Heating Coil: Nickel-chromium heating wire, free from expansion noise and hum, embedded in magnesium oxide refractory and sealed in corrosion-resistant metallic sheath. Terminate elements in stainless-steel, machine-staked terminals secured with stainless-steel hardware, and limit controls for high temperature protection.[Provide integral circuit breaker for overcurrent protection.]

G. Fan: Aluminum propeller directly connected to motor.
   1. Motor: Permanently lubricated[, multispeed]. Comply with requirements in Division 23 Section "Common Motor Requirements for HVAC Equipment."

H. Controls: Unit-mounted thermostat.[Low-voltage relay with transformer kit.]

I. Electrical Connection: Factory wire motors and controls for a single field connection[with disconnect switch].

PART 3 - EXECUTION

3.1 EXAMINATION
   A. Examine areas to receive unit heaters for compliance with requirements for installation tolerances and other conditions affecting performance.
   
   B. Examine roughing-in for [piping and] electrical connections to verify actual locations before unit heater installation.
   
   C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION
   A. Install wall boxes in finished wall assembly; seal and weatherproof. Joint-sealant materials and applications are specified in Division 07 Section "Joint Sealants."
   
   B. Install cabinet unit heaters to comply with NFPA 90A.
   
   C. Install propeller unit heaters level and plumb.
D. Suspend cabinet unit heaters from structure with elastomeric hangers.

E. Suspend cabinet unit heaters from structure with elastomeric hangers and seismic restraints. Vibration isolators and seismic restraints are specified in Division 23 Section "Vibration and Seismic Controls for HVAC Piping and Equipment."

F. Suspend propeller unit heaters from structure with all-thread hanger rods and elastomeric hangers.

G. Suspend propeller unit heaters from structure with all-thread hanger rods and elastomeric hangers, spring hangers, and spring hangers with vertical-limit stop. Hanger rods and attachments to structure are specified in Division 23 Section "Hangers and Supports for HVAC Piping and Equipment." Vibration hangers are specified in Division 23 Section "Vibration and Seismic Controls for HVAC Piping and Equipment."

H. Install wall-mounting thermostats and switch controls in electrical outlet boxes at heights to match lighting controls. Verify location of thermostats and other exposed control sensors with Drawings and room details before installation.

I. Install new filters in each cabinet heater within two weeks of Substantial Completion.

3.3 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 machine to allow service and maintenance.

C. Connect piping to cabinet unit heater’s factory, hot-water piping package. Install the piping package if shipped loose.

D. Connect supply and return ducts to cabinet unit heaters with flexible duct connectors specified in Division 23 Section "Air Duct Accessories."

E. Comply with safety requirements in UL 1995.

F. Unless otherwise indicated, install union and ball valve on supply-water connection and union and calibrated balancing valve on return-water connection of unit heater. Hydronic specialties are specified in Division 23 Section "Hydronic Piping."

G. Unless otherwise indicated, install union and gate valve on steam-supply connection and union, strainer, steam trap, and gate valve on condensate-return connection of unit heater. Steam specialties are specified in Division 23 Section "Steam and Condensate Heating Piping."

H. Ground equipment according to Division 26 Section "Grounding and Bonding for Electrical Systems."

I. Connect wiring according to Division 26 Section "Low-Voltage Electrical Power Conductors and Cables."
3.4 FIELD QUALITY CONTROL

A. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect, test, and adjust field-assembled components and equipment installation, including connections, and to assist in field testing. Report results in writing.

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

1. Leak Test: After installation, test coils and connections for leaks.
2. Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.
3. Operate electric heating elements through each stage to verify proper operation and electrical connections.
4. 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.

3.5 ADJUSTING

A. Adjust initial temperature set points.

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

3.6 DEMONSTRATION

A. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain cabinet unit heaters. Refer to Division 01 Section "Demonstration and Training."

END OF SECTION 23 8239
WMU Design Guidelines

WMU Design Guidelines Instructions: These guidelines are to be used by the Design Professional to inform the design process and outline WMU-specific desires for all University projects. These guidelines have been edited to reflect WMU preferences, and the intent is for the Design Professional to use this information to guide their normal specifications-writing process. Straying from what is indicated in the guidelines is not prohibited, but shall be discussed with WMU during the development of the project.

SECTION 23 8316 – RADIANT HEATING HYDRONIC PIPING

PART 1 - GENERAL

1.1 SUMMARY

A. This Section includes radiant heating piping, including pipes, fittings, and piping specialties.

B. Related Requirements:

1. [Section 07 2100 "Thermal Insulation" for insulation installed under concrete with radiant heat].

1.2 DEFINITIONS

A. PEX: Crosslinked polyethylene.

B. EPDM: Ethylene-propylene-diene terpolymer rubber.

C. PEX/AL/PEX: Crosslinked polyethylene/aluminum/crosslinked polyethylene.

1.3 ACTION SUBMITTALS

A. Product Data: For each type of radiant heating pipe, fitting, manifold, specialty, and control.

1. For radiant heating piping and manifolds, include pressure and temperature rating, oxygen-barrier performance, fire-performance characteristics, and water flow and pressure drop characteristics.

B. Shop Drawings: Show piping layout and details drawn to scale, including valves, manifolds, controls, and support assemblies, and their attachments to building structure.

1. Shop Drawing Scale: 1/8 inch = 1 foot.

1.4 CLOSEOUT SUBMITTALS

A. Operation and maintenance data.
1.5 COORDINATION

A. Coordinate thickening of slabs where required for adequate encasement of radiant heating piping components.

PART 2 - PRODUCTS

2.1 PEX PIPE AND FITTINGS

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

1. Mr. PEX
2. REHAU.
3. Viega LLC.
4. Uponor.
5. Watts Radiant, Inc.; a division of Watts Water Technologies, Inc.

B. [Pipe Material]: Crosslinked polyethylene (PEX) manufactured by PEX-a or Engle method, manufactured in accordance with ASTM F876 and ASTM F877.

C. Pipe Material: PEX plastic according to ASTM F 876.

D. Oxygen Barrier: Limit oxygen diffusion through the tube to maximum 0.10 mg per cu. m/day at 104 deg F according to DIN 4726.

E. Fittings: ASTM F1960 metal cold expansion.

F. Pressure/Temperature Rating: Minimum 100 psig and 180 deg F.

2.2 DISTRIBUTION MANIFOLDS

A. Manifold: Minimum NPS 1, brass, copper, stainless steel, or modular plastic.

B. Main Shutoff Valves:

1. Factory installed on supply and return connections.
2. [Two] [Three]-piece body.
3. Body: Brass or bronze.
4. Ball: Chrome-plated bronze.
5. Seals: PTFE.
7. Maximum Operating Temperature: 225 deg F.

C. Manual Air Vents:

1. Body: Bronze.
2. Internal Parts: Nonferrous.
3. Operator: Key furnished with valve, or screwdriver bit.
4. Inlet Connection: NPS 1/2.
7. Maximum Operating Temperature: 225 deg F.

D. Balancing Valves:
1. Body: Plastic or bronze, ball or plug, or globe cartridge type.
2. Ball or Plug: Brass or stainless steel.
4. Seat: PTFE.
7. Handle Style: Lever or knob, with memory stop to retain set position if used for shutoff.
8. CWP Rating: Minimum 125 psig.
9. Maximum Operating Temperature: 250 deg F.

E. Zone Control Valves:
1. Body: Plastic or bronze, ball or plug, or globe cartridge type.
2. Ball or Plug: Brass or stainless steel.
4. Seat: PTFE.
5. Actuator: Replaceable electric motor.
7. Maximum Operating Temperature: 250 deg F.

F. Thermometers:
1. Mount on supply and return connections.
2. Case: Dry type, metal or plastic, 2-inch diameter.
3. Element: Bourdon tube or other type of pressure element.
4. Movement: Mechanical, connecting element and pointer.
10. Accuracy: Plus or minus 1 percent of range or plus or minus 1 scale division to maximum of 1.5 percent of range.

G. Mounting Brackets: Copper, or plastic or copper-clad steel, where in contact with manifold.

H. Manifold Wall Cabinets: Painted steel or plastic recessed cabinet with removable or hinged door.
2.3 PIPING SPECIALTIES

A. Cable Ties:

1. Fungus-inert, self-extinguishing, 1-piece, self-locking, Type 6/6 nylon cable ties.
3. Tensile Strength: 20 lb, minimum.
4. Temperature Range: Minus 40 to plus 185 deg F.

B. Floor-Mounting Staples:

1. Steel, with corrosion-resistant coating and smooth finish without sharp edges.
3. Width: Minimum, wider than tubing.

C. Floor-Mounting Clamps:

1. Two bolt, steel, with corrosion-resistant coating and smooth finish without sharp edges.
3. Width: Minimum, wider than tubing.

2.4 YARD BOXES

A. Outdoor recessed manifold access yard boxes shall be waterproof material with a bolted cover. Box depth, width, and length shall be suitable for actual manifold size, including space for manifold isolation and balancing valves.

2.5 CONTROLS

A. Temperature-control devices and sequence of operations are specified in Division 23 Sections "Instrumentation and Control for HVAC" and "Sequence of Operations for HVAC Controls."

2.6 SNOW MELT SYSTEM CONTROLS

A. Refer to piping schematic on drawings.

B. Provide Tekmar or equivalent snow melt system controller with snow-melting slab detector and three-way control valve to operate system as follows:

1. Snow-melting slab detector shall start system by sending signal to snow melt system controller that appropriate conditions are present.
2. The snow melt system controller shall send enable command to multi-boiler controller which shall start-up condensing boilers to furnish heating water/glycol mixture at setpoint temperature. Refer to condensing boiler specification Section 23 5216.
3. The snow melt system controller shall send enable command to snow melt system circulation pump and modulate three-way control valve to maintain snow melt system water/glycol mixture at setpoint temperature (Maximum 110 degrees F).
4. Snow melt system controller shall operate system using manufacturers standard protocols through various standard and idling modes until snow melting is no longer required at which time the controller shall shut down system.

2.7 RADIANT FLOOR CONTROLS

A. Temperature-control devices and sequence of operations for radiant floor supply water temperature control are specified in Division 23 Sections "Instrumentation and Control for HVAC" and "Sequence of Operations for HVAC Controls."

B. For radiant floor system, provide the following control components:

1. Zone Control Valves:
   a. Body: Plastic or bronze, ball or plug, or globe cartridge type.
   b. Ball or Plug: Brass or stainless steel.
   d. Seat: PTFE.
   e. Actuator: Replaceable electric motor.
   f. CWP Rating: Minimum 125 psig.
   g. Maximum Operating Temperature: 250 deg F.

2. Wall-Mounting Thermostat:
   a. Minimum temperature range from 50 to 90 deg F.
   b. Manually operated.
   c. Open zone control valves if room temperature falls below the thermostat setting, and close zone control valves when room temperature rises above the thermostat setting.

PART 3 - EXECUTION

3.1 EXAMINATION

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

   1. Ensure that surfaces and pipes in contact with radiant heating piping are free of burrs and sharp protrusions.
   2. Ensure that surfaces and substrates are level and plumb.
   3. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 APPLICATIONS

A. Install the following types of radiant heating piping for the applications described:

   1. Piping in Exterior Pavement: PEX.
   2. Piping in Interior Concrete Floors: PEX.
   3. Piping in Exterior Pavement: PEX.
4. Piping in Interior Reinforced-Concrete Floors: PEX.
5. Piping in Level Fill Concrete Floors (Not Reinforced): [EPDM] [PEX] [PEX/AL/PEX].
6. Piping in Ceilings: PEX.

3.3 INSTALLATION

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 Shop or Coordination Drawings.

B. Install radiant heating piping continuous from the manifold through the heated panel and back to the manifold without piping joints in heated panels.

C. Connect radiant piping to manifold in a reverse-return arrangement.

D. Do not bend pipes in radii smaller than manufacturer's minimum bend radius dimensions.

E. Install yard boxes where indicated with tops level with grade.

F. Install slab sensors where indicated with tops level with concrete.

G. [Install manifolds] in recessed wall cabinet where indicated.

H. [Install manifolds] in accessible locations, or install access panels to provide maintenance access as required in Division 08 Section "Access Doors and Frames."

I. Refer to Division 23 Section "Hydronic Piping" for pipes and connections to hydronic systems.

J. Refer to Division 23 Section "Hydronic Piping" for pipes and connections to hydronic systems [and for glycol-solution fill requirements].

K. Refer to Division 23 Section "HVAC Water Treatment" for glycol-solution fill requirements.

L. Fire- and Smoke-Barrier Penetrations: Maintain indicated fire rating of walls, partitions, ceilings, and floors at pipe penetrations. Seal pipe penetrations with firestop materials according to Division 07 Section "Penetration Firestopping."

M. Piping in Exterior Pavement:
   1. Secure piping in concrete floors by attaching pipes to reinforcement using cable ties.
   2. Space cable ties a maximum of 18 inches o.c., and at center of turns or bends.
   3. Maintain 3-inch minimum cover.
   4. Install a sleeve of 3/8-inch thick, foam-type insulation or PE pipe around tubing and extending for a minimum of 10 inches on each side of slab joints to protect the tubing passing through expansion or control joints. Anchor sleeve to slab form at control joints to provide maximum clearance for saw cut.
   5. Maintain minimum 40-psig pressure in piping during concrete placement and continue for 24 hours after placement.

N. Piping in Interior Concrete Floors:
1. Secure piping in concrete floors by attaching pipes to reinforcement using cable ties.
2. Space cable ties a maximum of 18 inches o.c., and at center of turns or bends.
3. Maintain 2-inch minimum cover.
4. Install a sleeve of 3/8-inch-thick, foam-type insulation or PE pipe around tubing and extending for a minimum of 10 inches on each side of slab joints to protect the tubing passing through expansion or control joints. Anchor sleeve to slab form at control joints to provide maximum clearance for saw cut.
5. Maintain minimum 40-psig pressure in piping during concrete placement and continue for 24 hours after placement.

O. Piping in Level Fill Concrete Floors (Not Reinforced):
1. Secure piping in concrete floors by attaching pipes to subfloor using tracks, clamps, or staples.
2. Space tracks, clamps, or staples a maximum of 18 inches o.c., and at center of turns or bends.
4. Install a sleeve of 3/8-inch-thick, foam-type insulation or PE pipe around tubing and extending for a minimum of 10 inches on each side of slab joints to protect the tubing passing through expansion or control joints. Anchor sleeve to slab form at control joints to provide maximum clearance for saw cut.
5. Maintain minimum 40-psig pressure in piping during the concrete pour and continue for 24 hours during curing.

P. Piping in Ceiling:
1. Secure piping by attaching pipes to ceiling substrate using clamps or staples.
2. Space clamps or staples a maximum of 18 inches o.c., and at center of turns or bends.
3. Maintain 1-1/2-inch minimum plaster cover.
4. Maintain minimum 40-psig pressure in piping during the plaster application and continue for 24 hours during curing.

Q. Revise locations and elevations from those indicated as required to suit field conditions and ensure integrity of piping and as approved by Architect.

R. After system balancing has been completed, mark balancing valves to permanently indicate final position.

S. Perform the following adjustments before operating the system:
1. Open valves to fully open position.
2. Check operation of automatic valves.
3. Set temperature controls so all zones call for full flow.
4. Purge air from piping.

T. After the concrete heating panel has cured as recommended by supplier, operate radiant heating system as follows:
1. Start system heating at a maximum of 10 deg F above the ambient radiant panel temperature, and increase 10 deg F each following day until design temperature is achieved.
2. For freeze protection, operate at a maximum of 60 deg F supply-water temperature.
3.4 FIELD QUALITY CONTROL

A. Prepare radiant heating piping for testing as follows:
   1. Open all isolation valves and close bypass valves.
   2. Open and verify operation of zone control valves.
   3. Flush with clean water, and clean strainers.

B. Tests and Inspections:
   1. Leak Test: After installation and before encasement, charge system and test for leaks. Subject piping to hydrostatic test pressure that is not less than 1.5 times the design pressure but not more than 100 psig. Repair leaks and retest until no leaks exist.
   2. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.

C. Remove and replace malfunctioning radiant heating piping components that do not pass tests, and retest as specified above.

D. Prepare a written report of testing.

END OF SECTION 23 8316