MASTER SPECIFICATIONS

Division 23 – HEATING VENTILATING AND AIR CONDITIONING

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Facilities Management Operations
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Evanston, IL 60208-4301

NORTHWESTERN UNIVERSITY
PROJECT NAME ____________
JOB # ________

FOR: ___________
ISSUED: 03/29/2017

MASTER SPECIFICATIONS: DIVISION 23 – HEATING VENTILATING AND AIR CONDITIONING

*** End of List ***

SECTION 23 0000 - COMMON WORK RESULTS FOR HVAC

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

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

1.2 SUMMARY

A. This Section includes the following:

1. [Project LEED Requirements.]
2. Certain Definitions.
3. References and Standards.
4. Certain Submittals.
5. General Quality Assurance and Safety Requirements.
6. General Operation and Maintenance Manual Requirements.
7. Chicago and Evanston Campus Steam Service Information.
8. Special Warranties.
9. General Delivery, Storage and Handling Requirements.
10. General Coordination Requirements.
11. General Product and Material Requirements.
12. General Requirements for Grout.
13. General Requirements for HVAC Demolition, Equipment Installation, Concrete Bases, and Erection of Metal and Wood Supports and Anchorages.

B. [It is intended this project pursue a LEED ["SILVER"] ["Gold"] rating. LEED criteria will be followed for the installation of building systems. This Contractor shall be responsible for the following items to ensure the Facility achieves LEED certification:

1. SS credit 8 – Light Pollution Reduction.
2. EA prerequisite 2 – Minimum Energy Performance.
3. EA credit 1 – Optimize Energy Performance.
4. MR credit 2 – Construction Waste Management.
5. IEQ credit 4.1 – Low Emitting Materials: Adhesives and Sealants
6. IEQ credit 4.2 – Low Emitting Materials: Paints and Coatings.
7. IEQ credit 6.1 – Controllability of Systems: Lighting.

1.3 DEFINITIONS

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

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

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

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

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

1.4 REFERENCES AND STANDARDS:

A. The editions recognized by latest ***[City of Chicago Codes and Standards] [City of Evanston Codes and Standards]*** of the following are hereby included in and made a part of Division 23:

1. NFPA National Fire Protection Association
2. UL Underwriters' Laboratories, Inc.
3. AFI Air Filter Institute
4. NEMA National Electrical Manufacturer's Association
5. NEC National Electric Code
6. ASHRAE American Society of Heating, Refrigeration and Air Conditioning Engineers
7. ARI American Refrigeration Institute
8. AMCA Air Moving and Conditioning Association
9. ASME American Society of Mechanical Engineers
10. AWS American Welding Society
11. ANSI American National Standards Institute
12. AGA American Gas Association
13. SMACNA Sheet Metal and Air Conditioning Contractors National Association
14. HI Hydronics Institute
15. OSHA Occupational Safety and Health Act
16. MSS Manufacturer's Standardization Society of the Valve and Fittings Industry, Inc.
17. ASTM American Society for Testing and Materials

1.5 SUBMITTALS

A. [As required for LEED portion of project.]

B. Welding certificates.

C. For any equipment/components used by the contractor during construction, submit preventative maintenance records for same.

D. Shutdown "Methods of Procedures", see 1.11-E.

E. Notification to Work Forms, see 1.11-A.

F. Operation and Maintenance Manuals: In PDF format.

G. Northwestern University Maintenance Requirement Forms, see Division 01.

H. As specified elsewhere in this Section.

1.6 QUALITY ASSURANCE, COORDINATION, AND SAFETY

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

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

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

C. Electrical Characteristics for 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.

D. Meet all in-force University, OSHA, state, and local safety requirements.

E. To meet the University goals of safety, reliability, serviceability, and efficient operation, all contractors shall use the burn permit procedure Burn permits are issued b the Facilities Management Operations Engineering Department. The respective trades that are performing any hot work must pick up a Burn Permit prior to commencing any work. Prior to the Burn Permit being picked up, the respective contractor will provide and indicate on the Burn Permit the Northwestern University work order. All procedures indicated on the Burn Permit are to be followed.

F. All work to meet in-force local plumbing code. In the case of discrepancies between the project contract documents and the in-force local code, the most stringent shall govern.

G. Comply with most current edition of Northwestern University Design Standards.

H. All materials and installations shall meet applicable FM Global requirements.

I. Complete Project Closeout list, Pre-Occupancy checklist, and Project Turnover checklist prior to project turnover to Owner.

1.7 GENERAL OPERATION AND MAINTENANCE MANUAL REQUIREMENTS

A. Two weeks prior to shipment, the contractor shall submit three (3) bound copies (One copy for archive, two for shop use. One to the actual shop location and one left on site.) of operating and maintenance data on all equipment furnished (separated by individual unit) to include, but not limited to, the following: Shop Drawings; Model, system/tag and serial numbers of all equipment; Performance data/curves; Fan curves for fans with variable frequency drives shall show fan performance at various percentages of frequency/speed from 100% to 0% in 10% increments; Manufacturer's written instructions for the operation and maintenance of the component equipment; Lubrication schedule indicating all equipment to be lubricated, recommended lubrication interval, and type and quality of lubricant to be used; recommended spare parts. And, submitter must obtain signed proof in writing that the University received this information.

B. All of the above listed documents shall be provided in electronic format to each division in addition to the Northwestern University archives.

C. All assets that are going to be added to the University system will be submitted via Excel spreadsheet. A sample of the format with required information and format is located in Appendix XX. This information will be provided electronically to the representative PM and University Reliability Engineer.

FSI Data
Template'.xlsx

D. Two of the bound copies are to be distributed to the Evanston Engineer's Department. One copy is to be located in the associated mechanical room and another to the shop. The associated manuals will be stored on a project supplied book shelf. Prints are to be installed on a vertical wall mounted print storage rack.

1. Two copies Single line, full size, piping and ventilation prints laminated and stored on the respective print storage device. One copy is for the building and the other is for the shop files.
2. Two copies of the piping print showing floor and branch isolation valves indicated by the respective tag number.
3. Two copies of the ventilation print showing all smoke and fire dampers.

E. Provide verification with Northwestern University Engineering Department to make sure there is record of them receiving Operation and Maintenance Manual.

1.8 CHICAGO AND EVANSTON CAMPUS STEAM SYSTEM INFORMATION

A. For the Evanston campus, central steam is distributed at 150 ***(and/or at 90 psi, verify with NU Evanston campus during design and specification and specify here properly!!)*** psig (known as the "Campus Line"), and at 230 psig. These are distinct piping systems but they both originate from the same high pressure header in the CUP. Steam is and needs to be metered and reduced in pressure after entrance of each building as required. Condensate is returned to the Central Utility plant via pumped or high pressure condensate return.

B. For the Chicago campus, central steam is distributed at 170 psig. Steam is and needs to be metered and reduced in pressure after entrance of each building as required.

C. Both campus' utilize direct buried piping and piping run through tunnels.

1.9 SPECIAL WARRANTIES

A. Five years for new equipment and work, see Division 01.

B. Extended warranties for equipment/work utilized by contractor during construction, see Division 01.

1.10 DELIVERY, STORAGE, AND HANDLING

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

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

1.11 COORDINATION, INCLUDING WITH THE UNIVERSITY, FOR SHUTDOWNS

A. All contractors are to fill out and submit University Notification of Work Forms, and coordinate with the respective University Project Manager.

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

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

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

E. All shutdowns are to be requested with the respective University Project Manager. All shutdowns must have a shutdown request filled out for the applicable trade and submitted to the respective trades's shop calendar 48 hours in advance, they shall include Methods of Procedure. Emergency situations will be addresses and a case by case basis.

PART 2 - PRODUCTS

2.1 EQUIPMENT AND MATERIALS:

A. All equipment and materials shall be furnished in strict accordance with the equipment named and according to Specification requirements. Each bid shall be based upon one of the materials or manufacturers specified.

B. Equipment and materials specified shall be considered to have prior approval, but submittal for approval is required. Furnish construction drawings to other Contractors when required to coordinate construction.

C. Where multiple manufacturers are named the drawings and specifications are based on the requirements and layouts for the equipment of the first named manufacturer. Any change required by the use of other named manufacturers such as revisions to foundations, bases, piping, controls, wiring, openings, and appurtenances shall be made by the Contractor at no additional cost to the Owner. Changes must be submitted to the University for approval.

2.2 GROUT

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

1. Characteristics: Post-hardening, volume-adjusting, non-staining, noncorrosive, nongaseous, and recommended for interior and exterior applications.
2. Design Mix: 5000-psi (34.5-MPa), 28-day compressive strength.
3. Packaging: Premixed and factory packaged.

PART 3 - EXECUTION

3.1 DEMOLITION

A. Refer to Division 01 Section covering cutting and patching" and Division 02 Section covering demolition for general demolition requirements and procedures.

B. 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.
8. All piping and ductwork that is not to be reused shall be removed back to the nearest main and capped/plugged with similar material.

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

3.2 GENERAL REQUIREMENTS

A. All work shall be installed in a neat, workmanlike, and professional manner.

B. All materials and equipment provided under this contract shall be new (except where otherwise noted) and shall be listed, labeled or certified by Underwriters Laboratories, Inc., or other acceptable entity.

C. All materials, products, and equipment being installed which fall into a category covered by the <u>ENERGY STAR</u>® program must be labeled as such.

D. All equipment of the same type shall be by the same manufacturer.

E. Where any device or part of equipment is referred to in these specifications in the singular number (e.g., "the diffuser"), this reference shall be deemed to apply to as many such devices as are required to complete the installation as shown on the drawings.

F. During construction the contractor shall at all times maintain HVAC utilities of the building without interruption. Should it be necessary to interrupt any HVAC service or utility, the contractor shall secure permission in writing from the University for such interruption at least seven days in advance. Any interruption shall be made with minimum amount of inconvenience to the University and any shut-down time shall have to be on a premium time basis and such time to be included in the contractor's bid. Arrange to provide and pay for temporary HVAC if required by project conditions.

G. Measure indicated mounting heights to bottom of units/work for suspended items and to center of items of work for wall-mounted items.

H. Headroom Maintenance: If mounting heights or other location criteria are not indicated, arrange and install components and equipment to provide maximum possible headroom consistent with these requirements.

I. Working clearance around equipment shall not be less than that specified by the in-force codes, standards, and the equipment manufacturer's instructions.

J. The locations of sensors, grilles, registers, diffusers, equipment, piping, ductwork, etc. shown are approximate. The contractor shall use good judgment in placing the preceding items to eliminate all interference with lights, cabinetry, sprinklers, etc. The contractor shall check all furniture plans so that wall mounted sensors, panels, etc., are not located behind same. Relocate same as required, with approval from the Architect and Engineer. The University may direct relocation of sensors before installation, up to five (5) feet from the position indicated on the Drawings, without additional cost.

K. Equipment: Install to facilitate service, maintenance, and repair or replacement of components of both HVAC equipment and other nearby work/installations. Connect in such a way as to facilitate future disconnecting with minimum interference with other items in the vicinity. Normal maintenance shall not require the removal of protective guards from adjacent equipment. Install equipment as close as practical to the locations shown on the Drawings.

   1. Where the University determines that the Contractor has installed equipment not conveniently accessible for operations and maintenance, the equipment shall be removed and reinstalled as directed at no additional cost to the University.
   2. “Conveniently Accessible” is defined as being capable of being reached/serviced/maintained without climbing or crawling over or under obstacles such as ductwork, large conduits or banks of conduits, large piping or banks of piping, or similar.

L. Coordinate work with all other trades. This is to include coordinating to eliminate interference to allow proper access to equipment doors, access to valves, and to not interrupt equipment or devices proper operation.

M. Firestopping shall be applied to HVAC penetrations of fire-rated floor and wall assemblies to restore/create the required fire-resistance rating of the assembly according to appropriate Division 07 and 09 Sections and the University Fire Protection Group. All floor or wall penetrations will be sleeved with the same or compatible material and appropriately firestopped.

N. Owner Furnished Equipment: Equipment furnished by the University shall be received, stored, protected, uncrated, moved into position, and installed by the Contractor with all appurtenances required to place the equipment in operation, ready for use. The Contractor shall be responsible for the equipment as if he had purchased the equipment himself/herself.

3.3 EQUIPMENT INSTALLATION - COMMON REQUIREMENTS

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

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

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

D. Provide access to mechanical equipment, components, and work per manufacturer's recommendations.

E. Minimum service access size for HVAC equipment/components above ceilings shall be 24" cubed.

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

G. Install equipment to allow for proper access to all ancillary devices that are part of the equipment. This includes valves, circuit setters, building automation system controllers.

1. If valves are not readily accessible for proper isolation, adequate pipe spacing needs to be allowed with consideration given to insulation that will be installed.

2. Valves that are located in areas where access is difficult will be installed at the three or nine o'clock position to allow for service. If this any question about the serviceability, the owner’s appropriate representative will be consulted for review.

3.4 CONCRETE BASES

A. Concrete Bases: Anchor equipment to concrete base according to equipment manufacturer's written instructions.

1. Construct concrete bases of dimensions indicated, but not less than 4 inches larger in both directions than supported unit. Install dowel rods to connect concrete base to concrete floor.
2. 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 “Cast-in-Place Concrete” unless otherwise noted on the drawings.

3.5 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.

3.6 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.

D. All wood used to be fire retardant/treated wood, to be approved by the Architect, and is to be used minimally.

3.7 GROUTING

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

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

C. Provide forms as required for placement of grout.

D. Avoid air entrapment during placement of grout.

E. Place grout, completely filling equipment bases.

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

G. Place grout around anchors.

H. Cure placed grout.

END OF SECTION 23 0000

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SECTION 23 0513 - MOTORS

PART 1 - GENERAL

1.1 SUMMARY

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

1.2 SUBMITTALS

A. Motor product data including wiring diagrams.

B. Operation and maintenance data.

C. Northwestern University Maintenance Requirement Forms, see Division 01.

D. [Submittals for LEED as required.]

1.3 COORDINATION

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

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

1.4 QUALITY ASSURANCE

A. Comply with FM Global requirements for motors and VFD's and for monitoring and diagnosis of vibration in rotating machinery.

1.5 SPECIAL WARRANTY

A. Five (5) years, see Division 01.

PART 2 - PRODUCTS

2.1 MANUFACTURERS/MODELS

1. Siemens Electric Type RGZE.

2. Reliance Type XE.
3. US Electric Motors Type UTE or CE.
4. General Electric Type E4.
5. Marathon Electric XRI Blue Chip.

2.2 GENERAL MOTOR REQUIREMENTS

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

B. Comply with NEMA MG 1 unless otherwise indicated.

C. Motor efficiencies shall at a minimum comply with the most recent editions of the International Energy Conservation Code and ASHRAE 90.1 Energy Standard for Buildings Except Low-Rise Residential Buildings.

D. Motors shall be selected such that the brake horsepower (bhp), including drive losses of the driven equipment, does not exceed 90% of the motor nameplate at design conditions.

2.3 MOTOR CHARACTERISTICS

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

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

C. The service factor for HVAC motors shall be 1.15.

2.4 POLYPHASE MOTORS

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

B. Efficiency: Premium Efficiency, as defined in NEMA MG 1.

C. Multispeed Motors: Variable torque.

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

D. Rotor: Random-wound, squirrel cage.

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

F. Temperature Rise: Match insulation rating.

G. Insulation: Class F.

H. Code Letter Designation:

1. Motors 15 HP and Larger: NEMA starting Code F or Code G.

2. Motors Smaller than 15 HP: Manufacturer's standard starting characteristic.

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

2.5 POLYPHASE MOTORS WITH ADDITIONAL REQUIREMENTS

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

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

1. Windings: Copper magnet wire with moisture-resistant insulation varnish, designed and tested to resist transient spikes, high frequencies, and short time rise pulses produced by pulse-width modulated inverters.
2. Energy- and Premium-Efficient Motors: Class B temperature rise; Class F insulation.
3. Inverter-Duty Motors: Class F temperature rise; Class H insulation.
4. Thermal Protection: Comply with NEMA MG 1 requirements for thermally protected motors.
5. Motors driven by a VFD shall not operate in their service factor.
6. Motors driven by a VFD shall be provided with shaft grounding brushes/rings similar to AEGIS SGR's to prevent bearings from shaft currents.
7. See 2.7-F herein also.

2.6 SINGLE-PHASE MOTORS

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

1. Permanent-split capacitor.
2. Split phase.
3. Capacitor start, inductor run.
4. Capacitor start, capacitor run.

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

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

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

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

2.7 MORE SPECIFIC MOTOR REQUIREMENTS

A. Motors within air handling unit air streams shall be totally enclosed fan cooled (TEFC).

B. HVAC motors outdoors, not in an airstream, shall be totally enclosed fan cooled (TEFC) and shall have epoxy sealed windings using vacuum and pressure with rotor and stator surfaces protected with epoxy enamel. Bearings shall be double shielded with waterproof non-washing grease.

C. HVAC motors indoors, and not in an airstream, shall be open drip proof (ODP).

D. All motors over 5 hp shall have rigging fixtures for easy removal and installation.

E. All "critical" motors shall have vibration analysis monitoring tied into the BAS system. Coordinate with the University during bidding and construction.

  1. Critical is defined as any location that is serving a research location or a process that is essential to "day to day" operations of the University.

F. Additional Requirements for Three Phase Motors Used with Variable Frequency Drives:

  1. Motors hall be "inverter-ready" by complying with or exceeding MG1 Part 31 requirements regarding special purpose motors for use with variable frequency drives.
  2. Windings shall be copper magnet wire with moisture resistant insulation, varnish, and designed and tested to resist transient spikes, high frequencies, and short time pulses produced by PWM inverters.
  3. Motors shall be equipped with shaft grounding rings to dissipate potential VFD-induced motor shaft currents by grounding through the motor housings. ***(This provision for grounding devices shall not apply to motors used in environments defined as Class 1 Divison1, Division 2, or Class 1 Zone 1, Zone 2 hazardous locations.)***

PART 3 - EXECUTION (Not Applicable)

END OF SECTION 23 0513

SECTION 23 0514 - VARIABLE-FREQUENCY DRIVES (VFD's)

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

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

1.2 SUMMARY

A. Section includes separately enclosed, pre-assembled, combination VFDs, rated 600 V and less, for speed control of three-phase, squirrel-cage induction motors.

B. Harmonic analysis.

1.3 DEFINITIONS

A. AO - Analog Output.

B. BAS: Building automation system.

C. BI - Binary Input.

D. BO - Binary Output.

E. CE: Conformite Europeene (European Compliance).

F. CPT: Control power transformer.

G. EMI: Electromagnetic interference.

H. EMS - Energy Management System.

I. IGBT: Insulated-gate bipolar transistor.

J. LAN: Local area network.

K. LED: Light-emitting diode.

L. Local: Within 50 miles of job.

M. MCP: Motor-circuit protector.

N. NC: Normally closed.

O. NO: Normally open.

P. OCPD: Overcurrent protective device.

Q. PCC: Point of common coupling.

R. PID: Control action, proportional plus integral plus derivative.

S. PWM: Pulse-width modulated.

T. RFI: Radio-frequency interference.

U. TDD: Total demand (harmonic current) distortion.

V. THD(V): Total harmonic voltage demand.

W. VFD: Variable-frequency motor controller.

1.4 ACTION SUBMITTALS

A. Product Data: For each type and rating of VFD indicated. Include features, options, performance, electrical ratings, operating characteristics, shipping and operating weights, and furnished specialties and accessories.

1.5 INFORMATIONAL SUBMITTALS

A. Shop Drawings: For each VFD indicated. Include dimensioned plans, elevations, and sections; and conduit entry locations and sizes, mounting arrangements, and details, including required clearances and service space around equipment.

1. Show tabulations of installed devices, equipment features, and ratings. Include the following:

a. Each installed unit's type and details.
b. Factory-installed devices.
c. Enclosure types and details.
d. Nameplate legends.
e. Short-circuit current (withstand) rating of enclosed unit.
f. Features, characteristics, ratings, and factory settings of each VFD and installed devices.
g. Specified modifications.
h. Outline dimensions, conduit entry locations and weight.
i. Customer connection and power wiring diagrams.
j. Complete technical product description include a complete list of options provided. Any portions of this specification not met must be clearly indicated or the supplier and contractor shall be liable to provide all additional components required to meet this specification.

2. Schematic and Connection Wiring Diagrams: For power, signal, and control wiring.

B. Coordination Drawings: Floor plans, drawn to scale, showing dimensioned layout, required working clearances, and required area above and around VFDs. Show VFD layout and relationships between electrical components and adjacent structural and mechanical elements. Show support locations, type of support, and weight on each support. Indicate field measurements.

C. Qualification Data: For qualified testing agency.

D. Product Certificates: For each VFD, from manufacturer.

E. Source quality-control reports.

F. Field quality-control reports.

G. Results of harmonic analysis.

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

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

1.6 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For VFDs to include in emergency, operation, and maintenance manuals. In addition to items specified in ***Section 01 7000 "Execution and Closeout Requirements,"*** include the following:

1. Manufacturer's written instructions for testing and adjusting thermal-magnetic circuit breaker and MCP trip settings.
2. Manufacturer's written instructions for setting field-adjustable overload relays.
3. Manufacturer's written instructions for testing, adjusting, and reprogramming microprocessor control modules.
4. Manufacturer's written instructions for setting field-adjustable timers, controls, and status and alarm points.

B. Northwestern University Maintenance Requirement Forms, see Division 01.

1.7 MAINTENANCE MATERIAL SUBMITTALS

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

1. Power Fuses: Equal to 10 percent of quantity installed for each size and type, but no fewer than three of each size and type.
2. Control Power Fuses: Equal to 10 percent of quantity installed for each size and type, but no fewer than two of each size and type.
3. Indicating Lights: Two of each type and color installed.
4. Auxiliary Contacts: Furnish one spare(s) for each size and type of magnetic controller installed.
5. Power Contacts: Furnish three spares for each size and type of magnetic contactor installed.

1.8 QUALITY ASSURANCE

A. Factory Testing: Each drive, and all features of same, shall be factory tested under motor or other similar torque load that simulates the project duty.

B. Testing Agency Qualifications: Member company of NETA or an NRTL.

1. Testing Agency's Field Supervisor: Currently certified by NETA to supervise on-site testing.

C. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

D. Comply with NFPA 70.

E. IEC rated components are not acceptable.

F. Referenced Standards and Guidelines:

1. Institute of Electrical and Electronic Engineers (IEEE)

a. IEEE 519-1992, Guide for Harmonic Content and Control.

2. Underwriters Laboratories (as appropriate)

a. UL508
b. UL508A
c. UL508C

3. National Electrical Manufacturer’s Association (NEMA)

a. ICS 7.0, AC Adjustable Speed Drives

4. International Electrotechnical Commission (IEC)

a. EN/IEC 61800-3

5. National Electric Code (NEC)

a. NEC 430.120, Adjustable-Speed Drive Systems

G. Harmonic Analysis: The VFD manufacturer shall perform a harmonic analysis at no cost to the University. The maximum allowable Total Harmonic Distortion (THD) imparted to the facility electrical system shall be 5% for current and voltage per IEEE-519. The University "may" be able to provide certain assistance/information for this analysis, but verify during bidding. The project provided VFD's shall be outfitted to limit the THD to the final, coordinated, harmonic analysis results.

H. IEEE Analysis: The VFD supplier shall, with the aid of the Owner's detailed electrical power single line diagram showing all impedances in the power path to the VFD's, perform an analysis to initially demonstrate that the supplied drives will meet the IEEE recommendations after installation. If, as a result of the analysis, it is determined that additional filtering, isolation, or reactor equipment is required to meet IEEE recommendations, then the cost of such equipment shall be included in the drive supplier's quotation.

I. Qualifications:

1. VFDs and options shall be UL508 listed as a complete assembly. The base VFD shall be UL listed for 100 kA SCCR without the need for input fuses. Base VFDs with red label UL stickers requiring additional branch circuit protection are not acceptable.
2. CE Mark – The base VFD shall conform to the European Union Electromagnetic Compatibility directive, a requirement for CE marking. The VFD shall meet product standard EN 61800-3 for the First Environment restricted level (Category C2). Base drives that only meet the Second Environment (Category C3, C4) shall be supplied with external filters to bring the drive in compliance with the First Environment levels.

J. Comply with FM Global requirements for VFD's

1.9 DELIVERY, STORAGE, AND HANDLING

A. Store in space that is permanently enclosed and air conditioned.

1.10 PROJECT CONDITIONS

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

1. Ambient Temperature: Not less than 14 deg F (minus 10 deg C) and not exceeding 104 deg F (40 deg C).
2. Ambient Storage Temperature: Not less than minus 4 deg F (minus 20 deg C) and not exceeding 140 deg F (60 deg C)
3. Humidity: Less than 95 percent (noncondensing).
4. Altitude: Not exceeding 3300 feet (1005 m).

B. Interruption of Existing Electrical Systems: Do not interrupt electrical systems in facilities occupied by the University or others unless permitted under the following conditions and then only after arranging to provide temporary electrical service according to requirements indicated:

1. Notify the University no fewer than seven days in advance of proposed interruption of electrical systems.
2. Indicate method of providing temporary electrical service.
3. Do not proceed with interruption of electrical systems without the University's written permission.
4. Comply with NFPA 70E.

C. Product Selection for Restricted Space: Drawings indicate maximum dimensions for VFDs, including clearances between VFDs, and adjacent surfaces and other items.

1.11 COORDINATION

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

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

B. Coordinate sizes and locations of concrete bases with actual equipment provided. Cast anchor-bolt inserts into bases.

C. Coordinate sizes and locations of roof curbs, equipment supports, and roof penetrations with actual equipment provided.

D. Verify during bidding, and again prior to construction, the required communication protocol required for the drives and provide the required drive electronics for proper communication with other devices/systems on the job.

1.12 WARRANTY

A. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace VFDs that fail in materials or workmanship within specified warranty period.

1. Warranty Period: Five years from date of turnover to the University.

PART 2 - PRODUCTS

2.1 MANUFACTURED UNITS

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

1. ABB (Basis of Design and Highly Preferred).
2. Danfoss or Toshiba (if approved in writing as an acceptable alternate by the Electrical Shop).

2.2 VARIABLE FREQUENCY DRIVES

A. The VFD's to be purchased by local contractor from a local representative, factory authorized for start-up and service.

B. The VFD package as specified herein shall be enclosed in a UL Listed Type enclosure, exceeding NEMA enclosure design criteria (enclosures with only NEMA ratings are not acceptable), completely assembled and tested by the manufacturer in an ISO 9001 facility. Enclosure shall be determined by the environment where the VFD's are being installed.

C. The VFD's shall be minimum 12 pulse inverter types, providing full rated output from a line of ±10% of nominal voltage. The VFD shall continue to operate without faulting from a line of +30% to -35% of nominal voltage.

1. VFDs shall be capable of continuous full load operation under the following environmental operating conditions:

a. -15 to 40° C (5 to 104° F) ambient temperature. Operation to 50° C shall be allowed with a 10% reduction from VFD full load current.
b. Altitude 0 to 3300 feet above sea level Operation to 6600 shall be allowed with a 10% reduction from VFD full load current.
c. Humidity less than 95%, non-condensing.

d. Enclosure shall have a UL Type rating and shall be UL listed and available as a plenum rated VFD. VFDs without these ratings are not acceptable. Non UL Type enclosures (e.g. self-certified NEMA enclosures) are not acceptable.

D. All VFDs shall have the following features:

1. Main input circuit breakers with cover mounted handles.
2. Input Signal: 4 - 20 mA, (AO).
3. Output for a 4-20 mA feedback to EMS (AI) via communications link.
4. System enable terminal from EMS (BO) and system status contacts for EMS (BI).
5. Malfunction alarm contact for EMS (BI).
6. Digital current meter mounted on the door.
7. Overload relay.
8. DC link reactor and IGBT technology.
9. Minimum carrier frequency of 8kHz.
10. High motor winding temperatures shall shut down the driven device and alarm same.
11. Isolation transformer (if required per harmonics analysis).
12. 110% continuous current capability, and 120% overload capacity for 60 seconds minimum.
13. All circuit boards shall be coated. Drives that contain circuit boards that are not coated are not acceptable.
14. All VFDs shall have the same customer interface, including digital display, and keypad, regardless of horsepower rating. The keypad shall be removable, capable of remote mounting and allow for uploading and downloading of parameter settings as an aid for start-up of multiple VFDs. Complete set-up of drives shall be able to be accomplished through the keypad and display, and all drive points to be similarly accessible.
15. The keypad shall include Hand-Off-Auto selections and manual speed control. The drive shall incorporate “bumpless transfer” of speed reference when switching between “Hand” and “Auto” modes. There shall be fault reset and “Help” buttons on the keypad. The Help button shall include “on-line” assistance for programming and troubleshooting.
16. There shall be a built-in time clock in the VFD keypad. The clock shall have a battery backup with 10 years minimum life span. The clock shall be used to date and time stamp faults and record operating parameters at the time of fault. VFD programming shall be held in non-volatile memory and is not dependent on battery power
17. The VFD’s shall utilize pre-programmed application macros specifically designed to facilitate start-up. The Application Macros shall provide one command to reprogram all parameters and customer interfaces for a particular application to reduce programming time. The VFD shall have two user macros to allow the end-user to create and save custom settings.
18. The VFD shall have cooling fans that are designed for easy replacement. The fans shall be designed for replacement without requiring removing the VFD from the wall or removal of circuit boards. The VFD cooling fans shall operate only when required, based on the temperature of and run command to the drive. VFD protection shall be based on thermal sensing and not cooling fan operation.
19. The VFD shall be capable of starting into a coasting load (forward or reverse) up to full speed and accelerate or decelerate to set point without tripping or component damage (flying start).
20. The VFD shall have the ability to automatically restart after an over-current, over-voltage, under-voltage, or loss of input signal protective trip. The number of restart attempts, trial time, and time between attempts shall be programmable.
21. The overload rating of the drive shall be 110% of its normal duty current rating for 1 minute every 10 minutes, 130% overload for 2 seconds every minute. The minimum FLA rating shall meet or exceed the values in the NEC/UL table 430.250 for 4-pole motors.

22. The input current rating of the VFD shall not be greater than the output current rating. VFD's with higher input current ratings require the upstream wiring, protection devices, and source transformers to be oversized per NEC 430.122. Input and output current ratings must be shown on the VFD nameplate.
23. The VFD shall include a coordinated AC transient surge protection system consisting of 4 MOVs (phase to phase and phase to ground), a capacitor clamp, 1600 PIV Diode Bridge and internal chokes. VFDs that do not include coordinated AC transient surge protection shall include an external TVSS (Transient Voltage Surge Suppressor).
24. The VFD shall provide a programmable loss-of-load (broken belt / broken coupling) Form-C relay output. The drive shall be programmable to signal the loss-of-load condition via a keypad warning, Form-C relay output, and / or over the serial communications bus. The loss-of-load condition sensing algorithm shall include a programmable time delay that will allow for motor acceleration from zero speed without signaling a false loss-of-load condition.
25. The VFD shall include multiple "two zone" PID algorithms that allow the VFD to maintain PID control from two separate feedback signals (4-20mA, 0-10V, and / or serial communications). The two zone control PID algorithm will control motor speed based on a minimum, maximum, or average of the two feedback signals. All of the VFD PID controllers shall include the ability for "two zone" control.
26. If the input reference is lost, the VFD shall give the user the option of either (1) stopping and displaying a fault, (2) running at a programmable preset speed, (3) hold the VFD speed based on the last good reference received, or (4) cause a warning to be issued, as selected by the user. The drive shall be programmable to signal this condition via a keypad warning, Form-C relay output and / or over the serial communication bus.
27. The VFD shall have programmable "Sleep" and "Wake up" functions to allow the drive to be started and stopped from the level of a process feedback signal.
28. All VFD faults shall be time stamped in a VFD fault log to aid troubleshooting. The faults to display in plain language.

E. All VFDs to have the following adjustments:

1. Three (3) programmable critical frequency lockout ranges to prevent the VFD from operating the load continuously at an unstable speed. The lockout range must be fully adjustable, from 0 to full speed.
2. Two (2) PID Set point controllers shall be standard in the drive, allowing pressure or flow signals to be connected to the VFD, using the microprocessor in the VFD for the closed-loop control. The VFD shall have 250 ma of 24 VDC auxiliary power and be capable of loop powering a transmitter supplied by others. The PID set point shall be adjustable from the VFD keypad, analog inputs, or over the communications bus. There shall be two independent parameter sets for the PID controller and the capability to switch between the parameter sets via a digital input, serial communications or from the keypad. The independent parameter sets are typically used for night setback, switching between summer and winter set points, etc.
3. There shall be an independent, second PID loop that can utilize the second analog input and modulate one of the analog outputs to maintain the set point of an independent process (i.e. valves, dampers, etc.). All set points, process variables, etc. to be accessible from the serial communication network.
4. Two (2) programmable analog inputs shall accept current or voltage signals.
5. Two (2) programmable analog outputs (0-20ma or 4-20 ma). The outputs may be programmed to output proportional to Frequency, Motor Speed, Output Voltage, Output Current, Motor Torque, Motor Power (kW), DC Bus voltage, Active Reference, Active Feedback, and other data. Drives that have only one (1) analog output must provide an option card that provides additional analog outputs.

6. Six (6) programmable digital inputs for maximum flexibility in interfacing with external devices. All digital inputs shall be programmable to initiate upon an application or removal of 24VDC or 24VAC.
7. Three (3) programmable, digital Form-C relay outputs. The relay outputs shall include programmable on and off delay times and adjustable hysteresis. The relays shall be rated for maximum switching current 8 amps at 24 VDC and 0.4 A at 250 VAC; Maximum voltage 300 VDC and 250 VAC; continuous current rating of 2 amps RMS. Outputs shall be true Form-C type contacts; open collector outputs are not acceptable. Drives that have only two (2) relay outputs must provide an option card that provides additional relay outputs.
8. Run Permissive Circuit - There shall be a run permissive circuit for damper or valve control. Regardless of the source of a run command (keypad, input contact closure, time-clock control, or serial communications), the VFD shall provide a dry contact closure that will signal the damper to open (VFD motor does not operate). When the damper is fully open, a normally open dry contact (end-switch) shall close. The closed end-switch is wired to a VFD digital input and allows VFD motor operation. Two separate safety interlock inputs shall be provided. When either safety is opened, the motor shall be commanded to coast to stop and the damper shall be commanded to close. The keypad shall display “start enable 1 (or 2) missing”. The safety input status shall also be transmitted over the serial communications bus.
9. The VFD control shall include a programmable time delay for VFD start and a keypad indication that this time delay is active. A Form C relay output provides a contact closure to signal the VAV boxes open. This will allow VAV boxes to be driven open before the motor operates. The time delay shall be field programmable from 0 – 120 seconds. Start delay shall be active regardless of the start command source (keypad command, input contact closure, time-clock control, or serial communications), and when switching from drive to bypass.
10. Seven (7) programmable preset speeds.
11. Two independently adjustable accel and decel ramps with 1 – 1800 seconds adjustable time ramps.
12. The VFD shall include a motor flux optimization circuit that will automatically reduce applied motor voltage to the motor to optimize energy consumption and reduce audible motor noise. The VFD shall have selectable software for optimization of motor noise, energy consumption, and motor speed control.
13. The VFD shall include a carrier frequency control circuit that reduces the carrier frequency based on actual VFD temperature that allows higher carrier frequency settings without derating the VFD.
14. The VFD shall include password protection against parameter changes.

F. The Keypad shall include a backlit LCD display. The display shall be in complete English words for programming and fault diagnostics (alpha-numeric codes are not acceptable). All VFD faults shall be displayed in English words. The keypad shall include a minimum of 14 assistants including:

1. Start-up assistant
2. Parameter assistants

   a. PID assistant
   b. Reference assistant
   c. I/O assistant
   d. Serial communications assistant
   e. Option module assistant
   f. Panel display assistant
   g. Low noise set-up assistant

3. Maintenance assistant
4. Troubleshooting assistant
5. Drive optimizer assistants

G. All applicable operating values shall be capable of being displayed in engineering (user) units. A minimum of three operating values from the list below shall be capable of being displayed at all times. The display shall be in complete English words (alpha-numeric codes are not acceptable):

1. Output Frequency
2. Motor Speed (RPM, %, or Engineering units)
3. Motor Current
4. Motor Torque
5. Motor Power (kW)
6. DC Bus Voltage
7. Output Voltage

H. The VFD shall include a fireman's override input. Upon receipt of a contact closure from the fire / smoke control station, the VFD shall operate in one of two modes: 1) Operate at a programmed predetermined fixed speed ranging from -500Hz (reverse) to 500Hz (forward). 2) Operate in a specific fireman's override PID algorithm that automatically adjusts motor speed based on override set point and feedback. The mode shall override all other inputs (analog/digital, serial communication, and all keypad commands), except customer defined safety run interlocks, and force the motor to run in one of the two modes above. "FIREMODE" shall be displayed on the keypad. Upon removal of the override signal, the VFD shall resume normal operation, without the need to cycle the normal digital input run command.

I. Serial Communications

1. The VFD shall have an EIA-485 port as standard. The standard protocols shall be Modbus, Johnson Controls N2, Siemens Building Technologies FLN, and BACnet. Optional protocols for LonWorks, Profibus, EtherNet, BACnet IP, and DeviceNet shall be available, and be provided as required for the project. Each individual drive shall have the protocol in the base VFD. The use of third party gateways and multiplexers is not acceptable. All protocols shall be "certified" by the governing authority (i.e. BTL Listing for BACnet). Use of non-certified protocols is not allowed.
2. The BACnet connection shall be an EIA-485, MS/TP interface operating at 9.6, 19.2, 38.4, or 76.8 Kbps. The connection shall be tested by the BACnet Testing Labs (BTL) and be BTL Listed. The BACnet interface shall conform to the BACnet standard device type of an Applications Specific Controller (B-ASC). The interface shall support all BIBBs defined by the BACnet standard profile for a B-ASC including, but not limited to:

    a. Data Sharing – Read Property – B.
    b. Data Sharing – Write Property – B.
    c. Device Management – Dynamic Device Binding (Who-Is; I-Am).
    d. Device Management – Dynamic Object Binding (Who-Has; I-Have).
    e. Device Management – Communication Control – B.

3. If additional hardware is required to obtain the BACnet interface, the VFD manufacturer shall supply one BACnet gateway per drive. Multiple VFDs sharing one gateway shall not be acceptable.
4. Serial communication capabilities shall include, but not be limited to; run-stop controls, speed set adjustment, and lock and unlock the keypad. The drive shall have the capability of allowing the BAS to monitor feedback such as process variable feedback,

output speed / frequency, current (in amps), % torque, power (kW), kilowatt hours (resettable), operating hours (resettable), and drive temperature. The BAS shall also be capable of monitoring the VFD relay output status, digital input status, and all analog input and analog output values. All diagnostic warning and fault information shall be transmitted over the serial communications bus. Remote VFD fault reset shall be possible.

5. Serial communication in bypass (if bypass is specified) shall include, but not be limited to; bypass run-stop control, the ability to force the unit to bypass, and the ability to lock and unlock the keypad. The bypass shall have the capability of allowing the BAS to monitor feedback such as, current (in amps), kilowatt hours (resettable), operating hours (resettable), and bypass logic board temperature. The BAS shall also be capable of monitoring the bypass relay output status, and all digital input status. All bypass diagnostic warning and fault information shall be transmitted over the serial communications bus. Remote bypass fault reset shall be possible.
6. The VFD / bypass shall allow the BAS to control the drive and bypass digital and analog outputs via the serial interface. This control shall be independent of any VFD function. The analog outputs may be used for modulating chilled water valves or cooling tower bypass valves, if applicable. The drive and bypass' digital (Form-C relay) outputs may be used to actuate a damper, open a valve or control any other device that requires a maintained contact for operation. In addition, all of the drive and bypass' digital inputs shall be capable of being monitored by the BAS system. This allows for remote monitoring of which (of up to 4) safeties are open.
7. The VFD shall include an independent PID loop for customer use. The independent PID loop may be used for cooling tower bypass value control, chilled water value / hot water valve control, etc. Both the VFD PID control loop and the independent PID control loop shall continue functioning even if the serial communications connection is lost. As default, the VFD shall keep the last good set point command and last good DO & AO commands in memory in the event the serial communications connection is lost and continue controlling the process.

J. EMI / RFI filters. All VFD's shall include EMI/RFI filters. The onboard filters shall allow the VFD assembly to be CE Marked and the VFD shall meet product standard EN 61800-3 for the First Environment restricted level (Category C2) with up to 100 feet of motor cable. Second environment (Category C3, C4) is not acceptable, no Exceptions. Certified test reports shall be provided with the submittals confirming compliance to EN 61800-3, First Environment (C2).

K. DRIVE OPTIONS – Options shall be furnished and mounted by the drive manufacturer as defined by the VFD schedule. All optional features shall be UL Listed by the drive manufacturer as a complete assembly and carry a UL508 label.

1. Fieldbus adapters – The following optional fieldbus adapters shall be available as a plug in modules, and provided as required for the project.

   a. LonWorks
   b. DeviceNet
   c. Ethernet IP

      1) ControlNet over Ethernet & ModBus TCP

   d. BACnet IP
   e. Profibus

L. BYPASSES AND/OR REDUNDANT (Drives with primary and backup drives in same enclosure) DRIVES

1. ***[Based on duty (critical, non-critical, supply, return, exhaust, or other air, pumps, involved with smoke control or not, etc.), the design AE must select and fully specify here, either no bypass required, mechanical ATL bypass, redundant drives, or electronic (Smart) bypasses. Electronic bypasses are generally preferred by the University but may not be the right choice for all applications. Coordinate with the University and the Electrical Shop when final specifying.]***

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine areas, surfaces, and substrates to receive VFDs, with Installer present, for compliance with requirements for installation tolerances, and other conditions affecting performance.

B. Examine VFD before installation. Reject VFDs that are wet, moisture damaged, or mold damaged.

C. Examine roughing-in for conduit systems to verify actual locations of conduit connections before VFD installation.

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

3.2 INSTALLATION

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

B. Wall-Mounting Controllers: Install VFDs on walls with tops at uniform height and with disconnect operating handles not higher than 79 inches above finished floor unless otherwise indicated, and by mounting units on lightweight structural-steel channels bolted to wall. For controllers not on walls, provide freestanding racks complying with ***Section 26 0529 "Hangers and Supports for Electrical Systems."***

C. Floor-Mounting Controllers: Install VFDs on 4-inch nominal thickness concrete base. Comply with requirements for concrete base specified in

1. Install dowel rods to connect concrete base to concrete floor. Unless otherwise indicated, install dowel rods on 18-inch centers around the full perimeter of concrete base.
2. For supported equipment, install epoxy-coated anchor bolts that extend through concrete base and anchor into structural concrete floor.
3. Place and secure anchorage devices. Use setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
4. Install anchor bolts to elevations required for proper attachment to supported equipment.

D. Temporary Lifting Provisions: Remove temporary lifting eyes, channels, and brackets and temporary blocking of moving parts from enclosures and components.

E. Install fuses in each fusible-switch VFD.

F. Install fuses in control circuits if not factory installed. Comply with requirements in ***Section 26 2813 "Fuses."***

G. Install heaters in thermal-overload relays. Select heaters based on actual nameplate full-load amperes after motors have been installed.

H. Install, connect, and fuse thermal-protector monitoring relays furnished with motor-driven equipment.

I. Comply with NECA 1.

J. Drives to be located in a normal University area of work.

3.3 IDENTIFICATION

A. Identify VFDs, components, and control wiring. Comply with requirements for identification specified in ***Section 26 0553 "Identification for Electrical Systems."***

1. Identify field-installed conductors, interconnecting wiring, and components; provide warning signs.
2. Label each VFD with engraved nameplate.
3. Label each enclosure-mounted control and pilot device.

B. Operating Instructions: Frame printed operating instructions for VFDs, including control sequences and emergency procedures. Fabricate frame of finished metal, and cover instructions with clear acrylic plastic. Mount on front of VFD units.

3.4 CONTROL WIRING INSTALLATION

A. Install wiring between VFDs and remote devices and facility's central-control system. Comply with requirements in ***Section 26 0523 "Control-Voltage Electrical Power Cables."***

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

C. Connect selector switches and other automatic control devices where applicable.

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

3.5 FIELD QUALITY CONTROL

A. Testing Agency: The University will engage a qualified testing agency to perform tests and inspections.

B. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect, test, and adjust components, assemblies, and equipment installations, including connections.

C. Perform tests and inspections.

1. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing.

D. Acceptance Testing Preparation:

1. Test insulation resistance for each VFD element, bus, component, connecting supply, feeder, and control circuit.
2. Test continuity of each circuit.

E. Tests and Inspections:

1. Inspect VFD, wiring, components, connections, and equipment installation. Test and adjust controllers, components, and equipment.
2. Test insulation resistance for each VFD element, component, connecting motor supply, feeder, and control circuits.
3. Test continuity of each circuit.
4. Verify that voltages at VFD locations are within 10 percent of motor nameplate rated voltages. If outside this range for any motor, notify the University before starting the motor(s).
5. Test each motor for proper phase rotation.
6. Perform each electrical test and visual and mechanical inspection stated in NETA Acceptance Testing Specification. Certify compliance with test parameters.
7. Correct malfunctioning units on-site, where possible, and retest to demonstrate compliance; otherwise, replace with new units and retest.
8. Perform the following infrared (thermographic) scan tests and inspections and prepare reports:

   a. Initial Infrared Scanning: After Substantial Completion, but not more than 60 days after Final Acceptance, perform an infrared scan of each VFD. Remove front panels so joints and connections are accessible to portable scanner.
   b. Follow-up Infrared Scanning: Perform an additional follow-up infrared scan of each VFD 11 months after date of Substantial Completion.
   c. Instruments and Equipment: Use an infrared scanning device designed to measure temperature or to detect significant deviations from normal values. Provide calibration record for device.

9. Test and adjust controls, remote monitoring, and safeties. Replace damaged and malfunctioning controls and equipment.

F. VFDs will be considered defective if they do not pass tests and inspections.

G. Prepare test and inspection reports, including a certified report that identifies the VFD and describes scanning results. Include notation of deficiencies detected, remedial action taken, and observations made after remedial action.

3.6 STARTUP SERVICE

A. Engage a factory certified service technician to perform startup service.

1. To include complete installation and startup checks according to manufacturer's written instructions.

B. Sales personnel and other agents who are not factory certified shall not be acceptable.

3.7 ADJUSTING

A. Program microprocessors for required operational sequences, status indications, alarms, event recording, and display features. Clear events memory after final acceptance testing and prior to Substantial Completion.

B. Set field-adjustable switches, auxiliary relays, time-delay relays, timers, and overload-relay pickup and trip ranges.

C. Adjust the trip settings of MCPs and thermal-magnetic circuit breakers with adjustable, instantaneous trip elements. Initially adjust to six times the motor nameplate full-load amperes and attempt to start motors several times, allowing for motor cool-down between starts. If tripping occurs on motor inrush, adjust settings in increments until motors start without tripping. Do not exceed eight times the motor full-load amperes (or 11 times for NEMA Premium Efficient motors if required). Where these maximum settings do not allow starting of a motor, notify the University before increasing settings.

D. Set the taps on reduced-voltage autotransformer controllers.

E. Set field-adjustable circuit-breaker trip ranges as specified in applicable Division 26 Section.

F. Set field-adjustable pressure switches.

3.8 PROTECTION

A. Temporary Heating: Apply temporary heat to maintain temperature according to manufacturer's written instructions until controllers are ready to be energized and placed into service.

B. Replace VFDs whose interiors have been exposed to water or other liquids prior to Substantial Completion.

3.9 DEMONSTRATION AND TRAINING

A. Engage a factory-authorized service representative to train University maintenance personnel off-site to demonstrate, adjust, operate, program, troubleshoot, repair, and maintain VFDs, and a minimum of 24 hours to be included for this, over at least three days. Training to also include education on drive harmonics.

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SECTION 23 0516 - EXPANSION FITTINGS AND LOOPS FOR HVAC PIPING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

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

1.2 SUMMARY

A. Section Includes:

1. Flexible, ball-joint, packed expansion joints.
2. Slip-joint packed expansion joints.
3. Grooved-joint expansion joints.
4. Flexible – Hose Packless Expansion Joints.
5. Alignment guides and anchors.

1.3 PERFORMANCE REQUIREMENTS

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

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

1.4 ACTION SUBMITTALS

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

B. Delegated-Design Submittal: For each anchor and alignment guide 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 thermal expansion of piping systems and for selecting and designing expansion joints, loops, and swing connections.
2. Anchor Details: Detail fabrication of each anchor indicated. Show dimensions and methods of assembly and attachment to building structure.
3. Alignment Guide Details: Detail field assembly and attachment to building structure.
4. Schedule: Indicate type, manufacturer's number, size, material, pressure rating, end connections, and location for each expansion joint.

1.5 INFORMATIONAL SUBMITTALS

A. Welding certificates.

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

1.6 CLOSEOUT SUBMITTALS

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

1.7 QUALITY ASSURANCE

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

1. AWS D1.1/D1.1M, "Structural Welding Code - Steel."
2. ASME Boiler and Pressure Vessel Code: Section IX.

PART 2 - PRODUCTS

2.1 PACKED EXPANSION JOINTS

A. Flexible, Ball-Joint, Packed Expansion Joints:

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

a. Advanced Thermal Systems, Inc.

2. Standards: ASME Boiler and Pressure Vessel Code: Section II, "Materials"; and ASME B31.9, "Building Services Piping," for materials and design of pressure-containing parts and bolting.
3. Material: Carbon-steel assembly with asbestos-free composition packing.
4. Design: For 360-degree rotation and angular deflection.
5. Minimum Pressure Rating: 250 psig at 400 deg F (1725 kPa at 204 deg C).
6. Angular Deflection for NPS 6 (DN 150) and Smaller: 30 degree minimum.
7. Angular Deflection for NPS 8 (DN 200) and Larger: 15 degree minimum.
8. End Connections for NPS 2 (DN 50) and Smaller: Threaded.
9. End Connections for NPS 2-1/2 (DN 65) and Larger: Flanged.

B. Slip-Joint Packed Expansion Joints:

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

a. Advanced Thermal Systems, Inc.

2. Standard: ASTM F 1007.
3. Material: Carbon steel with asbestos-free PTFE packing.
4. Design: With internal guide and injection device for repacking under pressure. Include drip connection if used for steam piping.
5. Configuration: Single joint or single joint with base unless otherwise indicated.
6. End Connections: Flanged or weld ends to match piping system.

2.2 GROOVED-JOINT EXPANSION JOINTS

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

1. Anvil International, Inc.
2. Shurjoint Piping Products.
3. Victaulic Company.

B. Description: Factory-assembled expansion joint made of several grooved-end pipe nipples, couplings, and grooved joints.

C. Standard: AWWA C606, for grooved joints.

D. Nipples: Galvanized, ASTM A 53/A 53M, Schedule 40, Type E or S, steel pipe with grooved ends.

E. Couplings: Multiple (as required), flexible type for steel-pipe dimensions. Include ferrous housing sections, with EPDM gasket suitable for project fluids, and bolts and nuts.

2.3 FLEXIBLE-HOSE PACKLESS EXPANSION JOINTS

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

1. Metraflex, Inc.
2. Flexhose
3. Flexicraft

B. Description: Manufactured assembly with inlet and outlet elbow fittings and two flexible-metal-hose legs joined by long-radius, 180-degree return bend or center section of flexible hose.

C. Flexible Hose: Corrugated-metal inner hoses and braided outer sheaths.

D. Expansion Joints for Copper Tubing NPS 2 (DN 50) and Smaller: Copper-alloy fittings with solder-joint end connections.

1. Bronze hoses and double-braid bronze sheaths with 700 psig at 70 deg F (4830 kPa at 21 deg C) and 500 psig at 450 deg F (3450 kPa at 232 deg C) ratings.

E. Expansion Joints for Copper Tubing NPS 2-1/2 to NPS 4 (DN 65 to DN 100): Copper-alloy fittings with threaded end connections.

1. Stainless-steel hoses and double-braid, stainless-steel sheaths with 420 psig at 70 deg F (2890 kPa at 21 deg C) and 315 psig at 450 deg F (2170 kPa at 232 deg C) ratings.

F. Expansion Joints for Steel Piping NPS 2 (DN 50) and Smaller: Carbon-steel fittings with threaded end connections.

1. Stainless-steel hoses and double-braid, stainless-steel sheaths with 700 psig at 70 deg F (4830 kPa at 21 deg C) and 515 psig at 600 deg F (3550 kPa at 315 deg C) ratings.

G. Expansion Joints for Steel Piping NPS 2-1/2 to NPS 6 (DN 65 to DN 150): Carbon-steel fittings with flanged end connections.

1. Stainless-steel hoses and double-braid, stainless-steel sheaths with 275 psig at 70 deg F (1900 kPa at 21 deg C) and 200 psig at 600 deg F (1380 kPa at 315 deg C) ratings.

H. Expansion Joints for Steel Piping NPS 8 to NPS 12 (DN 200 to DN 300): Carbon-steel fittings with flanged end connections.

1. Stainless-steel hoses and double-braid, stainless-steel sheaths with 165 psig at 70 deg F (1130 kPa at 21 deg C) and 120 psig at 600 deg F (830 kPa at 315 deg C) ratings.

I. Expansion Joints for Steel Piping NPS 14 (DN 350) and Larger: Carbon-steel fittings with flanged end connections.

1. Stainless-steel hoses and double-braid, stainless-steel sheaths with 165 psig at 70 deg F (1130 kPa at 21 deg C) and 120 psig at 600 deg F (830 kPa at 315 deg C) ratings.

2.4 ALIGNMENT GUIDES AND ANCHORS

A. Alignment Guides:

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

a. Advanced Thermal Systems, Inc.

2. Description: Steel, factory-fabricated alignment guide, with bolted two-section outer cylinder and base for attaching to structure; with two-section guiding spider for bolting to pipe.

B. Anchor Materials:

1. Steel Shapes and Plates: ASTM A 36/A 36M.
2. Bolts and Nuts: ASME B18.10 or ASTM A 183, steel hex head.
3. Washers: ASTM F 844, steel, plain, flat washers.
4. Mechanical Fasteners: Insert-wedge-type stud with expansion plug anchor for use in hardened portland cement concrete, with tension and shear capacities appropriate for application.

a. Stud: Threaded, zinc-coated carbon steel.
b. Expansion Plug: Zinc-coated steel.
c. Washer and Nut: Zinc-coated steel.

5. Chemical Fasteners: Insert-type-stud, bonding-system anchor for use with hardened portland cement concrete, with tension and shear capacities appropriate for application.

a. Bonding Material: ASTM C 881/C 881M, Type IV, Grade 3, two-component epoxy resin suitable for surface temperature of hardened concrete where fastener is to be installed.
b. Stud: ASTM A 307, zinc-coated carbon steel with continuous thread on stud unless otherwise indicated.
c. Washer and Nut: Zinc-coated steel.

PART 3 - EXECUTION

3.1 EXPANSION-JOINT INSTALLATION

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

B. Install packed-type expansion joints with packing suitable for fluid service.

C. Install metal-bellows expansion joints according to EJMA's "Standards of the Expansion Joint Manufacturers Association, Inc."

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

E. Install grooved-joint expansion joints to grooved-end steel piping

3.2 PIPE LOOP AND SWING CONNECTION INSTALLATION

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

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

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

3.3 ALIGNMENT-GUIDE AND ANCHOR INSTALLATION

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

B. Install two guide(s) on each side of pipe expansion fittings and loops. Install guides nearest to expansion joint not more than four pipe diameters from expansion joint.

C. Attach guides to pipe and secure guides to building structure.

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

E. Anchor Attachments:

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

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

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

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

END OF SECTION 23 0516

SECTION 23 0517 - SLEEVES AND SLEEVE SEALS FOR HVAC PIPING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

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

1.2 SUMMARY

A. Section Includes:

1. Sleeves.
2. Sleeve-seal systems.
3. Sleeve-seal fittings.
4. Grout.

1.3 ACTION SUBMITTALS

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

PART 2 - PRODUCTS

2.1 SLEEVES

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

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

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

D. Galvanized-Steel-Sheet Sleeves: 0.0239-inch (0.6-mm) minimum thickness; round tube closed with welded longitudinal joint.

E. Molded-PE or -PP Sleeves: Removable, tapered-cup shaped, and smooth outer surface with nailing flange for attaching to wooden forms.

2.2 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.

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

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

2.3 SLEEVE-SEAL FITTINGS

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

1. Presealed Systems.

B. Description: Manufactured plastic, sleeve-type, waterstop assembly made for imbedding in concrete slab or wall. Unit has plastic or rubber waterstop collar with center opening to match piping OD.

2.4 GROUT

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

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

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

D. Packaging: Premixed and factory packaged.

PART 3 - EXECUTION

3.1 SLEEVE INSTALLATION

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

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

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 (50 mm) above finished floor level.

3. Using sealant, 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 (6.4-mm) annular clear space between sleeve and pipe or pipe insulation.
3. Seal annular space between sleeve and piping or piping insulation; use joint sealants appropriate for size, depth, and location of joint. Comply with requirements for sealants specified in Section 079200 "Joint Sealants."

E. Fire-Barrier Penetrations: Maintain indicated fire rating of walls, partitions, ceilings, and floors at pipe penetrations. Seal pipe penetrations with firestop materials. Comply with requirements for firestopping specified in Section 078413 "Penetration Firestopping."

3.2 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.

3.3 SLEEVE-SEAL-FITTING INSTALLATION

A. Install sleeve-seal fittings in new walls and slabs as they are constructed.

B. Assemble fitting components of length to be flush with both surfaces of concrete slabs and walls. Position waterstop flange to be centered in concrete slab or wall.

C. Secure nailing flanges to concrete forms.

D. Using grout, seal the space around outside of sleeve-seal fittings.

3.4 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 (DN 150): Cast-iron wall sleeves, Galvanized-steel-pipe sleeves, or Sleeve-seal fittings.

b. Piping NPS 6 (DN 150) and Larger: Cast-iron wall sleeves or Galvanized-steel-pipe sleeves.

2. Exterior Concrete Walls below Grade:

a. Piping Smaller Than NPS 6 (DN 150): Cast-iron wall sleeves with sleeve-seal system, galvanized-steel-pipe sleeves with sleeve-seal system, or sleeve-seal fittings.

1) Select sleeve size to allow for 1-inch (25-mm) annular clear space between piping and sleeve for installing sleeve-seal system.

b. Piping NPS 6 (DN 150) and Larger: Cast-iron wall sleeves with sleeve-seal system or Galvanized-steel-pipe sleeves with sleeve-seal system.

1) Select sleeve size to allow for 1-inch (25-mm) annular clear space between piping and sleeve for installing sleeve-seal system.

3. Concrete Slabs-on-Grade:

a. Piping Smaller Than NPS 6 (DN 150): Cast-iron wall sleeves with sleeve-seal system, Galvanized-steel-pipe sleeves with sleeve-seal system, or Sleeve-seal fittings.

1) Select sleeve size to allow for 1-inch (25-mm) annular clear space between piping and sleeve for installing sleeve-seal system.

b. Piping NPS 6 (DN 150) and Larger: Cast-iron wall sleeves with sleeve-seal system, Galvanized-steel-pipe sleeves with sleeve-seal system, or Galvanized-steel-pipe sleeves.

1) Select sleeve size to allow for 1-inch (25-mm) annular clear space between piping and sleeve for installing sleeve-seal system.

4. Concrete Slabs above Grade:

a. Piping Smaller Than NPS 6 (DN 150): Galvanized-steel-pipe sleeves orSleeve-seal fittings.
b. Piping NPS 6 (DN 150) and Larger: Galvanized-steel-pipe sleeves.

5. Interior Partitions:

a. Piping Smaller Than NPS 6 (DN 150): Galvanized-steel-pipe sleeves.
b. Piping NPS 6 (DN 150) and Larger: Galvanized-steel-sheet sleeves.

END OF SECTION 23 0517

SECTION 23 0518 - ESCUTCHEONS FOR HVAC PIPING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

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

1.2 SUMMARY

A. Section Includes:

1. Escutcheons.
2. Floor plates.

1.3 ACTION SUBMITTALS

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

PART 2 - PRODUCTS

2.1 ESCUTCHEONS

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

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

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

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

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

2.2 FLOOR PLATES

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

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

PART 3 - EXECUTION

3.1 INSTALLATION

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

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

1. Escutcheons for New Piping:

a. Piping with Fitting or Sleeve Protruding from Wall: One-piece, deep-pattern type.
b. Chrome-Plated Piping: One-piece, cast-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. Bare Piping at Wall and Floor Penetrations in Finished Spaces: One-piece, cast-brass or split-casting brass type with polished, chrome-plated finish.
e. Bare Piping at Ceiling Penetrations in Finished Spaces: One-piece, cast-brass type with polished, chrome-plated finish.
f. Bare Piping in Unfinished Service Spaces: One-piece, cast-brass or split-casting brass type with polished, chrome-plated finish.
g. Bare Piping in Equipment Rooms: One-piece, cast-brass or split-casting brass type with polished, chrome-plated finish.

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 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 Ceiling Penetrations in Finished Spaces: Split-casting brass type with polished, chrome-plated finish.
e. Bare Piping in Unfinished Service Spaces: Split-casting brass type with polished, chrome-plated finish.
f. Bare Piping in Equipment Rooms: Split-casting brass type with polished, chrome-plated finish.

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

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

1. New Piping: One-piece, floor-plate type.
2. Existing Piping: Split-casting, floor-plate type.

3.2 FIELD QUALITY CONTROL

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

END OF SECTION 23 0518

SECTION 23 0519 - METERS AND GAGES FOR HVAC PIPING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

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

1.2 SUMMARY

A. Section Includes:

1. Filled-system thermometers.
2. Thermowells.
3. Dial-type pressure gages.
4. Gage attachments.
5. Test plugs.
6. Test-plug kits.
7. Sight flow indicators.
8. Electromagnetic flowmeters.

B. Related Sections:

1. Section 232113 "Hydronic Piping."

1.3 ACTION SUBMITTALS

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

B. Wiring Diagrams: For power, signal, and control wiring.

1.4 INFORMATIONAL SUBMITTALS

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

1.5 CLOSEOUT SUBMITTALS

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

PART 2 - PRODUCTS

2.1 FILLED-SYSTEM THERMOMETERS

A. Direct-Mounted, Metal-Case, Vapor-Actuated Thermometers:

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

   a. Trerice, H. O. Co.
   b. Weksler Instrument Corporation.

2. Standard: ASME B40.200.
3. Case: Sealed type, cast aluminum, 6-inch (152-mm) nominal diameter.
4. Element: Bourdon tube or other type of pressure element.
5. Movement: Mechanical, dampening type**,** with link to pressure element and connection to pointer.
6. Dial: Nonreflective aluminum with permanently etched scale markings graduated in deg F and deg C.
7. Pointer: Dark-colored metal.
8. Window: Glass.
9. Ring: Metal.
10. Connector Type(s): Union joint, adjustable, 180 degrees in vertical plane; with ASME B1.1 screw threads.
11. Thermal System: Liquid-filled bulb in copper-plated steel, aluminum, or brass stem and of length to suit installation.

    a. Design for Air-Duct Installation: With ventilated shroud.
    b. Design for Thermowell Installation: Bare stem.

12. Accuracy: Plus or minus 1 percent of scale range.

B. Remote-Mounted, Metal-Case, Vapor-Actuated Thermometers:

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

   a. Trerice, H. O. Co.
   b. Weksler Instrument Corporation.

2. Standard: ASME B40.200.
3. Case: Sealed type, cast aluminum 6-inch (152-mm) nominal diameter with front flange and holes for panel mounting.
4. Element: Bourdon tube or other type of pressure element.
5. Movement: Mechanical, with link to pressure element and connection to pointer.
6. Dial: Nonreflective aluminum with permanently etched scale markings graduated in deg F and deg C.
7. Pointer: Dark-colored metal.
8. Window: Glass.
9. Ring: Metal.
10. Connector Type(s): Union joint, back or bottom (as best suited for panel); with ASME B1.1 screw threads.

11. Thermal System: Liquid-filled bulb in copper-plated steel, aluminum, or brass stem and of length to suit installation.

    a. Design for Air-Duct Installation: With ventilated shroud.
    b. Design for Thermowell Installation: Bare stem.

12. Accuracy: Plus or minus 1 percent of scale range.

2.2 DUCT-THERMOMETER MOUNTING BRACKETS

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

2.3 THERMOWELLS

A. Thermowells:

1. Standard: ASME B40.200.
2. Description: Pressure-tight, socket-type fitting made for insertion into piping tee fitting.
3. Material for Use with Copper Tubing: CNR or CUNI.
4. Material for Use with Steel Piping: CRES.
5. Type: Stepped shank unless straight or tapered shank is indicated.
6. External Threads: NPS 1/2, NPS 3/4, or NPS 1, (DN 15, DN 20, or NPS 25,) ASME B1.20.1 pipe threads.
7. Internal Threads: 1/2, 3/4, and 1 inch (13, 19, and 25 mm), with ASME B1.1 screw threads.
8. Bore: Diameter required to match thermometer bulb or stem.
9. Insertion Length: Refer to Table 23 2116-1 Immersion Length for Thermometer Wells, below.

Table 23 2116-1 Immersion Length for Thermometer Wells

Pipe Diameter, in.	Well Immersion Length, in.	
	Perpendicular Mount	Elbow Mount
3	N/A*	8½
4	N/A*	8½
6	4½-5½	8½
8	4½-5½	8½
10	4½-5½	8½
12 and larger	8½	8½

* Perpendicular mount shall not be used on 3 and 4-in. pipe. Stem cooling effects may occur.

10. Lagging Extension: Include on thermowells for insulated piping and tubing.
11. Bushings: For converting size of thermowell's internal screw thread to size of thermometer connection.

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

2.4 PRESSURE GAGES

A. Direct-Mounted, Metal-Case, Dial-Type Pressure Gages:

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

    a. Trerice, H. O. Co, 600 series
    b. Weksler Instrument Corporation.
    c. Weiss Instruments, Inc.

2. Standard: ASME B40.100.
3. Case: Liquid-filled type(s); cast aluminum; 4-1/2-inch (114-mm) nominal diameter.
4. Pressure-Element Assembly: Bourdon tube unless otherwise indicated.
5. Pressure Connection: Brass, with NPS 1/4 or NPS 1/2 (DN 8 or DN 15), ASME B1.20.1 pipe threads and bottom-outlet type unless back-outlet type is indicated.
6. Movement: Mechanical, with link to pressure element and connection to pointer.
7. Dial: Nonreflective aluminum with permanently etched scale markings graduated in psi and kPa.
8. Pointer: Dark-colored metal.
9. Window: Glass.
10. Ring: Metal.
11. Accuracy: Grade 1A, plus or minus 1 percent of full scale range.

B. Remote-Mounted, Metal-Case, Dial-Type Pressure Gages:

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

    a. Trerice, H. O. Co, 600 series
    b. Weksler Instrument Corporation.
    c. Weiss Instruments, Inc.

2. Standard: ASME B40.100.
3. Case: Liquid-filled type; cast aluminum; 4-1/2-inch (114-mm) nominal diameter with front flange and holes for panel mounting.
4. Pressure-Element Assembly: Bourdon tube unless otherwise indicated.
5. Pressure Connection: Brass, with NPS 1/4 or NPS 1/2 (DN 8 or DN 15), ASME B1.20.1 pipe threads and bottom-outlet type unless back-outlet type is indicated.
6. Movement: Mechanical, with link to pressure element and connection to pointer.
7. Dial: Nonreflective aluminum with permanently etched scale markings graduated in psi and kPa.
8. Pointer: Dark-colored metal.
9. Window: Glass or acrylic plastic.
10. Ring: Metal.

11. Accuracy: Grade A, plus or minus 1 percent of middle half of scale range.

2.5 GAGE ATTACHMENTS

A. Snubbers: ASME B40.100, brass; with NPS 1/4 (DN 8), ASME B1.20.1 pipe threads and piston or porous-metal-type surge-dampening device. Include extension for use on insulated piping.

B. Siphons: Loop-shaped section steel pipe with NPS 1/4 (DN 8) pipe threads.

C. Valves: Brass ball, with NPS 1/4 (DN 8), ASME B1.20.1 pipe threads.

2.6 TEST PLUGS

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

1. Flow Design, Inc.
2. Miljoco Corporation.
3. Peterson Equipment Co., Inc.
4. Sisco Manufacturing Company, Inc.
5. Trerice, H. O. Co.
6. Watts Regulator Co.; a div. of Watts Water Technologies, Inc.
7. Weiss Instruments, Inc.

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

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

D. Thread Size: NPS 1/4 (DN 8) or NPS 1/2 (DN 15), ASME B1.20.1 pipe thread.

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

F. Core Inserts: Chlorosulfonated polyethylene synthetic and EPDM self-sealing rubber, neoprene, or Nordel.

2.7 TEST-PLUG KITS

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

1. Flow Design, Inc.
2. Miljoco Corporation.
3. National Meter, Inc.
4. Peterson Equipment Co., Inc.
5. Sisco Manufacturing Company, Inc.
6. Trerice, H. O. Co.
7. Watts Regulator Co.; a div. of Watts Water Technologies, Inc.
8. Weiss Instruments, Inc.

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

1. Low-Range Thermometer: Small, bimetallic insertion type with 1- to 2-inch- (25- to 51-mm-) diameter dial and tapered-end sensing element. Dial range shall be at least 25 to 125 deg F (minus 4 to plus 52 deg C).
2. High-Range Thermometer: Small, bimetallic insertion type with 1- to 2-inch- (25- to 51-mm-) diameter dial and tapered-end sensing element. Dial range shall be at least 0 to 220 deg F (minus 18 to plus 104 deg C).
3. Pressure Gage: Small, Bourdon-tube insertion type with 2- to 3-inch- (51- to 76-mm-) diameter dial and probe. Dial range shall be at least 0 to 200 psig (0 to 1380 kPa).
4. Carrying Case: Metal or plastic, with formed instrument padding.

2.8 SIGHT FLOW INDICATORS

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

1. Archon Industries, Inc.
2. Dwyer Instruments, Inc.
3. Emerson Process Management; Brooks Instrument.
4. Ernst Co., John C., Inc.
5. Ernst Flow Industries.
6. KOBOLD Instruments, Inc. - USA; KOBOLD Messring GmbH.
7. OPW Engineered Systems; a Dover company.
8. Penberthy; A Brand of Tyco Valves & Controls - Prophetstown.

B. Description: Piping inline-installation device for visual verification of flow.

C. Construction: Bronze or stainless-steel body, with sight glass and ball, flapper, or paddle wheel indicator, and threaded or flanged ends.

D. Minimum Pressure Rating: 150 psig (1034 kPa).

E. Minimum Temperature Rating: 200 deg F (93 deg C).

F. End Connections for NPS 2 (DN 50) and Smaller: Threaded.

G. End Connections for NPS 2-1/2 (DN 65) and Larger: Flanged.

2.9 FLOWMETERS

A. Electromagnetic Flowmeters:

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

a. Onicon, Inc (Basis of Design)
b. ABB; Instrumentation and Analytical.
c. Krohne.
d. Emerson Rosemont..

2. Description: Flowmeter with calibrated flow-measuring element, hoses or tubing, fittings, valves, transmitters (with displays), indicator, and conversion chart. No moving parts allowed. Factory wet calibrated.
3. Flow Range: Sensor and indicator shall cover operating range of equipment or system served.
4. Sensor: Electromagnetic type, calibrated, flow-measuring element; for installation in piping.

    a. Design: Electromagnetic type measurement for water, in-line or insertion type, and bi-directional, as called for on drawings.
    b. Body Construction: Primed and painted or coated carbon steel, or stainless steel. Internal flow tube on in-line model to be stainless steel.
    c. Maximum Operating Pressure Rating: 230 to 400 psig.
    d. End Connections for In-Line Meters: Flanged.
    e. Accuracy of In-Line Models: +/- 2% of reading from 1.6 to 33 ft/s.
    f. Accuracy of Insertion Models: +/- 1% of reading from 2 to 20 ft/s.
    g. Power Supply Requirements: 18-45 VAC for in-line type, 20-28 VAC for insertion type.
    h. Output Requirements: 4 - 20 mA analog output.
    i. Insertion Type Insertion Design: "Simplified", with insertion and removal by hand without a system shutdown.

5. Permanent Indicators: Meter suitable for wall or bracket mounting, calibrated for connected flowmeter element, and having 6-inch- diameter, or equivalent, dial with fittings and copper tubing for connecting to flowmeter element.

    a. Scale: Gallons per minute (Liters per second).
    b. Accuracy: Plus or minus 1 percent between 20 and 80 percent of scale range.

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

PART 3 - EXECUTION

3.1 INSTALLATION

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

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

C. Install thermowells with extension on insulated piping.

D. Fill thermowells with heat-transfer medium.

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

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

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

H. Pack thermometers in a thermal conductive compound. Preferred products are: Honeywell Part No. 107408; Jonson Controls F-1000-182; York 013-00898-000.

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

J. Install remote-mounted pressure gages on panel.

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

L. Install valve and syphon fitting in piping for each pressure gage for steam.

M. Install test plugs in piping tees.

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

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

P. Install flowmeter elements in accessible positions in piping systems, and per manufacturer's requirements.

Q. Install wafer-orifice flowmeter elements between pipe flanges.

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

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

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

U. Mount thermal-energy meters on wall if accessible; if not, provide brackets to support meters.

V. Install thermometers in the following locations:

1. Inlet and outlet of each hydronic zone.
2. Inlet and outlet of each hydronic boiler.
3. Two inlets and two outlets of each chiller.
4. Inlet and outlet of each hydronic coil in air-handling units.
5. Two inlets and two outlets of each hydronic heat exchanger.
6. Inlet and outlet of each thermal-storage tank.
7. Outside-, return-, supply-, and mixed-air ducts.

W. Install pressure gages in the following locations:

1. Discharge of each pressure-reducing valve.
2. Inlet and outlet of each chiller chilled-water and condenser-water connection.
3. Suction and discharge of each pump.

3.2 CONNECTIONS

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

B. Connect flowmeter-system elements to meters.

C. Connect flowmeter transmitters to meters.

D. Connect thermal-energy meter transmitters to meters.

3.3 ADJUSTING

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

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

3.4 THERMOMETER SCALE-RANGE SCHEDULE

A. Scale Range for Chilled-Water Piping: 0 to 100 deg F.

B. Scale Range for Heating and Glycol, Hot-Water Piping: 30 to 250 deg F or 30 to 300 deg F.

C. Scale Range for Air Ducts: 0 to 100 deg F.

3.5 PRESSURE-GAGE SCALE-RANGE SCHEDULE

A. Scale Range for Hydronic Water Piping: As best suited for final project conditions.

3.6 FLOWMETER SCHEDULE

A. Flowmeters for Hydronic Piping: Electromagnetic type.

END OF SECTION 23 0519

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SECTION 23 0523 - GENERAL-DUTY VALVES FOR HVAC PIPING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

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

1.2 SUMMARY

A. Section Includes Valves and Valve Accessories for Hydronic Systems, Not Steam Systems:

1. Bronze ball valves.
2. Iron, butterfly valves.
3. High-performance butterfly valves.
4. Bronze lift check valves.
5. Bronze swing check valves.
6. Iron swing check valves.
7. Iron, grooved-end swing-check valves.
8. Chainwheels.

B. Related Sections:

1. Section 230553 "Identification for HVAC Piping and Equipment" for valve tags and schedules.

1.3 DEFINITIONS

A. CWP: Cold working pressure.

B. EPDM: Ethylene propylene copolymer rubber.

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

D. NRS: Nonrising stem.

E. OS&Y: Outside screw and yoke.

F. RS: Rising stem.

1.4 ACTION SUBMITTALS

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

1.5 QUALITY ASSURANCE

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

B. ASME Compliance:

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

1.6 DELIVERY, STORAGE, AND HANDLING

A. Prepare valves for shipping as follows:

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

B. Use the following precautions during storage:

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

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

PART 2 - PRODUCTS

2.1 GENERAL REQUIREMENTS FOR VALVES

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

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

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

D. Valve Actuator Types:

1. Gear Actuator: For quarter-turn valves NPS 8 (DN 200) and larger.
2. Handwheel: For valves other than quarter-turn types.
3. Handlever: For quarter-turn valves NPS 6 (DN 150) and smaller.
4. Chainwheel: Device for attachment to valve handwheel, stem, or other actuator; of size and with chain for mounting height, as indicated in the "Valve Installation" Article.

E. Valves in Insulated Piping: With 2-inch stem extensions and the following features:

1. Ball Valves: With extended operating handle of non-thermal-conductive material, and protective sleeve that allows operation of valve without breaking the vapor seal or disturbing insulation.
2. Butterfly Valves: With extended neck.

F. Valve-End Connections:

1. Flanged: With flanges according to ASME B16.1 for iron valves.
2. Grooved: With grooves according to AWWA C606.
3. Solder Joint: With sockets according to ASME B16.18.
4. Threaded: With threads according to ASME B1.20.1.

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

2.2 BRONZE BALL VALVES

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

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

a. Conbraco Industries, Inc.; Apollo Valves.
b. Neles-Jamesbury, Inc.
c. Watts Regulator Co.; a division of Watts Water Technologies, Inc.

2. Description:

a. Standard: MSS SP-110.
b. SWP Rating: 150 psig (1035 kPa).
c. CWP Rating: 600 psig (4140 kPa).
d. Body Design: Three piece.
e. Body Material: Bronze.
f. Ends: Threaded.
g. Seats: PTFE.
h. Stem: 316L Stainless steel.
i. Ball: 316L Stainless steel, vented.
j. Port: Full.

2.3 IRON, BUTTERFLY VALVES

A. Class 150B, Iron, Mechanical Joint or Flanged End Butterfly Valves:

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

a. Pratt Groundhoug
b. Approved equal

2. Description:

a. Standard: ANSI Class 150B tested to 200 psi.
b. Body Material: Coated, cast iron.
c. Mechanical Joint or Flanged end.

d. Stem: Two-piece stainless steel.
e. Disc: Coated, ductile iron.
f. Seal: EPDM.
g. Shaft: 304 stainless steel.

2.4 HIGH-PERFORMANCE BUTTERFLY VALVES

A. Class 150, Single-Flange, High-Performance Butterfly Valves:

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

a. Neles Jamesbury, Inc; Model No. 815L-11-2236TT
b. Approved Equal

2. Description:

a. Standard: ANSI Class 150 lugged design.
b. CWP Rating: 275 psig at 100 deg F.
c. Body Design: Lug type; suitable for bidirectional dead-end service at rated pressure without use of downstream flange, double offset design.
d. Body Material: Carbon steel, or stainless steel.
e. Seat: Reinforced PTFE or metal.
f. Stem: Stainless steel; offset from seat plane, one piece stem.
g. Disc: Carbon steel.
h. Service: Bidirectional.
i. Packing: PTFE V-ring.

2.5 BRONZE LIFT CHECK VALVES

A. Class 150, Lift Check Valves with Bronze Disc:

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

a. Nibco
b. Crane Co.; Crane Valve Group; Crane Valves.
c. Mueller.

2. Description:

a. Standard: MSS SP-80, Type 1.
b. CWP Rating: 250 psig (1380 kPa) wog.
c. Body Design: Vertical flow.
d. Body Material: ASTM B 61 or ASTM B 584, bronze.
e. Ends: Threaded.
f. Disc: Bronze.

2.6 BRONZE SWING CHECK VALVES

A. Class 125, Bronze Horizontal Swing Check Valves with Bronze Disc:

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

   a. Nibco
   b. Crane Co.; Crane Valve Group; Crane Valves.
   c. Mueller.

2. Description:

   a. Standard: MSS SP-80, Type 3.
   b. CWP Rating: 200 psig (1380 kPa).
   c. Body Design: Horizontal flow.
   d. Body Material: ASTM B 62, bronze.
   e. Ends: Threaded.
   f. Disc: Bronze.

B. Class 150, Bronze Swing Check Valves with Bronze Disc:

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

   a. Nibco
   b. Crane Co.; Crane Valve Group; Crane Valves.
   c. Mueller

2. Description:

   a. Standard: MSS SP-80, Type 3.
   b. CWP Rating: 300 psig (2070 kPa).
   c. Body Design: Horizontal flow.
   d. Body Material: ASTM B 62, bronze.
   e. Ends: Threaded.
   f. Disc: Bronze.

2.7 IRON SWING CHECK VALVES

A. Class 125, Iron Swing Check Valves with Metal Seats:

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

   a. Nibco
   b. Crane Co.; Crane Valve Group; Crane Valves.
   c. Mueller

2. Description:

   a. Standard: MSS SP-71, Type I.
   b. NPS 2-1/2 to NPS 12 (DN 65 to DN 300), CWP Rating: 200 psig (1380 kPa).
   c. NPS 14 to NPS 24 (DN 350 to DN 600), CWP Rating: 150 psig (1035 kPa).
   d. Body Design: Clear or full waterway.
   e. Body Material: ASTM A 126, gray iron with bolted bonnet.
   f. Ends: Flanged.

g. Trim: Bronze.
h. Gasket: Asbestos free.

B. Class 250, Iron Swing Check Valves with Metal Seats:

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

a. Nibco
b. Crane Co.; Crane Valve Group; Crane Valves.
c. Mueller

2. Description:

a. Standard: MSS SP-71, Type I.
b. NPS 2-1/2 to NPS 12 (DN 65 to DN 300), CWP Rating: 500 psig (3450 kPa).
c. NPS 14 to NPS 24 (DN 350 to DN 600), CWP Rating: 300 psig (2070 kPa).
d. Body Design: Clear or full waterway.
e. Body Material: ASTM A 126, gray iron with bolted bonnet.
f. Ends: Flanged.
g. Trim: Bronze.
h. Gasket: Asbestos free.

2.8 IRON, GROOVED-END SWING CHECK VALVES

A. 300 CWP, Iron, Grooved-End Swing Check Valves:

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

a. Nibco
b. Crane Co.; Crane Valve Group; Crane Valves.
c. Mueller

2. Description:

a. CWP Rating: 300 psig (2070 kPa).
b. Body Material: ASTM A 536, ductile iron.
c. Seal: EPDM.
d. Disc: Spring operated, ductile iron or stainless steel.

2.9 CHAINWHEELS

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

1. Babbitt Steam Specialty Co.
2. Roto Hammer Industries.
3. Trumbull Industries.

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

1. Brackets: Type, number, size, and fasteners required to mount actuator on valve.

2. Attachment: For connection to valve stems.
3. Sprocket Rim with Chain Guides: Ductile iron, of type and size required for valve. Include zinc coating.
4. 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.

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

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

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

3.2 VALVE INSTALLATION

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

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

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

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

E. Install chainwheels on operators for butterfly valves NPS 4 (DN 100) and larger and more than 96 inches above floor. Extend chains to 60 inches above finished floor.

F. Install check valves for proper direction of flow and as follows:

1. Swing Check Valves: In horizontal position with hinge pin level.
2. Lift Check Valves: With stem upright and plumb.

3.3 ADJUSTING

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

3.4 GENERAL REQUIREMENTS FOR VALVE APPLICATIONS

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

1. Shutoff Service:

a. NPS 2 (DN 50) and Smaller: Ball
b. NPS 2-1/2 (DN 65) and Larger: Butterfly

2. Dead-End Service: Single-flange (lug) type butterfly valves.
3. Throttling Service except Steam: Ball whenever allowable by size, and butterfly if larger required.
4. Pump-Discharge Check Valves:

a. NPS 2 (DN 50) and Smaller: Bronze swing check valves with bronze disc.
b. NPS 2-1/2 (DN 65) and Larger: Iron swing check valves with lever and weight or with spring or iron, center-guided, metal or resilient-seat check valves.

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

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

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

3.5 CHILLED-WATER VALVE SCHEDULE

A. Pipe NPS 2 (DN 50) and Smaller:

1. Bronze Valves: May be provided with solder-joint ends instead of threaded ends.
2. Ball Valves: Two piece, full port, bronze with stainless-steel trim.
3. Bronze Swing Check Valves: Class 150, bronze disc.

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

1. Iron, Grooved-End Butterfly Valves, NPS 2-1/2 to NPS 12 (DN 65 to DN 300): 175 CWP.
2. High-Performance Butterfly Valves: Class 300, single flange.
3. Iron Swing Check Valves: Class 250, metal seats.
4. Iron, Grooved-End Check Valves, NPS 3 to NPS 12 (DN 80 to DN 300): 300 CWP.

3.6 HEATING-WATER VALVE SCHEDULE

A. Pipe NPS 2 (DN 50) and Smaller:

1. Bronze Valves: May be provided with solder-joint ends instead of threaded ends.
2. Ball Valves: Two piece, full port, bronze with stainless-steel trim.
3. Bronze Swing Check Valves: Class 150, bronze disc.

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

1. Iron, Grooved-End Butterfly Valves, NPS 2-1/2 to NPS 12 (DN 65 to DN 300): 175 CWP.
2. High-Performance Butterfly Valves: Class 300, single flange.
3. Iron Swing Check Valves: Class 250, metal seats.
4. Iron, Grooved-End Check Valves, NPS 3 to NPS 12 (DN 80 to DN 300): 300 CWP.

3.7 STEAM AND STEAM CONDENSATE VALVE APPLICATION

A. See Section 232213 "Steam and Condensate Heating Piping."

END OF SECTION 23 0523

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SECTION 23 0529 - MECHANICAL SUPPORTING DEVICES

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

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

1.2 SUMMARY

A. Section Includes:

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

B. Related Sections:

1. Section 05 5000 "Metal Fabrications" for structural-steel shapes and plates for trapeze hangers for pipe and equipment supports.
2. Section 23 0516 "Expansion Fittings and Loops for HVAC Piping" for pipe guides and anchors.
3. Section 23 3114 "Ductwork" for duct hangers and supports.

1.3 DEFINITIONS

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

1.4 PERFORMANCE REQUIREMENTS

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

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

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

1.5 ACTION SUBMITTALS

A. Product Data: For each type of product used on the project.

1.6 INFORMATIONAL SUBMITTALS

A. Welding certificates.

B. Shop Drawings: Signed and sealed by a qualified professional engineer. Show fabrication and installation details and include calculations for the following; include Product Data for components:

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

C. Delegated-Design Submittal: For trapeze hangers 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 trapeze hangers.
2. Design Calculations: Calculate requirements for designing trapeze hangers.

1.7 QUALITY ASSURANCE

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

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

C. Hangers and Supports for mechanical and plumbing piping shall be in accordance with MSS Standards.

1. MSS SP-58 – Pipe Hangers and Supports – Materials, Design and Manufacturer
2. MSS SP-69 – Pipe Hangers and Supports – Selection and Application
3. MSS SP-89 – Pipe Hangers and Supports – Fabrication and Installation Practices

D. Hangers and Supports for fire protection piping shall be in accordance with NFPA Standards. Provide products which are UL listed and FM approved.

1. NFPA 13 – Standard for the Installation of Sprinkler Systems

PART 2 - PRODUCTS

2.1 METAL PIPE HANGERS AND SUPPORTS

A. Carbon-Steel Pipe Hangers and Supports:

1. Description: MSS SP-58, Types 1 through 58, factory-fabricated components, coated.
2. Galvanized Metallic Coating: Hot dip galvanized.
3. Hanger Rods: Continuous-thread rod, nuts, and washer made of carbon steel with either electro-plated zinc or hot dipped galvanized finish.

B. Copper Pipe Hangers:

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

C. Stainless Steel Pipe Hangers:

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

2.2 TRAPEZE PIPE HANGERS

A. Description: MSS SP-69, Type 59, shop or field-fabricated pipe-support assembly made from structural hot-dip galvanized, carbon-steel shapes with MSS SP-58 hot-dip galvanized or electro-coated zinc, carbon-steel hanger rods, nuts, saddles, and U-bolts. If used, they cannot impede serviceability of equipment.

B. See delegated design requirements in 1.4 above.

2.3 METAL FRAMING SYSTEMS

A. MFMA Manufacturer Metal Framing Systems:

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

   a. Allied Tube & Conduit.
   b. Cooper B-Line, Inc.
   c. Powerstrut.
   d. Unistrut Corporation; Tyco International, Ltd.

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

2.4 THERMAL-HANGER SHIELD INSERTS

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

1. Carpenter & Paterson, Inc.

2. Clement Support Services.
3. National Pipe Hanger Corporation.
4. PHS Industries, Inc.
5. Pipe Shields, Inc.; a subsidiary of Piping Technology & Products, Inc.
6. Piping Technology & Products, Inc.
7. Rilco Manufacturing Co., Inc.

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 (688-kPa) ASTM C 552, Type II cellular glass with 100-psig (688-kPa) minimum compressive strength.

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

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

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

2.5 FASTENER SYSTEMS

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

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

2.6 PIPE STANDS

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

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

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

D. High-Type, Single-Pipe Stand:

1. Description: Assembly of base, vertical and horizontal members, and pipe support, for roof installation without membrane penetration.
2. Base: Stainless steel.
3. Vertical Members: Two or more cadmium-plated-steel or stainless-steel, continuous-thread rods.
4. Horizontal Member: Cadmium-plated-steel or stainless-steel rod with plastic or stainless-steel, roller-type pipe support.

E. High-Type, Multiple-Pipe Stand:

1. Description: Assembly of bases, vertical and horizontal members, and pipe supports, for roof installation without membrane penetration.
2. Bases: One or more; plastic.
3. Vertical Members: Two or more protective-coated-steel channels.
4. Horizontal Member: Protective-coated-steel channel.
5. Pipe Supports: Galvanized-steel, clevis-type pipe hangers.

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

2.7 EQUIPMENT SUPPORTS

A. Description: Welded, shop- or field-fabricated equipment support made from structural carbon-steel shapes, with hot dip galvanized coating.

2.8 MISCELLANEOUS MATERIALS AND REQUIREMENTS

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

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

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

a. Hangers are required to be specific to pipe and ductwork independently and not shared.

PART 3 - EXECUTION

3.1 HANGER AND SUPPORT INSTALLATION

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

B. Metal Trapeze Pipe-Hanger Installation: Comply with MSS SP-69 and MSS SP-89. Arrange for grouping of parallel runs of horizontal piping, and support together on field-fabricated trapeze pipe hangers. Multiple, stacked trapeze's are not allowed.

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

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

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

E. Fastener System Installation:

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

F. Pipe Stand Installation:

1. Pipe Stand Types except Curb-Mounted Type: Assemble components and mount on smooth roof surface. Do not penetrate roof membrane.
2. Curb-Mounted-Type Pipe Stands: Assemble components or fabricate pipe stand and mount on permanent, stationary roof curb. See Section 077200 "Roof Accessories" for curbs.

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

H. Supports and hangers shall not interfere with equipment access.

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

J. 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.

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

L. Install building attachments within concrete slabs or attach to structural steel. Install additional attachments at concentrated loads, including valves, flanges, strainers, 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.

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

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

O. Insulated Piping:

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 allowed by 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 (DN 100) 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 (DN 100) 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 (DN 8 to DN 90): 12 inches long and 0.048 inch thick.
b. NPS 4 (DN 100): 12 inches long and 0.06 inch thick.
c. NPS 5 and NPS 6 (DN 125 and DN 150): 18 inches long and 0.06 inch thick.
d. NPS 8 to NPS 14 (DN 200 to DN 350): 24 inches long and 0.075 inch thick.

5. Pipes NPS 8 (DN 200) and Larger: Include wood or reinforced calcium-silicate-insulation inserts of length at least as long as protective shield.
6. Thermal-Hanger Shields: Install with insulation same thickness as piping insulation.
7. Un-insulated Piping:

a. Where insulation is not required, use similar metal hangers such as copper hangers for copper piping, stainless steel for stainless steel piping, etc.

3.2 EQUIPMENT SUPPORTS

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

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

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

3.3 METAL FABRICATIONS

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

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

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

1. Use materials and methods that minimize distortion and develop strength and corrosion resistance of base metals.

2. Obtain fusion without undercut or overlap.
3. Remove welding flux immediately.
4. Finish welds at exposed connections so no roughness shows after finishing and so contours of welded surfaces match adjacent contours.
5. Re-galvanize if galvanizing affected.

3.4 ADJUSTING

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

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

3.5 PAINTING

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

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

B. Touchup: Cleaning and touchup painting of field welds, bolted connections, and abraded areas of shop paint on miscellaneous metal are specified in Section 099100 "Painting"."

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

3.6 HANGER AND SUPPORT SCHEDULE

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

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

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

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

E. Use copper pipe hangers and copper attachments for copper piping and tubing. Likewise for stainless steel piping and tubing, use stainless steel hangers.

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

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

H. 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 non-insulated or insulated, stationary pipes NPS 1/2 to NPS 30 (DN 15 to DN 750).
2. Yoke-Type Pipe Clamps (MSS Type 2): For suspension of up to 1050 deg F, pipes NPS 4 to NPS 24 (DN 100 to DN 600), 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 36 (DN 20 to DN 900), 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 (DN 15 to DN 600) if little or no insulation is required.
5. Pipe Hangers (MSS Type 5): For suspension of pipes NPS 1/2 to NPS 4 (DN 15 to DN 100), 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 non-insulated, stationary pipes NPS 3/4 to NPS 8 (DN 20 to DN 200).
7. Adjustable, Steel Band Hangers (MSS Type 7): For suspension of non-insulated, stationary pipes NPS 1/2 to NPS 8 (DN 15 to DN 200).
8. Adjustable Band Hangers (MSS Type 9): For suspension of non-insulated, stationary pipes NPS 1/2 to NPS 8 (DN 15 to DN 200).
9. Adjustable, Swivel-Ring Band Hangers (MSS Type 10): For suspension of non-insulated, stationary pipes NPS 1/2 to NPS 8 (DN 15 to DN 200).
10. Split Pipe Ring with or without Turnbuckle Hangers (MSS Type 11): For suspension of non-insulated, stationary pipes NPS 3/8 to NPS 8 (DN 10 to DN 200).
11. Extension Hinged or Two-Bolt Split Pipe Clamps (MSS Type 12): For suspension of non-insulated, stationary pipes NPS 3/8 to NPS 3 (DN 10 to DN 80).
12. U-Bolts (MSS Type 24): For support of heavy pipes NPS 1/2 to NPS 30 (DN 15 to DN 750).
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 (DN 100 to DN 900), with steel-pipe base stanchion support and cast-iron floor flange or carbon-steel plate.
15. Pipe Stanchion Saddles (MSS Type 37): For support of pipes NPS 4 to NPS 36 (DN 100 to DN 900), with steel-pipe base stanchion support and cast-iron floor flange or carbon-steel plate, 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 (DN 65 to DN 900) 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 (DN 25 to DN 750), from two 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 24 (DN 65 to DN 600), 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 (DN 50 to DN 1050) 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 (DN 50 to DN 600) 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 (DN 50 to DN 750) if vertical and lateral adjustment during installation might be required in addition to expansion and contraction.

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

1. Extension Pipe or Riser Clamps (MSS Type 8): For support of pipe risers NPS 3/4 to NPS 24 (DN 24 to DN 600).
2. Carbon- or Alloy-Steel Riser Clamps (MSS Type 42): For support of pipe risers NPS 3/4 to NPS 24 (DN 20 to DN 600) if longer ends are required for riser clamps.

J. 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.

K. 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.

L. 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.

M. 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 (32 mm).
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 allow 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 allow 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 allow 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.

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

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

P. Use mechanical-expansion anchors instead of building attachments where required in concrete construction.

END OF SECTION 23 0529

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SECTION 23 0550 - VIBRATION ISOLATION

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

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

1.2 SUMMARY

A. This Section includes the following:

1. Vibration Isolation Mounts and Hangers

a. Isolation pads.
b. Isolation mounts.
c. Restrained elastomeric isolation mounts.
d. Restrained spring isolators.
e. Elastomeric hangers.
f. Spring hangers.
g. Spring hangers with vertical-limit stops.

2. Vibration Isolation Equipment Bases

a. Structural Steel Frame Inertia Bases
b. Concrete Inertia Bases

3. Rooftop Equipment Vibration Isolation

a. Curb-Mounted Fiberglass Strips
b. Curb-Mounted Spring Rail
c. Sheet Metal Restraint / Spring Isolation Curbs.

4. Acoustical Pipe Seals
5. All-Directional Acoustical Pipe Anchors.
6. Telescoping Type Vertical Sliding Guides.

1.3 DEFINITIONS

A. IBC: International Building Code.

B. ICC-ES: ICC-Evaluation Service.

C. ASCE-7, Minimum Design Loads for Buildings and Other Structures

D. Sheet Metal and Air Conditioning Contractors' National Association (SMACNA)

E. American Society for Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE)

F. The Vibration Isolation and Seismic Control Manufacturers Association (VISCMA)

1.4 PERFORMANCE REQUIREMENTS

A. Wind-Restraint Loading:

1. For Basic Wind Speed and Building Classification Category, please refer to the project Structural Drawings.
2. Project design value in lb/sq. ft. (kg/sq. m) multiplied by the maximum area of the HVAC component projected on a vertical plane that is normal to the wind direction, and 45 degrees either side of normal.

1.5 ACTION SUBMITTALS

A. All vibration isolation products and wind restraints must be by a single manufacturer.

B. Product Data: For the following:

1. Include rated load, rated deflection, and overload capacity for each vibration isolation device.
2. Illustrate and indicate style, material, strength, fastening provision, and finish for each type and size of seismic-restraint component used.

a. Tabulate types and sizes of seismic restraints, complete with report numbers and rated strength in tension and shear as evaluated by an evaluation service member of ICC-ES or an agency acceptable to authorities having jurisdiction.
b. Annotate to indicate application of each product submitted and compliance with requirements.

3. Interlocking Snubbers: Include ratings for horizontal, vertical, and combined loads.

C. Delegated-Design Submittal: For vibration isolation and restraint details 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 static and dynamic loading due to equipment weight and operation, and wind forces required to select vibration isolators, and wind restraints, and for designing vibration isolation bases.

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

2. Riser Supports: Include riser diagrams and calculations showing anticipated expansion and contraction at each support point, initial and final loads on building structure, spring deflection changes, and seismic loads. Include certification that riser system has been examined for excessive stress and that none will exist.
3. Vibration Isolation Base Details: Detail overall dimensions, including anchorages and attachments to structure and to supported equipment. Include auxiliary motor slides and rails, base weights, equipment static loads, power transmission, component misalignment, and cantilever loads.

4. Wind Restraint Details:

    a. Design Analysis: To support selection and arrangement of wind restraints. Include calculations of combined tensile and shear loads.
    b. Details: Indicate fabrication and arrangement. Detail attachments of restraints to the restrained items and to the structure. Show attachment locations, methods, and spacings. Identify components, list their strengths, and indicate directions and values of forces transmitted to the structure during wind events. Indicate association with vibration isolation devices.
    c. Coordinate restraint and vibration isolation details with wind-restraint details required for equipment mounted outdoors. Comply with requirements in other Sections for equipment mounted outdoors.
    d. Pre-approval and Evaluation Documentation: By an agency acceptable to authorities having jurisdiction, showing maximum ratings of restraint items and the basis for approval (tests or calculations).

1.6 INFORMATIONAL SUBMITTALS

A. Coordination Drawings: Show coordination of required clearances and bracing for HVAC duct and equipment with other systems and equipment in the vicinity, including other supports, wind restraints, housekeeping pads, and roof curbs.

B. Qualification Data: For professional engineer, manufacturer, installer, and testing agency.

C. Welding certificates.

D. Field quality-control test reports.

1.7 FIELD MEASURE

A. Verify field measurements prior to fabrication.

1.8 QUALITY ASSURANCE

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

B. Comply with wind design/restraint requirements in the IBC unless requirements in this Section are more stringent.

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

PART 2 - PRODUCTS

2.1 General

A. Metal parts of vibration isolation units installed out-of-doors shall be hot-dipped galvanized, cadmium-plated, or Neoprene-coated after fabrication. Galvanizing shall meet ASTM 44 “Salt Spray Test Standards and Federal Test Standard.”

B. Spring elements shall be powder coated and tested in salt spray fog test per ASTM B117 standards

C. Spring elements shall have a lateral stiffness greater than 0.8 times the rated vertical stiffness and shall be designed to provide up to 50% overload capacity before solid state is reached. Spring shall be safe at solid state.

D. Spring elements shall be color coded or otherwise identified to indicate load capacity.

E. Isolator types are scheduled to establish minimum standards. Optionally, labor-saving accessories can be an integral part of isolators supplied to provide initial lift of equipment to operating height, hold piping at fixed elevations during installation, and initial system filling operations, and similar installation advantages. Accessories shall not degrade vibration isolation systems.

F. Vibration Isolators shall be selected by the manufacturer for each specific application to comply with deflection requirements as shown on the vibration isolation schedule listed in this specification.

G. Refer to schedules on drawings covering devices specified herein.

2.2 VIBRATION ISOLATION MOUNTS AND HANGERS

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

1. Amber Booth Company.
2. Kinetics Noise Control.
3. Mason Industries.
4. Vibration Mountings and Controls, Inc.
5. Vibro-Acoustics.

B. Pads <**TYPE 1**>: Arranged in single or multiple layers of sufficient stiffness for uniform loading over pad area, molded with a nonslip pattern and galvanized-steel baseplates, and factory cut to sizes that match requirements of supported equipment. Minimum static deflection .25”

1. Resilient Material: Oil- and water-resistant neoprene, rubber, or hermetically sealed compressed fiberglass.

C. Mounts <**TYPE 2**>: Double-deflection type, with molded, oil-resistant rubber, hermetically sealed compressed fiberglass, or neoprene isolator elements with factory-drilled, encapsulated top plate for bolting to equipment and with baseplate for bolting to structure. Color-code or otherwise identify to indicate capacity range. Minimum static deflection .25”

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

D. Restrained Spring Isolators <**Type 3**>: Freestanding, steel, housed (Type C mounting), isolators with limit-stop restraint.

1. Housing: Steel with resilient vertical-limit stops to prevent spring extension due to weight being removed; factory-drilled baseplate bonded to 1/4-inch- (6-mm-) thick, neoprene or rubber isolator pad attached to baseplate underside; and adjustable equipment mounting and leveling bolt that acts as blocking during installation. A minimum clearance of ½" shall be maintained around restraining bolts and between the housing and the spring so as not to interfere with the spring action. Housing shall be designed to resist all wind forces as applicable per building codes.
2. Restraint: Limit stop as required for equipment and authorities having jurisdiction. Restraining bolts shall have a neoprene busing between the bolt and the housing. Limit stops shall be out of contact during normal operation.
3. Outside Spring Diameter: Not less than 80 percent of the compressed height of the spring at rated load.
4. Minimum Additional Travel: 50 percent of the required deflection at rated load.
5. Lateral Stiffness: More than 80 percent of rated vertical stiffness.
6. Overload Capacity: Support 200 percent of rated load, fully compressed, without deformation or failure.

E. Elastomeric Hangers <**Type 4**>: Single or double-deflection type, fitted with molded, oil-resistant elastomeric isolator elements bonded to steel housings with threaded connections for hanger rods. Color-code or otherwise identify to indicate capacity range.

F. Spring Hangers <**Type 5**>: Combination coil-spring and fiberglass-insert hanger with spring and insert in compression.

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

G. Spring Hangers with Vertical-Limit Stop <**Type 6**>: Combination coil-spring and fiberglass-insert hanger with spring and insert in compression and with a vertical-limit stop.

1. Frame: Steel, fabricated for connection to threaded hanger rods and to allow for a maximum of 30 degrees of angular hanger-rod misalignment without binding or reducing isolation efficiency.

2. Outside Spring Diameter: Not less than 80 percent of the compressed height of the spring at rated load.
3. Minimum Additional Travel: 50 percent of the required deflection at rated load.
4. Lateral Stiffness: More than 80 percent of rated vertical stiffness.
5. Overload Capacity: Support 200 percent of rated load, fully compressed, without deformation or failure.
6. Fiberglass Element: Molded, oil-resistant fiberglass.
7. Adjustable Vertical Stop: Steel washer with neoprene washer "up-stop" on lower threaded rod.
8. Self-centering hanger rod cap to ensure concentricity between hanger rod and support spring coil.

2.3 VIBRATION ISOLATION EQUIPMENT BASES

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

1. Amber Booth Company.
2. Kinetics Noise Control.
3. Mason Industries.
4. Vibration Mountings & Controls, Inc.
5. Vibro-Acoustics.

B. Steel Base <**Type A**>: Factory-fabricated, welded, structural-steel bases and rails.

1. Design Requirements: Lowest possible mounting height with not less than a 2-inch clearance above the floor. Include equipment anchor bolts and auxiliary motor slide bases or rails.
2. Include supports for suction and discharge elbows for pumps.
3. Structural Steel: Steel shapes, plates, and bars complying with ASTM A 36/A 36M. Bases shall have shape to accommodate supported equipment.
4. Support Brackets: Factory-welded steel brackets on frame for outrigger isolation mountings and to provide for anchor bolts and equipment support.
5. All vibration isolated structural frame base equipment shall have flexible connectors on all attached piping, duct, conduit, etc. as to fully isolate the unit.

C. Inertia Base <**Type B**>: Factory-fabricated, welded, structural-steel bases and rails including placement of cast-in-place concrete.

1. Design Requirements: Lowest possible mounting height with not less than a 2-inch clearance above the floor. Include equipment anchor bolts and auxiliary motor slide bases or rails.
2. Include supports for suction and discharge elbows for pumps.
3. Structural Steel: Steel shapes, plates, and bars complying with ASTM A 36/A 36M. Bases shall have shape to accommodate supported equipment.
4. Support Brackets: Factory-welded steel brackets on frame for isolation mountings and to provide for anchor bolts and equipment support.
5. Fabrication: Fabricate steel templates to hold equipment anchor-bolt sleeves and anchors in place during placement of concrete. Obtain anchor-bolt templates from supported equipment manufacturer.
6. All vibration isolated concrete inertia base equipment shall have flexible connectors on all attached piping, duct, conduit, etc as to fully isolate the unit.
7. Cast-In-Place Concrete: Fill base with concrete per bas manufacturer's instructions, using concrete meeting concrete specs.

2.4 ROOFTOP EQUIPMENT VIBRATION ISOLATION <Type C>

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

1. Kinetics Noise Control.
2. Mason Industries.
3. Thybar Corporation.
4. Vibration Eliminator Co., Inc.
5. 5. Vibration Mountings & Controls, Inc.

B. General Requirements

1. Factory-assembled, fully enclosed, insulated, air- and watertight curb rail designed to resiliently support equipment and to withstand project wind forces.
2. All components within the final product and including the final product are to be manufactured within the United States of America.
3. Complete curb and isolation assembly shall be stamped by a Professional Engineer licensed in the jurisdiction of the project.
4. Provide sloped and/or extended height curb assemblies as necessary to coordinate with roof slope and buildup.
5. All vibration isolated structural frame base equipment shall have flexible connectors on all attached piping, duct, conduit, etc. as to fully isolate the unit.

C. Curb-Mounted Fiberglass Strips <**Type D-1**>

1. Fiberglass continuous support material shall be high-density matrix of compressed molded fiberglass; individually coated with a flexible moisture-impervious elastomeric membrane.
2. Material is to be non-corrosive, non-combustible, non-absorbent, and resists rust, ozone, mildew, and fungus.
3. Material will not shrink, swell, or decompose.
4. Isolation characteristics of the media are to remain constant over a temperature range of -40F to 250F.

D. Curb Mounted Spring Rail <**Type D-2**>

1. Full-perimeter rail type isolator, spring components shall be 1” or 2” deflection, free-standing, un-housed, laterally stable steel spring. Springs have a lateral stiffness greater than 1.0 times the rated vertical stiffness and shall be designed for 50% overload to solid.
2. Rails shall provide continuous support for the rooftop equipment and shall consist of extruded aluminum top and bottom members connected by spring isolators and a continuous air and water-tight seal.
3. Curb Mounted Spring Rail is mounted on existing roof curb or curbs provided by others.

E. Sheet Metal Restraint / Spring Isolation Curbs <**Type D-3**>

1. Lower Support Assembly: Formed sheet-metal section containing steel springs that support upper frame. Upper frame shall provide continuous support for equipment and shall be captive to resiliently resist seismic and wind forces. Lower support assembly shall have a means for attaching to building structure and a wood nailer for attaching roof materials, and shall be insulated with a minimum of 2 inches (50 mm) of rigid, glass-fiber insulation on inside of assembly.

2. Spring Isolators: restrained spring isolators shall be mounted on 1/4-inch- (6-mm-) thick, elastomeric vibration isolation pads and shall have access ports, for level adjustment, with removable waterproof covers at all isolator locations. Isolators shall be located so they are accessible for adjustment at any time during the life of the installation without interfering with the integrity of the roof.

   a. Restrained Spring Isolators: Steel, open-spring isolators with wind restraint.

      1) Housing: Steel with resilient vertical-limit stops and adjustable equipment mounting and leveling bolt.
      2) Outside Spring Diameter: Not less than 80 percent of the compressed height of the spring at rated load.
      3) Minimum Additional Travel: 50 percent of the required deflection at rated load.
      4) Lateral Stiffness: More than 80 percent of rated vertical stiffness.
      5) Overload Capacity: Support 200 percent of rated load, fully compressed, without deformation or failure.

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

      1) Resilient Material: Oil- and water-resistant standard neoprene, natural rubber, or hermetically sealed compressed fiberglass.

3. Snubber Bushings: All-directional, elastomeric snubber bushings at least 1/4 inch (6 mm) thick.
4. Water Seal: EPDM or Galvanized sheet metal weather seal attached to upper support frame, extending down past wood nailer of lower support assembly, and counterflashed over roof materials.

2.5 ACOUSTICAL PIPE SEALS

A. Split seals shall consist of pipe halves with minimum 3/4" thick neoprene sponge cemented to the inner faces. The seal shall be tightened around the pipe to eliminate clearance between the inner sponge face and the piping. Concrete may be packed in around the seal to make it integral with the floor, wall, or ceiling if the seal is not in place prior to the construction of the building surface or member.

B. Seals shall project a minimum of 1" past either face of walls. Where temperatures exceed 240°F, 10 pound density fiberglass may be used in lieu of the sponge.

C. Seals shall be Type SWS by Mason Industries or approved equal.

2.6 TELESCOPING TYPE VERTICAL SLIDING GUIDES

A. Guides shall consist of a telescopic arrangement of two sizes of steel tubing separated by a minimum of 1/2" thickness of 60 durometer or softer neoprene. The height of the guides shall be preset with a set screw/bolt to allow vertical motion due to pipe expansion or contraction. Guides shall be capable of +/- 1.625" motion, or to meet location requirements.

B. Guides shall be Type VSG by Mason Industries or approved equal.

2.7 ALL DIRECTIONAL ACOUSTICAL PIPE ANCHORS

A. Guides shall consist of f two sizes of steel tubing separated by a minimum of 1/2" thickness of 60 durometer or softer neoprene. Vertical restraint shall be provided by similar material arranged to prevent up or down vertical travel. Allowable loads on the isolation material shall not exceed 500 psi and the design shall be balanced for equal resistance in any direction.

B. Guides shall be Type ADA by Mason Industries or approved equal.

2.8 FACTORY FINISHES

A. Finish: Manufacturer's standard prime-coat finish ready for field painting.

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

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

PART 3 - EXECUTION

3.1 EXAMINATION

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

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

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

3.2 APPLICATIONS

A. Multiple Pipe Supports: Secure pipes to trapeze member with clamps approved for application by an evaluation service member of ICC-ES or an agency acceptable to authorities having jurisdiction.

B. Hanger Rod Stiffeners: Install hanger rod stiffeners where indicated or scheduled on Drawings to receive them and where required to prevent buckling of hanger rods due to seismic forces.

C. All rotating equipment shall have vibration isolation from building structure.

D. Ducts within 50' of fan discharges shall be isolated by spring hangers with neoprene cups.

E. The first three hangers and floor supports from equipment (i.e. pumps, etc.) shall be isolated by spring hangers with neoprene cup for pipe and spring isolated concrete inertia base mounts respectively.

F. Pipes passing through equipment room walls, floors, or ceilings shall have all directional acoustical pipe seals.

G. Pipe risers shall bne suspended from or supported by all directional acoustical pipe anchors and telescoping type guides.

H. All supply fans and pumps are to have at least four isolation springs located at the corners of the equipment.

3.3 VIBRATION-CONTROL AND RESTRAINT DEVICE INSTALLATION

A. Comply with requirements in Section 077200 "Roof Accessories" for installation of roof curbs, equipment supports, and roof penetrations.

B. Equipment Restraints:

1. Install resilient bolt isolation washers on equipment anchor bolts where clearance between anchor and adjacent surface exceeds 0.125 inch (3.2 mm).

C. Piping Restraints:

1. Comply with requirements in MSS SP-127.
2. Space lateral supports and brace change of direction following SMACNA and VISCMA recommendations per a professional engineer.

D. Install bushing assemblies for anchor bolts for floor-mounted equipment, arranged to provide resilient media between anchor bolt and mounting hole in concrete base.

E. Install bushing assemblies for mounting bolts for wall-mounted equipment, arranged to provide resilient media where equipment or equipment-mounting channels are attached to wall.

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

G. Drilled-in Anchors:

1. Identify position of reinforcing steel and other embedded items prior to drilling holes for anchors. Do not damage existing reinforcing or embedded items during coring or drilling. Notify the structural engineer if reinforcing steel or other embedded items are encountered during drilling. Locate and avoid prestressed tendons, electrical and telecommunications conduit, and gas lines.
2. Do not drill holes in concrete or masonry until concrete, mortar, or grout has achieved full design strength.
3. Wedge Anchors: Protect threads from damage during anchor installation. Heavy-duty sleeve anchors shall be installed with sleeve fully engaged in the structural element to which anchor is to be fastened.
4. Adhesive Anchors: Clean holes to remove loose material and drilling dust prior to installation of adhesive. Place adhesive in holes proceeding from the bottom of the hole

and progressing toward the surface in such a manner as to avoid introduction of air pockets in the adhesive.
5. Set anchors to manufacturer's recommended torque, using a torque wrench.
6. Install zinc-coated steel anchors for interior and stainless-steel anchors for exterior applications.

3.4 FIELD QUALITY CONTROL

A. Testing Agency: The Owner shall engage a qualified testing agency to perform tests and inspections.

B. Tests and Inspections:

1. Provide evidence of recent calibration of test equipment by a testing agency acceptable to authorities having jurisdiction.
2. Schedule test through Architect, before connecting anchorage device to restrained component (unless post-connection testing has been approved), and with at least seven days' advance notice.
3. Obtain Architect's approval before transmitting test loads to structure. Provide temporary load-spreading members.
4. Test at least four of each type and size of installed anchors and fasteners selected by Architect.
5. Test to 90 percent of rated proof load of device.
6. Measure isolator restraint clearance.
7. Measure isolator deflection.
8. Verify snubber minimum clearances.
9. If a device fails test, modify all installations of same type and retest until satisfactory results are achieved.

C. Remove and replace malfunctioning units and retest as specified above.

D. Prepare test and inspection reports.

3.5 ADJUSTING

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

B. Adjust limit stops on restrained spring isolators to mount equipment at normal operating height. After equipment installation is complete, adjust limit stops so they are out of contact during normal operation.

C. Adjust active height of spring isolators.

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

3.6 DEMONSTRATION

A. Refer to Division 01 Section covering demonstration and training.

3.7 HVAC VIBRATION-CONTROL AND RESTRAINT DEVICE SCHEDULE AND SUPPLY FAN AND HVAC PUMP APPLICATION

A. See drawing schedules but, the minimum mounting deflection for spring isolators shall be as follows: 300 rpm, 3.5"; 500 rpm, 1.65"; 800 rpm, 1.00"; 1200 rpm and higher, 0.80".

B. All supply fans and HVAC pumps are to have at least (4) spring isolators located at the corners of the fans/pumps.

END OF SECTION 23 0550

SECTION 23 0553 - MECHANICAL SYSTEMS IDENTIFICATION

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.

B. Division 23 Section 23 2113 - Hydronic Piping

C. Division 23 Section 23 2116 - Hydronic Piping Specialties

D. Division 23 Section 23 2213 - Steam Piping

E. Division 23 Section 23 2216 - Steam Piping Specialties

F. Division 23 Section 23 3114 - Ductwork

G. Division 23 Section 23 3314 - Ductwork Specialties

1.2 SUMMARY

A. Section Includes:

1. Equipment labels.
2. Warning signs and labels.
3. Pipe labels.
4. Valve tags.
5. Duct labels.
6. Bar coding new equipment and components (see 3.7 at end of this section).

1.3 SUBMITTAL

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

PART 2 - PRODUCTS

2.1 MANUFACTURER'S for Labels: Brady, Kolbi, or Panduit.

2.2 EQUIPMENT LABELS

A. Metal Labels for Equipment:

1. Material and Thickness: Brass, 0.032-inch minimum thickness, and having pre-drilled 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 or 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, 1/8 inch thick, and having predrilled holes for attachment hardware.
2. Letter Color: White.
3. Background Color: Black.
4. Maximum Temperature: Able to withstand temperatures up to 160 deg F.
5. Minimum Label Size: Length and width vary for required label content, but not less than 2-1/2 by 3/4 inch.
6. Minimum Letter Size: 1/4 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.
7. Fasteners: Stainless-steel rivets or self-tapping screws.
8. Adhesive: Contact-type permanent adhesive, compatible with label and with substrate.

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

1. Label is to also indicate area and type of service being provided.

a. For Example AHU - 3 Services floors 1-4 etc.
b. P3 HHW Pump Services building perimeter

D. 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, 1/8 inch thick, and having predrilled holes for attachment hardware.

B. Letter Color: White.

C. Background Color: Red.

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

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

F. Minimum Letter Size: 1/4 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 or self-tapping screws.

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

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

2.4 PIPE LABELS

A. General Requirements for Manufactured Pipe Labels: Preprinted, color-coded, with lettering indicating service, showing flow direction, and area served (i.e. perimeter heating hot water).

B. Pre-tensioned Pipe Labels: Pre-coiled, semi-rigid plastic formed to cover full circumference of pipe and to attach to pipe without fasteners or adhesive.

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

D. 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, and visible all around pipe.
2. Lettering Size: At least 1-1/2 inches high.

2.5 VALVE TAGS

A. Valve tags shall be per University standards and according to project valve specification section(s). Unless required differently in project valve specification section(s), valve tags to be minimum 1.5" round brass, attached with metallic chains.

2.6 DUCT LABELS

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

B. Letter Color: White.

C. Background Color: Red.

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

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

F. Minimum Letter Size: 1/4 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 or 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.

J. OTHER SPECIALIZED LABELING AND REQUIREMENTS

1. Fire damper access panels shall be permanently identified on the exterior by labels not less than 2" in height reading "FIRE DAMPER".
2. Smoke damper access panels shall be permanently identified on the exterior by labels not less than 2" in height reading "SMOKE DAMPER".
3. Combination fire/smoke damper access panels shall be permanently identified on the exterior by labels not less than 2" in height reading "RESETTABLE FIRE/SMOKE DAMPER". Mark the other access panels "FIRE/SMOKE DAMPER."
4. Items listed in items 1-3 above, will also be listed on a full size, laminated print and left in the main mechanical room as indicated above.

K. Duct static pressure sensors shall be permanently identified on the exterior by labels not less than 2" in height reading "STATIC PRESSURE SENSOR".

1. Humidity sensors in ductwork shall be permanently identified on the exterior by labels not less than 2" in height reading "HUMIDITY SENSOR".
2. Abbreviations: No abbreviations to be used.
3. All smoke and fire damper locations are to be posted as a pdf on the DDC system per fan system. This information is also to be located in the fire command center for the building. Coordinate with other trades to make sure this happens, and support as required via that coordination.

a. STENCILING

1) Not allowed.

L. Barcoding New Equipment: Contractor to barcode any new equipment for the University, and in coordination with their requirements.

PART 3 - EXECUTION

3.1 GENERAL

A. Refer to and adhere to "Northwestern University Pipe, Valve, and Fittings Standards" for work of this section.

3.2 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.

3.3 EQUIPMENT LABEL INSTALLATION

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

B. Locate equipment labels where accessible and visible.

3.4 PIPE LABEL INSTALLATION

A. Piping Color-Coding: Painting of piping is specified in Division 09 Section "Interior Painting."

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

1. Near each valve and control device.
2. Near each branch connection, excluding short takeoffs for fixtures and terminal units. Where flow pattern is not obvious, mark each pipe at branch.
3. Near penetrations through walls, floors, ceilings, and inaccessible enclosures.
4. At access doors, manholes, and similar access points that permit view of concealed piping.
5. Near major equipment items and other points of origination and termination.
6. Spaced at maximum intervals of 10 feet along each run, and at every change in direction.
7. On piping above removable acoustical ceilings. Omit intermediately spaced labels.

C. Pipe Label Color and Marking:

1. Shall be in accordance with ANSI A13.1.

3.5 VALVE TAG INSTALLATION AND DOCUMENTATION

A. Tag valves according to project valve specification section(s), and provide typed list (loose and framed under glass) per same specification section(s).

1. A valve tag schedule is to be mounted in each mechanical room and on every floor (for that respective floor) in a location to be determined by the Evanston Engineer shop.
2. Each valve tag schedule will have an associated architectural print showing each valve location.
3. At project completion two additional hard copies are to be provided in addition to an electronic copy. One for University Archive and one for the FMO Engineers shop.
4. Two copies of the mechanical piping flow diagram will be supplied. All prints that are supplied that are located in mechancial rooms are to be laminated.

B. Pipe tags that are the first isolation for a utility in a mechanical room or building need to have indicated where the next upstream valve is located and the associated valve number indicated on the valve tag.

1. This is applicable for all utility isolation valves for each mechanical room space.

3.6 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.
3. Green: For exhaust-, outside-, relief-, return-, and mixed-air ducts.
4. ASME A13.1 Colors and Designs: For hazardous material exhaust.

B. Locate labels at maximum intervals of 10 feet, at every change in direction, and within 3' of wall and floor penetrations on both sides of same.

C. Along with all other ducting on the job, label toxic exhaust.

3.7 NEW EQUIPMENT BARCODING

A. Coordinate with University, and bar code all new Division 23 equipment and components for them, according to their requirements. Requirements include, but not limited to, being iPad compatible, have the ability to call up maps of the areas on bar code scans, must have safeguards built in to flag missing items, and the devices on the maps need to be color coded based on inspection status.

END OF SECTION 23 0553

SECTION 23 0594 - TESTING, ADJUSTING, AND BALANCING (TAB)

PART 1 - GENERAL

1.1 SUMMARY

A. This Section includes testing, adjusting and balancing HVAC systems to provide design conditions as indicated by the associated drawings. This Section includes, but is not limited to the following:

1. Balancing Air Systems - Constant air volume and variable-air-volume systems.
2. Balancing Hydronic Piping Systems - Constant and variable-flow hydronic systems, and primary-secondary systems.
3. Measuring the electrical performance of HVAC equipment.
4. Verification that automatic control devices are functioning properly.
5. Measurement of sound levels as related to rotating mechanical equipment.
6. Vibration testing and analysis of all rotating equipment greater than or equal to 10 hp.
7. Measurement of duct leakage.
8. Reporting results of the activities and procedures specified in this Section.

B. The testing, adjusting and balancing of the air and hydronic systems shall be performed by an independent TAB contractor contracted directly by the University, and approved companies are Arrow Testing and Balancing, CEPro, Hill Mechanical, and ITB (Independent Test and Balance).

1.2 DEFINITIONS

A. AABC: Associated Air Balance Council.

B. Adjust: To regulate fluid flow rates and air patterns at the system or terminal level. At the system level an example would be reducing fan speed; at the terminal level an example would be changing a damper position.

C. Balance: To proportion air or water flows within the distribution system, including submains, branches and terminals with respect to design quantities.

D. Draft: A current of air, when referring to localized effect caused by one or more factors of high air velocity, low ambient temperature, or direction of airflow, whereby more heat is withdrawn from a person’s skin than is normally dissipated.

E. Independent: Not affiliated with or in employment of any Contractor.

F. NEBB: National Environmental Balancing Bureau.

G. Procedure: An approach to and execution of a sequence of work operations to yield repeatable results.

H. Report Forms: Test data sheets for recording test data in logical order.

I. Static Head: The pressure due to the weight of the fluid above the point of measurement. In a closed system, static head is equal on both sides of the pump.

J. Suction Head: The height of fluid surface above the centerline of the pump on the suction side.

K. System Effect: A phenomenon that can create undesired or unpredicted conditions that cause reduced capacities in all or part of a system.

L. System Effect Factors: Allowances used to calculate a reduction of the performance ratings of a fan when installed under conditions different from those presented when the fan was performance tested.

M. TAB: Testing, adjusting, and balancing.

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

O. Testing, Adjusting and Balancing (TAB) Agent: The entity responsible for performing and reporting the TAB procedures.

P. Terminal: A point where the controlled medium (fluid or energy) enters or leaves the distribution system.

1.3 PREINSTALLATION MEETINGS

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

1. Minimum Agenda Items:

a. The Contract Documents examination report.
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.

B. 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.

C. Strategies and Procedures Plan: Within ***[30] [60] [90] <Insert number>*** days of Contractor's Notice to Proceed, submit TAB strategies and step-by-step procedures as specified in "Preparation" Article.

D. 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.

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

F. Certified TAB reports.

G. Sample report forms.

H. 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 or NEBB.

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

B. Instrumentation Type, Quantity, Accuracy, and Calibration: Comply with requirements in ASHRAE 111, Section 4, "Instrumentation" but in all cases, all instrumentation used for testing shall be calibrated within 6 months of use, an accuracy of the instrumentation shall not be less than what is specified by the instrument manufacturer.

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

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

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

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

1.7 FIELD CONDITIONS

A. 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.

B. 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 WARRANTY

A. Provide one of the following performance guarantees:

1. AABC National Project Performance Guarantee
2. NEBB Certificate of Conformance Certification
3. TABB Quality Assurance Program Guarantee

B. Guarantee shall include provisions that the certified TAB firm has tested and balanced systems according to the Contract Document and that the systems are balanced to optimum performance capabilities within design and installation limits.

PART 2 - PRODUCTS

2.1 INSTRUMENT TEST HOLES

A. To be Ventlock #699,

PART 3 - EXECUTION

3.1 EXAMINATION

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

3.2 PREPARATION

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

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

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

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

3.3 GENERAL PROCEDURES FOR TESTING AND BALANCING

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

1. Comply with requirements in ASHRAE 62.1-2007, Section 7.2.2, "Air Balancing."

B. Cut insulation, ducts, pipes, and equipment cabinets for installation of test holes and probes to the extent necessary for TAB procedures, and duct test hole fittings shall be provided where shown on the drawings or specified in the Data sheets. T&B instrument test holes to be Ventlock #699.

1. After testing and balancing, install and join new insulation that matches removed materials. Restore insulation, coverings, vapor barrier, and finish according to Division 23 Section "Mechanical System Insulation."

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

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

3.4 GENERAL PROCEDURES FOR BALANCING AIR SYSTEMS

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

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

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

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

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

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

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

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

I. Check for airflow blockages.

J. Check condensate drains for proper connections and functioning.

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

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

3.5 PROCEDURES FOR CONSTANT-VOLUME AIR SYSTEMS

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

1. Measure total airflow.

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

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

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

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

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

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

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

1. Measure airflow of submain and branch ducts.

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

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

C. Measure air outlets and inlets without making adjustments.

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

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

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

3.6 PROCEDURES FOR VARIABLE-AIR-VOLUME SYSTEMS

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

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

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

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

6. Re-measure the return airflow to the fan while operating at maximum return airflow and minimum outdoor airflow.

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

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

C. Pressure-Dependent, Variable-Air-Volume Systems with Diversity: After the fan systems have been adjusted, adjust the variable-air-volume systems as follows:

1. Set system at maximum indicated airflow by setting the required number of terminal units at minimum airflow. Select the reduced-airflow terminal units so they are distributed evenly among the branch ducts.
2. Adjust supply fan to maximum indicated airflow with the variable-airflow controller set at maximum airflow.
3. Set terminal units at full-airflow condition.
4. Adjust terminal units starting at the supply-fan end of the system and continuing progressively to the end of the system. Adjust inlet dampers of each terminal unit to indicated airflow. When total airflow is correct, balance the air outlets downstream from terminal units the same as described for constant-volume air systems.
5. Adjust terminal units for minimum airflow.
6. Measure static pressure at the sensor.
7. Measure the return airflow to the fan while operating at maximum return airflow and minimum outdoor airflow. Adjust the fan and balance the return-air ducts and inlets the same as described for constant-volume air systems.

3.7 GENERAL PROCEDURES FOR HYDRONIC SYSTEMS

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

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

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

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

3.8 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.

3. Monitor motor performance during procedures and do not operate motor in an overloaded condition.

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

1. Measure flow in main and branch pipes.
2. Adjust main and branch balance valves for design flow.
3. Re-measure each main and branch after all have been adjusted.

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

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

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

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

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

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

F. Verify final system conditions as follows:

1. Re-measure and confirm that total water flow is within design.
2. Re-measure final pumps' operating data, TDH, volts, amps, and static profile.
3. Mark final settings.
4. Verify that memory stops have been set.

3.9 PROCEDURES FOR VARIABLE-FLOW HYDRONIC SYSTEMS

A. Balance systems with automatic two- and three-way control valves by setting systems at maximum flow through heat-exchange terminals and proceed as specified above in section 3.7 for hydronic systems.

3.10 Systems installed with pressure independent control valves shall not require full hydronic system balancing. Flow shall be verified for the pressure independent valve assembly (valve and actuator combination) for field conditions using the pressure independent control valve manufacturer’s documented procedure for ***[20%] [50%] [100%]*** of the total installed product. Exact locations of tested product to be coordinated with the drawings.

3.11 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.

3. Monitor motor performance during procedures and do not operate motor in an overloaded condition.

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.

3.12 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.

3.13 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.

3.14 PROCEDURES FOR MOTORS

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

1. Manufacturer's name, model number, and serial number.
2. Motor horsepower rating.
3. Motor rpm.
4. 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.

3.15 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.

3.16 PROCEDURES FOR CONDENSING UNITS

A. Verify proper rotation of fans.

B. Measure entering- and leaving-air temperatures.

C. Record fan and motor operating data.

3.17 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.

3.18 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.
6. Capacity: Calculate in tons of cooling.
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 HEAT-TRANSFER COILS

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

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

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 and at each incremental stage.
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. Air pressure drop.
4. 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.
4. Air pressure drop.

5. Refrigerant suction pressure and temperature.

3.20 TOLERANCES/ACCEPTED CRITERIA

1. For most spaces, the total supply air quantity to each space of a system shall be within -5% to +10% of design. Review project specific requirements with NU Project Manager.
2. The percent tolerance of each outlet within a space shall be per Table 23 0594-1.

Table 23 0594-1			
System	Number of Outlets in Space		
	1	2	3 or More
Single Zone, Multizone, VAV	-5% +10%	±10%	± 15%
Heating and Ventilating	-5% +10%	±15%	±15%

3. Air quantity of each return air grille and diffuser shall be within ±10% of design. The design room pressurization must be maintained regardless of the tolerance at each individual diffuser.
4. Vivariums: In general, these laboratories shall be under negative pressure. The design should meet the current NIH Design Requirements Manual for Biomedical Laboratories and Animal Research Facilities. Any reduction in airflow shall be presented by the project Engineer of Record and reviewed by the NU Project Manager and Project Engineer.
5. Culture Rooms: These rooms shall be under positive pressure.
6. Hydronic Systems: Heating and cooling hydronic systems shall be balanced so that the flow is from 0 to +5% of design at each coil.
7. Combination fire/smoke dampers in dynamic smoke control systems shall be tested for closure under airflow conditions (International Mechanical Code – 2009, Section 607), and to assure positive pressure of certain zones, and negative pressure for other zones. Smoke dampers in dynamic smoke control systems must close under airflow conditions.

3.21 REPORTING

A. All test reports are to have an Executive Summary which shall state extent of system compliance, system deficiencies, and recommended changes.

B. 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.

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

3.22 FINAL REPORT

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

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

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

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

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

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

12. Nomenclature sheets for each item of equipment.
13. Data for terminal units, including manufacturer's name, type, size, and fittings.
14. Notes to explain why certain final data in the body of reports vary from indicated values.
15. Test conditions for fans 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. Settings for differential pressure, hydronic differential control
    i. 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 and steam flow rates.
3. Duct, outlet, and inlet sizes.

4. Pipe and valve sizes and locations.
5. Terminal units.
6. Balancing stations.
7. Position of balancing devices.

3.23 ADDITIONAL TESTS

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

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

END OF SECTION 23 0594

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SECTION 23 0700 - HVAC INSULATION

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:

1. Insulation Materials:

   a. Flexible elastomeric.
   b. Mineral fiber.

2. Duct Fire Wrap
3. Insulating cements.
4. Adhesives.
5. Mastics.
6. Sealants.
7. Field-applied jackets.
8. Removable insulation covers.
9. Tapes.
10. Securements.
11. Corner angles.

B. Related Sections:

1. Section 23 2113 "Hydronic Piping."
2. Section 23 2116 "Hydronic Piping Specialties."
3. Section 23 2123 "Pumps."
4. Section 23 2213 "Steam Piping."
5. Section 23 2216 "Steam Piping Specialties."
6. Section 23 3114 "Ductwork."
7. Section 23 5214 "Primary Heating Equipment."
8. Section 23 8216 "Coils."
9. Section 23 8413 "Humidification Equipment."

1.2 SUBMITTALS

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

B. ***]LEED Submittal:***

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

C. Shop Drawings:

1. Detail application of protective shields, saddles, and inserts at hangers for each type of insulation and hanger.

2. Detail attachment and covering of heat tracing inside insulation.
3. Detail insulation application at pipe expansion joints for each type of insulation.
4. Detail insulation application at elbows, fittings, flanges, valves, linkages of control devices, and specialties for each type of insulation.
5. Detail removable insulation at piping specialties, equipment connections, and access panels.
6. Detail application of field-applied jackets.
7. Detail field application for each equipment type.

D. Field quality-control reports.

1.3 QUALITY ASSURANCE

A. 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.

B. Materials and installation in accordance with NFPA 255, UL 723, and MICA (Midwest Insulation Contractors Association).

C. Insulation thickness shall meet the requirements of ASHRAE Standard 90.1 and Northwestern University Standards and shall be selected to eliminate avoid condensation.

1.4 SPECIAL WARRANTIES

A. Five (5) years, see Division 01.

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. 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.

1. Products: Subject to compliance with requirements, provide one of the following:

a. Aeroflex USA Inc.; Aerocel.
b. Armacell LLC; AP Armaflex (Preferred).
c. RBX Corporation; Insul-Sheet 1800 and Insul-Tube 180.

G. 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.

1. Products: Subject to compliance with requirements, provide one of the following:

a. CertainTeed Corp.; SoftTouch Duct Wrap.
b. Johns Manville; Microlite.
c. Knauf Insulation; Atmosphere Duct Wrap.
d. Owens Corning; All-Service SOFTR Duct Wrap.

H. 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. For equipment applications, provide insulation with factory-applied ASJ. Factory-applied jacket requirements are specified in "Factory-Applied Jackets" Article.

1. Products: Subject to compliance with requirements, provide one of the following:

a. CertainTeed Corp.; CertaPro Commercial Board.
b. Johns Manville; 800 Series Spin-Glas.
c. Knauf Insulation; Insulation Board.
d. Owens Corning; Fiberglas 700 Series.

I. Mineral-Fiber, Preformed Pipe Insulation:

1. Products: Subject to compliance with requirements, provide one of the following:

a. Johns Manville; Micro-Lok.
b. Knauf Insulation; Redi-Klad 1000 Pipe Insulation.
c. Owens Corning; Fiberglas Pipe Insulation.

2. Type I, 850 deg F Materials: Mineral or glass fibers bonded with a thermosetting resin. Comply with ASTM C 547, Type I, Grade A, with factory-applied ASJ. Factory-applied jacket requirements are specified in "Factory-Applied Jackets" Article. Densities per PART 3 schedules.

J. 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.

1. Products: Subject to compliance with requirements, provide one of the following:

a. Johns Manville; Fabrication Board.
b. Knauf Insulation; Pipe and Tank.
c. Owens Corning; Pipe and Tank.

2.2 Grease Duct Insulation

A. Products: Subject to compliance with requirements, provide one of the following:

1. 3M Fire Barrier Duct Wrap Type 15A
2. UNIFRAX Fyrewrap
3. Thermal Ceramics Firemaster

B. Joint free, lightweight, non-asbestos, high temperature, inorganic foil encapsulated ceramic fiber blanket duct wrap for use on commercial grease hood duct systems in accordance with ASTM E2336.

C. A zero inch clearance to combustible construction and two (2) hour fire resistive rated enclosure system shall be assured.

D. Adhesives: High performance filament tape, one inch wide, and aluminum foil tape to seal cut edges of blankets.

E. Banding Material: Two (2) hour requirement, ¾" wide, no less than 0.015 inches thick, Type 304 stainless steel, (stainless steel hose clamps, ½ inch may be substituted for hanger insulations only).

F. Insulation Pins: 10 gage, 4 inches to 5 inches long, copper coated steel no less than 1-1/2 inch by 1-1/2 inch or 1-1/2 inch diameter galvanized steel speed clip.

G. Fire Stopping Materials: UL No R9464 classified noncombustible fiber with a flame spread of 0, smoke development of 0 and fuel contribution of 0. Water based, mild chemical resistant putty complying with ASTM E136-82 may be used.

2.3 INSULATING CEMENTS

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

1. Products: Subject to compliance with requirements, provide one of the following:

a. Insulco, Division of MFS, Inc.; SmoothKote.
b. P. K. Insulation Mfg. Co., Inc.; PK No. 127, and Quik-Cote.
c. Rock Wool Manufacturing Company; Delta One Shot.

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. Adhesives to be waterproof fire-retardant type.

C. ***[Retain subparagraph below if low-emitting materials are required for LEED-NC Credit EQ 4.1.***

1. ***For indoor applications, use adhesive for Flexible Elastomeric, ASJ, and PVC Jacket that has a VOC content of 50 g/L or less and for Mineral-Fiber Adhesive that has a VOC content of 80 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.

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.
4. For indoor applications, use sealants that have a VOC content of 420 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).

B. FSK and Metal Jacket Flashing Sealants:

1. Products: Subject to compliance with requirements, provide one of the following:

   a. Childers Products, Division of ITW; CP-76-8.
   b. Foster Products Corporation, H. B. Fuller Company; 95-44.
   c. 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 420 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).

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

1. 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.
4. Color: White.
5. For indoor applications, use sealants that have a VOC content of 420 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).

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. FSK Jacket: Aluminum-foil, fiberglass-reinforced scrim with kraft-paper backing; complying with ASTM C 1136, Type II.

2.8 FIELD-APPLIED JACKETS

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

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

C. PVC Jacketing and Pre-Formed Fitting Covers: High-impact-resistant, UV-resistant PVC complying with ASTM D 1784, Class 16354-C; roll stock ready jacketing for shop or field cutting and forming, and pre-formed fitting covers. Thicknesses as indicated in field-applied jacket schedules.

1. Products: Subject to compliance with requirements, provide one of the following:

   a. Johns Manville; Zeston (Preferred), 300 Series if outdoors, 2000 series if indoors.
   b. P.I.C. Plastics, Inc.; FG Series.
   c. Proto PVC Corporation; LoSmoke.
   d. Speedline Corporation; SmokeSafe.

2. Adhesive: As recommended by jacket material manufacturer.
3. Color: White.
4. Factory-fabricated fitting covers to match jacket if available; otherwise, field fabricate.

   a. Shapes: 45- and 90-degree, short- and long-radius elbows, tees, valves, flanges, unions, reducers, end caps, soil-pipe hubs, traps, mechanical joints, and P-trap and supply covers for lavatories.

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. Products: Subject to compliance with requirements, provide one of the following:

   a. Childers Products, Division of ITW; Metal Jacketing Systems.
   b. PABCO Metals Corporation; Surefit.
   c. RPR Products, Inc.; Insul-Mate.

2. Finish and thickness are indicated in field-applied jacket schedules.
3. 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.

2.9 REMOVABLE INSULATION COVERS

A. Acceptable Manufacturers:

1. Advance Thermal Corp.
2. Thermal Energy Products, Inc.
3. Temptec.
4. Remco Technology, Inc.

B. Removable ceramic blanket type with Velcro tabs and box-stitched, 1.5" wide, D-ring straps, gussets, hot face inner jacketing, type 304 stainless steel tag with laser engraved data riveted to body, outer jacketing, type 304 stainless steel quilting pins, specifically shaped and constructed for insulated item.

2.10 TAPES

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

1. Products: Subject to compliance with requirements, provide one of the following:

a. Avery Dennison Corporation, Specialty Tapes Division; Fasson 0835.
b. Compac Corp.; 104 and 105.
c. Ideal Tape Co., Inc., an American Biltrite Company; 428 AWF ASJ.
d. Venture Tape; 1540 CW Plus, 1542 CW Plus, and 1542 CW Plus/SQ.

2. Width: 3 inches.
3. Thickness: 11.5 mils.
4. Adhesion: 90 ounces force/inch in width.
5. Elongation: 2 percent.
6. Tensile Strength: 40 lbf/inch in width.
7. ASJ Tape Disks and Squares: Precut disks or squares of ASJ tape.

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

1. Products: Subject to compliance with requirements, provide one of the following:

a. Avery Dennison Corporation, Specialty Tapes Division; Fasson 0827.
b. Compac Corp.; 110 and 111.
c. Ideal Tape Co., Inc., an American Biltrite Company; 491 AWF FSK.
d. Venture Tape; 1525 CW, 1528 CW, and 1528 CW/SQ.

2. Width: 3 inches.
3. Thickness: 6.5 mils.
4. Adhesion: 90 ounces force/inch in width.
5. Elongation: 2 percent.
6. Tensile Strength: 40 lbf/inch in width.
7. FSK Tape Disks and Squares: Precut disks or squares of FSK tape.

C. PVC Tape: White vapor-retarder tape matching field-applied PVC jacket with acrylic adhesive. Suitable for indoor and outdoor applications.

1. Products: Subject to compliance with requirements, provide one of the following:

    a. Avery Dennison Corporation, Specialty Tapes Division; Fasson 0555.
    b. Compac Corp.; 130.
    c. Ideal Tape Co., Inc., an American Biltrite Company; 370 White PVC tape.
    d. Venture Tape; 1506 CW NS.

2. Width: 2 inches.
3. Thickness: 6 mils.
4. Adhesion: 64 ounces force/inch in width.
5. Elongation: 500 percent.
6. Tensile Strength: 18 lbf/inch in width.

2.11 SECUREMENTS

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

B. 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, fully annealed, 0.106-inch-diameter shank, length to suit depth of insulation indicated.
    c. Adhesive: Recommended by hanger manufacturer. Product with demonstrated capability to bond insulation hanger securely to substrates indicated without damaging insulation, hangers, and substrates.

2. 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, fully annealed, 0.106-inch-diameter shank, length to suit depth of insulation indicated.
    c. Adhesive-backed base with a peel-off protective cover.

3. Insulation-Retaining Washers: Self-locking washers formed from 0.016-inch- thick, galvanized-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.

C. Wire: 0.062-inch soft-annealed, stainless 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.

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. 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.

B. 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.

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

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

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

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

G. Keep insulation materials dry during application and finishing.

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

I. Install insulation with least number of joints practical.

J. Where vapor barrier is indicated (all cold work at a minimum, and it shall be continuous), seal joints, seams, and penetrations in insulation at hangers, supports, anchors, and other projections with vapor-barrier mastic.

1. Install insulation continuously through hangers and around anchor attachments.
2. For insulation application where vapor barriers are indicated, extend insulation on anchor legs from point of attachment to supported item to point of attachment to structure. Taper and seal ends at attachment to structure with vapor-barrier mastic.
3. Install insert materials and install insulation to tightly join the insert. Seal insulation to insulation inserts with adhesive or sealing compound recommended by insulation material manufacturer.
4. Cover inserts with jacket material matching adjacent pipe insulation. Install shields over jacket, arranged to protect jacket from tear or puncture by hanger, support, and shield.

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

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

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

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

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

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

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

1. Vibration-control devices.
2. Testing agency labels and stamps.
3. Nameplates and data plates.
4. Manholes.
5. Handholes.
6. Cleanouts.

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. For applications requiring indoor and outdoor insulation,

install insulation for outdoor applications tightly joined to indoor insulation ends. Seal joint with joint sealant.

3. Extend jacket of outdoor insulation outside roof flashing at least 2 inches below top of roof flashing.
4. Seal jacket to roof flashing with flashing sealant.

B. Insulation Installation at Underground Exterior Wall Penetrations: Terminate insulation flush with sleeve seal. Seal terminations with flashing sealant.

C. Insulation Installation at Aboveground Exterior Wall Penetrations: Install insulation continuously through wall penetrations.

1. Seal penetrations with flashing sealant.
2. For applications requiring only indoor insulation, terminate insulation inside wall surface and seal with joint sealant. For applications requiring indoor and outdoor insulation, install insulation for outdoor applications tightly joined to indoor insulation ends. Seal joint with joint sealant.
3. Extend jacket of outdoor insulation outside wall flashing and overlap wall flashing at least 2 inches.
4. Seal jacket to wall flashing with flashing sealant.

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

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

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."

G. 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 aluminum, at least 0.050 inch thick.
3. 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.

3.4 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 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.
9. 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.

3.5 FLEXIBLE ELASTOMERIC INSULATION INSTALLATION

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

B. Insulation Installation on Pipe Flanges:

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

C. Insulation Installation on Pipe Fittings and Elbows:

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

D. Insulation Installation on Valves and Pipe Specialties:

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

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

1. Apply adhesives according to manufacturer's recommended coverage rates per unit area.
2. Apply adhesive to entire circumference of ducts and to all surfaces of fittings and transitions.
3. Install either capacitor-discharge-weld pins and speed washers or cupped-head, capacitor-discharge-weld pins on sides and bottom of horizontal ducts and sides of vertical ducts as follows:

   a. On duct sides with dimensions 18 inches and smaller, place pins along longitudinal centerline of duct. Space 3 inches maximum from insulation end joints, and 16 inches o.c.

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

4. For ducts and plenums with surface temperatures below ambient, install a continuous unbroken vapor barrier. Create a facing lap for longitudinal seams and end joints with insulation by removing 2 inches from 1 edge and 1 end of insulation segment. Secure laps to adjacent insulation section. 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. For Blanket Insulation 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. For Board Insulation, 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.
8. 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.

3.7 FIELD-APPLIED JACKET INSTALLATION

A. Where FSK jackets are indicated, install as follows:

1. Draw jacket material smooth and tight.
2. Install lap or joint strips with same material as jacket.
3. Secure jacket to insulation with manufacturer's recommended adhesive.
4. Install jacket with 1-1/2-inch laps at longitudinal seams and 3-inch- wide joint strips at end joints.
5. Seal openings, punctures, and breaks in vapor-retarder jackets and exposed insulation with vapor-barrier mastic.

B. Where PVC jackets are indicated, install with 1-inch overlap at longitudinal seams and end joints; for horizontal applications, install with longitudinal seams along top and bottom of tanks and vessels. Seal with manufacturer's recommended adhesive.

1. Apply two continuous beads of adhesive to seams and joints, one bead under lap and the finish bead along seam and joint edge.

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

3.8 FINISHES

A. Duct, Equipment, and Pipe Insulation with ASJ or Other Paintable Jacket Material: Paint jacket with paint system identified below and as specified in Division 09 Painting Sections.

1. Flat Acrylic Finish: Two finish coats over a primer that is compatible with jacket material and finish coat paint. Add fungicidal agent to render fabric mildew proof.

a. Finish Coat Material: Interior, flat, latex-emulsion size.

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

C. Color: 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 or stainless-steel jackets.

3.9 FIELD QUALITY CONTROL

A. Perform tests and inspections.

B. Tests and Inspections:

1. Inspect ductwork, randomly selected by Architect, by removing field-applied jacket and insulation in layers in reverse order of their installation. Extent of inspection shall be limited to three location(s) for each duct system defined in the "Duct Insulation Schedule, General" Article.
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 three 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 locations of straight pipe, three locations of threaded fittings, three locations of welded fittings, two locations of threaded strainers, two locations of welded strainers, three locations of threaded valves, and three 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.

3.10 DUCT INSULATION SCHEDULE, GENERAL ***[EOR TO FINAL DETERMINE ALL]***

A. Plenums and Ducts Requiring Insulation: ***[EDIT TO MATCH 3.11 AND BEYOND FOR EACH JOB]***

1. Indoor, concealed and exposed supply and outdoor air.
2. Indoor, concealed and exposed return located in non-conditioned non-plenum space.
3. Indoor, exhaust between isolation damper and penetration of building exterior.
4. Outdoor, exposed supply and return.

B. Items Not Insulated:

1. Metal ducts with duct liner of sufficient thickness to comply with energy code and ASHRAE/IESNA 90.1.
2. Factory-insulated flexible ducts.
3. Factory-insulated plenums and casings.
4. Flexible connectors.
5. Vibration-control devices.
6. Factory-insulated access panels and doors.

3.11 INDOOR DUCT AND PLENUM INSULATION SCHEDULE ***[EOR TO FINAL DETERMINE ALL]***

A. Concealed, Supply-Air Duct and Plenum Insulation: Mineral-fiber blanket, 1-1/2 inches thick and 0.75-lb/cu. ft. nominal density.

B. Exposed (in finished spaces), Supply-Air Duct and Plenum Insulation: Mineral-fiber blanket, 1-1/2 inches thick and 0.75-lb/cu. ft. nominal density.

C. Concealed, Return-Air Duct and Plenum Insulation: ***XXXX***.

D. Concealed, Outdoor Air Duct and Plenum Insulation: Mineral-fiber blanket, 1-1/2 inches thick and 0.75-lb/cu. ft. nominal density.

E. Exposed in Unconditioned Spaces or Mechanical Rooms, Supply-Air, Return-Air, and Outdoor Air Duct and Plenum Insulation: Mineral-fiber board, 1 inches thick and 3-lb/cu. ft. nominal density.

F. Concealed or Exposed Exhaust and Relief Between Isolation Damper and Penetration of Building Exterior, and Within 20' of the Building Exterior: Mineral-fiber blanket, 2 inches thick and 0.75-lb/cu. ft. nominal density.

G. Kitchen Hood exhaust ducts shall be insulated with minimum 2-hour rated grease duct wrap.

3.12 ABOVEGROUND, OUTDOOR DUCT AND PLENUM INSULATION SCHEDULE ***[EOR TO FINAL DETERMINE ALL]***

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. Exposed, Supply-Air and Return-Air Duct and Plenum Insulation: Mineral-fiber board, 3 inches thick and 6-lb/cu. ft. nominal density.

3.13 EQUIPMENT INSULATION SCHEDULE ***[EOR TO FINAL DETERMINE ALL]***

A. Insulation materials and thicknesses are identified below. If more than one material is listed for a type of equipment, selection from materials listed is Contractor's option.

B. Insulate indoor and outdoor equipment in paragraphs below that is not factory insulated.

C. Circuit Setters: Insulate with pre-formed insulation sections specifically designed for the specific circuit setters, and adjacent piping insulation and jacketing shall butt to same, and be sealed.

D. Heat-Exchangers Insulation: Removable insulation covers.

E. Heating-Hot-Water Pump Insulation: Mineral-Fiber Board/Pipe and Tank: 2 inches thick and 3-lb/cu. ft. nominal density.

F. Chilled-water air-separator insulation shall be one of the following:

1. Flexible Elastomeric: 1 inch thick.
2. Mineral-Fiber Pipe and Tank: 1 inch thick.

G. Re-heat Coils: VAV and FPVAV reheat coil sections shall have field installed insulation, coving the exposed coil u-bends on both sides of the coil section, coil headers, and the entire reheat section.

H. See 3.19 through 3.22 below also.

3.14 PIPING INSULATION SCHEDULE, GENERAL ***[EOR TO FINAL DETERMINE ALL DEPENDING ON CAMPUS, ETC]***

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

B. Items Not Insulated: Unless otherwise indicated, do not install insulation on the following:

1. Drainage piping located in crawl spaces.
2. [Underground piping.]

3.15 INDOOR PIPING INSULATION SCHEDULE ***[EOR TO FINAL DETERMINE ALL DEPENDING ON CAMPUS, ETC]***

A. Chilled Water and Refrigerant Suction: Insulation shall be one of the following:

1. Flexible Elastomeric
2. Mineral-Fiber, Preformed Pipe, Type I
3. Insulation Density (if Mineral-Fiber): ***XXX***
4. Insulation Thickness

   a. XXX

B. Heating-Hot-Water Supply and Return: Insulation shall be:

1. Mineral-Fiber, Preformed Pipe, Type I
2. Insulation Density: ***XXX***
3. Insulation Thickness

   a. XXX

C. Exposed Hot-Gas Piping. Insulation shall be:

1. Mineral-Fiber, Preformed Pipe, Type I
2. Insulation Density: ***XXX***
3. Insulation Thickness

   a. XXX

D. Low Pressure Steam and Steam Condensate: Insulation shall be:

1. Mineral-Fiber, Preformed Pipe, Type I
2. Insulation Density: ***XXX***
3. Insulation Thickness

   a. XXX

E. HP Steam and Steam Condensate: Insulation shall be:

1. Mineral-Fiber, Preformed Pipe, Type I
2. Insulation Density: ***XXX***
3. Insulation Thickness

   a. XXX

F. Pipe insulation subject to maintenance personnel traffic or within 60" of the floor in mechanical type spaces shall be minimum 12 pcf density (with a maximum conductivity of 0.45 BTU - inch/(hr-sf-F) at 100°F) and is to be PVC (30 mil thick Series 300) or metal jacketed with waterproof seams and joints. Thicknesses to be as follows (thickness derived normally from ASHRAE 90.1-2007/required thickness): (1"/2").

G. Cooling Coil Condensate Piping: ***XXX***

H. Condenser Water Piping: No Insulation Required.

3.16 INDOOR, FIELD-APPLIED JACKET SCHEDULE ***[EOR TO FINAL DETERMINE ALL DEPENDING ON CAMPUS, IN-FORCE ASHRAE 90.1 VERSION, IN-FORCE IMCC VERSION, ETC]***

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

B. Piping, Exposed:

1. PVC: Minimum 20 mils thick.
2. Aluminum, Smooth or Corrugated or Stucco Embossed: Minimum 0.016 inch thick.

3.17 OUTDOOR, ABOVEGROUND PIPING INSULATION SCHEDULE ***[EOR TO FINAL DETERMINE ALL DEPENDING ON CAMPUS, ETC]***

A. Chilled Water and Refrigerant Suction: Insulation shall be one of the following:

1. Flexible Elastomeric
2. Mineral-Fiber, Preformed Pipe, Type I
3. Insulation Density (if Mineral-Fiber): ***XXX***
4. Insulation Thickness

a. Pipe Size 1" and less = ***X"***
b. Pipe Size 1 ½"and up = ***X"***

B. Heating-Hot-Water Supply and Return, 200 Deg F and below: Insulation shall be:

1. Mineral-Fiber, Preformed Pipe, Type I
2. Insulation Density: ***XXX***
3. Insulation Thickness

a. All Pipe Sizes = ***X"***

C. Low Pressure Steam and Steam Condensate: Insulation shall be:

1. Mineral-Fiber, Preformed Pipe, Type I
2. Insulation Density: ***XXX***
3. Insulation Thickness

a. ***XXX***

D. HP Steam and Steam Condensate: Insulation shall be:

1. Mineral-Fiber, Preformed Pipe, Type I
2. Insulation Density: ***XXX***
3. Insulation Thickness

a. ***XXX***

4. See additional requirements in 23 0700, 3.24.

E. ***Cooling Coil Condensate (if heat traced): XXX***

3.18 OUTDOOR, FIELD-APPLIED JACKET SCHEDULE ***[EOR TO FINAL DETERMINE BASED ON SERVICE, CAMPUS, ETC.]***

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

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

C. Ducts and Plenums, Exposed, up to 48 Inches in Diameter or with Flat Surfaces up to 72 Inches:

1. Aluminum, Smooth or Corrugated or Stucco Embossed: Minimum 0.016 inch thick.

D. Ducts and Plenums, Exposed, Larger Than 48 Inches in Diameter or with Flat Surfaces Larger Than 72 Inches:

1. Aluminum, Smooth or Corrugated or Stucco Embossed: Minimum 0.032 inch thick.

E. Piping, Exposed:

1. PVC: 30 mils thick.
2. Aluminum, Smooth or Corrugated or Stucco Embossed: Minimum 0.016 inch thick.

3.19 REMOVABLE INSULATION COVERS

A. Use to cover steam valves, chilled water valves, heating hot water valves, steam expansion joints, condensate pump package receivers, heat exchanger faces, flash tanks, hurling tanks and similar vessels, and awkward surfaces not covered by insulation.

3.20 COLD HYDRONIC PUMP INSULATION

A. Each pump to be covered by minimum of 1" thick AP Armaflex (or thicker to eliminate condensation) applied with a waterproof adhesive. Removable components shall use Velcro applied to both the pump body and the insulation with waterproof adhesive such that pieces can be removed for servicing and inspection and re-installed without damage.

3.21 HOT PUMP INSULATION

A. Each pump to be covered by minimum of 1" thick fiberglass pipe and tank insulation applied with a high temperature adhesive and finish jacketing and banding/wiring. Removable components shall use Velcro applied to both the pump body and the insulation with high temperature adhesive such that pieces can be removed for servicing and inspection and re-installed without damage.

3.22 CHILLER INSULATION

A. Each chiller to be covered by minimum of 1" thick AP Armaflex (or thicker to eliminate condensation) applied with a waterproof adhesive. Removable components shall use Velcro applied to both the pump body and the insulation with waterproof adhesive such that pieces can be removed for servicing and inspection and re-installed without damage.

3.23 CONVERTOR INSULATION

A. Each convertor to be covered by removable insulation covers such that pieces can be removed for servicing and inspection and re-installed without damage (for heat exchanger face only).

3.24 INSULATION FOR STEAM AND CONDENSATE PIPING

A. Provide piping and equipment insulation as manufactured by Owens-Corning, CertainTeed, Knauf, or John Manville or as indicated. Insulation shall be UL listed with flame spread / fuel contributed/ smoke developed rating of 25/50/50 in accordance with ASTM E84, NFPA 90A, NFPA 255 and UL 723.

B. Low pressure condensate return piping shall be insulated with Owens Corning SSL-II fiberglass pipe insulation with factory applied all service vapor barrier jacketing. Provide PVC pipe fittings filled tightly with fiberglass. Insulation K factor shall be minimum of 0.23 at 75°F per ASTM C335.

C. High pressure steam and condensate return piping within buildings shall be insulated with 1200°F rated mineral wool piping insulation ASTM-C547 with factory vapor barrier jacket.

D. Provide stainless steel jacketing over factory vapor barrier covering for all piping in the vaults for entire straight lengths and jacket over PVC elbow and valve covers. Refer to specification of stainless steel coverings below. Insulation K factor shall be minimum of 0.23 at 75°F per ASTM C335. Thickness shall be 1.5" for piping up to 4" and 2" thick for piping 5" and larger. Provide calcium silicate 120° segment at points of support (under insulation protection shield). Insulation protection shield shall be installed over stainless steel jacketing.

E. High pressure steam and condensate return piping within vaults shall be insulated using IIG (Industrial Insulation Group, LLC) thermo-12 gold pre- formed, 1200°F rated pipe and block insulation composed of hydrous calcium silicate which is inorganic, non-combustible, and meets ASTM C533 and ASTM C411, Type 1. Thermal conductivity shall be 0.45 btu*in/(hr*ft*°f)at 300°F. Cover all insulated piping and fittings withing vault with stainless steel jacketing (see below).

1. Insulation thicknesses shall be as follows:

Fluid design operating temperature range, f	Nominal pipe diameter (in.)				
	< 1”	1” to < 1½”	1½” to < 4”	4” to < 8”	8” & up
Above 350°	4.5	5.0	5.0	5.0	5.0
251°-350°	3.0	4.0	4.5	4.5	4.5
201°-250°	2.5	2.5	2.5	3.0	3.0
100°-200°	1.5	1.5	2.0	2.0	2.0
40°-60°	1.5	1.5	1.5	1.5	1.5
Up to 39°	1.5	1.5	2.0	2.0	2.0

The table is based on ASHRAE 90.1-2013 and IMCC-2012. Insulation for pipe service 40-60F and <40F exceeds the requirements of ASHRAE 90.1 and IECC for condensation purposes.

F. If physical constraints will not allow the above thicknesses to be installed, contractor shell provide an equivalent insulating value thickness of Pyrogel XTF. Cover insulation with minimum 2 coats of wettable fabric.

G. Insulation shall be applied using manufacturer approved material and methods. Adhesives shall be waterproof retardant type in compliance with ASTM E84, NFPA 255 and UL 723.

H. No insulation shall be applied until after the system has been properly tested in presence of owner's representative. Ductwork shall be sealed, tested and proved air tight prior to insulation application.

I. No piping shall be insulated until pressure testing has been completed and accepted by the owner.

J. Insulate all valves and pipe fittings except omit insulation on the following: unions, traps and strainer blow-off valves.

K. Pipe fittings shall be covered with same thickness of insulation as the pipe and wrapped with wettable cloth fabric and sealed with approved adhesive.

L. Equipment to be insulated shall include all equipment which is a part of the piping system. Such includes but is not limited to: flash tanks.

M. New and existing insulated piping within manholes shall be enclosed with 304 stainless steel jacket with prefabricated stainless steel fitting covers. Jacket shall be provided with stainless steel straps at 12" O.C. seams shall be arranged to shed water, shall overlap shall be caulked with weather resistant industrial quality clear sealant. Jacket thickness shall be 0.16" up to 6" O.D. (including insulation) and 0.20" thick for piping with O.D. greater than 6". Metal jacketing shall be by ITW (ITWINSINSULATIONS.COM) or equal. Cover all valves and fittings located outside with same insulation type and thickness as piping. Installed custom fabricated or pre-fabricated valve jacketing covering entire valve and leaving only operating handle. Seal water tight with mastiques and sealant such that no insulation can become wet. Aluminum jacketing and PVC covers within manholes are not acceptable. Use of PVC covers within manholes is prohibited.

N. PVC fitting covers (see below) shall be used in mechanical rooms.

O. PVC factory insulation fitting and straight pipe covers for pipe fittings and valves: proto "Losmoke" fabricated of ASTM 1784 polyvinyl chloride. 160°F rated with 25/50 fire/smoke rating per ASTM E-84, bright gloss white. Fitting covers shall be commercial grade thickness. "light gauge" commercial thickness covers are not acceptable. Install covers using manufacturer-furnished adhesive mastic and sealant. Contractor shall use cover manufacturer furnished fiberglass insulation inserts for each specific application with fiberglass having k=0.26 at 75°F per ASTM C177. All fitting covers shall be one-piece. Space between PVC covers and piping shall be filled tightly with insulation.

P. Cover thickness shall be as follows:

1. Circumference including overlap up to 9", cover thickness 0.020
2. Circumference including overlap up to 9.5" to 13", cover thickness 0.030.
3. Circumference including overlap up 14" and larger, cover thickness 0.040

Q. When connecting new piping to existing piping within manhole existing insulation covering entire straight run of pipe to which new piping connects shall be stripped of the existing insulation and new insulation and jacketing in accordance with the specification shall be provided to the entire straight piece of existing pipe to which new pipe connects.

R. Where anchor is installed in the existing piping in the existing manhole, the straight run of pipe to which anchor is installed shall be stripped of existing insulation and new insulation and jacketing in accordance with the specification shall be provided to straight pipe.

S. Valves shall be insulated entirely leaving only stem and handle. Valves shall be operable without disturbing insulation. Should the insulating contractor notice that the valves installed by mechanical contractor cannot be properly insulated due to lack of extended handle, insulating contractor shall not insulate such valves until proper size handle has been installed by mechanical contractor. Do not insulate pipe unions and steam traps. Provide neat 45 degree taper at each side of union or trap.

T. Insulation shall be sealed with manufacturer's approved sealant and shall have neat finished appearance. No exposed insulation shall be visible.

U. At wall penetrations by high pressure steam piping provide calcium silicate ASTM C533 rigid white insulation

END OF SECTION 23 0700

SECTION 23 0800 - COMMISSIONING OF HVAC SYSTEMS

PART 1 - GENERAL

1.1 SUMMARY

A. The purpose of this section is to specify the Division 23 responsibilities and participation in the Commissioning Process.

B. Work under this contract shall conform to requirements of Division 01, General Requirements, Conditions of the Contract, and Supplementary Conditions. This specification covers commissioning of mechanical systems which are part of this project.

C. Commissioning work shall be a team effort to ensure that all mechanical equipment and systems have been completely and properly installed, function together correctly to meet the design intent, and document system performance. Commissioning shall coordinate system documentation, equipment start-up, control system calibration, testing and balancing, and verification and performance testing.

D. The Commissioning Team shall be made up of representatives from the owner, Design Team, General Contractor (GC), manufacturers, and construction trades. The trades represented on the Commissioning Team shall include, but not be limited to: sheet metal, piping and fitting, controls, test and balance, and electrical. The lead person for each trade who will actually perform or supervise the work is to be designated as the representative to the Commissioning Team. Responsibility for various steps of the Commissioning Process shall be divided among the members of the Commissioning Team, as described in this section.

E. The Commissioning Authority (CxA) shall have responsibility for coordinating and directing each step of the Commissioning Process.

F. Mechanical system installation, start-up, testing, balancing, preparation of O&M manuals, and operator training are the responsibility of the Division 23 Contractors, with coordination, observation, verification and commissioning the responsibility of Division 01, Section 01 9113. The 01 9113 Commissioning Process does not relieve Division 23 from the obligations to complete all portions of work in a satisfactory and fully operational manner.

G. Refer to Division 01, Section 01 9113, for a full list of commissioning related definitions. A few critical definitions are included below:

1. *Commissioning*. A systematic process that provides documented confirmation that specific and interconnected fire and life safety systems function according to the intended design criteria set forth in the project documents and satisfy the owner's operational needs, including compliance requirements of any applicable laws, regulations, codes, and standards requiring fire and life safety systems.
2. *Commissioning Authority (CxA*). The qualified person, company, or agency that plans, coordinates, and oversees the entire Cx process.
3. *Commissioning Plan*. The document prepared for each project, which identifies the processes and procedures necessary for a successful Cx process.

4. *Commissioning Record*. The complete set of commissioning documentation for the project, which is turned over to the owner at the end of the construction phase.
5. *Functional Testing*. Tests performed to verify compliance with manufacturers' specifications, applicable codes and standards, and the project BOD and OPR.

1.2 RELATED SECTIONS

A. Division 01 Section 01 9113 - General Commissioning Requirements

B. Division 21 Section 21 0800 - Commissioning of Fire Suppression

C. Division 22 Section 22 0800 - Commissioning of Plumbing Systems

D. Division 23 Section 23 0995 - Commissioning of Integrated Automation

E. Division 26 Section 26 0800 - Commissioning of Electrical Systems

F. Individual Division 01, 21, 22, 23, 25, and 26 sections contain requirements related to the commissioning process.

1.3 ROLES AND RESPONSIBILITIES

A. Refer to Section 01 9113 for Commissioning Authority, Owner, Architect, and General Contractor roles and responsibilities.

B. Refer to Section 21 0800 for fire protection contractor roles and responsibilities.

C. Refer to Section 22 0800 for plumbing contractor roles and responsibilities.

D. Refer to Section 25 0800 for integrated automation contractor roles and responsibilities.

E. Refer to Section 26 0800 for electrical contractor roles and responsibilities.

F. Design Team

1. Provide documentation of initial design concepts and Design Intent based on Owner's program.
2. Provide mechanical system design parameters and obtain approval of Owner.
3. Prepare contract documents incorporating Commissioning Specification requirements and description of the electrical systems.
4. The Design Team shall specify and verify adequate maintenance accessibility for each piece of equipment in shop drawings and the actual installation.
5. Periodic inspections as part of the Design Team's contract with the Architect and/or Owner.
6. Review and approve submittals.
7. Participate in commissioning meetings.
8. Review Pre-functional Checklists and Functional Performance Test procedures submitted by the Commissioning Authority.
9. Prepare punch lists.
10. Review as-built records as required by contract documents. Issue a report noting deficiencies requiring correction to the Commissioning Authority.
11. Review and comment on final commissioning report.

G. Mechanical Contractor

1. Include cost to complete commissioning requirements for mechanical systems in the contract price.
2. Include requirements for submittal data, O&M data, and training in each purchase order or sub contract written.
3. Ensure cooperation and participation of all subcontractors.
4. Ensure participation of major equipment manufacturers in appropriate training and testing activities.
5. Attend Construction Phase coordination meeting scheduled by the Commissioning Authority.
6. Conduct mechanical system orientation and inspection when equipment is set.
7. Respond to (in writing) and address items documented in the Contractor Commissioning Issues Log.
8. Notify the GC a minimum of two weeks in advance of system start-up and testing, so CxA may be on site to witness.
9. Notify the GC a minimum of two weeks in advance, of the time for start of the TAB work. Attend the initial TAB meeting for review of the TAB procedures.
10. Submit copies of all test results to the CxA.
11. Complete Pre-Functional Checklists for all equipment.

    a. If no other system is agreed upon by Commissioning Team, Mechanical Contractor shall be responsible for completion of Pre-Functional Checklists for all equipment for which it issued a purchase order.
    b. Mechanical Contractor shall coordinate completion of Pre-Functional Checklists with all other contractors that have made connections to equipment for which it issued a purchase order.
    c. Remedy any deficiencies identified in Pre-Functional Checklists and notify CxA in writing that deficiencies have been addressed.

12. Assist the Commissioning Authority in all Pre-Functional Checklist verifications and Functional Performance Tests.
13. Prepare preliminary schedule for mechanical system orientation and inspections, O&M manual submission, training sessions, pipe and duct system testing, flushing and cleaning, equipment start up, TAB, and task completion for use by the GC and Commissioning Authority. Update schedule as appropriate throughout the construction period.
14. Conduct mechanical system orientation and inspection when equipment is set in place.
15. Keep drawings updated as changes in the field are made, and review with the GC and Commissioning Authority.
16. Gather O&M data on all equipment, and assemble in binders as required by the Commissioning Specification. Submit to GC for review prior to the completion of construction.
17. Participate in, and schedule vendors and Contractors to participate in the training sessions as set up by the GC.
18. Provide written notification to the General Contractor and Commissioning Authority that the following work has been completed in accordance with the contract documents, and that the equipment, systems, and sub-systems are functioning as required.

    a. HVAC equipment including all fans, air handling units, dehumidification units, ductwork, dampers, terminals, and all Division 23 equipment.
    b. Refrigeration equipment, pumping systems and heat rejection equipment.
    c. Fire stopping in the fire rated construction, including fire and smoke damper installation, caulking, gasketing and sealing of smoke barriers.
    d. Dedicated smoke control systems including stairway pressurization and atrium systems.
    e. Non-dedicated systems using the air handling units for smoke control.

f. Fire detection and smoke detection devices furnished under other divisions of this specification as they affect the operation of the smoke control systems.
g. That building control systems are functioning to control mechanical equipment and smoke control systems.

19. Submit training syllabus for approval to Commissioning Authority.
20. Participate in, and schedule vendors and Contractors to participate in the training sessions as set up by the GC. Provide site-specific training information on digital media/electronic format (flash drive, CD, DVD). If training is videotaped, provide on digital media/electronic format (flash drive, CD, DVD).
21. Provide a complete set of as-built records to the GC. Hard Copy and Electronic Format (Flash Drive, CD, DVD, etc….) are required.

H. Test, Adjust, and Balance Contractor

1. Include cost for commissioning requirements in the contract price.
2. Attend initial commissioning coordination meeting scheduled by the Commissioning Authority.
3. Submit the TAB procedures to the GC for review and acceptance.
4. Attend the TAB review meeting scheduled by the GC. Be prepared to discuss the procedures that shall be followed in testing, adjusting and balancing the HVAC system.
5. Participate in training sessions as scheduled by the GC.
6. At the completion of the TAB work, and submittal of final TAB report, notify the Mechanical Contractor.
7. Participate in verification of the TAB report, which will consist of repeating any selected measurement contained in the TAB report where required by the Commissioning Authority for verification or diagnostic purposes.

I. Integrated Automation Contractors

1. Include cost for commissioning requirements in the contract price, including assisting the Commissioning Authority with implementation of Functional Test Procedures and reviewing control system operation with the Commissioning Authority.
2. Review design for controllability with respect to selected manufacturer's equipment:

a. Verify proper hardware specification exists for functional performance required by specification and sequence of operation.
b. Verify proper safeties and interlocks are included in design.
c. Verify proper sizing of control valves and actuators based on design pressure drops. Verify control valve authority to control coil properly.
d. Verify proper sizing of control dampers. Verify damper authority to control air stream. Verify proper damper positioning for mixing to prevent stratification. Verify actuator vs. damper sections for smooth operation.
e. Verify proper selection of sensor ranges.
f. Clarify all questions of operation.

3. Attend initial commissioning coordination meeting scheduled by the Commissioning Authority.
4. Provide the following submittals to the GC:

a. Hardware and software submittals.
b. Control panel construction shop drawings.
c. Narrative description of each control sequence for each piece of equipment controlled.

d. Diagrams showing all control points, sensor locations, point names, actuators, controllers and, where necessary, points of access, superimposed on diagrams of the physical equipment.
e. Logic diagrams showing the logic flow of the system.
f. A list of all control points, including analog inputs, analog outputs, digital inputs, and digital outputs. Include the values of all parameters for each system point. Provide a separate list for each stand-alone control unit.
g. A complete control language program listing including all software routines employed in operating the control system. Also provide a program write-up, organized in the same manner as the control software. This narrative shall describe the logic flow of the software and the functions of each routine and sub-routine. It should also explain individual math or logic operations that are not clear from reading the software listing.
h. Hardware operation and maintenance manuals.
i. Application software and project applications code manuals.

5. Verify proper installation and performance of controls/BAS hardware and software provided by others.
6. Integrate installation and programming schedule with construction and commissioning schedules.
7. Provide thorough training to operating personnel on hardware operations and programming, and the application program for the system.
8. Demonstrate system performance to Commissioning Authority including all modes of system operation (e.g. normal, abnormal, and emergency).
9. Provide control system technician for use during Pre-Functional Checklists and Functional Performance Testing.
10. Provide system modifications as required.
11. Provide support and coordination with TAB contractor on all interfaces between their scopes of work. Provide all devices, such as portable operator terminals, for TAB use in completing TAB procedures.
12. Provide trend logs as required to facilitate the Commissioning Process.

J. Equipment Manufacturers and Miscellaneous Contractors

1. Include cost for commissioning requirements in the contract price.
2. Provide submittals, and appropriate O&M manual section(s).
3. Attend initial commissioning coordination meeting scheduled by the Commissioning Authority.
4. Participate in training sessions as scheduled by the GC.
5. Demonstrate performance of equipment as applicable.

1.4 SCOPE OF WORK

A. Commissioning work of Division 23 shall include, but not be limited to:

1. Testing and start-up of the equipment.
2. Logging in and checking the WCxS at least once a week for outstanding items.
3. Completion of Pre-Functional Checklists on the WCxS.
4. Testing, adjusting and balancing of hydronic and air systems.
5. Cooperation with the Commissioning Authority.
6. Providing qualified personnel for participation in commissioning tests, including seasonal testing required after the initial testing.
7. Providing equipment, materials, and labor as necessary to correct construction and/or equipment deficiencies found during the Commissioning Process.

8. Providing operation and maintenance manuals and as-built drawings to the Commissioning Authority for verification.
9. Providing training and demonstrations for the systems specified in this Division.

B. The work included in the Commissioning Process involves a complete and thorough evaluation of the operation and performance of all components, systems, and sub-systems. The following equipment and systems shall be evaluated:

1. Air Handling Units
2. Chiller
3. Cooling tower
4. Cooling system pumps
5. Heat exchangers and associated pumps
6. Steam PRV station
7. Space pressurization for critical rooms including operating rooms, interventional rooms and isolation rooms
8. Atrium smoke exhaust
9. Unit heaters (15 percent sampling)
10. Refrigerant purge exhaust
11. Variable air volume terminals (15 percent sampling up to 60 VAV boxes)
12. Temperature control systems
13. Vertical transportation
14. Pneumatic tube system
15. Refrigeration systems including clinical refrigerators and freezers.
16. Air distribution systems, including ductwork, fittings, insulation, fire dampers, diffusers, grilles, balancing dampers, sound attenuators, etc.
17. Hydronic distribution systems, including piping, valves, fittings, insulation, air separators, expansion tanks, etc.
18. Fire alarm and fire protection devices.
19. Fire alarm interface with HVAC, life safety and elevators.
20. Fire protection system for the South Addition Main Entrance Canopy.
21. Fire protection system for the CT and MRI rooms.

C. Timely and accurate documentation is essential for the Commissioning Process to be effective. Documentation required as part of the Commissioning Process shall include but not be limited to:

1. Commissioning Process Reports, which may include the following:

   a. Commissioning Field Reports
   b. Design Team Issues Log
   c. Contractor Commissioning Issues Log from the WCxS
   d. Meeting Minutes

2. Pre-start, and start-up procedures
3. Pre-Functional Checklists on the WCxS
4. Functional Performance Tests on the WCxS
5. Training agenda and materials
6. As-built records
7. Final commissioning report
8. Operation and maintenance (O&M) manuals

D. Detailed testing maybe performed on all installed equipment and systems to ensure that operation and performance conform to contract documents. All tests shall be witnessed by the Commissioning Authority. The following testing is required as part of the Commissioning process:

1. Pre-Functional Checklists (PFC) are comprised of a full range of checks and tests to determine that all components, equipment, systems, and interfaces between systems operate in accordance with contract documents. Verification is completed by the Division 22, 23 and 26 contractors and documented using Pre-Functional Checklists.
2. Functional Performance Tests (FPT) shall determine if the HVAC system is operating in accordance with the design intent. This includes all operating modes, interlocks, control responses, and specific responses to abnormal or emergency conditions.

E. Comprehensive training of O&M personnel shall be performed by the Mechanical Contractor, and where appropriate, by other sub-contractors, and vendors prior to turnover of building to the owner. The training shall include classroom instruction, along with hands-on instruction on the installed equipment and systems.

1.5 DOCUMENTATION

A. The Commissioning Authority shall oversee and maintain the development of the document process. The GC shall facilitate project documentation through the web-based commissioning software. The commissioning documentation shall include, but not be limited to, the following:

1. Commissioning Plan
2. Commissioning Schedule
3. Document Request Log
4. Commissioning RFIs
5. Commissioning Field Reports on the WCxS
6. Design Team Issues Log on the WCxS
7. Contractor Commissioning Issues Log on the WCxS
8. Pre-Functional Checklists on the WCxS
9. Functional Performance Tests on the WCxS
10. See 01 9113 for additional information on the commissioning documentation.

B. See 01 9113 for additional information on the commissioning documentation.

PART 2 - PRODUCTS

2.1 TEST EQUIPMENT

A. The appropriate Contractor(s) shall furnish all special tools and equipment required for testing during the commissioning process. A list of all tools and equipment to be used during commissioning shall be submitted to the Commissioning Authority for approval. The owner shall furnish necessary utilities for the Commissioning Process.

2.2 TEST EQUIPMENT – PROPRIETARY

A. Proprietary test equipment and software required by any equipment manufacturer for programming and/or start-up, whether specified or not, shall be provided by the manufacturer of the equipment. Manufacturer shall provide the test equipment, demonstrate its use, and assist in the Commissioning Process as needed. Proprietary test equipment (and software) shall become the property of the owner upon completion of the Commissioning Process.

PART 3 - EXECUTION

3.1 GENERAL

A. A pre-construction meeting of all Commissioning Team members shall be held at a time and place designated by the owner. The purpose shall be to familiarize all parties with the Commissioning Process, and to ensure that the responsibilities of each party are clearly understood.

B. The Contractor shall complete all phases of work so the systems can be started, tested, balanced, and commissioning procedures undertaken. This includes the complete installation of all equipment, materials, pipe, duct, wire, insulation, controls, etc., per the contract documents and related directives, clarifications, and change orders.

C. A Commissioning Plan shall be developed by the Commissioning Authority. The Contractor shall assist the Commissioning Authority in preparing the Commissioning Plan by providing all necessary information pertaining to the actual equipment and installation. If contractor-initiated system changes have been made that alter the Commissioning Process, the Commissioning Authority shall notify the Owner.

D. Acceptance procedures are normally intended to begin prior to completion of a system and/or sub-systems, and shall be coordinated with the Division 23 contractor. Start of acceptance procedures before system completion does not relieve the contractor from completing those systems as per the schedule.

3.2 PARTICIPATION IN COMMISSIONING

A. The Contractor shall provide skilled technicians to start-up and debug all systems within Division 15. These same technicians shall be made available to assist the Commissioning Authority in completing the commissioning program. Work schedules, time required for testing, etc., shall be requested by the Commissioning Authority and coordinated by the contractor. Contractor shall ensure that the qualified technician(s) are available and present during the agreed upon schedules and of sufficient duration to complete the necessary tests, adjustments, and/or problem resolutions.

B. System performance problems and discrepancies may require additional technician time, Commissioning Authority time, reconstruction of systems, and/or replacement of system components. The additional technician time shall be made available for subsequent commissioning periods until the required system performance is obtained.

C. The Commissioning Authority reserves the right to question the appropriateness and qualifications of the technicians relative to each item of equipment, system, and/or sub-system. Qualifications of technicians shall include expert knowledge relative to the specific equipment involved and a willingness to work with the Commissioning Authority. Contractor shall provide adequate documentation and tools to start up and test the equipment, system, and/or sub-system.

3.3 DEFICIENCY RESOLUTION

A. In some systems, maladjustments, misapplied equipment, and/or deficient performance under varying loads will result in additional work being required to commission the systems. This work shall be completed under the direction of the Owner, with input from the contractor, equipment manufacturer, and Commissioning Authority. Whereas all members shall have input and the opportunity to discuss, debate, and work out problems, the Owner shall make final determination over any additional required work to achieve performance.

B. Corrective work shall be completed in a timely fashion to permit the completion of the Commissioning Process. Experimentation to demonstrate system performance may be permitted. If the Commissioning Authority deems the experimentation work to be ineffective or untimely as it relates to the Commissioning Process, the Commissioning Authority shall notify the Owner, indicating the nature of the problem, expected steps to be taken, and suggested deadline(s) for completion of activities. If the deadline(s) pass without resolution of the problem, the Owner reserves the right to obtain supplementary services and/or equipment to resolve the problem. Costs incurred to solve the problems in an expeditious manner shall be the contractor's responsibility.

C. The Owner's contract with the Commissioning Authority includes up to two Functional Performance Tests of each piece of equipment or system included in the commissioning scope. Commissioning Authority time and expenses required for retests beyond two, if required, due to incomplete installation or otherwise, will be paid by the Owner and reimbursed by the contractor.

3.4 ADDITIONAL COMMISSIONING

A. Additional commissioning activities may be required after system adjustments, replacements, etc., are completed. The contractor(s), manufacturers, and Commissioning Authority shall include a reasonable reserve to complete this work as part of their contractual obligations.

3.5 SEASONAL COMMISSIONING

A. Seasonal commissioning pertains to testing under full load conditions during peak heating and peak cooling seasons, as well as part load conditions during off-peak periods. Initial commissioning shall be done as soon as contract work is completed, regardless of season. Subsequent commissioning may be undertaken at any time thereafter to ascertain adequate performance during the different peak and off-peak conditions. Each contractor and manufacturer shall be responsible to participate in the initial and the alternate peak and off-peak tests of the systems as required to demonstrate performance.

3.6 CONSTRUCTION PHASE OBSERVATION

A. Scope of Construction Phase Observation

1. The Commissioning Authority will conduct periodic observations during the Construction Phase to monitor progress and compliance with the design intent and contract documents. It is the responsibility of the contractor to address the issues noted on the Issues Log and notify Commissioning Authority of completion.
2. Commissioning Authority observations will coincide with Design Team observations and are not intended to take the place of this work.

B. Documentation and Reporting

1. Issues identified by the Commissioning Authority during Construction Phase will be documented on the WCxS and distributed to Commissioning Team members.
2. Progress during the Construction Phase will also be documented by the Commissioning Authority using Commissioning Process Reports.

3.7 ACCEPTANCE PROCEDURES

A. Pre-Functional Checklists

1. Pre-Functional Checklist Scope

a. Tests and verifications included in the Pre-Functional Checklists shall determine if all components, equipment, systems, and interfaces between systems are installed and are ready to operate in accordance with contract documents.

2. Pre-Functional Checklist Roles and Responsibilities

a. The Commissioning Authority shall be responsible for creating the Checklists, which will be completed by the installing contractors and then verified (via spot checking and Functional Performance Testing). Participating contractors, manufacturers, etc. shall include all costs to do the work involved in these tests in their proposals. The following is a list of tasks and supporting information that shall be required:
b. The Mechanical Contractor shall provide the services of a technician(s) who is (are) familiar with the construction and operation of the applicable system. Provide access to the contract plans, shop drawings, and equipment cut sheets of all installed equipment.
c. The controls contractor shall provide the services of a controls engineer who is familiar with the details of the project. Provide details of the control system, schematics, and a narrative description of control sequences of operation.
d. The electrical contractor shall provide a foreman electrician familiar with the electrical interlocks, interfaces with emergency power supply, and interfaces with alarm and life-safety systems. Provide access to the contract plans, and all as-built schematics of sub-systems, interfaces, and interlocks.

3. Documentation and Reporting Requirements

a. Pre-Functional Checklists shall be provided for each component, piece of equipment, system, and sub-system, including all interfaces, interlocks, etc. Each item to be tested shall have a different entry line with space provided for comments. The checklists will include spaces for each party to sign off on.
b. Completed checklists shall be submitted to the Commissioning Authority for acceptance and inclusion in the commissioning report.

4. Acceptance of Pre-Functional Checklists

a. The Commissioning Authority will select, at random, 10 percent of the checklists for verification.
b. If 10 percent or more of the checklists are found to be inaccurate for each system or equipment type, all of the checklists for that system or equipment type will be rejected. Complete, accurate checklists will need to be resubmitted.

B. Test, Adjust, and Balance Verification

1. The Commissioning Authority shall select, at random, 10 percent of the report data for verification.
2. The TAB contractor shall be given sufficient advance notice of the date of field verification. However, they shall not be informed in advance of the data points to be verified.
3. Failure of an item is defined as:

a. For all readings other than sound, a deviation of more than 10 percent.
b. For sound pressure readings, a deviation of 3 decibels. (Note: variations in background noise must be considered).

4. A failure of more than 10 percent of the selected items shall result in the rejection of the final TAB report.

C. Functional Performance Testing

1. Scope of Functional Performance Testing

a. Functional Performance Tests shall determine if equipment, system, and/or sub-system is operating in accordance with the final design intent. This includes all operating modes, interlocks, control responses, and specific responses to abnormal or emergency conditions. The following is a list of test examples:

1) Determine capability of chilled water system to deliver chilled water at the design supply temperature, and required rate of flow.
2) Determine capacity of electric heating system to deliver heating at the design temperature.
3) Determine the ability of the HVAC unit to deliver the cooling and/or heating services to the distribution system, at the design supply air temperature, required static pressure, and proper outside air ventilation rate.

2. Functional Performance Test Report

a. Detailed procedures for each series of tests will be developed by the Commissioning Authority for review and acceptance by the GC and Owner. The procedures shall include samples of the data sheets that will be part of the reports.
b. The Funtional Performance Test Report will be integrated as part of the WCxS.

3. Participants in Functional Performance Tests

a. Participants in the Functional Performance Tests shall be the same as those listed in the Pre-Functional Checklists.

4. Functional Performance Test Procedures

a. The Commissioning Authority shall supervise and direct all Functional Performance Tests.

1) Set the system equipment (i.e. chiller, boiler, pumps, fans, etc.) into the operating mode to be tested (i.e. normal shut-down, normal auto position, normal manual position, unoccupied cycle, emergency power, and alarm conditions).
2) The Commissioning Authority shall inspect and verify the position of each device and interlock identified in the test procedure. Each item shall be signed off as acceptable (yes) or failed (no).
3) This test shall be repeated for each operating cycle that applies to the mechanical system being tested.
4) Operating checks shall include all safety cutouts, alarms, and interlocks with smoke control and life safety systems during all modes of operation of the mechanical system.

5) If during a test an operating deficiency is observed, appropriate comments will be added to the Test Procedure form and the Issues Log.

6) Confirmation of the TAB results shall be verified utilizing the Building Automation System. This shall include, but not be limited to, the following:

a) Verify supply and return flow rates for VAV and constant volume systems in all modes of operation of the HVAC system.
b) Verify operation of the terminal units in both heating and cooling cycles.
c) Verify minimum outdoor air intake in all modes of operation and at minimum and maximum total airflow rates.
d) Verify building pressurization.
e) Verify total exhaust airflow, and total outdoor air intake.

7) Verification of the proper responses of BAS system controllers and sensors shall be as follows:

a) For each controller or sensor, record the indicated BAS system reading, and the test instrument reading.
b) If the initial test indicates that the test reading is outside of the control range of the installed device, the calibration of the installed device shall be checked and adjusted as required. The deficient device shall be re-tested and the results recorded on the Functional Performance Test form on the WCxS.

b. If deficiencies are identified during Functional Performance Testing, the General Contractor will be notified, and action taken to remedy the deficiency. The final Functional Test Procedure forms will be reviewed by the Commissioning Authority to determine if testing is complete and the system is functioning in accordance with the contract documents.

5. Documentation and Reporting Requirements

a. All measured data, data sheets, and a comprehensive summary, describing the operation of the HVAC system at the time of testing shall be submitted to the Commissioning Authority.
b. A preliminary Functional Performance Test report shall be prepared by the Commissioning Authority and submitted to the Design Team for review. Any identified deficiencies need to be evaluated by the Design Team and General Contractor to determine if they are part of the contractor’s or sub-contractor’s contractual obligations. Construction deficiencies shall be corrected by the responsible contractor(s), and the specific Functional Performance Test repeated.
c. If it is determined that the HVAC system is constructed in accordance with the contract documents, and the performance deficiencies are not part of the contract documents, the Owner must decide whether any required modifications needed to bring the performance of the HVAC system up to the finalized design intent shall be implemented, or if the test shall be accepted as submitted. If corrective work is performed, the owner shall determine if a portion or all required Functional Performance Tests should be repeated, and a revised report submitted.

3.8 SYSTEMS MANUAL:

A. The Systems Manual shall be submitted in paper AND/OR electronic format and shall contain the following major sections:

1. System Descriptions:

   a. Each major system shall be described, typewritten, in general terms, including major components, interconnections, theory of operation, theory of controls, unusual features and major safety precautions. This information should correlate with information provided in the manufacturers' instructions book. This section shall include, but not be limited to, the following data:

      1) Detailed description of each system and each of its components showing piping, valves, controls, and other components, with diagrams and illustrations where applicable.
      2) Wiring and control diagrams with data to explain detailed operation and control of each component.
      3) Control sequences describing start-up, all modes of operation, and shut down.
      4) Corrected shop drawings.
      5) Approved product data including all performance curves and rating data.
      6) Copies of approved certifications and laboratory or factory test reports (where applicable).
      7) Copies of warranties.

   b. System diagrams, described in the following section, shall be incorporated in the appropriate systems descriptions. These should be reduced in size or folded to usefully fit into the manual.

2. Operating Instructions:

   a. Condensed, typewritten, suitable for posting, instructions shall be provided for each major piece of equipment. Where more than one (1) common unit is installed, one instruction is adequate. The instructions shall provide procedures for:

      1) Starting up the equipment/system
      2) Shutting down the equipment/system
      3) Operating the equipment in emergency or unusual conditions
      4) Safety precautions
      5) Trouble shooting suggestions
      6) Other pertinent data applicable to the operation of particular systems or equipment

   b. The instructions shall be suitable for posting adjacent to the equipment concerned.
   c. The contractor shall provide instructions for (at minimum):

      1) Air Handling Units
      2) Chillers
      3) HVAC pumps
      4) Boilers
      5) Heating hot water pumps
      6) Make-up air units
      7) Café Exhaust
      8) Classroom and lab exhaust (representative sampling)
      9) Variable air volume terminals (25 percent sampling, with 100 percent of critical space VAVs)
      10) Temperature control systems
      11) Air and hydronic test and balance

12) Air distribution systems, including ductwork, fittings, insulation, fire dampers, diffusers, grilles, balancing dampers, sound attenuators, etc.
13) Hydronic distribution systems, including piping, valves, fittings, insulation, air separators, expansion tanks, etc.
14) Domestic hot water heaters

3. Ongoing and Preventive Maintenance:

a. Condensed, typewritten procedures for recommended ongoing and preventive maintenance actions shall be provided for each category of equipment/system listed above. This information shall include, but not be limited to the following:

1) Maintenance and overhaul instructions.
2) Lubricating schedule including type, grade, temperature, and frequency range.
3) Parts list, including source of supply and recommended spare parts.
4) Name, address, and 24 hour telephone number of each subcontractor who installed equipment and systems, and local representative for each type of system.
5) Other pertinent data applicable to the maintenance of particular systems or equipment.

b. These recommended preventive maintenance actions shall be categorized by the following recommended frequencies:

1) Weekly
2) Monthly
3) Quarterly
4) Semi Annual
5) Annual
6) Other

B. Posted Operating Instructions and Diagrams:

1. Operating Instructions:

a. Copies of operating instructions provided in the Systems Manual shall be posted in the near vicinity of each piece of applicable equipment. The instructions shall be mounted neatly in frames under Plexiglas, where they can be easily read by operating personnel. Instructions mounted outdoors shall be suitably protected from weather.

2. Posted Systems Diagrams:

a. Simplified one (1) line diagrams of the systems listed shall be developed using AutoCAD and posted neatly under Plexiglas in the main or most appropriate equipment room for easy reference by operating and maintenance personnel. These drawings shall be done in a professional manner which is acceptable to the Owner. The diagrams shall show each component including all valves installed in the system, with name and identifying number. If space does not permit valve numbers on the diagrams, valve charts shall be provided. Explanatory notes, where needed, shall be provided.

1) HVAC controls diagrams

2) Hydronic distribution systems
3) Air handling/ventilation systems
4) Domestic water systems
5) Other systems as applicable

b. These diagrams shall be suitable for reduction in size and use in the Systems Manual system descriptions previously covered.

3.9 SYSTEMS TRAINING:

A. The Mechanical Contractor, and appropriate sub-contractors, shall provide comprehensive systems instruction on building systems prior to delivery. The instruction shall include classroom instruction delivered by competent instructors based upon the contents of the Systems Manual. Emphasis shall be placed upon overall systems diagrams and descriptions, and how system components interact. The classroom instruction shall also include detailed equipment instruction by qualified manufacturer's representatives for which operating instructions are provided. The manufacturer's representative training shall emphasize operating instructions and preventive maintenance as described in the Systems Manual. At a minimum, the training sessions shall cover the following items:

1. Types of installed systems
2. Theory of operation

   a. Design intent
   b. Occupied vs. unoccupied or partial occupancy
   c. Seasonal modes of operation
   d. Emergency conditions and procedures
   e. Comfort conditions
   f. Indoor air quality
   g. Energy efficiency
   h. Other issues important to facility operation

3. System operations
4. Use of control system

   a. Sequence of operation
   b. Problem indicators
   c. Diagnostics
   d. Corrective actions

5. Service, maintenance, diagnostics and repair
6. Use of reports and logs
7. Troubleshooting, investigation of malfunctions, and determining reasons for the problem

B. Each classroom training period shall be followed by an inspection, explanation, and demonstration of the system by the instructors. The applicable equipment shall be demonstrated including system startup and shutdown, with the exception of sprinkler systems.

C. The contractor shall be responsible for organizing, arranging, and delivering this instruction in an efficient and effective manner on a schedule agreeable to the Owner.

D. The contractor shall provide, at or before substantial completion, a proposed agenda and schedule of the above training for approval by the Commissioning Authority and the Owner.

END OF SECTION 23 0800

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 certain specialties for the following:

1. Chilled water piping in CUP.
2. Underground chilled water piping.
3. Chilled water piping in tunnels.
4. Chilled water piping above the floor in buildings where used.
5. Pressurized waste water piping.
6. Unions and flanges.
7. Dielectric fittings.
8. Butterfly valves.
9. Ball valves.
10. Drain and vent valves.
11. Swing check valves.
12. Pressure equalizing valves.
13. Heating hot water piping.
14. Condenser water piping.
15. Make-up water piping.
16. Condensate drain piping.
17. Blowdown drain piping.
18. Air-vent piping.
19. Safety vent piping.
20. Tracer wire.
21. [***From pages 2 and 3 of NU Tech Standards Section 23 2113, Item 3 Pipe support guides, Item 4 Expansion loops, moment guided, ells and tees, Item 5 Anchors, Item 6 End seals and gland seals, and Item 7 Field joints. AE MUST DETERMINE HOW THESE REQUIREMENTS FIT IN AND FOR WHICH SYSTEMS ON EACH PROJECT AND ADD TO THIS SPECIFICATION AS REQUIRED.]***

B. Related Section:

1. Section 23 0529 "Mechanical Supporting Devices."
2. Section 23 0550 "Vibration Isolation."
3. Section 23 0553 "Mechanical Systems Identification."
4. Section 23 0594 'Testing, Adjusting, and Balancing (TAB)."
5. Section 23 0700 "Mechanical System Insulation."
6. Section 23 2116 "Hydronic Piping Specialties."
7. Section 23 2123 "Pumps."
8. Section 23 8216 "Coils."

1.2 PERFORMANCE REQUIREMENTS

A. Hydronic piping components and installation shall be capable of withstanding the following minimum working pressure and temperature:

1. Hot-Water Heating Piping: 100 psig at 200 deg F.
2. Makeup-Water Piping: 80 psig at 150 deg F.
3. Condensate Drain Piping: 150 deg F.
4. Blowdown Drain Piping: Equal to pressure of the piping system to which it is attached.
5. Chilled water piping in CUP: 120 psig at 50 deg. F.
6. Chilled water piping in tunnel: 120 psig at 50 deg. F.
7. Chilled water piping above the floor in buildings where used: 120 psig at 50 deg. F.
8. Underground chilled water piping: 300 psig minimum working pressure.
9. Condenser water piping: 120 psig at 50 deg. F.
10. Air-Vent Piping: Equal to pressure of the piping system to which it is attached.

1.3 SUBMITTALS

A. Product Data: For each type of the following:

1. Pipe and pipe fittings.
2. Unions and flanges.
3. Dielectric fittings.
4. Valves: And include flow and pressure drop curves based on manufacturer's testing for calibrated-orifice balancing valves and automatic flow-control valves.
5. Grooved joint couplings and fittings specifically identified with the applicable style or series number

B. ***[LEED Submittal:***

1. Product Data for Credit EQ 4.1: For solvent cements and adhesive primers, including printed statement of VOC content.]

C. Shop Drawings: Detail the piping layout, fabrication of pipe anchors, hangers, supports for multiple pipes, alignment guides, expansion joints and loops, and attachments of the same to the building structure. Detail location of anchors, alignment guides, and expansion joints and loops.

D. Field quality-control test reports.

E. Operation and maintenance data.

F. Northwestern University Maintenance Requirement Forms, see Division 01.

1.4 QUALITY ASSURANCE

A. ASME Compliance: Comply with ASME B31.9, "Building Services Piping," for materials, products, and installation.

B. To assure uniformity and compatibility of piping components in grooved end piping systems, all grooved products utilized shall be supplied by the same manufacturer. Grooving tools shall be supplied by the same manufacturer as the grooved components.

C. Piping materials shall bear label, stamp, or other markings of specified testing agency, and shall conform to ASTM standards.

D. Comply with FM Global requirements for pressure vessels and piping and for pressure relief devices.

1.5 SPECIAL WARRANTIES

A. Five (5) years, see Division 01.

PART 2 - PRODUCTS

2.1 CHILLED WATER IN CENTRAL UTILITY PLANT (CUP)

A. 2½ inches and Smaller:

1. Pipe: ASTM A106, Grade B, extra strong, carbon steel.
2. Fittings: ASME A105, Grade II/ASME B16.11, 3000 lb., forged steel, socket weld.
3. Unions: Forged steel, 3000 lb., socket weld. Refer to Unions and Flanges in this Section

B. 3 inches through 24 inches:

1. Pipe: ASTM A53, Grade B, Type E or S, standard weight, carbon steel.
2. Fittings: ASTM A234 Grade WPB/ASME B16.9, standard weight, seamless, carbon steel weld.
3. Flanges: Class 150. Refer to Unions and Flanges in this Section.

C. 30 inches through 42 inches:

1. Pipe: API-5L, Grade B, Type DSAW, 0.375” wall thickness, carbon steel.
2. Fittings: ASTM A234, Grade WPB/ASME B16.9, 0.375” wall thickness, seamless, carbon steel weld.
3. Flanges: Class 150. Refer to Unions and Flanges in this Section.

2.2 CHILLED WATER (UNDERGROUND)

A. Piping and Fittings 6 inches through 36 inches:

1. Same as existing or as run by the site utility contractor, refer to their drawings and specs.

2.3 TRACER WIRE

A. Non-electrical pipe installed below grade shall have 19 AWG Trace-Safe water blocking tracing wire with Copperhead Snakepit access boxes, or approved equal. Tracer wire to be accessible at each end in manholes.

2.4 COPPER TUBE AND FITTINGS

A. Drawn-Temper Copper Tubing: ASTM B 88, Type L.

B. Annealed-Temper Copper Tubing: ASTM B 88, Type K.

C. DWV Copper Tubing: ASTM B 306, Type DWV.

D. Wrought-Copper Fittings: ASME B16.22.

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

a. Anvil International, Inc.
b. Grinnell
c. Victaulic Company of America.

E. Grooved-End Copper Fittings: ASTM B 75, copper tube or ASTM B 584, bronze casting.

F. Grooved-End-Tube Couplings: Rigid pattern, unless otherwise indicated; gasketed fitting. Ductile-iron housing with keys matching pipe and fitting grooves, EPDM gasket rated for minimum 230 deg F for use with housing, and steel bolts and nuts.

G. Wrought-Copper Unions: ASME B16.22.

2.5 STEEL PIPE AND FITTINGS

A. Steel Pipe: ASTM A 53/A 53M, black steel with plain ends; type, grade, and wall thickness or schedule as indicated in Part 3 "Piping Applications" Article.

B. Cast-Iron Threaded Fittings: ASME B16.4; Classes 125 and 250 as indicated in Part 3 "Piping Applications" Article.

C. Malleable-Iron Threaded Fittings: ASME B16.3, Classes 150 and 300 as indicated in Part 3 "Piping Applications" Article.

D. Malleable-Iron Unions: ASME B16.39; Classes 150, 250, and 300 as indicated in Part 3 "Piping Applications" Article.

E. Cast-Iron Pipe Flanges and Flanged Fittings: ASME B16.1, Classes 25, 125, and 250; raised ground face, and bolt holes spot faced.

F. Wrought Cast- and Forged-Steel Flanges and Flanged Fittings: ASME B16.5, including bolts, nuts, and gaskets of the following material group, end connections, and facings:

1. Material Group: 1.1.
2. End Connections: Butt welding.
3. Facings: Raised face.

G. Steel Pipe Nipples: ASTM A 733, made of same materials and wall thicknesses as pipe in which they are installed.

2.6 PRESSURIZED WASTE WATER

A. Pressurized Waste Water:

1. Type K copper water tube, (drawn) temper, ASTM B88; with copper drainage fittings (DWV), ANSI B16.23; wrought copper drainage fittings (DWV), ANSI B16.29; lead free (<.2%) solder ASTM B32; flux, ASTM B813.

2.7 JOINING MATERIALS

A. Pipe-Flange Gasket Materials: Suitable for chemical and thermal conditions of piping system contents.

1. ASME B16.21, nonmetallic, flat, asbestos free, 1/8-inch maximum thickness unless thickness or specific material is indicated.

a. Full-Face Type: For flat-face, Class 125, cast-iron and cast-bronze flanges.
b. Narrow-Face Type: For raised-face, Class 250, cast-iron and steel flanges.

B. Flange Bolts and Nuts: ASME B18.2.1, carbon steel, unless otherwise indicated.

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

D. 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.

E. Gasket Material: Thickness, material, and type suitable for fluid to be handled and working temperatures and pressures.

2.8 UNIONS AND FLANGES

A. Unions:

1. 2½ inches and Smaller:

a. Forged steel, ASTM A105 Grade 2, ASME B16.11, socket weld, 3000 lb. WOG with steel to steel seats.

B. Flanges:

1. 3 inches and Larger:

a. ASTM A105, ANSI B16.5, hot forged steel flanges, welding neck pattern. Slip-on pattern flanges are not allowed. Bore dimension of welding neck flange shall match inside diameter of connected pipe. Use raised face flanges for mating with other raised face flanges with self-centering flat ring gaskets. Use flat face flanges for mating with other flat face flanges with full face gaskets.

2. Flange pressure class indicated in respective piping service is minimum required. Mating flange pressure class shall match pressure class of device connected to such as valves and piping specialties. Flanged connection will on be permitted at specialty connections such as at a vessel or specialty valve.

C. Flange Gaskets:

1. Gasket material to be asbestos free and suitable for pressure temperatures and fluid of piping system. Non-metallic gaskets shall be in accordance with ANSI/ASME B16.21 and ASTM F104.
2. Gaskets shall be equal to Flexitallic Style CG, graphite filler, 304 SS winding, carbon steel centering ring, 0.175” thickness.

D. Bolting:

1. For all connections to valves, use bolts studs.
2. Bolts, bolt studs, nuts and washers used on piping systems in Central Utility Plant (CUP), tunnel and manholes shall have zinc plated finish.
3. Threads shall be in accordance with ANSI/ASME B1.1, Class 2A tolerance for external threads and Class 2B tolerance for internal threads. Threads shall be coarse-thread series except that alloy steel bolting 1 1/8” and larger in diameter shall be 8 pitch thread series.
4. Threaded rods are not allowed as fastening elements on steam systems.
5. For Class 150 and Class 300 flanges at 400°F or lower temperature, use carbon steel bolts or stud bolts conforming to ASTM A307, Grade B with nuts conforming to ASTM A307.
6. For Class 300 flanges at 500°F or lower temperature, use alloy steel bolts or stud bolts conforming to ASTM A193, Grade B7 or B16, with nuts conforming ASTM A194, Grade 2H.

2.9 VALVES- GENERAL

A. General: Install valves as shown on plans, details, and according to the valve manufacturer’s installation recommendations.

B. Provide chain operators for manually operated valves 4” and larger, located more than 8’-0” above normal working surface.

C. ***Refer to Division 23 Section "General-Duty Valves for HVAC Piping" for additional requirements for valves and, from that section, refer to this section!***

2.10 BUTTERFLY VALVES FOR LINES IN CHILLED WATER TUNNELS

A. Valves to conform to latest revision of AWWA C-504. Valves to be tight closing, rubber seated. Valves to be zero-leakage at 200 psig, and shall be suitable for throttling service and operation after long periods of inactivity. Valves shall be rated for 250-psi non-shock working pressure minimum.

B. Cast iron body ASTM A-126B, Class B, restrained flanged (ANSI B16.1) ends. Valves shall be furnished complete with joint accessories (bolts, nuts, and gaskets). Flanging shall be lugged type permitting removal of downstream piping while using valve for system shutoff.

C. Resilient seat shall be Ethylene Propylene Diene Monomer (M-class) rubber (EPDM). EPDM seats shall be peroxide cured.

D. Valves 20" and smaller shall have the seat bonded directly to the body. Valve 24" and larger shall have seats that are mechanically retained in the valve body. Either seat shall be capable of mechanical adjustment in the field and field replacement.

E. Valve discs shall be constructed of cast iron ASTM A-126, Class B or ductile iron ASTM A-536. Disc shall have stainless steel seating edge to mate with valve seat.

F. Valve shaft to be 18-8, Type 304 stainless steel with "V" / "cup" PTF style self-adjusting packing.

G. Valve assembly shall be furnished with a non-adjustable factory set thrust bearing designed to center the valve disc at all times.

H. Shaft bearings shall be contained in the integral hubs of the valve body and shall be self-lubricated sleeve type and shall be sealed in place with "V" / "cup" PTF style self-adjusting packing.

I. Prior to shipment, valves to be hydrostatically and leak tested at the factory in accordance with AWWA C-504. Factory hydrostatic test shall be performed at 200 psig for all valves.

1. NU and Architect / Engineer shall have option to be present to witness factory testing for the first valves that are 20" and smaller and the first valves that are 24" and larger. Valve manufacturer shall be responsible for providing transportation and accommodations for two (2) NU representatives and one (1) representative of the Architect / Engineer.

J. Provide worm gear operators. Provide rotary hand wheels with adjustable position stop and position indicators. Size hand wheel operators with no higher than 40 lb rim pull at full valve pressure rating.

2.11 BUTTERFLY VALVES FOR UNDERGROUND CHILLED WATER LINES

A. Valves to conform to latest revision of AWWA C-504. Valves to be tight closing, rubber seated. Valves to be zero-leakage at 200 psig, and shall be suitable for throttling service and operation after long periods of inactivity. Valves shall be rated for 250-psi non-shock working pressure minimum. Valves to be designed for direct buried application.

B. Cast iron body ASTM A-126B, Class B, restrained mechanical joint (AWWA C-151/ANSI 21.11) or flanged (ANSI B16.1) ends. Valves shall be furnished complete with joint accessories (bolts, nuts, gaskets and glands).

C. Resilient seat shall be Ethylene Propylene Diene Monomer (M-class) rubber (EPDM). EPDM seats shall be peroxide cured.

D. Valves 20" and smaller shall have the seat bonded directly to the body. Valves 24" and larger shall have seats that are mechanically retained in the valve body. Either seat shall be capable of mechanical adjustment in the field and field replacement.

E. Valve discs shall be constructed of ASTM A-126 cast iron, Class B or ductile iron ASTM A-536. Disc shall have stainless steel seating edge to mate with valve seat.

F. Valve shaft to be 18-8, Type 304 stainless steel with "V" / "cup" PTF style self-adjusting packing.

G. Valve assembly shall be furnished with a non-adjustable factory set thrust bearing designed to center the valve disc at all times.

H. Shaft bearings shall be contained in the integral hubs of the valve body and shall be self-lubricated sleeve type and shall be sealed in place with "V" / "cup" PTF style self-adjusting packing.

I. Prior to shipment, valves to be hydrostatically and leak tested at the factory in accordance with AWWA C-504. Factory hydrostatic test shall be performed at 200 psig for all valves.

1. NU and Architect / Engineer shall have option to be present to witness factory testing for the first valves that are 20" and smaller and the first valves that are 24" and larger. Valve manufacturer shall be responsible for providing transportation and accommodations for two (2) NU representatives and one (1) representative of the Architect / Engineer.

J. Valves to be complete with grease packed buried service gear operator, shaft extensions with centering disk located on shaft, to within one foot of finished grade and soil pipe.

K. Refer to drawings for length of shaft extensions and soil pipes.

L. Valves shall be Pratt Groundhog or approved equal.

2.12 BALL VALVES IN TUNNELS

A. 2" and Smaller: bronze body, threaded, stainless steel ball and stem, full port, teflon seat rings, blowout-proof stem, three piece construction, 600 psi WOG, 150 psi SWP.

2.13 DRAIN AND VENT VALVES IN TUNNELS

A. Ball valves as specified above with hose thread adapter and cap. Provide 2” minimum drain valves provided with short threaded nipple and cap. All vent valves shall be minimum ¾” in size.

2.14 DIELECTRIC FITTINGS

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

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

C. Dielectric Nipples: With like material unions, for 250-psig minimum working pressure at 180 deg F.

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

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

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

PART 3 - EXECUTION

3.1 PIPING APPLICATIONS

A. For chilled water piping in CUP, underground chilled water piping, chilled water piping in tunnels, and pressurized waste water piping, install per normal University standards and procedures.

B. Hot-water heating and chilled water piping, aboveground, NPS 4 and smaller, shall be Type L, drawn-temper copper tubing, wrought-copper fittings, with soldered joints 2" and smaller, and brazed joints larger than 2".

C. Hot-water heating and chilled water piping, aboveground, larger than NPS 4, shall be any of the following:

1. Schedule 40 Type E or S, Grade B steel pipe, wrought-steel fittings and wrought-cast or forged-steel flanges and flange fittings, and welded and flanged joints. Flanged joints only at valves, etc.
2. Schedule 40 Type E or S, Grade B steel pipe; grooved, mechanical joint coupling and fittings; and grooved, mechanical joints with the approval of the Engineer.

D. Condenser-water piping, aboveground, NPS 2 and smaller, shall be the following:

1. Schedule 40 steel pipe; Class 125 cast-iron or 150 malleable-iron fittings; cast-iron flanges and flange fittings; and threaded joints.

E. Condenser-water piping, aboveground, NPS 2-1/2 and larger, shall be any of the following:

1. Schedule 40 type E or S grade B black steel pipe, wrought-steel fittings and wrought-cast or forged-steel flanges and flange fittings, and welded and flanged joints. Flanged joints only at valves, etc.

F. Makeup-water piping installed aboveground shall be Type L, drawn-temper copper tubing, wrought-copper fittings, and soldered joints.

G. Condensate-Drain Piping: Type DWV, drawn-temper copper tubing, wrought-copper fittings, and soldered joints.

H. Blowdown-Drain Piping: Same materials and joining methods as for piping specified for the service in which blowdown drain is installed.

I. Air-Vent Piping:

1. Inlet: Same materials and joining methods as for piping specified for the service in which air vent piping is installed.
2. Outlet: Type K, annealed-temper copper tubing with soldered or flared joints.

J. Safety-Valve-Inlet and -Outlet Piping for Hot Water and Chilled Water Piping: Same materials and joining methods as for piping specified for the service in which safety valve is installed

3.2 VALVE APPLICATIONS AND INSTALLATION

A. Install shutoff-duty valves at each branch connection to supply mains, at supply connections to each piece of equipment, and at other locations in systems for convenient system isolation.

B. Install calibrated-orifice, balancing valves in the return pipe of each heating or cooling terminal.

C. Install check valves at each pump discharge and elsewhere as required to control flow direction.

D. Install safety valves at hot-water generators and elsewhere as required by ASME Boiler and Pressure Vessel Code. Pipe drain to nearest floor drain or as indicated on Drawings. Comply with ASME Boiler and Pressure Vessel Code: Section VIII, Division 1, for installation requirements.

E. Install pressure-reducing valves at makeup-water connection to regulate system fill pressure.

F. All valves with position indicators are to be installed so that the indicators are facing in a direction that is visible from floor level. Ball valve handles, if located near ceilings, are to be located on the 3 or 9 o'clock positions to allow for actuation. All butterfly isolation valves that are higher than 5' above the floor are to have chains for actuation. All valves need to have free and clear access, minimum of 24" from valves to adjacent work.

3.3 PIPING INSTALLATIONS

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

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

C. Install piping indicated to be exposed and piping in equipment rooms and service areas at right angles or parallel to building walls. Diagonal runs are prohibited unless specifically indicated otherwise, and are allowed if necessary, at common lines of chilled water bridges.

D. 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 or flexible, where required, grooved-end-pipe couplings. The gasket style and elastomeric material (grade) shall be verified as suitable for the intended service as specified. A factory trained field representative shall provide on-site training for contractor's field personnel in the use of grooving tools, application of groove, and installation of grooved piping products. Factory trained representative shall periodically review the product installation. Contractor shall remove and replace any improperly installed products.

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

F. Install piping to permit valve servicing.

G. Install piping at indicated slopes.

H. Install piping free of sags and bends.

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

J. Install piping to allow application of insulation.

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

L. Install 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 ball valve, and short NPS 3/4 threaded hose end with brass cap, at low points in piping system mains and elsewhere as required for complete system drainage. Locate as shown on drawings, and as required based on actual installed conditions.

N. Install piping at a uniform grade of 0.2 percent upward in direction of flow for supply and 0.2 percent downward in direction of flow for return.

O. Install branch connections to mains using tee fittings in main pipe, with the branch connected to the side or 45 degrees from the bottom of the main pipe.

P. ***Install valves according to Division 23 Section "General-Duty Valves for HVAC Piping."***

Q. Install unions in piping, NPS 2 and smaller at final connections of equipment, and elsewhere as indicated.

R. Install flanges in piping, NPS 2-1/2 and larger, at final connections of equipment and elsewhere as indicated.

S. Install strainers on inlet side of each coil, 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 blow-off connection for strainers smaller than NPS 2.

T. Install expansion loops, expansion joints, anchors, and pipe alignment guides as specified in ***Division 23 Section "Expansion Fittings and Loops for HVAC Piping."***

U. Identify piping as specified in Division 23 Section "Mechanical Systems Identification."

V. Install sleeves for piping penetrations of walls, ceilings, and floors. Comply with requirements for sleeves specified in ***Division 23 Section "Sleeves and Sleeve Seals for HVAC Piping."***

W. Install sleeve seals for piping penetrations of concrete walls and slabs. Comply with requirements for sleeve seals specified in ***Division 23 Section "Sleeves and Sleeve Seals for HVAC Piping."***

X. Install escutcheons for piping penetrations of walls, ceilings, and floors. Comply with requirements for escutcheons specified in ***Division 23 Section "Escutcheons for HVAC Piping."***

3.4 TRACER WIRES

A. Tracer wire shall be installed on the piping as shown on the contract drawings.

B. Tracer wires shall terminate in each tunnel and manhole where new utilities penetrate. Tracer wires shall be provided with labels noting what pipe the wire is affixed to (ie. Chilled Water Supply, Pumped Condensate Return, etc).

C. Tracer wires shall be installed with a separate access point from and next to vault.

3.5 HANGERS AND SUPPORTS

A. Hanger, support, and anchor devices are specified in Division 23 Section "Mechanical Supporting Devices." Comply with the following requirements for maximum spacing of supports and minimum rod diameters.

B. 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.

C. Install hangers for steel piping with the following maximum spacing (with minimum rod sizes per MSS):

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 3 and larger: Maximum span, 12 feet.

D. 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 3 and larger: Maximum span, 10 feet; minimum rod size, 3/8 inch.

E. Support vertical runs at roof, at each floor, and at 10-foot intervals between floors.

3.6 PIPE JOINT CONSTRUCTION

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

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

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

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

E. Brazed Joints: Construct joints according to AWS's "Brazing Handbook," "Pipe and Tube" Chapter, using copper-phosphorus brazing filler metal complying with AWS A5.8.

F. Threaded Joints: Thread pipe with tapered pipe threads according to ASME B1.20.1. Cut threads full and clean using sharp dies. Ream threaded pipe ends to remove burrs and restore full ID. Join pipe fittings and valves as follows:

1. Apply appropriate tape or thread compound to external pipe threads unless dry seal threading is specified.
2. Damaged Threads: Do not use pipe or pipe fittings with threads that are corroded or damaged. Do not use pipe sections that have cracked or open welds.

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

H. Grooved Joints If Used In Copper Systems: Assemble joints with coupling and gasket, lubricant, and bolts. Create grooves in ends of pipe based on pipe and coupling manufacturer's written instructions for pipe wall thickness. Use grooved-end fittings and HVAC Shop approved grooved-end-pipe couplings.

3.7 HYDRONIC SPECIALTIES INSTALLATION

A. Install manual air vents at high points in piping, at heat-transfer coils, and elsewhere as shown and required for complete system air venting. Vents points to have isolation valves, pressure gages, and drain valves with hose connections.

3.8 TERMINAL EQUIPMENT CONNECTIONS

A. Sizes for supply and return piping connections shall be the same as or larger than equipment connections.

B. Install control valves in accessible locations close to connected equipment.

C. Install ports for pressure gages and thermometers at coil inlet and outlet connections according to ***Division 23 Section "Meters and Gages for HVAC Piping."***

3.9 FIELD QUALITY CONTROL

A. Prepare hydronic piping according to ASME B31.9 and as follows:

1. Leave joints, including welds, uninsulated and exposed for examination during test.
2. Provide temporary restraints for expansion joints that cannot sustain reactions due to test pressure. If temporary restraints are impractical, isolate expansion joints from testing.
3. Flush hydronic piping systems with clean water; then remove and clean or replace strainer screens.
4. Isolate equipment from piping. If a valve is used to isolate equipment, its closure shall be capable of sealing against test pressure without damage to valve. Install blinds in flanged joints to isolate equipment.

5. Install safety valve, set at a pressure no more than one-third higher than test pressure, to protect against damage by expanding liquid or other source of overpressure during test.

B. Perform the following tests on hydronic piping:

1. Use ambient temperature water as a testing medium unless there is risk of damage due to freezing. Another liquid that is safe for workers and compatible with piping may be used.
2. While filling system, use vents installed at high points of system to release air. Use drains installed at low points for complete draining of test liquid.
3. Isolate expansion tanks and determine that hydronic system is full of water.
4. Subject piping system to hydrostatic test pressure that is not less than 1.5 times the system's working pressure. Test pressure shall not exceed maximum pressure for any vessel, pump, valve, or other component in system under test. Verify that stress due to pressure at bottom of vertical runs does not exceed 90 percent of specified minimum yield strength or 1.7 times "SE" value in Appendix A in ASME B31.9, "Building Services Piping."
5. After hydrostatic test pressure has been applied for at least 10 minutes, examine piping, joints, and connections for leakage. Eliminate leaks by tightening, repairing, or replacing components, and repeat hydrostatic test until there are no leaks.
6. Prepare written report of testing.

C. Perform the following before operating the system:

1. Open manual valves fully.
2. Inspect pumps for proper rotation.
3. Set makeup pressure-reducing valves for required system pressure.
4. Inspect air vents at high points of system and determine if all are installed and operating freely (automatic type), or bleed air completely (manual type).
5. Set temperature controls so all coils are calling for full flow.
6. Inspect and set operating temperatures of hydronic equipment, such as boilers, chillers, cooling towers, to specified values.
7. Verify lubrication of motors and bearings.

END OF SECTION 23 2113

SECTION 23 2116 - HYDRONIC PIPING SPECIALTIES

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 certain special-duty valves and specialties for the following:

1. Hot-water heating piping.
2. Chilled-water piping.
3. Condenser-water piping.
4. Glycol cooling-water or heating water piping.
5. Makeup-water piping.
6. Condensate-drain piping.
7. Blowdown-drain piping.
8. Air-vent piping.
9. Safety-valve-inlet and -outlet piping.

1.3 ACTION SUBMITTALS

A. Product Data: For each type of the following:

1. Valves: Include flow and pressure drop curves based on manufacturer's testing for calibrated-orifice balancing valves and automatic flow-control valves.
2. Air-control devices.
3. Hydronic specialties.

1.4 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For air-control devices, hydronic specialties, and special-duty valves to include in emergency, operation, and maintenance manuals.

B. Northwestern University Maintenance Requirement Forms, see Division 01.

1.5 MAINTENANCE MATERIAL SUBMITTALS

A. Differential Pressure Meter: For each type of balancing valve and automatic flow control valve, include flowmeter, probes, hoses, flow charts, and carrying case.

1.6 QUALITY ASSURANCE

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

1. Safety valves and pressure vessels shall bear the appropriate ASME label. Fabricate and stamp air separators and expansion tanks to comply with ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.

B. Comply with FM Global requirements for pressure vessels and piping and for pressure relief devices.

1.7 SPECIAL WARRANTY

A. Five (5) years, see Division 01.

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

A. Hydronic piping components and installation shall be capable of withstanding the following minimum working pressure and temperature unless otherwise indicated:

1. Hot-Water Heating Piping: 100 psig at 200 deg F.
2. Chilled-Water Piping: 120 psig at 50 deg F.
3. Condenser-Water Piping: 120 psig at 50 deg. F.
4. Glycol Cooling-Water Piping: 120 psig at 50 deg. F.
5. Glycol Heating Water Piping: 100 psig at 200 deg F.
6. Makeup-Water Piping: 80 psig 150 deg F.
7. Condensate-Drain Piping: 150 deg F.
8. Blowdown-Drain Piping: Equal to the pressure of the piping system to which it is attached.
9. Air-Vent Piping: Equal to the pressure of the piping system to which it is attached.
10. Safety-Valve-Inlet and -Outlet Piping: Equal to the pressure of the piping system to which it is attached.

2.2 VALVES

A. Check, Ball, and Butterfly Valves: Comply with requirements specified in Section 23 0523 "General Duty Valves for HVAC."

B. Automatic Temperature-Control Valves, Actuators, and Sensors: Comply with requirements specified in Section 25 0000 "Integrated Automation."

C. Bronze, Calibrated-Orifice, Balancing Valves:

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

a. Bell & Gossett; a Xylem brand.

2. Body: Bronze, ball or plug type with calibrated orifice or venturi.
3. Ball: Brass or stainless steel.
4. Plug: Resin.
5. Seat: PTFE.
6. End Connections: Threaded or socket.
7. Pressure Gage Connections: Integral seals for portable differential pressure meter.
8. Handle Style: Lever, with memory stop to retain set position.
9. CWP Rating: Minimum 125 psig (860 kPa).
10. Maximum Operating Temperature: 250 deg F (121 deg C).

D. Cast-Iron or Steel, Calibrated-Orifice, Balancing Valves:

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

   a. Bell & Gossett; a Xylem brand.

2. Body: Cast-iron or steel body, ball, plug, or globe pattern with calibrated orifice or venturi.
3. Ball: Brass or stainless steel.
4. Stem Seals: EPDM O-rings.
5. Disc: Glass and carbon-filled PTFE.
6. Seat: PTFE.
7. End Connections: Flanged.
8. Pressure Gage Connections: Integral seals for portable differential pressure meter.
9. Handle Style: Lever, with memory stop to retain set position.
10. CWP Rating: Minimum 125 psig (860 kPa).
11. Maximum Operating Temperature: 250 deg F (121 deg C).

E. Diaphragm-Operated, Pressure-Reducing Valves: ASME labeled.

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

   a. Bell & Gossett; a Xylem brand.
   b. Conbraco Industries, Inc.
   c. Watts; a Watts Water Technologies company.

2. Body: Bronze or brass.
3. Disc: Glass and carbon-filled PTFE.
4. Seat: Brass.
5. Stem Seals: EPDM O-rings.
6. Diaphragm: EPT.
7. Low inlet-pressure check valve.
8. Inlet Strainer: ***<Insert materials>***, removable without system shutdown.
9. Valve Seat and Stem: Non-corrosive.
10. Valve Size, Capacity, and Operating Pressure: Selected to suit system in which installed, with operating pressure and capacity factory set and field adjustable.

F. Diaphragm-Operated Safety Valves: ASME labeled.

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

   a. Bell & Gossett; a Xylem brand.

b. Conbraco Industries, Inc.
c. Watts; a Watts Water Technologies company.

2. Body: Bronze or brass.
3. Disc: Glass and carbon-filled PTFE.
4. Seat: Brass.
5. Stem Seals: EPDM O-rings.
6. Diaphragm: EPT.
7. Wetted, Internal Work Parts: Brass and rubber.
8. Inlet Strainer: ***<Insert materials>***, removable without system shutdown.
9. Valve Seat and Stem: Noncorrosive.
10. Valve Size, Capacity, and Operating Pressure: Comply with ASME Boiler and Pressure Vessel Code: Section IV, and selected to suit system in which installed, with operating pressure and capacity factory set and field adjustable.

G. Triple Duty Valves

1. Not Allowed.

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.
c. Nexus Valve, Inc.

2. Body: Brass or ferrous metal.
3. Piston and Spring Assembly: ***[Stainless steel] [Corrosion resistant]***, 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.
8. Minimum CWP Rating: ***[175 psig (1207 kPa)] [300 psig (2070 kPa)]***.
9. Maximum Operating Temperature: ***[200 deg F (93 deg C)] [250 deg F (121 deg C)]***.

2.3 AIR CONTROL DEVICES, EXPANSION TANKS, AND AIR AND DIRT SEPARATORS

A. Manual Air Vents:

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

a. Bell & Gossett Domestic Pump; a division of ITT Industries.

2. Body: Bronze.
3. Internal Parts: Nonferrous.
4. Operator: Screwdriver or thumbscrew.
5. Inlet Connection: NPS 1/2.
6. Discharge Connection: NPS 1/8.

7. CWP Rating: 150 psig.
8. Maximum Operating Temperature: 225 deg F.

B. Expansion Tanks:

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. Amtrol, Inc.

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. Pressurization system: Replaceable bladder-type expansion tank which will accommodate the expanded water of the system generated within the normal operating temperature range, limiting this pressure increase at those components in the system to the maximum allowable pressure at those components. It shall maintain minimum operating pressure necessary to eliminate all air. the only air in the system shall be the permanent sealed-in air cushion contained in the replaceable bladder-type tank, with dimensions as indicated on the drawings.

C. Automatic Air Vents:

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

   a. Bell & Gossett; a Xylem brand.
   b. Nexus Valve, Inc.
   c. Taco, Inc.

2. Body: Bronze or cast iron.
3. Internal Parts: Nonferrous.
4. Operator: Noncorrosive metal float.
5. Inlet Connection: NPS 1/2 (DN 15).
6. Discharge Connection: NPS 1/4 (DN 8).
7. CWP Rating: 150 psig (1035 kPa).
8. Maximum Operating Temperature: 240 deg F (116 deg C).

D. Air and Dirt Separators:

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

   a. Spirotherm VDR, VDT, VHT, VDN, VHN.
   b. Bell & Gossett; a Xylem brand.

2. Body: ASME welded steel, with inlet and outlet connections, bottom valved blowdown and top vent connections, brass vent head/valve, non-ferrous float, Viton seals and O-rings, brass skim valve, copper coalescing medium, and other internal components that effectively separate the air from solution and divert it to the vent for quick removal, and that effectively remove dirt and divert it for removal.
3. Maximum Working Pressure: 150 psig.

4. Maximum Operating Temperature: 270 deg F.

E. Air Purgers:

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

   a. Bell & Gossett; a Xylem brand.
   b. Taco, Inc.

2. 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 Working Pressure: 150 psig (1035 kPa).
4. Maximum Operating Temperature: 250 deg F (121 deg C).

2.4 HYDRONIC PIPING SPECIALTIES

A. Y-Pattern Strainers:

1. Body: ASTM A 126, Class B, cast iron with bolted cover and bottom drain connection.
2. End Connections: Threaded ends for NPS 2 (DN 50) and smaller; flanged ends for NPS 2-1/2 (DN 65) and larger.
3. Strainer Screen: Stainless-steel, [**20**] [**40**] [**60**]-mesh strainer, or perforated stainless-steel basket.
4. CWP Rating: 125 psig (860 kPa).

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 (DN 50) and smaller; flanged ends for NPS 2-1/2 (DN 65) and larger.
3. Strainer Screen: [**40**] [**60**]-mesh startup strainer, and perforated stainless-steel basket with 50 percent free area.
4. CWP Rating: 125 psig (860 kPa).

C. T-Pattern Strainers:

1. Body: Ductile or malleable iron with removable access coupling and end cap for strainer maintenance.
2. End Connections: Flanged ends.
3. Strainer Screen: [**40**] [**60**]-mesh startup strainer, and perforated stainless-steel basket with 57 percent free area.
4. CWP Rating: 750 psig (5170 kPa).

D. Stainless-Steel Bellow, Flexible Connectors:

1. Body: Stainless-steel bellows with woven, flexible, bronze, wire-reinforcing protective jacket.
2. End Connections: Threaded or flanged to match equipment connected.
3. Performance: Capable of 3/4-inch (20-mm) misalignment.
4. CWP Rating: 150 psig (1035 kPa).
5. Maximum Operating Temperature: 250 deg F (121 deg C).

E. Spherical, Rubber, Flexible Connectors:

1. Body: Fiber-reinforced rubber body.
2. End Connections: Steel flanges drilled to align with Classes 150 and 300 steel flanges.
3. Performance: Capable of misalignment.
4. CWP Rating: 150 psig (1035 kPa).
5. Maximum Operating Temperature: 250 deg F (121 deg C).

F. Expansion Fittings: Comply with requirements in Section 230516 "Expansion Fittings and Loops for HVAC Piping."Section 15124 "Expansion Fittings and Loops for HVAC Piping."

G. Flexible Stainless Steel Hose Connectors (Up thru 2")

1. Hose: Corrugated 300 series stainless steel.
2. Braided Jacketing: Woven 300 series stainless-steel.
3. End Connections: Threaded (NPT) stainless steel to match equipment connected.
4. Maximum Working Pressure: Minimum of 250 psig @ 200F.
5. Manufacturer's: Flexicraft, Flexonics, or Metraflex (Superflex).

PART 3 - EXECUTION

3.1 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 ***[throttling-duty] [calibrated-orifice, balancing]*** valves at each branch connection to return main.

C. Install calibrated-orifice, balancing valves in the return pipe of each heating or cooling terminal.

D. Install check valves at each pump discharge and elsewhere as required to control flow direction.

E. Install safety valves at hot-water generators and elsewhere as required by ASME Boiler and Pressure Vessel Code. Install drip-pan elbow on safety-valve outlet and pipe without valves to the outdoors; pipe drain to nearest floor drain or as indicated on Drawings. Comply with ASME Boiler and Pressure Vessel Code: Section VIII, Division 1, for installation requirements.

F. Install pressure-reducing valves at makeup-water connection to regulate system fill pressure.

G. Install automatic flow control valves as shown on drawings.

H. Install components in accordance with manufacturer's recommendations.

3.2 HYDRONIC SPECIALTIES INSTALLATION

A. Install manual air vents at high points in piping, at heat-transfer coils, and elsewhere as required for system air venting.

B. Install automatic air vents at high points of system piping in mechanical equipment rooms only. Install manual vents at heat-transfer coils and elsewhere as required for air venting.

C. Install piping from boiler air outlet, air separator, or air purger to expansion tank with a 2 percent upward slope toward tank.

D. Install in-line air separators in pump suction. Install drain valve on air separators NPS 2 (DN 50) and larger.

E. Install tangential air separator in pump suction. Install blowdown piping with gate or full-port ball valve; extend full size to nearest floor drain.

F. Install air and dirt separators as shown on drawing and with blowdown piping with gate or full-port ball valve; extend full size to nearest floor drain. These separators are required to be installed for any new chilled water and heating hot water connections to a building, on closed loop hydronic systems involved with renovations, and as otherwise shown on the drawings.

G. 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.

H. Install expansion tanks on the floor. Vent and purge air from hydronic system, and ensure that tank is properly charged with air to suit system Project requirements.

I. Install Y-pattern, basket, and/or T-pattern strainers as shown on the drawings.

J. Install stainless steel bellows type and/or spherical rubber type flexible connectors as shown on the drawings.

K. Install flexible stainless steel hose connectors at HVAC equipment utilizing hydronic piping and as shown on drawings.

L. All valves with position indicators are to be installed so that the indicators are facing in a direction that is visible from floor level. Ball valve handles, if located near ceilings, are to be located on the 3 or 9 o'clock positions to allow for actuation. All butterfly isolation valves that are higher than 5' above the floor are to have chains for actuation. All valves need to have free and clear access, minimum of 24" from valves to adjacent work.

M. This contractor shall install pump differential pressure switches/devices provided by the Division 25 contractor.

END OF SECTION 23 2116

SECTION 23 2123 - PUMPS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

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

1.2 SUMMARY

A. This Section includes the following:

1. Close-coupled, in-line centrifugal pumps.
2. Close-coupled, end-suction centrifugal pumps.
3. Separately coupled, horizontal, in-line centrifugal pumps.
4. Separately coupled, vertical, in-line centrifugal pumps.
5. Separately coupled, base-mounted, end-suction centrifugal pumps.
6. Pump specialty fittings

1.3 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.

B. Shop Drawings: Show pump layout and connections. Include setting drawings with templates for installing foundation and anchor bolts and other anchorages.

C. Operation and maintenance data.

D. Grooved joint couplings and fittings specifically identified with the applicable style or series number.

E. Northwestern University Maintenance Requirement Forms, see Division 01.

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. UL Compliance: Comply with UL 778 for motor-operated water pumps.

C. Source Limitations: Obtain hydronic pumps through one source from a single manufacturer.

D. To assure uniformity and compatibility of piping components in grooved end piping systems, all grooved products utilized shall be supplied by the same manufacturer. Grooving tools shall be supplied by the same manufacturer as the grooved components.

E. All grooved couplings shall be installed strictly according to grooved manufacturer's instructions including torque verification and specific lubrication as published.

1.5 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 wooden 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.

1.6 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.

1.7 SPECIAL WARRANTY

A. Five (5) years, see Division 01.

PART 2 - PRODUCTS

2.1 GENERAL REQUIREMENTS

A. Pump motors shall be 1750 rpm maximum unless otherwise scheduled on drawings and sized for non-overloading service.

B. Pump impeller shall be shaved to a minimum of **[110%] [120%]** of design flow at the required pump head after balancing.

C. Pumps motors operated by Variable Frequency Drives shall have pump impellor balanced for variable speed operation.

D. All pumps to be provided with permanently affixed nameplates which include impeller diameter, rated capacity in gpm, rated head in feet, rpm, and motor horsepower.

E. Pumps to be maintenance free, or as close to maintenance free. Of course, this depends on size and performance requirements.

2.2 MANUFACTURERS FOR CHICAGO CAMPUS

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

1. Grundfos CR and maintenance free (Basis of Design)
2. Armstrong Pumps Inc
3. Bell & Gossett; Div. of ITT Industries.

2.3 MANUFACTURERS FOR EVANSTON CAMPUS

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

1. Bell & Gossett; Div. of ITT Industries (Preferred).
2. Armstrong Pumps Inc
3. Grundfos CR and maintenance free

B. Maintenance free pumps to be used first within engineering parameters.

2.4 CLOSE-COUPLED, IN-LINE CENTRIFUGAL PUMPS

A. Description: Factory-assembled and tested, centrifugal, overhung-impeller, close-coupled, in-line pump as defined in HI 1.1-1.2 and HI 1.3; designed for installation with pump and motor shafts mounted horizontally or vertically. Rate pump for 175-psig minimum working pressure and a continuous water temperature of 225 deg F.

B. Pump Construction:

1. Casing: Radially split, cast iron, with replaceable bronze wear rings, threaded gage tappings at inlet and outlet, and threaded companion-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 copper-alloy shaft sleeve.

C. Motor: Single speed, with permanently lubricated ball bearings, unless otherwise indicated; and rigidly mounted to pump casing. Comply with requirements in Division 23 Section "Motors."

2.5 CLOSE-COUPLED, END-SUCTION CENTRIFUGAL PUMPS

A. 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.

B. 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.
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: Stainless steel.

4. Mechanical Seal: Carbon rotating ring against a ceramic seat held by a stainless-steel spring, and Buna-N bellows and gasket. Equal to John Crane Type 21.
5. Pump Bearings: Permanently lubricated ball bearings through 5 hp. Over 5 hp : grease-lubricated ball bearings.
6. Motor: Single speed, with permanently lubricated ball bearings, unless otherwise indicated; rigidly mounted to pump casing with integral pump support. Comply with requirements in Division 23 Section "Motors."

2.6 SEPARATELY COUPLED, HORIZONTAL, IN-LINE CENTRIFUGAL PUMPS

A. Description: Factory-assembled and tested, centrifugal, overhung-impeller, separately coupled, in-line pump as defined in HI 1.1-1.2 and HI 1.3; designed for installation with pump and motor shafts mounted horizontally. Rate pump for 125-psig minimum working pressure and a continuous water temperature of 225 deg F.

B. Pump Construction:

1. Casing: Radially split, cast iron, with threaded gage tappings at inlet and outlet, and threaded [**companion-flange**] [**union end**] 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**] [**Stainless steel**].
4. 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.
5. Pump Bearings: Permanently lubricated ball bearings.

C. Shaft Coupling: [**Molded rubber insert with interlocking spider**] [**Interlocking frame with interconnecting springs**] capable of absorbing vibration.

D. Motor: Single speed, with [**permanently lubricated ball**] [**oil-lubricated sleeve**] bearings, unless otherwise indicated; and [**resiliently**] [**rigidly**] mounted to pump casing. Comply with requirements in Division 23 Section "Motors."

2.7 SEPARATELY COUPLED, VERTICAL, IN-LINE CENTRIFUGAL PUMPS

A. Description: Factory-assembled and tested, centrifugal, overhung-impeller, separately coupled, in-line pump as defined in HI 1.1-1.2 and HI 1.3; designed for installation with pump and motor shafts mounted vertically. Rate pump for [**125-psig**] [**175-psig**] [**250-psig**] minimum working pressure and a continuous water temperature of [**200 deg F**] [**225 deg F**] [**250 deg F**].

B. Pump Construction:

1. Casing: Radially split, cast iron, with[**replaceable bronze wear rings,**] threaded gage tappings at inlet and outlet, and threaded [**companion-flange**] [**union end**] 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 copper-alloy shaft sleeve**] [**Stainless steel**].
4. 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.

5. Packing Seal: Stuffing box, with a minimum of four rings of graphite-impregnated braided yarn with bronze lantern ring between center two graphite rings, and bronze packing gland.
6. Pump Bearings: [**Permanently lubricated ball bearings**] [**Oil lubricated; bronze-journal or thrust type**].

C. Shaft Coupling: Axially split spacer coupling.

D. Motor: Single speed, with [**permanently lubricated**] [**grease-lubricated**] ball bearings, unless otherwise indicated; rigidly mounted to pump casing with lifting eye and supporting lugs in motor enclosure. Comply with requirements in Division 23 Section "Motors."

2.8 SEPARATELY COUPLED, BASE-MOUNTED, END-SUCTION CENTRIFUGAL PUMPS

A. 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.

B. 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.
2. Impeller: ASTM B 584, cast bronze; statically and dynamically balanced, keyed to shaft, and secured with a locking cap screw.
3. Pump Shaft: Stainless steel.
4. Mechanical Seal: Carbon rotating ring against a ceramic seat held by a stainless-steel spring, and Buna-N bellows and gasket. Equal to John Crane Type 21.
5. Pump Bearings: Permanently lubricated ball bearings through 5 hp. Over 5 hp : grease-lubricated ball bearings.

C. 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**].

D. Coupling Guard: Dual rated; ANSI B15.1, Section 8; OSHA 1910.219 approved; steel; removable; attached to mounting frame.

E. 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.

F. Motor: **[Open Drip Proof] [TEFC]** Single speed, with permanently lubricated ball bearings, unless otherwise indicated; secured to mounting frame, with adjustable alignment. Comply with requirements in Division 23 Section "Motors."

2.9 PUMP SPECIALTY FITTINGS

A. Suction Diffusers:

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

a. Same manufacturer as associated pump.
b. Victaulic.

2. Angle pattern, 175-psig pressure rating at 250 degree F, cast ductile-iron body and end cap, pump-inlet fitting; with removable strainer (bronze for startup and stainless-steel for permanent); bronze or stainless-steel full length straightening vanes; drain plug; and factory-fabricated support. Provide optional magnetic insert.
3. Angle pattern, grooved pump inlet with flanged outlet system connections, 300-psig pressure rating at 250 degree F, ductile-iron body, coupling and cap, 304 stainless steel frame and perforated sheet diffuser with 3/16” diameter holes. Integral flow straightening device. Removable 16 mesh bronze start-up pre-filter, pressure port with drain plug. Provide optional magnetic insert.

B. Triple-Duty Valve or Tri-Service Assembly:

1. Not allowed.

PART 3 - EXECUTION

3.1 PUMP INSTALLATION

A. Comply with HI 1.4.

B. Install all pumps in strict accordance with manufacturer’s instructions. Provide service space around pumps as recommended by the pump manufacturer.

C. Independently support pumps and piping so weight of piping is not supported by pumps and weight of pumps is not supported by piping.

D. Install continuous-thread hanger rods and spring hangers of sufficient size to support pump weight. Vibration isolation devices are specified in Division 23 Section "Vibration Isolation." Fabricate brackets or supports as required. Hanger and support materials are specified in Division 23 Section "Mechanical Supporting Devices."

E. Suspend vertically mounted, in-line centrifugal pumps independent of piping. Install pumps with motor and pump shafts vertical. Use continuous-thread hanger rods and spring hangers of sufficient size to support pump weight. Vibration isolation devices are specified in Division 23 Section "Vibration Isolation." Hanger and support materials are specified in Division 23 Section "Mechanical Supporting Devices."

F. Set base-mounted pumps on concrete foundation. 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.

G. Do not mount pumps on walls that are common to critical areas such as offices, conference rooms, classrooms, etc. In-line pumps shall be installed directly in the piping system, and supported independently from the piping.

H. Install grooved piping products in accordance with the manufacturer's guidelines and recommendations. Grooved end shall be clean and free from indentations, projections and roll marks in the area from pipe end to groove.

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. The gasket style and elastomeric material (grade) shall be verified as suitable for the intended service as specified. A field representative shall provide on-site training for contractor's field personnel in the use of grooving tools, application of groove, and installation of grooved piping products. Factory trained representative shall periodically review the product installation. Contractor shall remove and replace any improperly installed products.

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.

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. After alignment is correct, tighten foundation bolts evenly but not too firmly. Completely fill baseplate with non-shrink, nonmetallic grout while metal blocks and shims or wedges are in place. After grout has cured, fully tighten foundation bolts.

E. Grout pump mounting base full after piping is connected but before pump drive is aligned. After grouting, align pump drive shaft to 5 mils, even if pump is factory aligned, and conduct vibration test.

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 check valve and throttling valve on discharge side of pumps.

F. Install Y-type strainer and shutoff valve on suction side of pumps. Suction diffusers can be used in lieu of in-line strainers, long radius elbow and spool piece.

G. Install flexible connectors or Victaulic flexible couplings on suction and discharge sides of base-mounted pumps between pump casing and valves.

H. Install pressure gages on pump suction and discharge, at integral pressure-gage tapping, or install single gage with multiple input selector valve.

I. Install check valve and ball valve on each condensate pump unit discharge.

J. Install electrical connections for power, controls, and devices.

3.4 STARTUP SERVICE

A. Engage a factory-authorized service representative to perform startup service.

1. Complete installation and startup checks according to manufacturer's written instructions.
2. Check piping connections for tightness.
3. Clean strainers on suction piping.
4. Perform the following startup checks for each pump before starting:

a. 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.
b. Verify that pump is rotating in the correct direction.

3.5 DEMONSTRATION

A. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain hydronic pumps. Refer to Division 01 Section covering demonstration and training.

END OF SECTION 23 2123

SECTION 23 2213 - STEAM PIPING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

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

1.2 SUMMARY

A. This Section includes the following for HP (High Pressure) and LP (Low Pressure) steam and condensate piping:

1. Pipe, fittings, unions and flanges, and joints.
2. Pipe support guides and anchors.
3. Expansion loops.
4. Valves, chainwheels, and certain other specialties for HP steam and condensate systems.
5. Unions, flanges, and joining materials.
6. Isolation, check, and pressure equalization, and drain valves for HP steam and condensate systems.
7. Tracer wire.

B. Related Requirements:

1. Section 23 0000 "Common Work Requirements for HVAC."
2. Section 23 0516 "Expansion Fittings and Loops for HVAC Piping."
3. Section 23 0517 "Sleeves and Sleeve Seals for HVAC Piping."
4. Section 23 0518 "Escutcheons for HVAC Piping."
5. Section 23 0529 "Mechanical Supporting Devices."
6. Section 23 0553 "Mechanical Systems Identification."
7. Section 23 2216 "Steam Piping Specialties."
8. Section 33 6313 "Exterior Underground Steam Distribution System."

1.3 DEFINITIONS AND CAMPUS STEAM SYSTEM INFORMATION

A. HP Steam Systems: High-pressure piping operating at more than 15 psig as required by ASME B31.1.

B. LP Steam Systems: Low-pressure piping operating at 15 psig or less as required by ASME B31.9.

C. For the Evanston campus, central steam is distributed at 150 psig (known as the "Campus Line"), and at 230 psig. These are distinct piping systems but they both originate from the same high pressure header in the CUP. Steam is and needs to be metered and reduced in pressure after entrance of each building as required. On the condensate return side, there is high pressure condensate return and pumped condensate return.

D. For the Chicago campus, central steam is distributed at 170 psig. Steam is and needs to be metered and reduced in pressure after entrance of each building as required.

E. Both campus's utilize direct buried piping and piping run through tunnels.

1.4 PERFORMANCE REQUIREMENTS

A. Components and installation shall be capable of withstanding the following minimum working pressures and temperatures:

1. HP Steam and Medium Pressure (MP) Piping: XXX psig and XXXF.
2. LP Steam Piping: 15 psig and 300F.
3. HP and MP Condensate Piping: XXX psig at XXX deg F.
4. LP Condensate Piping: 15 psig at 250 deg F.
5. Blowdown-Drain Piping: Equal to pressure of the piping system to which it is attached.
6. Air-Vent and Vacuum-Breaker Piping: Equal to pressure of the piping system to which it is attached.
7. Safety-Valve-Inlet and -Outlet Piping: Equal to pressure of the piping system to which it is attached.

1.5 SUBMITTALS

A. Product Data: For each type of the following:

1. Pipe, fittings, unions and flanges.
2. Pipe support guides and anchors.
3. All valves, and chainwheels.
4. Tracer wire.

B. Shop Drawings ***(For Use Amongst the Contractors and For University Reference, Not for Engineer Approval)***: Detail fabrication of pipe anchors, hangers, pipe, multiple pipes, alignment guides, and expansion loops and their attachment to the building structure. Detail locations of anchors, alignment guides, and expansion loops.

C. Coordination Drawings ***(For Use Amongst the Contractors and For University Reference, Not for Engineer Approval)***: 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. Other building services.
2. Lighting.
3. Structural members.
4. Supports.

D. Welding certificates (For Information).

E. Field quality-control test reports.

F. Operation and Maintenance Data: For valves and expansion joints, to include in emergency, operation, and maintenance manuals.

G. Delegated-Design Submittal ***(For Use Amongst the Contractors and For University Reference, Not for Engineer Approval)***:

1. Design calculations and detailed fabrication and assembly of pipe anchors and alignment guides, hangers and supports for multiple pipes, expansion 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 penetration and fire-stopping for fire- and smoke-rated wall and floor and ceiling assemblies.

H. Northwestern Maintenance Requirement Forms, see Division 01.

1.6 QUALITY ASSURANCE

A. Pipe Welding: Qualify processes and operators according to the following:

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.

Retain applicable codes in paragraph below: B31.1 for HP steam system and B31.9 for LP steam system.

B. ASME Compliance: Comply with ASME B31.1, "Power Piping" and ASME B31.9, "Building Services Piping," for materials, products, and installation. Safety valves and pressure vessels shall bear the appropriate ASME label.

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

D. Comply with FM Global requirements for pressure vessels and piping and for pressure relief devices.

E. Piping materials shall bear label, stamp, or other markings of specified testing agency.

1.7 DELIVERY, STORAGE AND HANDLING

A. Product Delivery Requirements: Accept valves and accessories on site in shipping containers with labeling in place.

B. Product Storage and Handling Requirements: Protect piping and fittings from soil and debris with temporary and caps and closures. Maintain in place until installation. Provide temporary protective coating on steel valves and specialties.

1.8 SITE CONDITIONS

A. Verify field conditions prior to fabrication.

1.9 SPECIAL WARRANTIES

A. Five (5) years, see Division 01.

PART 2 - PRODUCTS

2.1 GENERAL

A. Materials: Piping shall be meet ASTM requirements.

B. Piping shall be routed orthogonally (no diagonal shortcuts).

2.2 TRACER WIRE:

A. All non-electrical pipe installed below grade shall have a 19 AWG Trace-Safe water blocking tracing wire with Copperhead Snakepit access boxes, or equal. Tracer wire to be accessible at each end in manholes.

B. Tracer wire shall be installed on the pipe as shown on the contract drawings.

C. Tracer wires shall terminate in each tunnel and manhole where new utilities penetrate. Tracer wires shall be provided with labels noting what pipe the wire is affixed to (i.e., HP Steam Supply, Pumped Condensate Return, etc.)

2.3 HIGH PRESSURE STEAM IN CUP, IN INTERIOR MANHOLES (IF APPLICABLE), AND SHORT SECTIONS JUST ENTERING BUILDING MECHANICAL ROOMS

A. 2½ inches and Smaller:

1. Pipe: ASTM A106, Grade B, extra strong, carbon steel.
2. Fittings: ASTM A105 Grade II/ASME B16.11, 3000 lb. forged steel, socket weld.
3. Unions: Forged steel, 3000 lb., socket well. Refer to Unions and Flanges in this Section.

B. 3 inches and Larger:

1. Pipe: ASTM A106, Grade B, extra strong, carbon steel.
2. Fittings: ASTM A234 Grade WPB/ASME B16.9, extra strong, seamless, carbon steel weld.
3. Flanges: Class 300. Refer to Unions and Flanges in this Section.

2.4 PUMPED CONDENSATE AND STEAM TRAP CONDENSATE IN CUP, IN INTERIOR MANHOLES (IF APPLICABLE), AND SHORT SECTIONS JUST ENTERING BUILDING MECHANICAL ROOMS:

A. 2½ and Smaller:

1. Pipe: ASTM A106, Grade B, extra strong, carbon steel.
2. Fittings: ASTM A105 Grade II/ASME B16.11, 3000 lb. forged steel, socket weld.
3. Unions: Forged steel, 3000 lb., socket weld. Refer to Unions and Flanges in this Section.

B. 3 inches and Larger:

1. Pipe: ASTM A106, Grade B, extra strong, carbon steel.
2. Fittings: ASTM A234 Grade WPB/ASME B16.9, extra strong, seamless, carbon steel weld.
3. Flanges: Class 300. Refer to Unions and Flanges in this Section.

2.5 PUMPED CONDENSATE AND STEAM TRAP CONDENSATE IN INTERIOR MANHOLES (IF APPLICABLE), AND SHORT SECTIONS WITHIN BUILDING MECHANICAL ROOMS:

A. 2½ inches and Smaller:

1. Pipe: ASTM A312, 304L, Schedule 40S, seamless stainless steel.
2. Fittings: ASTM 182, Gr. F304, ASME B16.11, 3000 lb socket-weld.
3. Unions: 3000 lb socket-weld, stainless steel ground joint.

B. 3 inches and Larger:

1. Pipe: ASTM A312, 304L, Schedule 40S, seamless stainless steel.
2. Fittings: ASTM A403, Gr. WP, Class S or Class W, ASME 16.9.
3. Flanges: ASTM A182, GR. F304, ASME B16.5, 150 lb std. with 1/16" raised face, serrated face finish and welding neck.
4. Bolts: Stud bolts, ASTM A193, Gr. B7.
5. Nuts: ASTM A194, Gr. 2H.

2.6 HIGH PRESSURE STEAM AND CONDENSATE (UNDERGROUND) – GENERAL:

A. Same as existing, or same as new as installed by the site utility contractor, and work of this section for this application only meant to cover new piping in from 5'-0" outside of building if the site utility responsibility ends there, refer to their drawings and specs. Contractor fabricated piping and fittings are not allowed. No metal components shall be exposed to earth. Refer to Section 33 6313 for information and requirements on site HP steam and condensate piping systems (including vaults) and also including (but not limited to) pipe support guides, expansion loops, moment guided, elbows and tees, anchors, end seals and gland seals, and field joints.

B. If drainable/dryable type, all straight sections, fittings, anchors and other accessories shall be factory prefabricated to job dimensions, and designed to minimize the number of field welds. The design shall be computer analyzed by the piping system manufacturer to determine stresses and movements of the service pipe and to ensure that the system design is in strict conformance with ANSI B31.1 latest edition, and stamped by a registered professional engineer licensed in the state of Illinois. The analysis shall include piping and structures inside the manholes.

C. The piping manufacturer shall provide minimum of 2 days of on-site technical assistance during installation of the piping. The factory representative shall be a factory trained technician to witness requirements outlined in the installation portion of this specification.

D. Contractor shall perform a computerized pipe stress analysis for the piping systems in the underground steam system. Submit stress analysis report including input data, system graphics, output data including: system forces and moments, system deflections, system stresses, hanger, support and anchor loading summary and other pertinent data. Analysis shall consider actual materials of construction and a system pressure and temperature of 250 PSIG and 450°F, base temperature is 50°F. Analysis output data shall be utilized to select proper supports, guides and anchors to resist actual loads calculated. Pipe stress analysis calculations to be submitted to the Engineer for review along with the re-engineered piping system shop drawings.

2.7 LP STEAM AND CONDENSATE PIPING

A. LP Steam: 2" and smaller: ASTM A53, Grade B, ERW, schedule 40 carbon steel, with screwed joints. Fittings, unions, flanges, and couplings to be ANSI/ASTM B16.3. malleable iron, Class 150.

B. LP Steam: 2-1/2" and larger: ASTM A53, Grade B, ERW, schedule 40, carbon steel, with ANSI/AWS D1.1 butt welded joints. Fittings to be ASTM A234, forged steel, Class 150. Flanges to be Class 150 forged steel slip-on type, or weld-neck flanges for carbon steel.

C. LP Steam Condensate: 2" and smaller: ASTM A53, Grade B, ERW, schedule 80 carbon steel, with screwed joints. Fittings, unions, flanges, and couplings to be ANSI/ASTM B16.3. malleable iron, Class 150.

D. LP Steam Condensate: 2-1/2" and larger: ASTM A53, Grade B, ERW, schedule 80, carbon steel, with ANSI/AWS D1.1 butt welded joints. Fittings to be ASTM A234, forged steel, Class 150. Flanges to be Class 150 forged steel slip-on type, or weld-neck flanges for carbon steel.

E. Pumped Condensate, 2" and smaller: ASTM A53, Grade B, ERW, schedule 80 carbon steel, with screwed joints. Fittings, unions, flanges, and couplings to be ANSI/ASTM B16.3. malleable iron, Class 150.

F. Pumped Condensate, 2-1/2" and larger: ASTM A53, Grade B, ERW, schedule 80, carbon steel, with ANSI/AWS D1.1 butt welded joints. Fittings to be ASTM A234, forged steel, Class 150. Flanges to be Class 150 forged steel slip-on type, or weld-neck flanges for carbon steel.

G. Steel Pipe Nipples: ASTM A733, made of ASTM A 53/A 53M, black steel, of same type, grade, and schedule as pipe in which installed.

2.8 UNIONS AND FLANGES:

A. Unions:

1. 2½ inches and Smaller:

a. Forged steel, ASTM A105 Grade 2, ASME B16.11, socket weld, 3000 lb. WOG with steel to steel seats.

B. Flanges:

1. 3 inches and Larger:

a. ASTM A105, ANSI B16.5, hot forged steel flanges, welding neck pattern. Slip-on pattern flanges are not allowed. Bore dimension of welding neck flange shall match inside diameter of connected pipe. Use raised face flanges for mating with other raised face flanges with self-centering flat ring gaskets. Use flat face flanges for mating with other flat face flanges with full face gaskets.

2. Flange pressure class indicated in respective piping service is minimum required. Mating flange pressure class shall match pressure class of device connected to such as valves and piping specialties. Flanged connection will on be permitted at specialty connections such as at a vessel or specialty valve.

C. Flange Gaskets:

1. Gasket material to be asbestos free and suitable for pressure temperatures and fluid of piping system. Non-metallic gaskets shall be in accordance with ANSI/ASME B16.21 and ASTM F104.
2. Gaskets shall be equal to Flexitallic Style CG, graphite filler, 304 SS winding, carbon steel centering ring, 0.175” thickness.

D. Bolting:

1. For all connections to valves, use bolts studs.
2. Bolts, bolt studs, nuts and washers used on piping systems in CUP, tunnel and manholes shall have zinc plated finish.
3. Thread shall be in accordance with ANSI/ASME B1.1, Class 2A tolerance for external threads and Class 2B tolerance for internal threads. Threads shall be coarse-thread series except that alloy steel bolting 1-1/8” and larger in diameter shall be 8 pitch thread series.
4. Threaded rods are not allowed as fastening elements on steam systems.
5. For Class 150 and Class 300 flanges at 400°F or lower temperature, use carbon steel bolts or stud bolts conforming to ASTM A307, Grade B with nuts conforming to ASTM A307.
6. For Class 300 flanges at 500°F or lower temperature, use alloy steel bolts or stud bolts conforming to ASTM A193, Grade B7 or B16, with nuts conforming to ASTM A194, Grade 2H.

2.9 VALVES – GENERAL:

A. General: Install valves as shown on plans, details and according to the valve manufacturer’s installation recommendations.

B. Provide chain operators for manually operated valves 4” and larger, located more than 8’-0” above normal working surface.

2.10 HIGH PRESSURE STEAM, PUMPED CONDENSATE, AND STEAM TRAP CONDENSATE SYSTEM VALVES (100 TO 230 PSIG/450°F):

A. Isolation Valves:

1. High pressure steam and condensate isolation valves shall be ANSI Class 300.

a. Up thru 2½ inches:

1) Description: Ball, full port, carbon steel body, 316 SS ball & stem, “Xtreme” seats & PTFE seals or reinforced PTFE seats & seals, rated for 300 psi at 600°F, threaded end connections, 4” steam extension, Jamesbury: ASTM A193 Grade B7 bolts with ASTM A194 Grade 2H nuts.
2) Manufacturer and Model No.:

a) Apollo 83-540-64-04.
b) Jamesbury 4BX-22236XT-1.

b. 3 inches and Larger:

1) Description: Butterfly ANSI Class 300, rated for 300 psi at 600°F, lugged, carbon steel body as follows:

a) Disc: Stainless steel or carbon steel
b) Seat: laminated Type 321 SS & graphic disc seat, or carbon steel body with a SS welded overlay for the body seat.
c) Shaft: A276 Type 431 stainless steel shaft.
d) Bi-directional dead end.
e) Valve shall be triple offset.
f) Valve shutoff shall be ANSI Class IV.
g) All valves shall have a manual-gear actuator.
h) All valves located more than 8 ft. above the equipment room floor shall have a chain wheel.

2) Manufacturer and Model No:

a) Zwick A1-YZA11AG.

2. Prior to shipment, valves to be hydrostatically and leak tested at the factory. Factory hydrostatic test shall be performed at 300 psig for all valves.

a. NU and Architect/Engineer shall have option to be present to witness factory testing for the first valves that are 2½" and smaller and the first valves that are 3" and larger. Valve manufacturer shall be responsible for providing transportation and accommodations for two (2) NU representatives and one (1) representative of the Architect/Engineer.

B. Swing Check Valves:

1. 2" and Smaller: ASTM B62, cast steel body, threaded ends, regrinding, Y-pattern swing type, renewable TFE seat disc, Class 300 (300 psi WOG), conforming to MSS SP-80.

C. Globe Valves:

1. 2" and Smaller: ANSI Class 600, steel body, stainless steel disc & seat ring, threaded ends.
2. 2½" and Larger: ANSI Class 300, steel body, stainless steel disc & seat ring, butt weld ends, constructed in accordance with ASME B16.34

D. Pressure Equalizing Valves

1. Use 1-1/4" globe valve for use on valves 3" and 4" valves.
2. Use 1½" globe valve for use on valves 6" to 10".
3. Use 2" globe valves for use on valves larger than 12".

E. Drain Valves:

1. Gate valves as specified above with hose thread adapter and cap. Provide 1" minimum drain valve except strainer blowdown valves to be blowdown connection size. Drain valves shall be provided with short threaded nipple and cap.

2.11 VALVES AND SPECIALTIES FOR LP STEAM AND CONDENSATE PIPING

A. See Section 23 2216.

2.12 JOINING MATERIALS

A. Gaskets:

1. Suitable for chemical and thermal conditions of piping system contents.
2. Anti-Seize compound, if required, shall be Loctite C5-A Copper Based or approved equal.
3. High Pressure Steam and Condensate Piping: Flexitallic spiral wound gaskets Class 150, ASME B16.20 with 304 SS metal winding strip and Flexicarb flexible graphite filler material; or approved equal.
4. Low Pressure Steam and Condensate Piping: Flexitallic spiral wound gaskets Class 150, ASME B16.20 with 304 SS metal winding strip and Flexicarb flexible graphite filler material, Graphonic corrugated metal gaskets Class 150 with 316 SS metal core and flexible graphite sealing element; or approved equal.

B. Joint Sealers:

1. Use a pipe compound approved for the type of service.
2. All purpose PTFE soft-set thread sealing compound. Jomar "Gimmie The White Stuff", Rectorseal No. 5, or approved equal.

C. Flange Bolts and Nuts: Unless required otherwise, conform to ASTM A-354 Grade BD and SAE J-429 Grade 8 for steam and condensate application.

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

E. 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.

2.13 CHAINWHEELS

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

1. Babbitt Steam Specialty Co.
2. Roto Hammer Industries.
3. Trumbull Industries.

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

1. Brackets: Type, number, size, and fasteners required to mount actuator on valve.
2. Attachment: For connection to valve stems.
3. Sprocket Rim with Chain Guides: Ductile iron, of type and size required for valve. Include zinc coating.
4. Chain: Hot-dip, galvanized steel, of size required to fit sprocket rim and long enough to reach from particular valve height to 3' from finished floor.

PART 3 - EXECUTION

3.1 STEAM PIPING APPLICATIONS

A. See PART 2 above.

3.2 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. Air-Vent Piping:

1. Inlet: Same as service where installed.
2. Outlet: Type Kannealed-temper copper tubing with soldered or flared joints.

C. Vacuum-Breaker Piping: Outlet, same material as service where installed.

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.

E. As detailed on drawings, install manual pressure relief assemblies to allow safer access to system components for servicing. Assemblies to be made up of tees, nipples, ball valves, and strainers with nipple and cap.

3.3 VALVE APPLICATIONS

A. As shown and detailed, and as called out in conjunction with Section 23 2216.

B. First isolation valves off of mains to be high performance, triple offset butterfly valves. Downstream from these points for isolation, non-high performance valves may be used.

3.4 PIPING INSTALLATION

A. Refer to Division 23 Section “Common Work Results for HVAC” for basic installation requirements.

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

C. 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 mechanical rooms and service areas at right angles or parallel to building walls. Diagonal runs are prohibited unless otherwise indicated.

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

F. Install piping to permit valve and trap servicing (minimum 14" unobstructed area around traps).

G. Install piping free of bends and sags.

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

I. Install piping to allow installation 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, properly rated NPS 3/4 full port ball valve, and short NPS 3/4 threaded nipple with cap, at low points in piping system mains an elsewhere as required for system drainage.

M. Install piping, as well as expansion loops, guides and anchors, to allow controlled movement of piping systems and components, and to minimize stresses from same.

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, at a 45 degree angle.

R. Install properly rated unions in piping, NPS 2 and smaller, adjacent to valves, at final connections of equipment, and elsewhere as indicated.

S. Install properly rated flanges in piping, NPS 2-1/2 and larger, at final connections of equipment and elsewhere as indicated.

T. Install properly rated 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 blow-off connection for strainers smaller than NPS 2.

U. Strainers ahead of steam pressure regulating and control valves shall be mounted on the side and have blow-off valves.

V. Install properly rated strainers installed ahead of traps on steam main drip legs.

W. Identify piping as specified in Division 23 Section "Mechanical Systems Identification."

X. Install valved steam system warm-up assemblies as shown and as detailed.

Y. 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 150 feet.
2. Size drip legs same size as main. In steam mains NPS 6and larger, drip leg size can be reduced, but to no less than NPS 4.
3. Install dirt pockets of the drip legs and strainer blow downs with gate valves to remove dirt and scale.

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 of Section 23 0553 "Mechanical Systems Identification" for identifying piping.

BB. Install sleeves for piping penetrations of walls, floors, and ceilings. Comply with requirements for sleeves specified in ***Section 23 0517 "Sleeves and Sleeve Seals for HVAC Piping."***

CC. Install sleeve seals for piping penetrations of concrete walls, floors, and slabs. Comply with requirements for sleeves specified in ***Section 23 0517 "Sleeves and sleeve Seals for HVAC Piping."***

DD. 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 PIPE JOINT CONSTRUCTION

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

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

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

D. 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.

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

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

G. Welded Steel Pipe:

1. All welding shall be done in accordance with the ANSI B-31.1 and the ASME welding code.

2. Pipe ends on welded pipe lines shall be suitably beveled to permit butt-welding.
3. All welds shall be of sound metal thoroughly fused to the base metal and penetrating to the bottom of the joints.
4. Use welding bends in changing pipe directions. Mitered joints will not be accepted.
5. Welders shall be experienced in the type of work to be done. Any welder, who, in the opinion of the Architect/Engineer or Construction Representative, is not competent to perform the work required, shall be dismissed from the job. At no time shall any welder not approved by the Architect/Engineer be allowed to weld pipe on the project.
6. All welders shall be certified under the procedure of the ANSI B-31.1 and the ASME Welding Code, Section 9, for the thickness and type of high pressure piping and equipment they work on. Tests shall be conducted by Hartford Insurance Co., or equivalent certifying agency. The Engineer shall be sent a copy of the certification of all welders employed on the project.

3.6 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 vacuum breakers downstream from control valve, close to coil inlet connection.

D. Install bypass piping with globe valve around control valves. If parallel valves are installed, only one bypass is required.

E. Install a drip leg at coil outlet.

3.7 FIELD QUALITY CONTROL

A. Prepare steam and condensate piping according to ASME B31.1, "Power Piping" and/or ASME B31.9, "Building Services Piping," as applicable, 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.

B. Test steam and condensate piping according to ASME B31.1, "Power Piping" and/or ASME B31.9, "Building Services Piping," as applicable, and as follows:

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.

C. Prepare written report of testing.

END OF SECTION 23 2213

SECTION 23 2216 - STEAM PIPING SPECIALTIES

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

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

1.2 SUMMARY

A. This Section includes the following for LP (Low Pressure) and HP (High Pressure) steam and condensate piping:

1. Butterfly valves.
2. Check valves.
3. Chainwheels.
4. Strainers.
5. Safety valves.
6. Pressure regulating/reducing valves.
7. Sound attenuators.
8. Steam traps.
9. Thermostatic air vents and vacuum breakers.
10. Pressure gages and gage attachments.
11. Condensate receiver sets.
12. Drip pan elbows.
13. Steam and condensate meters.

1.3 DEFINITIONS AND CAMPUS STEAM SYSTEM INFORMATION

A. HP Steam Systems: High-pressure piping operating at more than 15 psig as required by ASME B31.1.

B. LP Steam Systems: Low-pressure piping operating at 15 psig or less as required by ASME B31.9.

C. For the Evanston campus, central steam is distributed at 150 psig (known as the "Campus Line"), and at 230 psig. These are distinct piping systems but they both originate from the same high pressure header in the CUP. Steam is and needs to be metered and reduced in pressure after entrance of each building as required. On the condensate return side, there is high pressure condensate return and pumped condensate return.

D. For the Chicago campus, central steam is distributed at 170 psig. Steam is and needs to be metered and reduced in pressure after entrance of each building as required.

E. Both campus's utilize direct buried piping and piping run through tunnels.

1.4 PERFORMANCE REQUIREMENTS

A. Components and installation shall be capable of withstanding the following minimum working pressures and temperatures:

1. HP Steam Piping: ***XXX*** psig and ***XXX***F.
2. LP Steam Piping: ***XX*** psig and 300F.
3. LP Condensate Piping: ***XX*** psig at 250 deg F.
4. HP Condensate Piping: ***XX*** psig at ***XXX*** deg F.
5. Blowdown-Drain Piping: Equal to pressure of the piping system to which it is attached.
6. Air-Vent and Vacuum-Breaker Piping: Equal to pressure of the piping system to which it is attached.
7. Safety Valve Inlet and Outlet Piping: Equal to pressure of the piping system to which it is attached.

1.5 SUBMITTALS

A. Product Data: For each type of the following:

1. All valves and chainwheels.
2. Steam traps.
3. Air vents and vacuum breakers.
4. Meters, gages, and gage attachments.
5. Strainers.
6. Condensate receiver sets.
7. Drip pan elbows.
8. Sound attenuators.

B. Shop Drawings: Detail condensate receiver set installations, steam pressure reducing valve and station assemblies, and sound attenuator installations.

C. Field quality-control test reports.

D. Operation and Maintenance Data: For all valves, steam traps, air vents, vacuum breakers, strainers, condensate receiver sets, sound attenuators, and meters to include in emergency, operation, and maintenance manuals.

E. Coordination Drawings (For Use Amongst the Contractors and For Owner Reference, Not for Engineer Approval): 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. Other building services.
2. Lighting.
3. Structural members.
4. Supports.

F. Welding certificates (For Information).

G. Field quality-control test reports (For Information).

H. Delegated-Design Submittal (For Use Amongst the Contractors and For Owner Reference, Not for Engineer Approval):

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 penetration and firestopping for fire- and smoke-rated wall and floor and ceiling assemblies.

I. Northwestern University Maintenance Requirement Forms, see Division 01.

1.6 QUALITY ASSURANCE

A. ASME Compliance: Comply with ASME B31.1, “Power Piping” and 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.

B. Pipe Welding: Qualify processes and operators according to the following:

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

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

D. Piping materials shall bear label, stamp, or other markings of specified testing agency.

E. Comply with FM Global requirements for pressure vessels and piping and for pressure relief devices.

PART 2 - PRODUCTS

2.1 HIGH-PERFORMANCE BUTTERFLY VALVES

A. Class 300, Single-Flange, Triple Offset, High-Performance Butterfly Valves:

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

   a. Zwick.

2. Description:

   a. Standard: MSS SP-68.
   b. CWP Rating: 720 psig at 100 deg F.
   c. Body Design: Triple offset, lug type; suitable for bidirectional dead-end service at rated pressure without use of downstream flange.
   d. Body Material: Carbon steel or stainless steel as called for in PART 3.
   e. Seat: Metal.
   f. Stem: Stainless steel; offset from seat plane.
   g. Disc: Stainless steel/ENP.

h. Service: Bidirectional.

2.2 CHECK VALVES

A. Up To and Including 2 Inch:

1. Class 800:

a. Manufacturers:

1) Kitz (Preferred).
2) Aloyco.
3) Smith.

b. Description: ASME B16.34, Class 800, ASTM A105/A105M forged steel body, conventional port, horizontal type, bolted bonnet, piston check, spiral wound gasket, 13 percent chromium stainless steel hard faced seats, threaded or socket weld ends to match adjacent piping.

B. Over 2 Inch:

1. Class 150:

a. Manufacturers:

1) Crane Valves; 147.
2) Smith.
3) Velan; F-0114C-02TY.

b. Description: ASME B16.34, Class 150, ASTM A216/A216M Grade WCB cast steel body, bolted bonnet, swing check, 13 percent chromium stainless steel hard faced seats, flanged ends.

c. Accessories (Where Indicated):

1) Tapped drain hole(s).

2. Class 300:

a. Manufacturers:

1) Crane Valves; 159.
2) Smith.

b. Description: ASME B16.34, Class 300, ASTM A216/A216M Grade WCB cast steel body, bolted bonnet, swing check, 13 percent chromium stainless steel hard faced seats, flanged ends.

c. Accessories (Where Indicated):

1) Tapped drain hole(s).

2.3 CHAINWHEELS

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

1. Babbitt Steam Specialty Co.
2. Roto Hammer Industries.
3. Trumbull Industries.

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

1. Brackets: Type, number, size, and fasteners required to mount actuator on valve.
2. Attachment: For connection to valve stems.
3. Sprocket Rim with Chain Guides: Ductile iron, of type and size required for valve. Include zinc coating.
4. Chain: Hot-dip, galvanized steel, of size required to fit sprocket rim and long enough to reach from particular valve height to 3' from finished floor.

2.4 STRAINERS

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

1. Keckley.

B. LP 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 strainers NPS 2and smaller; flanged ends for strainers NPS 2-1/2and larger.
3. Strainer Screen: Monel metal or stainless-steel, 0.033” dia. for steam and 0.045” for condensate. Free area through the screen shall be at least 2-1/2 times the pipe area in which it is installed.
4. CWP Rating: 250-psig working steam pressure.

C. LP 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 2and smaller; flanged ends for strainers NPS 2-1/2and larger.
3. Strainer Screen: Stainless-steel, 20 mesh strainer, and perforated stainless-steel basket with 50 percent free area.
4. CWP Rating: 250-psigworking steam pressure.

D. HP Y-Pattern Strainers:

1. ASME, Class 600, cast carbon or cast alloy steel or stainless steel models, properly outfitted for the duty and with suitable end connections.

E. HP Basket Strainers:

1. ASME, Class 600, cast carbon steel or stainless steel with bolted bonnet, properly outfitted for the duty and with suitable end connections. ValvSource/Spence 150V2 or approved equal by Mueller or Sarco.

2.5 SAFETY VALVES

A. LP Bronze Safety Valves:

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

   a. Kunkle Valve; a Pentair Company; Fig. #6010
   b. Spirax Sarco, Inc.
   c. Spence

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.

B. LP Cast-Iron Safety Valves:

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

   a. Kunkle Valve; a Pentair Company; Fig. #6252
   b. Spirax Sarco, Inc.
   c. Spence

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.
8. Size and Capacity: As required for equipment according to ASME Boiler and Pressure Vessel Code.

C. HP Safety Valves:

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

   a. Kunkle Valve; a Pentair Company.
   b. Spirax Sarco, Inc.

2. ASME, cast steel or stainless steel, Series 300/600/900 by Kunkle, or equal form Sarco, properly outfitted for specific project duty.
3. Size and Capacity: As required for equipment according to ASME Boiler and Pressure Vessel Code.

2.6 PRESSURE REGULATING VALVES

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

1. Fisher 92B

B. Description: Single seated, normally closed, pilot operated, packless type, with stainless steel diaphragms, hardened seats and discs, and stainless steel stems.

C. Factory set for inlet and outlet pressures indicated.

D. Rated for specific project application as far as maximum working pressures and temperatures.

E. Limit inlet velocity to 10,000 FPM, and exit velocity to 30,000 FPM.

F. Maximum sound Pressure Level: 92 dBA.

G. Pilot: Externally-mounted for valves 6" and larger, and top or externally-mounted for 5" and smaller.

H. Body: Cast iron or ductile iron for LP, cast steel or ductile iron for HP.

I. End Connections: Threaded connections for valves NPS 2 and smaller and flanged connections for valves NPS 2-1/2 and larger.

J. Trim: Hardened stainless steel.

K. Head and Seat: Replaceable, main head stem guide fitted with flushing and pressure-arresting device cover over pilot diaphragm.

L. Gaskets: Non-asbestos materials.

2.7 SOUND ATTENUATORS

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

1. Fisher, Whisperdisc.
2. Spirax Sarco, Inc.

B. Description: Dissipative reactive type to provide maximum sound attenuation for each individual application, with minimal pressure drop.

C. Noise suppressor: Consist of a welded steel expanded outlet shell suitable for up to 300 psig steam maximum working pressure, containing a deflector assembly and acoustic packing of stainless steel.

D. Muffling orifice(s): Consist of a steel plate with primary orifices to which is welded a stainless steel plate with secondary orifices.

E. Acoustic blankets: Teflon coated fiberglass jacket with fiberglass insulation.

2.8 STEAM TRAPS

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

1. Armstrong.

B. LP Float and Thermostatic Steam Traps:

1. Cast iron body and cover, non-asbestos gasket, screwed ends, stainless steel heads, seats and thermostatic air vent.
2. Basis of Design: Armstrong – Models as commonly used on campus. Confirm with EVENG shop.

C. LP Inverted Bucket Steam Traps:

1. Cast iron body and cover, threaded connections, stainless steel bucket, renewable hardened stainless steel head and seat.
2. Basis of Design: Armstrong – Models as commonly used on campus. Confirm with EVENG shop.

D. HP Float and Thermostatic Steam Traps:

1. Cast steel body and cover, non-asbestos gasket, ends as needed, stainless steel heads, seats and thermostatic air vent.
2. Basis of Design: Armstrong – Models as commonly used on campus. Confirm with EVENG shop.

E. HP Inverted Bucket Steam Traps:

1. Cast steel or stainless steel, connections as required, stainless steel bucket, renewable hardened stainless steel head and seat.
2. Basis of Design: Armstrong models as commonly used on Campus, confirm with HVAC Shop.

F. LP and HP Thermodynamic Traps (To be used to drip/drain all mains):

1. ASTM A743 GR. CA40F 420F, stainless steel, 600 psig PMO, NPT connections.
2. Spirax Sarco TD-52.

2.9 THERMOSTATIC AIR VENTS AND VACUUM BREAKERS

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

1. Armstrong International, Inc.
2. Hoffman Specialty; Division of ITT Industries.
3. Spirax Sarco, Inc.
4. Watson McDaniel.

B. Thermostatic Air Vents:

1. Body: Cast iron, bronze or stainless steel.
2. End Connections: Threaded.
3. Float, Valve, and Seat: Stainless steel.
4. Thermostatic Element: Phosphor bronze bellows in a stainless-steel cage.
5. Basis of Design: Cast bronze Armstrong TV-2's for lower pressures, stainless steel Armstrong TTF's for higher pressures.

C. Vacuum Breakers:

1. Body: Stainless steel.
2. End Connections: Threaded.
3. Stainless steel fitted.
4. Basis of Design: Watson McDaniel WVBSS.

2.10 PRESSURE GAGES

A. Direct-Mounted, Metal-Case, Dial-Type Pressure Gages:

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

    a. Trerice, H. O. Co.
    b. Weiss Instruments, Inc.
    c. Weksler.

2. Standard: ASME B40.100.
3. Case: Sealed type(s); cast aluminum, stainless or drawn steel; 4-1/2-inch nominal diameter.
4. Pressure-Element Assembly: Bourdon tube unless otherwise indicated.
5. Pressure Connection: Brass, with NPS 1/4 or NPS 1/2 (DN 8 or DN 15), ASME B1.20.1 pipe threads and bottom-outlet type unless back-outlet type is indicated.
6. Movement: Mechanical, with link to pressure element and connection to pointer.
7. Dial: Non-reflective aluminum with permanently etched scale markings graduated in psi and kPa.
8. Pointer: Dark-colored metal.
9. Window: Glass.
10. Ring: Stainless steel.
11. Accuracy: Grade A, plus or minus 1 percent full scale.

2.11 GAGE ATTACHMENTS

A. Snubbers: ASME B40.100, brass; with NPS 1/4 or NPS 1/2 (DN 8 or DN 15), ASME B1.20.1 pipe threads and porous-metal-type surge-dampening device. Include extension for use on insulated piping.

B. Siphons: Loop-shaped section of stainless-steel or steel pipe with NPS 1/4 or NPS 1/2 (DN 8 or DN 15) pipe threads.

C. Valves: Brass ball, with NPS 1/4 or NPS 1/2 (DN 8 or DN 15), ASME B1.20.1 pipe threads.

2.12 STEAM CONDENSATE RECEIVER SET WITH DUPLEX CENTRIFUGAL PUMPS AND FLOOR-MOUNTED RECEIVER (FOR NORMAL DUTY)

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

1. ITT Hoffman.

B. Description: Factory-fabricated, packaged, electric-driven pumps; with receiver, pumps, controls, low inlet, 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. Primed and painted or coated steel.
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. Inlet vent and an overflow.
9. Cast-iron inlet strainer with self-cleaning bronze screen and large dirt pocket.
10. Inlet centerline no higher than 7" above mounting surface.

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.
7. Each pump sized for maximum load.
8. NPSH: Maximum 2'.

F. Motors:

1. Comply with NEMA designation, temperature rating, service factor, and efficiency requirements for motors specified in Section 23 0513 "Motors."
2. Enclosure: TEFC.
3. Efficiency: Meet in force energy code.
4. NEMA Design: To suit installation location.
5. Service Factor: Manufacturer's standard.
6. RPM: 1800 maximum.

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 enclosure (as properly suited for installation location) with hinged door and grounding lug, mounted on pump.
4. Motor controller for each pump.
5. Electrical pump alternator to operate pumps in lead-lag sequence and allow both pumps to operate on receiver high level.
6. Manual lead-lag control to override electrical pump alternator and manually select the lead pump.
7. Momentary-contact "TEST" push button on cover for each pump.
8. Numbered terminal strip.
9. Disconnect switch.

2.13 DRIP PAN ELBOWS

A. ASTM A126 CL B cast iron, with female NPT connections up thru 4" and ANSI 125 flanges for 6" and 8" sizes. Pipe and support as shown on drawings.

2.14 STEAM AND STEAM CONDENSATE METERS

A. Steam - All buildings that purchase steam from Northwestern University, or are research facilities with a steam turndown ratio less than 15:1, shall have a direct measurement of steam. Steam flow shall be measured using a differential pressure flow meter. Condensate meters shall also be provided in these buildings.

1. All buildings where steam is not directly measured shall have condensate metered to determine the steam usage.
2. Steam flow meters shall measure volumetric flow. The flow processor shall input the volumetric flow rate, and utilize internal steam tables and a static steam pressure sensor to determine the mass flow rate of the steam. The flow processor shall assume that the steam is saturated.

B. Steam Condensate - Condensate shall be measured using a positive displacement type meter for pipe sizes less than 1”, and a vortex shedding flow meter for pipe sizes 1” and greater. Flow Switches shall be installed on all condensate receiver drain pipes. Provide a valved (removable/lockable handle) meter bypass and a bleed-off drain pipes sizes greater than 1”.

C. Flow meters used to measure Energy Consumption or Mass Flow require a flow processor to input the flow meter and pressure sensors (steam), calculate the Energy Consumption or Mass Flow, and send a pulse output signal to the BAS that represents the results of this calculation. Spare flow processor analog outputs shall be used to output real-time flow rate and steam pressure. The Northwestern FMO Instrumentation Specialist shall define the ranges of these output(s) for proper scaling of the 4-20mA signal.

D. Differential pressure steam flow meters to be InFlow MacroFlow, McCrometer V-Cone, or approved equal. Features and performance data as follows:

1. Pipe sizes: 1/2" to 30".
2. Factory tested accuracy: ±0.5%.
3. Repeatability: ±0.1%.
4. Turndown: 30:1.
5. Input power: 24 VDC or 120 VAC.

6. Output signal: Frequency output.
7. Wetted parts: Stainless steel.
8. Body: Carbon steel.
9. Connection: ANSI 300 flanged.
10. Install requirements: 3 diameters upstream and downstream.
11. Transmitters: Two DP transmitters, Rosemount 3051 CD or Foxboro IDP10, with pipe mounting brackets, support pipes, and factory calibrated with certificates.
12. Other: No moving parts.
13. Steam usage: Pressure input used to calculate mass flow.
14. Special: Three valve manifold per transmitter, and flow processor for mass flow calculation.

E. Positive displacement impeller type condensate meters shall be Data Industrial BR-250 Tee Flow Sensor with conduit adaptor, or approved equal. Features and performance data as follows:

1. Pipe sizes: < 1".
2. Maximum fluid temperature: 300F.
3. Accuracy: ±1.0%.
4. Repeatability: ±0.7%.
5. Rangeability: 60:1.
6. Output signal: Frequency output, and include factory calibrated transmitters.
7. Body: Bronze.
8. Connection: NPT.
9. Interface: Data Industrial Model 320 with pulse signal input to BAS.
10. Special: Three valve manifold per transmitter, and flow processor for mass flow calculation.

F. Vortex Shedding Flow Meter with Integral Pressure and Temperature Measurement:

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

   a. Onicon.
   b. Krohne.

2. Description:

   a. Mass flow measurement corrected for density using vortex shedder body with integral piezoelectric pressure sensors and 1000-ohm platinum RTD.
   b. Meter NPS 1/2 through NPS 12.
   c. Each meter shall be factory calibrated at five points from Zero to 250 fps and tagged accordingly against the manufacturer's flow standards. The manufacturer shall provide a certificate of calibration for meter.
   d. Each meter shall be programmed using project-specific application data.
   e. Meter shall include integral diagnostics to verify installation conditions and proper operation.

3. Performance:

   a. Volumetric Flow Accuracy for Liquid: Within 0.75 percent of reading for Reynolds numbers 20000 and larger.
   b. Volumetric Flow Accuracy for Steam and Gas: Within 1 percent of reading for Reynolds numbers 20000 and larger.

c. Mass Flow Accuracy for Steam and Gas: Within 1.5 percent of reading for Reynolds numbers 20000 and larger.
d. Repeatability: Within 0.1 percent.
e. Long-Term Stability: Within 0.1 percent per year.
f. Ambient Temperature: Minus 40 to plus 185 deg F.
g. Process Temperature: Minus 40 to plus 464 deg F.
h. Pressure: Equal to flange rating.

4. Output Signals:

a. Analog Current Signal of Flow Rate:

1) Two-wire, 4- to 20-mA dc current source.
2) Signal capable of operating into 1000-ohm load.

b. Analog Current Signals for Pressure and Temperature: Separate 4- to 20-mA signals for gage pressure and temperature.
c. Digital Signal:

1) Pulse output for flow totalization. Two wire, scaled pulse, 0.5 Hz, 100 mA at 30-V dc.
2) Protocol: compatible with project DDC/BAS, see Section 25 0000.

5. Operator Interface:

a. Keypad.
b. Digital Display: Two-line digital display of alphanumerical characters. The meter shall display flow rate, flow totalization, pressure, temperature, and support field programming of all parameters.

6. Construction:

a. Material: Type 316L stainless steel.
b. Connection: Class 300 flange.
c. Enclosure:

1) Epoxy-painted cast aluminum.
2) Removable screw-on cover.
3) NEMA 250, Type 6.
4) Electrical Connection: Screw terminals.
5) Conduit Connection: Two, 1/2-inchtrade size.

7. Upstream Flow Straightener:

a. Meter manufacturer shall provide flow straightener where required by installation to comply with manufacturer's installation recommendations.
b. Straightener shall be wafer type, constructed of Type 304 stainless steel, designed to be installed between field-installed flanges.
c. Straightener size shall match meter size.

PART 3 - EXECUTION

3.1 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. Air-Vent Piping:

1. Inlet: Same as service where installed.
2. Outlet: Type K annealed-temper copper tubing with soldered or flared joints.

C. Vacuum-Breaker Piping: Outlet, same material as service where installed.

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.

E. Drip Pan Elbows: Pipe per drip pan elbow and safety valve manufacturer's instructions, coordinate with GC for roof penetrations.

F. As detailed on drawings, install manual pressure relief assemblies to allow safer access to system components for servicing. Assemblies to be made up of tees, nipples, ball valves, and strainers with nipple and cap.

3.2 VALVE APPLICATIONS

A. Install shutoff duty valves at branch connections to steam supply mains, at steam supply connections to equipment, at the outlet of steam traps, and as shown or noted on the drawings.

B. Install safety valves at pressure-reducing stations and elsewhere as required by ASME Boiler and Pressure Vessel Code. Comply with ASME Boiler and Pressure Vessel Code: Section VIII, Division 1, for installation requirements.

C. Install check valves at traps as detailed and as otherwise required to control flow direction.

D. For anything over 3” and 75 psi, the first isolation valves off of mains to be high performance, triple offset butterfly valves. Downstream from these points for isolation, non-high performance valves may be used.

E. Add chainwheels to valves 6" or larger and mounted 8 feet above the floor or higher. Provide gear operators for valves 8" and larger.

3.3 PIPING INSTALLATION

A. Install piping to permit valve servicing.

B. 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.

C. Install valves according to Section 23 0523 "General Duty Valves for HVAC" and per this section.

D. Install unions in piping, NPT 1-1/4 and smaller, adjacent to valves, at final connections of equipment, and elsewhere as indicated.

E. Install flanges in piping, NPS 1-1/2 and larger, at final connections of equipment and elsewhere as indicated.

F. Install shutoff valve immediately upstream of each dielectric fitting.

G. 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.

3.4 STEAM-TRAP INSTALLATION

A. Install steam traps as shown and as required in accessible locations as close as possible to connected equipment. Minimum of 14" unobstructed space around traps required.

B. Provide test port downstream of each steam trap assembly. The test port assembly is to consist of a tee, nipple, ball valve, and nipple plug. The test port assembly is to be before the check.

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. Install two full-port ball valves, union, and strainer upstream of trap; and check valve, union, and two full-port ball valves after trap.

D. All low points and drip legs in steam lines and the bottom of down feed risers shall have traps of proper size.

E. Return ends of all equipment where steam is condensed, shall have traps of proper size and type.

F. Install traps as shown and as detailed.

G. Install traps with isolation valves and unions on both sides. Ahead of each high pressure drip, install a dirt pocket not less than 8 inches long and fitted with threaded reducer, 1” rising stem valve, nipple and a threaded cap on the bottom for 2” and smaller; and with welded cap, 1” thread-o-let, isolation valve, nipple and threaded cap for 2-1/2” and larger.

H. Steam trap of temperature-regulated equipment must not be located at less than 14" below the bottom of the coil outlet, and condensate discharge from the trap must flow by gravity, without any lifts in the piping, to the condensate receiver.

3.5 PRESSURE REGULATING/REDUCING VALVE INSTALLATION (AND OTHER RELATED PIPING AND SPECIALTIES)

A. Install pressure regulating/reducing valves in accessible location for maintenance and inspection.

B. Install gate or butterfly valves on both sides of pressure-reducing valves. A warmup line shall be provided around butterfly valves where used in this application.

C. Install unions or flanges on both sides of pressure-reducing valves having threaded or flanged end connections respectively.

D. Install pressure gages on high and low-pressure sides of pressure-reducing valves (after the bypass connections) according to Division 23 Section "Meters and Gages for HVAC Piping" and this section.

E. Install strainers upstream for pressure-reducing valves. Install strainers with blow-off valves on side.

F. Install safety valves downstream from pressure-reducing valve stations.

G. Install steam noise suppressor on each pressure reducing valve.

H. Provide straight run of pipe on sides of the PRVs, at least 10 pipe diameters to the inlet and 20 pipe diameters of expanded line size from the outlet.

I. Install bypass piping around pressure regulating/reducing valves with globe valve equal in size to the pressure regulating/reducing valve seat ring, unless indicated otherwise.

J. Avoid abrupt changes in pipe size. Use eccentric reducers upstream and concentric increasers downstream of the PRVs.

3.6 AIR VENT AND VACUMM BREAKER INSTALLATION

A. Install as detailed and according to device manufacturer's instructions.

3.7 STEAM OR CONDENSATE METER INSTALLATION

A. Install meters with lengths of straight pipe upstream and downstream according to meter manufacturer's instructions.

B. Provide data acquisition wiring. See Section 25 0000.

3.8 SAFETY VALVE INSTALLATION

A. Install safety valves according to ASME B31.1, "Power Piping" and/or ASME B31.9, "Building Services Piping."

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 CONDENSATE RECEIVER SET INSTALLATION

A. Install as detailed and according to device manufacturer's instructions.

B. Coordinate any venting through roof with GC.

3.10 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 vacuum breakers downstream from control valve, close to coil inlet connection.

D. Install a drip leg at coil outlet.

3.11 FIELD QUALITY CONTROL

A. Prepare steam and condensate piping according to ASME B31.1, "Power Piping" and/or 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.

B. Perform the following tests on steam and condensate 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. 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.

C. Prepare written report of testing.

END OF SECTION 23 2213

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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.

1.2 SUBMITTALS

A. Product Data: For each type of valve and refrigerant piping specialty indicated. Include pressure drop based on manufacturer's test data.

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. 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.

C. Field quality-control test reports.

D. Operation and maintenance data.

1.3 QUALITY ASSURANCE

A. Comply with ASHRAE 15 (latest edition), "Safety Code for Refrigeration Systems."

B. Comply with ASME B31.5 (latest edition), "Refrigeration Piping & Heat Transfer Components."

C. UL 207 Refrigerant Containing Components and Accessories.

1.4 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.

1.5 INSTALLATION

A. Provide filter/dryer assemblies, moisture indicators, thermal expansion valve and solenoid valves for each refrigeration circuit.

B. Pressure test refrigerant piping system at 300 psi for high side and 150 psi for low side. Maintain pressure for a minimum of 24 hours.

C. Leak test piping and joints with an electronic or halide leak detector.

D. Evacuate entire system with an approved high vacuum pump system to 500 microns.

PART 2 - PRODUCTS

2.1 COPPER TUBE AND FITTINGS

A. Copper Tube: ASTM B 280, Type ACR.

B. Wrought-Copper Fittings: ASME B16.22.

C. Wrought-Copper Unions: ASME B16.22.

D. Brazing Filler Metals: AWS A5.8.

2.2 VALVES AND SPECIALTIES

A. To be per Manufacturer’s instructions including but not limited to the following:

1. Moisture/Liquid Indicators:
2. Replaceable-Core Filter Dryers: Comply with ARI 730.
3. Permanent Filter Dryers: Comply with ARI 730.
4. Liquid Accumulators: Comply with ARI 495.

PART 3 - EXECUTION

3.1 PIPING APPLICATIONS

A. Suction Lines, Hot Gas and Liquid Lines All Sizes to be Copper, Type ACR, annealed-temper tubing and wrought-copper fittings with brazed joints.

B. Safety-Relief-Valve Discharge Piping: Copper, Type ACR, drawn-temper tubing and wrought-copper fittings with brazed joints.

3.2 VALVE AND SPECIALTY APPLICATIONS

A. Install all valves and specialties per manufacturer’s instructions.

3.3 PIPING INSTALLATION

A. 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 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 Operations for HVAC Controls" 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 rigid or flexible conduit in locations where exposed to mechanical injury.

N. Slope refrigerant piping as follows:

1. Install horizontal hot-gas discharge piping with a uniform slope downward away from compressor.
2. Install horizontal suction lines with a uniform slope downward to compressor.
3. Install traps and double risers to entrain oil in vertical runs.
4. Liquid lines may be installed level.

O. When brazing, remove solenoid-valve coils and sight glasses; also remove valve stems, seats, and packing, and accessible internal parts of refrigerant specialties. Do not apply heat near expansion-valve bulb.

P. Install piping with adequate clearance between pipe and adjacent walls and hangers or between pipes for insulation installation. Insulate suction lines with 1.5" of flexible elastomeric insulation, and weather-proof same outdoors with two coats of insulation manufacturer's weather-proofing coating. Refer to Section 230719 for further general requirements pertaining to pipe insulation.

Q. Identify refrigerant piping and valves according to Division 23 Section "Identification for HVAC Piping and Equipment."

R. Install sleeves for piping penetrations of walls, ceilings, and floors. Comply with requirements for sleeves specified in applicable Division 23 Section. Install sleeve seals for piping penetrations of concrete walls and slabs. Comply with requirements for sleeve seals specified in applicable Division 23 Section. Install escutcheons for piping penetrations of walls, ceilings, and floors. Comply with requirements for escutcheons specified in applicable Division 23 Section.

3.4 PIPE JOINT CONSTRUCTION

A. Brazed Joints: Construct joints according to AWS's "Brazing Handbook," Chapter "Pipe and Tube."

3.5 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.

D. Support multi-floor vertical runs at least at each floor.

3.6 FIELD QUALITY CONTROL

A. Perform tests and inspections and prepare test reports.

B. Piping shall be evacuated, tested, adjusted, and charged in strict accordance with the equipment manufacturer's instructions.

END OF SECTION 23 2300

SECTION 23 2500 - PIPE CLEANING, FLUSHING AND CHEMICAL TREATMENT

PART 1 - GENERAL

1.1 SECTION INCLUDES

A. Cleaning of piping systems

1.2 REGULATORY REQUIREMENTS

A. Conform to applicable EPA code for addition of non-potable chemicals to building mechanical systems and for discharge to public sewage systems.

PART 2 - PRODUCTS

2.1 MATERIALS

A. All materials proposed must be compatible with existing treatment systems and chemicals.

B. System Cleaner:

1. Liquid alkaline compound with emulsifying agents and detergents to remove grease and petroleum products.

2.2 EQUIPMENT

A. Water Meter: Displacement type cold water meter with sealed, tamper proof magnetic drive, impulse contact register, single pole, double throw dry contact switch.

PART 3 - EXECUTION

3.1 PREPARATION

A. Systems shall be operational, filled, started and vented prior to cleaning. Use water meter to record capacity in each system.

B. Place terminal control valves in OPEN position during cleaning.

3.2 CLEANING SEQUENCE

A. Add cleaner to closed systems at concentration as recommended by manufacturer.

B. Hot Water Heating Systems: Apply heat while circulating, slowly raising temperature to 160°F and maintain for 12 hours minimum. Remove heat and circulate to 100°F or less; drain systems as quickly as possible and refill with clean water. Circulate for 6 hours at design temperatures, then drain. Refill with clean water and repeat until system cleaner is removed.

C. Chilled Water Systems: Circulate for 48 hours, then drain systems as quickly as possible. Refill with clean water, circulate for 24 hours, then drain. Refill with clean water and repeat until system cleaner is removed.

D. Steam Systems: Apply heat, slowly raising boiler temperature to 160°F and maintain for 12 hours minimum. Cool, then drain as quickly as possible. Refill with clean water, drain, refill and check for sludge. Repeat until system is free of sludge. Apply heat to produce steam for piping system and maintain for 8 hours minimum. Bypass traps and waste condensate.

E. Use neutralizer agents on recommendation of system cleaner supplier and approval of Owner.

F. Flush open systems with clean water for one hour minimum. Drain completely and refill.

G. Remove, clean and replace strainer screens.

H. Inspect, remove sludge and flush low points with clean water after cleaning process is completed. Include disassembly of components as required.

END OF SECTION 23 2500

SECTION 23 3114 - DUCTWORK

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

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

1.2 SUMMARY

A. Section Includes:

1. Single-wall rectangular ducts and fittings.
2. Double-wall rectangular ducts and fittings.
3. Single-wall round and flat-oval ducts and fittings.
4. Double-wall round and flat-oval ducts and fittings.
5. Laboratory exhaust ductwork.
6. Sheet metal materials.
7. Duct cleaning and contamination protection.
8. Sealants and gaskets.
9. Hangers and supports.

B. Related Sections:

1. Section 23 0529 "Mechanical Supporting Devices."
2. Section 23 0550 "Vibration Isolation."
3. Section 23 0553 "Mechanical Systems Identification."
4. Section 23 0594 "Testing, Adjusting, and Balancing (TAB)."
5. Section 23 0700 "Mechanical System Insulation."
6. Section 23 3314 "Ductwork Specialties" for dampers, sound-control devices, duct-mounting access doors and panels, turning vanes, flange connectors, flexible connectors, duct accessory hardware, louvers, and flexible ducts.

1.3 PERFORMANCE REQUIREMENTS

A. Delegated Duct Design: Duct construction, including sheet metal thicknesses, seam and joint construction, reinforcements, and hangers and supports, shall comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" and performance requirements and design criteria indicated in the "Duct Schedule" Article and on the drawings.

B. Structural Performance: Duct hangers and supports shall withstand the effects of gravity loads and stresses within limits and under conditions described in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

C. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.

D. SMACNA's 3rd Edition, 2005, "HVAC Duct Construction Standards - Metal and Flexible," as referenced herein.

1.4 ACTION SUBMITTALS/INFORMATION

A. Product Data: For each type of the following products:

1. Factory fabricated ductwork and fittings.
2. Factory fabricated hangers and supports.
3. Transverse joint components.
4. Sealants and gaskets.

B. Delegated-Design Information (for Contractor Use and University Reference, Not For Engineer Approval) :

1. Sheet metal thicknesses.
2. Joint and seam construction and sealing.
3. Reinforcement details and spacing.
4. Materials, fabrication, assembly, and spacing of hangers and supports.
5. Design Calculations: Calculations, including analysis data signed and sealed by the qualified professional engineer responsible for their preparation for selecting hangers and supports.

1.5 INFORMATIONAL SUBMITTALS (For Use Amongst the Contractors and For Owner Reference, Not For Engineer Approval)

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, and other building services. Indicate proposed changes to duct layout.
2. Fabrication, assembly, and installation, including plans, elevations, sections, components, and attachments to other work.
3. Factory and shop fabricated ducts and fittings.
4. Duct layout indicating sizes, configuration, liner material, and static-pressure classes.
5. Elevation of tops or bottoms of ducts.
6. Dimensions of main duct runs from building grid lines.
7. Fittings.
8. Reinforcement and spacing.
9. Seam and joint construction.
10. Penetrations through fire-rated and other partitions.
11. Equipment installation based on equipment being used on Project.
12. Locations for duct accessories, including dampers, turning vanes, and access doors and panels.
13. Hangers and supports, including methods for duct and building attachment and vibration isolation.
14. Suspended ceiling components.
15. Structural members to which duct will be attached.
16. Size and location of initial access modules for acoustical tile.
17. Penetrations of smoke barriers and fire-rated construction.
18. Items penetrating finished ceiling including the following:

a. Lighting fixtures.
b. Air outlets and inlets.
c. Speakers.
d. Sprinklers.
e. Access panels.
f. Perimeter moldings.

B. Welding certificates.

C. Field quality-control reports.

1.6 QUALITY ASSURANCE

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

1. AWS D1.1/D1.1M, "Structural Welding Code - Steel," for hangers and supports.
2. AWS D1.2/D1.2M, "Structural Welding Code - Aluminum," for aluminum supports.
3. AWS D9.1M/D9.1, "Sheet Metal Welding Code," for duct joint and seam welding.

B. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1, Section 5 - "Systems and Equipment" and Section 7 - "Construction and System Start-up."

C. ASHRAE/IESNA Compliance: Applicable requirements in ASHRAE/IESNA 90.1, Section 6.4.4 - "HVAC System Construction and Insulation."

1.7 SPECIAL WARRANTIES

A. Five (5) years, see Division 01.

PART 2 - PRODUCTS

2.1 FIBROUS GLASS (DUCTBOARD) DUCTS

A. Not allowed.

2.2 LINED DUCTWORK

A. Not allowed.

2.3 ELBOWS, TRANSITIONS, OFFSETS, BRANCH CONNECTIONS, LATERALS, AND OTHER DUCT CONSTRUCTION REQUIREMENTS

A. Fabricate and install all duct fittings, branches, inlets, outlets, transitions, take-offs, laterals, offsets, and elbows to minimize air turbulence and resistance and to ensure proper airflows.

B. Extractors and splitter dampers not allowed.

C. Elbows, Transitions, Offsets, Branch Connections, and Other Duct Construction: Select types and fabricate according to SMACNA's 2005 "HVAC Duct Construction Standards - Metal and

Flexible," Chapters 3 and 4, for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's 2005 "HVAC Duct Construction Standards - Metal and Flexible." But:

1. Mitered elbows with turning vanes not permitted, use radius elbows.
2. Radius elbows shall have minimum centerline radius to width or diameter ratio of 1.5. If 1.5 ratio elbows do not fit, use 1.0 radius elbows. Where 1.0 radius elbows do not fit, use square throat elbows with turning vanes.
3. Pleated or adjustable elbows not allowed.
4. No straight taps, branch or lateral take-offs, or connections, all to be expanded or conical, and taken off at an angle < 90° if possible.
5. No bullhead tees for either diverging or converging flow.
6. For transitions, where the shape of the duct changes, ensure the angle of the side of the transition piece does not exceed 15° from the straight run of duct connected thereto. Where equipment is installed in the ductwork, ensure the angle of the side of the transition piece from the straight run of duct connected thereto does not exceed 15° on the upstream side of the equipment and 22.5° on the downstream side of the equipment.
7. Special duct branch requirements: Where a duct branch handles over 25% of the air transported by the duct main, use a complete 90° increasing elbow, with an inside radius of 0.75 times the duct branch width. Ensure the size of the trailing end of the increasing elbow within the duct main is in the same ratio to the main duct size as the ratio of the relative air quantities being handled. Where a duct branch is to handle 25% or less of the air handled by the duct main, provide a branch connection with an inside radius of 0.75 times the branch duct width, a minimum arc length of 45°, and an outside radius of 1.75 times the duct branch width. Place arc tangent to the duct main.
8. Saddle taps are not allowed on new or existing ducts.
9. See more information and requirements in PART 3 herein.

2.4 SINGLE-WALL RECTANGULAR DUCTS AND FITTINGS

A. General Fabrication Requirements: Comply with SMACNA's 2005 "HVAC Duct Construction Standards - Metal and Flexible" based on indicated static-pressure class unless otherwise indicated. But, duct wall thickness to be minimum 22 gage except where any welding other than longitudinal seams is performed, then the minimum thickness shall be 18 gage, and, no crimp joints allowed.

B. Transverse Joints: Select joint types and fabricate according to SMACNA's 2005 "HVAC Duct Construction Standards - Metal and Flexible," Figure 2-1, "Rectangular Duct/Transverse Joints," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible." But, transverse (girth) joints T-4, 9, 17 through 20, and 23 not permitted.

C. Longitudinal Seams: Select seam types and fabricate according to SMACNA's 2005 "HVAC Duct Construction Standards - Metal and Flexible," Figure 2-2, "Rectangular Duct/Longitudinal Seams," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible." But, button punch snaplock seams are not permitted.

2.5 DOUBLE-WALL RECTANGULAR DUCTS AND FITTINGS

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

1. McGill AirFlow LLC.
2. SEMCO.

B. General Fabrication Requirements: Comply with SMACNA's 2005 "HVAC Duct Construction Standards - Metal and Flexible" based on indicated static-pressure class unless otherwise indicated. Duct wall thickness to be minimum 22 gage except where any welding other than longitudinal seams is performed, then the minimum thickness shall be 18 gage.

C. Contractor Fabricated Ductwork: Ductwork of this section (2.5) may be fabricated by the contractor if it can be demonstrated that it meets or exceeds the performance of the manufacturer's products listed directly above.

D. Rectangular Ducts: Fabricate ducts with indicated dimensions for the inner duct. But, duct wall thicknesses to be minimum 22 gage except where any welding other than longitudinal seams is performed, then the minimum thickness shall be 18 gage.

E. Outer Duct: Comply with SMACNA's 2005 "HVAC Duct Construction Standards - Metal and Flexible" based on indicated static-pressure class unless otherwise indicated.

F. Transverse Joints: Select joint types and fabricate according to SMACNA's 2005 "HVAC Duct Construction Standards - Metal and Flexible," Figure 2-1, "Rectangular Duct/Transverse Joints," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible." But, transverse (girth) joints T-4, 9, 17 through 20, and 23 not permitted.

G. Longitudinal Seams: Select seam types and fabricate according to SMACNA's 2005 "HVAC Duct Construction Standards - Metal and Flexible," Figure 2-2, "Rectangular Duct/Longitudinal Seams," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible." But, button punch snaplock seams are not permitted.

H. Interstitial Insulation: Fibrous-glass liner complying with ASTM C 1071, NFPA 90A, or NFPA 90B; and with NAIMA AH124, "Fibrous Glass Duct Liner Standard."

1. Maximum Thermal Conductivity: 0.27 Btu x in./h x sq. ft. x deg F (0.039 W/m x K) at 75 deg F mean temperature.
2. Install spacers that position the inner duct at uniform distance from outer duct without compressing insulation.
3. Coat insulation with antimicrobial coating.
4. Cover insulation with polyester film complying with UL 181, Class 1.
5. Insulation Thickness: See PART 3.

I. Inner Duct: Minimum 0.028-inch thick solid sheet galvanized steel.

J. Formed-on Transverse Joints (Flanges): Select joint types and fabricate according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 2-1, "Rectangular Duct/Traverse Joints," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's 2005 "HVAC Duct Construction Standards - Metal and Flexible." But, transverse (girth) joints T-4, 9, 17 through 20, and 23 not permitted.

2.6 SINGLE-WALL ROUND AND FLAT-OVAL DUCTS AND FITTINGS

A. General Fabrication Requirements: Comply with SMACNA's 2005 "HVAC Duct Construction Standards - Metal and Flexible," Chapter 3, "Round, Oval, and Flexible Duct," based on indicated static-pressure class unless otherwise indicated but, only spiral seam or fully welded longitudinal seam duct is to be used. And, longitudinal seam ductwork not to be used if exposed.

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

a. McGill AirFlow LLC.
b. SEMCO Incorporated.
c. Spiral Manufacturing Co., Inc.

B. Contractor Fabricated Ductwork: Ductwork of this section (2.6) may be fabricated by the contractor if it can be demonstrated that it meets or exceeds the performance of the manufacturer's products listed directly above.

C. Flat-Oval Ducts: Indicated dimensions are the duct width (major dimension) and diameter of the round sides connecting the flat portions of the duct (minor dimension). SMACNA Type 1 reinforcement (Figure 3-6 of SMACNA's Duct Construction Standards) is not allowed.

D. Transverse Joints: Select joint types and fabricate according to SMACNA's 2005 "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-1, "Round Duct Transverse Joints," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's 2005 "HVAC Duct Construction Standards - Metal and Flexible." But, no crimp joints allowed.

1. Transverse Joints in Ducts Larger Than 60 Inches in Diameter: Flanged.

E. Longitudinal Seams: Select seam types and fabricate according to SMACNA's 2005 "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-2, "Round Duct Longitudinal Seams," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's 2005 "HVAC Duct Construction Standards - Metal and Flexible." But, snaplock seams not allowed.

1. Fabricate round ducts larger than 90 inches in diameter with butt-welded longitudinal seams.
2. Fabricate flat-oval ducts larger than 72 inches in width (major dimension) with butt-welded longitudinal seams.

2.7 DOUBLE-WALL ROUND AND FLAT-OVAL DUCTS AND FITTINGS

A. General Fabrication Requirements: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Chapter 3, "Round, Oval, and Flexible Duct," based on indicated static-pressure class unless otherwise indicated but, only spiral seam or fully welded longitudinal seam duct is to be used. And, longitudinal seam ductwork not to be used if exposed.

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

a. McGill AirFlow LLC.
b. SEMCO Incorporated.
c. Spiral Manufacturing Co., Inc.

B. Contractor Fabricated Ductwork: Ductwork of this section (2.7) may be fabricated by the contractor if it can be demonstrated that it meets or exceeds the performance of the manufacturer's products listed directly above.

C. Flat-Oval Ducts: Indicated dimensions are the duct width (major dimension) and diameter of the round sides connecting the flat portions of the duct (minor dimension) of the inner duct. SMACNA Type 1 reinforcement (Figure 3-6 of SMACNA's Duct Construction Standards) is not allowed.

D. Outer Duct: Comply with SMACNA's 2005 "HVAC Duct Construction Standards - Metal and Flexible," Chapter 3, "Round, Oval, and Flexible Duct," based on static-pressure class unless otherwise indicated.

E. Transverse Joints: Select joint types and fabricate according to SMACNA's 2005 "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-1, "Round Duct Transverse Joints," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's 2005 "HVAC Duct Construction Standards - Metal and Flexible." And, no crimp joints allowed.

1. Transverse Joints in Ducts Larger Than 60 Inches in Diameter: Flanged.

F. Longitudinal Seams: Select seam types and fabricate according to SMACNA's 2005 "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-2, "Round Duct Longitudinal Seams," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's 2005 "HVAC Duct Construction Standards - Metal and Flexible." But, no snaplock seams allowed.

1. Fabricate round ducts larger than 90 inches in diameter with butt-welded longitudinal seams.
2. Fabricate flat-oval ducts larger than 72 inches in width (major dimension) with butt-welded longitudinal seams.

G. Inner Duct: Minimum 0.028-inch thick solid sheet steel. Factory fabricated, insulated round duct to be McGill Airflow, Acoustic K-27, or approved equal by SEMCO or Spiral Manufacturing Co., Inc.

H. Interstitial Insulation: Fibrous-glass liner complying with ASTM C 1071, NFPA 90A, or NFPA 90B; and with NAIMA AH124, "Fibrous Glass Duct Liner Standard."

1. Maximum Thermal Conductivity: 0.27 Btu x in./h x sq. ft. x deg F (0.039 W/m x K) at 75 deg F mean temperature.
2. Install spacers that position the inner duct at uniform distance from outer duct without compressing insulation.
3. Thickness for ducts inside the building minimum 1.5", 3" thickness for ducts outside.

2.8 LABORATORY EXHAUST DUCTWORK

A. Ductwork and shall be all welded Type 316 stainless steel, minimum 18 gage.

2.9 SHEET METAL MATERIALS

A. General Material Requirements: Comply with SMACNA's 2005 "HVAC Duct Construction Standards - Metal and Flexible" for acceptable materials, material thicknesses, and duct construction methods unless otherwise indicated. Duct wall thickness to be minimum 22 gage except where any welding other than longitudinal seams is performed, then the minimum thickness shall be 18 gage.

B. Sheet metal materials shall be free of pitting, seam marks, roller marks, stains, discolorations, and other imperfections.

C. Galvanized Sheet Steel: Comply with ASTM A 653/A 653M.

1. Galvanized Coating Designation: G90 (Z275).
2. Finishes for Surfaces Exposed to View: Mill phosphatized.

D. Stainless-Steel Sheets: Comply with ASTM A 480/A 480M, Type 304 or 316 (Type 316 only for Lab exhaust), as indicated in the "Duct Schedule" Article; cold rolled, annealed, sheet. Exposed surface finish shall be No. 2B, No. 2D, No. 3, or No. 4 as indicated in the "Duct Schedule" Article.

E. Aluminum Sheets: Comply with ASTM B 209 (ASTM B 209M) Alloy 3003, H14 temper; with mill finish for concealed ducts, and standard, one-side bright finish for duct surfaces exposed to view.

F. Reinforcement Shapes and Plates for Galvanized Ducts: ASTM A 36/A 36M, steel plates, shapes, and bars; black and galvanized.

1. Where black and galvanized-steel shapes and plates are used to reinforce aluminum or stainless steel ducts, isolate the different metals with butyl rubber, neoprene, or EPDM gasket materials.

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.

2.10 SEALANT AND GASKETS

A. General Sealant and Gasket Requirements: Surface-burning characteristics for sealants and gaskets shall be a maximum flame-spread index of 25 and a maximum smoke-developed index of 50 when tested according to UL 723; certified by an NRTL.

B. Water-Based Joint and Seam Sealant:

1. Application Method: Brush on.
2. Solids Content: Minimum 65 percent.
3. Shore A Hardness: Minimum 20.
4. Water resistant.
5. Mold and mildew resistant.
6. VOC: Maximum 75 g/L (less water).
7. Maximum Static-Pressure Class: 10-inch wg (2500 Pa), positive and negative.
8. Service: Indoor or outdoor.
9. Substrate: Compatible with galvanized sheet steel (both PVC coated and bare), stainless steel, or aluminum sheets.

C. Solvent-Based Joint and Seam Sealant:

1. Application Method: Brush on.
2. Base: Synthetic rubber resin.
3. Solvent: Toluene and heptane.
4. Solids Content: Minimum 60 percent.
5. Shore A Hardness: Minimum 60.
6. Water resistant.
7. Mold and mildew resistant.
8. For indoor applications, sealant shall have a VOC content of 250 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
9. VOC: Maximum 395 g/L.
10. Maximum Static-Pressure Class: 10-inch wg (2500 Pa), positive or negative.
11. Service: Indoor or outdoor.
12. Substrate: Compatible with galvanized sheet steel (both PVC coated and bare), stainless steel, or aluminum sheets.

D. Flanged Joint (SMACNA Joints T-24, T-25, and proprietary slip-on flanges) Sealant: Comply with ASTM C 920.

1. General: Single-component, acid-curing, silicone, elastomeric.
2. Type: S.
3. Grade: NS.
4. Class: 25.
5. Use: O.
6. For indoor applications, sealant shall have a VOC content of 250 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).

E. Flange Gaskets: Butyl rubber, neoprene, or EPDM polymer with polyisobutylene plasticizer.

F. Pressure Sensitive Tapes for Primary Sealing of Ducts: Not allowed.

G. Duct Sealer Manufacturers/Products: United Airseal - United Duct Seal, Mon-Eco Industries 44/48, or Foster 32.

H. Lab Exhaust Duct/System Sealant: For any non-welded joints or connections, sealants shall be custom selected for the duty, including proper chemical resistance against whatever is to be transported in the duct system.

2.11 HANGERS AND SUPPORTS

A. Shall be in accordance with SMACNA's 2005 "HVAC Duct Construction Standards - Metal and Flexible" except non-engineered wire hangers are not permitted. Engineered cable support systems may be used if they meet SMACNA, Ductmate or approved equal.

B. Hanger Rods for Noncorrosive Environments: Cadmium-plated steel rods and nuts.

C. Hanger Rods for Corrosive Environments: Electrogalvanized, all-thread rods or galvanized rods with threads painted with zinc-chromate primer after installation.

D. Strap and Rod Sizes: Comply with SMACNA's 2005 "HVAC Duct Construction Standards - Metal and Flexible," Table 5-1 (Table 5-1M), "Rectangular Duct Hangers Minimum Size," and Table 5-2, "Minimum Hanger Sizes for Round Duct."

E. Steel Cables for Galvanized-Steel Ducts: Galvanized steel complying with ASTM A 603.

F. Steel Cables for Stainless-Steel Ducts: Stainless steel complying with ASTM A 492.

G. Steel Cable End Connections: Cadmium-plated steel assemblies with brackets, swivel, and bolts designed for duct hanger service; with an automatic-locking and clamping device.

H. Duct Attachments: Sheet metal screws, blind rivets, or self-tapping metal screws; compatible with duct materials.

I. Trapeze and Riser Supports:

1. Supports for Galvanized-Steel Ducts: Galvanized-steel shapes and plates.
2. Supports for Stainless-Steel Ducts: Stainless-steel shapes and plates.
3. Supports for Aluminum Ducts: Aluminum or galvanized steel coated with zinc chromate.

PART 3 - EXECUTION

3.1 DUCT INSTALLATION

A. Drawing plans, schematics, and diagrams indicate general location and arrangement of duct system. Indicated duct locations, configurations, and arrangements were used to size ducts and calculate friction loss for air-handling equipment sizing and for other design considerations. Install duct systems as indicated unless deviations to layout are approved on Shop Drawings and Coordination Drawings.

B. Install ducts according to SMACNA's 2005 "HVAC Duct Construction Standards - Metal and Flexible" unless otherwise indicated.

C. Install round ducts in maximum practical lengths.

D. Install ducts with fewest possible joints.

E. Install factory or shop fabricated fittings for changes in direction, size, and shape and for branch connections.

F. Unless otherwise indicated, install ducts vertically and horizontally, and parallel and perpendicular to building lines.

G. Install ducts close to walls, overhead construction, columns, and other structural and permanent enclosure elements of building.

H. Install ducts with a clearance of 1 inch, plus allowance for insulation thickness.

I. Route ducts to avoid passing through transformer vaults and electrical equipment rooms and enclosures.

J. Where ducts pass through non-fire-rated interior partitions and exterior walls and are exposed to view, cover the opening between the partition and duct or duct insulation with sheet metal flanges of same metal thickness as the duct. Overlap openings on four sides by at least 1-1/2 inches.

K. Where ducts pass through fire and/or smoke and/or fire/smoke rated surfaces, install appropriate safety dampers. Comply with requirements in Section 23 3314 "Duct Specialties" for safety dampers.

L. Protect duct interiors from moisture, construction debris and dust, and other foreign materials. Comply with SMACNA's "IAQ Guidelines for Occupied Buildings Under Construction," Appendix G, "Duct Cleanliness for New Construction Guidelines."

3.2 INSTALLATION OF EXPOSED DUCTWORK

A. Protect ducts exposed in finished spaces from being dented, scratched, or damaged.

B. Trim duct sealants flush with metal. Create a smooth and uniform exposed bead. Do not use two-part tape sealing system.

C. Grind welds to provide smooth surface free of burrs, sharp edges, and weld splatter. When welding stainless steel with a No. 3 or 4 finish, grind the welds flush, polish the exposed welds, and treat the welds to remove discoloration caused by welding.

D. Maintain consistency, symmetry, and uniformity in the arrangement and fabrication of fittings, hangers and supports, duct accessories, and air outlets.

E. Repair or replace damaged sections and finished work that does not comply with these requirements.

3.3 ADDITIONAL INSTALLATION REQUIREMENTS FOR COMMERCIAL KITCHEN HOOD EXHAUST DUCT

A. Install commercial kitchen hood exhaust ducts without dips and traps that may hold grease, and sloped a minimum of 2 percent to drain grease back to the hood.

B. Install fire-rated access panel assemblies at each change in direction and at maximum intervals of 10 feet in horizontal ducts, and at every floor for vertical ducts, or as indicated on Drawings.

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 fire rated covers of same material as duct.

D. Do not penetrate fire-rated assemblies except as allowed by applicable building codes and authorities having jurisdiction.

3.4 DUCT SEALING AND CONTAMINATION PROTECTION

A. Contamination Protection: Ductwork shall be sealed at the point of fabrication/manufacture, and remain sealed until installed. Ductwork must be sealed at all times, even if being worked on. Seals can be removed only during immediate installation and must be restored immediately upon non-work activity. Ductwork being worked on shall be sealed at the end of each work day.

B. Seal ducts for duct static-pressure, seal classes, and leakage classes specified in "Duct Schedule" Article according to SMACNA's 2005 "HVAC Duct Construction Standards - Metal and Flexible."

C. Seal all ducts to Seal Class A according to SMACNA's 2005 "HVAC Duct Construction Standards - Metal and Flexible."

3.5 HANGER AND SUPPORT INSTALLATION

A. Comply with SMACNA's 2005 "HVAC Duct Construction Standards - Metal and Flexible," Chapter 5, "Hangers and Supports."

B. Building Attachments: Concrete inserts, powder-actuated fasteners, or structural-steel fasteners appropriate for construction materials to which hangers are being attached.

1. Where practical, install concrete inserts before placing concrete.
2. Install powder-actuated concrete fasteners after concrete is placed and completely cured.
3. Use powder-actuated concrete fasteners for standard-weight aggregate concretes or for slabs more than 4 inches thick.
4. Do not use powder-actuated concrete fasteners for lightweight-aggregate concretes or for slabs less than 4 inches thick.
5. Do not use powder-actuated concrete fasteners for seismic restraints.

C. Hanger Spacing: Comply with SMACNA's 2005 "HVAC Duct Construction Standards - Metal and Flexible," Table 5-1 (Table 5-1M), "Rectangular Duct Hangers Minimum Size," and Table 5-2, "Minimum Hanger Sizes for Round Duct," for maximum hanger spacing; install hangers and supports within 24 inches of each elbow and within 48 inches of each branch intersection.

D. Hangers Exposed to View: Threaded rod and angle or channel supports.

E. Support vertical ducts with steel angles or channel secured to the sides of the duct with welds, bolts, sheet metal screws, or blind rivets; support at each floor and at a maximum intervals of 16 feet.

F. Install upper attachments to structures. Select and size upper attachments with pull-out, tension, and shear capacities appropriate for supported loads and building materials where used.

3.6 CONNECTIONS

A. Make connections to equipment with flexible connectors complying with Section 23 3314 "Duct Specialties."

B. Comply with SMACNA's 2005 "HVAC Duct Construction Standards - Metal and Flexible" for branch, outlet and inlet, and terminal unit connections, and see drawings/details.

3.7 PAINTING

A. Prime and paint interior of metal ducts that are visible through registers and grilles and that do not have duct liner. Apply one coat of flat, black, latex paint over a compatible galvanized-steel primer.

3.8 FIELD QUALITY CONTROL

A. Perform tests and inspections.

B. Leakage Tests:

1. Leakage tests shall be conducted in accordance with 1985, 1st Edition, of SMACNA's "HVAC Air Duct Leakage Test Manual," Sections 3 and 5. Positive pressure ductwork to be tested under positive pressure. Negative pressure ductwork to be tested under positive and negative pressure. Submit a test report for each test.
2. Test the following systems:

   a. Supply Ducts with a Pressure Class of 3-Inch wg (750 Pa) or Higher: Test representative duct sections, selected by Engineer from sections installed, totaling no less than 50 percent of total installed duct area for each designated pressure class.
   b. All Lab exhaust ductwork.

3. Leakage tests to be witnessed by the University.
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 and before ducts are concealed.
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 system at maximum system design pressure. Do not pressurize systems above maximum design operating pressure.
7. Give seven days' advance notice for testing.
8. Leakage shall not exceed the values in the following Table 23-3114-3:

Table 23-3114-3 – Allowable Leakage Rates, cfm/100 ft^2 Surface Area

Location	Test Pressure in. wg	Rectangular Ductwork	Round Ductwork	Flat Oval Ductwork
Low Pressure Ductwork[a]	2	9.4	4.7	4.7
All Other Ductwork[b]	4	14.8	7.4	7.4

[a.] Supply Ductwork: Ductwork downstream of VAV/CAV Terminals, Return Ductwork: Ductwork upstream of VAV/CAV Terminals.

[b.] Supply, Return, and Exhaust Ductwork

C. Duct System Cleanliness Tests:

1. Visually inspect duct system to ensure that no visible contaminants are present.
2. Test sections of metal duct system, chosen randomly by Owner, for cleanliness according to "Vacuum Test" in NADCA ACR, "Assessment, Cleaning and Restoration of HVAC Systems."

   a. Acceptable Cleanliness Level: Net weight of debris collected on the filter media shall not exceed 0.75 mg/100 sq. cm.

D. Duct system will be considered defective if it does not pass tests and inspections.

E. Prepare test and inspection reports.

3.9 DUCT CLEANING

A. Clean new duct system(s) before testing, adjusting, and balancing.

B. Clean existing ducts 10' each direction which become open due to equipment or duct removal, and clean before testing, adjusting, and balancing.

C. Use service openings for entry and inspection.

1. Create new openings and install access panels appropriate for duct static-pressure class if required for cleaning access. Provide insulated panels for insulated or lined duct. Patch insulation and liner as recommended by duct liner manufacturer. Comply with Section 23 3314 "Duct Specialties" 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.

D. Particulate Collection and Odor Control:

1. When venting vacuuming system inside the building, use HEPA filtration with 99.97 percent collection efficiency for 0.3-micron-size (or larger) particles.
2. When venting vacuuming system to outdoors, use filter to collect debris removed from HVAC system, and locate exhaust downwind and away from air intakes and other points of entry into building.

E. 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, scrolls, blades or vanes, shafts, baffles, dampers, and drive assemblies.
3. Air-handling unit internal surfaces and components including mixing box, coil section, condensate drain pans, humidifiers, filters and filter sections, and condensate collectors and drains.
4. Coils and related components.
5. Return-air ducts, dampers, actuators, and turning vanes except in ceiling plenums and mechanical equipment rooms.
6. Supply-air ducts, dampers, actuators, and turning vanes.

F. Mechanical Cleaning Methodology:

1. Clean metal duct systems using mechanical cleaning methods that extract contaminants from within duct systems and remove contaminants from building.
2. Use vacuum-collection devices that are operated continuously during cleaning. Connect vacuum device to downstream end of duct sections so areas being cleaned are under negative pressure.
3. Use mechanical agitation to dislodge debris adhered to interior duct surfaces without damaging integrity of metal ducts, duct liner, or duct accessories.
4. Clean fibrous-glass duct liner with HEPA vacuuming equipment; do not permit duct liner to get wet. Replace fibrous-glass duct liner that is damaged, deteriorated, or delaminated or that has friable material, mold, or fungus growth.

5. Clean coils and coil drain pans according to NADCA 1992. Keep drain pan operational. Rinse coils with clean water to remove latent residues and cleaning materials; comb and straighten fins.
6. Provide drainage and cleanup for wash-down procedures.
7. Antimicrobial Agents and Coatings: Apply EPA-registered antimicrobial agents if fungus is present. Apply antimicrobial agents according to manufacturer's written instructions after removal of surface deposits and debris.

3.10 START UP

A. Air Balance: Comply with project TAB requirements.

3.11 DUCT SCHEDULE AND OTHER REQUIREMENTS

A. Fabricate ducts with galvanized sheet steel unless called for as another material on drawings, or if Lab exhaust, dishwasher exhaust, and any other high humidity applications or areas, ducting to be stainless steel, sloped, and drained.

B. For outdoor ducts exposed to wind forces, anchor and brace as required.

C. Flat-oval ducts shall not be used for exhaust.

D. Fabricate underground ducts with galvanized sheet steel except as otherwise indicated and as follows:

1. Underground Ducts: Concrete-encased, [galvanized sheet steel] [PVC-coated, galvanized sheet steel with thicker coating on duct exterior] [stainless steel].
2. <Insert requirements>.

E. Supply Ducts:

1. Ducts Connected to Fan Coil Units, Furnaces, Heat Pumps, and Terminal Units:

a. Pressure Class: Positive ***2-inch wg (500 Pa)***.
b. Minimum SMACNA Seal Class: A.
c. SMACNA Leakage Class for Rectangular: 12.
d. SMACNA Leakage Class for Round and Flat Oval: 12.

2. Ducts Connected to Constant-Volume Air-Handling Units <Insert equipment>:

a. Pressure Class: Positive ***3-inch wg (750 Pa)*** <Insert value>.
b. Minimum SMACNA Seal Class: A.
c. SMACNA Leakage Class for Rectangular: 6.
d. SMACNA Leakage Class for Round and Flat Oval: 6.

3. Ducts Connected to Variable-Air-Volume Air-Handling Units <Insert equipment>:

a. Pressure Class: Positive ***4-inch wg (1000 Pa)*** <Insert value>.
b. Minimum SMACNA Seal Class: A.
c. SMACNA Leakage Class for Rectangular: 3.
d. SMACNA Leakage Class for Round and Flat Oval: 3.

4. Ducts Connected to Equipment Not Listed Above:

a. Pressure Class: Positive ***2-inch wg (500 Pa)*** <Insert value>.
b. Minimum SMACNA Seal Class: A.
c. SMACNA Leakage Class for Rectangular: 6.
d. SMACNA Leakage Class for Round and Flat Oval: 6.

F. Return Ducts:

1. Ducts Connected to Fan Coil Units, Furnaces, Heat Pumps, and Terminal Units <Insert equipment>:

a. Pressure Class: Positive or negative ***2-inch wg (500 Pa).***
b. Minimum SMACNA Seal Class: A.
c. SMACNA Leakage Class for Rectangular: 12.
d. SMACNA Leakage Class for Round and Flat Oval: 12.

2. Ducts Connected to Air-Handling Units <Insert equipment>:

a. Pressure Class: Positive or negative ***3-inch wg (750 Pa)***.
b. Minimum SMACNA Seal Class: A.
c. SMACNA Leakage Class for Rectangular: 6.
d. SMACNA Leakage Class for Round and Flat Oval: 6.

3. Ducts Connected to Equipment Not Listed Above:

a. Pressure Class: Positive or negative ***3-inch wg (750 Pa)***.
b. Minimum SMACNA Seal Class: A.
c. SMACNA Leakage Class for Rectangular: 6.
d. SMACNA Leakage Class for Round and Flat Oval: 6.

G. Exhaust Ducts:

1. Ducts Connected to Fans Exhausting (ASHRAE 62.1, Class 1 and 2) Air:

a. Pressure Class: Negative ***3-inch wg (750 Pa)***.
b. Minimum SMACNA Seal Class: A if negative pressure, and A if positive pressure.
c. SMACNA Leakage Class for Rectangular: 6.
d. SMACNA Leakage Class for Round and Flat Oval: 6.

2. Ducts Connected to Air-Handling Units <Insert equipment>:

a. Pressure Class: Positive or negative ***3-inch wg (750 Pa)***.
b. Minimum SMACNA Seal Class: A if negative pressure, and A if positive pressure.
c. SMACNA Leakage Class for Rectangular: 6.
d. SMACNA Leakage Class for Round and Flat Oval: 6.

3. Ducts Connected to Commercial Kitchen Hoods: Comply with NFPA 96.

a. Exposed to View: Type 304, stainless-steel sheet, No. 4 finish.
b. Concealed: Carbon-steel sheet.
c. Welded seams and joints.
d. Pressure Class: Positive or negative ***3-inch wg (750 Pa)***.
e. Minimum SMACNA Seal Class: Welded seams, joints, and penetrations.
f. SMACNA Leakage Class: 3.

4. ***Ducts Connected to Dishwasher Hoods:***

   a. ***Type 304, stainless-steel sheet.***
   b. ***Exposed to View: No. 4 finish.***
   c. ***Concealed: No. 2D finish.***
   d. ***Welded seams and flanged joints with watertight EPDM gaskets.***
   e. ***Pressure Class: Positive or negative 3-inch wg (750 Pa).***
   f. ***Minimum SMACNA Seal Class: Welded seams, joints, and penetrations.***
   g. ***SMACNA Leakage Class: 3.***

5. ***Ducts Connected to Fans Exhausting Laboratory and Process (ASHRAE 62.1, Class 3 and 4) Air:***

   a. ***Type 316, stainless-steel sheet.***

      1) ***Exposed to View: No. 4.***
      2) ***Concealed: No. 2B finish.***

   b. ***Pressure Class: Positive or negative 4-inch wg (1000 Pa).***
   c. ***Minimum SMACNA Seal Class: A, Welded seams, joints, and penetrations.***
   d. ***SMACNA Leakage Class: 3.***

6. ***Ducts Connected to Equipment Not Listed Above:***

   a. ***Pressure Class: Positive or negative 3-inch wg (750 Pa).***
   b. ***Minimum SMACNA Seal Class: A if negative pressure, and A if positive pressure.***
   c. ***SMACNA Leakage Class for Rectangular: 3.***
   d. ***SMACNA Leakage Class for Round and Flat Oval: 3.***

H. ***Outdoor-Air (Not Filtered, Heated, or Cooled) Ducts:***

1. ***Ducts Connected to Fan Coil Units, Furnaces, Heat Pumps, and Terminal Units <Insert equipment>:***

   a. ***Pressure Class: Positive or negative 2-inch wg (500 Pa).***
   b. ***Minimum SMACNA Seal Class: A.***
   c. ***SMACNA Leakage Class for Rectangular: 6.***
   d. ***SMACNA Leakage Class for Round and Flat Oval: 3.***

2. ***Ducts Connected to Air-Handling Units <Insert equipment>:***

   a. ***Pressure Class: Positive or negative 3-inch wg (750 Pa).***
   b. ***Minimum SMACNA Seal Class: A.***
   c. ***SMACNA Leakage Class for Rectangular: 6.***
   d. ***SMACNA Leakage Class for Round and Flat Oval: 3.***

3. ***Ducts Connected to Equipment Not Listed Above:***

   a. ***Pressure Class: Positive or negative 3-inch wg (750 Pa).***
   b. ***Minimum SMACNA Seal Class: A.***
   c. ***SMACNA Leakage Class for Rectangular: 6.***
   d. ***SMACNA Leakage Class for Round and Flat Oval: 6.***

I. Intermediate Reinforcement:

1. Galvanized-Steel Ducts: Galvanized steel.
2. PVC-Coated Ducts:

a. Exposed to Airstream: Match duct material.
b. Not Exposed to Airstream: Match duct material.

3. Stainless-Steel Ducts:

a. Exposed to Airstream: Match duct material.
b. Not Exposed to Airstream: Match duct material.

4. Aluminum Ducts: Aluminum.

J. Double-Wall Duct Interstitial Insulation:

1. Supply Air Ducts: 2 inches (51 mm) thick.
2. Return Air Ducts: 2 inches (51 mm) thick.
3. Exhaust Air Ducts: 2 inches (51 mm) thick.

K. Elbow Configurations To Be Use, Unless More Stringent Requirements Are Required Per PART 2 of This Section:

1. Rectangular Duct: Comply with SMACNA's 2005 "HVAC Duct Construction Standards - Metal and Flexible," Figure 4-2, "Rectangular Elbows."

a. Velocity 1000 fpm (5 m/s) or Lower:

1) Radius Type RE 1 with minimum 1.5 radius-to-diameter ratio.
2) Mitered Type RE 4 without vanes.

b. Velocity 1000 to 1500 fpm (5 to 7.6 m/s):

1) Radius Type RE 1 with minimum 1.5 radius-to-diameter ratio.
2) Radius Type RE 3 with minimum 1.5 radius-to-diameter ratio and two vanes.
3) Mitered Type RE 2 with vanes complying with SMACNA's 2005 "HVAC Duct Construction Standards - Metal and Flexible," Figure 4-3, "Vanes and Vane Runners," and Figure 4-4, "Vane Support in Elbows."

c. Velocity 1500 fpm (7.6 m/s) or Higher:

1) Radius Type RE 1 with minimum 1.5 radius-to-diameter ratio.
2) Radius Type RE 3 with minimum 1.5 radius-to-diameter ratio and two vanes.
3) Mitered Type RE 2 with vanes complying with SMACNA's 2005 "HVAC Duct Construction Standards - Metal and Flexible," Figure 4-3, "Vanes and Vane Runners," and Figure 4-4, "Vane Support in Elbows."

2. Rectangular Duct: Comply with SMACNA's 2005 "HVAC Duct Construction Standards - Metal and Flexible," Figure 4-2, "Rectangular Elbows."

a. Radius Type RE 1 with minimum 1.5 radius-to-diameter ratio.
b. Radius Type RE 3 with minimum 1.5 radius-to-diameter ratio and two vanes.

c. Mitered Type RE 2 with vanes complying with SMACNA's 2005 "HVAC Duct Construction Standards - Metal and Flexible," Figure 4-3, "Vanes and Vane Runners," and Figure 4-4, "Vane Support in Elbows."

3. Round Duct: Comply with SMACNA's 2005 "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-4, "Round Duct Elbows."

a. Minimum Radius-to-Diameter Ratio and Elbow Segments: Comply with SMACNA's 2005 "HVAC Duct Construction Standards - Metal and Flexible," Table 3-1, "Mitered Elbows." Elbows with less than 90-degree change of direction have proportionately fewer segments.

1) Velocity 1000 fpm (5 m/s) or Lower: 1.5 radius-to-diameter ratio and three segments for 90-degree elbow.
2) Velocity 1000 to 1500 fpm (5 to 7.6 m/s): 1.5 radius-to-diameter ratio and four segments for 90-degree elbow.
3) Velocity 1500 fpm (7.6 m/s) or Higher: 1.5 radius-to-diameter ratio and five segments for 90-degree elbow.
4) Radius-to Diameter Ratio: 1.5.

b. Round Elbows, 12 Inches (305 mm) and Smaller in Diameter: Stamped.
c. Round Elbows, 14 Inches (356 mm) and Larger in Diameter: Welded.

L. Branch Configurations To Be Use, Unless More Stringent Requirements Are Required Per PART 2 of This Section:

1. Rectangular Duct: Comply with SMACNA's 2005 "HVAC Duct Construction Standards - Metal and Flexible," Figure 4-6, "Branch Connection."

a. Rectangular Main to Rectangular Branch: 45-degree entry.
b. Rectangular Main to Round Branch: 45-degree entry and transition.

2. Round and Flat Oval: Comply with SMACNA's 2005 "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-5, "90 Degree Tees and Laterals," and Figure 3-6, "Conical Tees."

a. Velocity 1000 fpm (5 m/s) or Lower: 90-degree tap, conical.
b. Velocity 1000 to 1500 fpm (5 to 7.6 m/s): Conical tap.
c. Velocity 1500 fpm (7.6 m/s) or Higher: 45-degree lateral.

END OF SECTION 23 3113

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SECTION 23 3314 - DUCTWORK SPECIALTIES

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:

1. Backdraft and pressure relief dampers.
2. Manual volume dampers.
3. Fire dampers.
4. Smoke dampers.
5. Combination fire/smoke dampers.
6. Flange connectors.
7. Turning vanes.
8. Duct-mounted access doors and panels.
9. Flexible connectors.
10. Flexible ducts.
11. Duct accessory hardware.
12. Louvers.
13. Duct Sound Attenuators.

1.2 SUBMITTALS

A. Product and Technical Data: For each type of product indicated, including (but not limited to) installation requirements, dimensions, color charts and water penetration data for louvers, wiring diagrams, dynamic insertion loss and self-noise data for attenuators, and air pressure drop information.

B. [LEED Submittals:

1. Product Data for Prerequisite EQ 1: Documentation indicating that units comply with ASHRAE 62.1-2007, Section 5 - "Systems and Equipment."
2. Any data that can be used for recycled content and regional materials credits.]

C. Operation and maintenance data.

D. Northwestern University Maintenance Requirement Forms, see Division 01.

1.3 QUALITY ASSURANCE

A. Comply with NFPA 90A, "Installation of Air Conditioning and Ventilating Systems," and with NFPA 90B, "Installation of Warm Air Heating and Air Conditioning Systems."

B. Comply with AMCA 500-D testing for damper rating, and with AMCA 500-L for louver performance.

C. For louver finishes, comply with applicable SSPC and AAMA requirements.

D. For duct sound attenuators, they shall be tested in accordance with ASTM E-477-99 silencer test standard in a certified test facility which is NVLAP accredited for the testing.

1.4 SPECIAL WARRANTIES

A. Five (5) years, see Division 01.

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.

1. Exposed-Surface Finish: Mill phosphatized.

C. Stainless-Steel Sheets: Comply with ASTM A 480/A 480M, Type 304 except for Lab exhaust, which shall be Type 316.

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, except for louvers, which are to be Temper T5.

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 DAMPERS – BACKDRAFT, VOLUME, FIRE, SMOKE, FIRE/SMOKE

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

1. Air Balance.
2. Cesco.
3. Greenheck Fan Corporation.
4. Nailor Industries Inc.
5. Prefco (Basis of Design)
6. Ruskin Company.

2.3 BACKDRAFT AND PRESSURE RELIEF DAMPERS

A. Description: Gravity balanced.

B. Maximum Air Velocity: 3000 fpm.

C. Maximum System Pressure: 2-inch wg.

D. Frame: 0.052-inch- thick, galvanized sheet steel, with welded corners.

E. Blades: Multiple single-piece blades, maximum 6-inch width with sealed edges.

F. Blade Action: Parallel.

G. Return Spring: Adjustable tension.

H. Bearings: Provide end bearings on all dampers. On multiple blade dampers bearing shall be oil-impregnated nylon or sintered bronze.

I. 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 Material: Galvanized steel.
6. Screen Type: Bird.
7. 90-degree stops.

2.4 MANUAL VOLUME DAMPERS

1. Show dampers on Drawings.
2. Damper and blade material to match ductwork material
3. Standard leakage rating.
4. Suitable for horizontal or vertical applications.
5. Frames:

    a. Hat-shaped, galvanized-steel channels, 0.064-inch minimum thickness.
    b. Mitered and welded corners.
    c. Flanges for attaching to walls and flangeless frames for installing in ducts.

6. Blades:

    a. Rectangular dampers shall be single blade type in ducts up to 11" high and shall be opposed blade type in ducts 12" high and above.
    b. Round dampers shall be single blade type.
    c. Stiffen damper blades for stability.

7. Provide end bearings on all dampers. On multiple blade dampers bearing shall be oil-impregnated nylon or sintered bronze.
8. Provide locking indicating quadrant regulators on all dampers. Where rod lengths exceed 30-inches, provide a regulator at both ends.
9. On insulated ducts mount quadrant regulators on stand-off mounting brackets, bases, or adapters.
10. Jackshaft:

    a. Size: 1-inch diameter.

b. Material: Galvanized-steel pipe rotating within pipe-bearing assembly mounted on supports at each mullion and at each end of multiple-damper assemblies.
c. Length and Number of Mountings: As required to connect linkage of each damper in multiple-damper assembly.

11. Damper Hardware:

a. Zinc-plated, die-cast core with dial and handle made of 3/32-inch- thick zinc-plated steel, and a 3/4-inch hexagon locking nut.
b. Include center hole to suit damper operating-rod size.
c. Include elevated platform for insulated duct mounting.

2.5 FIRE DAMPERS

A. Fire dampers shall be dynamic, multiple airfoil blade type (not curtain type) with integral wall sleeve, constructed in accordance with UL Standard 555.

B. Closing rating in ducts up to 8-inch wg static pressure class and minimum 4000-fpm velocity.

C. Dampers shall be for horizontal or vertical mounting and shall be of sizes shown on the drawings.

D. Dampers shall have 1-1/2 or 3 hour rating as shown on drawings, replaceable 212 degree F fusible link, and access panels (with UL 181 rated viewports), for installation on both sides of damper.

2.6 SMOKE DAMPERS

A. General Requirements: Label according to UL 555S by an NRTL.

B. Smoke Detector: Integral, factory wired for single-point connection.

C. Frame: Multiple blade type (not curtain type); fabricated with roll-formed, 0.034-inch- thick galvanized steel; with mitered and interlocking corners.

D. Blades: Airfoil, multiple.

E. Leakage: Class III, and, all seals to be metal-to-metal.

F. Rated pressure and velocity to exceed design airflow conditions, and dampers to be rated for 4,000 fpm and 8" pressure minimum.

G. Mounting Sleeve: Factory-installed, 0.052-inch- thick, galvanized sheet steel; length to suit wall or floor application with factory-furnished silicone calking.

H. Damper Motors: [**Modulating**] [**or**] [**two-position**] action, electric.

I. Comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements for motors specified in Division 23 Section "Motors."

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 25 Section "Integrated Automation."] [Division 26 Sections.]
3. Permanent-Split-Capacitor or Shaded-Pole Motors: With oil-immersed and sealed gear trains.
4. 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.
5. 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.
6. 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.
7. Electrical Connection: 115 V, single phase, 60 Hz.

J. Dampers shall be supplied/installed with access panels (with UL 181 rated viewports), for installation on both sides of damper.

K. Accessories:

1. Auxiliary switches for [signaling] [fan control] [or] [position indication].
2. [Momentary test switch] [Test and reset switches], [damper] [remote] mounted.

2.7 COMBINATION FIRE/SMOKE DAMPERS

A. Type: Dynamic; rated and labeled according to UL 555 and UL 555S by an NRTL, multiple blade, not curtain type. Basis of Design Prefco Model 5010.

B. Closing rating in ducts up to 4-inch wg (1-kPa) static pressure class and minimum 4000-fpm velocity.

C. Fire Rating: 3 hours.

D. Frame: Hat-shaped, 0.094-inch- (2.4-mm-) thick, galvanized sheet steel, with welded or mechanically attached corners and mounting flange.

E. Heat-Responsive Device: Reusable electric "McCabe™" link, with an external manual reset lever (see drawing details). The releasing device shall be 24Vdc in compliance with UL 873. The resettable link shall be 280°F, and UL 33 listed.

F. Smoke Detector: Furnished by electrical.

G. Blades: Roll-formed, horizontal, interlocking, minimum 0.034-inch- thick, galvanized sheet steel.

H. Leakage: Class I

I. Rated pressure and velocity to exceed design airflow conditions.

J. Mounting Sleeve: Factory-installed, minimum 0.05-inch- (1.3-mm-) thick, galvanized sheet steel; length to suit wall or floor application with factory-furnished silicone calking.

K. Master control panel for use in dynamic smoke-management systems.

L. Damper Motors: two-position action.

M. 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 Division 25.
3. Permanent-Split-Capacitor or Shaded-Pole Motors: With oil-immersed and sealed gear trains.
4. 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 (17 N x m) and breakaway torque rating of 150 in. x lbf (17 N x m).
5. 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 (minus 40 deg C).
6. Non-spring-Return Motors: For dampers larger than 25 sq. ft. (2.3 sq. m), size motor for running torque rating of 150 in. x lbf (17 N x m) and breakaway torque rating of 300 in. x lbf (34 N x m).
7. Electrical Connection: 24 or 115 V as called for by control systems specifications, sequences, or on drawings, and as required, single phase, 60 Hz, and as coordinated with electrical contractor.

N. Accessories:

1. Auxiliary switches for signaling or position indication.
2. Test and reset switches, remote mounted.
3. Access panels (with UL 181 rated viewports), for installation on both sides of damper.
4. Other as required.

2.8 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.
3. Ward Industries, Inc.; a division of Hart & Cooley, Inc.

B. Description: Factory-fabricated, slide-on transverse flange connectors, gaskets, and components.

C. Material: Galvanized steel.

D. Gage and Shape: Match connecting ductwork.

2.9 TURNING VANES

A. General Requirements: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible"; Figures 2-3, "Vanes and Vane Runners," and 2-4, "Vane Support in Elbows."

B. Vane Construction: Single wall for ducts up to 48 inches wide and double wall for larger dimensions.

2.10 DUCT-MOUNTED ACCESS DOORS

A. Duct-Mounted Access Doors: Fabricate access panels according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible"; Figures 2-10, "Duct Access Doors and Panels," and 2-11, "Access Panels - Round Duct."

1. Door:

a. Double wall, rectangular, and 24" x 24" or as close to 24" x 24" as possible.
b. Galvanized sheet metal with insulation fill and thickness as indicated for duct pressure class.
c. Hinges and Latches: 1-by-1-inch butt or piano hinge and cam latches.
d. Fabricate doors airtight and suitable for duct pressure class.

2. Frame: Galvanized sheet steel, with bend-over tabs and foam gaskets.
3. Number of Hinges and Locks:

a. Access Doors Less Than 12 Inches 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 48 Inches: Three hinges and two compression latches

2.11 DUCT ACCESS PANEL ASSEMBLIES

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. Ductmate Industries, Inc.
2. Flame Gard, Inc.
3. 3M.

B. Labeled according to UL 1978 by an NRTL.

C. Panel and Frame: Minimum thickness 0.0428-inch stainless steel.

D. Fasteners: 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.

2.12 FLEXIBLE CONNECTORS

A. Manufacturer: Ventfabrics, Model Ventglas.

B. Materials: Flame-retardant or non-combustible fabrics.

C. Coatings and Adhesives: Comply with UL 181, Class 1.

D. Material shall be crimped into a metal edging strip and shall be approximately 3 inches wide.

E. Indoor System, Flexible Connector Fabric: Minimum 0.024 " thick glass fabric double coated with neoprene.

1. Minimum Weight: 30 oz./sq. yd..
2. Tensile Strength: Minimum 480 lbf/inch in the warp and 360 lbf/inch in the filling.
3. Service Temperature: Minus 40 to plus 200 deg F.

F. Outdoor System, Flexible Connector Fabric: Minimum 0.024" thick glass fabric double coated with weatherproof, synthetic rubber resistant to UV rays and ozone.

1. Minimum Weight: 30 oz./sq. yd..
2. Minimum Tensile Strength: 500 lbf/inch in the warp and 440 lbf/inch in the filling.
3. Service Temperature: Minus 50 to plus 250 deg F.

2.13 FLEXIBLE DUCTS

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. Casco.
2. Flexmaster U.S.A., Inc., Type 6.
3. Thermaflex, Model M-KE.

B. Non-insulated, 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.
2. Maximum Air Velocity: 4000 fpm.
3. Temperature Range: Minus 10 to plus 160 deg F.

C. Insulated, Flexible Duct: UL 181, Class 1, black polymer film supported by helically wound, spring-steel wire; fibrous-glass insulation; fire resistive vapor-barrier film.

1. Pressure Rating: 4-inch wg positive and 0.5-inch wg negative.
2. Maximum Air Velocity: 4000 fpm.
3. Temperature Range: Minus 20 to plus 175 deg F.
4. Insulation R-Value: Comply with ASHRAE/IESNA 90.1-2007.

D. Insulated, Flexible Duct: UL 181, Class 1, multiple layers of aluminum laminate supported by helically wound, spring-steel wire; fibrous-glass insulation; fire resistive vapor-barrier film.

1. Pressure Rating: 10-inch wg positive and 1.0-inch wg negative.
2. Maximum Air Velocity: 4000 fpm.
3. Temperature Range: Minus 20 to plus 210 deg F.
4. Insulation R-value: Comply with ASHRAE/IESNA 90.1-2007.

E. Flexible Duct Securement:

1. Clamps: Stainless-steel band with hex screw to tighten band with a worm-gear action or Nylon strap in sizes 3 through 18 inches, to suit duct size.

2.14 DUCT ACCESSORY HARDWARE

A. Instrument Test Holes: Cast iron or cast aluminum to suit duct material, including screw cap and gasket. Size to allow insertion of pitot tube and other testing instruments and of length to suit duct-insulation thickness.

B. Adhesives: High strength, quick setting, neoprene based, waterproof, and resistant to gasoline and grease.

2.15 LOUVERS

A. Horizontal, Drainable-Blade Louvers:

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

   a. Air Balance Inc.; a division of MESTEK, Inc.
   b. Airolite Company, LLC (The), Basis of Design, Model K6856.
   c. Cesco Products; a divsion of MESTEK, Inc.
   d. Greenheck Fan Corporation.
   e. Ruskin Company.

2. Louver Depth, Blade Angle, and Free Area: 6 inch depth, blades at 45° angle, and minimum free area of 49.4%.
3. Frame and Blade Materials of Construction and Nominal Thickness: Not less than 0.081 inch, and constructed of ASTM B221 aluminum extrusions, Alloy 6063-T5.
4. Fabrication: Welded.
5. Frame Type: XXXXXXXXX
6. Sill Type: Extended.
7. Mullion Type: Exposed.
8. Sleeve: Minimum 16 gage galvanized steel, by contractor.
9. Size and performance data: See schedules/drawings.
10. Finish: 2-coat, oven cured Kynar 500, 2.0 mils dry film coating thickness per AAMA 2605.
11. Louver Performance Ratings:

   a. Free Area: Not less than 7.9 sq. ft. for 48-inch wide by 48-inch high louver.
   b. Point of Beginning Water Penetration: Not less than 1065 fpm.
   c. Air Performance: Not more than 0.072-inch wg static pressure drop at 700-fpm free-area intake velocity.
   d. Air Performance: Not more than 0.17-inch wg static pressure drop at 1000-fpm free-area exhaust velocity.

12. Wind Loads: Determine loads based on a uniform pressure of ***XX lbf/sq. ft. based upon project structural wind values and other data***, acting inward or outward.
13. AMCA Seal: Mark units with AMCA Certified Ratings Seal.
14. Screens: 1/2" aluminum birdscreen finished same as louver, located **XXXXX.**
15. Insulated Blank-off Panels: XXXXXXXXXXXXX.

2.16 DUCT SOUND ATTENUATORS

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

1. Aerocoustic.
2. Aerosonics.
3. Commercial Acoustics, Metalform Corp.
4. Industrial Acoustics.
5. McGill AirFlow LLC.
6. Pottorff/Dynasonics.
7. Ruskin Sound..
8. Semco.
9. Vibro-Acoustics.

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.

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 (Z275) galvanized sheet steel minimum 22 ga.

E. Round Silencer Outer Casing: ASTM A 653/A 653M, G90 (Z275) galvanized sheet steel.

1. Sheet Metal Thickness for Units up to 24 Inches (600 mm) in Diameter: 0.034 inch (0.85 mm) thick.
2. Sheet Metal Thickness for Units 26 through 40 Inches (660 through 1000 mm) in Diameter: 0.040 inch (1.02 mm) thick.
3. Sheet Metal Thickness for Units 42 through 52 Inches (1060 through 1300 mm) in Diameter: 0.05 inch (1.3 mm) thick.
4. Sheet Metal Thickness for Units 54 through 60 Inches (1370 through 1500 mm) in Diameter: 0.064 inch (1.62 mm) thick.

F. Inner Casing and Baffles: ASTM A 653/A 653M, [G90 (Z275)] [G60 (Z180)] galvanized sheet metal, 0.034 inch (0.85 mm) thick, and with 1/8-inch- (3-mm-) diameter perforations.

G. Special Construction:

1. Suitable for outdoor use.
2. High transmission loss **to achieve STC XX**

H. Connection Sizes: Match connecting ductwork unless otherwise indicated.

I. Principal Sound-Absorbing Mechanism:

1. [Select type from 1 and 2]

a. Reactive type (No Media) Controlled impedance membranes and broadly tuned resonators without absorptive media.
b. Dissipative Film-lined type with fill material for Hospital use.

1) Fill Material: Inert and vermin-proof fibrous material
2) Erosion Barrier: Polymer bag enclosing fill, and heat sealed before assembly.
3) Lining : Mylar film

J. 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. Joints: slip or flanged connections.
2. Suspended Units: Factory-installed suspension hooks or lugs attached to frame in quantities and spaced to prevent deflection or distortion.
3. Reinforcement: Cross or trapeze angles for rigid suspension.

K. Accessories:

1. Factory-installed end caps to prevent contamination during shipping.

L. Source Quality Control: Test according to ASTM E 477.

1. Testing **to** be witnessed by [**Architect**].
2. Record acoustic ratings, including dynamic insertion loss and generated-noise power levels with an airflow of at least 2000-fpm (10-m/s) face velocity.
3. Leak Test: Test units for airtightness at 200 percent of associated fan static pressure or 6-inch wg (1500-Pa) static pressure, whichever is greater.

M. Performance and Characteristics: See schedules.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Install duct accessories according to applicable details in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" for metal ducts, and according to manufacturer's instructions/recommendations..

B. Install duct accessories of materials suited to duct materials; use galvanized-steel accessories in galvanized-steel ducts, stainless-steel accessories in stainless-steel ducts, and aluminum accessories in aluminum ducts.

C. Install backdraft dampers at inlet of exhaust fans or exhaust ducts as close as possible to exhaust fan unless otherwise indicated.

D. Install volume dampers at points on supply, return, and exhaust systems where branches extend from larger ducts. 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.

E. Set dampers to fully open position before testing, adjusting, and balancing.

F. All dampers to be accessible and labeled, and are to have at least 24" around them for servicing, adding up to and including valves, actuators, and other devices that need service or need to be accessed to provide service.

G. Install test holes at fan inlets and outlets and elsewhere as indicated.

H. Install fire ***[and smoke]*** dampers according to UL Listing.

I. Install combination fire/smoke dampers according to UL Listing.

J. 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 and VAV box reheat coils.
2. Upstream from duct filters.
3. At outdoor-air intakes and mixed-air plenums.
4. At drain pans and seals.
5. Upstream from manual volume dampers, modulating dampers, backdraft dampers, humidifiers, and equipment.
6. Adjacent to and close enough (and on both sides of) to fire, smoke, and combination fire/smoke dampers, to reset or reinstall fusible links. Access doors for access to fire or smoke dampers having fusible links shall be pressure relief access doors; and shall be outward operation for access doors installed upstream from dampers and inward operation for access doors installed downstream from dampers.
7. Maximum 20**-foot** spacing.
8. Upstream from turning vanes.
9. Maximum 10-feet from every 90° elbow.
10. Control devices requiring inspection.
11. Up and down stream of airflow measuring stations.
12. Elsewhere as indicated.

K. Install access doors with swing against duct static pressure.

L. Access Door Sizes:

1. Hand Access: 24" x 24", or 24" by the duct height/width.
2. Head and Hand Access: 18 by 16 inches.
3. Head and Shoulders Access: 21 by 16 inches.
4. Body Access: 25 by 16 inches.
5. Body plus Ladder Access: 25 by 17 inches.
6. Where fusible links are located, there must be a 24" access panel installed.

M. Label access doors according to Division 23 Section "Identification for HVAC Piping and Equipment" to indicate the purpose of access door.

N. Install flexible connectors to connect ducts to equipment.

O. For fans developing static pressures of 5-inch wg and more, cover flexible connectors with loaded vinyl sheet held in place with metal straps.

P. Connect terminal units to supply ducts directly or with maximum 12-inch lengths of flexible duct. Do not use flexible ducts to change directions.

Q. Flexible duct elbows at diffusers are not allowed, elbows at diffusers must be sheet metal, see drawing detail(s).

R. Connect flexible ducts to metal ducts with draw bands.

S. Locate and place louvers level, plumb, and at indicated alignment with adjacent work.

T. For louvers, use concealed anchorages where possible. Provide brass or lead washers fitted to screws where required to protect metal surfaces and to make a weather-tight connection. Form closely fitted joints with exposed connections accurately located and secured. Provide perimeter reveals and openings of uniform width for sealants and joint fillers, as indicated. 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. Install concealed gaskets, flashings, joint fillers, and insulation as louver installation progresses, where weather-tight louver joints are required. Comply with Section 07 9200 "Joint Sealants" for sealants applied during louver installation.

3.2 FIELD QUALITY CONTROL

A. Tests and Inspections:

1. Operate dampers to verify full range of movement.
2. Inspect locations of access doors/panels and verify that purpose of access doors/panels can be performed.
3. Operate fire, smoke, and combination fire/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.

END OF SECTION 23 3314

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SECTION 23 3400 - FANS

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.

B. For fans in air handling units, refer to project air handling unit section(s) for additional requirements.

1.2 SUMMARY

A. Section Includes: For each product.

1. Airfoil centrifugal fans.
2. Backward-inclined centrifugal fans.
3. Plenum fans.
4. High Blow Lab Exhaust Fans
5. Fan Arrays.

1.3 REFERENCES

A. ANSI/AMCA Standards 99-10, 204-05, 300-08, 500-D-12, 500-L-12, and 210-07.

B. ANSI/AMCA Publications 211-05 and 311-05.

C. AMCA Standard 260-07.

D. SMACNA - Medium Pressure Plenum Construction Standard.

E. OSHA Guidelines 1910.212, 1910.219, and 1926.300.

F. UL 705.

G. ASHRAE - Lab Design Guide.

H. ANSI/AIHA Z9.5-2012.

I. ABMA Method of Evaluating Load Ratings of Bearings ANSI-11 (r1999).

1.4 QUALITY ASSURANCE

A. Performance ratings: Conform to applicable ANSI/AMCA Standards 210, 260 and 300. Fans must be tested in accordance with applicable AMCA Publications 211, 260 and 311 in an AMCA accredited laboratory and certified for air and sound performance. Fans shall be licensed to bear the AMCA ratings seal for air performance (AMCA 210), sound performance (AMCA 300), and induced flow fan for high plume dilution blowers (AMCA 260). Manufacturers that are not licensed to bear the AMCA 210 and 260 ratings seal, must provide performance witness testing (at the manufacturer's expense), per paragraph 1.4.D.

B. Classification for Spark Resistant Construction shall conform to ANSI/AMCA Standard 99.

C. Each fan shall be vibration tested before shipping, as an assembly, in accordance with ANSI/AMCA Standard 204. Each assembled fan shall be test run at the factory at the specified fan RPM and vibration signatures shall be taken on each bearing in three planes - horizontal, vertical, and axial. The maximum allowable fan vibration shall be less than 0.08 in. /sec peak velocity; filter-in reading as measured at the fan RPM. This report shall be provided at no charge to the customer upon request.

D. Manufacturers that do not comply with paragraph 1.4.A must also provide, at the owner and engineer's option and manufacturer's expense, witness testing of fan discharge and entrainment airflow, performed in an AMCA accredited laboratory, in accordance with AMCA 210 and 260. This test shall verify the critical and safety related dilution performance of high plume dilution blowers, as stated by the manufacturer.

E. Comply with FM Global requirements for fans and blowers and for monitoring and diagnosis of vibration in rotating machinery.

1.5 ACTION SUBMITTALS

A. Product Data:

1. Include rated capacities, furnished specialties, and accessories for each fan.
2. Certified fan performance curves with system operating conditions indicated.
3. Certified fan sound-power ratings.
4. Motor ratings and electrical characteristics, plus motor and electrical accessories.
5. Material thickness and finishes, including color charts.
6. Dampers, including housings, linkages, and operators.

B. Shop Drawings:

1. Include plans, elevations, sections, and attachment details.
2. Include details of equipment assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
3. Include diagrams for power, signal, and control wiring.
4. Design Calculations: Calculate requirements for selecting vibration isolators and restraints and for designing vibration isolation bases.
5. 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.

1.6 INFORMATIONAL SUBMITTALS

A. Coordination Drawings: Show fan room layout and relationships between components and adjacent structural and mechanical elements. Show support locations, type of support, and weight on each support. Indicate and certify field measurements.

B. Field quality-control reports.

1.7 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For centrifugal fans to include in emergency, operation, and maintenance manuals.

B. Northwestern University Maintenance Requirement Forms, see Division 01.

1.8 DELIVERY, STORAGE AND HANDLING

A. Deliver materials to site in manufacturer’s original, unopened containers and packaging, with labels clearly indicating manufacturer, material, products included, and location of installation.

B. Store materials in a dry area indoor, protected from damage, and in accordance with manufacturer’s instructions. For long term storage, follow manufacturer’s Installation, Operation and Maintenance manual.

C. Handle and lift fans in accordance with the manufacturer’s instructions. Protect materials and finishes during handling and installation to prevent damage. Follow all safety warnings posted by the manufacturer.

1.9 MAINTENANCE MATERIAL SUBMITTALS

A. Belts: One set for each belt-driven unit.

1.10 SPECIAL WARRANTIES

A. Five (5) years, see Division 01.

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

A. Fan arrays are the standard for the University air handlers, and other fan types for air handling units are considered exceptions.

B. AMCA Compliance:

1. Comply with AMCA performance requirements and bear the AMCA-Certified Ratings Seal.
2. Operating Limits: Classify according to AMCA 99.

C. Unusual Service Conditions:

1. Ambient Temperature: <**Insert deg C**>.
2. Altitude: <**Insert** feet (m)> above sea level.
3. High humidity.

D. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

E. Capacities and Characteristics:

1. See Schedule(s) on Drawings.

2.2 AIRFOIL CENTRIFUGAL FANS

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

1. Barry Blower.
2. Howden/Buffalo.
3. Chicago Blower.
4. Greenheck Fan Corporation.
5. Industrial Air.
6. Twin City

B. Description:

1. Factory-fabricated, -assembled, -tested, and -finished, belt-driven centrifugal fans consisting of housing, wheel, fan shaft, bearings, motor, drive assembly, and support structure.
2. Deliver fans as factory-assembled units, to the extent allowable by shipping limitations.
3. Factory-installed and -wired disconnect switch.

C. Housings:

1. Formed panels to make curved-scroll housings with shaped cutoff.
2. Panel Bracing: Steel angle- or channel-iron member supports for mounting and supporting fan scroll, wheel, motor, and accessories.
3. Horizontally split, bolted-flange housing.
4. Spun inlet cone with flange.
5. Outlet flange.

D. Airfoil Wheels:

1. Single-width-single-inlet and double-width-double-inlet construction with curved inlet flange.
2. Heavy backplate.
3. Hollow die-formed, airfoil-shaped blades continuously welded at tip flange and backplate.
4. Cast-iron or cast-steel hub riveted to backplate and fastened to shaft with set screws.

E. Shafts:

1. Statically and dynamically balanced and selected for continuous operation at maximum rated fan speed and motor horsepower, with adjustable alignment and belt tensioning.
2. Turned, ground, and polished hot-rolled steel with keyway. Ship with protective coating of lubricating oil.
3. Designed to operate at no more than 70 percent of first critical speed at top of fan's speed range.

F. Grease-Lubricated Shaft Bearings:

1. Self-aligning, pillow-block-type, tapered roller bearings with double-locking collars and two-piece, cast-iron housing.
2. ***[Retain "Ball-Bearing Rating Life" or "Roller-Bearing Rating Life" Subparagraph below.]***
3. ***Ball-Bearing Rating Life: ABMA 9, Ll0 at [50,000] [120,000] hours.***
4. ***Roller-Bearing Rating Life: ABMA 11, Ll0 at [50,000] [120,000] hours.***

G. Grease-Lubricated Shaft Bearings:

1. Self-aligning, pillow-block-type, ball or roller bearings with adapter mount and two-piece, cast-iron housing.
2. [Retain "Ball-Bearing Rating Life" or "Roller-Bearing Rating Life" Subparagraph below.]
3. Ball-Bearing Rating Life: ABMA 9, Ll0 at [**50,000**] [**120,000**] hours.
4. Roller-Bearing Rating Life: ABMA 11, Ll0 at [**50,000**] [**120,000**] hours.

H. Belt Drives:

1. Factory mounted, with adjustable alignment and belt tensioning.
2. Service Factor Based on Fan Motor Size: [**1.5**] [**1.4**] [**1.3**] [**1.2**].
3. Fan Pulleys: Cast iron or cast steel with split, tapered bushing; dynamically balanced at factory.
4. 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.
5. Belts: Oil resistant, non-sparking, and non-static; matched sets for multiple belt drives.
6. Belt Guards: Fabricate to comply with OSHA and SMACNA requirements of diamond-mesh wire screen welded to steel angle frame or equivalent, prime coated. Secure to fan or fan supports without short circuiting vibration isolation. Include provisions for adjustment of belt tension, lubrication, and use of tachometer with guard in place.
7. Motor Mount: Adjustable for belt tensioning.

I. Accessories:

1. ***Access for Inspection, Cleaning, and Maintenance: Comply with requirements in ASHRAE 62.1.***
2. ***Scroll Drain Connection: NPS 1 (DN 25) steel pipe coupling welded to low point of fan scroll.***
3. ***Companion Flanges: Rolled flanges for duct connections of same material as housing.***
4. ***Inlet Screens: Grid screen of same material as housing.***
5. ***Shaft Cooler: Metal disk between bearings and fan wheel, designed to dissipate heat from shaft.***
6. ***Spark-Resistant Construction: AMCA 99.***
7. ***Shaft Seals: Airtight seals installed around shaft on drive side of single-width fans.***

2.3 BACKWARD-INCLINED CENTRIFUGAL FANS

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

1. Barry Blower.
2. Howden/Buffalo.
3. Chicago Blower.
4. Greenheck Fan Corporation.
5. Industrial Air.
6. Twin City

B. Description:

1. Factory-fabricated, -assembled, -tested, and -finished, belt-driven centrifugal fans consisting of housing, wheel, fan shaft, bearings, motor, drive assembly, and support structure.
2. Deliver fans as factory-assembled units, to the extent allowable by shipping limitations.
3. Factory-installed and -wired disconnect switch.

C. Housings:

1. Formed panels to make curved-scroll housings with shaped cutoff.
2. Panel Bracing: Steel angle- or channel-iron member supports for mounting and supporting fan scroll, wheel, motor, and accessories.
3. Horizontally split, bolted-flange housing.
4. Spun inlet cone with flange.
5. Outlet flange.

D. Backward-Inclined Wheels:

1. Single-width-single-inlet and double-width-double-inlet construction with curved inlet flange, backplate, backward-inclined blades, and fastened to shaft with set screws.
2. Welded or riveted to flange and backplate; cast-iron or cast-steel hub riveted to backplate.

E. Shafts:

1. Statically and dynamically balanced and selected for continuous operation at maximum rated fan speed and motor horsepower, with adjustable alignment and belt tensioning.
2. Turned, ground, and polished hot-rolled steel with keyway. Ship with protective coating of lubricating oil.
3. Designed to operate at no more than 70 percent of first critical speed at top of fan's speed range.

F. Grease-Lubricated Shaft Bearings:

1. Self-aligning, pillow-block-type, tapered roller bearings with double-locking collars and two-piece, cast-iron housing.
2. [Retain "Ball-Bearing Rating Life" or "Roller-Bearing Rating Life" Subparagraph below.]
3. Ball-Bearing Rating Life: ABMA 9, Ll0 at [50,000] [120,000] hours.
4. Roller-Bearing Rating Life: ABMA 11, Ll0 at [50,000] [120,000] hours.

G. Belt Drives:

1. Factory mounted, with adjustable alignment and belt tensioning.
2. Service Factor Based on Fan Motor Size: [**1.5**] [**1.4**] [**1.3**] [**1.2**].

3. Fan Pulleys: Cast iron or cast steel with split, tapered bushing; dynamically balanced at factory.
4. 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.
5. Belts: Oil resistant, non-sparking, and non-static; matched sets for multiple belt drives.
6. Belt Guards: Fabricate to comply with OSHA and SMACNA requirements of diamond-mesh wire screen welded to steel angle frame or equivalent, prime coated. Secure to fan or fan supports without short circuiting vibration isolation. Include provisions for adjustment of belt tension, lubrication, and use of tachometer with guard in place.
7. Motor Mount: Adjustable for belt tensioning.

H. Accessories:

1. Access for Inspection, Cleaning, and Maintenance: Comply with requirements in ASHRAE 62.1.
2. Scroll Drain Connection: NPS 1 (DN 25) steel pipe coupling welded to low point of fan scroll.
3. Companion Flanges: Rolled flanges for duct connections of same material as housing.
4. Inlet Screens: Grid screen of same material as housing.
5. Shaft Cooler: Metal disk between bearings and fan wheel, designed to dissipate heat from shaft.
6. Spark-Resistant Construction: AMCA 99.
7. Shaft Seals: Airtight seals installed around shaft on drive side of single-width fans.

2.4 PLENUM FANS

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

1. Barry Blower.
2. Howden/Buffalo.
3. Chicago Blower.
4. Greenheck Fan Corporation.
5. Industrial Air.
6. Twin City

B. Description:

1. Factory-fabricated, -assembled, -tested, and -finished, ***belt-driven or direct driven*** centrifugal fans consisting of wheel, fan shaft, bearings, motor, drive assembly, and support structure.
2. Deliver fans as factory-assembled units, to the extent allowable by shipping limitations.
3. Factory-installed and -wired disconnect switch.

C. Airfoil Wheels:

1. Single-width-single-inlet construction with smooth-curved inlet flange.
2. Heavy backplate.
3. Hollow die-formed, airfoil-shaped blades continuously welded at tip flange and backplate.
4. Cast-iron or cast-steel hub riveted to backplate and fastened to shaft with set screws.

D. Shafts:

1. Statically and dynamically balanced and selected for continuous operation at maximum-rated fan speed and motor horsepower, with adjustable alignment and belt tensioning.
2. Turned, ground, and polished hot-rolled steel with keyway. Ship with protective coating of lubricating oil.
3. Designed to operate at no more than 70 percent of first critical speed at top of fan's speed range.

E. Grease-Lubricated Shaft Bearings ***(If belt drive)***:

1. Self-aligning, pillow-block-type, tapered roller bearings with double-locking collars and two-piece, cast-iron housing.
2. ***[Retain "Ball-Bearing Rating Life" or "Roller-Bearing Rating Life" Subparagraph below.]***
3. ***Ball-Bearing Rating Life: ABMA 9, Ll0 at [50,000] [120,000] hours.***
4. ***Roller-Bearing Rating Life: ABMA 11, Ll0 at [50,000] [120,000] hours.***

F. Belt Drives ***(If belt driven)***:

1. Factory mounted, with adjustable alignment and belt tensioning.
2. Service Factor Based on Fan Motor Size: [**1.5**] [**1.4**] [**1.3**] [**1.2**].
3. Fan Pulleys: Cast iron or cast steel with split, tapered bushing; dynamically balanced at factory.
4. 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.
5. Belts: Oil resistant, nonsparking, and nonstatic; matched sets for multiple belt drives.
6. Belt Guards: Fabricate to comply with OSHA and SMACNA requirements of diamond-mesh wire screen welded to steel angle frame or equivalent, prime coated. Secure to fan or fan supports without short circuiting vibration isolation. Include provisions for adjustment of belt tension, lubrication, and use of tachometer with guard in place.
7. Motor Mount: Adjustable for belt tensioning.

G. Accessories:

1. ***Shaft Cooler: Metal disk between bearings and fan wheel, designed to dissipate heat from shaft.***
2. ***Spark-Resistant Construction: AMCA 99.***
3. ***Shaft Seals: Airtight seals installed around shaft on drive side of single-width fans.***

2.5 HIGH BLOW LAB EXHAUST FANS

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

1. Greenheck Fan Corporation.
2. Strobic Air.

B. General

1. Base fan performance at standard conditions (density 0.075 Lb. /ft^3).

2. Each fan shall be direct driven in AMCA arrangement 2 according to drawings.
3. Each fan to be equipped with 316 stainless steel lifting lugs for corrosion resistance.
4. Fasteners exposed to corrosive exhaust shall be stainless steel.
5. Curb cap shall be hot rolled steel ***[316 stainless steel]*** coated with corrosion resistant coating.
6. Fan assemblies that use flexible connectors that can fail and cause loss of laboratory containment shall not be acceptable.
7. Fan assembly shall be designed for project design wind loading, without the use of guy wires.
8. Fans to be constant plume design.

C. Corrosion Resistant Coating

1. All fan and system components (fan, nozzle, windband and plenum) shall be corrosion resistant coated with a two part electrostatically applied and baked, sustainable, corrosion resistant coating system, or equal. Standard finish color to be chosen by University.
2. 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.
3. 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.
4. 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.
5. Note that 10-20 mil thick wet coating systems pollute the environment (air and water), and that these manually applied coatings are not uniform over the impeller surface and can cause fan imbalance and vibration.

D. Fan Housing and Outlet

1. Fan housing to be aerodynamically designed with high-efficiency inlet, engineered to reduce incoming air turbulence.
2. Fan housing shall be bifurcated, allowing all drive components, including the motor, to be serviced without contact of the contaminated airstream. Must be manufactured of welded steel and meet specification section 2.5-C for corrosion resistant coating. No uncoated metal fan parts will be acceptable.
3. 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.
4. A multi-stage air induction discharge nozzle shall be supplied by the fan manufacturer designed to efficiently handle an outlet velocity of up to 7000 FPM. The multi-stage nozzle shall induce ambient air up to 270% of fan capacity. Nozzle / Wind band assemblies that are manufactured by third party vendors or that are fabricated of plastic or resins, having mechanical properties less than steel shall not be acceptable.
5. An integral fan housing drain shall be used to drain rainwater when the fan is de-energized.
6. A bolted & gasketed access door shall be supplied for impeller inspection and service.
7. Fan assembly shall be AMCA type C spark resistant construction minimum or as noted on the schedule.

E. Fan Impeller

1. Fan impeller shall be mixed flow design with non-stall characteristics. The impeller shall be electronically balanced both statically and dynamically exceeding AMCA Standards.
2. Fan impeller shall be manufactured of welded and coated steel. Reference specification section 2.5-C for corrosion resistant coating.
3. Fan impellers that are fabricated of polypropylene or fiberglass that have lower mechanical properties than steel, and lower maximum tip speeds are not acceptable.
4. Vacuum Seal: Fan impeller shall include a secondary fan blade located on the impeller back plate. This secondary impeller shall create a negative pressure at the shaft opening; preventing hazardous or toxic exhaust fumes from escaping through the housing shaft opening. Mechanical shaft seals that wear out and need to be replaced or seal systems that use hoses or tubes that can leak, are not acceptable.

F. Bypass Air Plenum

1. For constant volume systems, the fan / nozzle assembly shall be connected directly to roof curb and exhaust duct without the need of the bypass air plenum. Fans mounted directly to roof curb shall be provided with a damper tray located in the roof curb for mounting of the gravity isolation damper.
2. For variable volume systems, a bypass air plenum shall be provided as shown on drawings. The plenum shall be provided with bypass air damper(s) for introducing outside air at roof level upstream of the fan, complete with bypass air weatherhood and bird screen.
3. The plenum shall be constructed of welded and coated steel and meet specification section 2.5-C for corrosion resistant coating. Plenums that are fabricated of plastics or resins that are combustible and have mechanical properties less than steel shall not be acceptable.
4. The bypass air plenum shall be mounted on factory fabricated roof curb provided by the fan manufacturer, as shown on the project drawings.
5. Fan designs that use inlet flexible connectors that can leak causing loss of lab exhaust shall not be permitted.
6. Bypass air damper(s) shall be opposed-blade design for airflow control, airfoil design, fabricated of galvanized steel ***[316 stainless steel]*** for structural rigidity as standard. Bypass damper(s) shall have plated steel damper rods, stainless steel sleeved bearings, 301 stainless steel jamb seals and the blades shall have polymer edge seals. Damper model shall be equal to or exceed a heavy duty control damper, Greenheck HCD-130 or equal. Damper blade drive linkage shall be set by manufacturer and welded to eliminate linkage slippage. All damper access and service (drive actuators) shall be performed outside of the contaminated airstream.
7. If stated in the schedule notes, an optional, integral bypass air packed acoustic attenuator fabricated of galvanized steel ***[galvanneal or stainless steel construction]*** shall be provided by the fan manufacturer (if shown on the drawings).
8. Fan isolation damper(s), shall be parallel-blade design, airfoil design, fabricated of steel ***[304 stainless steel construction]*** for structural rigidity as standard. Damper(s) shall be coated up to 4 mils of chemically resistant Hi-Pro Polyester resin (or equal), electrostatically applied and baked. Isolation damper(s) shall have plated steel damper rods (if specified as 304 stainless steel damper, stainless steel damper rods will be provided), stainless steel sleeved bearings, 301 stainless steel jamb seals and the blades shall have polymer edge seals. Damper model shall be equal to or exceed a heavy duty control damper, Greenheck HCD-130 or equal. Damper blade drive linkage shall be set by manufacturer and welded to eliminate linkage slippage. All damper access and service (drive actuators) shall be performed outside of the contaminated airstream.

9. Isolation damper actuator(s), if scheduled shall be factory mounted and shall be wired to a step-down transformer. Actuator and transformer are located in a weatherproof enclosure.
10. Blower / Plenum vibration isolation shall be limited to neoprene / cork vibration pads.

G. Bypass Air Plenum Curb

1. Exhaust system manufacturer shall supply a structural support curb for the plenum of specified height as shown on the drawings.
2. Curb shall be fabricated of a minimum of 12 gauge corrosion-resistant coated steel and structurally reinforced.
3. Curb shall be insulated.
4. When properly anchored to the roof structure, the standard curb / plenum / blower assembly shall withstand project required wind loadswithout additional structural support.

H. Fan Motor and Drive

1. Motors shall be premium efficiency, standard NEMA frame, 1800 or 3600 RPM, TEFC with a 1.15 service factor. A factory-mounted NEMA 3R ***[NEMA 4X]*** disconnect switch shall be provided for each fan.
2. Motor maintenance shall be accomplished without fan or fan impeller removal, or requiring maintenance personnel to access the contaminated exhaust components.
3. Motor mounting shall be "C-face" and / or foot mount.
4. Drive arrangement shall be AMCA arrangement 2, utilizing a direct mount coupling connecting the motor shaft and fan impeller shaft. Belt drive arrangement 9 or 10, or direct drive arrangement 4 requiring access and handling of hazardous and contaminated fan components are not acceptable.
5. Fan shaft to be turned and polished of 1040 steel material ***[316 stainless steel]*** as standard, coated with corrosion resistant coating.
6. Fan shaft bearing shall be Air Handling Quality, ball or roller pillow block type, and sized for an L-10 life of no less than 200,000 hours.
7. All shaft bearings and non-permanently lubricated motors shall have nylon [stainless steel braided] extended lube lines with zerk fittings.
8. Motor, coupling, and bearing shall all be outside the contaminated exhaust, and be capable of replacement without disassembling fan and accessing hazardous and contaminated fan components.

2.6 FAN ARRAYS

1. Fan Array

a. Fan array system shall consist of multiple, direct driven, arrangement 4 plenum fans constructed per AMCA requirements for duty specified. Fans shall be selected to deliver scheduled airflow quantity at scheduled operating total static pressure and scheduled fan/motor speed. Fan array shall be selected to operate at system total static pressure that does not exceed 90% of scheduled fan's peak static pressure producing capability at scheduled fan/motor speed.
b. Fan intake wall, inlet funnel, and motor support structure shall be powder coated for superior corrosion resistance. Motors shall be standard pedestal mounted type, T-frame motors selected at specified operating voltage, rpm, and efficiency as needed to meet performance requirements. Motors shall include isolated bearings or shaft grounding. Each fan/motor cartridge shall be dynamically balanced to

meet AMCA standard 204-96, category BV-5, to meet or exceed Grade 2.5 residual unbalance.

1) Fan array shall provide uniform air flow and velocity profile across entire air way tunnel cross section. Airflow and velocity shall not exceed scheduled cooling coil and/or filter bank face velocity when measured at a point 12 inches from intake side of fan wall array intake plenum wall, and distance of 48 inches from discharge side of fan wall intake plenum wall.
2) Provide partition between fans to minimize system effect.
3) Provide structural frame to support upper fans with solid floor panel partition between fans as shown on drawings to minimize system effect.
4) Each fan in array shall be provided with back flow prevention means that produces less than 0.10 inches wc of static pressure drop and/or system effect when that fan is enabled. Any such system effects and/or pressure drops shall be submitted and included as component in determining fan system total static pressure as submitted. Manufacturer's pressure drop ratings of any such equipment, developed from straight run test conditions will not be accepted.
5) Provide 2 separate variable frequency drives for fan array. Each VFD shall control half of fans in array. Provide one backup VFD for air handling unit.
6) Fan array shall be sized such that upon single fan failure, remaining fans could ramp up and provide same 100% design capacity.
7) Technology with multiple fans having individual VFDs may be considered.
8) Provide local electrical disconnect for each fan.
9) Contractor shall provide all wiring to air handling unit components that require power.

2.7 MOTORS

A. Comply with NEMA designation, temperature rating, service factor, and efficiency requirements for motors specified in Section 23 0513 "Motors."

2.8 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/ASHRAE 51, "Laboratory Methods of Testing Fans for Certified Aerodynamic Performance Rating."

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine areas to receive fans. Notify the Engineer of conditions that would adversely affect installation or subsequent utilization and maintenance of fans. Do not proceed with installation until unsatisfactory conditions are corrected.

3.2 INSTALLATION AND ACCESS

A. Install fans level and plumb and according to fan manufacturer's instructions..

B. Disassemble and reassemble units, as required for moving to the final location, according to manufacturer's written instructions.

C. Lift and support units with manufacturer's designated lifting or supporting points.

D. Equipment Mounting: Install centrifugal fans on cast-in-place concrete equipment base(s) using [**elastomeric pads**] [**elastomeric mounts**] [**restrained spring isolators**]. Comply with requirements for equipment bases specified in [**Section 03 3000 "Cast-in-Place Concrete."**] [**Section 03 3053 "Miscellaneous Cast-in-Place Concrete."**] Comply with requirements for vibration isolation devices specified in Section 23 0550 "Vibration Isolation."

1. Minimum Deflection: [1/4 inch (6 mm)] [1 inch (25 mm)].
2. Coordinate sizes and locations of concrete bases with actual equipment provided. Cast anchor-bolt inserts into bases.
3. Install dowel rods to connect concrete base to concrete floor. Unless otherwise indicated, install dowel rods on 18-inch (450-mm) centers around the full perimeter of concrete base.
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.
6. Install anchor bolts to elevations required for proper attachment to supported equipment.
7. Install on [4-inch- (100-mm-)] [6-inch- (150-mm-)] high concrete base.

E. Equipment Mounting: Install centrifugal fans using [**elastomeric pads**] [**elastomeric mounts**] [**restrained spring isolators**]. Comply with requirements for vibration isolation devices specified in Section 23 0550 "Vibration Isolation."

1. Minimum Deflection: [1/4 inch (6 mm)] [1 inch (25 mm)].

F. Equipment Mounting: Install centrifugal fans on vibration isolation equipment base. Comply with requirements specified in Section 23 0550 "Vibration Isolation."

G. Equipment Mounting: Install continuous-thread hanger rods and [**elastomeric hangers**] [**spring hangers**] [**spring hangers with vertical-limit stop**] of size required to support weight of dehumidification unit.

1. Comply with requirements for seismic-restraint devices specified in Section 23 0550 "Vibration Isolation."
2. Comply with requirements for hangers and supports specified in Section 23 0529 "Mechanical Supporting Devices."

H. Curb Support: Install roof curb on roof structure, level and secure, according to "The NRCA Roofing and Waterproofing Manual," Low-Slope Membrane Roofing Construction Details Section, Illustration "Raised Curb Detail for Rooftop Air Handling Units and Ducts." Install and secure centrifugal fans on curbs, and coordinate roof penetrations and flashing with roof construction.[**Secure units to curb support with anchor bolts.**]

I. Unit Support: Install centrifugal fans level on structural [**curbs**] [**pilings**]. Coordinate wall penetrations and flashing with wall construction.[**Secure units to structural support with anchor bolts.**]

J. Isolation Curb Support: Install centrifugal fans on isolation curbs, and install[**flexible duct connectors**] and vibration isolation devices.

1. Comply with requirements in Section 23 3314 "Ductwork Specialties" for flexible duct connectors.
2. Comply with requirements in Section 23 0550 "Vibration Isolation" for vibration isolation devices.

K. Install units with clearances for service and maintenance.

L. Pipe housing drains to nearest point of proper discharge.

M. Label fans according to requirements specified in Section 23 0553 "Mechanical System Identification."

N. Provide/build OSHA approved engineered platforms for preventative maintenance for items not accessible from a normal area standing position.

3.3 CONNECTIONS

A. Drawings indicate general arrangement of ducts and duct accessories. Make final duct connections with flexible connectors. Flexible connectors are specified in Section 23 3314 "Ductwork Specialties."

B. Install ducts adjacent to fans to allow service and maintenance.

C. Install piping from scroll drain connection, with trap with seal equal to 1.5 times specified static pressure, to nearest floor drain with pipe sizes matching the drain connection.

3.4 FIELD QUALITY CONTROL

A. Testing Agency: University will engage a qualified testing agency to perform tests and inspections.

B. Manufacturer's Field Service: Engage a factory-authorized service representative to test and inspect components, assemblies, and equipment installations, including connections.

C. Perform the following tests and inspections with the assistance of a factory-authorized service representative:

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. See Section 23 0594 "Testing, Adjusting, and Balancing (TAB)" for testing, adjusting, and balancing procedures.
10. Remove and replace malfunctioning units and retest as specified above.

D. Test and adjust controls and safeties. Controls and equipment will be considered defective if they do not pass tests and inspections.

E. Prepare test and inspection reports.

3.5 DEMONSTRATION

A. Engage a factory-authorized service representative to train University maintenance personnel to adjust, operate, and maintain the equipment of this section.

END OF SECTION 23 3400

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SECTION 23 3600 - AIR TERMINAL DEVICES

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:

1. Fan-powered air terminal units/devices.
2. Shut off air terminal units/devices.
3. Dual duct terminal units/devices.

1.2 SUBMITTALS

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

B. [LEED Submittal:

1. Product Data for Prerequisite EQ 1: Documentation indicating that units comply with ASHRAE 62.1-2007, Section 5 - "Systems and Equipment."]

C. Shop Drawings: For air terminal units. Include plans, elevations, sections, details, and attachments to other work.

D. Field quality-control reports.

E. Operation and maintenance data.

F. Northwestern University Maintenance Requirement Forms, see Division 01.

1.3 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: Applicable requirements in ASHRAE 62.1-2007, Section 5 - "Systems and Equipment" and Section 7 - "Construction and System Start-Up."

1.4 SPECIAL WARRANTIES

A. Five (5) years, see Division 01.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. Subject to compliance with requirements, provide products by one of the following (see schedules for Basis of Design):

1. Nailor
2. Price
3. Titus
4. Tuttle and Bailey

2.2 TERMINAL UNIT WALL CONSTRUCTION FOR CRITICAL AREAS/AIR AND NON-CRITICAL AREAS/AIR

A. For critical areas/air, all units to be double wall. For high humidity areas/air (which are also considered critical, units to be stainless steel (and this requirement for stainless steel for critical areas/air overrides any conflicting material requirements that may exist below). For non-critical areas/air, units can be double wall or single wall fiber free lined.

2.3 SERIES FAN-POWERED AIR TERMINAL UNITS

A. Configuration: Volume-damper assembly and fan in series arrangement inside unit casing with control components inside a protective metal shroud for installation above a ceiling and in areas without a ceiling.

B. Casing: ***minimum 22 gauge*** steel, single wall or double wall for non-critical areas/air, double wall for critical areas/air.

1. Casing Lining:

   a. Adhesive attached, 3/4" foil faced fibrous-glass insulation complying with ASTM C 1071, with a reinforced foil facing on the airstream side, and having a maximum flame/smoke index of 25/50, for both insulation and adhesive, when tested according to ASTM E 84.
   b. Elastomeric Closed Cell Foam Insulation is an acceptable alternate. Insulation must meet 25/50 flame/smoke index, and comply with antimicrobial performance of no observed growth per ASTM G-21

2. Air Inlets: Round stub connections or S-slip and drive connections for duct attachment.
3. Air Outlet: S-slip and drive connections.
4. Access: Removable top and bottom panels for access to parts requiring service, adjustment, or maintenance; with airtight gasket and quarter-turn latches.
5. Fan: Forward-curved centrifugal.
6. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1-2007.

C. Volume Damper: Minimum 22 gauge steel with shaft rotating in self-lubricating bearings. Shaft shall be clearly marked on the end to indicate damper position.

1. Mechanical stop to prevent overstroking of damper.

2. The air valve leakage shall not exceed 1% of maximum inlet rated airflow at 3" W.G. inlet pressure.

D. Velocity Sensors: Single axis sensor shall not be acceptable for duct diameters 6" or larger. Multiple pressure sensing points shall be utilized. The total pressure inputs shall be averaged using a pressure chamber located at the center of the sensor. Sensor shall have an error of plus or minus 5% or better.

E. Motor:

1. 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."
2. Type: Electronically commutated motor.
3. Fan-Motor Assembly Isolation: Rubber isolators.
4. Efficiency: Premium efficient.
5. Motor Speed: Variable, SCR controlled.
6. Electrical Characteristics: as scheduled on drawings.

F. Filters: Terminals shall include a 1" thick disposable MERV 7 polyester filter (spun fiberglass is not acceptable). Filter shall be secured with quick release clips, allowing removal without horizontal sliding.

G. Hydronic Coils: Copper tube, with mechanically bonded aluminum fins spaced no closer than 0.1 inch***, and rated for a minimum working pressure of*** 300 psig ***and a maximum entering-water temperature of*** 200 deg F***. Include manual air vent and drain valve.***

H. Control Panel Enclosure: Electrical components mounted in control box with removable cover and mounted on side of unit. Incorporate single-point electrical connection to power source.

1. Control Transformer: Factory mounted for control voltage on electric and electronic control units with terminal strip in control box for field wiring of thermostat and power source.
2. Wiring Terminations: Fan and controls to terminal strip. Terminal lugs to match quantities, sizes, and materials of branch-circuit conductors. Enclose terminal lugs in terminal box that is sized according to NFPA 70.
3. Disconnect Switch: Factory-mounted, fuse type.

I. Direct Digital Controls : Single phase unitary controller and actuator as specified in Division 25.

J. All boxes shall have a maximum NC (Rad.) as scheduled on drawings. If required provide attenuation to meet the NC level as scheduled.

2.4 PARALLEL FAN-POWERED AIR TERMINAL UNITS

A. Configuration: Volume-damper assembly and fan in parallel arrangement inside unit casing with control components inside a protective metal shroud.

B. Casing: [0.034-inch (0.85-mm) steel] [0.032-inch (0.8-mm) aluminum], single or double wall for non-critical areas/air, double wall for critical areas/air.

1. Casing Lining: Adhesive attached, [1/2-inch- (13-mm-)] [3/4-inch- (19-mm-)] [1-inch- (25-mm-)] thick, coated, fibrous-glass duct liner complying with

ASTM C 1071, and having a maximum flame-spread index of 25 and a maximum smoke-developed index of 50, for both insulation and adhesive, when tested according to ASTM E 84.

   a. ***Cover liner with nonporous foil.***
   b. ***Cover liner with nonporous foil and perforated metal.***

2. Air Inlets: Round stub connections or S-slip and drive connections for duct attachment.
3. Air Outlet: S-slip and drive connections.
4. Access: Removable panels for access to parts requiring service, adjustment, or maintenance; with airtight gasket and quarter-turn latches.
5. Fan: Forward-curved centrifugal, located at plenum air inlet.
6. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1-2004.

C. Volume Damper: Galvanized steel with flow-sensing ring and peripheral gasket and self-lubricating bearings.

   1. Maximum Damper Leakage: ARI 880 rated, [**2**] [**3**] percent of nominal airflow at [***3-inch wg (750-Pa)***] [***6-inch wg (1500-Pa)***] inlet static pressure.
   2. Damper Position: Normally [**open**] [**closed**].

D. Velocity Sensors: Multipoint array with velocity sensors in cold- and hot-deck air inlets and air outlets.

E. Motor:

   1. 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."
   2. Type: [**Permanent-split capacitor with SCR for speed adjustment**] [**Electronically commutated motor**].
   3. Fan-Motor Assembly Isolation: Rubber isolators.
   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**].
   6. Motor Bearings: <**Insert special requirements**>.
   7. Unusual Service Conditions:

      a. Ambient Temperature: <**Insert *deg F (deg C)***>.
      b. Altitude: <**Insert *feet (m)***> above sea level.
      c. High humidity.
      d. <**Insert conditions**>.

   8. Efficiency: Premium efficient.
   9. NEMA Design: <**Insert designation**>.
   10. Service Factor: <**Insert value**>.
   11. Motor Speed: [**Single speed**] [**Multispeed**].

      a. Speed Control: Infinitely adjustable with electronic controls.

   12. Electrical Characteristics: See schedules.

F. Filters: Minimum arrestance according to ASHRAE 52.1 and a minimum efficiency reporting value (MERV) according to ASHRAE 52.2.

1. ***Material: Polyurethane foam having 70 percent arrestance and 3 MERV.***
2. ***Material: Glass fiber treated with adhesive; having 80 percent arrestance and 5 MERV.***
3. ***Material: Pleated cotton-polyester media having 90 percent arrestance and 7 MERV.***
4. ***Thickness: [2 inches (50 mm)] [1 inch (25 mm)].***

G. Attenuator Section: [***0.034-inch (0.85-mm)*** **steel**] [***0.032-inch (0.8-mm)*** **aluminum**] sheet.

1. ***Lining: Adhesive attached, [1/2-inch- (13-mm-)] [3/4-inch- (19-mm-)] [1-inch- (25-mm-)] thick, coated, fibrous-glass duct liner complying with ASTM C 1071, and having a maximum flame-spread index of 25 and a maximum smoke-developed index of 50, for both insulation and adhesive, when tested according to ASTM E 84.***

   a. ***Cover liner with nonporous foil.***
   b. ***Cover liner with nonporous foil and perforated metal.***

2. ***Lining: Adhesive attached, 3/4-inch- (19-mm-) thick, polyurethane foam insulation complying with UL 181 erosion requirements, and having a maximum flame-spread index of 25 and a maximum smoke-developed index of 50, for both insulation and adhesive, when tested according to ASTM E 84.***
3. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1-2004.

H. Hydronic Coils: Copper tube, with mechanically bonded aluminum fins spaced no closer than 0.1 inch (2.5 mm), and rated for a minimum working pressure of 200 psig (1380 kPa) and a maximum entering-water temperature of 220 deg F (104 deg C). Include manual air vent and drain valve.

1. ***Location: Plenum air inlet.***

I. Electric-Resistance Heating Coils: Nickel-chromium heating wire, free of expansion noise and hum, mounted in ceramic inserts in a galvanized-steel housing; with primary automatic, and secondary manual, reset thermal cutouts. Terminate elements in stainless-steel, machine-staked terminals secured with stainless-steel hardware.

1. ***Location: Plenum air inlet.***
2. ***Stage(s): [1] [2] [3].***
3. ***Access door interlocked disconnect switch.***
4. ***Downstream air temperature sensor with local connection to override discharge-air temperature to not exceed a maximum temperature set point (adjustable.)***
5. ***Nickel chrome 80/20 heating elements.***
6. ***Airflow switch for proof of airflow.***
7. ***Fan interlock contacts.***
8. ***Fuses in terminal box for overcurrent protection (for coils more than 48 A).***
9. ***Mercury contactors.***
10. ***Magnetic contactor for each step of control (for three-phase coils).***

J. Factory-Mounted and -Wired Controls: Electrical components mounted in control box with removable cover. Incorporate single-point electrical connection to power source.

1. ***Control Transformer: Factory mounted for control voltage on electric and electronic control units with terminal strip in control box for field wiring of thermostat and power source.***
2. ***Wiring Terminations: Fan and controls to terminal strip. Terminal lugs to match quantities, sizes, and materials of branch-circuit conductors. Enclose terminal lugs in terminal box that is sized according to NFPA 70.***
3. ***Disconnect Switch: Factory-mounted, fuse type.***

K. Control Panel Enclosure: NEMA 250, Type 1, with access panel sealed from airflow and mounted on side of unit.

L. Electric Controls: 24-V damper actuator with wall-mounted electric thermostat and appropriate mounting hardware.

M. Electronic Controls: Bidirectional damper operator and microprocessor-based controller with integral airflow transducer and room sensor. Control devices shall be compatible with temperature controls specified in Division 23 Section "Instrumentation and Control for HVAC" and shall have the following features:

1. ***Occupied and unoccupied operating mode.***
2. ***Remote reset of airflow or temperature set points.***
3. ***Adjusting and monitoring with portable terminal.***
4. ***Communication with temperature-control system specified in Division 25.***

2.5 SHUTOFF, SINGLE-DUCT AIR TERMINAL UNITS

A. Configuration: Volume-damper assembly inside unit casing with control components inside a protective metal shroud.

B. Casing: ***minimum 22 gauge*** steel, single wall or double wall for non-critical areas/air, double wall for critical areas/air.

1. Casing Lining:

    a. Adhesive attached, 3/4" foil faced fibrous-glass insulation complying with ASTM C 1071, with a reinforced foil facing on the airstream side, and having a maximum flame/smoke index of 25/50, for both insulation and adhesive, when tested according to ASTM E 84.
    b. Elastomeric Closed Cell Foam Insulation is an acceptable alternate. Insulation must meet 25/50 flame/smoke index, and comply with antimicrobial performance of no observed growth per ASTM G-21

2. Air Inlet: Round stub connection or S-slip and drive connections for duct attachment.
3. Air Outlet: S-slip and drive connections.
4. Access: Removable panels for access to parts requiring service, adjustment, or maintenance; with airtight gasket.
5. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1-2007.

C. Velocity Sensors: Single axis sensor shall not be acceptable for duct diameters 6" or larger. Multiple pressure sensing points shall be utilized. The total pressure inputs shall be averaged using a pressure chamber located at the center of the sensor. Sensor shall have an error of plus or minus 5% or better.

D. Volume Damper: Minimum 22 gauge steel with shaft rotating in self-lubricating bearings. Shaft shall be clearly marked on the end to indicate damper position.

1. Mechanical stop to prevent overstroking of damper.
2. The air valve leakage shall not exceed 1% of maximum inlet rated airflow at 3" W.G. inlet pressure.

E. Attenuator Section: [***0.034-inch (0.85-mm)*** **steel**] [***0.032-inch (0.8-mm)*** **aluminum**] sheet.

1. Lining: Adhesive attached, [1/2-inch- (13-mm-)] [3/4-inch- (19-mm-)] [1-inch- (25-mm-)] thick, coated, fibrous-glass duct liner complying with ASTM C 1071, and having a maximum flame-spread index of 25 and a maximum smoke-developed index of 50, for both insulation and adhesive, when tested according to ASTM E 84.

a. Cover liner with nonporous foil.
b. Cover liner with nonporous foil and perforated metal.

2. Lining: Adhesive attached, 3/4-inch- (19-mm-) thick, polyurethane foam insulation complying with UL 181 erosion requirements, and having a maximum flame-spread index of 25 and a maximum smoke-developed index of 50, for both insulation and adhesive, when tested according to ASTM E 84.
3. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1-2004.

F. Hydronic Coils: Copper tube, with mechanically bonded aluminum fins spaced no closer than 0.1 inch, and rated for a minimum working pressure of 300 psig and a maximum entering-water temperature of 200 deg F. Include manual air vent and drain valve.

G. Electric-Resistance Heating Coils: Nickel-chromium heating wire, free of expansion noise and hum, mounted in ceramic inserts in a galvanized-steel housing; with primary automatic, and secondary manual, reset thermal cutouts. Terminate elements in stainless-steel, machine-staked terminals secured with stainless-steel hardware.

1. Access door interlocked disconnect switch.
2. Downstream air temperature sensor with local connection to override discharge-air temperature to not exceed a maximum temperature set point (adjustable.)
3. Nickel chrome 80/20 heating elements.
4. Airflow switch for proof of airflow.
5. Fan interlock contacts.
6. Fuses in terminal box for overcurrent protection (for coils more than 48 A).
7. Mercury contactors.
8. Magnetic contactor for each step of control (for three-phase coils).

H. Electric Controls: Damper actuator and thermostat.

1. Damper Actuator: 24 V, powered closed, [spring return open] [powered open].
2. Thermostat: Wall-mounted electronic type with clock display, temperature display in Fahrenheit and Celsius, and space temperature set point.

I. Electronic Controls: Bidirectional damper operator and microprocessor-based thermostat with integral airflow transducer and room sensor. Control devices shall be compatible with temperature controls specified in Division 23 Section "Instrumentation and Control for HVAC" and shall have the following features:

1. Damper Actuator: 24 V, powered closed, [spring return open] [powered open].
2. Velocity Controller: Factory calibrated and field adjustable to minimum and maximum air volumes; shall maintain constant airflow dictated by thermostat within 5 percent of set point while compensating for inlet static-pressure variations up to 4-inch wg (1000 Pa); and shall have a multipoint velocity sensor at air inlet.
3. Thermostat: Wall-mounted electronic type with temperature set-point display in Fahrenheit and Celsius.

2.6 DUAL DUCT AIR TERMINAL UNITS

A. Configuration: [**Mixing**] [**and**] [**non-mixing**] with two volume dampers inside unit casing with mixing attenuator section and control components inside a protective metal shroud[**with a third primary air inlet with volume damper**].

B. Casing: [***0.040-inch- (1.0-mm-)***] [***0.034-inch- (0.85-mm-)***] <Insert dimension> thick galvanized steel, single wall or double wall for non-critical areas/air, double wall for critical areas/air.

1. Casing Liner: Comply with requirements in "Casing Liner" Article for [fibrous-glass] [flexible elastomeric] duct liner.
2. Air Inlets: Round stub connections or S-slip and drive connections for duct attachment.
3. Air Outlet: S-slip and drive connections.
4. Access: Removable panels for access to parts requiring service, adjustment, or maintenance; with airtight gasket.
5. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.

C. Volume Damper: Galvanized steel with peripheral gasket and self-lubricating bearings.

1. Maximum Damper Leakage: AHRI 880 rated, 3 percent of nominal airflow at [***3-inch wg (750-Pa)***] [***6-inch wg (1500-Pa)***] inlet static pressure.
2. Damper Position: Normally [**open**] [**closed**].

D. Velocity Sensors: Multipoint array with velocity sensors in air inlets and air outlets.

E. Attenuator Section: [***0.034-inch (0.85-mm)*** galvanized steel] [***0.032-inch (0.8-mm)*** aluminum] sheet.

1. Attenuator Section Liner: Comply with requirements in "Casing Liner" Article for [**fibrous-glass**] [**flexible elastomeric**] duct liner.
2. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.

F. Multioutlet Attenuator Section: With [**two**] [**three**] [**four**] <**Insert number**> [***6-inch- (150-mm-)***] [***8-inch- (200-mm-)***] [***10-inch- (250-mm-)***] [***12-inch- (300-mm-)***] diameter collars, each with locking butterfly balancing damper.

1. Attenuator Section Liner: Comply with requirements in "Casing Liner" Article for [**fibrous-glass**] [**flexible elastomeric**] duct liner.

G. Control devices shall be compatible with temperature controls system specified in Division 25.

1. Electric Damper Actuator: 24 V, powered open, [spring] [capacitous] return.

2. ***Pneumatic Damper Operator: [0- to 13-psig (0- to 90-kPa)] <Insert range> spring range.***
3. ***Electronic Damper Actuator: 24 V, powered open, [spring] [capacitous] return.***
4. ***Electric Thermostat: Wall-mounted electronic type with clock display, temperature display in Fahrenheit and Celsius, and space temperature set point.***
5. ***Pneumatic Thermostat: Wall-mounted pneumatic type with appropriate mounting hardware.***
6. ***Electronic Thermostat: Wall-mounted electronic type with temperature set-point display in Fahrenheit and Celsius.***
7. ***Pneumatic Velocity Controller: Factory calibrated and field adjustable to minimum and maximum air volumes; shall maintain constant airflow dictated by thermostat within 5 percent of set point while compensating for inlet static-pressure variations up to 4-inch wg (1000 Pa); and shall have a multipoint velocity sensor at air inlet.***
8. ***Electronic Velocity Controller: Factory calibrated and field adjustable to minimum and maximum air volumes; shall maintain constant airflow dictated by thermostat within 5 percent of set point while compensating for inlet static-pressure variations up to 4-inch wg (1000 Pa); and shall have a multipoint velocity sensor at air inlet.***
9. ***Terminal Unit Controller: Pressure-independent, VAV controller with electronic airflow transducer with multipoint velocity sensor at air inlet, factory calibrated to minimum and maximum air volumes, and having the following features:***

H. Control Sequence:

1. ***[System] [Room thermostat] modulates VAV damper and dual-duct damper.[Room sensor reports temperature.]***
2. ***When Space Temperature Is below Set Point: Close VAV damper, open hot-deck dampers and close cold-deck dampers, then open VAV damper.***
3. ***When Space Temperature Is above Set Point: Close VAV damper, close hot-deck dampers and open cold-deck dampers, then open VAV damper.***
4. ***Occupancy sensor reports occupancy and enables occupied temperature set point.***
5. ***Occupancy sensor switches set point from occupied setting to unoccupied setting.***

2.7 HANGERS AND SUPPORTS

A. Hanger Rods for Noncorrosive Environments: Steel rods and nuts.

B. Steel Cables: Galvanized steel complying with ASTM A 603.

C. Steel Cable End Connections: Steel assemblies with brackets, swivel, and bolts designed for duct hanger service; with an automatic-locking and clamping device.

D. Air Terminal Unit Attachments: Sheet metal screws, blind rivets, or self-tapping metal screws; compatible with duct materials.

E. Trapeze and Riser Supports: Steel shapes and plates for units with steel casings; aluminum for units with aluminum casings.

2.8 SOURCE QUALITY CONTROL

A. Factory Tests: Test assembled air terminal units according to ARI 880.

1. Label each air terminal unit with plan number, nominal airflow, maximum and minimum factory-set airflows, and ARI certification seal.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Install air terminal units according to NFPA 90A, "Standard for the Installation of Air Conditioning and Ventilating Systems."

B. Install air terminal units level and plumb. Maintain sufficient clearance for normal service and maintenance.

C. If boxes have coils, install duct access doors downstream of same per Section 23 3314.

D. Install boxes per the installation details on drawing XXXXX.

3.2 HANGER AND SUPPORT INSTALLATION

A. Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Chapter 4, "Hangers and Supports."

B. Building Attachments: Concrete inserts, or structural-steel fasteners appropriate for construction materials to which hangers are being attached.

1. Where practical, install concrete inserts before placing concrete.
2. Install powder-actuated concrete fasteners after concrete is placed and completely cured.
3. Use powder-actuated concrete fasteners for standard-weight aggregate concretes and for slabs more than 4 inches (100 mm) thick.
4. Do not use powder-actuated concrete fasteners for lightweight-aggregate concretes and for slabs less than 4 inches (100 mm) thick.

C. Hangers Exposed to View: Threaded rod and angle or channel supports.

D. Install upper attachments to structures. Select and size upper attachments with pull-out, tension, and shear capacities appropriate for supported loads and building materials where used.

3.3 CONNECTIONS

A. Install piping adjacent to air terminal unit to allow service and maintenance.

B. Connect ducts to air terminal units according to Division 23 Section "Ductwork."

C. Make connections to inlets of air terminal units with flexible connectors complying with requirements in Division 23 Section "Ductwork Specialties."

3.4 IDENTIFICATION

A. Label each air terminal unit with plan number, nominal airflow, and maximum and minimum factory-set airflows. Comply with requirements in Division 23 Section "Mechanical Systems Identification" for equipment labels and warning signs and labels.

3.5 FIELD QUALITY CONTROL

A. Perform Tests and Inspections:

1. After installing air terminal units and after electrical circuitry has been energized, test for compliance with requirements.
2. Leak Test: After installation, fill water coils and test for leaks. Repair leaks and retest until no leaks exist.
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.

B. Air terminal unit will be considered defective if it does not pass tests and inspections.

C. Prepare test and inspection reports.

3.6 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 inlet duct connections are as recommended by air terminal unit manufacturer to achieve proper performance.
3. Verify that controls and control enclosure are accessible.
4. Verify that control connections are complete.
5. Verify that nameplate and identification tag are visible.
6. Verify that controls respond to inputs as specified.

3.7 DEMONSTRATION

A. Train Owner's maintenance personnel to adjust, operate, and maintain air terminal units.

END OF SECTION 23 3600

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SECTION 23 4114 - FILTERS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

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

1.2 SUMMARY

A. Section Includes:

1. Pleated panel filters.
2. Non-supported bag filters.
3. Front- and rear-access filter frames.
4. Electronic air cleaners.
5. Side-service housings.
6. Filter gages.

1.3 ACTION SUBMITTALS

A. Product Data: For each type of product indicated. Include dimensions; operating characteristics; required clearances and access; rated flow capacity, including initial and final pressure drop at rated airflow; efficiency and test method; fire classification; furnished specialties; and accessories for each model indicated.

B. [LEED Submittals:

1. Product Data for Prerequisite IEQ 1: Documentation indicating that units comply with ASHRAE 62.1, Section 5 - "Systems and Equipment."

2. Product Data for Credit IEQ 4.1: For adhesives and sealants, documentation including printed statement of VOC content.

3. 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 Public Health's "Standard Method for the Testing and Evaluation of Volatile Organic Chemical Emissions from Indoor Sources Using Environmental Chambers."]

C. Shop Drawings: For air filters. Include plans, elevations, sections, details, and attachments to other work.

1. Show filter rack assembly, dimensions, materials, and methods of assembly of components.
2. Include setting drawings, templates, and requirements for installing anchor bolts and anchorages.
3. Include diagram for power, signal, and control wiring if applicable.

1.4 INFORMATIONAL SUBMITTALS

A. Field quality-control reports.

1.5 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For each type of filter and rack to include in emergency, operation, and maintenance manuals.

B. Northwestern University Maintenance Requirement Forms, see Division 01.

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. Provide three complete set(s) of pre-filters for each pre-filter bank, one set for use during construction, one set for building turnover to University, and one spare set.
2. Provide two complete set(s) of after and final filters for each after and final filter bank, one set for building turnover to University, and one spare set.

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

A. ASHRAE Compliance:

1. Comply with applicable requirements in ASHRAE 62.1, Section 4 - "Outdoor Air Quality"; Section 5 - "Systems and Equipment"; and Section 7 - "Construction and Startup."
2. Comply with ASHRAE 52.2 for MERV for methods of testing and rating air-filter units.

B. Comply with NFPA 90A and NFPA 90B.

C. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

2.2 PLEATED PANEL FILTERS

A. Description: Factory-fabricated, self-supported, extended-surface, pleated, panel-type, disposable air filters with holding frames, ***MERV 7, 4" thick.***

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

a. AAF International.
b. Camfil Farr.
c. Flanders Corporation.

B. Filter Unit Class: UL 900, Class 1 or Class 2.

C. Media: Interlaced glass or synthetic fibers coated with nonflammable adhesive.

1. Adhesive: As recommended by air-filter manufacturer and with a VOC content of 80 g/L or less.
2. Media shall be coated with an antimicrobial agent.
3. Separators shall be bonded to the media to maintain pleat configuration.
4. Welded-wire grid shall be on downstream side to maintain pleat.
5. Media shall be bonded to frame to prevent air bypass.
6. Support members on upstream and downstream sides to maintain pleat spacing.

D. Filter-Media Frame: Cardboard frame with perforated metal retainer sealed or bonded to the media.

E. Mounting Frames: Welded galvanized steel, with gaskets and fasteners; suitable for bolting together into built-up filter banks.

F. See schedule on drawing for performance information.

2.3 NON-SUPPORTED BAG FILTERS

A. Description: Factory-fabricated, dry, extended-surface, non-supported filters with header frames, ***MERV 13 or 14*** as required for particular application on the project.

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

a. AAF International.
b. Camfil Farr.
c. Flanders Corporation.

B. Filter Unit Class: UL 900, Class 1 or Class 2.

C. Media: [**Glass-fiber**] [**Synthetic**] material constructed so individual pockets are maintained in tapered form under rated-airflow conditions by flexible internal supports.

1. Media shall be coated with an antimicrobial agent.

D. Filter-Media Frame: [**Galvanized steel**] [**Hard polyurethane foam**].

E. Mounting Frames: Welded galvanized steel, with gaskets and fasteners; suitable for bolting together into built-up filter banks.

F. See schedule on drawing for performance information.

2.4 FRONT AND REAR ACCESS FILTER FRAMES

A. Framing System: Galvanized-steel (minimum 16 gage) framing members with access for either upstream (front) or downstream (rear) filter servicing, cut to size and pre-punched for assembly into modules. Vertically support filters to prevent deflection of horizontal members without interfering with either filter installation or operation.

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

a. AAF International.
b. Camfil Farr.
c. Flanders Corporation.

B. Pre-filters: Incorporate a separate track with spring clips, removable from front [**or back**].

C. Access Doors: Hinged, with continuous gaskets on perimeter and positive-locking cam or lever type devices, and arranged so filter cartridges can be loaded from either side and access door.

D. Sealing: Factory-installed, positive-sealing device for each row of filters, to ensure seal between gasketed filter elements and to prevent bypass of unfiltered air.

2.5 ELECTRONIC AIR CLEANERS

A. Description: Factory-fabricated electronic air cleaner operating by electrostatic precipitation principles.

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

a. Dynamic Air Quality Solutions.
b. Trion, Inc.
c. Flanders Corporation.

B. Collection Cells: Aluminum, independently supported and nested.

1. Ionizing Section: Alternately spaced grounded struts and charged ionizing wires.
2. Collecting Section: Alternately grounded and charged plates, with insulators located out of airstream.

C. Power Pack: Self-contained, prewired rectifying unit to convert 24-V ac, single-phase, 60-Hz power to approximately 9,500-V dc; include overload protection, on-off switch, pilot light showing operating status, and access door interlock.

D. Safety Accessories: Manual-reset safety switches and warning lights for filter plenum access doors, signal lights and safety switching upstream and downstream from unit within duct, and enameled high-voltage warning signs.

E. Controls: Programmable logic controller in remotely mounted NEMA 250, Type 12 enclosure; with integral time clock and manual override.

1. Contacts for enable-disable control by building automation system.

F. Finish of Interior Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.

2.6 SIDE-SERVICE HOUSINGS

A. Description: Factory-assembled, side-service housings, constructed of [**galvanized steel**] [**aluminum**], with flanges to connect to duct or casing system.

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

a. AAF International.
b. Camfil Farr.
c. Flanders Corporation.

B. Pre-filters: Integral tracks to accommodate project depth disposable filters.

C. Access Doors: Hinged, with continuous gaskets on perimeter and positive-locking cam or lever type devices, and arranged so filter cartridges can be loaded from either side and access door.

D. Sealing: Incorporate positive-sealing gasket material on channels to seal top and bottom of filter cartridge frames and to prevent bypass of unfiltered air.

2.7 FILTER GAGES

A. Diaphragm-type gage with dial and pointer in metal case, vent valves, black figures on white background, and front recalibration adjustment.

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

a. Dwyer Instruments, Inc.

2. Diameter: 4-1/2 inches (115 mm).
3. Scale Range for Filter Media Having a Recommended Final Resistance of 0.5-Inch wg (125 Pa) or Less: 0- to 0.5-inch wg (0 to 125 Pa).
4. Scale Range for Filter Media Having a Recommended Final Resistance of 0.5- to 1.0-Inch wg (125 to 250 Pa) or Less: 0- to 1.0-inch wg (0 to 250 Pa).
5. Scale Range for Filter Media Having a Recommended Final Resistance of 1.0- to 2.0-Inch wg (250 to 500 Pa) or Less: 0- to 2.0-inch wg (0 to 500 Pa).
6. Scale Range for Filter Media Having a Recommended Final Resistance of 2.0- to 3.0-Inch wg (500 to 750 Pa) or Less: 0- to 3.0-inch wg (0 to 750 Pa).
7. Scale Range for Filter Media Having a Recommended Final Resistance of 3.0- to 4.0-Inch wg (750 to 1000 Pa) or Less: 0- to 4.0-inch wg (0 to 1000 Pa).

B. Accessories: Static-pressure tips, tubing, gage connections, and mounting bracket.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Equipment Mounting:

1. Install filter assemblies on cast-in-place concrete equipment base(s). Comply with requirements for equipment bases and foundations specified in [Section 033000 "Cast-in-Place Concrete."] [Section 033053 "Miscellaneous Cast-in-Place Concrete."]

2. Comply with requirements for vibration isolation devices specified in Section 23 0550 "Vibration Isolation."

B. Position each filter unit with clearance for normal service and maintenance. Anchor filter holding frames to substrate.

C. Install filters in position to prevent passage of unfiltered air.

D. Install filter gage for each filter bank.

E. 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.

F. Install filter-gage, static-pressure taps upstream and downstream from filters. Install filter gages on filter banks with separate static-pressure taps upstream and downstream from filters. Mount filter gages on outside of filter housing or filter plenum in an accessible position. Adjust and level inclined gages.

G. Coordinate filter installations with duct and air-handling-unit installations.

3.2 FIELD QUALITY CONTROL

A. Testing Agency: Engage a qualified testing agency to perform tests and inspections.

B. Manufacturer's Field Service: Engage a factory-authorized service representative to test and inspect components, assemblies, and equipment installations, including connections.

C. Perform the following tests and inspections:

1. Test for leakage of unfiltered air while system is operating.

D. Air filter will be considered defective if it does not pass tests and inspections.

E. Prepare test and inspection reports.

3.3 CLEANING

A. After completing system installation and testing, adjusting, and balancing of air-handling and air-distribution systems, clean filter housings and install new filter media.

END OF SECTION 23 4114

SECTION 23 5214 - PRIMARY HEATING EQUIPMENT

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

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

1.2 SUMMARY

A. Section includes shell-and-tube heat exchangers.

1.3 DEFINITIONS

A. TEMA: Tubular Exchanger Manufacturers Association.

1.4 ACTION SUBMITTALS

A. Product Data: For each type of product.

1. Include rated capacities, operating characteristics, and furnished specialties and accessories.

B. Shop Drawings: Signed and sealed by a qualified professional engineer. Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.

1. Design Calculations: Calculate requirements for selecting seismic restraints and for designing bases.
2. Base Details: Detail fabrication including anchorages and attachments to structure and to supported equipment.

1.5 INFORMATIONAL SUBMITTALS

A. Coordination Drawings: Equipment room, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:

1. Tube-removal space.
2. Structural members to which heat exchangers will be attached.

B. Product Certificates: For each type of shell-and-tube heat exchanger. Documentation that shell-and-tube heat exchangers comply with "TEMA Standards."

C. Source quality-control reports.

D. Field quality-control reports.

E. Sample Warranty: For manufacturer's warranty.

1.6 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For heat exchangers to include in emergency, operation, and maintenance manuals.

B. Northwestern University Maintenance Requirement Forms, see Division 01.

1.7 QULAITY ASSURANCE

A. Comply with applicable ASME requirements.

B. Comply with FM Global requirements for pressure vessels and piping and for pressure relief devices.

1.8 SPECIAL WARRANTIES

A. Five (5) years, see Division 01.

PART 2 - PRODUCTS

2.1 SHELL-AND-TUBE HEAT EXCHANGERS

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

1. ITT Corporation; Bell & Gossett.

B. Description: Packaged assembly of shell, heat-exchanger coils/tubes, and specialties.

C. Construction:

1. Fabricate and label heat exchangers to comply with ASME Boiler and Pressure Vessel Code, Section VIII, "Pressure Vessels," Division 1, National Board registered, and registered with pressure vessel inspector.
2. Fabricate and label shell-and-tube heat exchangers to comply with "TEMA Standards."

D. Configuration: U-tube with removable bundle.

E. Shell Materials: Steel.

F. Head:

1. Materials: Fabricated steel with removable cover
2. Flanged and bolted to shell.

G. Tubes:

1. Copper.
2. Tube diameter is determined by manufacturer based on service.

H. Tubesheet Material: Steel.

I. Baffles: Steel.

J. Piping Connections: Factory fabricated of materials compatible with heat-exchanger shell. Attach tappings to shell before testing and labeling.

1. NPS 2 (DN 50) and Smaller: Threaded ends according to ASME B1.20.1.
2. NPS 2-1/2 (DN 65) and Larger: Flanged ends according to ASME B16.5 for steel and stainless-steel flanges and according to ASME B16.24 for copper and copper-alloy flanges.

K. Support Saddles:

1. Fabricated of material similar to shell.
2. Fabricate foot mount with provision for anchoring to support.
3. Fabricate attachment of saddle supports to pressure vessel with reinforcement strong enough to resist heat-exchanger movement during seismic event when heat-exchanger saddles are anchored to building structure.

L. Certain Characteristics (See Drawing Schedules for Additional):

1. Shell Side:

a. Fluid: Steam.
b. Working Pressure: 150 psig.
c. Test Pressure: 195 psig.

2. Tube Side:

a. Working Pressure: 125 psig.
b. Test Pressure: 250 psig.

2.2 ACCESSORIES

A. Hangers and Supports:

1. Custom, steel [supports] [cradles] for mounting on [floor] [wall] [structural steel].

a. Minimum Number of Cradles: <Insert number>.

2. Factory-fabricated steel [supports] [cradles] to ensure both horizontal and vertical support of heat exchanger. Comply with requirements in Section 230529 "Hangers and Supports for HVAC Piping and Equipment."

B. Shroud: [Steel] [Stainless-steel] [Aluminum] sheet.

2.3 SOURCE QUALITY CONTROL

A. Factory Tests: Test and inspect heat exchangers according to ASME Boiler and Pressure Vessel Code, Section VIII, "Pressure Vessels," Division 1. Affix ASME label.

B. Hydrostatically test heat exchangers to minimum of one and one-half times pressure rating before shipment.

C. Heat exchangers will be considered defective if they do not pass tests and inspections.

D. Prepare test and inspection reports.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine areas for compliance with requirements for installation tolerances and for structural rigidity, strength, anchors, and other conditions affecting performance of heat exchangers.

B. Examine roughing-in for heat-exchanger piping to verify actual locations of piping connections before equipment installation.

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

3.2 SHELL-AND-TUBE HEAT-EXCHANGER INSTALLATION

A. Equipment Mounting: Install heat exchangers on cast-in-place concrete equipment base(s). Comply with requirements for equipment bases specified in [**Section 033000 "Cast-in-Place Concrete."**] [**Section 033053 "Miscellaneous Cast-in-Place Concrete."**]

1. Coordinate sizes and locations of concrete bases with actual equipment provided.
2. Construct bases to withstand, without damage to equipment, seismic force required by code.
3. Construct concrete bases ***[4 inches (100 mm)]*** high and extend base not less than 6 inches (150 mm) in all directions beyond the maximum dimensions of heat exchangers unless otherwise indicated or unless required for seismic anchor support.
4. Minimum Compressive Strength: ***[5000 psi (34.5 MPa)] [4500 psi (31 MPa)] [4000 psi (27.6 MPa)] [3500 psi (24.1 MPa)] [3000 psi (20.7 MPa)] at 28 days.***
5. Install dowel rods to connect concrete base to concrete floor. Unless otherwise indicated, install dowel rods on 18-inch (450-mm) centers around the full perimeter of concrete base.
6. For supported equipment, install epoxy-coated anchor bolts that extend through concrete base, and anchor into structural concrete floor.
7. Place and secure anchorage devices. Use setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
8. Install anchor bolts to elevations required for proper attachment to supported equipment.

B. Equipment Mounting: Install heat exchangers with continuous-thread hanger rods and [**elastomeric hangers**] [**spring hangers**] [**spring hangers with vertical-limit stop**] of size required to support weight of heat exchangers filled with water.

1. Comply with requirements for vibration isolation devices specified in Section 23 0550 "Vibration Isolation."
2. Comply with requirements for hangers and supports specified in Section 23 0529 "Mechanical Supporting Devices."

C. Install heat exchangers on saddle supports.

D. Heat-Exchanger Supports: Use factory-fabricated steel cradles and supports specifically designed for each heat exchanger.

3.3 CONNECTIONS

A. Comply with requirements for piping specified in other Section 23 2113 "Hydronic Piping." Drawings indicate general arrangement of piping, fittings, and specialties.

B. Comply with requirements for steam and condensate piping specified in Section 23 2213 "Steam Piping."

C. Maintain manufacturer's recommended clearances for tube removal, service, and maintenance.

D. Install piping adjacent to heat exchangers to allow space for service and maintenance of heat exchangers. Arrange piping for easy removal of heat exchangers.

E. Install shutoff valves at heat-exchanger inlet and outlet connections.

F. Install relief valves on heat-exchanger heated-fluid connection and install pipe relief valves, full size of valve connection, to floor drain.

G. Install vacuum breaker at heat-exchanger steam inlet connection.

H. Install hose end valve to drain shell.

I. Install thermometer on heat-exchanger and inlet and outlet piping, and install thermometer on heating-fluid inlet and outlet piping. Comply with requirements for thermometers specified in ***Section 23 0519 "Meters and Gages for HVAC Piping."***

J. Install pressure gages on heat-exchanger and heating-fluid piping. Comply with requirements for pressure gages specified in ***Section 23 0519 "Meters and Gages for HVAC Piping."***

3.4 FIELD QUALITY CONTROL

A. Perform the following tests and inspections with the assistance of a factory-authorized service representative:

1. Leak Test: After installation, charge system and test for leaks. Repair leaks and retest until no leaks exist.
2. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.

B. Heat exchanger will be considered defective if it does not pass tests and inspections.

C. Prepare test and inspection reports.

3.5 CLEANING

A. After completing system installation, including outlet fitting and devices, inspect exposed finish. Remove burrs, dirt, and construction debris and repair damaged finishes.

3.6 DEMONSTRATION

A. Engage a factory-authorized service representative to train University maintenance personnel to adjust, operate, and maintain heat exchangers.

END OF SECTION 23 5214

SECTION 23 6423 – SCREW WATER CHILLERS

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. Packaged, air-cooled, electric-motor-driven, screw water chillers.

1.3 DEFINITIONS

A. 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.

B. DDC: Direct digital control.

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.

1.4 ACTION SUBMITTALS

A. Product Data: 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. Refrigerant capacity of water chiller.
5. Oil capacity of water chiller.
6. Fluid capacity of evaporator.
7. Characteristics of safety relief valves.

8. Minimum entering condenser-air temperature
9. Performance at varying capacity with constant design entering condenser-air temperature. Repeat performance at varying capacity for different entering condenser-air temperatures from design to minimum in 10 deg F (6 deg C) increments.

B. Shop Drawings: Complete set of manufacturer's prints of water chiller 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. Size and location of piping and wiring connections.
5. 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. Source quality-control test reports.

D. Startup service reports.

E. Warranty: Sample of special warranty.

1.6 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For each water chiller to include in emergency, operation, and maintenance manuals.

1.7 SYSTEM DESCRIPTION

A. Microprocessor-controlled liquid chiller shall use a semi-hermetic screw compressor using refrigerant HFC-134a only.

B. If a manufacturer proposes a liquid chiller using HCFC-123 refrigerant, which has a planned phase out date, then the manufacturer shall include in the chiller price:

1. A vapor activated alarm system consisting of all alarms, sensors, safeties, and ventilation equipment as required by ANSI/ASHRAE (American National Standards Institute/American Society of Heating, Refrigerating and Air-Conditioning Engineers) Standard 15 Safety Code for Mechanical Refrigeration (latest edition) with the quotation. System shall be capable of responding to HCFC-123 levels of 10 ppm Allowable Exposure Limit (AEL).

2. A free-standing refrigerant storage tank and pumpout unit shall be provided. The storage vessels shall be designed per ASME (American Society of Mechanical Engineers) Section VIII Division 1 code with 300 psig (2068 kPa) design pressure. Double relief valves per ANSI/ ASHRAE 15, latest edition, shall be provided. The tank shall include a liquid level gage and pressure gage. The pumpout unit shall use a semi-hermetic reciprocating compressor with water-cooled condenser. Condenser water piping, 3-phase motor power, and 115-volt control power shall be installed at the jobsite by the installing contractor.
3. Zero emission purge unit capable of operating even when the chiller is not operating.
4. Back-up relief valve to rupture disk.
5. Factory-installed chiller pressurizing system to prevent leakage of noncondensables into the chiller during shutdown periods.
6. Plant room ventilation.
7. Removal and disposal of refrigerant at the end of the phase out period.
8. Chillers utilizing a purge unit shall include in the machine price the costs to perform the following regular maintenance procedures:

    a. Weekly: Check refrigerant charge.
    b. Quarterly: Charge purge unit dehydrator at least quarterly, more often if necessary. Clean foul gas strainer. Perform chemical analysis of oil.
    c. Annually: Clean and inspect all valves. Drain and flush purge shell. Clean orifices.

1.8 QUALITY ASSURANCE

A. Chiller performance shall be rated in accordance with AHRI (Air-Conditioning, Heating and Refrigeration Institute) Standard 550/590, latest edition.

B. Equipment and installation shall be in compliance with ANSI/ASHRAE 15 (latest edition).

C. Cooler and condenser refrigerant side shall include ASME “U” stamp and nameplate certifying compliance with ASME Section VIII, Division 1 code for unfired pressure vessels.

D. A manufacturer’s data report is required to verify pressure vessel construction adherence to ASME vessel construction requirements. Form U-1 as required per ASME code rules is to be furnished to the owner. The U-1 Form must be signed by a qualified inspector, holding a National Board Commission, certifying that construction conforms to the latest ASME Code Section VIII, Div. 1 for pressure vessels. The ASME symbol “U” must also be stamped on the heat exchanger. Vessels specifically exempted from the scope of the code must come with material, test, and construction methods certification and detailed documents similar to ASME U-1; further, these must be signed by an officer of the company.

E. Chiller shall be designed and constructed to meet UL and UL of Canada requirements and have labels appropriately affixed.

F. Unit shall be manufactured in a facility registered to ISO (International Organization for Standardization) 9001 Manufacturing Quality Standard.

G. Each compressor assembly shall undergo a mechanical run-in test to verify vibration levels, oil pressures, and temperatures are within acceptable limits. Each compressor assembly shall be proof tested at a minimum 204 psig (1407 kPa) and leak tested at 185 psig (1276 kPa) with a tracer gas mixture.

H. Entire chiller assembly shall be proof tested at 204 psig (1407 kPa) and leak tested at 185 psig (1276 kPa) with a tracer gas mixture on the refrigerant side. The leak test shall not allow any leaks greater than 0.5 oz per year of refrigerant. The water side of each heat exchanger shall be hydrostatically tested at 1.3 times rated working pressure.

I. Prior to shipment, the chiller automated controls test shall be executed to check for proper wiring and ensure correct controls operation.

J. Chillers shall have factory-mounted, factory-wired and factory-tested unit-mounted variable frequency drive (VFD). Proper VFD operation shall be confirmed prior to shipment.

1.9 DELIVERY, STORAGE AND HANDLING

A. Unit shall be stored and handled in accordance with manufacturer’s instructions.

B. Unit shall be shipped with all refrigerant piping and control wiring factory-installed.

C. Unit shall be shipped charged with oil and full charge of refrigerant HFC-134a or a nitrogen holding charge as specified on the equipment schedule.

D. Unit shall be shipped with firmly attached labels that indicate name of manufacturer, chiller model number, chiller serial number, and refrigerant used.

E. If the unit is to be exported, the manufacturer shall provide sufficient protection against sea water corrosion, making the unit suitable for shipment in a standard open top ocean shipping container.

F. Chiller and starter shall be stored indoors, protected from construction dirt and moisture. Chiller shall be inspected under shipping tarps, bags, or crates to be sure water has not collected during transit. Protective shipping covers shall be kept in place until machine is ready for installation. The inside of the protective cover shall meet the following criteria:

1. Temperature is between 40 F (4.4 C) and 120 F (48.9 C)
2. Relative humidity is between 10% and 80% non-condensing.

1.10 WARRANTY

A. Warranty shall include parts and labor for one year after start-up or 18 months from shipment, whichever occurs first. A refrigerant warranty shall be provided for a period of 5 years (North America only).

B. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace components of water chillers that fail in materials or workmanship within specified period.

1. Compressor Warranty Period: Five years from date of Substantial Completion.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

2.2 ACCEPTABLE MANUFACTURERS

A. Carrier model 23XRV

2.3 GENERAL

A. General:

1. Factory-assembled, single piece, liquid chiller shall consist of compressor, motor, VFD, lubrication system, cooler, condenser, initial oil and refrigerant operating charges, microprocessor control system, and documentation required prior to start-up.

B. Compressor:

1. One variable speed screw compressor of the high performance type.
2. Compressor and motor shall be hermetically sealed into a common assembly and arranged for easy field servicing.
3. The compressor motor shall be accessible for servicing without removing the compressor base from the chiller. Connections to the compressor casing shall use O-rings and gaskets to reduce the occurrence of refrigerant leakage. Connections to the compressor shall be flanged or bolted for easy disassembly.
4. Compressor bearings must have individual design life of 50 years or greater when operating at AHRI conditions.
5. Compressor shall provide capacity modulation from 100% to 15% capacity without the use of hot gas bypass or mechanical unloaders.
6. Compressor shall be provided with a factory-installed positive pressure lubrication system to deliver oil under pressure to bearings and rotors at all operating conditions. Lubrication system shall include:

   a. Oil pump with factory-installed motor contactor with overload protection.
   b. Oil pressure sensor with differential readout at main control center.
   c. Oil pressure regulator.
   d. Oil filter with isolation valves to allow filter change without removal of refrigerant charge.
   e. Oil sump heater [115 v, 50 or 60 Hz] controlled from unit microprocessor.
   f. Oil reservoir temperature sensor with main control center digital readout.
   g. All wiring to oil pump, oil heater, and controls shall be pre-wired in the factory and power shall be applied to check proper operation prior to shipment.

7. Compressor shall be fully field serviceable. Compressors that must be removed and returned to the factory for service shall be unacceptable.
8. Acoustical attenuation shall be provided as required, to achieve a maximum (full load) sound level, measured per AHRI Standard 575 (latest edition).

C. Motor:

1. Compressor motor shall be of the semi-hermetic, liquid refrigerant cooled, squirrel cage, induction type suitable for voltage shown on the equipment schedule.

2. If an open (air-cooled) motor is provided, a compressor shaft seal leakage containment system shall be provided:

    a. An oil reservoir shall collect oil and refrigerant that leaks past the seal.
    b. A float device shall be provided to open when the reservoir is full, directing the refrigerant/oil mixture back into the compressor housing.
    c. A refrigerant sensor shall be located next to the open drive seal to detect leaks.

3. Motors shall be suitable for operation in a refrigerant atmosphere and shall be cooled by atomized refrigerant in contact with the motor windings.
4. Motor stator shall be arranged for service or removal with only minor compressor disassembly and without removing main refrigerant piping connections.
5. Full load operation of the motor shall not exceed nameplate rating.
6. One motor winding temperature sensor (and one spare) shall be provided.
7. Should mechanical contractor choose to provide a chiller with an air-cooled motor instead of the specified semi-hermetic motor, the contractor shall install additional cooling equipment to dissipate the motor heat.

    a. The following formula applies:

        1) Btuh = (FLkW motor) (0.05) (3413)
        2) Btuh = (FLkW motor) (171)
        3) CFM = Btuh/1.08 x 20F (additional air flow) and, alternately
        4) Tons = Btuh/12,000

    b. The additional piping, valves, air-handling equipment, insulation, wiring, switchgear changes, ductwork, and coordination with other trades shall be the responsibility of the mechanical contractor. Shop drawings reflecting any changes to the design shall be included in the submittal, and incorporated into the final as built drawings for the project.

8. Also, if an open motor is provided, a mechanical room thermostat shall be provided and set at 104 F (40 C). If this temperature is exceeded, the chillers shall shut down and an alarm signal shall be generated to the central Energy Management System (EMS) display module, prompting the service personnel to diagnose and repair the cause of the overtemperature condition. The mechanical contractor shall be responsible for all changes to the design, including coordination with temperature control, electrical and other trades. In addition, the electrical power consumption of any auxiliary ventilation and/or mechanical cooling required to maintain the mechanical room conditions stated above shall be considered in the determination of conformance to the scheduled chiller energy efficiency requirement.

D. Evaporator and Condenser:

1. Evaporator and condenser shall be of shell and tube type construction, each in separate shells. Units shall be fabricated with high-performance tubing, steel shell and tube sheets with waterboxes. Waterboxes shall be nozzle-in-head type with stub out nozzles having Victaulic grooves to allow for use of Victaulic couplings.
2. Tubing shall be copper, high-efficiency type, with integral internal and external enhancement unless otherwise noted. Tubes shall be nominal 3/4-in. OD with nominal wall thickness of 0.025 in. measured at the root of the fin unless otherwise noted. Tubes shall be rolled into tube sheets and shall be individually replaceable. Tube sheet holes shall be double grooved for joint structural integrity. Intermediate support sheet spacing shall not exceed 36 in. (914 mm).

3. Waterboxes and nozzle connections shall be designed for 150 psig (1034 kPa) minimum working pressure unless otherwise noted. Nozzles should have grooves to allow use of Victaulic couplings.
4. The tube sheets of the cooler and condenser shall be bolted together to allow for field disassembly and reassembly.
5. The vessel shall display an ASME nameplate that shows the pressure and temperature data and the “U” stamp for ASME Section VIII, Division 1. A re-seating pressure relief valve(s) shall be installed on each heat exchanger. If a non-reseating type is used, a backup reseating type shall be installed in series.
6. Waterboxes shall have vents, drains, and covers to permit tube cleaning within the space shown on the drawings. A thermistor type temperature sensor with quick connects shall be factory-installed in each water nozzle.
7. Cooler shall be designed to prevent liquid refrigerant from entering the compressor. Devices that introduce pressure losses (such as mist eliminators) shall not be acceptable because they are subject to structural failures that can result in extensive compressor damage.
8. Tubes shall be individually replaceable from either end of the heat exchanger without affecting the strength and durability of the tube sheet and without causing leakage in adjacent tubes.
9. The subcooler, located in the bottom of the condenser, shall increase the refrigeration effect by cooling the condensed liquid refrigerant to a lower temperature, thereby reducing compressor power consumption.

E. Refrigerant Flow Control:

1. The variable flow control system regulates refrigerant flow according to load conditions, providing a liquid seal at all operating conditions, eliminating unintentional hot gas bypass.

F. Controls, Safeties, and Diagnostics:

1. Controls:

a. The chiller shall be provided with a factory-installed and factory-wired microprocessor control center. The control center shall include a 16-line by 40-character liquid crystal display, 4 function keys, stop button, and alarm light. Other languages are available using the international language translator software.
b. All chiller and motor control monitoring shall be displayed at the chiller control panel.
c. The controls shall make use of non-volatile memory.
d. The chiller control system shall have the ability to interface and communicate directly to the building control system.
e. The default standard display screen shall simultaneously indicate the following minimum information:

1) Date and time of day
2) 24-character primary system status message
3) 24-character secondary status message
4) Chiller operating hours
5) Entering chilled water temperature
6) Leaving chilled water temperature
7) Evaporator refrigerant temperature
8) Entering condenser water temperature
9) Leaving condenser water temperature

10) Condenser refrigerant temperature
11) Oil supply pressure
12) Oil sump temperature
13) Percent motor rated load amps (RLA)

f. In addition to the default screen, status screens shall be accessible to view the status of every point monitored by the control center including:

1) Evaporator pressure
2) Condenser pressure
3) Compressor speed
4) Bearing oil supply temperature
5) Compressor discharge temperature
6) Motor winding temperature
7) Number of compressor starts
8) Control point settings
9) Discrete output status of various devices
10) Variable frequency drive status
11) Optional spare input channels
12) Line current and voltage for each phase
13) Frequency, kW, kWhr, demand kW

g. Schedule Function:

1) The chiller controls shall be configurable for manual or automatic start-up and shutdown. In automatic operation mode, the controls shall be capable of automatically starting and stopping the chiller according to a stored user programmable occupancy schedule. The controls shall include built-in provisions for accepting:

a) A minimum of two 365-day occupancy schedules.
b) Minimum of 8 separate occupied/unoccupied periods per day
c) Daylight savings start/end
d) 18 user-defined holidays
e) Means of configuring an occupancy timed override
f) Chiller start-up and shutdown via remote contact closure

h. Service Function:

1) The controls shall provide a password protected service function which allows authorized individuals to view an alarm history file which shall contain the last 25 alarm/alert messages with time and date stamp. These messages shall be displayed in text form, not codes.

i. Network Window Function:

1) Each chiller control panel shall be capable of viewing multiple point values and statuses from other like controls connected on a common network, including controller maintenance data. The operator shall be able to alter the remote controller’s set points or time schedule and to force point values or statuses for those points that are operator forcible. The control panel shall also have access to the alarm history file of all like controllers connected on the network.

j. Pump Control:

1) Upon request to start the compressor, the control system shall start the chilled and condenser water pumps and shall verify that flows have been established.

k. Ramp Loading:

1) A user-configurable ramp loading rate, effective during the chilled water temperature pulldown period, shall prevent a rapid increase in compressor power consumption. The controls shall allow configuration of the ramp loading rate in either degrees per minute of chilled water temperature pulldown or percent motor amps per minute. During the ramp loading period, a message shall be displayed informing the operator that the chiller is operating in ramp loading mode.

l. Chilled Water Reset:

1) The control center shall allow reset of the chilled water temperature set point based on any one of the following criteria:

a) Chilled water reset based on an external 4 to 20 mA signal.
b) Chilled water reset based on a remote temperature sensor (such as outdoor air).
c) Chilled water reset based on water temperature rise across the evaporator.

m. Demand Limit:

1) The control center shall limit amp draw of the compressor to the rated load amps or to a lower value based on one of the following criteria:

a) Demand limit based on a user input ranging from 40% to 100% of compressor rated load amps
b) Demand limit based on external 4 to 20 mA signal.

n. Controlled Compressor Shutdown:

1) The controls shall be capable of being configured to soft stop the compressor. The display shall indicate “shutdown in progress.”

2. Safeties:

a. Unit shall automatically shut down when any of the following conditions occur (each of these protective limits shall require manual reset and cause an alarm message to be displayed on the control panel screen, informing the operator of the shutdown cause):

1) Motor overcurrent
2) Over voltage*
3) Under voltage*
4) Single cycle dropout* (LF-2 VFDs only)
5) Low oil sump temperature
6) Low evaporator refrigerant temperature

7) High condenser pressure
8) High motor temperature
9) High compressor discharge temperature
10) Low oil pressure
11) Prolonged stall
12) Loss of cooler water flow
13) Loss of condenser water flow
14) Variable frequency drive fault
15) High variable frequency drive temperature

a) * Shall not require manual reset or cause an alarm if auto-restart after power failure is enabled.

b. The control system shall detect conditions that approach protective limits and take self-corrective action prior to an alarm occurring. The system shall automatically reduce chiller capacity when any of the following parameters are outside their normal operating range:

1) High condenser pressure
2) High motor temperature
3) Low evaporator refrigerant temperature
4) High motor amps
5) High VFD inverter temperature

c. During the capacity override period, a pre-alarm (alert) message shall be displayed informing the operator which condition is causing the capacity override. Once the condition is again within acceptable limits, the override condition shall be terminated and the chiller shall revert to normal chilled water control. If during either condition the protective limit is reached, the chiller shall shut down and a message shall be displayed informing the operator which condition caused the shutdown and alarm.

d. Internal built-in safeties shall protect the chiller from loss of water flow. Differential pressure switches shall not be allowed to be the only form of freeze protection.

3. Diagnostics and Service:

a. A self-diagnostic controls test shall be an integral part of the control system to allow quick identification of malfunctioning components.

b. Once the controls test has been initiated, all pressure and temperature sensors shall be checked to ensure they are within normal operating range. A pump test shall automatically energize the chilled water pump, condenser water pump, and oil pump. The control system shall confirm that water flow and oil pressure have been established and require operator confirmation before proceeding to the next test.

c. In addition to the automated controls test, the controls shall provide a manual test which permits selection and testing of individual control components and inputs. A thermistor test and transducer test shall display on the ICVC screen the actual reading of each transducer and each thermistor installed on the chiller. All out-of-range sensors shall be identified. Pressure transducers shall be serviceable without the need for refrigerant charge removal or isolation.

4. Multiple Chiller Control:

a. The chiller controls shall be supplied as standard with a two-chiller lead/lag and a third chiller standby system. The control system shall automatically start and stop a lag or second chiller on a two-chiller system. If one of the two chillers on line goes into a fault mode, the third standby chiller shall be automatically started. The two-chiller lead/lag system shall allow manual rotation of the lead chiller and a staggered restart of the chillers after a power failure. The lead/lag system shall include load balancing if configured to do so.

G. Electrical Requirements:

1. Electrical contractor shall supply and install main electrical power line, disconnect switches, circuit breakers, and electrical protection devices per local code requirements and as indicated necessary by the chiller manufacturer.
2. Electrical contractor shall wire the chilled water pump and flow, condenser water pump and flow, and tower fan control circuit to the chiller control circuit.
3. Electrical contractor shall supply and install electrical wiring and devices required to interface the chiller controls with the building control system if applicable.
4. Electrical power shall be supplied to the unit at the voltage, phase, and frequency listed in the equipment schedule.

H. Piping Requirements — Instrumentation and Safeties:

1. Mechanical contractor shall supply and install pressure gages in readily accessible locations in piping adjacent to the chiller such that they can be easily read from a standing position on the floor. Scale range shall be such that design values shall be indicated at approximately midscale.
2. Gages shall be installed in the entering and leaving water lines of the cooler and condenser.

I. Vibration Isolation:

1. Chiller manufacturer shall furnish neoprene isolator pads for mounting equipment on a level concrete surface.

J. Start-Up:

1. The chiller manufacturer shall provide a factory-trained representative, employed by the chiller manufacturer, to perform the start-up procedures as outlined in the Start-Up, Operation and Maintenance manual provided by the chiller manufacturer.
2. Manufacturer shall supply the following literature:

   a. Start-up, operation and maintenance instructions.
   b. Installation instructions.
   c. Field wiring diagrams.
   d. One complete set of certified drawings.

K. Special Features:

1. Soleplate Package:

   a. Unit manufacturer shall furnish a soleplate package consisting of soleplates, jacking screws, leveling pads, and neoprene pads.

2. Spring Isolators:

a. Spring isolators shall be field furnished and selected for the desired degree of isolation.

3. Spare Sensors with Leads:

a. Unit manufacturer shall furnish additional temperature sensors and leads.

4. Stand-Alone Pumpout Unit:

a. A free-standing pumpout unit shall be provided. The pumpout unit shall use a semi-hermetic reciprocating compressor with liquid-cooled condenser. Condenser liquid piping and 3-phase motor power shall be installed at the jobsite by the installing contractor.

5. Separate Storage Tank and Pumpout Unit:

a. A free-standing refrigerant storage tank and pumpout unit shall be provided. The storage vessels shall be designed per ASME Section VIII Division 1 code with 150 psig (1034 kPa) design pressure. Double relief valves per ANSI/ ASHRAE 15, latest edition, shall be provided. The tank shall include a liquid level gage and pressure gage. The pumpout shall use a hermetic reciprocating compressor with water-cooled condenser. Condenser water piping and 3-phase motor power shall be installed at the jobsite by the installing contractor.

6. BACnet Communication Option:

a. Shall provide factory-installed communication capability with a BACnet MS/TP network. Allows integration with i-Vu® Open control system or a BACnet building automation system.

7. Building Control System Interface (LON):

a. The chiller control system shall have the ability to interface and communicate directly to the building control using a LON based system. The LonWorks Carrier Translator shall output data in standard LON profiles.

8. Refrigerant Charge:

a. The chiller shall ship from the factory fully charged with R-134a refrigerant and oil.

9. 9. Thermal Insulation:

a. Unit manufacturer shall insulate the cooler shell, economizer, suction elbow, motor shell and motor cooling lines. Insulation shall be 1 in. (25.4 mm) thick with a thermal conductivity not exceeding and shall conform to UL standard 94, classification 94 HF-1.

$$0.28 \ \frac{(\text{Btu} \cdot \text{in.})}{\text{hr. Ft}^2\ \text{F}} \left(0.0404 \ \frac{\text{W}}{\text{m C}} \right)$$

10. Automatic Hot Gas Bypass:

a. Hot gas bypass valve and piping shall be factory-furnished to permit chiller operation for extended periods of time.

11. Cooler and Condenser Tubes:

    a. Contact your local Carrier Representative for other tube offerings.

12. Cooler and Condenser Passes:

    a. Unit manufacturer shall provide the cooler and/ or condenser with 1, 2 or 3 pass configuration on the water side.

13. Nozzle-In-Head, 300 psig (2068 kPa):

    a. Unit manufacturer shall furnish nozzle-in-head style waterboxes on the cooler and/or condenser rated at 300 psig (2068 kPa).

14. Marine Waterboxes, 150 psig (1034 kPa):

    a. Unit manufacturer shall furnish marine style waterboxes on cooler and/or condenser rated at 150 psig (1034 kPa).

15. Marine Waterboxes, 300 psig (2068 kPa):

    a. Unit manufacturer shall furnish marine style waterboxes on cooler and/or condenser rated at 300 psig (2068 kPa).

16. Flanged Water Nozzles:

    a. Unit manufacturer shall furnish standard flanged piping connections on the cooler and/ or condenser.

17. Hinges:

    a. Unit manufacturer shall furnish hinges on waterboxes to facilitate tube cleaning.

18. Optional Compressor Discharge Isolation Valve and Liquid Line Ball Valve:

    a. These items shall be factory-installed to allow isolation of the refrigerant charge in the condenser for servicing the compressor.

19. Pumpout Unit:

    a. A refrigerant pumpout system shall be installed on the chiller. Pumpout system shall include a hermetic compressor and drive, internal piping, internal wiring, and motor. Field-supplied main power wiring and water piping shall be required. (Q and R compressor only)

20. Optional Seismic Isolation Package:

    a. Package shall meet International Building Code and ASCE 7 seismic qualification requirements in concurrence with ICC ES AC156 Acceptance Criteria for Seismic

Qualification by Shake-Table Testing of Nonstructural Components and Systems. Manufacturer shall provide seismic certificate from OSHPD (California only).

21. Unit-Mounted Variable Frequency Drive (VFD) with Built-In Harmonic LiquiFlo™ II Filter (Q and R compressor only):

a. Design:

1) The VFD shall be refrigerant cooled, microprocessor based, pulse width modulated design. Water-cooled designs are not acceptable.
2) Input and output power devices shall be Insulated Gate Bipolar Transistors (IGBTs).
3) Rectifier shall convert incoming fixed voltage/frequency to fixed DC voltage.
4) Transistorized inverter and control regulator shall convert fixed DC voltage to a sinusoidal PWM waveform.
5) Low voltage control sections and main power sections shall be physically isolated.
6) Integrated controls shall coordinate motor speed to optimize chiller performance over a wide variety of operating conditions.

b. Enclosure:

1) Pre-painted unit mounted, NEMA (National Electrical Manufacturers Association) 1 cabinet shall include hinged, lockable doors and removable lifting lugs.
2) The VFD shall have a short circuit current rating of at least 65,000 amps.
3) Provisions to padlock main disconnect handle in “Off” positions shall be provided. Mechanical interlock to prevent opening cabinet door with disconnect in the “On” position or moving disconnect to the “On” position while the door is open shall be provided.
4) Provisions shall be made for top entry of incoming line power cables.

c. Heat Sink:

1) The heat sink (frame sizes 3, 4, 5 heat exchangers only) shall be refrigerant cooled. Heat sink and mating flanges shall be suitable for ASME design working pressure of 185 psig (1276 kPa).
2) Refrigerant cooling shall be metered to maintain heat sink temperature within acceptable limits for ambient temperature.

d. VFD Rating:

1) Drive shall be suitable for operation at nameplate voltage ±10%.
2) Drive shall be suitable for continuous operation at 100% of nameplate amps and 150% of nameplate amps for 5 seconds.
3) Drive shall comply with applicable ANSI, NEMA, UL (Underwriters Laboratories) and NEC (National Electrical Code) standards.
4) Drive shall be suitable for operation in ambient temperatures between 40 and 122 F (4 and 50 C), 95% humidity (noncondensing) for altitudes up to 6000 ft (1829 m) above sea level. Specific drive performance at jobsite ambient temperature and elevation shall be provided by the manufacturer in the bid.

e. User Interface:

1) A single display shall provide interface for programming and display of VFD and chiller parameters. Viewable parameters include:

a) Operating, configuration, and fault messages
b) Frequency in hertz
c) Load and line side voltage and current (at the VFD)
d) kW
e) IGBT temperature

f. VFD Performance:

1) The VFD Voltage Total Harmonic Distortion (THD) and Harmonic Current Total Demand Distortion (TDD) shall not exceed IEEE-519 requirements using the VFD circuit breaker input terminals as the point of common coupling (PCC).
2) The VFD full load efficiency shall meet or exceed 97% at 100% VFD rated ampacity.
3) Active rectifier shall regulate unity displacement power factor to 0.99 or higher.
4) Voltage boost capability to provide full motor voltage at reduced line voltage conditions.
5) The VFD shall feature soft start, linear acceleration, and coast to stop capabilities.
6) Base motor frequency shall permit motor to be utilized at nameplate voltage. Adjustable frequency range shall permit capacity control down to 15%.
7) The VFD shall have 150% instantaneous torque generation.

g. VFD Electrical Service (single point power):

1) The VFD shall have input circuit breaker with minimum 65,000 amp interrupt capacity.
2) The VFD shall have standard branch oil pump circuit breaker to provide power for chiller oil pump.
3) The VFD shall have standard 3 KVA control power transformer with circuit breaker to provide power for oil heater, VFD controls and chiller controls.
4) The branch oil pump circuit breaker and control power transformer shall be factory- wired.
5) Input power shall be 380/460 vac, ±10%, 3 Phase, 50/60 Hz, ±2% Hz.

h. Discrete Outputs:

1) 115-v discrete contact outputs shall be provided for:

a) Circuit breaker shunt trip
b) Chilled water pump
c) Condenser water pump
d) Alarm status

i. Analog Output:

1) An analog (4 to 20 mA) output for head pressure reference shall be provided. This signal shall be suitable to control a 2-way or 3-way water regulating valve in the condenser piping.

j. Protection (the following shall be supplied):

1) Under-voltage
2) Over voltage
3) Phase loss
4) Phase reversal
5) Ground fault
6) Phase unbalance protection
7) Single cycle voltage loss protection (LF-2 VFD only)
8) Programmable auto re-start after loss of power
9) Motor overload protection (NEMA Class 10)
10) Motor over temperature protection

k. VFD Testing:

1) The VFD shall be factory-mounted, factory-wired and factory-tested on the chiller prior to shipment.

22. Unit-Mounted Variable Frequency Drive (VFD) without Built-In Harmonic Filter:

a. Design:

1) VFD shall be air or refrigerant cooled, microprocessor based, pulse width modulated design. Water-cooled designs are not acceptable.
2) Output power devices shall be insulated gate bipolar transistors (IGBTs).
3) Converter section with full-wave fixed diode bridge rectifier shall convert incoming fixed voltage/frequency to fixed DC voltage.
4) DC link shall filter and smooth the converted DC voltage.
5) Transistorized inverter and control regulator shall convert fixed DC voltage to a sinusoidal PWM waveform.
6) Integrated controls shall coordinate the motor speed to optimize chiller performance over a wide variety of operating conditions.

b. Enclosure:

1) Pre-painted unit mounted, NEMA 1 cabinet shall include hinged, lockable doors and removable lifting lugs.
2) VFD shall have a short circuit current rating of at least 100,000 amps.
3) Provisions to padlock main disconnect handle in the “Off” positions shall be provided. Mechanical interlock to prevent opening cabinet door with disconnect in the “On” position or moving disconnect to the “ON” position while the door is open shall be provided.
4) Provisions shall be made for top entry of incoming line power cables.

c. Heat Sink:

1) The heat sink (frame sizes 3, 4, 5 heat exchangers only) shall be refrigerant cooled. Heat sink and mating flanges shall be suitable for ASME design working pressure of 185 psig (1276 kPa).
2) Refrigerant cooling shall be metered by integrated standard controls to maintain heat sink temperature within acceptable limits for ambient temperature.

d. VFD Rating:

1) Drive shall be suitable for nameplate voltage ±10%.
2) Drive shall be suitable for continuous operation at 100% of nameplate amps and 150% of nameplate amps for 3 seconds.
3) Drive shall comply with applicable UL, CE, and NEMA standards.
4) Drive shall be suitable for operation in ambient temperatures between 40 and 104 F (4.4 and 40 C), 95% humidity (non-condensing) for altitudes up to 3300 feet (1006 m) above sea level. Specific drive performance at jobsite ambient temperature and elevation shall be provided by the manufacturer in the bid.

e. User Interface:

1) Displays shall provide interface for programming and display of VFD and chiller parameters. Viewable parameters include:

a) Operating, configuration and fault messages
b) Frequency in hertz
c) Load side voltage and current (at the VFD)
d) kW (on the VFD interface)

f. VFD Performance:

1) VFD full load efficiency shall meet or exceed 97% at 100% VFD Rated Ampacity.
2) Base motor frequency shall be either 50 or 60 hertz.

g. VFD Electrical Service: (single point power):

1) VFD shall have input circuit breaker with minimum 65,000 amp interrupt capacity.
2) VFD shall have standard 15 amp branch oil pump circuit breaker to provide power for chiller oil pump.
3) VFD shall have standard 3 kva control power transformer with circuit breaker provides power for oil heater, VFD controls and chiller controls.
4) The branch oil pump circuit breaker and control power transformer shall be factory wired.
5) Input power shall be 380/480 vac, ±10 percent, 3 phase, 50/60 Hz, ±3 Hz.

h. Discrete Outputs:

1) 115-v discrete contact outputs shall be provided for:

a) Chilled water pump
b) Condenser water pump
c) Alarm status.

i. Analog Output:

1) An analog (4 to 20 mA) output for head pressure reference shall be provided. This signal shall be suitable to control a 2-way or 3-way water regulating valve in the condenser piping.

j. Protection (the following shall be supplied):

1) Under-voltage
2) Over voltage
3) Phase loss
4) Phase unbalance protection
5) Programmable auto re-start after loss of power
6) Motor overload protection (NEMA Class 10)
7) Motor over temperature protection

k. VFD Testing:

1) The VFD shall be factory mounted, wire and tested on the chiller prior to shipment.

23. Unit-Mounted Variable Frequency Drive (575-v VFD) without Built-In Harmonic Filter (Q and R compressor only):

a. Design:

1) VFD shall be air or refrigerant cooled, microprocessor based, pulse width modulated design. Water-cooled designs are not acceptable.
2) Output power devices shall be insulated gate bipolar transistors (IGBTs).
3) Converter section with full-wave fixed-diode bridge rectifier shall convert incoming fixed voltage/frequency to fixed DC voltage.
4) DC link shall filter and smooth the converted DC voltage.
5) Transistorized inverter and control regulator shall convert fixed DC voltage to a sinusoidal PWM waveform.
6) Integrated controls shall coordinate the motor speed to optimize chiller performance over a wide variety of operating conditions.

b. Enclosure:

1) Pre-painted unit mounted, NEMA 1 cabinet shall include hinged, lockable doors and removable lifting lugs.
2) VFD shall have an Amp Interrupt Capacity (AIC) of 35,000 amps and a short circuit current rating of 25,000 amps.
3) Provisions to padlock main disconnect handle in the “Off” positions shall be provided. Mechanical interlock to prevent opening cabinet door with disconnect in the “On” position or moving disconnect to the “On” position while the door is open shall be provided.
4) Provisions shall be made for top entry of incoming line power cables.

c. Heat Sink:

1) The heat sink shall be refrigerant cooled. Heat sink and mating flanges shall be suitable for ASME design working pressure of 185 psig (1276 kPa).
2) Refrigerant cooling shall be metered by integrated standard controls to maintain heat sink temperature within acceptable limits for ambient temperature.

d. VFD Rating:

1) Drive shall be suitable for nameplate voltage ±10%.
2) Drive shall be suitable for continuous operation at 100% of nameplate amps and 150% of nameplate amps for 3 seconds.

3) Drive shall comply with applicable UL and NEMA standards.
4) Drive shall be suitable for operation in ambient temperatures between 40 and 104 F (4.4 and 40 C), 95% humidity (non-condensing) for altitudes up to 3300 feet (1006 m) above sea level. Specific drive performance at jobsite ambient temperature and elevation shall be provided by the manufacturer in the bid.

e. User Interface:

1) Displays shall provide interface for programming and display of VFD and chiller parameters. Viewable parameters include:

a) Operating, configuration and fault messages
b) Frequency in hertz
c) Load side voltage and current (at the VFD)
d) kW (on the VFD interface)

f. VFD Performance:

1) VFD full load efficiency shall meet or exceed 97% at 100% VFD Rated Ampacity.
2) Base motor frequency shall be 60 hertz.

g. VFD Electrical Service: (single point power):

1) VFD shall have input circuit breaker with minimum 35,000 amp interrupt capacity.
2) VFD shall have standard 15 amp branch oil pump circuit breaker to provide power for chiller oil pump.
3) VFD shall have standard 3 kva control power transformer with circuit breaker provides power for oil heater, VFD controls and chiller controls.
4) The branch oil pump circuit breaker and control power transformer shall be factory wired.
5) Input power shall be 575 vac, ±10 percent, 3 phase, 60 Hz, ±3 Hz.

h. Discrete Outputs:

1) 115-v discrete contact outputs shall be provided for:

a) Chilled water pump
b) Condenser water pump
c) Alarm status.

i. Analog Output:

1) An analog (4 to 20 mA) output for head pressure reference shall be provided. This signal shall be suitable to control a 2-way or 3-way water regulating valve in the condenser piping.

j. Protection (the following shall be supplied):

1) Under-voltage
2) Over voltage
3) Phase loss

4) Phase unbalance protection
5) Programmable auto re-start after loss of power
6) Motor overload protection (NEMA Class 10)
7) Motor over temperature protection

k. VFD Testing:

1) The VFD shall be factory mounted, wire and tested on the chiller prior to shipment.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Before water chiller installation, examine roughing-in for equipment support, anchor-bolt sizes and locations, piping, and electrical connections to verify actual locations, sizes, and other conditions affecting water chiller performance, maintenance, and operations.

1. Water chiller 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 WATER CHILLER INSTALLATION

A. Install water chillers on support structure indicated.

B. Equipment Mounting:

1. Install water chillers on cast-in-place concrete equipment bases. Comply with requirements for equipment bases and foundations specified in Section 033000 "Cast-in-Place Concrete."
2. Comply with requirements for vibration isolation and seismic control devices specified in Section 230550 "Vibration and Seismic Controls for HVAC."

C. Maintain manufacturer's recommended clearances for service and maintenance.

D. Charge water chiller with refrigerant if not factory charged and fill with oil if not factory installed.

E. Install separate devices furnished by manufacturer and not factory installed.

3.3 CONNECTIONS

A. Comply with requirements in Section 232113 "Hydronic Piping" and Section 232116 Hydronic Piping Specialties." 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 pressure gage, flow meter, and drain connection with valve. Make connections to water chiller with a flange.

D. Refrigerant Pressure Relief Valve Connections: For water chillers installed indoors, extend vent piping to the outside without valves or restrictions. Comply with ASHRAE 15.

E. Connect each 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 if required.

3.4 STARTUP SERVICE

A. Engage a factory-authorized service representative to perform startup service.

B. Inspect field-assembled components, equipment installation, and piping and electrical connections for proper assemblies, installations, and connections.

C. Complete installation and startup checks according to manufacturer's written instructions and perform the following:

1. Verify that refrigerant charge is sufficient and water chiller has been leak tested.
2. Verify that pumps are installed and functional.
3. Verify that thermometers and gages are installed.
4. Operate water chiller for run-in period.
5. Check bearing lubrication and oil levels.
6. Verify that refrigerant pressure relief device for chillers installed indoors is vented outside.
7. Verify proper motor rotation.
8. Verify static deflection of vibration isolators, including deflection during water chiller startup and shutdown.
9. Verify and record performance of chilled water flow and low-temperature interlocks.
10. Verify and record performance of water chiller protection devices.
11. Test and adjust controls and safeties. Replace damaged or malfunctioning controls and equipment.

D. Prepare a written startup report that records results of tests and inspections.

3.5 DEMONSTRATION

A. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain water chillers. Video record the training sessions.

END OF SECTION 23 6423

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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 factory-assembled, open-circuit, induced-draft, crossflow cooling towers.

1.3 DEFINITIONS

A. SCCR: Short-circuit current rating.

1.4 ACTION SUBMITTALS

A. Product Data: For each type of product.

1. Include rated capacities, pressure drop, fan performance data, rating at selected points indicated, and furnished specialties and accessories.
2. Maximum flow rate.
3. Minimum flow rate.
4. Pressure required at cooling tower supply piping connections.

5. Pressure required at basin heater supply piping connections.
6. Pressure required at collection basin sweeper supply piping connections.
7. Drift loss as percent of design flow rate.

8. Volume of water in suspension for purposes of sizing remote storage.
9. Sound:

a. Sound pressure levels for operation with fan off, fan at minimum speed, and design speed. If sound requirements are indicated at a specific distance, submit performance using same distance for comparative analysis.

b. Sound power levels in eight octave bands for operation with fans off, fans at minimum speed, and design speed.

10. Performance curves for the following:

a. Varying entering-water temperatures from design to minimum in one-degree temperature increments.
b. Varying ambient wet-bulb temperatures from design to minimum in one-degree temperature increments.

c. Varying water flow rates from design to minimum in increments of 10 percent of flow rate difference between design and minimum flow rates.
d. Varying fan operation from design to minimum speed in 5 percent speed increments, and with fan off.

11. Fan airflow at design conditions, brake horsepower, and drive losses (indicated in horsepower and percent of brake horsepower).
12. Fan motor electrical characteristics including, but not limited to, speed, voltage, phase, hertz, amperage, efficiency, and power factor at 100, 75, 50, and 25 percent of nameplate horsepower.
13. Electrical power requirements for each cooling tower component requiring power.

B. Shop Drawings:

1. Manufacturer's drawings of assembled cooling towers, control panels, sections, and elevations.
2. Assembled unit dimensions.
3. Diagram showing each separate piece requiring field assembly.
4. Shipped sub-assembly dimensions and weights for field assembly.
5. Assembled unit weight without water.
6. Operating weight and load distribution.
7. Unit vibration isolation [**and seismic controls**].
8. Required clearances for maintenance and operation.
9. Sizes and dimensioned locations of piping and wiring connections.
10. 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.
3. Design Calculations: Calculate requirements for selecting vibration isolators [**and seismic restraints**] [**and wind restraints**] and for designing vibration isolation bases.

1.5 INFORMATIONAL SUBMITTALS

A. Coordination Drawings:

1. Drawings on which the following items are shown and coordinated with each other, using input from installers of the items involved:

a. Structural supports.
b. Piping roughing-in requirements.
c. Conduit and wiring roughing-in requirements for controls and electrical power, including spaces reserved for controls and electrical equipment.
d. Access requirements, including working clearances for controls and electrical equipment, and service clearances. Mark and label clearances on drawings.

2. Drawings showing plans, sections, and elevation views, drawn to scale of at least 1/4” = 1’-0”.
3. Each view to show screened background with the following:

a. Structural grids.
b. Adjacent walls, floors, and roofs.
c. Equipment and products of other trades that are located in vicinity of cooling towers and are part of final installation, such as, controls, power, lighting, fire-suppression systems, and plumbing systems.

B. Seismic Qualification Data: Certificates, for cooling towers, 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. Product Certificates: For certification required in "Quality Assurance" Article.

D. Field Test Reports: Include startup service reports.

E. Source quality-control reports.

F. Field quality-control reports.

G. Sample Warranty: For special warranty.

1.6 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For each cooling tower to include in emergency, operation, and maintenance manuals.

B. Instructional Videos: Including those that are prerecorded and those that are recorded during training.

1.7 MAINTENANCE MATERIAL SUBMITTALS

A. Belts:

1. Furnish one set of matching belts for each unique belt configuration and size furnished.

B. Tool Kit:

1. A tool kit specially designed by cooling tower manufacturer for use in servicing cooling tower(s) furnished.
2. Special tools required to service components not readily available to Owner service personnel in performing routine maintenance.
3. Lockable case with hinged cover, marked with large and permanent text to indicate the special purpose of tool kit, such as "Cooling Tower Tool Kit." Text size shall be at least 1 inch (25 mm) high.
4. A list of each tool furnished. Permanently attach the list to underside of case cover. Text size shall be at least 1/2 inch (13 mm) high.

C. Touchup Coating: **32-oz. (1-L)** container of paint coating used. Label outside of container with detailed description of coating to allow for procurement of a matching coating in the future.

1.8 QUALITY ASSURANCE

A. Testing Agency Qualifications: Certified by CTI.

B. CTI Certification: Cooling tower thermal performance according to CTI STD 201RS.

C. FM Global: Approval and listing in the latest edition of FM Global's "Approval Guide."

1.9 DELIVERY, STORAGE, AND HANDLING

A. Coordinate requirements for multi-piece assembly for shipment. Limit the number of separate pieces for field installation to as few as possible.

B. If factory assembly of multiple pieces is required for testing or other reasons, disassemble cooling tower into major assemblies as required by installation before packaging for shipment.

1. Clearly label each separate package with a unique designation and include assembly instructions for complete cooling tower.

C. Install seals on gear-drive assemblies to eliminate oil leakage during shipment if shipped with oil.

1.10 WARRANTY

A. The entire tower, including structure, casing, basins, decking, fan(s), motor(s), and all mechanical drive components (including belts, if used) shall be warranted against failure due to defects in materials and workmanship for a period of five (5) years from the date of shipment to the job. Towers not covered by a warranty of this scope will not be accepted.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. Marley Cooling Technologies; SPX Cooling Technologies; NC Series

2.2 PERFORMANCE REQUIREMENTS

A. Delegated Design: Engage a qualified professional engineer, as defined in Section 014000 "Quality Requirements," to design cooling tower support structure[**and seismic restraints**] [**and wind restraints**], including comprehensive engineering analysis.

B. The tower structure, anchorage and all its components shall be designed by licensed professional engineers, employed by the manufacturer, per the International Building Code to withstand a wind load of 30 psf, as well as a .3g seismic load. The fan deck, hot-water basin covers and, where specified, maintenance platforms shall be designed for 60 psf live load or a 200 lb concentrated load. Guardrails, where specified, shall be capable of withstanding a 200 lb concentrated live load in any direction, and shall be designed in accordance with OSHA guidelines.

C. The tower shall be structurally capable of being supported at the four outer corners of the tower cell. Alternatively, the tower manufacturer shall provide supporting steel to adapt tower to be supported at four outer corners. *NC8401-NC8414 only.*

D. Seismic Performance: Cooling towers shall withstand the effects of earthquake motions determined according to **ASCE/SEI 7**.

1. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified and the unit will be fully operational after the seismic event."

2. Component Importance Factor: [**1.5**] [**1.0**].

3. Component Amplification Factor: <**Insert value**>.
4. Component Response Modification Factor: <**Insert value**>.

E. ASHRAE/IES 90.1 Compliance: Applicable requirements in ASHRAE/IES 90.1.

F. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

G. Operation Following Loss of Normal Power:

1. Equipment, associated factory- and field-installed controls, and associated electrical equipment and power supply connected to backup power system shall automatically return equipment and associated controls to the operating state occurring immediately before loss of normal power without need for manual intervention by an operator when power is restored either through a backup power source, or through normal power if restored before backup power is brought on-line.
2. Include means and methods required to satisfy requirement even if not explicitly indicated.

H. Vibration:

1. Rotating assemblies shall be dynamically balanced to achieve a balance level of "good" while complying with industry-standard requirements for cooling towers.
2. Critical speed shall be at least 115 percent of design speed.

2.3 BASE

A. Provide an induced draft, crossflow type, factory assembled, film fill, industrial duty, galvanized steel cooling tower situated as shown on the plans. The limiting overall dimensions of the tower shall be _____ wide, _____ long, and _____ high. Total operating horsepower of all fans shall not exceed ____ hp, consisting of ___ @ _____ hp motor(s). Tower shall be similar and equal in all respects to Marley Model ____________.

B. Provide alternate pricing to provide an induced draft, crossflow type, factory assembled, film fill, industrial duty, stainless steel cooling tower situated as shown on the plans. The limiting overall dimensions of the tower shall be _____ wide, _____ long, and _____ high. Total operating horsepower of all fans shall not exceed ____ hp, consisting of ___ @ _____ hp motor(s). Tower shall be similar and equal in all respects to Marley Model ____________.

C. The cooling tower shall be designed for quiet operation, and shall produce an overall level of sound not higher than _______ dB(A) measured at _______ ft from the locations in the following table. Sound levels shall be independently verified by a CTI-licensed sound test agency to ensure validity and reliability of the manufacturer's published values. Measurement and analysis of the sound levels shall be conducted by a certified Professional Engineer in Acoustical Engineering. Sound pressure levels shall be measured and recorded in the acoustic near-field and far-field locations using ANSI S1.4 Type 1 precision instrumentation and in full conformance with CTI ATC-128 test code published by the Cooling Technology Institute (CTI). All low sound options shall be CTI certified for thermal performance.

2.4 THERMAL PERFORMANCE AND EFFICIENCY

A. The tower shall be capable of cooling _____ gpm of water from ____ °F to _____ °F at a design entering air wet-bulb temperature of _____ °F, and its thermal rating shall be certified by the Cooling Technology Institute and Eurovent.

B. The tower shall be capable of a minimum _____ gpm/hp efficiency per ASHRAE Standard 90.1.

C. CTI and Eurovent certification notwithstanding, the cooling tower manufacturer shall guarantee that the tower supplied will meet the specified performance conditions when the tower is installed according to plan. If, because of a suspected thermal performance deficiency, the owner chooses to conduct an on-site thermal performance test under the supervision of a qualified, disinterested third party in accordance with CTI, Eurovent or ASME standards during the first year of operation; and if the tower fails to perform within the limits of test tolerance; then the cooling tower manufacturer will pay for the cost of the test and will make such corrections as are appropriate and agreeable to the owner to compensate for the performance deficiency.

2.5 CONSTRUCTION

A. Except where otherwise specified, all components of the cooling tower shall be fabricated of steel, protected against corrosion by G-235 galvanizing. The tower shall be capable of withstanding water having a pH of 6.5 to 8.0; a chloride content (NaCl) up to 300 ppm; a sulfate content (SO_4) up to 250 ppm; a calcium content ($CaCO_3$) up to 500 ppm; and silica (SiO_2) up to 150 ppm. The circulating water shall contain no oil, grease, fatty acids or organic solvents.

B. Provide alternate pricing to provide except where otherwise specified, all components of the cooling tower shall be fabricated of 301L stainless steel. The tower shall be capable of withstanding water having a chloride content (NaCl) up to 750 ppm; a sulfate content (SO4) up to 1200 ppm; a calcium content (CaCO3) up to 800 ppm; and silica (SiO2) up to 150 ppm. The circulating water shall contain no oil, grease, fatty acids, or organic solvents.

C. Fiberglass casing, polyurethane barriers, and thermosetting hybrids and the components they are adhered to shall be considered non-recyclable and not allowed.

D. The specifications, as written, are intended to indicate those materials that will be capable of withstanding the above water quality in continuing service, as well as the loads described in paragraph 4.1. They are to be regarded as minimum requirements. Where component materials peculiar to individual tower designs are not specified, the manufacturers shall take the above water quality and load carrying capabilities into account in the selection of their materials of manufacture.

E. The tower shall be listed in the current FM Approval Guide (approvalguide.com) and conform to the FM Approval Standard for Cooling Towers, Class Number 4930 that is approved for use without sprinkler systems. The tower shall have successfully passed full scale fire testing, static and cyclic wind pressure testing, large missile impact testing (for Zone HM), and structural design evaluation as administered by FM Approvals. The tower shall be capable of +70/-140 psf for Zone H as defined by FM Global. A copy of the FM Approval Certificate of Compliance dated November 2013 or later shall be available upon request.

2.6 MECHANICAL EQUIPMENT

A. Fan(s) shall be propeller-type, incorporating wide-chord acoustic geometry, corrosion and fire resistant marine grade aluminum blades and aluminum hubs. Blades shall be resiliently mounted to fan hub and individually adjustable. Fan blades shall be open cavity with suitable drainage to avoid accumulation of moisture. Foam filled blades are not allowed due to potential moisture contamination of the foam core causing an imbalance of the fan leading to vibration issues. Maximum fan tip speed shall be 10,000 ft/min. Fan(s) shall be driven through a right angle, industrial duty, oil lubricated, geared speed reducer that requires no oil changes for the first five (5) years of operation. The gearbox bearings shall be rated at an L10A service life of 100,000 hours or greater. The gear sets to have AGMA Quality Class of 9 or greater.

a) Available on models NC8402 through NC8414.

(alternate)* Fan(s) shall be propeller-type, incorporating aluminum alloy blades attached to galvanized hubs with U-bolts. Blades shall be individually adjustable. Maximum fan tip speed shall be 13,000 ft/min. Fan(s) shall be driven through a one-piece multi-groove, solid back V-type belt, pulleys and tapered roller bearings. Bearings and fan shaft shall be contained in a cast steel housing to ensure proper fan shaft alignment, pillow block bearings shall not be allowed. Bearings shall be rated at an L_{10A} service life of 40,000 hours or greater.

*Currently available on NC models up to 60 hp.

B. Two-speed motor(s) shall be ____ hp maximum, TEFC, 1.15 service factor, variable torque, and specially insulated for cooling tower duty (Class F). Speed and electrical characteristics shall be ______ RPM, 3 phase, ____ hertz, ____ volts. Motor shall operate in the shaft-horizontal position for geardrive towers and the shaft-down position for belt drive towers. Nameplate horsepower shall not be exceeded at design operation.

C. The motor to gearbox close coupling shall be a tire-type, single piece, flexible element design to accommodate frequent speed changes that are inherent with VFD applications.

D. The complete mechanical equipment assembly for each cell shall be supported by two horizontal steel beams that resist misalignment between the motor and the gear reducer/belt drive system. The mechanical equipment assembly shall be warranted against any failure caused by defects in materials and workmanship for no less than five (5) years following the date of tower shipment. This warranty shall cover the fan, speed reducer, drive shaft and couplings, and the mechanical equipment support. The electric motor shall carry a manufacturer's warranty of at least one year.

E. A factory installed terminal box shall be furnished and mounted to the outside of the tower where applicable. The fan motor and optional components—including the vibration switch and water level probes—shall be factory wired to terminal points inside the terminal box. Optional tower components which ship loose, including the oil level switch and immersion heaters shall be field wired to the terminal box. Enclosure shall be NEMA 3R or NEMA 4X with hinged and lockable door meeting UL and CSA standards. Terminal box shall include lockable stainless steel snap-latch door fasteners, terminal blocks marked with wire numbers, sub-pan and a wiring diagram. Complete assembly shall be built to UL 508A standards. Conduit entry and exit points shall be the bottom of the enclosure preventing water collection in the enclosure.

F. A vibration limit switch in a NEMA 4X housing shall be installed on the mechanical equipment support and wired to the shutdown circuit of the fan motor starter or VFD. The purpose of this switch will be to interrupt control power voltage to a safety circuit in the event of excessive vibration causing the starter or VFD equipment to de-energize the motor. It shall be adjustable for sensitivity and include a means to reset the switch.

G. For fan control a complete UL listed variable speed drive system in a NEMA 1 indoor, NEMA 12 indoor or NEMA 3R outdoor enclosure shall be provided. The VFD shall use PWM technology with IGBT switching. VFD output switching signal shall be programmed to not cause mechanical vibration issues with backlash in gearbox teeth or vibration issues associated with long driveshafts. The VFD shall be programmed for variable torque applications and shall catch a fan spinning in the forward or reverse direction without tripping. VFD panel construction shall include a main disconnect with short circuit and thermal overload protection with external operating handle, lockable in the off position for lock-out tag-out safety procedures. A service switch directly ahead of the VFD shall be provided for voltage isolation during VFD maintenance. An integrated full voltage non-reversing bypass starter shall be furnished allowing fan motor operation if VFD has failed. The VFD system shall receive a speed reference signal from the building management system monitoring the cooling tower cold-water temperature. As an option to receiving the speed reference signal from a building management system, the drive must have the capability to receive a 4-20 mA temperature signal from an RTD transmitter. When using an RTD for temperature monitoring and speed control the VFD shall have an internal PI regulator to modulate fan speed maintaining set point temperature. The drive's panel shall display the set-point temperature and cold-water temperature on two separate lines. The bypass shall include a complete electromechanical magnetic bypass circuit with the capability to isolate the VFD when in the bypass mode. Transfer to the bypass mode shall be manual in the event of VFD failure. Once the motor is transferred to the bypass circuit the fan motor will run at constant full speed. Operator controls shall be mounted on the front of the enclosure and shall consist of Start and Stop control, Bypass/VFD selection, Auto/Manual selections and manual speed control. To prevent heating problems in the fan motor the VFD system shall de-energize the motor once 25% motor speed is reached and cooling is no longer required. The cooling tower manufacturer shall offer VFD start-up assistance to assure proper VFD programming for cooling tower operation.

H. Each cell of the cooling tower shall be equipped with a UL/CUL 508 listed SPPC (Single Point Power Connection) control panel in a NEMA 3R or 4X outdoor enclosure. The SPPC panel shall include a main circuit breaker with an external operating handle, lockable in the off position for safety. The SPPC main circuit breaker will feed various control circuits integrated into the SPPC panel including but not limited to: fan motor starter, basin heater controls and water level controls. In the event a VFD is furnished for the cooling tower fan, a feeder breaker in the SPPC panel shall be provided to feed power to a remotely mounted VFD. Operational status contacts wired to user terminal points shall be provided.

I. A portable davit crane shall be mounted on the fan deck of the tower and shall be capable of lifting, extending, and lowering the heaviest mechanical component up to 1000 lb over the fan deck and down the air inlet face of the tower. The davit crane system shall include a winch, cable, and load hook. NC8401-NC8414 only.

J. An external oil level dipstick shall be located adjacent to the motor at the fan deck surface and shall be accessible from a portable maintenance ladder.

2.7 FILL, LOUVERS AND DRIFT ELIMINATORS

A. Fill shall be film type, thermoformed PVC, with louvers and eliminators formed as part of each fill sheet. Fill shall be suspended from hot dip galvanized structural tubing supported from the tower structure, and shall be elevated above the floor of the cold-water basin to facilitate cleaning. Air inlet faces of the tower shall be free of water splash out.

B. Drift eliminators shall be PVC, triple-pass, and shall limit drift losses to 0.005% or less of the design water flow rate.

2.8 HOT WATER DISTRIBUTION SYSTEM

A. Two open 301L stainless steel basins (one above each bank of fill) shall receive hot water piped to each cell of the tower. These basin components shall be installed and sealed at the factory and assembled with bolted connections. Tap screws shall not be acceptable due to their potential to develop leaks. The basins shall be equipped with removable, stainless steel covers capable of withstanding the loads described in paragraph 4.1. The water distribution system shall be accessible and maintainable during tower fan and water operation.

B. Each basin shall include an inlet hole and bolt circle to accept a 125# flange connection per ANSI B16.1. Removable, interchangeable polypropylene nozzles installed in the floor of these basins shall provide full coverage of the fill by gravity flow.

C. The water distribution system shall be accessible and maintainable while tower is operating.

2.9 CASING, FAN DECK AND FAN GUARD

A. The casing and fan deck shall be galvanized steel, and shall be capable of withstanding the loads described in paragraph 4.1. The top of the fan opening shall be equipped with a conical, non-sagging, removable fan guard, fabricated of welded 5⁄16" and 7 gauge rods, and hot dip galvanized after fabrication. Fan cylinders 5'-0" in height and over shall not be required to have a fan guard.

B. Provide alternate pricing to provide the casing and fan deck shall be 301L stainless steel, and shall be capable of withstanding the loads described in paragraph 4.1. The top of the fan shall be equipped with a conical, non-sagging, removable fan guard, fabricated of welded 5/16" and 7 gauge rods, and hot dip galvanized after fabrication. Fan cylinders 5'-0" in height and over shall not be required to have a fan guard.

C. The air inlet faces of the tower shall be covered by 1" mesh hot-dipped galvanized welded wire screens. Screens shall be secured to removable galvanized U-edge frames. Screens shall be designed to permit full access to the cold-water basin by removal of one panel on each air inlet.

2.10 ACCESS:

A. A large galvanized, rectangular access door shall be located on both cased faces for entry into the cold-water basin. Doors shall provide convenient access to the fan plenum area to facilitate inspection and allow maintenance to the fan drive system. The access doors shall be _____" wide by _____" high.

B. Provide alternate pricing to provide a large 301L stainless steel, rectangular access door shall be located on both cased faces for entry into the cold-water basin. Doors shall provide convenient access to the fan plenum area to facilitate inspection and allow maintenance to the fan drive system. The access doors shall be _____" wide by _____" high.

C. The top of the tower shall be equipped with a guardrail complete with kneerail and toeboard, designed according to OSHA guidelines and factory welded into sub-assemblies for ease of field installation. Posts, toprails and kneerails shall be 1.5" square tubing. The guardrail assembly shall be hot dipped galvanized after welding and capable of withstanding a 200 pound concentrated live load in any direction. Posts shall be spaced on centers of 8'-0" or less. A 1'-6" wide aluminum ladder with 3" I-beam side rails and 1.25" diameter rungs shall be permanently attached to the endwall casing of the tower, rising from the base of the tower to the top of the guardrail. Provide a ladder extension for connection to the foot of the ladder attached to the tower casing. This extension shall be long enough to rise from the roof (grade) level to the base of the tower. The installing contractor shall be responsible for cutting the ladder to length; attaching it to the foot of the tower ladder; and anchoring it at its base. A steel, self-closing gate shall be provided at the guardrail level of the ladder.

D. A heavy gauge aluminum safety cage, welded into subassemblies for ease of field installation, shall surround the ladder, extending from a point approximately 7'-0" above the foot of the ladder to the top of the guardrail. Maximum weight of welded subassemblies shall not exceed 20 lb for ease of installation.

E. There shall be an access platform at the base of the tower extending from the vertical ladder to the access door. The platform shall be surrounded by an OSHA compliant guardrail system welded into subassemblies for ease of installation. The walking surface of the platform shall be perforated to provide a non-slip surface for personnel safety.

F. Provide a factory-installed walkway extending from one cased-face access door to the other cased face. A steel framework shall support the walkway and the top of the walkway shall be at or above the cold-water basin overflow level. The walkway and framework to be equivalent material as the tower basin and have a minimum width of 36".

G. Interior Mechanical Equipment Access Platform: NC8402 thru NC8409: A factory-installed, elevated platform convenient for the care and maintenance of the tower's mechanical equipment shall be provided. The walkway and framework to be equivalent material as the tower basin.

H. Interior Mechanical Equipment Access Platform: NC8410 thru NC8422*:* An internal ladder shall extend upward from the plenum walkway to an elevated fiberglass bar grating platform convenient for the care and maintenance of the tower's mechanical equipment. The platform shall be surrounded by an OSHA compliant guardrail system welded into subassemblies for ease of installation.

2.11 COLD WATER COLLECTION BASIN

A. The collection basin shall be welded 301L stainless steel construction. Only low-carbon stainless steel alloys will be accepted in order to minimize the risk of intergranular corrosion in the weld zones. The basin shall include the number and type of suction connections required to accommodate the outflow piping system shown on the plans. Suction connections shall be equipped with stainless steel debris screens. A factory-installed, float-operated, mechanical make-up valve shall be included. An overflow and drain connection shall be provided in each cell of the cooling tower. The basin floor shall slope toward the drain to allow complete flush out of debris and silt that may accumulate. Towers of more than one cell shall include a method for flow and equalization between cells. The basin shall be accessible and maintainable while water is circulating.

B. Provide a system of electric immersion heaters and controls for each cell of the tower to prevent freezing of water in the collection basin during periods of shutdown. The system shall consist of one or more stainless steel electric immersion heaters installed in threaded couplings provided in the side of the basin. A NEMA 4 control panel and associated temperature probe shall include circuitry to monitor cold water temperature and low water level, providing ON OFF thermostatic like control. The temperature probe shall be located in the cold-water basin. The system shall be capable of maintaining 40°F water temperature at an ambient air temperature of _____ °F.

C. Provide a water level control system including a NEMA 4X control panel, water level probes and probe stilling chamber. The control system shall monitor the water level in the cold-water basin to determine level events used for cold-water make-up, high and low alarms or pump shut down. The control panel shall use electromechanical relays providing power for the make-up solenoid and electrical contacts for alarm and pump shutdown control circuits. Probes shall be contained in a vertical stilling chamber to stabilize the water in the cold-water basin. Probes shall have replaceable stainless steel tips and level height shall be field adjustable. The water distribution system shall be equipped with a method to operate under variable flow conditions while maintaining a uniform air-side pressure drop through the fill to maximize cooling efficiency and minimize the risk of ice and scale formation in the fill. System must accommodate flow rates down to _______% of design flow.

D. A hole and bolt circle shall be provided in the depressed section of the basin for equalizer piping between cells. A full-face, .25" thick, 50 durometer gasket shall be provided at each equalizer location.

E. The cold water basin shall be equipped with PVC sweeper piping with plastic nozzles. The piping shall be factory installed under the fill and designed to force all dirt and debris to the depressed section of the collection basin. NC8401-NC8414 only.

F. The cold-water basin shall be equipped with basin inlet covers to help shield basin from debris and sunlight exposure.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine cooling towers before installation. Reject cooling towers that are damaged.

B. Before cooling tower installation, examine roughing-in for tower support, anchor-bolt sizes and locations, piping, controls, and electrical connections to verify actual locations, sizes, and other conditions affecting cooling tower performance, maintenance, and operation.

1. Cooling tower locations indicated on Drawings are approximate. Determine exact locations before roughing-in for piping, controls, and electrical connections.
2. Verify sizes and locations of concrete bases and support structure with actual equipment.
3. Verify sizes, locations, and anchoring attachments of structural-steel support structures.
4. Verify sizes and locations of roof curbs, equipment supports, and roof penetrations with actual equipment.

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

3.2 INSTALLATION

A. Install cooling towers on support structure.

B. Equipment Mounting:

1. Install cooling towers on cast-in-place concrete equipment bases. Comply with requirements for equipment bases and foundations specified in [**Section 033000 "Cast-in-Place Concrete."**] [**Section 033053 "Miscellaneous Cast-in-Place Concrete."**]
2. Comply with requirements for vibration isolation and seismic-control devices specified in Section 230548 "Vibration and Seismic Controls for HVAC."
3. Comply with requirements for vibration isolation devices specified in Section 230548.13 "Vibration Controls for HVAC."

C. Install anchor bolts to elevations required for proper attachment to supported equipment.

D. Maintain manufacturer's recommended clearances for service and maintenance.

E. Maintain clearances required by governing code.

F. Loose Components: Install components, devices and accessories furnished by manufacturer, with cooling tower, that are not factory mounted.

1. Loose components shall be installed by [**manufacturer's factory-trained service personnel**] [**Contractor under supervision of manufacturer's factory-trained service personnel**].

3.3 PIPING CONNECTIONS

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

B. Where installing piping adjacent to cooling towers, allow space for service and maintenance.

C. Install flexible pipe connectors at pipe connections of cooling towers mounted on vibration isolators.

D. Install 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. Makeup-Water Piping:

1. Comply with applicable requirements in Section 221116 "Domestic Water Piping."
2. Connect to makeup-water connections with shutoff valve, plugged tee with pressure gage, flow meter, and drain connection with valve and union.

G. Supply and Return Piping:

1. Comply with applicable requirements in Section 232113 "Hydronic Piping" and Section 232116 "Hydronic Piping Specialties."
2. Connect to entering cooling tower connections with shutoff valve, strainer, balancing valve, thermometer, plugged tee with pressure gage, flow meter, and drain connection with valve.
3. Connect to leaving cooling tower connection with shutoff valve thermometer, plugged tee with full port ball valve for portable field instruments, and drain connection with valve.
4. Make connections to cooling tower with a flange.

H. Equalizer Piping:

1. Piping requirements to match supply and return piping.
2. Connect an equalizer pipe, full size of cooling tower connection, between tower cells.
3. Connect to cooling tower with shutoff valve and drain connection with valve.
4. Make connections to cooling tower with a flange.

I. Basin Heater Hot-Water Piping:

1. Comply with applicable requirements in Section 232113 "Hydronic Piping" and Section 232116 "Hydronic Piping Specialties."
2. Connect to supply connections with shutoff valve, strainer, control valve thermometer, plugged tee with pressure gage, flow meter, and drain connection with valve.
3. Connect to return connections with shutoff valve, balancing valve, thermometer, plugged tee with pressure gage, flow meter, and drain connection with valve.
4. Make connections with a flange, union, or mechanical coupling.

J. Basin Heater Steam and Condensate Piping:

1. Comply with applicable requirements in Section 232213 "Steam and Condensate Heating Piping" and Section 232216 "Steam and Condensate Piping Specialties."
2. Connect steam supply connection with shutoff valve, strainer, control valve, pressure gage, and flow meter.
3. Connect to condensate connection with shutoff valve, strainer, and an appropriate steam trap assembly.
4. Make connections with a flange or union.

K. Basin Sweeper Piping:

1. Comply with applicable requirements in Section 232113 "Hydronic Piping" and Section 232116 "Hydronic Piping Specialties."
2. Connect to supply connections with shutoff valve, flow meter, and drain connection with valve.
3. Connect to return connections with shutoff valve, balancing valve, flow meter, and drain connection with valve.
4. Make connections with a flange.

3.4 ELECTRICAL POWER CONNECTIONS

A. Connect field electrical power source to each separate electrical device requiring field electrical power. Coordinate termination point and connection type with Installer.

B. Comply with requirements in Section 260519 "Low-Voltage Electrical Power Conductors and Cables" for wiring connections.

C. Comply with requirements in Section 260526 "Grounding and Bonding for Electrical Systems" for grounding connections.

D. Install nameplate for each electrical connection indicating electrical equipment designation and circuit number feeding connection. Nameplate shall be laminated phenolic layers of black with engraved white letters at least 1/2 inch (13 mm) high. Locate nameplate where easily visible.

3.5 CONTROLS CONNECTIONS

A. Install control and electrical power wiring to field-mounted control devices.

B. Connect control wiring between cooling towers and other equipment to interlock operation as required to achieve a complete and functioning system.

C. Connect control wiring between cooling tower control interface and control system for HVAC for remote monitoring and control of cooling towers. Comply with requirements in Section 25 0000 "Integrated Automation."

D. Install label at each termination indicating control equipment designation serving cooling tower and the I/O point designation for each control connection. Comply with requirements in Section 260553 "Identification for Electrical Systems" for labeling and identifying products and installations.

3.6 FIELD TESTING PROVISIONS

A. Include provisions for cooling tower future field-performance testing complying with ASME PTC 23 and CTI ATC 105.

B. Include provisions in field piping for future field-performance testing complying with ASME PTC 23 and CTI ATC 105.

3.7 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. Tests and Inspections: Comply with ASME PTC 23 and CTI ATC 105.

F. Cooling towers will be considered defective if they do not pass tests and inspections.

G. Prepare test and inspection reports.

3.8 STARTUP SERVICE

A. Engage a factory-authorized service representative to perform startup service.

B. Inspect field-assembled components, equipment installation, and piping; controls; 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.

3.9 ADJUSTING

A. Set and balance water flow to each tower inlet.

B. Adjust water-level control for proper operating level.

C. Adjust basin heater control for proper operating set point.

3.10 DEMONSTRATION

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

1. Video record the training sessions.
2. Instructor shall be factory trained and certified.
3. Perform not less than 8 hours of training.
4. Train personnel in operation and maintenance and to obtain maximum efficiency in plant operation.
5. Perform instructional videos showing general operation and maintenance that are coordinated with operation and maintenance manuals.
6. Obtain Owner sign-off that training is complete.
7. Owner training shall be held at Project site.

END OF SECTION 23 6514

SECTION 23 7313 - PACKAGED (MODULAR) AIR HANDLING UNITS

PART 1 - GENERAL

1.1 SECTION INCLUDES

A. Outdoor and/or indoor modular air handling units and components as scheduled and shown on drawings.

1.2 RELATED DOCUMENTS

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

1.3 REFERENCES

A. AMCA 99 – Standard Handbook

B. AMCA 210 – Laboratory Methods of Testing Fans for Rating Purposes

C. AMCA 500 – Test Methods for Louvers, Dampers, and Shutters

D. AMCA 611-95 – Methods of Testing Airflow Measurement Stations for Rating

E. ANSI/AFBMA 9 – Load Ratings and Fatigue Life for Ball Bearings

F. ANSI/UL 900 – Test Performance of Air Filter Units

G. AHRI 260 – Sound Rating of Ducted Air Moving and Conditioning Equipment

H. AHRI 410 – Forced-Circulation Air Cooling and Air Heating Coils

I. ANSI/AHRI 430 – Performance Rating of Central-Station Air Handling Units

J. ASHRAE 52.1/52.2 – Method of Testing General Ventilation Air Cleaning Devices for Removal Efficiency by Particle Size

K. ASHRAE 62 – Ventilation for Acceptable Indoor Air Quality

L. ASHRAE 90.1 – Energy Standard for Buildings Except Low-Rise Residential Buildings

M. ASTM-C 1338 – Standard Test Method for Determining Fungi Resistance of Insulation Material and Facings.

N. NFPA 70 – National Electric Code (conductors, equipment and raceways)

O. NFPA 90A – Installation of Air Conditioning and Ventilation Systems

P. SMACNA – HVAC Duct Construction Standards

Q. UL-181 – Mold Growth and Humidity Test

R. UL-1995 – Standard for Safety for Heating and Cooling Equipment

1.4 QUALITY ASSURANCE

A. Manufacturer shall have a minimum of 25 years of experience in designing, manufacturing, and servicing air-handling units.

B. The design indicated on the schedules and shown on the drawings is based upon the products of the named manufacturer. Alternate equipment manufacturers are acceptable if equipment meets scheduled performance requirements and dimensional requirements.

C. ARI Compliance:

1. Comply with ARI 203/110 and ARI 303/110 for testing and rating energy efficiencies for RTUs.
2. Comply with ARI 270 for testing and rating sound performance for RTUs.

D. ASHRAE Compliance:

1. Comply with applicable requirements in ASHRAE 62.1, Section 5 - "Systems and Equipment" and Section 7 - "Construction and Startup."

E. ASHRAE/IESNA 90.1 Compliance: Applicable requirements in ASHRAE/IESNA 90.1, Section 6 - "Heating, Ventilating, and Air-Conditioning."

F. NFPA Compliance: Comply with NFPA 90A and NFPA 90B.

G. UL Compliance: Comply with UL 1995.

H. 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.

I. Comply with FM Global requirements for fans and blowers, motors and VFD's, and for monitoring and diagnosis of vibration in rotating machinery.

1.5 COORDINATION

A. If equipment is supplied by a manufacturer other than the one named, coordinate with the General Contractor and affected subcontractors to ensure the specified performance is met. This coordination shall include (but is not limited to) the following:

1. Structural supports for units.
2. Size and location of concrete bases/housekeeping pads
3. Location of roof curbs, unit supports and roof penetrations
4. Ductwork sizes and connection locations
5. Piping size and connection/header locations
6. Interference with existing or planned ductwork, piping and wiring
7. Electrical power requirements and wire/conduit and over current protection sizes.

8. Trap height requirements

B. The Mechanical Contractor shall be responsible for costs incurred by the General Contractor, Subcontractors, and Consulting Engineers to accommodate units furnished by a manufacturer other than manufacturer named as basis of design.

1.6 RATINGS AND CERTIFICATIONS

A. Air Handling Unit safety: ETL or UL 1995

B. Air Handling Unit energy use: ASHRAE 90.1

C. Fans: AMCA 210

D. Air Coils: AHRI 410

E. Air Handling Unit certification program: ANSI/AHRI 430

F. Filter media: ANSI/UL 900 listed Class I or Class II

G. Control wiring: NEC codes & ETL requirements

H. Motors: Federally mandated Energy Policy Act (EPACT).

I. Airflow Monitoring Stations: AMCA 611-95

1.7 PERFORMANCE REQUIREMENTS

A. Delegated Design: Design outdoor units/supports to comply with project wind performance requirements, including comprehensive engineering analysis by a qualified professional engineer, using performance requirements and design criteria indicated.

1. Wind-Restraint Performance:

a. Basic Wind Speed: Refer to structural drawings.
b. Building Classification Category: [I] [II] [III] [IV].
c. Minimum XX 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.

1.8 SUBMITTAL DOCUMENTATION REQUIRED

A. [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."]

B. Delegated-Design Submittal: For unit 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 for designing vibration isolation bases.
2. If outdoor, roof mounted unit, detail mounting, securing, and flashing of roof curb to roof structure. Indicate coordinating requirements with roof membrane system.
3. Wind-Restraint Details (if unit subject to wind): Detail fabrication and attachment of wind restraints and snubbers. Show anchorage details and indicate quantity, diameter, and depth of penetration of anchors.

C. 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 packaged air handling units will be attached.
2. Roof openings
3. Roof curbs and flashing.

D. Manufacturer Wind Loading Qualification Certification: Submit certification that specified equipment will withstand wind forces identified in "Performance Requirements" Article and in Section 23 0550 "Vibration Isolation."

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.

E. Furnish fan performance ratings and fan curves with specified operating point clearly plotted.

F. Furnish drawings indicating unit dimensions, required clearances, field connection locations, wiring diagrams, shipping drawings, and curb drawings.

G. Furnish performance report showing unit level performance data including: fan(s), motor(s), coil(s) and other functional components. Performance report shall also include unit casing performance.

H. Furnish operation and maintenance data, including instructions for lubrication, filter replacement, motor and drive replacement, and condensate pan cleaning; spare parts lists, and wiring diagrams.

I. Adjust and report performance ratings for the proper altitude of operation.

J. Report air-handling unit performance ratings in accordance with ANSI/AHRI-430 (static pressure, airflow, fan speed, and fan brake horsepower).

K. Report static pressure profiles by component section.

L. Report coil ratings in accordance with AHRI-410 (capacities and pressure drops).

M. Report unweighted octave band AHU sound power for inlets and outlets rated in accordance with AHRI Standard 260. Provide eight data points, the first for the octave centered at 63 Hz, and the eighth centered at 8,000 Hz. Manufacturer shall not use sound estimates based on bare fan data (AMCA ratings), nor use calculations like the substitution method based on AHRI 260 tests of other AHU products. Provide data for inlets and outlets as scheduled. Report unweighted casing radiated sound power over the same 8 octave bands in accordance with ISO 9614 Parts 1&2 and ANSI S12.12.

N. Airflow measuring device performance shall be certified and rated in accordance with AMCA-611. Report data in accordance with AMCA-611. Provide AMCA Certified Rating Seal for Airflow Measurement Performance.

O. Report panel deflection at +/-8 w.g., stated in terms of 'L/X' where 'L' is the casing panel length and 'X' is a constant provided by the AHU manufacturer.

P. Report casing leakage rate at +/-8" w .g., specified in terms of percentage of design airflow.

Q. Report weight loads and distributions by component section.

R. Report product data for filter media, filter performance data, filter assembly, and filter frames.

S. Report electrical requirements for power supply wiring including wiring diagrams for interlock and control wiring, clearly indicating factory-installed and field-installed wiring.

T. Report motor electrical characteristics.

U. Operation and Maintenance Data: For units to include in emergency, operation, and maintenance manuals.

V. Northwestern University Maintenance Requirement Forms, see Division 01.

1.9 DELIVERY, STORAGE AND HANDLING

A. Comply with ASHRAE 62, Section 5 (mold and corrosion resistant casings, filters upstream of wetted surfaces, and drain pan design).

B. Comply with ASHRAE 62, Section 7 (practices to be followed during construction and startup). Protect equipment from moisture by appropriate in-transit and on-site procedures.

C. Follow manufacturer's recommendations for handling, unloading and storage.

D. Protect, pack, and secure loose-shipped items within the air-handling units. Include detailed packing list of loose-shipped items, including illustrations and instructions for application.

E. Protect, pack and secure controls devices, motor control devices and other electronic equipment. Do not store electronic equipment in wet or damp areas even when they are sealed and secured.

F. Enclose and protect control panels, electronic, and variable frequency drives. Do not store equipment in wet or damp areas even when they are sealed and secured.

G. Seal openings to protect against damage during shipping, handling and storage.

H. Wrap indoor units with a tight sealing membrane. Wrapping membrane shall cover entire AHU during shipping and storage. Cover equipment, regardless of size or shape. Alternatively AHU must be tarped for shipment and storage.

I. Wrap equipment, including electrical components, for protection against rain, snow, wind, dirt, sun fading, road salt/chemicals, rust and corrosion. Keep equipment clean and dry.

J. Tarp outdoor units to protect against rain and road debris during shipping.

K. Clearly mark AHU sections with unit tag number, segment sequence number, and direction of airflow. Securely affix safety-warning labels.

1.10 EXTRA MATERIALS

A. Provide one set of filters for balancing, and one additional set for final turnover to owner.

B. Provide one extra set of fan belts, in addition to the factory-installed set.

1.11 SPECIAL WARRANTY

A. Five (5) years, see Division 01.

1.12 SYSTEM STARTUP

A. Do not operate units for any purpose, temporary or permanent, until ductwork is clean, filters are in place, bearings lubricated, and fan has been test run under observation.

B. Comply with manufacturer's start-up requirements to ensure safe and correct operation and integrity of warranty.

PART 2 - PRODUCTS

2.1 ACCEPTABLE MANUFACTURERS

A. Basis-of-Design Product: Subject to compliance with requirements, provide product indicated on schedule as JCI/York Solutions, or comparable product by one of the following:

1. Buffalo Air Handling.
2. Daikin.
3. HuntAir.
4. Temtrol.
5. Airflow Equipment.

2.2 GENERAL DESCRIPTION/REQUIREMENTS

A. Air-handling units are to be designed and built to meet the performance detailed in this submittal and as called for on the drawings.

B. Units will be complete with fans, motors, motor controls, coils, dampers, access doors and other components/options, as shown on product drawings, wiring diagrams, and as described in performance specifications.

C. Fans and drives will be balanced to limit vibration at operating speeds.

D. Unit will ship in one (1) piece whenever possible. Shipping splits will be provided when necessary. Lifting lugs will be provided where required for proper lifting.

E. Unit casing and frame will be factory insulated.

F. Units will be ETL labeled.

2.3 UNIT CASING

A. Unit shall be specifically designed for specific indoor or outdoor application.

B. Unit casing will consist of a structural frame with insulated roof, wall, and floor panels, with panels fabricated from minimum 16 gauge, G-90, galvanized steel. Construction shall be bolted standing seam type.

C. Removal of wall panels will not affect structural integrity of units.

D. Unit casing will be insulated with spray injected foam to achieve thermal resistance of minimum of R13 hr-ft2-°F/BTU. Insulation application will meet the requirements of NFPA 90A.

E. Unit base shall be minimum 2.5" welded structural steel channel construction with full walk-on G-90 galvanized steel floors in all sections. No paint is permitted.

F. Unit will conform to ASHRAE Standard 111 Class 6 for casing leakage no more than 1% of design airflow at 1.25 times design static pressure up to a maximum of +8 inches w.g. in positive pressure sections and -8 inches w.g. in negative pressure sections.

G. Wall panels and access doors will deflect no more than L/240 when subjected to 1.5 times design static pressure up to a maximum of +8 inches w.g. in positive pressure sections and -8 inches w.g. in negative pressure sections. ‘L’ is the panel-span length and ‘L/240’ is the deflection at panel midpoint.

H. Access sections shall be 24" minimum and shall have access doors on both sides.

I. Unit will have double wall, 2” insulated panels for walls, roof, and floor. Exterior skin will be galvanized sheet steel as described above. Individual segments will have galvanized solid sheet steel interior liner except for fan sections, which shall be perforated.

1. Panels with perforated liners will have 1” of minimum 3 lb/ft.3 fiberglass board insulation, faced to prevent fiber erosion, and 1” of foam insulation. Exterior skin will be galvanized sheet steel. Interior liner will be perforated galvanized. Minimum perforated panel thermal resistance will be R11 hr-ft2-°F/BTU.

J. For outdoor units, roofs will be double-sloped with a longitudinal peak and a minimum pitch of 1/4” per foot.

1. Roof snow-loads capacity will be at least 50 lb/ft2.
2. Roof overhangs unit perimeter by 1-1/2”.

K. Floor panels will be double wall construction, designed to provide at most L/240 deflection when subjected to a 300 lb. load at mid-span.

L. Double wall access doors will be provided on sections as shown on product drawings.

1. Stainless steel hinges permit a 180° door swing.
2. Access door will be of the same material type as exterior/interior casing.
3. Access door latches will use a roller cam latching mechanism.

M. View ports will be single pane Plexiglas.

N. Drain pans will comply with the guidelines of ASHRAE 62, and are to be minimum 16 gauge, Type 304 stainless steel.

1. Drain pans will be double sloped at least 1/8” per foot, and have no horizontal surfaces.
2. Drain connection material will be the same as drain pan.
3. Drain pans will drain to one point and to be insulated double bottom type.
4. Drain connections will be welded to drain pans
5. Drain pans will have at least 1” clearance between pan and coil supports.

O. Optional pipe chases will be furnished, as shown on drawings.

1. Pipe chases will be constructed in the same manner as units.
2. Pipe chase doors will be provided, as shown on drawings.
3. Pipe chases will have the same base rail options as units.

2.4 FANS

A. Refer to Section 23 3400 "Fans."

1. Blank off Panels — Each Multiple Fan section to be provided with one fan blank-off panel to enable manual isolation of fan for servicing.
2. Fan Options — The following options will be available for multiple fans:

a. Piezometer Ring: Airflow station will be factory installed in each fan inlet. Tubing will be manifolded so that the measurement is representative of all fans in the array. The device will have a measurement accuracy of ± 5%.
b. Backdraft Damper: Backdraft dampers will be available for automatic isolation of individual fans.

2.5 ELECTRICAL MOTORS

A. Refer to Section 23 0513 "Motors."

2.6 FAN MOTOR DISCONNECTS

A. Fan motor disconnects will be provided with unit, as shown in performance specifications.

B. Disconnect will be housed in a NEMA 3R enclosure, and will be mounted on the primary access side of segment.

C. Disconnect will be suitable for use as an OSHA lockout/tagout disconnect when applied in accordance with part IV, Department of Labor OSHA 29 CFR Part 1910, Control of Hazardous Energy Source (lockout/tagout): Final Rule.

D. Disconnect handles can be padlocked in the “off” position with up to three padlocks. Switch mechanism can be directly padlocked in the “off” position when door is open.

E. Disconnects will be provided with an integral ground lug.

1. 16A to 100A disconnects will have two (2) #14 ground wires.
2. 200A to 400A disconnects will have one (1) #6-250 ground wire.

2.7 ACROSS-THE-LINE FAN MOTOR STARTERS

A. Constant speed motor starters will be furnished (shipped loose) or provided (factory mounted and wired to motor) with units, as shown in submittal documents.

B. For outdoor units, motor starters will be housed in a dedicated, weather resistant compartment.

1. Shipped loose starters and starters provided on units without single point power will be housed in a NEMA 3R enclosure.
2. Weatherproof compartments will be provided on units with single point power.

C. Motor starter panels will include:

1. Main power block
2. Motor contactor(s)
3. Individual short circuit and overload protection
4. 120 volt control power transformer with primary and secondary protection
5. 5 point terminal strip for field connections
6. Main power disconnect
7. Hand-Off-Auto switch

2.8 FAN VARIABLE FREQUENCY DRIVES

A. Refer to Section 23 0514 "Variable Frequency Drives (VFD)."

B. Variable frequency drives will be furnished (shipped loose) or provided (factory mounted and wired to motor) with units, as shown in submittal documents.

C. For outdoor units, VFDs will be housed in a dedicated, weather resistant compartment.

1. Shipped loose VFDs and VFDs provided on units without single point power will be housed in a NEMA 3R enclosure.
2. Weatherproof compartments will be provided on units with single point power.

D. VFDs furnished or provided with units will be programmed and started by a drive factory authorized and trained technician.

2.9 HEATING AND COOLING COILS

A. Refer to Section 23 8216 "Coils."

B. Cooling coil segments will have a full-width IAQ drain pan that extends at least 6” downstream of the last coil in the section.

C. Coils will be removable from the side of unit, via removable AHU panels. No more than one panel must be removed to remove a coil.

D. Coils will have frames constructed of galvanized steel. Casing channels will be free-draining and do not block fin area.

E. Cooling coils with finned height greater than 48” will have an intermediate drain pan with downspout to drain condensate to main drain pan. Intermediate drain pan material will match coil frame material.

F. Coil segment door clearances will allow for at least 2-inches of field installed piping insulation.

G. Coil bulkheads and blank-offs will prevent air from bypassing coils.

H. Coil segment casing to accommodate full-face or reduced-face coils will be provided. Provide face and bypass coil segments with factory installed bypass damper

I. Coil connections will be extended through unit casing.

J. Water and glycol coils will have a 1/4" FPT plugged vent or drain tap on each connection that is accessible from outside the unit.

K. Spool shaped coil grommets will be provided to insulate and seal coil penetrations.

2.10 FILTERS

A. Refer to Section 23 4114 "Filters."

B. Filter segments will be provided, as shown on product drawings. Filter tracks/frames will be an integral part of the unit.

C. Filter types, nominal sizes, efficiencies, and performance characteristics will be as shown in drawing schedules.

D. Filter access will be provided via access doors on filter segments or adjacent segments as required by filter loading scheme. See product drawings for details.

E. Performance of installed HEPA filtration systems is certified via a DOP test and classified as UL Class 1 when tested in accordance with UL Standard 586.

F. Flush mounted, factory installed differential pressure gauge on the drive side of unit to measure pressure drop across filters will be provided

2.11 DAMPERS

A. Refer to Section 23 3314 if smoke dampers are required, Section 23 3314 if isolation dampers are required, or Division 25 if control dampers are required.

B. Dampers will be factory installed.

C. Dampers will have airfoil blades with extruded vinyl edge seals and flexible metal compressible jamb seals.

D. Dampers will have a maximum leakage rate of 4 CFM/square foot at 1" w.g. and comply with ASHRAE 90.1.

E. Maximum damper torque requirement will be 7 in. lbs./ft^2.

F. Damper blades will be parallel acting unless submitted otherwise.

G. Damper blades will be galvanized steel or aluminum.

2.12 AIR FLOW MONITORING STATIONS

A. Optional airflow monitoring stations will be provided on air inlets, as shown in performance specifications.

B. Airflow monitoring stations will bear the AMCA Certified Ratings Seal for Airflow Measurement Performance.

C. Airflow monitoring station dampers will comply with leakage rates per ASHRAE 90.1.

D. Airflow monitoring stations will be accurate within 5% of actual airflow between 350 FPM and 4000 FPM free area velocity.

E. Outdoor air intake openings with air flow monitoring stations will have rain louver.

1. Louver will be a wind-driven rain penetration class A louver.
2. Louver effectiveness ratio will be 100% at the following conditions:

a. Wind velocity, 29 mph into louver.
b. Rain fall rate, 3 in./hr.
c. Free area air velocity, 1500 FPM.

2.13 DIFFUSERS

A. Diffuser segments will be provided, as shown on product drawings.

B. Perforated steel diffuser plates will be installed between fans and downstream components when required to ensure proper velocity profiles across downstream components.

2.14 ROOF CURBS

A. Roof curbs for roof mounted units will be furnished, as shown on product drawings.

B. Roof curbs will be galvanized steel and support the perimeter of units, including pipe chases.

C. Roof curbs will have a wood nailing strip.

D. Roof curbs will be shipped loose for installation prior to unit installation.

2.15 APPURTENANCES

A. Safety grates capable of supporting a 300 lb. center load will be provided over bottom openings, as scheduled.

B. Formed ***[Welded structural]*** steel base rails suitable for rigging and lifting will be provided, as shown on product drawings.

C. Lifting lugs will be provided where required for proper lifting.

2.16 FINISHES

A. External unit surfaces will be factory cleaned prior to finishing or shipping.

B. Unpainted air-handling units constructed of galvanized steel will pass the ASTM B-117 test for 220-hour salt spray solution (5%) without any sign of red rust.

2.17 HUMIDIFIERS

A. Refer to Section 23 8413 Humidification Equipment.

2.18 TESTS AND INSPECTIONS

A. Fan skid(s) will be run-balanced at specified speed to insure smooth, operation.

1. Constant volume fan assemblies will be balanced at design RPM.
2. Variable volume fan assemblies will be balanced from 10% to 100% of design RPM.
3. Filter-in measurements will be taken in horizontal and vertical axes on drive and opposite-drive sides of fan shafts.
4. Constant speed fan vibration limits: filter-in measurements will not exceed 4 mils.
5. Variable speed fan vibration limits: filter -in measurements will not exceed 7 mils.

B. Unit wiring with voltage greater than 30VAC will be hipot tested prior to shipping.

2.19 OTHER UNIT FEATURES/REQUIREMENTS:

A. Provide all required framing, safing, supports, etc., for all components to be installed in the unit, including (but not limited to): Fans, dampers. coils, piping, humidifier grids, attenuators, heat exchangers, etc.

B. Stainless steel coil raising structures inside unit if required for proper cooling coil drain trapping and/or steam condensate trapping/drainage.

C. Humidifier control valves, strainers and valves shall be outside the airstream.

D. Do not locate humidifiers upstream of fan sections. The preferred location for humidifier sections are downstream of the fans.

E. Humidifiers shall be located 18" downstream of heating coils and a minimum of 3' upstream of cooling coils.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Install equipment per industry standards, applicable codes, and manufacturer's instructions.

B. Do not use AHU's for temporary heating, cooling or ventilation prior to complete inspection and startup performed per this specification.

C. Install AHU's on a concrete pad, roof curb, or structural steel base, as shown on drawings.

D. Install AHU's with manufacturer's recommended clearances for access, coil pull, and fan removal.

E. Provide one complete set of filters for testing, balancing, and commissioning. Provide second complete set of filters at time of transfer to owner.

F. Install AHU's plumb and level. Connect piping and ductwork according to manufacturer's instructions.

G. Install pipe chases per manufacturer's instructions.

H. Insulate plumbing associated with drain pan drains and connections.

I. Install insulation on all staggered coil piping connections, both internal and external to the unit.

3.2 FIELD QUALITY CONTROL

A. Store per AHU manufacturer's written recommendations. Store AHUs indoors in a warm, clean, dry place where units will be protected from weather, construction traffic, dirt, dust, water and moisture. If units will be stored for more than 6 months, follow manufacturer's instruction for long-term storage.

B. Rig and lift units according manufacturer's instructions.

3.3 AHU INSPECTION

A. Hire manufacturer's factory-trained and factory-employed service technician to perform an inspection of unit and installation prior to startup. Technician shall inspect and verify the following as a minimum:

1. Damage of any kind
2. Level installation of unit
3. Proper reassembly and sealing of unit segments at shipping splits.
4. Tight seal around perimeter of unit at the roof curb
5. Installation of shipped-loose parts, including filters, air hoods, bird screens and mist eliminators.
6. Completion and tightness of electrical, ductwork and piping
7. Tight seals around wiring, conduit and piping penetrations through AHU casing.
8. Supply of electricity from the building's permanent source
9. Integrity of condensate trap for positive or negative pressure operation
10. Condensate traps charged with water

11. Removal of shipping bolts and shipping restraints
12. Sealing of pipe chase floor(s) at penetration locations.
13. Tightness and full motion range of damper linkages (operate manually)
14. Complete installation of control system including end devices and wiring
15. Cleanliness of AHU interior and connecting ductwork
16. Proper service and access clearances
17. Proper installation of filters
18. Filter gauge set to zero

B. Resolve any non-compliant items prior to unit start-up.

3.4 INSPECTION AND ADJUSTMENT: AHU FAN ASSEMBLY

A. Hire the manufacturer’s factory-trained and factory-employed service technician perform an inspection of the AHU fan assembly subsequent to general AHU inspection and prior to startup. Technician shall inspect and verify the following as a minimum:

1. Fan isolation base and thrust restraint alignment
2. Tight set screws on pulleys, bearings and fan
3. Tight fan bearing bolts
4. Tight fan and motor sheaves
5. Tight motor base and mounting bolts
6. Blower wheel tight and aligned to fan shaft
7. Sheave alignment and belt tension
8. Fan discharge alignment with discharge opening
9. Fan bearing lubrication
10. Free rotation of moving components (rotate manually)

3.5 STARTUP SERVICE and OWNER TRAINING

A. Manufacturer’s factory-trained and factory-employed service technician shall startup AHUs. Technician shall perform the following steps as a minimum:

1. Energize the unit disconnect switch
2. Verify correct voltage, phases and cycles
3. Energize fan motor briefly (“bump”) and verify correct direction of rotation.
4. Re-check damper operation; verify that unit cannot and will not operate with all dampers in the closed position.
5. Energize fan motors and verify that motor FLA is within manufacturer’s tolerance of nameplate FLA for each phase.

B. Provide a minimum of 8 hours of training for owner’s personnel by manufacturer’s factory-trained and factory-employed service technician. Training shall include AHU controls, motor starters, VFD's, and AHU's.

C. Training shall include startup and shutdown procedures as well as regular operation and maintenance requirements.

D. If AHU is provided with a factory-mounted variable frequency drive (VFD), hire the VFD manufacturer’s factory-trained and factory-employed service technician to inspect, test, adjust, program and start the VFD. Ensure that critical resonant frequencies are programmed as ‘skip frequencies’ in the VFD controller.

E. Submit a startup report summarizing any problems found and remedies performed.

3.6 FIELD PERFORMANCE VERIFICATION

A. Leakage: Pressurize casing to maximum operating static pressure (up to +/-8” w.g.) and measure leakage. If leakage exceeds 1% of design airflow, seal leakage points with a permanent solution. Repeat test. If the AHU still does not pass, contact the manufacturer to seal unit.

B. Submit a field test report with testing data recorded. Include description of corrective actions taken.

3.7 CLEANING

A. Clean unit interior prior to operating. Remove tools, debris, dust and dirt.

B. Clean exterior prior to transfer to owner.

3.8 DOCUMENTATION

A. Provide Installation Instruction Manual, & Startup checklist in the supply fan section of each unit.

B. Provide six copies of Spare Parts Manual for owner’s project system manual.

END OF SECTION 23 7323

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SECTION 23 7323 - FACTORY FABRICATED CUSTOM AIR HANDLING UNITS

PART 1 - GENERAL

1.1 SECTION INCLUDES

A. Indoor and outdoor air handling units and components as scheduled and shown on drawings.

B. Motor disconnects, motor starters, and variable frequency drives.

C. Other required features.

1.2 RELATED DOCUMENTS

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

1.3 REFERENCES

A. AMCA 99 – Standard Handbook

B. AMCA 210 – Laboratory Methods of Testing Fans for Rating Purposes

C. AMCA 500 – Test Methods for Louvers, Dampers, and Shutters

D. AMCA 611-95 – Methods of Testing Airflow Measurement Stations for Rating

E. ANSI/AFBMA 9 – Load Ratings and Fatigue Life for Ball Bearings

F. ANSI/UL 900 – Test Performance of Air Filter Units

G. AHRI 260 – Sound Rating of Ducted Air Moving and Conditioning Equipment

H. AHRI 410 – Forced-Circulation Air Cooling and Air Heating Coils

I. ANSI/AHRI 430 – Performance Rating of Central-Station Air Handling Units

J. ASHRAE 52.1/52.2 – Method of Testing General Ventilation Air Cleaning Devices for Removal Efficiency by Particle Size

K. ASHRAE 62 – Ventilation for Acceptable Indoor Air Quality

L. ASHRAE 90.1 – Energy Standard for Buildings Except Low-Rise Residential Buildings

M. ASTM-C 1338 – Standard Test Method for Determining Fungi Resistance of Insulation Material and Facings.

N. NFPA 70 – National Electric Code (conductors, equipment and raceways)

O. NFPA 90A – Installation of Air Conditioning and Ventilation Systems

P. SMACNA – HVAC Duct Construction Standards

Q. UL-181 – Mold Growth and Humidity Test

R. UL-1995 – Standard for Safety for Heating and Cooling Equipment

1.4 QUALITY ASSURANCE

A. Manufacturer shall have a minimum of 25 years of experience in designing, manufacturing, and servicing air-handling units.

B. The design indicated on the schedules and shown on the drawings is based upon the products of the named manufacturer. Alternate equipment manufacturers are acceptable if equipment meets scheduled performance requirements and dimensional requirements.

C. ARI Compliance:

1. Comply with ARI 203/110 and ARI 303/110 for testing and rating energy efficiencies for RTUs.
2. Comply with ARI 270 for testing and rating sound performance for RTUs.

D. ASHRAE Compliance:

1. Comply with applicable requirements in ASHRAE 62.1, Section 5 - "Systems and Equipment" and Section 7 - "Construction and Startup."

E. ASHRAE/IESNA 90.1 Compliance: Applicable requirements in ASHRAE/IESNA 90.1, Section 6 - "Heating, Ventilating, and Air-Conditioning."

F. NFPA Compliance: Comply with NFPA 90A and NFPA 90B.

G. UL Compliance: Comply with UL 1995.

H. 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.

I. Comply with FM Global requirements for fans and blowers, motors and VFD's, and for monitoring and diagnosis of vibration in rotating machinery.

1.5 COORDINATION

A. If equipment is supplied by a manufacturer other than the one named, coordinate with the General Contractor and affected subcontractors to ensure the specified performance is met. This coordination shall include (but is not limited to) the following:

1. Structural supports for units.
2. Size and location of concrete bases/housekeeping pads
3. Location of roof curbs, unit supports and roof penetrations
4. Ductwork sizes and connection locations
5. Piping size and connection/header locations

6. Interference with existing or planned ductwork, piping and wiring
7. Electrical power requirements and wire/conduit and over current protection sizes.
8. Trap height requirements

B. The Mechanical Contractor shall be responsible for costs incurred by the General Contractor, Subcontractors, and Consulting Engineers to accommodate units furnished by a manufacturer other than manufacturer named as basis of design.

1.6 RATINGS AND CERTIFICATIONS

A. Air Handling Unit safety: ETL or UL 1995

B. Air Handling Unit energy use: ASHRAE 90.1

C. Fans: AMCA 210

D. Air Coils: AHRI 410

E. Air Handling Unit certification program: ANSI/AHRI 430

F. Filter media: ANSI/UL 900 listed Class I or Class II

G. Control wiring: NEC codes & ETL requirements

H. Motors: Federally mandated Energy Policy Act (EPACT).

I. Airflow Monitoring Stations: AMCA 611-95

1.7 PERFORMANCE REQUIREMENTS

A. Delegated Design: Design RTU supports to comply with project wind performance requirements, including comprehensive engineering analysis by a qualified professional engineer, using performance requirements and design criteria indicated.

1. Wind-Restraint Performance:

a. Basic Wind Speed: <Insert value>.
b. Building Classification Category: [I] [II] [III] [IV].
c. Minimum XX 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.

1.8 SUBMITTAL DOCUMENTATION REQUIRED

A. [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."]

B. 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 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-Restraint Details: Detail fabrication and attachment of wind restraints and snubbers. Show anchorage details and indicate quantity, diameter, and depth of penetration of anchors.

C. 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.

D. Manufacturer Wind Loading Qualification Certification: Submit certification that specified equipment will withstand wind forces identified in "Performance Requirements" Article and in Section 23 0550 "Vibration Isolation."

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.

E. Furnish fan performance ratings and fan curves with specified operating point clearly plotted.

F. Furnish drawings indicating unit dimensions, required clearances, field connection locations, wiring diagrams, shipping drawings, and curb drawings.

G. Furnish performance report showing unit level performance data including: fan(s), motor(s), coil(s) and other functional components. Performance report shall also include unit casing performance.

H. Furnish operation and maintenance data, including instructions for lubrication, filter replacement, motor and drive replacement, and condensate pan cleaning; spare parts lists, and wiring diagrams.

I. Adjust and report performance ratings for the proper altitude of operation.

J. Report air-handling unit performance ratings in accordance with ANSI/AHRI-430 (static pressure, airflow, fan speed, and fan brake horsepower).

K. Report static pressure profiles by component section.

L. Report coil ratings in accordance with AHRI-410 (capacities and pressure drops).

M. Report unweighted octave band AHU sound power for inlets and outlets rated in accordance with AHRI Standard 260. Provide eight data points, the first for the octave centered at 63 Hz, and the eighth centered at 8,000 Hz. Manufacturer shall not use sound estimates based on bare fan data (AMCA ratings), nor use calculations like the substitution method based on AHRI 260 tests of other AHU products. Provide data for inlets and outlets as scheduled. Report unweighted casing radiated sound power over the same 8 octave bands in accordance with ISO 9614 Parts 1&2 and ANSI S12.12.

N. Airflow measuring device performance shall be certified and rated in accordance with AMCA-611. Report data in accordance with AMCA-611. Provide AMCA Certified Rating Seal for Airflow Measurement Performance.

O. Report panel deflection at **+/-10” [12”] w.g.**, stated in terms of ‘L/X’ where ‘L’ is the casing panel length and ‘X’ is a constant provided by the AHU manufacturer.

P. Report casing leakage rate at ***+/-10” [12”] w.g.***, specified in terms of percentage of design airflow.

Q. Report weight loads and distributions by component section.

R. Report product data for filter media, filter performance data, filter assembly, and filter frames.

S. Report electrical requirements for power supply wiring including wiring diagrams for interlock and control wiring, clearly indicating factory-installed and field-installed wiring.

T. Report motor electrical characteristics.

U. Operation and Maintenance Data: For RTUs to include in emergency, operation, and maintenance manuals.

V. List of items for project turnover to the University, when they received same, and University sign-off.

W. Northwestern University Maintenance Requirement Forms, see Division 01.

1.9 DELIVERY, STORAGE AND HANDLING

A. Comply with ASHRAE 62, Section 5 (mold and corrosion resistant casings, filters upstream of wetted surfaces, and drain pan design).

B. Comply with ASHRAE 62, Section 7 (practices to be followed during construction and startup). Protect equipment from moisture by appropriate in-transit and on-site procedures.

C. Follow manufacturer’s recommendations for handling, unloading and storage.

D. Protect, pack, and secure loose-shipped items within the air-handling units. Include detailed packing list of loose-shipped items, including illustrations and instructions for application.

E. Protect, pack and secure controls devices, motor control devices and other electronic equipment. Do not store electronic equipment in wet or damp areas even when they are sealed and secured.

F. Enclose and protect control panels, electronic or pneumatic devices, and variable frequency drives. Do not store equipment in wet or damp areas even when they are sealed and secured.

G. Seal openings to protect against damage during shipping, handling and storage.

H. Wrap indoor units with a tight sealing membrane. Wrapping membrane shall cover entire AHU during shipping and storage. Cover equipment, regardless of size or shape. Alternatively AHU must be tarped for shipment and storage.

I. Wrap equipment, including electrical components, for protection against rain, snow, wind, dirt, sun fading, road salt/chemicals, rust and corrosion. Keep equipment clean and dry.

J. Tarp outdoor units to protect against rain and road debris during shipping.

K. Clearly mark AHU sections with unit tag number, segment sequence number, and direction of airflow. Securely affix safety-warning labels.

1.10 EXTRA MATERIALS

A. Provide one set of filters for balancing, and one additional set for final turnover to owner.

B. Provide one extra set of belts, in addition to the factory-installed set.

1.11 WARRANTY

A. Provide warranty for 5 years from date of turnover to the Owner at substantial completion, see Division 01. Warranty shall cover manufacturer defects. Warranty work shall be performed by manufacturer’s factory-trained and factory- employed technician.

B. Include factory-provided controls in the parts warranties.

C. Parts associated with routine maintenance, such as belts and air filters shall be excluded.

1.12 SYSTEM STARTUP

A. Do not operate units for any purpose, temporary or permanent, until ductwork is clean, filters are in place, bearings lubricated, and fan has been test run under observation.

B. Comply with manufacturer’s start-up requirements to ensure safe and correct operation and integrity of warranty.

PART 2 - PRODUCTS

2.1 ACCEPTABLE MANUFACTURERS

A. Basis-of-Design Product: Subject to compliance with requirements, provide product indicated on schedule as **YORK Custom, div. of Johnson Controls Inc.** or comparable product by one of the following:

1. Buffalo Air Handling.
2. Governaire Corp.
3. HuntAir.
4. TMI.

5. Trane Custom TCFS, div of Ingersoll Rand Inc.

2.2 GENERAL UNIT REQUIREMENTS

A. Coils shall be arranged so that space between the coils is a minimum of 24".

B. Fan compartments shall be arranged such that the space between the fan inlets and the housing is a minimum of one fan diameter.

C. Arrangement of components shall be such that coil face velocity distribution shall not vary by more than 20% from the average coil velocity.

D. Coil assemblies shall have provisions to facilitate total or partial removal from coil bank. Removal panels shall be provided on both sides of the unit.

E. Multiple coil banks shall have coils independently supported.

F. Outdoor and return air mixing sections shall be arranged to minimize stratification.

2.3 UNIT CASINGS

A. Unit Casing Performance

1. Leakage shall be no more than 1/2% of rated unit CFM at +/- 10” static pressure. Manufacturer shall perform a factory leakage test on at least one unit. Customer shall select which unit to test. Perform test at 10” static pressure. If unit fails at the factory, manufacturer shall seal and retest unit until it meets specified performance.
2. Deflection shall be no more than L/240 of panel length at +/- 10” static pressure. Manufacturer shall perform a factory deflection test on at least one unit. Customer shall select which unit to test. Measure deflection on the largest wall panel. Perform test at 10” static pressure. If unit fails, manufacturer shall add structural support required to achieve specified performance.
3. Thermal performance:

a. Unit wall shall not sweat with interior air temperature of XX°F and exterior air at XX/XX db/wb
b. R-value of wall shall be R-13[R19] [R25] at the center of panel.

B. 4” foam injected thermal break (thermal breaks in cooling coil sections and downstream from same) in walls: Construct walls with interior and exterior sheet metal surfaces, welded internal post structure, and 4’ of injected foam insulation. Foam board or fiberglass insulation is not acceptable.

1. Interior Liner:

a. Galvanized Steel, G90 shall be 22 ga [20 ga, 18 ga].
b. Stainless Steel, 304 shall be 20 ga [18 ga, 16 ga].
c. Stainless Steel, 316L shall be 22 ga.
d. Pre-painted galvanized steel shall be 18 ga [16 ga].
e. Aluminum, 3003 shall be 0.05” thick (0.05” thickness is equivalent to 16 ga. Aluminum).
f. For fan sections, liner to be perforated with stand-offs for insulation liner and minimum 1 mil Tedlar liner

2. Exterior surface

   a. Galvanized Steel, G90 shall be 20 ga [18 ga, 16 ga, 14 ga].
   b. Stainless Steel, 304 shall be 20 ga [18 ga, 16 ga].
   c. Stainless Steel, 316L shall be 16 ga.
   d. Pre-painted galvanized steel shall be 18 ga [16 ga].
   e. Aluminum, 3003 shall be 0.04" thick, textured (0.04" thickness is equivalent to 18 ga. Aluminum).

3. Internal Post Structure: Formed galvanized 16 ga steel C-channel. Structure shall be fully welded. Post spacing shall be designed to provide L/240 wall deflection at +/- 10"
4. w.g. Maximum post spacing shall be 24" on centers.
5. Fasteners

   a. Exterior Fasteners

      1) For outdoor units, units with stainless steel or aluminum exterior walls use self-tapping series 400 stainless steel sheet metal screws to fasten exterior sheet metal walls to post frame structure on 18" centers
      2) For indoor units use self-tapping rust inhibited sheet metal screws to fasten exterior sheet metal walls to post frame structure on 18" centers.

   b. Interior Fasteners

      1) For Galvanized interior liner: use self-tapping rust inhibited sheet metal screws to fasten interior and exterior sheet metal walls to post frame structure on 27" centers.
      2) For Stainless steel or aluminum interior liner: use self-tapping series 400 stainless steel sheet metal screws to fasten exterior sheet metal walls to post frame structure on 27" centers

6. Casing Joints: Joints shall be mechanically fastened. Fasteners shall not extend from the outside to the inside of the unit. Use angle to fasten and seal walls at corners, floors, and roofs.
7. Sealing: Seal joints with polyurethane water resistant sealant, no additional coating.
8. Mill finish for galvanized steel casings: Immediately after cleaning and pre-treating, apply manufacturer's standard two-coat, baked-on enamel finish, consisting of polyurethane prime coat and polyester thermosetting topcoat. Coating shall pass ASTM B-117 1,000 hour salt spray test. Color shall be manufacturer's standard champagne.
9. Factory applied high build (3 to 5 mils) alkyd enamel. Coating shall pass ASTM B-117 500 hour salt spray test. Color shall be manufacturer's standard champagne, or Architect shall specify color.
10. Factory applied single coat industrial 2-part epoxy shall be 3 – 4 mils and pass ASTM B- 117 3,500 hours salt spray test. Color shall be manufacturer's standard champagne, or Architect shall specify color.
11. Factory applied double coat industrial 2-part epoxy shall be 6 – 8 mils and pass ASTM B- 117 3,500 hours salt spray test. Color shall be manufacturer's standard champagne, or Architect shall specify color.
12. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1-2013.

C. Roofs

1. Construction of the roof shall be identical to the wall construction specified.
2. Unit roof for outdoor units are to be sloped a minimum pitch of ¼" per foot.
3. The roof shall overhang all side and end panels to prevent precipitation drainage from streaming down the unit wall panels. Gutter systems are not acceptable.
4. Roofs less than 12' wide shall be sloped to the non-door side of the unit; roofs 12' wide and wider shall be peaked in the center and sloped to both sides of the unit.
5. Roof construction shall accommodate a minimum snow-load of 30 lb/ft^2.
6. Roof shall be designed to hold a 300lb load for service and maintenance.
7. The roofing system shall consist of a white (or custom color) 100% acrylic elastomeric coating with "Mildewcide". Coating shall be a minimum 20 mils thick. Coating shall meet the following requirements:

    a. CRRC Solar Index Rating of 112 per ASTM E1980-01
    b. CRRC Initial Solar Reflectance of 0.89; 0.81 after 3 years
    c. CRRC Initial Thermal Emittance of 0.89; 0.87 after 3 years
    d. Fungi Resistance per ASTM G21 of zero growth

8. Outdoor roofs supplied with non-sloped roofs or standing seam roof systems are not acceptable.
9. For all outdoor roof duct connections provide a minimum 1.5" duct flange.

D. Casing Insulation and Adhesive:

1. Materials: ASTM C 1071, [**Type I**] [**Type II**].
2. Location and Application: Factory applied with adhesive and mechanical fasteners to the internal surface of section panels downstream from, and including, the cooling-coil section.

    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.

3. Location and Application: Encased between outside and inside casing.

E. Inspection and Access Panels and Access Doors:

1. Panel and Door Fabrication: Formed and reinforced, double-wall, 4-inch insulated panels of same material type and thickness as unit casing.
2. Inspection and Access Panels:

    a. Fasteners: Attached to unit casing with tek screws with EPDM washers on maximum 9-inch centers.
    b. Gasket: 3/4" wide x 1/8" thick PVC gasket applied around entire perimeters of panel frames ***[and the access opening]***.
    c. Construction: Factory shall provide double sided tape where liner is attached to internal supports.

3. Access Doors:

a. Frames: Type 6063-T6 aluminum extrusion, **[with thermal break for "no through metal" construction]**, welded at the corners and attached to the unit casing with **[plated, stainless steel]** hardware**.**

b. Hinges: A full height stainless-steel piano hinge with minimum two roller cam latches per door, operable from inside and outside**.** Rotating knife-edge or “paw” latches are not acceptable. **[Provide galvanized, Z-type safety latch for all outward opening access doors opening with unit pressure.]**

c. Handles: Glass fiber reinforced, UV rated, padlockable, nylon polyamide as manufactured by Allegis Corporation.

d. Gasket: EPDM-sponge, applied around entire perimeters of panel frames. [Provide one set of spare door gaskets for each access door.]

e. Viewports: Provide **[8”x8”, 12”x12”]**, **[single pane, thermal pane]** viewing window centered in each access door with wire-reinforced safety glass**.**

f. Test Ports: Ventlok No. 699 instrument test holes installed in door locations as required to measure pressure drops across unit.

g. Rain Lip: Provide rain lip of same material type as unit casing attached with tek screws above all access doors.

h. Interlock Switch: Provide Nema 3R, plunger type interlock switch mounted on doors as noted on submittal drawing.

F. Service Vestibule (recommended on outdoor units with at least six (6) ft. of interior clearance): Air handling unit(s) shall be provided with a service vestibule equivalent to the unit casing, having a minimum thermal conductivity R of 12 /hr-ft2-°F/BTU.

1. Service vestibule shall be a minimum six (6) ft. wide by full height and length of the unit.
2. Service vestibule floor construction shall be the same as the unit floor.
3. Selected access doors are provided as indicated in door section of this specification.
4. Selected lighting and outlets provided as indicated in the electrical section of this specification (if selected). Lights shall provide a minimum of 10 foot-candles of illumination per OSHA 1926.56(a) standards for mechanical equipment rooms.
5. ***Vestibule shall be provided with [208/240V 1-3Phase, 5KW or 480V 3Phase, 5KW] electric heater with integral thermostat set to maintain a minimum of 50 deg F. (if selected).***
6. ***Vestibule shall be provided with hot water unit heater with wall mounted thermostat set to maintain a minimum of 50 deg F. (if selected).***
7. Provide ventilation for removing heat of motor starters or other devices located within the vestibule.

G. Pipe-Chase:

1. Air handling unit(s) shall be provided with an external pipe-chase consisting of casing equivalent to the unit casing, having a minimum thermal conductivity R of 12 hr-ft2-°F/BTU.

a. Pipe-chase shall be ***[24”][36”][48”]*** to provide sufficient space for coil connections to be installed without interference.

b. [Loose-shipped pipe-chase enclosures shall be provided with lifting lugs for field installation (if any loose shipped).]

c. Pipe-chase shall be provided with ***[18”][24”][30”]*** doors. Doors shall be the same construction as the main unit doors. Door quantities shall match contract drawings.

d. Pipe chase floor construction shall be the same as that of the unit.

2. Air handling unit(s) shall be provided with a recessed pipe chase consisting of casing equivalent to the unit casing, having a minimum thermal conductivity R of 12 hr-ft2-°F/BTU. Pipe chase shall be flush with the unit exterior.

   a. Pipe-chase shall be **[24”][36”][48”]** to provide sufficient space for coil connections to be installed without interference.
   b. [Optional: Internal pipe chase shall be furnished with an additional **[24”][36”][48”]** external pipe chase extension.]
   c. Pipe-chase shall be provided with **[18”][24”][30”]** doors. Doors shall be the same construction as the main unit doors. Door quantities shall match contract drawings.
   d. Pipe chase floor construction shall be the same as that of the unit.

H. Floors:

1. Floor shall be 10 ga. hot rolled steel [stitch welded, caulked and sealed] [full seam welded] to the base.

   1) [Floor shall be 18 ga [10 ga., 12 ga., 14 ga., 16 ga.] G90 galvanized steel stitch welded, caulked and sealed to the base.]
   2) [Floor shall be [12 ga., 16 ga.], Type [304, 316L] stainless steel [stitch welded, caulked and sealed] [full seam welded] to the base.]
   3) [Floor shall be [0.125-in, 0.100-in] aluminum diamond plate [stitch welded, caulked and sealed] [full seam welded] to the base.]
   4) [Floor shall be [0.125-in, 14 ga.] hot rolled steel diamond plate [stitch welded, caulked and sealed] [full seam welded] to the base.]
   5) [Floor shall be 0.125-in, Type 304 stainless steel diamond plate [stitch welded, caulked and sealed] [full seam welded] to the base.]
   6) Floor shall be insulated with [2-inch, 3-inch, 4-inch] polyurethane spray foam insulation.

2. Floor shall be thermally isolated from welded base frame members (perimeter and internal supports). Construction without thermally isolated floor and walls shall not be acceptable.

   1) Floor shall have upturned lip with fully welded seams, and be capable of holding 2-inch of water. Penetrations through the floor shall not exist. Construction allowing screws or bolts to penetrate floor shall not be allowed. All floor openings shall have a fully welded 2” upturned lip.
   2) Each section shall be equipped with drain connection to facilitate washdown and maintenance. Drain connection shall be extended through the base and have a removable cap installed.
   3) All internal equipment shall be provided with a minimum 2-inch high base to raise equipment and components off the unit floor for housekeeping.

   b. Floor Paint:

   1) [Factory applied high build (3 to 5 mils) alkyd enamel. Coating shall pass ASTM B-117 500 hour salt spray test. Color shall be manufacturer’s standard champagne or as specified by Architect.]
   2) [Factory applied single coat industrial 2-part epoxy shall be 3 – 4 mils and pass ASTM B-117 3,500 hours salt spray test. Color shall be manufacturer’s standard champagne.]

3) ***[Factory applied double coat industrial 2-part epoxy shall be 6 – 8 mils and pass ASTM B-117 3,500 hours salt spray test. Color shall be manufacturer's standard champagne.]***

c. Subfloors:

1) ***[Subfloor shall be 0.05" Aluminum screwed to the base channel.]***
2) ***[Subfloor shall be [16 ga., 20 ga., 22 ga.] G90 Galvanized Steel screwed to the base channel.]***
3) ***[Subfloor shall be 20 ga. Type 304 Stainless Steel screwed to the base channel.]***

d. Floor Drains:

1) Factory shall provide 1-1/4" floor drain in segments where noted on the unit drawing.
2) Floor drain piping shall be **[Schedule 40 black steel, 304 stainless steel]** extended from the floor drain and terminated with a 1-1/4" MPT threaded connection to the exterior through the unit base.

e. Floor Openings:

1) Factory shall provide c-channel support around perimeter of all floor openings.
2) Factory shall provide **[galvanized steel, 304 stainless steel]** flattened expanded metal safety screen attached with screws over all floor openings.
3) Factory shall provide **[galvanized steel, 304 stainless steel, aluminum]** walk on grate attached with screws over all floor openings.

I. Baserails:

1. ***[Type ASTM A36 welded structural steel c-channel, [6-inch, 8-inch, 10-inch, 12-inch] height, with cross supports spaced at regular intervals and removable lifting lugs. Factory shall provide curb angle welded to the base for outdoor curb mounted units.] [Type 6061 T6 welded structural aluminum, [6-inch, 8-inch, 10-inch, 12-inch] height, with cross supports spaced at regular intervals and removable lifting lugs.]***
2. ***[Factory applied high build (3 to 5 mils) alkyd enamel. Coating shall pass ASTM B-117 500 hour salt spray test. Color shall be manufacturer's standard champagne or as specified by Architect.]***
3. ***[Factory applied single coat industrial 2-part epoxy shall be 3 – 4 mils and pass ASTM B- 117 3,500 hours salt spray test. Color shall be manufacturer's standard champagne.] [Factory applied double coat industrial 2-part epoxy shall be 6 – 8 mils and pass ASTM B-117 3,500 hours salt spray test. Color shall be manufacturer's standard champagne.]***

J. Fan Removal Beams: For any units with fans 4'-0" or higher, fan removal beams/devices shall be included in unit.

2.4 FAN ARRAYS (Also Refer to Section 23 3400 "Fans"):

A. Fan Arrays: Fan arrays shall consist of multiple direct-drive, arrangement 4, modular plenum fans selected to provide the scheduled airflow at the scheduled total static pressure. Fans shall be statically and dynamically balanced and designed for continuous operation at maximum- rated fan speed and motor horsepower. Fans shall have a sharply rising pressure characteristic extending through the operating range and continuing to rise beyond the peak efficiency to ensure quiet and stable operation. Fans shall have a non-overloading design with self-limiting horsepower characteristics and shall reach a peak in the normal selection area. All fans shall be capable of operating over the minimum pressure class limits as specified in AMCA's Standard 2408-69.

B. Internal Vibration Isolation: Refer to Section 23 0550.

C. Fan Options

1. Back-Draft Dampers: Each fan shall have an individual industrial grade low leak back-draft damper. Frame shall be minimum 9" deep x 2" (229 x 51) flanged 12 (2.8) gage galvanized steel channel. The blades shall be maximum 7" (178) wide, minimum .080 (2) thick, 6063T5 extruded aluminum airfoil shaped with integral structural reinforcing tube running full length of each blade. Damper blades shall be equipped with silicone rubber seals mechanically locked into extruded blade slots. Adhesive type seals are not acceptable. Adhesive type seals are not acceptable. Dampers shall be equipped with vinyl jamb seals for low leakage application. Wind stop type seals are not acceptable. Axles shall be minimum 3/4" (19) diameter with machined edge to provide positive locking connection to blades. Full round axles are not acceptable. Bearings shall be ball style pressed into frame. Linkage shall be minimum 3/16" thick 3/4" (5 x 19) bar located on face of blade in airstream. Submittal must include leakage, pressure drop, and maximum pressure data based on AMCA Publication 500 testing.
2. Airflow Measuring: Each fan shall include an Airflow Measuring System (AFMS) consisting of a piezometer ring mounted in the throat and a static pressure tap mounted on the face of the inlet cone. ***[A differential pressure transducer [and an analog display] shall be provided. Transducer shall have a field configurable 0-5 VDC or 0-10 VDC output, as well as a 4-20 mA output. Transducer shall have a standard accuracy of ±1% FS.]*** AFMS shall not obstruct the airflow in any way and shall have no effect on fan airflow performance, static pressure, or sound power levels.

2.5 MOTORS

A. All fan motors shall comply with NEMA and IEEE for temperature rating, service factor, enclosure type, and efficiency requirements for motors specified in Section 23 0513 "Motors."

2.6 COILS AND COIL DRAIN PANS

A. For coils, refer to Section 23 8216 "Coils" and meet requirements below

1. Cooling coil maximum face velocities at maximum design airflow to be 350 fpm.
2. Provide cooling coil drain pans that are sufficient to contain coil condensate. Drain pan shall be 16 ga. 304 Stainless steel **[16 ga. G-90 Steel][316L Stainless Steel]** construction and ex- tend a minimum of 6 **[12] [18]** inches downstream of leaving face of the coil to allow for condensate pan access and maintenance and meet requirements for ASHRAE 62-2007. IAQ drain pan must slope in 3 directions and have single 304 Stainless steel 1.5 **[2]** inch connection for trapping at jobsite. Pans to be insulated double wall.

3. Provide a minimum of 24 inches clearance between preheat and cooling coil banks and pro- vide access door as shown on drawings.
4. Locate access doors near coils connections to provide minimum clearance of 2 inches for field installed external piping insulation. Space shall allow a minimum of 90 degrees of door swing.
5. Provide coil segment casing that meets or exceeds casing thermal performance of the unit. Provide coil pull panel that are easily removable with no special tools. Coils shall be re- movable from the side of the AHU. **[For units with multiple stacked coils, provide a G-90 steel [304 stainless steel] [316L Stainless Steel] stacking rack to allow individual coils to be removed from side of AHU without disturbing any other coils]**.

2.7 AIR FILTRATION

A. Refer to Section 23 4114 "Filters".

B. General Requirements for Air Filtration Section:

1. Provide filter segments with filters and frames as scheduled, and per Section 23 4114 "Filters."

C. Filter Gages:

1. ***[3-1/2-inch- (90-mm-)] [2-inch- (50-mm-)]*** diameter, diaphragm-actuated dial in metal case.
2. Vent valves.
3. Black figures on white background.
4. Front recalibration adjustment.
5. ***[2] [3] percent of full-scale accuracy.***
6. ***Range: [0- to 0.5-inch wg (0 to 125 Pa)] [0- to 1.0-inch wg (0 to 250 Pa)] [0- to 2.0-inch wg (0 to 500 Pa)] [0- to 3.0-inch wg (0 to 750 Pa)] [0- to 4.0-inch wg (0 to 1000 Pa)].***
7. ***Accessories: Static-pressure tips with integral compression fittings, 1/4-inch (6-mm) [aluminum] [plastic] tubing, and 2- or 3-way vent valves.***

2.8 DAMPERS

A. ***Refer to Section XX XXXX if smoke dampers required, Section XX XXXX if isolation dampers required, and Division 25 if control dampers required.***

2.9 HUMIDIFIERS

A. Refer to Section 23 8413 "Humidification Equipment."

2.10 SOUND ATTENUATORS

A. If the required sound attenuation can be provided with integral fan housing attenuators, that is acceptable, but if not, see below.

B. Sound attenuator (silencer) segments shall be provided as shown on drawings and as scheduled. Silencers shall be rectangular, 24” ***[36”, 60”]*** long sound attenuators as indicated on drawings and equipment schedule.

C. Outer casings of rectangular silencers shall be made of 22 gauge type #G-90 lock-former- quality galvanized steel ***[304 stainless steel]***.

D. Interior partitions for rectangular silencers shall be not less than 26 gauge type #G-90 galvanized lock-former-quality perforated steel ***[304 stainless steel]***.

E. Filler material shall be inorganic glass fiber of a proper density to obtain the specified acoustic performance and be packed under not less than 5% compression to eliminate voids due to vibration and settling. Material shall be inert, vermin- and moisture-proof. ***[Filler material shall be totally encapsulated and sealed with polymeric film of an appropriate thickness. The encapsulated fill material shall be separated from the interior perforated baffles by means of a noncombustible, erosion resistant, factory-installed, acoustic stand-off. It shall not be acceptable to omit the acoustic stand-off and try to compensate for its absence by means of corrugated baffles. (Hospital grade)]***

F. Combustion ratings for the silencer acoustic fill shall be not greater than the following when tested to ASTM E 84, NFPA Standard 255, or UL No. 723:

1. Flamespread Classification 20
2. Smoke Development Rating 20

2.11 AIR BLENDERS

A. Multiple-blade, air-mixer assembly shall mix air to prevent stratification.

B. Air blenders shall be of the rotary turbulating design consisting of radially extending blades. Units shall be completely fixed devices, with no moving parts.

C. Static air mixers material shall be .080” or .125” thick aluminum ***[.095” 304 Stainless Steel]***. Static air mixers shall be welded.

D. When multiple air blenders are used, they shall impart a counter rotational mixing of the airstreams relative to each other. Simple mixing devices that do not produce expanding discharge with counter rotational mixing will not be acceptable.

E. The air blenders shall be installed such that the blender shall be capable of providing a minimum mixing effectiveness of 75% and ± 6 °F standard deviation when mixing 50% OA with 50% RAS at 50 °F inlet temperature differential, and minimum mixing effectiveness of 80% and ± 5 °F standard deviation when mixing 30% OA with 70% RAS at 50 °F inlet temperature differential.

2.12 SUPPLY FAN DISCHARGE AIR SOUND ATTENUATION BARRIER

A. Unit shall include a discharge air sound attenuation barrier. The passive sound attenuator barrier shall be mounted on the downstream side of the supply fan and shall block line of sight between the fan and the unit discharge opening. End panel sound attenuator shall be used with top, bottom and side discharge openings

2.13 TESTING

A. [Perform factory test on a fully assembled unit with sections joined per manufacturer’s installation instructions. Use of additional material (tape, sealant, caulk) shall be

minimized to only that required to simulate permanent jobsite conditions not otherwise duplicable in the factory.]

B. [Factory performance to be witnessed by owner's representative. Owner's representative shall select one unit, at time of release, to be tested. Manufacturer shall notify contractor and/or owner 14 days prior to test for witnessing. (Travel expenses are not part of this contract). A written report shall be provided showing the test results and the test methods used.]

C. [Factory Panel Deflection Test: The unit manufacturer shall provide a factory deflection test on one unit. Casing panel deflection shall not exceed L/240 at +/- 10" w.g. (or as required by AHRI 1350.) 'L" is defined as the panel span length and 'L/X' is the deflection at panel midpoint. Measurements shall be taken along the vertical seam of the largest panel on the side.]

D. ***[Factory Leak Testing: The unit manufacturer shall provide a factory leak test on one unit across the cabinet exterior walls. Casing leakage shall not exceed 0.5% of design CFM at +/-10" w.g. (or as required by AHRI 1350.)]*** Sections that will be negative pressure shall be tested under negative pressure and sections that will be positive pressure shall be tested under positive pressure.

E. [Factory Sound Pressure Testing: The unit manufacturer shall test one unit for sound power of AHU discharge and/or return openings using sound pressure measurements. All sound pressure level measurements shall be made with a Type 1, Precision Sound Level Meter that complies with both ANSI S1.4 & ANSI S1.4A. Sound meter's octave band filters shall conform to ANSI1.11 and be calibrated with handheld acoustical calibrator immediately before each measurement session. Sound pressure readings shall be reviewed and converted to sound power level by a professional engineer (acoustical engineer) using established ANSI S12.34 and ISO 3744 methods. Testing per AHRI 260 or AMCA 300 will be considered acceptable alternative methods. All other test methods must be approved by Engineer prior to bid.]

F. [Factory Sound Power Testing: The unit manufacturer shall test one unit for sound power of AHU discharge and/or return openings using sound intensity measurements. All sound intensity level measurements shall be made with a Type 1-D analyzer meeting the requirements of ANSI S1.11 for octave and 1/3 octave band filters. Analyzer shall be periodically calibrated with reference sound source as specified in Section 5.8 of ANSI S12.12. Sound Intensity measurements shall be performed by professional engineer (acoustical engineer) using methods based on AHRI Standard 230. Testing per AHRI 260 or AMCA 300 will be considered acceptable alternative methods. All other test methods must be approved by Engineer prior to bid.]

G. Should a unit fail a test, the unit shall be treated with a permanent remedy at manufacturer's expense until test is successfully passed.

H. Unit(s) shall be tested at the extreme winter and summer ambient and airway conditions stated in the design and performance data sheets.

2.14 LIGHTS AND OUTLETS

A. Lights

1. Vapor Resistant Pendant: Factory shall provide vapor resistant pendant, marine type light fixture with clear globe, metal guard, and **[100W incandescent, 23W compact fluorescent]** bulb in segments and quantity as noted on drawings.
2. Fluorescent Twin Tube: Factory shall provide 48" fluorescent light fixture with corrosion resistant housing, acrylic diffuser and twin 32W, T8 lamps and rated for installation in damp environment.
3. Provide low temperature ballasts for fixtures in low temperature locations. Ballasts to be electronic.
4. Factory shall wire all light fixtures to a common 120v switch located on the supply fan segment.
5. Factory shall wire each light fixture to a separate 120v switch located near the access door of the segment with the light fixture.

B. Outlets

1. Factory shall provide a 15A GFI duplex outlet mounted in a weatherproof enclosure in segments and quantity as indicated on the drawings.

2.15 LOUVERS AND HOODS

A. Louvers

1. Provide 16 ga., galvanized steel, stationary type, drainable blade louver with downspouts in the jamb and mullions and 1/4" sq. galvanized mesh birdscreen. Blades shall be housed inside a 16 ga. galvanized steel frame flush mounted to the unit exterior. Louver to be pre-painted with baked enamel finish in a manufacturer's standard color as selected by the Architect.

B. Weather Hood

1. Provide weather hood of same material type and thickness as unit exterior skin with 1/4" ***[1/2"]*** sq. galvanized mesh birdscreen.

2.16 OTHER UNIT FEATURES/REQUIREMENTS:

A. Provide galvanized steel safety step assemblies with railing(s) from roof up to service corridor entry door(s).

B. Provide gutters over unit exterior doors with downspouts extending to below doors.

C. For all exterior and interior doors, provide sleeves and seals.

D. Provide gasketed and capped test ports for all sections of the unit.

E. Provide all required framing, safing, supports, etc., for all components to be installed in the unit, including (but not limited to): Fans, dampers. coils, piping, humidifier grids, attenuators, heat exchangers, etc.

F. Fixed or telescoping fan motor removal beams.

G. Moisture eliminators.

H. Washdown construction with capped drains

I. ***Stainless steel coil raising structures inside unit if required for proper cooling coil drain trapping and/or steam condensate trapping/drainage.***

J. ***Humidifier control valves, strainers and valves shall be outside the airstream.***

K. ***Do not locate humidifiers upstream of fan sections. The preferred location for humidifier sections are downstream of the fans.***

L. ***Humidifiers shall be located 18" downstream of heating coils and a minimum of 3' upstream of cooling coils.***

PART 3 - EXECUTION

3.1 INSTALLATION

A. Install equipment per industry standards, applicable codes, and manufacturer’s instructions.

B. Do not use AHUs for temporary heating, cooling or ventilation prior to complete inspection and startup performed per this specification.

C. Install AHUs on a concrete pad, roof curb, or structural steel base, as shown on drawings.

D. Install AHUs with manufacturer’s recommended clearances for access, coil pull, and fan removal.

E. Provide one complete set of filters for testing, balancing, and commissioning. Provide second complete set of filters at time of transfer to owner.

F. Install AHU plumb and level. Connect piping and ductwork according to manufacturer’s instructions.

G. Install pipe chases per manufacturer’s instructions.

H. Insulate plumbing associated with drain pan drains and connections.

I. Install insulation on all staggered coil piping connections, both internal and external to the unit.

3.2 FIELD QUALITY CONTROL

A. Store per AHU manufacturer’s written recommendations. Store AHUs indoors in a warm, clean, dry place where units will be protected from weather, construction traffic, dirt, dust, water and moisture. If units will be stored for more than 6 months, follow manufacturer’s instruction for long-term storage.

B. Rig and lift units according to manufacturer’s instructions.

3.3 AHU INSPECTION

A. Hire manufacturer's factory-trained and factory-employed service technician to perform an inspection of unit and installation prior to startup. Technician shall inspect and verify the following as a minimum:

1. Damage of any kind
2. Level installation of unit
3. Proper reassembly and sealing of unit segments at shipping splits.
4. Tight seal around perimeter of unit at the roof curb
5. Installation of shipped-loose parts, including filters, air hoods, bird screens and mist eliminators.
6. Completion and tightness of electrical, ductwork and piping
7. Tight seals around wiring, conduit and piping penetrations through AHU casing.
8. Supply of electricity from the building's permanent source
9. Integrity of condensate trap for positive or negative pressure operation
10. Condensate traps charged with water
11. Removal of shipping bolts and shipping restraints
12. Sealing of pipe chase floor(s) at penetration locations.
13. Tightness and full motion range of damper linkages (operate manually)
14. Complete installation of control system including end devices and wiring
15. Cleanliness of AHU interior and connecting ductwork
16. Proper service and access clearances
17. Proper installation of filters
18. Filter gauge set to zero

B. Resolve any non-compliant items prior to unit start-up.

3.4 INSPECTION AND ADJUSTMENT: AHU FAN ASSEMBLIES

A. Hire the manufacturer's factory-trained and factory-employed service technician perform an inspection of the AHU fan assemblies subsequent to general AHU inspection and prior to startup. Technician shall inspect and verify the following as a minimum:

1. Fan isolation base and thrust restraint alignment
2. Tight set screws on pulleys, bearings and fan
3. Tight fan bearing bolts
4. Tight fan and motor sheaves
5. Tight motor base and mounting bolts
6. Blower wheel tight and aligned to fan shaft
7. Sheave alignment and belt tension
8. Fan discharge alignment with discharge opening
9. Fan bearing lubrication
10. Free rotation of moving components (rotate manually)

3.5 STARTUP SERVICE and OWNER TRAINING

A. Manufacturer's factory-trained and factory-employed service technician shall startup AHUs. Technician shall perform the following steps as a minimum:

1. Energize the unit disconnect switch
2. Verify correct voltage, phases and cycles
3. Energize fan motor briefly ("bump") and verify correct direction of rotation.

4. Re-check damper operation; verify that unit cannot and will not operate with all dampers in the closed position.
5. Energize fan motors and verify that motor FLA is within manufacturer’s tolerance of nameplate FLA for each phase.

B. Provide a minimum of 16 hours (but more if required based on actual project conditions and complexity, coordinate with University and HVAC Shop) of training for owner’s personnel by manufacturer’s factory- trained and factory-employed service technician. Training shall include AHU controls, motor starters, VFD's, and AHU's. Training shall be videoed and DVD's of same given to the University.

C. Training shall include startup and shutdown procedures as well as regular operation and maintenance requirements.

D. If AHU is provided with a factory-mounted variable frequency drive (VFD), hire the VFD manufacturer’s factory-trained and factory-employed service technician to inspect, test, adjust, program and start the VFD. Ensure that critical resonant frequencies are programmed as ‘skip frequencies’ in the VFD controller.

E. Submit a startup report summarizing any problems found and remedies performed.

3.6 FIELD PERFORMANCE VERIFICATION

A. Leakage: Pressurize casing to maximum operating static pressure and measure leakage. If leakage exceeds 1% of design airflow, seal leakage points with a permanent solution. Repeat test. If the AHU still does not pass, contact the manufacturer to seal unit.

B. Submit a field test report with testing data recorded. Include description of corrective actions taken.

3.7 CLEANING

A. Clean unit interior prior to operating. Remove tools, debris, dust and dirt.

B. Clean exterior prior to transfer to owner.

3.8 DOCUMENTATION

A. Provide Installation Instruction Manual, & Startup checklist in the supply fan section of each unit.

B. Provide six copies of Spare Parts Manual for owner’s project system manual.

END OF SECTION 23 7323

SECTION 23 8126 – DUCT FREE SPLIT SYSTEM AIR CONDITIONERS

PART 1 - GENERAL

1.1 SUMMARY

A. Section includes split-system air-conditioning units consisting of separate evaporator-fan and compressor-condenser components.

1.2 SUBMITTALS

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

B. Operation and maintenance data.

C. Warranty

1.3 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. Applicable requirements in ASHRAE 62.1-2010, Section 4 - "Outdoor Air Quality," Section 5 - "Systems and Equipment," Section 6 - " Procedures," and Section 7 - "Construction and System Start-Up."

C. ASHRAE/IESNA Compliance: Applicable requirements in ASHRAE/IESNA 90.1-2010.

1.4 WARRANTY

A. One (1) year manufacturer's warranty, provide an additional four (4) year warranty on all compressors (5 years total).

PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. Basis-of-Design Product: Subject to compliance with requirements, provide product indicated on Drawings or comparable product by one of the following:

1. Carrier

2. Mitsubishi Electric

2.2 GENERAL

A. Description:

1. Outdoor--mounted, air--cooled, split--system air conditioner unit suitable for ground or rooftop installation. Unit consists of a hermetic compressor, an air--cooled coil, propeller—type condenser fan, and a control box. Unit will discharge supply air horizontally as shown on contract drawings. Unit will be used in a refrigeration circuit to match up to a packaged fan coil or coil unit.
2. Indoor, direct--expansion, wall--mounted fan coil. Unit shall be complete with cooling coil, fan, fan motor, piping connectors, electrical controls, microprocessor control system, and integral temperature sensing. Unit shall be furnished with integral wall mounting bracket and mounting hardware.

B. Refrigeration Components:

1. Refrigeration circuit components will include liquid--line front--seating shutoff valve with sweat connections, vapor--line front--seating shutoff valve with sweat connections, system charge of R--410A refrigerant, and compressor oil. Unit will be equipped with high--pressure switch, low pressure switch and filter drier for R-410A refrigerant.

2.3 INDOOR WALL-MOUNTED DUCT FREE UNIT (SAHU-1)

A. Unit Cabinet

1. Cabinet discharge and inlet grilles shall be attractively styled, high--impact polystyrene. Cabinet shall be fully insulated for improved thermal and acoustic performance.

B. Fans

1. Fan shall be tangential direct--drive blower type with air intake at the top of the unit and discharge at the bottom front. Automatic, motor--driven vertical air sweep shall be provided standard.
2. Air sweep operation shall be user selectable. The vertical sweep may be adjusted (using the remote control) and the horizontal air direction may be set manually.

C. Coil

1. Coil shall be copper tube with aluminum fins and galvanized steel tube sheets. Fins shall be bonded to the tubes by mechanical expansion.
2. A drip pan under the coil shall have two drain connections for hose attachment, on either the left or right--hand side, to remove condensate. Condensate pan shall have internal trap.

D. Motors

1. Motors shall be open drip--proof, permanently lubricated ball bearing with inherent overload protection. Fan motors shall be 3--speed.

E. Filters

1. Unit shall have filter track with factory--supplied cleanable filters.

F. Operating Characteristics

1. SAHU-1 when matched with the appropriate outdoor section, shall have a minimum listed SEER (seasonal energy efficiency ratio) of 13 at ARI conditions.
2. All other operating characteristics as scheduled on the drawings.

2.4 OUTDOOR CONDENSING UNIT (CU-1)

A. Unit Cabinet

1. Unit cabinet shall be will be constructed of galvanized steel, bonderized, and coated with a powder coat paint.

B. Fans

1. Fan shall be direct-drive propeller type discharging air horizontally.
2. Condenser fan motors will be totally enclosed, 1—phase type with class B insulation and permanently lubricated bearings. Shafts will be corrosion resistant.
3. Fan blades will be statically and dynamically balanced.
4. Condenser fan openings will be equipped with coated steel wire safety guards.

C. Compressor

1. Compressor will be hermetically sealed.
2. Compressor will be mounted on rubber vibration isolators.
3. Condenser coil will be air cooled.
4. Coil will be constructed of aluminum fins mechanically bonded to copper tubes which are then cleaned, dehydrated, and sealed.

2.5 CONTROLS

A. Controls shall consist of a microprocessor-based control system which shall control space temperature, determine optimum speed, and run self diagnostics.

1. User interface with the unit shall be accomplished through a wired controller.

B. The unit shall have the following functions as a minimum:

1. An automatic restart after power failure at the same operating conditions as at failure.
2. A timer function to provide a minimum 24--hour timer cycle for system Auto Start/Stop.
3. Temperature--sensing controls shall sense return air temperature.
4. Indoor coil freeze protection.
5. Automatic vertical air sweep control to provide on or off activation of air sweep louvers.
6. Dehumidification mode shall provide increased latent removal capability by modulating system operation and set point temperature.
7. Fan--only operation to provide room air circulation when no cooling is required.
8. Diagnostics shall provide continuous checks of unit operation and warn of possible malfunctions. Error messages shall be displayed at the unit.

9. Fan speed control shall be user--selectable: high, medium, low, or microprocessor controlled automatic operation during all operating modes.

2.6 OPTIONAL FEATURES:

A. Provide Low Ambient Kit: Control shall regulate fan--motor cycles in response to saturated condensing temperature of the unit. The control shall be capable of maintaining a condensing temperature of 100 F ± 10 F with outdoor temperatures to –20 F

B. Provide crankcase heater

C. Provide wind baffle

2.7 ELECTRICAL REQUIREMENTS:

A. Unit shall operate on the voltage shown on drawings.

B. Only control wiring shall run between the indoor and outdoor units.

C. Indoor and Outdoor unit electrical power shall be single point connection.

D. Voltage as scheduled on drawings.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Condenser shall be installed in strict accordance with the manufacturer's printed instructions.

B. Install units level and plumb.

C. Install evaporator-fan components using manufacturer's standard mounting devices securely fastened to building structure.

D. Install compressor-condenser components on equipment supports specified in Division 07. Anchor units to supports with removable, fasteners.

E. Test, dehydrate, and charge the refrigeration system in strict accordance with the manufacturer's instructions.

F. Insulate both refrigerant lines.

3.2 CONNECTIONS

A. For Refrigerant Piping Refer to Section 232300

3.3 FIELD QUALITY CONTROL

A. Perform tests and inspections.

1. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing.

B. Tests and Inspections:

1. 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.

C. Remove and replace malfunctioning units and retest as specified above.

D. Prepare test and inspection reports.

3.4 DEMONSTRATION

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

END OF SECTION 23 8126

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SECTION 23 8216 - COILS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

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

B. Refer to project air handling unit specification section(s) for additional requirements and conditions affecting coil selections for AHU's.

1.2 SUMMARY

A. Section includes hydronic air coils.

1.3 ACTION SUBMITTALS

A. Product Data: For each type of product.

1. Include construction details, material descriptions, dimensions of individual components and profiles, and finishes for each air coil.
2. Include rated capacities, operating characteristics, and pressure drops for each air coil.

1.4 INFORMATIONAL SUBMITTALS

A. Coordination Drawings for Duct Mounted Coils: Reflected ceiling plans, drawn to scale, on which coil location and ceiling-mounted access panels are shown and coordinated with each other.

1.5 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For air coils to include in operation and maintenance manuals.

B. Northwestern University Maintenance Requirement Forms, see Division 01.

1.6 SPECIAL WARRANTY

A. Five (5) years, see Division 01.

PART 2 - PRODUCTS

2.1 DESCRIPTION

A. ASHRAE Compliance: Comply with applicable requirements in ASHRAE 62.1, Section 5 - "Systems and Equipment" and Section 7 - "Construction and Startup."

2.2 COILS - GENERAL

A. Performance Ratings: Tested and rated according to AHRI 410 and ASHRAE 33.

B. Minimum Working-Pressure/Temperature Ratings: 200 psig (1380 kPa), 325 deg F.

C. Source Quality Control: Factory tested to 300 psig (2070 kPa).

D. Coils for air handling units shall be slide-out style, not face bolted, so they can be removed without affecting the structural integrity of the unit. Coil connections to be Schedule 40 red brass. Vent and drain connections shall be stainless steel pipe and extend to the exteriors of the units.

E. Tubes: ASTM B 743 copper, minimum 0.020 inch thick.

F. Fins: Aluminum, minimum 0.006 inch thick.

G. Headers: Cast iron with cleaning plugs and drain and air vent tappings, seamless copper tube with brazed joints, prime coated, or steel with brazed joints, prime coated.

H. Frames: Galvanized-steel channel frame, minimum 0.052 inch thick for slip-in or flanged mounting, as best suited to actual field conditions (verify in field).

I. Maximum face velocity for cooling coils to be ***[Determined by AE for the project and listed here and/or shown on drawing schedules.]***

J. Maximum face velocity for heating and other non-cooling coils to be ***[Determined by AE for the project and listed here and/or shown on drawing schedules.]***

K. Manufacturers: Same as associated air handling unit if in a unit, or by Heatcraft, Marlo, or Aerofin.

2.3 COILS - HEAT RECOVERY

A. Tubes: ASTM B 743 seamless copper, minimum 0.024 inch thick, 5/8" O.D..

B. Fins: Aluminum, minimum 0.006 inch thick. Maximum allowable fin spacing shall be 10 fins per inch.

C. Rows: Maximum number of rows deep to be 8.

D. Casings: Minimum 16 gage, Type 304 stainless steel, with stainless steel end supports top and bottom.

2.4 COILS - HOT WATER PREHEAT AND REHEAT

A. Tubes: ASTM B 743 seamless copper, minimum 0.024 inch thick, 5/8" O.D..

B. Fins: Aluminum, minimum 0.006 inch thick. Maximum allowable fin spacing shall be 10 fins per inch.

C. Rows: Maximum number of rows deep to be 8.

D. Casings: Minimum 16 gage, galvanized steel, with galvanized steel end supports top and bottom.

2.5 COILS - CHILLED WATER

A. Tubes: ASTM B 743 seamless copper, minimum 0.035 inch thick, 5/8" O.D..

B. Fins: Aluminum, continuous plate type, minimum 0.006 inch thick. Maximum allowable fin spacing shall be 10 fins per inch.

C. Rows: Maximum number of rows deep to be 8.

D. Casings: Minimum 16 gage, Type 304 stainless steel, with stainless steel end supports top and bottom.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine units, ducts, plenums, and casings to receive air coils for compliance with requirements for installation tolerances and other conditions affecting coil performance.

B. Examine roughing-in for piping systems to verify actual locations of piping connections before coil installation.

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

3.2 INSTALLATION

A. Install coils level and plumb.

B. Install coils in metal ducts and casings constructed according to SMACNA's "HVAC Duct Construction Standards, Metal and Flexible." Provide new adjacent ductwork/transitions as required, and re-insulate.

C. Straighten bent fins on air coils.

D. Clean coils using materials and methods recommended in writing by manufacturers, and clean inside of casings and enclosures to remove dust and debris.

3.3 CONNECTIONS

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

B. Install piping adjacent to coils to allow service and maintenance.

C. Connect water piping with unions and shutoff valves to allow coils to be disconnected without draining piping. Control valves are specified in Section 25 0000 "Integrated Automation" and other piping specialties are specified in Section 23 2113 "Hydronic Piping" and Section 23 2116 "Hydronic Piping Specialties."

END OF SECTION 23 8216

SECTION 23 8413 - HUMIDIFIERS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

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

1.2 SUMMARY

A. This Section includes the following:

1. Heat exchanger humidifiers.
2. Dispersion grids/manifolds.
3. Condensate drain cooling equipment.
4. Clean steam generators.

1.3 DEFINITION

A. Low Voltage: As defined in NFPA 70 for circuits and equipment operating at less than 50 V or for remote-control, signaling power-limited circuits.

1.4 ACTION SUBMITTALS

A. Product Data: Include rated capacities, operating characteristics, furnished specialties, and accessories.

B. Shop Drawings: Detail fabrication and installation of humidifiers, grids, and coolers. Include piping details, plans, elevations, sections, details of components, manifolds, and attachments to other work.

1. Wiring Diagrams: Power, signal, and control wiring.

1.5 INFORMATIONAL SUBMITTALS

A. Coordination Drawings: Detail humidifiers, grids, and drain coolers and adjacent equipment. Show support locations, type of support, weight on each support, required clearances, 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. Structural members to which humidifiers will be attached.
2. Size and location of initial access modules for acoustical tile.

B. Field quality-control test reports.

1.6 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For humidifiers, grids and coolers to include in operation and maintenance manuals.

B. Northwestern University Maintenance Requirement Forms, see Division 01.

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. Comply with ARI 640, "Commercial and Industrial Humidifiers."

C. Comply with FM Global requirements for and pressure vessels, piping, and pressure relief devices.

1.8 COORDINATION

A. Coordinate location and installation of humidifiers with manifolds in ducts and air-handling units or occupied space. Revise locations and elevations to suit field conditions and to ensure proper humidifier operation.

1.9 SPECIAL WARRANTIES

A. Five (5) years, see Division 01.

PART 2 - PRODUCTS

2.1 HEAT-EXCHANGER HUMIDIFIERS (STEAM-TO-STEAM)

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

1. Armstrong International, Inc.
2. Carel.
3. Dri-Steem Model STS (Basis of Design).
4. Pure Humidifier Company.
5. Penn Separator (for alternate condensate drain cooler only).

B. Fabricate and label steam generator to comply with ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.

C. For campus "Clean Steam" applications, generator, Clean Steam and condensate piping, dispersion grids/manifolds, and condensate drain cooler all to be rated for use with provided RO or DI water. Type 304 stainless steel is acceptable.

D. Fabrication requirements:

1. Tank and cover: Minimum 14-gauge, 304-stainless steel with Heli-arc welded seams.
2. Removable cover with ¼" screws (M6).
3. Easily accessible cleanout plate.
4. Steam outlet on top of tank configured to connect to hose, pipe, or flange connection.
5. Tubular copper heat exchanger and header with nickel coating.

E. Mounting:

1. Humidifier shall be mounted on a pair of trapeze hangers with factory-provided threaded steel rods, hardware, and predrilled angle irons for smaller models, and on painted H-legs for larger models.

F. Water requirements: The humidifier shall be capable of generating steam from tap, softened, or DI/RO water.

G. Drain: An electric operated drain valve shall be mounted on the humidifier assembly to allow tank to drain automatically at the end of a humidification season.

H. Steam trap and strainer: Humidifier shall include a float/thermostatic steam trap and steam supply line strainer.

I. Humidifier Options

1. Fabrication options:

a. Tank and cover shall be 316 stainless steel with Heli-arc welded seams.
b. Factory insulation: Humidifier shall be covered with 1" thick (25 mm) rigid, foil-faced fiberglass insulation. All surfaces except front face panel shall have insulation.
c. Humidifier shall have a tubular 316 stainless steel heat exchanger and header with no coating.

2. Mounting options:

a. Four support legs shall provide a minimum of 24" (610 mm) between underside of humidifier and floor.
b. Two welded and painted steel wall brackets shall support humidifier on a vertical surface (for smaller units).

3. Options for use with DI/RO water:

a. Humidifier shall have a stainless steel manually operated drain valve and a stainless steel float operated fill valve (standard on DI/RO models).
b. Humidifier shall have a stainless steel electric operated drain valve and a stainless steel float operated fill valve with an electric solenoid to prevent tank from filling when the tank drains automatically at the end of a humidification season (requires Vapor-logic controller, which allows user to define the number of hours of humidifier inactivity that must occur before automatic end-of-season draining begins).
c. Low water float switch. Humidifier shall have a field-wired float switch to provide water level indication for building management systems.

4. Outdoor enclosure system:

a. *Factory assembled and tested with the humidifier installed to provide complete weather protection and to operate within the following temperature limits: -40 to 120 °F (-40 to 50 °C)*
b. *Humidifier and outdoor enclosure shall be shipped as one unit.*
c. *Frame construction: 5" (127 mm), 12-gauge, G-90 galvanized steel formed frame, suitably reinforced and braced to permit loading, shipping, unloading and rigging to the unit destination without damage to external or internal components. The base frame shall be corrosion resistant without painting or further coating.*
d. *Housing construction: 16-gauge, G-90 galvanized steel panels fabricated into self-framing, double standing seam-type construction. All joints shall be caulked weather-tight with a silicone sealant. All interior surfaces shall be insulated with 1" (25 mm), 2.2 lbs/sq ft (10.8 kg/m^2) rigid, noncombustible glass fiber insulation. No exposed insulation shall be permitted on the top-wearing surface of the floor of the unit. The floor shall be insulated from underneath. The floor shall have a drain connection.*
e. *Access door construction: Access door shall provide access to all internal components, be constructed of 16-gauge, G-90 galvanized steel with a gasket around the full perimeter of the doorframe, with heavy-duty stainless steel hinges, and latches.*
f. *Ventilation fans: wired to a thermostat to ventilate the control cabinet and the enclosure.*
g. *Heaters:*

    1) *Thermostatically-controlled heaters to ensure proper operation during cold weather*
    2) *Outdoor enclosure less heaters (option). The outdoor enclosure shall be provided without electric heaters, control thermostat and wiring.*

h. *Roof curb option. The roof curb shall be manufactured of 16-gauge, galvanized steel and provided with necessary hardware for bolt-together assembly. The curb is to be a minimum of 14" (356 mm) high. A 2" (50 mm) by 1/2" (13 mm) closed cell curb gasket with adhesive on one side is to be supplied with the hardware.*
i. *Internal steam vapor plumbing option. The outdoor enclosure shall have piping to discharge steam through the base of the unit.*

J. *Humidifier Controls*

1. *Steam valve: Valve shall be a normally closed modulating type with modified linear flow characteristics, stainless steel trim, and electric actuator.*
2. *Control cabinet: Control cabinet shall be shipped loose and shall be a UL/CSA listed JIC enclosure. Control devices shall be mounted on a subpanel within the cabinet. A wiring diagram shall be included in the control cabinet.*
3. *Vapor-logic®4 (or approved equal by alternate listed manufacturer) microprocessor controller with the following features or functions:*

    a. *Web interface and server, included standard on all models:*

        1) *Web interface shall have same functionality as Vapor-logic keypad/display*
        2) *Web interface shall allow multiple remotely located users to simultaneously view system operation and/or change system parameters.*

3) *Web interface shall have password-protected secure access.*
4) *Web interface shall be compatible with standard Internet browsers.*
5) *Web interface shall connect directly to a personal computer or through a system network via Ethernet cable.*

a) *Automatic cable configuration shall allow straight-through or crossover cables.*

b. *Interoperable with any Modbus® network*
c. *Fully modulating (0% to100%) control of humidifier outputs*
d. *PID control capability with field-adjustable settings*
e. *Water level control for softened or hard water:*

1) *Automatic refill, low water cutoff, field-adjustable skimmer bleed-off functions and automatic drain-down of humidifier. System shall consist of:*

a) *A water level sensing unit comprised of three metallic probes screwed into a threaded probe head. Probe head shall incorporate probe isolation chamber to eliminate short-circuiting between probes caused by mineral coating of probe head. Probe head shall be mounted on the humidifier assembly.*
b) *A slow opening solenoid operated fill valve factory mounted on the humidifier assembly*
c) *End-of-season drain automatically drains humidifier tank after a user-defined period of system inactivity.*

f. *Temperature sensor: A factory mounted sensor, with a temperature range of -40 to 248 °F (-40 to 120 °C) mounted on the humidifier to enable the following functions:*

1) *Maintain the evaporating chamber water temperature above freezing*
2) *Maintain a user-defined preset evaporating chamber water temperature*
3) *Allow rapid warm-up of water in evaporating chamber after a call for humidity, providing 100% operation until steam production occurs*

g. *USB port on the control board for software updates, data backups, and data restoration*
h. *Up-time optimizer function to keep humidifier(s) operating through conditions such as fill, drain, or run-time faults, as long as safety conditions are met, minimizing production down-time*
i. *Real-time clock to allow time-stamped alarm/message tracking, and scheduled events*
j. *Factory commissioning of humidifier and control board, including system configuration as-ordered*
k. *Keypad/display operable within a temperature range of 32 to 158 °F (0 to 70 °C), and that provides backlighting for viewing in low light*
l. *Alarms, unit configuration, and usage timer values shall remain in nonvolatile memory indefinitely during a power outage.*
m. *The capability to monitor, control, and/or adjust the following parameters:*

1) *Relative humidity (RH) set point, actual conditions in the space (from humidity transmitter), RH offset*

2) Dew point set point, actual conditions in the space (from dew point transmitter), dew point offset
3) Relative humidity (RH) duct high limit set point (switch) and actual conditions
4) Relative humidity (RH) duct high limit set point, actual conditions (from transmitter), high limit span, and high limit offset
5) Total system demand in % of humidifier capacity
6) Total system output in lbs/hour (kg/h)
7) Drain/flush duration
8) End-of-season drain status (on standard water systems and if ordered as a DI water option) and hours humidifier is idle before end of season draining occurs
9) Window glass surface temperature (in % RH offset application using sensor ordered as an option) with programmable offset
10) Air temperature or other auxiliary temperature monitoring with programmable offset (using sensor ordered as an option)
11) System alarms and system messages, current and previous
12) Adjustable water skim duration
13) Programmable outputs for remote signaling of alarms and/or messages, device activation (such as a fan), or for signaling tank heating and/or steam production
14) System diagnostics that include:

a) Test outputs function to verify component operation
b) Test humidifier function, by simulating demand to validate performance
c) Data collection of RH, air temperature, water use, energy use, alarms, and service messages for viewing from the keypad/display or Web interface

15) Service notification scheduling
16) Password-protected system parameters
17) Keypad/display or Web interface displays in English, French, or German languages
18) Numerical units displayed in inch-pound or SI units

K. Humidifier Control Options

1. Interoperability using BACnet®
2. Multiple humidifier tank control. Vapor-logic shall be programmed and configured at the factory to control multiple humidifier tanks. Controller functions shall include all Vapor-logic functions listed above plus:

a. The controller shall control up to 16 humidifier tanks.
b. Automatic run-time balancing. The controller shall assign duty to all humidifier tanks in the multi-tank group such that each humidifier accrues approximately the same hours of duty, thereby ensuring equal wear across all humidifiers in the multi-tank group.
c. One humidifier tank shall be capable of being controlled as a redundant tank.
d. One Vapor-logic keypad/display shall be included with each multi-tank group.

3. Water level control for DI/RO water:

a. System shall provide for continuous control of water level and will accommodate the use of deionized or reverse osmosis water with resistance up to 18 M-ohm/cm.

b. System shall:

1) Have a water level sensing unit comprised of a float operated stainless steel valve for water makeup

2) Have a low water cutoff float switch

3) Operate within inlet water pressure range of 25 to 80 psi (172 to 552 kPa)

4. Control cabinet mounted: Control cabinet shall be a UL/CSA listed NEMA-12 enclosure. Control devices shall be mounted on a subpanel within the cabinet. A wiring diagram shall be included in the control cabinet. Control cabinet shall be factory attached to the side of humidifier with all wiring between cabinet and humidifier completed at factory.

5. Microprocessor water level controller with the following features or functions:

a. Makeup water valve control and low water safety shutdown

b. Field adjustable auto-drain and flush sequence whereby microprocessor activates auto-drain and flush sequence after a user-defined run time

c. Self-diagnostic test at start-up

d. Water level sensing unit comprised of three metallic probes screwed into a threaded probe head

e. Probe head mounted on the vaporizing chamber

f. A solenoid operated water fill valve factory mounted on humidifier

6. Valve options:

a. Modulating electronic control valve: Valve shall be a normally closed modulating type with an electronic actuator. Actuator to respond to a variable electronic signal. Available signal inputs 4 to 20 mA and 2 to 10 VDC.

7. Remote keypad: Provide a keypad with cable for remote mounting. Available cable lengths: 10' (3 m), 25' (7.6 m), 50' (15 m), 100' (30 m) or 500' (152 m)

8. Keypad mounted on cabinet: The keypad shall be factory-mounted on the side of the control cabinet.

9. Cabinet door interlock switch: The control cabinet shall have an interlock control switch with manual override to remove control voltage when door is opened

10. Control cabinet door lock: Control cabinet shall have a lock with keys provided.

11. Freeze protection: A factory-mounted aquastat shall be mounted on the front of humidifier to sense and maintain the evaporating chamber water temperature above freezing. Set point adjustable from 40 to 180 °F (4 to 82 °C).

12. Control input accessory options:

a. Humidity transmitter, room: Humidity transmitter shall be a room-mounted device that measures from 0% to 100% of RH range and provides a linear output (10% to 90% RH) from 4 to 20 mA. Accuracy ± 2% RH. Supply voltage 21 VDC. Operating temperature range: -4 to 140 °F (-20 to 60 °C). (Vapor-logic only)

b. Humidity transmitter, duct: Humidity transmitter shall be a duct-mounted device that measures from 0 to 100% RH range and provides a linear output (10% to 90% RH) from 4 to 20 mA. Accuracy ± 2% RH. Supply voltage 21

VDC. Operating temperature range: -4 to 140 °F (-20 to 60 °C). (Vapor-logic only)

c. ***Dew point transmitter: A dew point transmitter (duct- or room-mounted) shall measure the humidity and temperature in the environment and then compute the dew point. Output 4 to 20 mA (700 ohms maximum). Supply voltage 24 VDC. Operating temperature range <u>when duct mounted</u>: -40 to 185 °F (-40 to 85 °C). Operating temperature range <u>when room mounted</u>: -32 to 122 °F (0 to 50 °C). (Vapor-logic only)***

d. ***Cold snap offset transmitter: A window surface temperature transmitter, operating temperature range -20 to 160 °F (-29 to 71 °C), shall be provided for field installation. Transmitter shall supply its signal (4 to 20 mA) to the microprocessor control system, which shall lower the indoor RH set point to a level 5% or more below the dew point temperature during a cold spell, thus preventing window condensation. The indoor RH shall be returned automatically to the normal setting when the glass temperature rises. (Vapor-logic only)***

e. ***Humidistat, modulating, room: Electric humidistat control shall be a modulating style, room mounted with a control range of 20% to 80% RH. Compatible with 24 VAC. Output signals shall be 0 to 10 VDC. Operating temperature range 32 to 122 °F (0 to 50 °C). (Not available for Vapor-logic)***

f. ***Humidistat, modulating, duct: Electric humidistat control shall be a modulating style, duct mounted with a control range of 20% to 80% RH. Compatible with 24 VAC. Output signals shall be 0 to 10 VDC. Operating temperature range 40 to 125 °F (4 to 52 °C). (Not available for Vapor-logic)***

g. ***Humidistat, on-off, high limit: Electric humidistat control shall be an on-off style, duct mounted with a control range of 15% to 95% RH. Compatible with 24, 120, and 240 VAC. Operating temperature range 40 to 125 °F (4 to 52 °C).***

h. ***VAV control package: The VAV control package shall be a modulating control system with two modulating electronic humidity transmitters (one space mounted, the other duct mounted downstream of the humidifier). Both shall transmit to the microprocessor controller to modulate humidifier output and maintain the highest desired space humidity possible, at all airflow volumes, without saturation of the airstream. (For this application, it is recommended to use a sail type airflow proving switch.) (Vapor-logic only)***

i. ***Airflow proving switch, pressure type: Airflow proving switch shall be diaphragm operated with pitot tube for field installation. Switch shall have an adjustable control point range of 0.05" to 12" wc (12.5 to 2,988 Pa). Operating temperature range -40 to 180 °F (-40 to 82 °C). Compatible with 24, 120, and 240 VAC.***

j. ***Airflow proving switch, sail type: Airflow proving switch shall be a sail-operated electric switch for field installation. Switch makes @ 250 fpm (1.3 m/s), breaks @ 75 fpm (0.4 m/s). Maximum operating temperature for <u>sail</u>: 170 °F (77 °C). Maximum operating temperature for <u>switch</u>: 125 °F (52 °C).***

2.2 CLEAN STEAM GENERATORS (VERTICAL TANK TYPE)

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

1. CEMLINE Model Series USG (Basis of Design).
2. Approved equal.

B. Unfired steam generators shall be furnished as a complete package ready for installation and shall be shall be ASME Code constructed and stamped in accordance with Section VIII, Division I, for Unfired Steam Generators, they shall bear the ASME "UB" stamp, and they shall be registered with the National Board of Boiler and Pressure Vessel Inspectors (with a signed copy of shop inspection report shall furnished).

C. The generators and all components subject to steam side shall be 316-L grade stainless steel, they shall have submerged coils of 18 BWG ***(316) (304)*** stainless steel tubes expanded into a ***(316) (304)*** stainless steel tube sheet with cast iron heads, they shall be insulated with not less than 3" of fiberglass insulation, protected by not less than 20 ga. thick enameled steel jacket, and they shall be mounted on a suitable I-Beam support skid, which shall be permanently welded to the shell.

D. Steam Control Valve(s): Generators shall be furnished with an electric operated control valve to modulate the in-coming steam to maintain the desired output of steam pressure +2 psi. Control valves shall be suitable for 150 psi and control valve pilot shall monitor output steam pressure and modulate the steam to maintain constant output pressure.

E. Steam Traps, Strainers, Relief Valves, Gages, and Other Specialties: Generators shall be factory supplied with dual float and thermostatic traps, one for the coil and one for the drip before the control valve, and the generators shall have incoming strainers. The generators shall be furnished with ASME Code Section I pressure relief valve or valves with a capacity to relieve the total BTU of output of the generators. Generators shall be furnished with a vessel steam gauges, electronic level controllers, water columns with gauge glasses, and tandem blow off valves.

F. All components for the generators shall be factory mounted, piped, and tested and the unit shall be shipped from the factory as a complete unit ready for installation, and they be furnished with steam separators.

G. Unfired steam generators shall be supplied with solid-state control module with LED backlit LCD display and LED pilot lights to indicate on off, high pressure, low pressure, low water, and water feed. Solid-state control module shall allow the owner to set pressure limits on display screen. Solid-state control module shall have flashing red alarm light and alarm horn with built in alarm silence relay. Solid-state control module shall be supplied with dry contact closure outputs to indicate to building automation controls (BAC) the occurrence of power on, high pressure, low pressure, low water, and water feed. The control module shall allow the BAC to turn the unfired steam generator on or off through a remote relay suitable for 24 VAC, 1 amp. The control module shall allow the BAC to remotely monitor the operating pressure. Control module shall be supplied with an on-off switch and shall be mounted in a NEMA 1 panel. All solenoids and limits shall be 24 VAC.

H. Furnish a factory installed stainless steel feed water slow opening solenoid valve sized to feed the capacity of the boiler with a maximum pressure drop of 5 psi. Slow opening solenoid valve shall be factory wired to the level controller. Furnish a factory installed check valve between the solenoid valve and Unfired Steam Generator.

I. Other features:

1. Package shall be supplied with vacuum breaker.
2. Package shall be supplied with alarm bell and light to signal low water or high pressure. Alarm silence relay shall be provided to silence the bell but not the light.
3. Package shall be provided with relay with 120-volt coil to remotely start or stop the Generator.

4. ***Package shall include a centrifugal boiler blow off condensate cooler.***
5. ***High water shut off shall be factory furnished. High water cut off shall be factory furnished. High water cut off shall include an electronic probe mounted in the top of the unit connected to an (air) (electric) operated power to open spring to close ball valve. In the event of high water, ball valve will close.***

J. ***ADDITIONAL MAKE UP WATER FEEDING OPTIONS (CHOOSE)***

1. ***FEED WATER CONDENSATE PUMP WITH RECIEVER:***

a. ***Furnish a factory installed feed water condensate system consisting of a receiver, inlet strainer, pump, water make up assembly, NEMA 1 panel with fused starter. Furnish factory installed check valve between the feed water condensate system and the unfired steam generator. Pump shall be factory wired to level controller.***

2. ***FEED WATER PUMP:***

a. ***Furnish and install a feed water pump with flexible connector, shut off valve, and check valve. Feed water pump shall be factory wired to level controller and furnished with fused starter in NEMA 1 enclosure.***

K. ***AUTOMATIC BLOWDOWN (CHOOSE ONE)***

1. ***AUTOMATIC BLOWDOWN TDS SAMPLING METHOD***

a. ***Time sample Walchem WBL-400, feed water system. Furnish a factory installed time sample feed water system consisting of a control which measures the total dissolved solids of the unfired steam generator on a timed basis. If the total dissolved solids exceed the set point shall blow the boiler off until fresh water brings the total dissolved solids level to the desired setting. Automatic blow off system shall be furnished with a NEMA 1 control system and all factory wired to a single point 120 volt connection. Tie into BAS for monitoring and alarming of TDS.***

2.3 ***HUMIDIFIER ACCESSORIES (CONDENSATE PUMPS AND DRAIN COOLERS)***

A. ***Pump, low-flow, high-temperature: Pump shall be suitable for pumping water up to 212 °F (100 °C). Maximum pump flow rate shall be 3.8 gpm (228 gph) with a 12-foot head (36 kPa). Pump shall have a 1-gallon cast aluminum reservoir with a 3/8" pipe thread (DN10) outlet connection, two 1-1/4" (DN32) inlet openings, and integral float switch. Pump shall be used with 115 VAC. Pump also available with 230 VAC. Pump shall be UL recognized and wired per NEC requirements.***

B. ***Pump, high-flow, high-temperature: Pump shall be suitable for pumping water up to 212 °F (100 °C). Maximum pump flow rate shall be 55 gpm (3300 gph) with a 12-foot head (36 kPa). Pump shall have a 4-gallon cast aluminum reservoir with vapor seal, a 3/4" pipe thread (DN20) outlet connection, a 1-1/2" pipe thread (DN40) inlet connection, and integral float switch. Pump shall be used with 115 VAC. Pump can be wired for use with 115/230 VAC. Pump shall be UL recognized and wired per NEC requirements.***

C. ***Pump, high-flow, low-temperature: Pump shall be suitable for pumping water up to 150 °F (65.5 °C). Maximum pump flow rate shall be 55 gpm (3300 gph) with a 12-foot head***

(36 kPa). Pump shall have a 2-gallon cast aluminum reservoir, a 1" pipe thread (DN25) outlet connection, a 1-1/2" pipe thread (DN40) inlet connection, and integral float switch. Pump shall be used with 115 VAC. Pump can be wired for use with 115/230 VAC. Pump shall be UL recognized and wired per NEC requirements.

D. Drane-kooler (Dri-Steem model, or approved equal by alternate listed manufacturer): A thermostatically controlled water valve shall meter an amount of cold water into a stainless steel mixing chamber to temper 212 °F (100 °C) water with a 6 gpm (0.38 l/s) in-flow rate to a 140 °F (60 °C) discharge temperature to sanitary system.

2.4 HUMIDIFIER DISPERSION OPTIONS

A. See drawing schedules and details.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine ducts, air-handling units, and conditions for compliance with requirements for installation tolerances and other conditions affecting performance.

B. Examine roughing-in for piping systems to verify actual locations of piping connections before humidifier installation.

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

3.2 INSTALLATION

A. Install humidifiers, generators, and dispersion with required clearance for service and maintenance.[**Maintain path, downstream from humidifiers, clear of obstructions as required by ASHRAE 62.1.**]

B. Seal humidifier manifold duct or plenum penetrations with flange.

C. Install humidifier manifolds in metal ducts and casings constructed according to SMACNA's "HVAC Duct Construction Standards, Metal and Flexible."

D. Install stainless-steel drain pan under each manifold mounted in duct.

1. Construct drain pans with connection for drain; insulated and complying with ASHRAE 62.1.
2. Connect to condensate trap and drainage piping.
3. Extend drain pan upstream and downstream from manifold a minimum distance recommended by manufacturer but not less than required by ASHRAE 62.1.

E. Install manifold supply piping pitched to drain condensate back to humidifier.

F. Install drip leg upstream from steam trap a minimum of [***12 inches (300 mm)***] <**Insert height**> tall for proper operation of trap.

G. Equipment Mounting:

1. Install steam generators 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."**]
2. Comply with requirements for vibration isolation devices specified in Section 23 0550 "Vibration Isolation."

3.3 CONNECTIONS

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

1. Install piping adjacent to humidifiers to allow service and maintenance.
2. Install shutoff valve, strainer, backflow preventer, and union in humidifier makeup line.

B. Install electrical devices and piping specialties furnished by manufacturer but not factory mounted.

C. Install piping from safety relief valves to nearest floor drain.

D. Ground equipment according to Section 26 0526 "Grounding and Bonding for Electrical Systems."

E. Connect wiring according to Section 26 0519 "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 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. 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.

3.5 DEMONSTRATION

A. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain humidifiers. ***Refer to Section 01 7900 "Demonstration and Training."***

END OF SECTION 23 8413

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