Division 23 – Heating, Ventilation, and Air Conditioning

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23 00 00 Heating, Ventilation and Air Conditioning (HVAC)

1. General
   1.1. Recognized Industry Standards:
       1.1.A. The design and construction shall conform to the latest edition of the following standards where applicable:
         1.1.A.1. American Concrete Institute
         1.1.A.2. American Conference of Governmental Industrial Hygienists
         1.1.A.3. American Institute of Steel Construction
         1.1.A.5. American Society of Mechanical Engineers
         1.1.A.7. American Water Works Association
         1.1.A.8. American Welding Society
         1.1.A.9. ANSI Code for Power Piping B31.1
         1.1.A.10. Associated Air Balance Council
         1.1.A.11. Hydraulic Institute Standards for Centrifugal, Rotary and Reciprocating Pumps
         1.1.A.12. Institute of Electrical and Electronic Engineers
         1.1.A.13. National Association of Sheet Metal and Air Conditioning Contractors
         1.1.A.14. National Board of Boiler and Pressure Vessel Inspectors
         1.1.A.16. National Commercial and Industrial Insulation standards
         1.1.A.17. National Environmental Balancing Bureau
         1.1.A.21. ASME BioProcessing Equipment and Piping

2. Design Documents
   2.1. Design Intent:
       2.1.A. Architect/Engineer (A/E) shall provide a design intent report at the predesign phase that documents the following:
         2.1.A.1. Energy conservation measures and energy requirements for the proposed facility.
         2.1.A.2. Noise criteria
         2.1.A.3. Choice of equipment with life cycle cost analysis
         2.1.A.4. Variances to the Standards
         2.1.A.5. B3, SB-2030 and/or LEED compliance measures when required.
         2.1.A.6. 50-year design considerations and its impact on mechanical equipment selection.
         2.1.A.7. Alternates and proposed value engineered construction materials and construction methods.

   2.2. Mechanical drawings
       2.2.A. Drawings shall be clearly delineated at appropriate scale to accurately define piping, ductwork and equipment.
       2.2.B. The A/E shall provide coordination drawings when necessary.
         2.2.B.1. These are different from the construction coordination drawings, normally in 3D format.

   2.3. Energy Information:
2.3.A. The U of M operates its own central steam, chilled water, central compressed air, and primary electric distribution systems. For utility services to new buildings or remodels of existing buildings, contact the University Energy Management department for information on utility services availability and installation requirements to connect to the central systems.

2.4. Sustainability:
2.4.A. Refer to the Sustainable Design Standards section (General Information) for energy conservation design requirements.

3. Scope
3.1. This division covers the following mechanical systems:
3.1.A. Heating, Ventilating, and air-conditioning (HVAC), including
3.1.A.1. All ducting
3.1.A.2. Air handling equipment
3.1.A.3. All supply, return, and exhaust fans
3.1.A.4. All heat recovery equipment
3.1.A.5. Any other air flow equipment for buildings environmental controls
3.1.A.6. All HVAC equipment piping
3.1.A.7. All ventilation for research related equipment
3.1.A.8. All bio-tech related piping
3.1.A.9. Steam distribution and individual applications
3.1.A.10. Chilled water and glycol distribution and individual applications
3.1.A.11. Hydronic heating distribution and individual applications
3.1.A.12. Compressed air generation and distribution for the laboratory applications
3.1.A.13. All process piping for all research related equipment
3.1.A.14. All piping in utilities tunnels and shafts.
3.1.A.15. All direct buried piping for all utilities, including the factory insulated steam and condensate piping.

4. Coordination
4.1. The HVAC specifications shall be properly coordinated with Division 01 00 00 - General Requirements and other divisions, and shall conform to the format and organizational requirements stated in the introduction of these standards.
4.2. Mechanical standards shall be properly coordinated with the CSI sections of Section 01 00 00 - General Requirements and other sections, and shall conform to the format and organizational requirements stated in the Introduction of this manual.
4.3. Mechanical systems shall be coordinated with the building design and construction, as well as with electrical, plumbing, fire protection, temperature controls, and other systems to eliminate construction conflicts.
4.4. University Departments. The architectural and engineering consulting firm (A/E) shall coordinate with the following departments to determine the mechanical system performance requirements:
4.4.A. Department of Public Safety (DPS)
4.4.A.2. Public Safety Emergency Communications Center (PSECC)
4.4.A.3. University of Minnesota Police (UMP)
4.4.B. University Health and Safety (UHS)
4.4.B.1. U of M Building Codes Department (BCD)
4.4.B.2. Department of Environmental Health and Safety (DEHS)
4.4.B.3. Biosafety and Occupational Health Department (BOHD)
4.4.B.4. Department of Emergency Management (DEM)
4.4.B.5. Department of Radiation Safety (DRS)
4.4.C. University Services
   4.4.C.1. Capital Project Management (CPM)
   4.4.C.2. Facilities Management (FM)
       4.4.C.2.a. Energy Management (EM)
       4.4.C.2.b. FM District Maintenance (FM)
   4.4.C.3. Planning, Space, and Real Estate
   4.4.C.4. Office of Sustainability
   4.4.C.5. Parking and Transportation Services (PTS)
   4.4.C.6. Housing and Residential Life (HRL)
   4.4.C.7. M Dining
4.4.D. Office of Classroom Management (OCM)
4.4.E. Office for Equity and Diversity
   4.4.E.1. Disability Resource Center
4.4.F. Office of Information Technology (OIT)

   4.5.A. The A/E shall also coordinate with Energy Management to determine availability of steam, chilled water, compressed air, and 13.8 kV electrical feeds for connection to campus utility systems.

4.6. Building air intakes shall be located a minimum of 30 feet above the grade or on the roof.

5. Maintenance Access
   5.1. **Prohibited**: Locating rooftop equipment that requires service or inspection within 15 feet of any roof edge.
   5.2. **Prohibited**: Tie offs as a means of providing fall protection.
       5.2.A. Fall protection for roof-mounted equipment shall be by guardrail systems.

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The owner’s intent is to eliminate hazards associated with rooftop maintenance by keeping equipment away from the roof edge. If an exception is approved to locate roof-mounted equipment closer than 15 feet from the roof edge then guardrail systems are to be used for fall protection.

Adding tie off points is not an acceptable alternative due to the cost of maintaining the certification of the tie off points. In addition, tie off requirements significantly increase costs for common maintenance tasks.

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5.3. Location of equipment shall be determined by its service need, so it can be easily maintained.
5.4. In mechanical spaces, when the equipment is located 6 feet or higher above the ground, a service platform shall be provided that complies with MN OSHA requirements for service and maintainability.
5.5. The A/E shall provide sectional drawings of the mechanical rooms and shall meet with Facilities Management early in the schematic design phase to review maintenance access.
5.6. For all equipment on flat and pitched roofs service platforms shall be provided
       5.6.A. Platforms shall meet applicable MN OSHA and MN building codes even if the platforms themselves are not required by code.
       5.6.B. Ladders shall not be the primary means of access to roof-mounted equipment.
5.7. Access Panels:
5.7.A. The A/E shall coordinate the mechanical design with other disciplines to provide adequately sized and properly located access panels.

5.8. Below Ground Pits
5.8.A. Any required below-ground pits shall meet the following:
   5.8.A.1. Minimum 6'x6'
   5.8.A.2. Permanent ladders, gratings, and railings installed
   5.8.A.3. A minimum 20 A GFI outlet
   5.8.A.4. A floor drain
   5.8.A.5. Proper labeling
5.8.B. University EHS shall review pit design for confined space requirements.

6. Mechanical Equipment Rooms
6.1. All equipment rooms shall be properly ventilated to maintain space conditions as required for equipment operation.
6.2. Mechanical equipment shall be located, sized and arranged in a space that provides easy access for maintenance, repair and future replacement.
6.3. Where heat-generating equipment is located adjacent to, above, or below occupied spaces, the equipment space shall be ventilated. In addition, the floors, walls and ceilings shall be insulated with permanently attached, durable, and fire-resistant insulation. The overall heat transfer coefficient (U value) shall be selected to prevent the heat generating equipment from impacting the thermal control of the adjacent occupied spaces and shall not to exceed 0.15 BTU/hr. sq. ft. °F. The insulating materials shall be reviewed and approved by the Owner.
6.4. Equipment, piping and ductwork in equipment rooms shall be mounted or suspended in a manner that will isolate it from the system and from the structure to prevent noise and vibrations in adjacent spaces.
6.5. No mechanical equipment of any type shall be placed in building areaways or tunnels without prior approval from the Owner. No piping shall run into or through fresh air plenums or air ducts.

7. Equipment Isolation:
7.1. The specifications shall include isolation valves.
   7.1.A. All equipment must be installed with isolation valves for shutoff service.
   7.1.B. The valves must have flanged or screwed ends.
   7.1.B.1. If screwed valves are used, provide a union between equipment and valve.
7.2. All systems such as potable water, heating systems and cooling systems must have a minimum of one isolation valve per floor.

8. Painting:
8.1. All exposed piping, ducts, radiation, grills, diffusers and other equipment installed in finished and unfinished spaces shall be painted in accordance with Division 09 91 00 under finishes.
8.2. Painting of exposed piping, ducts and other equipment in the equipment spaces, tunnels, crawl spaces, shafts, and other unfinished spaces shall be included in the mechanical specifications. See Division 09 91 00 under finishes.

9. Telecommunication Rooms:
9.1. See DIV 27 of these Standards for definitions and requirements for MDF and IDF telecommunications rooms.
9.2. MDF and IDF rooms shall be provided with continuous (24/7-365) environmental control.
   9.2.A. The maximum allowable space temperature is 78°F.
   9.2.B. The relative humidity shall be maintained between 20% and 55% year round.
9.2.C. Temperature and relative humidity shall be monitored and alarmed via the BAS.

The design intent is to use hydronic systems to cool telecom rooms when possible. Additional options include refrigerant-based split systems. The use of building air handling systems for telecom cooling is not preferred for most applications. The 24/7 nature of the MDF/IDF loads require the AHUs to operate 24/7 as well.

Telecom rooms are considered unoccupied spaces and therefore do not require outdoor air ventilation. FCUs or other terminal units are typically configured as 100% recirculation systems.

The expectation is that most buildings will limit the indoor humidity to 55% RH in the summer as part of conditioning the overall building and that the MDF/IDF rooms will have a similar dewpoint and RH. Dehumidification systems or sequences are not generally required unless the overall building is expected to experience high humidity levels that could influence the conditions in the MDF/IDF rooms.

The reason for the low humidity limit is to reduce the likelihood of electrostatic discharges in the MDF/IDF rooms. For humidified buildings the expectation is that the RH in the overall building will be maintain high enough to meet the needs of the MDF/IDF rooms. For buildings without humidification or other buildings where very low humidity levels are expected the design team should contact OIT and determine if dedicated humidification systems are needed.

9.3. MDF and IDF HVAC system sizing shall be based on the expected heat loads (equipment plus envelope).
   9.3.A. Sizing calculations shall provide 50% additional capacity for future load growth.
   9.3.B. Hydronic piping shall be sized to accommodate twice the required flow for the selected terminal unit.

The Owner’s intent is to minimize operating costs while providing some room for future load growth. Grossly oversizing terminal units can, depending on the system type, increase energy consumption, noise, and first cost. It is also common for the actual heat loads in MDF/IDF rooms to be significantly less than the design or nameplate loads, which can result in even more oversizing. Designers are encouraged to size the terminal devices for the expected loads and to make provisions to easily replace the terminal unit with a larger size if the space loads increase. This may include choosing larger pipe sizes or electrical feeds. Since future load growth is difficult to predict and not certain to happen, the goal is to allow the Owner to increase cooling capacity in the future without severe disruption.

10. Materials, Manufacturers and Suppliers:
   10.1. Whenever possible, equipment specified and provided shall be of a type and manufacturer that has a local representative and a local replacement and service outlet to give complete coverage on parts and service at all times.
10.2. All factory-assembled equipment shall incorporate materials and fabrication methods consistent with these standards and shall meet all MN codes including but not limited to welding and pressure piping.

11. Building Service Outages
11.1. The A/E shall specify the requirements for building service outages and impairments.
11.1.A. Service Outage Request: The contractor shall request all building service outages through the Project Manager. Outages are typically scheduled Monday thru Thursday. The contractor shall give a 2 week notice to the Project Manager for any planned service outages.
11.1.B. Impairment Procedures: Request for impairments of fire protection system or fire alarm system requires a 24-hour notice. Refer to Division 21 00 00 - Fire Protection Systems and Division 21 30 00 - Fire Pumps for specific impairment procedures.

11.2. Fire Safety Precautions
11.2.A. A smoke mitigation plan is required for all construction activities that have the potential to create smoke.
11.2.A.1. A smoke mitigation plan is not required for new construction or renovations where the building is unoccupied and any smoke generated will not affect connected occupied buildings (e.g. buildings connected via tunnel or skyway).
11.2.A.2. The A/E shall include the requirement for smoke mitigation in the contract documents
11.2.A.3. The general contractor and the subcontractor(s) performing the work that may cause smoke will meet with the Owner’s maintenance staff to develop the mitigation plan prior to scheduling any smoke generating work.
11.2.B. The A/E shall include the following statement in the specifications with regard to protective measures for the contractor during grinding, cutting, brazing, sweating or welding operations.
11.2.B.1. All grinding, cutting, brazing, sweating or welding operations carried on in the vicinity of, or accessible to combustible material, shall be adequately protected to make certain that a spark or hot slag does not reach the combustible material and start a fire.
11.2.B.2. When it is necessary to do grinding, cutting, brazing, sweating or welding close to wood construction in pipe shafts or other locations where combustible materials cannot be removed or adequately protected, employ fireproof blankets and proper fire extinguishers. A helper shall be stationed nearby to guard against sparks and fire.
11.2.B.3. Whenever combustible material has been exposed to molten metal or hot slag from welding or cutting operations or spatter from electric arc, a fireguard shall be kept at the place of the work for at least one hour after completion to make sure that smoldering fires do not start.
11.2.B.4. When welding or cutting in a vertical pipe shaft or floor opening, a fireguard shall examine all floors below the welding or cutting operation. The fireguard shall be kept on duty for at least one hour after completion of work to guard against fire.
11.2.B.5. Before grinding, cutting, brazing, sweating or welding, consult with the A/E as to particular safety precautions.
11.2.C. In the case of a remodeling project in an existing building or connection of a new building to an existing building, the A/E also shall include in the
specifications all the mandatory requirements described in Appendix R:
STANDARD OPERATING PROCEDURE FOR HOT WORKS.

12. Welding and Brazing:
12.1. Certified and licensed trades persons shall perform all mechanical welding and brazing.
    12.1.A. Certification shall be for the type of work being performed and shall be accomplished in accordance with the “Qualification Standard for Welding Procedure, Welders and Welding Operators” as specified by ASME or appropriate governing agency for brazing.

12.2. An independent testing laboratory shall radiograph selected joints, which shall be evaluated on the basis of API and ANSI construction standards appropriate for the service. The A/E shall identify the standard applicable for each welded system.

12.3. Steam condensate piping trades persons shall follow procedures identified in the Procedure Qualification Record and Welding Procedure Specifications in these standards.

12.4. All underground and in tunnels steam and condensate piping welding joints shall be 100% radiographed.

13. Excavation and Backfill for Underground Mechanical Work
13.1. The requirements specified in Division 31 - Earth Work shall be applicable to this work, including protecting, sheathing and shoring, blasting, compaction filling, compaction testing and grading.

14. Equipment and System Cleaning:
14.1. The specifications shall include system-cleaning requirements.

15. Electrical Requirements:
15.1. The A/E shall supplement specifications with the necessary control diagrams for mechanical equipment. The diagrams shall clearly define the sequence of operation, as well as the responsibilities of mechanical and electrical subcontractors.

15.2. To ensure that the temperature control system is complete, control wiring for automatic temperature control systems and other special systems as noted shall be specified in this division.

15.3. All motor starters and disconnects and other electrical components that are not integral part of the shipped equipment shall be installed and wired by the electrical trade.

16. Basic Tunnel Requirements:
16.1. General: These services and equipment are provided by appropriate contractors.
    16.1.A. Lighting
        16.1.A.1. Lighting must be equivalent to equipment rooms.
        16.1.A.2. LED, surface-mounted, low profile fixtures that are free from sharp edges are preferred.
        16.1.A.3. Locate fixtures to avoid creating a hazard for head injuries.
    16.1.B. Power:
        16.1.B.1. Four-way convenience outlets shall be no farther than 100 feet apart.
        16.1.B.2. Welding outlets that match existing standard welding outlets shall be no farther than 200 feet apart.
    16.1.C. Ventilation:
        16.1.C.1. Fresh air sources shall be controlled with manual dampers.
    16.1.D. Water:
        16.1.D.1. Surface and groundwater must be drained to the nearest storm sewer.
            16.1.D.1.a. Drainage pipes and trenches must be designed so that trash, sand, mineral deposits and other debris can be easily removed.
    16.1.E. Security:
16.1.E.1. Secure all access points by padlock, key lock, or electronic card entry. Full-sized doors require panic hardware. Dampers may be provided on doors for ventilation.

16.1.E.2. Designers shall contact University Energy Management personnel regarding specific design requirements for equipment that detects intrusion into tunnels and steam system sensors.

16.2. Tunnel Communications Cable Installation

16.2.A. This section covers standards for planning and installing all communication cable in the steam tunnels on the Minneapolis and St. Paul campuses. This standard covers cable installations by any university department and outside contractors. These services and equipment are provided by appropriate contractors.

16.2.B. Planning

16.2.B.1. New cable installations shall go through a planning stage. The installing department/contractor shall show the locations of all new cable on a scalable drawing. Drawings shall be submitted to the building code official's office and University Energy Management for approval prior to installation. Drawings shall be submitted at least two weeks before the planned start of construction. Drawings shall include sections that precisely detail the intended cable routing. Drawings shall clearly point out locations where headroom or other safety compromises cannot be avoided.

16.2.B.2. Because there are numerous existing tunnels with varying needs for cable installation, it is impractical to create details on standard installation layout. Where there is doubt, contact University Energy Management for the best routes for new cable installation.

16.2.C. Installation

16.2.C.1. The Building Officials Office and University Energy Management shall approve the drawings before cable installation.

16.2.C.2. Cable installation shall be done in a safe and professional manner.

16.2.C.3. New installation shall not create unnecessary safety hazards.

16.2.C.4. Headroom shall be maintained at all times in all locations.

16.2.C.5. Install cables where they will not interfere with existing mechanical equipment, existing lighting and electrical power equipment, ladders and tunnel carts.

16.2.C.6. Cable installation shall be free of sharp edges.

16.2.C.7. Remove unused cable at the earliest possible time.

16.2.C.8. Place tags with installation date and responsible party on the cable every 200 feet and at every juncture and turn.

17. Operating Instructions:

17.1. Complete temperature control drawings and operations sequence shall be mounted in a conspicuous location on or immediately adjacent to major equipment such as air handlers and converters.

17.2. Refer to Division 01 00 00 - General Requirements, Section 01 70 00 - Contract Closeout for additional information on equipment maintenance and operations manuals.

17.3. Specifications shall clearly define the responsibilities of the contractor and the manufacturers to provide instruction to designated university personnel in the proper operation and maintenance of all mechanical equipment provided. The schedule for the
training shall be coordinated with the Project Manager and the commissioning agent as appropriate.
1. For new construction, all HVAC ducts shall be cleaned prior to the commissioning of HVAC equipment and acceptance of the mechanical work.

2. For remodeling, all ductwork shall be cleaned as required and as directed by the A/E and in coordination with the Owner’s maintenance staff.

1. Special attention shall be provided to eliminate leaks and accidental discharge of any refrigerant to the atmosphere.
   1.1. All refrigerants shall be recovered and recycled per local and national standards and codes.
   1.2. Recovered refrigerant is the property of the U of M. Contractors shall arrange for the final disposition of all recovered refrigerant as directed by the U of M authorized personnel.
23 05 00  Common Work Results for HVAC

23 05 05 Selective Demolition for Heating, Ventilating, and Air Conditioning (HVAC)

23 05 13 Common Motor Requirements for HVAC Equipment

1. All electrical motors up to and including 0.5 HP shall be 115-1-60. All motors above 0.5 HP shall be 460-3-60 or 208-3-60. All three phase motors shall be dual voltage; 208/230 and 460 volts.

2. All electrical motors:
   2.1. Shall be premium efficiency
   2.2. Shall have a service factor of 1.15
   2.3. Shall be TEFC if:
      2.3.A. Located in any airstream (supply, return, exhaust, etc.)
      2.3.B. Located outdoors but not in a moisture-proof enclosure
   2.4. Shall be suitable for use with variable frequency drives and have factory installed shaft grounding rings
      2.4.A. Motors 25 HP and larger shall also have ceramic bearings

See Division 26 for variable frequency drive requirements.

The Owner’s intent is for all AC induction motors to be compatible with variable frequency drives. Current experience indicates that shaft grounding reduces, but does not eliminate the potential for damage so ceramic bearings are required as additional mitigation for larger motors.

23 05 16 Expansion Fittings and Loops for HVAC Piping

1. Expansion loops and piping offsets are the preferred method to compensate for thermal expansion in piping systems and should be used whenever practical.
   1.1. The use of expansion joints in lieu of loops or offsets is allowed only with the express permission of the Owner.

2. A structural engineer shall design anchors and guides for expansion loops and joints as required.
   2.1. Show details for the anchors and guides on the drawings.
   2.2. Design calculations signed by a registered structural engineer shall be submitted to the Owner for review.

3. Expansion compensators in hot water systems shall be Flexonics Model H or the U of M approved equal. The compensators shall incorporate guides and anchors.

4. Where loops cannot be used, the following expansion joints shall be specified:
   4.1. Low Pressure Steam Lines (15 psig and less)
      4.1.A. Expansion joints shall be the packed slip tube-type that allows for additional packing to be injected under full system pressure.
      4.1.B. Expansion joints shall be designed for steam at a maximum working pressure of 150 psig and a maximum temperature of 350 degrees F. The steam system, for which the expansion joints will be installed, shall be designed to 15 psig with 100 degree F superheat.
      4.1.C. Expansion joints shall be either the single-slip design that is furnished with or without an anchor base or double-slip design that is furnished with an anchor base. The ends of the slip shall be ANSI Class 150 raised face forged steel.
flanges. The stuffing box shall have integral internal and external guide surfaces, and be furnished with low friction, non-metallic guide inserts.

4.1.D. The total traverse of an expansion joint shall be a minimum of 1 inch greater than the nominal traverse. All expansion joints shall be shipped with a minimum of 1-inch pre-compression to allow for 1-inch extension and the nominal traverse in compression.

4.1.E. Specify Advanced Thermal Systems Inc. or the U of M approved equal.

4.2. High Pressure Steam Lines (greater than 15 psig)

4.2.A. All expansion joints shall be ANSI Class 300 #, steel body, lubricated slip joint type, internally/externally guided with weld ends. Specify Yarway Gun-Pakt or university-approved equal.

4.2.B. Expansion joints shall be the packed slip tube-type that allows for additional packing to be injected under full system pressure.

4.2.C. Expansion joints shall be designed for steam at a maximum working pressure of 300 psig and a maximum temperature of 506 degrees F. The steam system, for which the expansion joints shall be installed, shall be designed to 250 psig and 500°F.

4.2.D. Expansion joints shall be either single-slip design that is furnished with or without an anchor base or double-slip design that is furnished with an anchor base. The ends of the slip shall be ANSI Class 300 raised face forged steel flanges. The stuffing box shall have integral internal and external guide surfaces and be furnished with low-friction, non-metallic guide inserts.

4.2.E. The total traverse of an expansion joint shall be a minimum of 1 inch greater than the nominal traverse. All expansion joints shall be shipped with a minimum of 1-inch pre-compression to allow for 1-inch extension and the nominal traverse in compression.

4.2.F. Specify Advanced Thermal Systems Inc. or university-approved equal.

23 05 17 Sleeves and Sleeve Seals for HVAC Piping

23 05 19 Meters and Gages for HVAC Piping

1. General

1.1. Prohibited: Dry pressure gauges. Select glycerin filled gauges (wet gauges) that are compatible with the fluid and ambient temperature ranges for the particular system and location.

1.2. Prohibited: 1/8” NPT pipe connections. All gauge ports in pipe shall be a minimum 1/4” NPT with a line size isolation valve installed as close to the port as practical.

2. Meters - General

2.1. Definition: “Thermal Energy Meter” refers to a BTU computer plus all of its connected instruments whose primary purpose is to totalize energy flow. This totalized energy value plus all instrument indications shall also be remotely-accessible via Modbus RTU protocol.

2.2. Non-thermal meters, such as those pertaining to plumbing and electrical, are covered separately elsewhere in the University design standards.

2.3. University Energy Management Utility Engineering is solely responsible for the sizing of thermal energy meters. In order for Energy Management to provide correct thermal meter sizing information to the A/E in a timely manner, the A/E shall provide University Energy Management with building GSF and program type as determined by GSF within that facility (office, classroom, RAR space, BSL2 lab, BSL3 lab, special process, etc.). The A/E shall indicate anticipated year-round process loads not driven
by the HVAC requirement of the facility. These estimates shall be calculated in accordance with the ASHRAE bin method described in the ASHRAE fundamentals handbook. Include estimated building or system design requirements, demand peak, minimum usage and hourly consumption for electricity, steam, chilled water, domestic water and sanitary sewer. These demands will be taken into account with sizing the meter; however, benchmarking of similar facilities within the University’s inventory of over 300 buildings will be used to ultimately right size the metering.

2.4. Once the thermal meter size is provided by Energy Management, the A/E shall specify the components of the various meters only according to the pre-approved model and part numbers included in the applicable sections found in this standard in order to ensure the proper options are included and ensure compatibility with the existing campus meter infrastructure. The A/E is responsible for proper system design such that the meters’ installed conditions comply with manufacturers’ requirements and recommendations, including but not limited to:

2.4.A. Ensuring sufficient straight upstream and downstream pipe diameters to ensure fully-developed flow for all flowmeters.

2.4.B. Piping configuration is correct at meter location (i.e. ensuring flooded piping for fluid flowmeters, no liquid in pipe for steam meters).

2.4.C. Flowmeter orientation (3-o clock, 9-o clock, 12-o clock, etc).

2.4.D. Flowmeter wiring (with special attention to remote-mounted transmitters).

2.4.E. Flowmeter grounding (especially with mag. flowmeters).

2.4.F. Proper insulation around flowmeter, particularly steam vortex meters.

2.4.G. Instrumentation wiring.

2.4.H. Dedicated 120 VAC circuit and receptacles to power all metering equipment (consider mag meters, BTU computers, PLCs, and gateway).

2.5. The A/E shall specify one Ethernet data jack per thermal energy meter. Contractor to provide patch cabling from jack to thermal energy meter. Leave Ethernet cable disconnected, Energy Management will configure network settings.

2.6. The A/E shall specify any required network equipment such as serial-to-Ethernet converters (“gateways”) and programmable logic controllers (PLCs) using pre-approved equipment provided later in this standard.


2.8. Where required by the Program, the A/E shall develop a sub-metering plan with Energy Management and the Project Manager.

2.9. Provide a keyed switch (two-prong type such as Eaton-Arrow Hart Catalog No. AH1221L) to act as a local disconnect for all meters, and provide sufficient receptacles to power any PLC(s) and network devices (gateways).

2.10. The A/E shall design a metering system that includes piping diagrams and electrical wiring diagrams of sufficient detail such that accuracy and maintainability are not compromised.

2.11. The design specifications shall call for the contractor to furnish the proper documentation on all meters, including:

2.11.A. High resolution photos (to ensure legibility) of all flowmeter nameplates

2.11.B. Meter piping diagrams, wiring diagrams, and parts lists

2.11.C. Maintenance instructions

2.11.D. Meter instrument calibration certificates

3. Meters - Steam
3.1. Steam meters shall be incorporated into the design of the steam distribution systems for all new buildings that consume steam supplied by a central heating plant.

3.2. Steam flow meters shall be specified according to the University Energy Management approved make/model numbers found in Appendix 23-A Utility Meter Systems in this standard.

3.3. Steam flow meters shall have a bypass line no smaller than the metering line with sufficient isolation valves such that meter may be removed from service without interruption to the metered load.

3.4. Steam meter temperature measurement devices (RTDs) shall be specified according to the University Energy Management approved model number(s) found in Appendix 23-A Utility Meter Systems of this standard.

3.5. Steam meters shall be pressure and temperature-compensated, and pressure and temperature sensing devices shall be specified according to the University Energy Management approved model numbers found in Appendix 23-A Utility Meter Systems of this standard.

3.6. Steam meter electronic BTU totalizers shall be specified according to the University Energy Management approved model number(s) found in Appendix 23-A Utility Meter Systems of this standard.

4. Meters - Chilled Water

4.1. Chilled water meters shall be incorporated into the design of the chilled water distribution systems for all new buildings. Chilled water metering shall also be included to monitor the chilled water output of a stand-alone chiller plant.

4.2. Chilled water flow meters shall be full bore ANSI Class 125/150 flanged electromagnetic-type and specified according to the University Energy Management approved model numbers found in Appendix 23-A Utility Meter Systems of this standard. Ultrasonic flow meters may only be specified in retro-fit applications or by University design standards exception request process for new construction.

4.3. Chilled water meter temperature measurement devices shall be specified according to the University Energy Management approved model numbers found in Appendix 23-A Utility Meter Systems of this standard and shall measure temperature differences as small as 1 degree Fahrenheit or about 0.5 degree Celsius using matched RTD sensors, have best-in-class accuracy, and shall utilize 4-20 mA transmitters.

4.4. The electronic BTU totalizer shall be specified according to the University Energy Management approved model number(s) found in Appendix 23-A Utility Meter Systems of this standard.

5. Meters – Hot Water Heat

5.1. Hot water flow meters shall be electromagnetic-type and specified according to the University Energy Management approved model numbers found in Appendix 23-A Utility Meter Systems of this standard. Note the requirements for hot water electromagnetic-type flowmeters have different liner material requirements for the higher temperature fluid when compared to flowmeters for chilled water or condenser water.

5.2. Follow all other requirements for Chilled Water Meters.

6. Meters Steam Condensate

6.1. Steam condensate meters shall be incorporated into the design of the steam condensate return systems for all new buildings that consume steam supplied by a central heating plant.

6.2. Whenever possible, the A/E shall specify gravity-return condensate piping to minimize maintenance costs and permit the use of a low-head, positive displacement drum meter manufactured by Lincoln Meter Co. per University Energy Management approved...
model numbers found in Appendix 23-A Utility Meter Systems of this standard, or a university-approved equal.

6.3. Provide vapor bypass line around positive displacement drum meter as shown in the detail in Appendix 23-A Utility Meter Systems Figure 7 and Figure 8.

6.4. If necessary, for gravity return condensate meters, provide liquid bypass line for over-design flows.

6.5. When gravity-return is not possible and the building design requires the use of a condensate pump, a turbine hot water meter, Niagara WPX series turbine flowmeter per University Energy Management approved model numbers found in Appendix 23-A Utility Meter Systems of this standard, or Energy Management approved equal shall be used.

6.6. Condensate meters shall have a full-port bypass line with sufficient isolation valves such that the meter may be removed from service without utility interruption to the metered load.

6.7. Condensate meters shall include an RTD downstream of the condensate flowmeter.

6.8. Condensate meters shall include local flow totalization display for taking manual reads.

6.9. The electronic BTU totalizer shall be specified according to the University Energy Management approved model number(s) found in Appendix 23-A Utility Meter Systems of this standard.

7. Gages

7.1. Temperature: Adjustable angle thermometer, 9” scale with well and separable socket, range to be one and half times the maximum operating range.

7.2. Chilled water and hot water/glycol systems shall have gauges for pressure, temperatures, and test plugs for differential pressure measurements.

7.3. All pressure gauges shall have stainless steel casing with a liquid-filled gauge and a shut off valve (unless not applicable for usage or specifically noted in the standards).

7.4. Specify a single common gauge connected to the suction and discharge of pumps as well as across the strainer, with appropriate valves to isolate each side.

7.5. Specify gauges at pressure-reducing stations, and at each point of pressure change. Specify pressure gauges with a maximum range of 1-1/2 times the highest operating pressure.

7.6. Compound gauges shall be specified wherever pressure might be below atmospheric pressure.

7.7. On steam lines up to 15 psi, specify Ashcroft No. 1010 pressure gauge, 6-inch dial complete with pigtail and Ashcroft No. 50-700IL shutoff.

7.8. On steam lines greater than 15 psi, specify Ashcroft No. 1010 pressure gauge, 6-inch dial complete with pigtail and Ashcroft No. 50-700IL shutoff.

7.9. Medical gas and medical vacuum gauges shall comply with the current edition of NFPA 99, Standard for Health Care Facilities. Refer to Section 226000 - Plumbing, 1. Medical Gas Piping for more information.

23 05 23 General-Duty Valves for HVAC Piping

1. General

1.1. **Prohibited:**

1.1.A. Plug valves for gas service.

1.1.B. Ball valves, spring check valves and trip stop valves for steam unless specifically approved by the U of M Energy Management Utility Group.

1.2. Access
1.2.A. Valves located in areas accessible to the public shall be secured against tampering to prevent unauthorized personnel from operating the valves.

1.2.B. Access to all valves shall be reviewed and approved by Owner.
   1.2.B.1. Chain operators shall be provided for valves that cannot be accessed safely using a ladder.
   1.2.B.2. Emergency isolation valves shall be operable from the floor level or shall have a chain operator accessible from floor level.

1.3. Valve Selection
   1.3.A. Isolation valves shall be ball or butterfly type, except for steam service.
   1.3.B. PVC Valves
       1.3.B.1. PVC ball valves shall be true union type.
       1.3.B.2. PVC/thermoplastic valves that are 3 inches and smaller shall have sockets.
       1.3.B.3. PVC/thermoplastic valves that are 4 inches and larger shall be flanged.
   1.3.C. Use threaded connections for pipes that are 2 inches and smaller
       1.3.C.1. Exception: High-pressure steam system that is welded or concealed gas piping. For those applications, the valves shall be welded.
   1.3.D. Use flanged connections for pipes 2-1/2 inches and larger
   1.3.E. The minimum rating for valves shall be one and a half times the maximum system pressure
       1.3.E.1. Exception: High-pressure steam shall be ANSI Class 300 and low-pressure steam shall be ANSI Class 150.

2. Balancing Valves:
   2.1. Ball valves with memory stops shall be specified for balancing hydronic systems.
   2.2. Triple duty hydronic valves are not allowed for variable speed pump applications. Butterfly isolation valves with check valves shall be used instead.
   2.2.A. For hydronic systems where pump capacity must be limited by discharge throttling, triple-duty valves may be used if approved by Owner.

*Triple duty valves are an effective compromise when space constraints prevent installing separate isolation, check, and balancing valves. However, for variable volume pumping systems there is no need for a balance valve on the pump discharge and the triple duty compromise is less attractive.*

3. Gate Valves
   3.1. Compressed air service:
       3.1.A. See Table 2. HVAC Piping Valve Standard
   3.2. Chilled water service:
       3.2.A. See Table 2. HVAC Piping Valve Standard
   3.3. Heating water service:
       3.3.A. See Table 2. HVAC Piping Valve Standard
   3.4. Condenser water service:
       3.4.A. See Table 2. HVAC Piping Valve Standard
   3.5. Low pressure steam condensate service:
       3.5.A. See Table 1. Low Pressure Condensate Valve Standards
   3.6. Low-pressure steam service (15 psi and below):
       3.6.A. Valves up to 2 inches shall be weld end or screwed. They shall be made with a steel body, ANSI Class 800, rising stem, outside stem and yoke, stainless
3.6.B. Valves 2-1/2 inches and larger shall be flanged, steel body, ANSI Class 150, rising stem, outside stem and yoke, renewable seat, solid wedge type. Milwaukee No. 1550 or U of M approved equal.

3.7. High-pressure steam service (more than 15 psi):

3.7.A. Valves up to 2 inches shall be weld end. They shall be made with a forged steel body, ANSI Class 800, rising stem, outside stem and yoke, stainless steel seat rings, solid wedge, welded bonnet, Bonney Forge W-11-SW.

3.7.B. Valves 2-1/2 inches and larger shall be weld end or flanged, cast steel body, ANSI Class 300, rising stem, outside stem and yoke, stainless steel seat rings, solid wedge: Milwaukee No. 3050 or university-approved equal.

3.7.C. Valves in main service required for warm-ups shall have externally tapped bypass and be so noted on drawings.

3.7.C.1. Warm up lines shall be installed with two valves, a union and two pressure gauges.

4. Butterfly Valves

4.1. General

4.1.A. Valves shall be rated for 150% of design maximum pressure

4.1.B. Butterfly valves that are 3 inches and larger only may be specified for use in lieu of gate or globe valves where applicable.

4.1.C. Butterfly valves used for isolation shall be bubble-tight.

4.2. Compressed air service:

4.2.A. See Table 2. HVAC Piping Valve Standard

4.3. Chilled water service:

4.3.A. See Table 2. HVAC Piping Valve Standard

4.4. Heating water service:

4.4.A. See Table 2. HVAC Piping Valve Standard

4.5. Condenser water service:

4.5.A. See Table 2. HVAC Piping Valve Standard

4.6. Low pressure steam condensate service:

4.6.A. See Table 1. Low Pressure Condensate Valve Standards

4.7. For high-pressure steam service 3 inches and larger

4.7.A. All isolation valves must be Vanessa series 30,000 or the U of M approved equal.

5. Ball Valves

5.1. General

5.1.A. All ball valves shall be full port.

5.1.B. All ball valves shall be supplied with stainless steel trim unless material is not compatible with the fluid.

5.1.C. Ball valves specified for insulated piping systems shall have extended stems. Stems shall be of sufficient length to allow free operation of handle.

5.1.D. PVC ball valves shall be rated at a minimum of 150 psig, and shall be true union.

5.2. Compressed air service:

5.2.A. See Table 2. HVAC Piping Valve Standard

5.3. Chilled water service:

5.3.A. See Table 2. HVAC Piping Valve Standard

5.4. Heating water service:

5.4.A. See Table 2. HVAC Piping Valve Standard

5.5. Condenser water service:
5.5.A. See Table 2. HVAC Piping Valve Standard

6. Globe Valves
   6.1. General
   6.2. Compressed air service:
      6.2.A. See Table 2. HVAC Piping Valve Standard
   6.3. Chilled water service:
      6.3.A. See Table 2. HVAC Piping Valve Standard
   6.4. Heating water service:
      6.4.A. See Table 2. HVAC Piping Valve Standard
   6.5. Condenser water service:
      6.5.A. See Table 2. HVAC Piping Valve Standard
   6.6. Low pressure steam condensate service:
      6.6.A. See Table 1. Low Pressure Condensate Valve Standards
   6.7. Globe valves used for low-pressure steam up to 15 psig shall be the following:
      6.7.A. Globe valves 2 inches and smaller shall be ANSI Class 800 and made of forged steel body. They also shall have screwed ends, a rising stem, O.S. & Y. stainless steel seat and disc, and renewable composition disc: Bonney W-31-T or the U of M approved equal.
      6.7.B. Globe valves 2-1/2 inches and larger shall be ANSI Class 150 and made of weld end steel body. They also shall have flanged ends, a rising stem, O.S. & Y. renewable stainless steel disc and seat, Milwaukee No. 1560 or the U of M approved equal.
   6.8. Valves used for high-pressure steam more than 15 psig shall be the following:
      6.8.A. Valves 2 inches and smaller shall be ANSI Class 800, made of forged steel body and have weld ends. They also shall have a rising stem, and O.S. & Y. stainless steel seat and disc: Bonney W-31-SW or the U of M approved equal.
      6.8.B. Valves 2-1/2 inches and larger shall be ANSI Class 300, made of forged steel body and have weld ends. They also shall have a rising stem, and O.S. & Y. stainless steel seat and disc: Milwaukee No. 3065 or the U of M approved equal.

7. Check Valves
   7.1. General
      7.1.A. Spring loaded check valves are prohibited on steam and condensate.
   7.2. Compressed air service:
      7.2.A. See Table 2. HVAC Piping Valve Standard
   7.3. Chilled water service:
      7.3.A. See Table 2. HVAC Piping Valve Standard
   7.4. Heating water service:
      7.4.A. See Table 2. HVAC Piping Valve Standard
   7.5. Condenser water service:
      7.5.A. See Table 2. HVAC Piping Valve Standard
   7.6. Low pressure steam condensate service:
      7.6.A. See Table 1. Low Pressure Condensate Valve Standards
   7.7. Valves for high-pressure steam more than 15 psig shall be as follows:
      7.7.A. Check valves 2 inches and smaller shall be ANSI Class 800 screwed forged steel body. Swing check shall be Bonney H-60-SW.
      7.7.B. Check valves 2-1/2 inches and larger shall be ANSI Class 300 cast steel body, non-slam, swing check valve, bolted bonnet and flanged. Specify Milwaukee No. 3070 or the U of M approved equal.

8. Pressure Regulating Valves
   8.1. Steam pressure-reducing stations
8.1.A. Pressure reducing stations shall have duplex valves in parallel with a globe valve by-pass.
8.1.B. One valve shall be sized to handle one-third of the maximum load, while the other shall be sized to handle the remaining load.
8.1.C. The by-pass shall be designed to facilitate inspection of the pressure regulator without interrupting service.
8.1.D. The control valve shall be single-seated.
8.1.E. Pressure-reducing valves shall be pilot-operated, Spence ED or the U of M approved equal.
8.1.F. Provide an isolation valve on each pilot line.
8.1.G. The pressure-reducing station shall be vented to the outside through a pressure-relief valve.
   8.1.G.1. Follow B31.1 design requirements with non-mandatory appendix II for the design of safety valve installations.
8.1.H. The A/E shall specify a strainer ahead of each pressure-reducing valve. Each pressure-reducing valve shall be isolated by gate valves at both ends, and be rated for the higher pressure. Isolation valves shall be the same size as the pipe connected to header.
8.1.I. The A/E shall provide a detail showing piping and valve arrangement, and including headroom above the regulator and clearance under the regulator for maintenance and replacement.
8.1.J. Each header shall have a drip leg with valve and trap to be gravity drained to condensate system.

9. Pressure Relief Valves
9.1. General
9.1.A. All safety valves shall be ASME-approved. All valves shall be flanged on lines that are 2-1/2 inches or larger.

9.2. Steam
9.2.A. Pressure Reducing Stations
   9.2.A.1. Pressure relief valves for the steam pressure-reducing station shall be sized for the total steam capacity of the steam station.
   9.2.A.2. The valves shall be rated at the maximum possible pressure of the supply branch if the steam plant pressure has been reduced. Otherwise, the pressure shall be equal to the relief valve setting at the steam plant boiler. Contact University Energy Management for pressure to be used.
9.2.B. All safety valves for steam shall be vented to the outside of the building away from pedestrian traffic.
9.2.C. Maximum pressure drop in the discharge piping shall not exceed 10% of the operating pressure.
9.2.D. The pressure relief piping shall be pitched upward and designed with proper drains.
9.2.E. Calculations for pressure drop in the pressure relief piping shall be provided for review and approval. All safety valves on hot water systems shall be piped to the nearest floor drain.
9.2.F. Use ASME B31.1 Appendix II criteria.
9.2.G. Steam pressure relief valves that are 2 inches or larger shall be connected to a drip pan elbow per B31.1.

9.3. Hot Water
9.3.A. All safety valves on hot water systems shall be piped to the nearest floor drain.
# Building Standards
Division 23 HVAC

## Table 1. Low Pressure Condensate Valve Standards

**System:** Low Pressure Condensate Valves  
**Area of Use:** Low pressure condensate in building and district energy distribution systems within the rated design pressure and temperature.  
**Design Pressure:** 30 PSIG  
**Design Temperature:** 250°F

<table>
<thead>
<tr>
<th>Valve Components</th>
<th>Item</th>
<th>Size</th>
<th>ASTM MATL</th>
<th>Grade</th>
<th>Sched/Rating</th>
<th>Spec</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>Gate</td>
<td>Up to 2”</td>
<td>Socket Weld, Screwed</td>
<td>A105</td>
<td>WCB</td>
<td>Class 800</td>
<td>B16.34</td>
<td>Bonney Forge or approved equal</td>
</tr>
<tr>
<td></td>
<td>Over 2”</td>
<td>Flanged</td>
<td>WCB</td>
<td>Class 150</td>
<td>B16.34</td>
<td>Velan Wedge Gate Valve or approved equal</td>
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<tr>
<td>Globe</td>
<td>Up to 2”</td>
<td>Socket Weld, Screwed</td>
<td>A105</td>
<td>WCB</td>
<td>Class 800</td>
<td>B16.34</td>
<td>Bonney Forge or approved equal</td>
</tr>
<tr>
<td></td>
<td>Over 2”</td>
<td>Flanged</td>
<td>WCB</td>
<td>Class 150</td>
<td>B16.34</td>
<td>Bonney Forge or approved equal</td>
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<tr>
<td>Butterfly</td>
<td>6” &amp; smaller</td>
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<td>8” &amp; larger</td>
<td>Flanged</td>
<td>WCB</td>
<td>Class 150</td>
<td>B16.34</td>
<td>Bray or Keystone High Performance or approved equal</td>
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<tr>
<td>Check</td>
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<td>Screwed Spring check</td>
<td>Stainless</td>
<td>Class 800</td>
<td>B16.34</td>
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<td></td>
<td>Over 2”</td>
<td>Flanged Swing Check</td>
<td>WCB</td>
<td>Class 150</td>
<td>B16.34</td>
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<tr>
<td>Strainer</td>
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<td>Screwed</td>
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<tr>
<td></td>
<td>Over 2”</td>
<td>Flanged</td>
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<tr>
<td>Gaskets</td>
<td>Spiral wound stainless w/ flexible graphite filler and centering ring</td>
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<tr>
<td>Bolts</td>
<td>Stud Bolt, ASTM A-193 Gr B7 w/ A194 extra heavy nuts</td>
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<tr>
<td>Notes</td>
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</table>
### Table 2. HVAC Piping Valve Standard

<table>
<thead>
<tr>
<th>Item</th>
<th>Size</th>
<th>Connection</th>
<th>Body</th>
<th>Class/Rating</th>
<th>Spec</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>Gate</td>
<td>Up to 2”</td>
<td>Screwed</td>
<td>Bronze/B62</td>
<td>Class 150</td>
<td>B16.34</td>
<td>Union bonnet, rising stem, solid wedge gate. Milwaukee No. 1151 or approved equal</td>
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<td></td>
<td>Over 2”</td>
<td>Flanged</td>
<td>Cast Steel/ A216</td>
<td>Class 150</td>
<td>B16.34</td>
<td>Rising stem, OS&amp;Y, renewable seat and solid wedge. Milwaukee No. 1150 or approved equal</td>
</tr>
<tr>
<td>Globe</td>
<td>Up to 2”</td>
<td></td>
<td>Brass body</td>
<td>Class 150</td>
<td>B16.34</td>
<td>Rising stem, stainless steel trim</td>
</tr>
<tr>
<td></td>
<td>Over 2”</td>
<td></td>
<td>Brass body</td>
<td>Class 150</td>
<td>B16.34</td>
<td>Rising stem, stainless steel trim</td>
</tr>
<tr>
<td>Butterfly</td>
<td>All</td>
<td>Flanged</td>
<td>Cast Iron</td>
<td>Class 125/150</td>
<td></td>
<td>316 S.S. shaft and disc, EPDM seat. Threaded lug style or flanged with extended neck. Hand level with 10-pos notch plate.</td>
</tr>
<tr>
<td>Check</td>
<td>Up to 2”</td>
<td>Screwed</td>
<td>Bronze</td>
<td>Class 150</td>
<td></td>
<td>Swing check: Milwaukee 510 or approved equal</td>
</tr>
<tr>
<td></td>
<td>Over 2”</td>
<td>Flanged</td>
<td>Cast steel</td>
<td>Class 150</td>
<td></td>
<td>Milwaukee 1570 or approved equal</td>
</tr>
<tr>
<td>Ball</td>
<td>Up to 2”</td>
<td>Screwed</td>
<td>Bronze</td>
<td>Class 150</td>
<td></td>
<td>Stainless ball and stem, Teflon seat</td>
</tr>
<tr>
<td></td>
<td>Over 2”</td>
<td>Flanged</td>
<td>Cast Iron</td>
<td>Class 150</td>
<td></td>
<td>American Valve Model 4000 or approved equal</td>
</tr>
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</table>
23 05 29 Hangers and Supports for HVAC Piping and Equipment

1. General.
   1.1. **Prohibited:**
      1.1.A. Torch cut hanger rods and support members in trapeze hangers are prohibited.
   1.2. Suitable trapeze hangers, Clevis hangers, approved Phillips shields or heavy line hangers shall support piping. Hangers shall be supported from concrete inserts or U of M approved concrete anchors.
   1.3. Hangers for insulated piping shall be large enough to encompass the insulation and the metal saddle.
   1.4. Specify riser clamps to support vertical risers at every floor.
   1.5. **Sleeves**
      1.5.A. All pipe sleeves through slabs, walls and partitions shall be fabricated from new material, cut square and reamed. Sleeves shall be large enough to allow full thickness of pipe insulation.
      1.5.B. Space between the piping/insulation and sleeve shall be sealed:
         1.5.B.1. With an approved fire-rated caulking material on all fire-rated walls.
         1.5.B.2. With an approved waterproof caulking at wet walls and through floor slabs.
         1.5.B.3. With linkseal or the U of M approved equal mechanical sealing system between sleeve and pipe. Where necessary, provide fire-rated caulking and waterproof caulking material.
         1.5.B.4. On vertical sleeves, the sealant shall be applied flush with the top of the sleeve to make a watertight joint. Refer to Division 7, Section 07 27 00 Fire-stopping.
      1.5.C. **Sleeves through Walls**
         1.5.C.1. Sleeves through interior masonry partitions and exterior building walls shall be made of Schedule #40 steel pipe that extends through the wall. The sleeves also shall be flush with the finished surface.
         1.5.C.2. Sleeves through gypsum wallboard partitions shall be made of 22-gauge galvanized steel up to 3 inches in diameter, and minimum 16-gauge for anything larger. The sleeves also shall be flush with the finished surface.
      1.5.D. **Sleeves through Slabs**
         1.5.D.1. Generally, no sleeves are required through slabs on grade.
         1.5.D.2. Sleeves through roof slabs shall be made of minimum 16-gauge galvanized steel.
         1.5.D.3. Sleeves through floor slabs in exposed areas such as classrooms, offices and corridors, shall be made of Schedule #40 steel pipe that extends 1/2 inch above the finished floor.
         1.5.D.4. Sleeves through floor slabs for piping in chases, and within walls and partitions shall be made of minimum 16-gauge galvanized steel. Sleeves shall extend 1/2 inch above the floor surface. Sleeves for water closets shall be of 16-gauge galvanized steel.
         1.5.D.5. Sleeves through floor slabs in kitchen areas, damp areas or concealed under cabinets or laboratory equipment, as well as mechanical areas, shall be made of Schedule #40 steel pipe that extends 2 inches above the finished floor.
         1.5.D.6. Sleeves for heating piping shall be anchored midway with three anchors, 120 degrees apart.
1.5.D.7. Where exposed covered piping passes through floor slabs in kitchen areas and hospital areas, the covering at floor shall be encased with an 18-gauge, stainless steel, cylindrical sleeve that is 6 inches high with lap joints fastened by two stainless steel metal screws. In other exposed areas, an 18-gauge galvanized steel sleeve may be used.

1.5.D.8. Fire-stopping and waterproofing design for materials between the pipe and the sleeve must be detailed on the plans.

23 05 33 Heat Tracing for HVAC Piping
23 05 48 Vibration and Seismic Controls for HVAC

1. Equipment Bases:
   1.1. Concrete bases with a 4-inch minimum height shall be provided under all floor-mounted mechanical equipment.
       1.1.A. The concrete base height shall be adequate to accommodate condensate ‘P’ traps and proper condensate flow.
       1.1.B. Base size and location shall be coordinated with the equipment specified and shall be shown on the architectural and structural drawings.

1.2. Mechanical equipment shall be installed using vibration isolators.
   1.2.A. The vibration isolators shall be per equipment manufacturer’s recommendations.
   1.2.B. Vibration isolation is generally not needed for equipment mounted to slab on grade floors. Instead, consider using an "isolation slab" for common equipment bases.

23 05 48.13 Vibration Controls for HVAC
23 05 53 Identification for HVAC Piping and Equipment

1. Identification Labels
   1.1. Prohibited: Hand written markings

2. Label Application
   2.1. Ducting
       2.1.A. Mark all ducts every 20 feet with minimum 2” high white letters on black background
       2.1.B. Ducts shall be marked with air type (supply, return, exhaust, etc.) and the name of the system per the design documents.

   2.2. Chilled and Hot Water
       2.2.A. Supply and return pipes shall be marked using ASME, ANSI standards and follow NFPA54 and NFPA58 guidelines.
       2.2.B. All piping shall be labeled every 20 feet and every change of direction as to type of service and direction of flow.
       2.2.C. Labels shall include the system name per the design documents.

   2.3. Natural Gas: ASME and ANSI standards
   2.4. Refrigerant: ASME and ANSI standards
   2.5. Steam: ASME and ANSI standards
   2.6. Valves: All manually operated service valves and automatic control valves not immediately in sight of the fixture or equipment it serves shall include approved 19 gauge brass or 0.032-inch aluminum tags secured with brass “S” hooks or chain.
2.6.A.  Tags shall be stamped with an identifying number.
2.6.B.  The contractor shall provide a tabulation that cross-references the valve numbers to a description of the valves and equipment or piping controlled in terms of A/E room numbers.

2.7.  Traps: Each steam trap shall be tagged with a triangular steel tag that contains the number of trap, and its orifice size.

2.7.A.  The U of M shall provide the contractor with a sequence of numbers to be used in numbering the traps.
2.7.B.  The A/E shall specify the necessary clearance for the maintenance, repair and replacement of valves, traps and other fittings.

23 05 63 Anti-Microbial Coatings for HVAC Ducts and Equipment
23 05 66 Anti-Microbial Ultraviolet Emitters for HVAC Ducts and Equipment
23 05 93 Testing, Adjusting, and Balancing for HVAC

1.  General: The contractor shall be responsible for testing, adjusting and balancing all mechanical systems. The A/E shall specify detailed testing, balancing and adjusting procedures based on the content of this section.

2.  Fume Hood Testing: The contractor shall evaluate the installed fume hoods to ensure that they conform to ANSI/AIHA Z9.5 Class A Performance Standards.

2.1.  Fume Hood Evaluation Procedures: These procedures are based on SEFA 1.2 - 1996, Laboratory Fume Hoods, Recommended Practices.

2.1.A.  Equipment List

2.1.A.1.  A properly calibrated anemometer with a velocity grid
2.1.A.2.  A supply of 30-second to 60-second smoke candles or a theater fog generator
2.1.A.3.  A bottle of titanium tetrachloride and supply of cotton swabs or another smoke-producing device such as a MSA tube

2.1.B.  Caution: Titanium tetrachloride fumes are toxic and corrosive. Use it sparingly. Avoid breathing fumes and avoid exposure to body, clothing and equipment.

2.1.C.  Room Conditions

2.1.C.1.  Verify that the cross draft velocity does not exceed 20 fpm.
2.1.C.2.  Check room conditions in front of the fume hood by using an anemometer and a smoke source to ensure that supply air turbulence does not cause out flow of air from the hood.
2.1.C.3.  Correct conditions causing cross drafts that exceed 20 fpm before performing fume hood testing.

2.1.D.  Note: No fume hood can adequately contain fumes if there is excessive cross draft.

2.1.E.  Face Velocity Check. Verify with DEHS for the minimum acceptable face velocity.

2.1.E.1.  The average face velocity for each fume hood shall be within 10 fpm of the design face velocity when the fume hood sash is located at the sash lock. If the hood has combination sashes, the hood must satisfy two tests. First, the face velocity with the horizontal sashes closed and second, the face velocity with the vertical sash at its lowest position and the horizontal sashes fully open.
2.1.E.2. The average face velocity shall be determined by taking at least six velocity readings at evenly distributed points across the open fume hood face.

2.1.F. Sash Operation
2.1.F.1. Sashes shall function smoothly through their full range of motion. Vertical rising sashes shall hold at any height without creeping up or down.

2.1.F.2. Qualitative Verification of Proper Air Flow and Patterns Using Smoke
2.1.F.2.a. Fume hoods shall contain smoke from a smoke candle or fog generator. Smoke shall be contained within the fume hoods and rapidly exhausted. Reverse flow of smoke out of the hoods on any test indicates that the hoods failed.

2.1.F.2.b. Direct smoke across the work surface and against the sidewalls and baffle. Fume hoods with horizontal sliding sashes or a safety shield shall show reverse flow and turbulence behind the sash panel, but no outflow of smoke shall be evident.

2.1.F.2.c. On fume hoods with a vertical sliding sash, position the sash at the sash lock. Move the safety shield to each side and to the middle during the test.

2.1.F.2.d. On fume hoods with combination sashes, close the vertical sash and check airflow while sliding the horizontal sashes to various positions.

2.1.F.2.e. Traverse along the fume hood face area with a smoke-producing device to verify that airflow is into the fume hood.

2.1.F.2.f. When a hood fails a test, the contractor shall adjust the system and retest until the hood passes.

2.1.G. Disputes
2.1.G.1. The university typically will accept a hood that passes a qualitative verification of proper airflow and patterns using smoke.

2.1.G.2. When a university representative disagrees that a hood passed the smoke test, the contractor shall perform an ASHRAE 110 test. The smoke test is a qualitative test and is subject to errors of observation, while the ASHRAE test is considered to be quantifiable and objective.

2.1.H. Evaluate the Low Airflow Monitor
2.1.H.1. Verify that the monitor sounds a local audible alarm when the face velocity is more than 20% below the face velocity design setpoint.

2.1.H.2. The contractor shall report fume hood evaluation results to the university.

3. Biological Safety Cabinet Testing: HEPA filter leak tests and inward airflow work access opening tests shall be conducted in compliance with National Sanitation Foundation (NSF) Standard 49 for Class II Biological Safety Cabinets.

4. Testing and Balancing of Air Distribution Systems:
4.1. Certifications.
4.1.A. The A/E shall specify testing and balancing procedures based on NEBB or AABC specification.
4.1.B. The use of NEBB or AABC forms in the balancing report is required.
4.1.C. The TAB contractor shall be NEBB or AABC certified.

4.2. Duct Leakage Testing
4.2.A. Each ductwork shall be tested for leaks using the maximum allowable class pressure. Follow MN Mechanical codes and nationally recognized standards.

4.3. Air Terminal Calibration
4.3.A. VAV Boxes
4.3.A.1. For pressure independent air terminals using flow feedback (e.g. VAV boxes with flow stations) individual terminal flow stations may be calibrated before the air system is fully functional provided the system can generate adequate duct static pressure and airflow at the terminal being calibrated.

4.3.A.2. Once an air terminal is calibrated the outlets served by the terminal may be proportioned prior to the overall air system being fully operational if the terminal can deliver design airflow.

4.3.A.3. Exception: When construction activities or system readiness produce room pressures that are significantly different than what is expected once the system is complete (e.g. ceilings missing, return/exhaust not operational, etc.).

A VAV box flow station can be calibrated with or without a completed air distribution system. The purpose of the calibration is to adjust the parameters in the flow station electronics so the flow reading matches the flow measured by a reference instrument. This calibration is not significantly influenced by duct static pressures or downstream conditions.

Similarly, once a VAV box is delivering design flow it is usually possible to balance the system downstream of the VAV box. Also known as proportioning the outlets, this process typically adjusts manual dampers at individual diffusers and grills until the total flow from the VAV box is directed as indicated on the design drawings. This proportioning step can typically be done successfully prior to the completion of the rooms if the room pressure relationships are similar to what they will be when the facility is completed. In cases where a VAV box serves a single room then the proportioning step can be performed as soon as the VAV box is calibrated and the downstream ductwork is completed.

4.3.B. Venturi Air Valves

4.3.B.1. The term Venturi Air Valve refers to any air device that uses mechanical means to maintain pressure independence whether or not the device is also equipped with a flow measuring station.

4.3.B.2. Venturi air valves shall be tested for both airflow and for the differential pressure across the air valve. To be considered acceptable the air valve must deliver the design flow while the differential pressure across the air valve is within the manufacturer’s rating for the valve.

Venturi air valves (and similar devices) use spring loaded plungers to automatically maintain a constant airflow over a wide range of duct static pressures. The manufacturer provides a range over which the air valve can operate with a pressure independent characteristic. If the differential pressure across the air valve (difference in duct static pressure at the inlet of the valve compared to the pressure at the outlet) is greater than or less than the manufacturers
specified range then the air valve will not be pressure independent. Instead of remaining constant, the airflow will vary as the duct pressures vary.

Adjustable venturi air valves change the airflow by moving a rod or other device to change the position of the spring loaded plunger. It is possible for a venturi air valve to deliver the design flow even if the differential pressure across the valve is higher or lower than the manufacturer’s range for the valve. For this reason both airflow and differential pressure must be measured. The installation will be accepted only if both the airflow and the differential pressure are acceptable.

4.4. Air System Capacity Testing
   4.4.A. Once all devices have been calibrated and proportioned the TAB contractor shall test the system at design capacity.
   4.4.B. All systems components must be operational for testing to take place
       4.4.B.1. This includes supply, return, and exhaust systems
       4.4.B.2. Building envelope must be completed and closed
       4.4.B.3. Ceilings and doors must be installed
   4.4.C. Drive all air control devices to design maximum flow
       4.4.C.1. For systems with a design diversity of less than 100% it may be necessary to drive only select air control devices to get a total system air demand that meets the design maximum
       4.4.C.2. Identify the duct static pressure setpoint required to satisfy all air control devices simultaneously.
       4.4.C.3. If all devices cannot be satisfied at the same time, identify the air devices that are not able to make setpoint and the maximum duct static pressure setpoint that can be achieved.

5. Testing and Balancing of Hydronic System
5.1. Certifications.
   5.1.A. Each hydronic system shall be balanced following NEBB or AABC specification.
   5.1.B. The A/E shall specify the use of NEBB or AABC forms for the balancing report.
   5.1.C. The TAB contractor shall be NEBB or AABC certified.
**23 06 00 Schedules for HVAC**

1. All HVAC equipment schedules shall be shown on drawings.
2. All Chilled water equipment schedules shall be shown on drawings.
3. All Heating water equipment schedules shall be shown on drawings.
4. All Steam heating equipment schedules shall be shown on drawings.
5. All Refrigerant equipment schedules shall be shown on drawings.

23 06 10 Schedules for Facility Fuel Service Systems
23 06 20 Schedules for HVAC Piping and Pumps
23 06 20.13 Hydronic Pump Schedule
23 06 30 Schedules for HVAC Air Distribution
23 06 30.13 HVAC Fan Schedule
23 06 30.16 Air Terminal Unit Schedule
23 06 30.19 Air Outlet and Inlet Schedule
23 06 30.23 HVAC Air Cleaning Device Schedule
23 06 50 Schedules for Central Heating Equipment
23 06 50.13 Heating Boiler Schedule
23 06 60 Schedules for Central Cooling Equipment
23 06 60.13 Refrigerant Condenser Schedule
23 06 60.16 Packaged Water Chiller Schedule
23 06 70 Schedules for Central HVAC Equipment
23 06 70.13 Indoor, Central-Station Air-Handling Unit Schedule
23 06 70.16 Packaged Outdoor HVAC Equipment Schedule
23 06 80 Schedules for Decentralized HVAC Equipment
23 06 80.13 Decentralized Unitary HVAC Equipment Schedule
23 06 80.16 Convection Heating and Cooling Unit Schedule
23 06 80.19 Radiant Heating Unit Schedule
23 07 00 HVAC Insulation

23 07 13 Duct Insulation

1. **Prohibited**: Interior thermal insulation of air ducts.
2. Internal sound attenuation material for each individual project must be reviewed and is subject to approval by the Owner before design is completed.
3. Ductwork in accessible locations installed lower than 8 feet AFF shall be specified with a puncture resistant jacket.
4. Thickness of supply air duct and plenum insulation shall be selected to prevent condensation on the surface of insulation when the ambient relative humidity is 90 percent at the maximum difference between the ambient air temperature and the supply air temperature. Fresh air intake ducts shall be insulated with fiberglass board insulation 2 inches thick, mechanically fastened, and shall have a finish suitable to the location and surrounding conditions. Fastenings shall not penetrate the inside of ducts. Insulation pins shall be fastened to ductwork by welding.
5. Insulate ducts located in mechanical equipment rooms or other areas where insulation is exposed and may be subject to mechanical damage with 1-inch thick fiberglass board, including glass cloth or canvas jacket with vapor barrier. In concealed areas, ducts shall be insulated with 1-1/2 inch thick fiberglass blanket, 3/4-pound density.
6. Insulation shall be suitably framed at all access panels.
7. Class I kitchen ventilation systems must be insulated as specified in NFPA 96.

23 07 16 HVAC Equipment Insulation

1. **Prohibited**: Insulated steam traps, hot water and condensate return pumps, and hot water expansion tanks. Hog rings and staples are also prohibited.
2. Equipment with a surface temperature warmer than 130 degrees F or at a temperature that causes condensation at ambient relative humidity of 90 percent shall be insulated.
3. Equipment condensate drain pans shall be insulated. The type and thickness of insulation shall be as specified for piping.
4. Specify factory insulation of autoclaves and sterilizers.
5. Boiler breeching shall be insulated as specified for piping with an operating temperature of 400 degrees F and warmer. Provide a minimum of 1/2 inch of air space between boiler breeching and insulation.
6. Blankets
   6.1. In locations that are not accessible to the public such as crawl spaces, equipment rooms and tunnels, steam-piping specialties/equipment shall be insulated with removable blankets or university-approved equal insulation system. The types of fittings included are valves, slip joints and steam condensate meters.
   6.2. Each removable cover shall have a close contour fit for appearance and proper thermal performance.
   6.3. Blanket material shall be as follows:
      6.3.A. Inner and outer jacketing and gussets: 17-ounce, Teflon-coated Nomex cloth
      6.3.B. Insulation: 2-inch, high-density fiberglass insulation, Temp-mat or university-approved equal
      6.3.C. Sewing thread: Teflon-coated Nomex
6.3.D. Seam fasteners: 17-ounce, Teflon-coated fiberglass cloth belts with stainless steel double D-rings or Velcro tabs
6.3.E. ID Tags: stainless steel
6.3.F. Terminal ends: 17-ounce, Teflon-coated fiberglass cloth flaps with Nomex drawcord
6.3.G. All hardware: stainless steel

6.4. Covers shall be of one-piece construction, except where one-piece construction would weigh more than 60 pounds. Covers shall be constructed and installed to shed water.

6.5. All seams shall be sewn using a locking stitch with a minimum of seven stitches per inch.

6.6. Insulation shall be held in place with stainless steel quilt pins.

6.7. Cover fasteners shall be made of two layers of outer cover material sewn together and two stainless steel D-rings with Velcro fasteners.

6.8. Covers shall be constructed and installed so that the end flaps can be tightened securely over adjacent pipe insulation.

6.9. Covers shall be as manufactured by Advance Thermal Corp or university-approved equal.

23 07 19 HVAC Piping Insulation

1. General
   1.1. **Prohibited:** Insulated steam traps and steam condensate return pumps.

2. Steam
   2.1. low-pressure steam condensate piping systems 15 psi and less
       2.1.A. For piping systems located in tunnels, tunnel shafts and manholes insulate with calcium silicate, mineral wool, or university-approved equal.
       2.1.B. For piping systems outside of tunnels, tunnel shafts and manholes insulate with fiberglass, pre-molded pipe covering or a factory-applied jacket.

   2.2. Insulate high-pressure steam condensate piping systems greater than 15 psi with calcium silicate, mineral wool, or university-approved equal that is molded in sections. Install insulation with double-layered staggered joints.

   2.3. Fittings 3 inches and larger shall have mitered segments. Provide staggered joints when a two-layer system requires them.

3. Pipe and Fittings Insulation for Chilled Water Supply and Return Systems, and Condensate Drain Lines
   3.1. Chilled water supply and return pipes shall be insulated with fiberglass, foamed plastic or flexible elastomeric material.
   3.2. Below ground (direct buried) chilled water piping shall have no insulation.

4. Piping and Fitting Insulation for Hot Water Heating Systems
   4.1. **Prohibited:** Foamed plastic or flexible elastomeric material.
   4.2. No insulation is required on hot water recirculating pumps and hot water expansion tanks.
   4.3. Hot water heating supply and return pipes shall be insulated with fiberglass.

5. Materials
   5.1. General Provisions for Fire and Smoke Hazard Rating: All insulation shall have a system fire and smoke hazard rating as tested by procedure ASTM-E84, NFPA 255 and UL 723, not exceeding Flame Spread 25 and Smoke Developed 50. The system rating shall be based on insulation, jacket, adhesives, coatings, fittings and cements. Any treatment of jackets or facings to impede flame and/or smoke shall last the life span of the jacket.
5.2. **Jacket**

5.2.A. **Prohibited**: Stapling pipe covering

5.2.B. **Prohibited**: Paper jacket on high-pressure steam condensate return systems

5.2.C. **Piping in Shafts, Manholes, and Tunnels**

5.2.C.1. On piping 3 inches and larger, install 30-mil thick PVC covering over insulation of all piping.

5.2.C.2. On piping smaller than 3 inches, install 20-mil thick PVC covering.

5.2.C.3. Stop PVC jacket 2 inches from exposed metal on valves, traps and unions, and finish with CP-11.

5.2.D. **Piping not located in Shafts, Manholes, and Tunnels**

5.2.D.1. A 6-ounce canvas jacket shall be installed on all piping and equipment located in mechanical equipment rooms or other areas where insulation is exposed and may be subject to mechanical damage.

5.2.D.2. Coat canvas with waterproof mastic, CP11 or the U of M approved equal. Paint the canvas pink.

5.2.D.3. PVC jacket may be used in lieu of canvas in mechanical rooms, equipment rooms or other areas where insulation is exposed and may be subject to mechanical damage.

5.2.E. **Piping Located Outdoors**

5.2.E.1. Insulated piping lines running outdoors shall have a 30 mil ultraviolet-rated PVC jacket installed over the insulation and vapor barrier.

5.2.E.2. Install PVC covering for outside applications that are subject to exposure to water

5.2.F. All jacketing shall be continuous with vapor seal throughout system.

5.2.G. All fiberglass pipe covering shall have a factory-applied, all-service jacket.

5.3. **Protection at Hangers**

5.3.A. **Prohibited**: Wood block inserts on steam condensate return systems

5.3.B. On steam condensate return piping where rigid insulation is required, install calcium silicate insulation inserts of proper length between pipe and insulation protection shield to prevent sagging of pipe covering at hanger points. Specify that inserts be installed as pipe is erected.

5.3.C. Pipe insulation shall be continuous, and protected at hangers and support points. Specify Buckaroo shields with flared ends or the U of M approved equal for installation at each hanger or support point. Shields on pipe/insulation that are 2-1/2 inches to 5 inches in diameter shall be 22 gauge. Shields on pipe/insulation that are 6 inches to 12 inches in diameter shall be 20 gauge.

5.4. **Pipe and Fittings Insulation**

5.4.A. **General Requirements**

5.4.A.1. Insulate the following piping:

5.4.A.1.a. Steam lines
5.4.A.1.b. Domestic hot and recirculating water lines
5.4.A.1.c. Steam condensate lines
5.4.A.1.d. Chilled water lines, except for buried lines
5.4.A.1.e. Refrigerant lines, where necessary
5.4.A.1.f. Fuel oil lines, where necessary or exposed to low temperature
5.4.A.1.g. Heating water lines
5.4.A.1.h. Other piping systems above and below ambient temperature
5.4.B. The maximum temperature limit of the insulation must be above the maximum operating temperature of the piping. The minimum temperature limit of the insulation must be below the minimum operating temperature of the piping.

5.4.C. New insulation covering shall be colored pink to indicate non-asbestos material. If this conflicts with existing color-coding of pipes, stencil new insulation per OSHA 29 CFR 1926.1101 to identify it as non-asbestos covering.

5.4.D. Insulate fittings, flanges, unions and valves. Insulation covers shall be either prefabricated or fabricated of pipe insulation. Insulation efficiency shall not be less than that of the adjoining piping. Specify that insulation vapor barrier be installed continuous and unbroken.

5.4.E. The A/E shall specify the type and thickness of the insulation based on the pipe size and the exposure. Select a thickness of insulation for cold piping that prevents condensation on the surface of the insulation, as well as has an ambient temperature 50 degrees F warmer than the pipe temperature. Specify that the insulation be installed with a continuous unbroken and non-punctured factory-applied vapor barrier. Insulation shall meet or exceed ASHRAE Standard 90.1

5.5. Piping and Fitting Insulation for Refrigerant Lines

5.5.A. Elastomeric material for piping when temperature is 32 degrees F and colder is prohibited.

5.5.B. Refrigerant lines and equipment 32 degrees F and colder shall be insulated with closed cell rigid insulation, Styrofoam or the U of M approved equal. Seal all insulation joints per manufacturer's recommended sealant.

5.5.C. Provide refrigerant lines and equipment warmer than 32 degrees F with fiberglass, foam plastic or flexible elastomeric material.

5.5.D. Pipe and Fitting Insulation for Fuel Oil Lines. Fuel oil lines shall be insulated with fiberglass, foam plastic or flexible elastomeric material where necessary.

6. Insulation Thickness: Surface temperature of insulation for heated piping in still ambient air at 80 degrees F shall not be warmer than 110 degrees F at the pipe operating temperature below 400 degrees F
23 08 00  Commissioning of HVAC
1. General
   1.1. See U of M Standards Division 25 Integrated Automation
   1.2. Control systems shall be installed by experienced personnel regularly engaged in such installations and in the full employ of the manufacturer or in the employ of a franchised licensee of the manufacturer.
   1.2.A. Approved Installation Contractors
      1.2.A.1. Johnson Controls Branch Office – Minneapolis
      1.2.A.2. Siemens Building Technologies Branch Office – Minneapolis

2. Submittals
   2.1. Submittals Prior To Construction
      2.1.A. System Architecture Design Diagram
         2.1.A.1. A riser diagram that shows the IP layer and all of the field bus layers.
         2.1.A.2. Show each router, repeater, controller, and protocol translator that is connected to either the IP layer or any of the field busses.
         2.1.A.3. Where applicable, this diagram shall include the existing control system that is to be integrated into the new system.
         2.1.A.4. Each component that is shown shall have a name that is representative of how it will be identified in the completed database and the manufacturer’s name and model number.
         2.1.A.5. The physical relationship of one component to another component shall reflect the proposed installation.
         2.1.A.6. The Field Bus wiring diagram shall clearly show the use of daisy chain wiring, the order in which the devices are connected to the Field Bus, and the location of end of segment termination devices and repeaters (if any). All wire identification numbers shall be annotated on the diagram.
         2.1.A.7. This diagram shall not include power supplies, sensors or end devices.
      2.1.B. System Flow Design Diagram for each controlled system.
         2.1.B.1. A two dimensional cross sectional diagram showing key components such as fans, coils, dampers, valves, pump, etc.
         2.1.B.2. Identify the locations and names of all sensors and end devices that are associated with the control system. Label the panel name and terminal numbers where the connections are terminated.
         2.1.B.3. Where pneumatic devices are monitored or controlled by the DDC systems, a pneumatic piping diagram for all components must be included.
         2.1.B.4. A legend shall be provided for all symbols used.
      2.1.C. Sequence of Control: A sequence of control for each system being controlled. Include the following as a minimum.
         2.1.C.1. A narrative explaining the sequence associated with each major control function (heating, cooling, occupied, unoccupied, smoke mode, etc.) including both normal and emergency operating modes. The narrative must contain:
            2.1.C.1.a. Local (stand alone) control sequences.
            2.1.C.1.b. Supervisory logic sequence of control (e.g. dynamic setpoint resets from the network controller(s), smoke mode initiation, demand limit control, etc.).
2.1.C.2. Within the sequence of control, all application parameters that are to be user adjustable from an OWS shall be annotated with (adj) after the name of the parameter. This shall include set points, reset schedule parameters, calibration offsets, timer settings, control loop parameters such as gain, integral time constant, sample rates, differentials, etc.

2.1.C.3. All functions that can be manually initiated by an operator without the use of the OWS (e.g. HOA switch, occupancy overrides from T-stats, etc.)

2.1.C.4. A list of all alarm points including a description of the alarm and of the alarm criteria.

2.1.D. Installation Design Detail for each I/O device.
- 2.1.D.1. A drawing of the wiring details for each sensor and/or end device.
- 2.1.D.2. For devices with multiple quantities, a standard detail may be submitted.

2.1.E. Direct Digital Control System Hardware Technical Data.
- 2.1.E.1. A complete bill of materials of equipment to be used indicating quantity, manufacturer, and model number.

2.2. Submittals During Construction

2.3. Submittals After Construction

3. Project Record Documents
- 3.1. The Contractor shall provide a set of Record Drawings (i.e. As-Built Drawings). The record drawing shall show the locations of all controllers, power supplies, network switches, and any other similar components.
  - 3.1.A. A marked up drawing set is acceptable provided it is legible and shows the required devices.
  - 3.1.B. The power supplies shall be identified on the record drawing. The 120V power panel and circuit number serving each power supply must be included.
  - 3.1.C. Submit electronic versions of all Record Drawings, points lists, and operating sequences. The electronic copies shall saved in an editable format. Acceptable formats include:
    - 3.1.C.1. Microsoft Office program formats (i.e. Word, Excel, Access, etc.)
    - 3.1.C.2. Visio
    - 3.1.C.3. AutoCAD.
    - 3.1.C.4. Other formats must be approved by the University at time of project award.

23 09 13 Instrumentation and Control Devices for HVAC

23 09 13.13 Actuators and Operators

23 09 13.23 Sensors and Transmitters

1. General
- 1.1. The contractor shall install all sensors in accessible locations.
- 1.2. Room temperature sensors shall be installed on concealed junction boxes properly supported by the wall framing.
- 1.3. All wires attached to sensors shall be air sealed in their raceways or in the wall to prevent air transmitted from other areas from affecting sensor readings.
- 1.4. Sensors used in mixing plenums and hot and cold decks shall be of the averaging type.
  - 1.4.A. Averaging sensors shall be installed in a serpentine manner vertically across the duct. Each bend shall be supported with a capillary clip.
1.4.B. Low-limit sensors used in mixing plenums shall be installed in a serpentine manner horizontally across the duct. Each bend shall be supported with a capillary clip. Provide 1 foot of sensing element for each square foot of coil area.

2. All pipe-mounted temperature sensors shall be installed in wells. Install all liquid temperature sensors with heat-conducting fluid in the thermal wells.

3. Install outdoor air temperature sensors on the north wall, complete with a sun shield at the designated location.

4. Differential air static pressure sensors
   4.1. For supply duct static pressure, pipe the high pressure tap to a duct probe that measures at a 90 degree angle to flow (to measure only the static pressure and not the effects of velocity). Pipe the low-pressure port to the plenum.
   4.2. For return duct static pressure, pipe the low pressure tap to a duct probe that measures at a 90 degree angle to flow (to measure only the static pressure and not the effects of velocity). Pipe the high-pressure port to the plenum.
   4.3. For building static pressure, pipe the low-pressure port of the sensor to the static pressure port located on the outside of the building through a high-volume accumulator. Pipe the high-pressure port to a location behind a thermostat cover.
   4.4. The piping to the pressure ports on all pressure transducers shall contain a capped test port located adjacent to the transducer.
   4.5. Mount transducers in a location accessible for service without the use of ladders or special equipment to the maximum extent possible.

5. All water differential pressure sensors shall have gauge tees mounted adjacent to the taps. Water gauges shall also have shutoff valves installed before the tee.

6. Annular pitot tubes shall be installed so that the total head pressure ports are set-in-line with the pipe axis upstream and the static port facing downstream. The total head pressure ports shall extend diametrically across the entire pipe. Annular pitot tubes shall not be used where the flow is pulsating or where pipe vibration exists.

23 09 13.33 Control Valves

1. General
   1.1. See Table 3 for standard control valve by application and size.
   1.2. Install in an accessible location, with room for actuator removal and service.
   1.3. Provide valve stem indicator and adjust to indicate proper travel.
   1.4. Where butterfly valves are used, permanently mark the end of the valve shaft to indicate the valve position.

2. Pressure Independent Control Valves
   2.1. Pressure independent control valves are required for equipment served directly by a campus district chilled water system.
   2.2. Pressure independent control valves are not required (optional) for equipment served by dedicated stand-alone heating and cooling systems. However, PI valves shall be specified on chilled water systems in buildings that will likely be connected to a district chilled water system in the future. Contact Energy Management for the most current utility master plan information.
Table 3. HVAC Control Valve Standard

<table>
<thead>
<tr>
<th>Service</th>
<th>Size</th>
<th>Type</th>
<th>Connection</th>
<th>Body</th>
<th>Trim</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heating Hot Water</td>
<td>Up to 2”</td>
<td>Ball Valve</td>
<td>Screwed</td>
<td>Brass</td>
<td>Stainless</td>
<td>JCI VG1000 Series with Series 300 Stainless Trim, Belimo B2XX Series Characterized Control Valve, or approved equal.</td>
</tr>
<tr>
<td></td>
<td>Over 2”</td>
<td>Ball or Globe</td>
<td>Flanged</td>
<td>Cast Iron</td>
<td>Stainless</td>
<td>Belimo B6X00 Series Flanged Characterized Control Valve, Belimo G6XX Series Flanged Globe Valve, or approved equal.</td>
</tr>
<tr>
<td>Chilled Water</td>
<td>Up to 2”</td>
<td>Ball Valve</td>
<td>Screwed</td>
<td>Brass</td>
<td>Stainless</td>
<td>JCI VG1000 Series with Series 300 Stainless Trim, Belimo B2XX Series Characterized Control Valve, or approved equal.</td>
</tr>
<tr>
<td></td>
<td>Over 2”</td>
<td>Ball or Globe</td>
<td>Flanged</td>
<td>Cast Iron</td>
<td>Stainless</td>
<td>Belimo B6X00 Series Flanged Characterized Control Valve, Belimo G6XX Series Flanged Globe Valve, or approved equal.</td>
</tr>
<tr>
<td>Chilled / Hot Water - PI</td>
<td>Up to 2”</td>
<td>Ball Valve</td>
<td>Screwed</td>
<td>Brass</td>
<td>Chrome or Stainless</td>
<td>JCI VP140 Series, Belimo PIQCV Series (1/2” and 3/4”), Belimo EPIV (1” through 2”), or approved equal.</td>
</tr>
<tr>
<td></td>
<td>Over 2”</td>
<td>Ball or Globe</td>
<td>Flanged</td>
<td>Cast Iron</td>
<td>Stainless</td>
<td>Belimo EPIV, Belimo Energy Valve, or approved equal</td>
</tr>
</tbody>
</table>
23 09 13.43 Control Dampers

23 09 13.43 Direct Digital Control System for HVAC

1. General
   1.1. Enclosures
      1.1.A. Enclosures shall meet the following minimum requirements:
         1.1.A.1. Outdoors: Enclosures located outdoors shall meet NEMA Type 4
                 requirements.
         1.1.A.2. Mechanical and Electrical Rooms: Enclosures shall meet NEMA 250
                 Type 12 requirements. If no water source is located above or closer than
                 20 feet horizontally from the panel location a Type 1 enclosure can be
                 used with prior approval from the Owner.
         1.1.A.3. Wet Locations: Enclosures shall meet NEMA 250 Type 4 requirements.
         1.1.A.4. All Other Dry Locations: Enclosures shall meet NEMA 250 Type 1
                 requirements.
         1.1.A.5. All panels shall be self-supporting enclosures with keyed lock.
         1.1.A.6. Each panel shall be UL/ETL listed and stamped.
   1.2. Weather Shields
      1.2.A. Weather shields shall meet the following minimum requirements:
         1.2.A.1. They shall prevent the sun from directly striking the sensor.
         1.2.A.2. They shall provide sufficient ventilation so that the sensing element
                 measures the ambient conditions of the surroundings.
         1.2.A.3. They shall prevent rain from directly striking or dripping onto the sensor.
         1.2.A.4. When installed near outside air intake ducts, they shall be installed such
                 that normal outside air flow does not cause rainwater to strike the sensor.
         1.2.A.5. They shall be unpainted aluminum or they shall be white galvanized steel
                 aluminum or PVC.
   1.3. WIRE, CABLE, AND TRANSFORMERS
      1.3.A. Refer to Division 26 for conduits and conductors, except as noted.
      1.3.B. All wire and cable shall meet the requirements of NFPA 70 and NFPA 90A.
      1.3.C. Terminal blocks, which are not integral to other equipment, shall be insulated,
             modular, feed trough, clamp style with recessed captive screw-type clamping
             mechanism, shall be suitable for rail mounting, and shall have end plates and
             partition plates for separation or enclosed sides.
      1.3.D. Control wiring for binary sensors shall be 18 AWG copper and shall be rated
             for 300-volt service.
      1.3.E. Wiring for 120-volt circuits shall be 18 AWG or thicker stranded copper and
             shall be rated for 600-volt service.
      1.3.F. Control wiring for analog signals shall be 18 AWG, copper, multiple strand,
             twisted (minimum 50 mm lay of twist), and shall have 300 volt insulation.
             For applications requiring shielded cable, each pair shall have a 20 AWG tinned-
             copper drain wire and individual overall pair insulation.
      1.3.G. Transformers shall be UL 1585 approved and shall be sized so that the
             connected load is no greater than 80% of the transformer rated capacity.
   1.4. Other Equipment Requirements
      1.4.A. All controllers used for smoke control shall be UL 864 UUKL listed.
1.4.B. If the DDC system is controlling a piece of equipment that is on emergency power, the DDC panel shall be connected to the same source of emergency power.

1.4.C. All DDC primary LAN controllers, PCs and communication equipment that monitor life safety and critical points (such as fire alarm and elevator emergency) shall be connected to emergency power and have an online UPS with full-load rectification and inversion (double conversion). If a generator supports the electrical circuit, then a four-hour UPS is required. If a generator does not support the electrical circuit, then a 24-hour UPS is required. The University must approve any deviations from this requirement in writing prior to bidding.

1.5. HVAC Control Hardware Identification

1.5.A. Automatic Control Valve Tags
   1.5.A.1. Use metal tags with a 2-inch minimum diameter, fabricated of brass, stainless steel, or aluminum. Attach the tags with a chain of the same material.
   1.5.A.2. For lubrication instructions, use linen or a heavy duty shipping tag.
   1.5.A.3. Tag the valves with identifying number and system.
   1.5.A.4. Prepare a list of all tagged valves showing location, floor level, tag number, and use. Organize the list by system. Include copies in each maintenance manual.

1.5.B. Wire Tags: All multi-conductor cables in all pull boxes and terminal strip cabinets shall be tagged.

1.5.C. Conduit Tags: Provide tagging or labeling of all conduits so that it is readily observable which conduit was installed or used in implementation of this work.

1.5.D. Panels and Control Devices
   1.5.D.1. Control Panels (Enclosures) shall be labeled.
   1.5.D.2. All sensors, controllers, and controlled devices shall also be labeled.
   1.5.D.3. Where physical space permits, the labels shall be made of black lamicoid sheet with white lettering. They shall be affixed to the panel or device by screws if possible or glue if screws are not feasible. If physical space does not permit the use of labels with readable text, tags shall be used.
   1.5.D.4. Identification on the labels or tags shall match the identification documented on the submittals/as-builts.

1.6. General Installation

1.6.A. Install equipment, piping, and wiring/raceway parallel to building lines (i.e., horizontal, vertical, and parallel to walls) wherever possible.

1.6.B. Provide sufficient slack and flexible connections to allow for vibration of piping and equipment.

1.6.C. Install all equipment in readily accessible locations as defined by Chapter 1, Article 100, Part A of the Nations Electrical Code (NEC).

1.6.D. Do not run any conduit or wiring exposed below the finished ceiling or on any finished walls, unless approved by the Owner.

1.7. Wiring

1.7.A. Class 1 (line voltage)
   1.7.A.1. Class 1 wiring shall be UL Listed in approved raceway.
1.7.A.2. Maximum allowable voltage for control wiring shall be 120 Volts. If only higher voltages are available, the contractor shall provide step-down transformers.

1.7.B. Class 2 (Low Voltage)
1.7.B.1. Low voltage wiring shall meet NEC Class 2 requirements.
1.7.B.2. Sub-fuse low voltage power circuits as required to meet Class 2 current limits.
1.7.B.3. Maximum control transformer size is 100VA without prior approval form Owner.
1.7.B.4. Class 2 wiring installed above hard ceilings or other inaccessible locations shall be run in approved raceway.
1.7.B.5. All exposed Class 2 wiring shall be enclosed in metallic conduit or raceway.
1.7.B.6. All wiring in mechanical, electrical, or service rooms, or where subject to mechanical damage, shall be installed in raceway at levels below 10 feet.
1.7.B.7. Open cable installations are allowed for concealed low voltage wiring installed above lay-in or other accessible ceilings. If used, open cable installations will adhere to the requirements of this section.
1.7.B.8. Where NEC Class 2 (current-limited) wires are in concealed and accessible locations, including ceiling return air plenums, approved cables not in raceway may be used provided that cables are UL Listed for the intended application.
1.7.B.9. Install plenum wiring in sleeves where it passes through walls and floors. Maintain the fire rating at all penetrations.
1.7.B.10. Where Class 2 wiring is run without raceways:
   1.7.B.10.a. Wiring is to be run parallel along a surface or perpendicular to it
   1.7.B.10.b. Wiring will be neatly tied at 10 foot intervals or less as required to prevent excessive sagging.
   1.7.B.10.c. Wiring shall be supported from or anchored to structural members. Cables shall not be supported by or anchored to ductwork, electrical raceways, piping, or ceiling suspension systems.
1.7.B.11. Class 2 wiring shall not be installed in raceway containing Class 1 wiring. Boxes and panels containing high-voltage wiring and equipment may not be used for low-voltage wiring except for the purpose of interfacing the two (e.g., relays and transformers).
1.7.B.12. Wiring shall not be installed in raceway containing pneumatic tubing.
1.7.B.13. All wire-to-device connections shall be made at a terminal block or terminal strip. All wire to wire connections shall be at a terminal block.
1.7.B.14. All wiring within enclosures shall be neatly bundled and anchored to permit access and prevent restriction to devices and terminals.
1.7.B.15. All wiring shall be installed as continuous lengths, with no splices permitted between termination points.

1.8. Other Requirements
1.8.A. Control and status relays are to be located in designated enclosures only. These enclosures include packaged equipment control panel enclosures unless they also contain Class 1 starters.
1.8.B. Unless required for life safety system operation, wire all safeties so the fan shuts down even if the HOA switch is in the hand position.

1.9. Warning Labels
1.9.A. The contractor shall affix permanent warning labels to all equipment that can be automatically started by the DDC system.
   1.9.A.1. Labels shall use white lettering, 12 point type or larger, on a red background.
   1.9.A.2. The labels shall read: “CAUTION: This equipment is operating under automatic control and may start or stop at any time without warning. Switch disconnect to the OFF position before servicing.”

1.9.B. The contractor shall affix permanent warning labels to all motor starters and all control panels that are connected to multiple power sources utilizing separate disconnects.
   1.9.B.1. Labels shall use white lettering, 12 point type or larger, on a red background.
   1.9.B.2. The labels shall read: “CAUTION: This equipment is fed from more than one power source with separate disconnects. Disconnect all power sources before servicing.”

1.10. Identification of Hardware and Wiring

1.10.A. Label all wiring and cable, including that within factory-fabricated panels, at each end and within 2 inches of the end of the cable with the DDC address or termination number.

1.10.B. Label all pneumatic tubing at each end within 2 inches of the end with a descriptive identifier.

1.10.C. Label all control panels with minimum ½ inch letters on laminated plastic nameplates.

1.10.D. All plug-in components shall be labeled on both the removable component and the permanently installed base such that it is obvious where the removed component is to be re-installed.

1.10.E. Label room sensors relating to terminal box or valves with nameplates.

1.10.F. Manufacturer’s nameplates and UL or CSA labels are to be visible and legible after equipment is installed.

23 09 23.11 Control Valves

1. Actuators
   1.1. Shall be connected to the valve with adapters approved by the actuator manufacturer.

23 09 23.12 Control Dampers

1. Electric Actuators
   1.1. When spring return actuators are used on normally closed dampers, the seals shall be compressed when the dampers have been closed by the actuator.
   1.2. The total damper area operated by an actuator shall not exceed 80% of the manufacturer’s maximum area rating. Provide at least one actuator for each damper section. Each damper actuator shall not power more than 20 square feet of damper area.
   1.3. Use line shafting or shaft couplings (jackshafting) in lieu of blade-to-blade linkages or shaft coupling when driving axially aligned damper sections.

2. Pneumatic Actuators
   2.1. Where two or more pneumatic damper actuators are installed for interrelated operation in unison, such as dampers used for mixing, provide the dampers with a positive pilot...
positioning device. The positive pilot positioning device shall be directly mounted to the pneumatic damper actuator and have pressure gauges for supply input and output pressures.

23 09 23.13 Energy Meters  
23 09 23.14 Flow Instruments  
23 09 23.16 Gas Instruments  
23 09 23.17 Level Instruments  
23 09 23.18 Leak Detection Instruments  
23 09 23.19 Moisture Instruments  
23 09 23.21 Motion Instruments  
23 09 23.22 Position Instruments  
23 09 23.23 Pressure Instruments  
23 09 23.24 Speed Instruments  
23 09 23.27 Temperature Instruments  
23 09 23.33 Vibration Instruments  
23 09 23.43 Weather Stations  
23 09 33 Electric and Electronic Control System for HVAC  
23 09 43 Pneumatic Control System for HVAC

1.  General  
1.1. Pneumatic lines shall be installed such that they are not exposed to outside air temperatures.  
1.2. Pneumatic lines shall be concealed except in mechanical rooms and other areas where other tubing and piping is exposed.  
1.3. All tubes and tube bundles exposed to view shall be installed neatly in lines parallel to the lines of the building.  
1.4. Tubing in mechanical/electrical spaces shall be routed so that the lines are easily traceable.  
1.5. All lines shall be purged of dirt, impurities and moisture before connecting to the control equipment.  
1.6. Air lines shall be number coded or color coded and keyed in the as-built drawings for future identification and servicing of the control system.  
1.7. Piping shall be hard-drawn, seamless copper tubing with extruded or wrought copper fittings joined with 95-5 solder.  
1.8. Polyethylene tubing and approved fittings may be specified and used subject to the following conditions  
1.8.A. All polyethylene control air tubing shall be installed in rigid conduit or metallic raceways that run parallel to the building structure.  
1.8.B. Conduit or raceways may terminate 12 inches from individual controllers. A flexible metal sheath shall protect tubing from conduit to controller.

2.  PNEUMATIC LINES IN MECHANICAL/ELECTRICAL SPACES  
2.1. In mechanical/electrical spaces, pneumatic lines shall be plastic or copper tubing.  
2.2. Horizontal and vertical runs of plastic tubing or soft copper tubing shall be installed in raceways or rigid conduit dedicated to tubing.
2.3. Dedicated raceways, conduit and hard copper tubing not installed in raceways shall be supported every 6 feet for horizontal runs and every 8 feet for vertical runs.

3. PNEUMATIC LINES EXTERNAL TO MECHANICAL/ELECTRICAL SPACES
   3.1. Pneumatic lines shall be soft copper with sweat fittings or plastic tubing in raceways not containing power wiring.
   3.2. Raceways and tubing not in raceways shall be supported every 8 feet.
   3.3. Pneumatic lines concealed in walls shall be hard-drawn copper tubing or plastic tubing in rigid conduit.
   3.4. Plastic tubing in a protective sheath, run parallel to the building lines and supported as specified, may be used above accessible ceilings and in other concealed, but accessible locations.

4. TERMINAL SINGLE LINES
   4.1. Shall be hard-drawn copper tubing, except when the run is less than 12 inches in length.
   4.2. When the length is less than 12 inches, flexible polyethylene may be used.

5. CONNECTION TO LIQUID AND STEAM LINES
   5.1. Tubing for connection of sensing elements and transmitters to liquid and steam lines shall be copper or series 300 stainless steel.
   5.2. Fittings shall be brass or stainless steel compression type fittings compatible with the tubing material.

6. CONNECTION TO DUCTWORK:
   6.1. Tubing shall be plastic.

7. TUBING IN CONCRETE
   7.1. Shall be installed in rigid conduit.
   7.2. Tubing in walls containing insulation, fill or other packing materials shall be installed in raceways dedicated to tubing.

8. CONNECTIONS TO ACTUATORS:
   8.1. Final connections to actuators shall be plastic tubing, 12 inches long and unsupported at the actuator.

9. COMPRESSED AIR STATIONS:
   9.1. The air line shall be connected to the tank with a flexible pipe connector.
1.1.E. Other building systems where a failure of multiple devices will cause significant disruption to building operations.

1.2. All process control loops for an integral system shall reside in a single controller. Examples of integral systems are:

   1.2.A. Air handling units.
   1.2.B. Packaged chillers.
   1.2.C. Chillers, excluding pumps and tower.
   1.2.D. Boilers.
23 10 00 Facility Fuel Systems

23 11 00 Facility Fuel Piping

23 11 13 Facility Fuel-Oil Piping
23 11 16 Facility Gasoline Piping
23 11 23 Facility Natural-Gas Piping
23 11 26 Facility Liquefied-Petroleum Gas Piping

23 12 00 Facility Fuel Pumps

23 12 13 Facility Fuel-Oil Pumps
23 12 16 Facility Gasoline Dispensing Pumps
23 12 26 Facility Liquefied-Petroleum Gas Pumps

23 13 00 Facility Fuel-Storage Tanks

23 13 13 Facility Underground Fuel-Oil, Storage Tanks
23 13 13.13 Double-Wall Steel, Underground Fuel-Oil, Storage Tanks
23 13 13.16 Composite, Steel, Underground Fuel-Oil, Storage Tanks
23 13 13.19 Jacketed, Steel, Underground Fuel-Oil, Storage Tanks
23 13 13.23 Glass-Fiber-Reinforced-Plastic, Underground Fuel-Oil, Storage Tanks
23 13 13.33 Fuel-Oil Storage Tank Pumps
23 13 23 Facility Aboveground Fuel-Oil, Storage Tanks
23 13 23.13 Vertical, Steel, Aboveground Fuel-Oil, Storage Tanks
23 13 23.16 Horizontal, Steel, Aboveground Fuel-Oil, Storage Tanks
23 13 23.19 Containment-Dike, Steel, Aboveground Fuel-Oil, Storage Tanks
23 13 23.23 Insulated, Steel, Aboveground Fuel-Oil, Storage Tanks
23 13 23.26 Concrete-Vaulted, Steel, Aboveground Fuel-Oil, Storage Tanks
23 13 26 Facility Aboveground Liquefied-Petroleum Gas Storage Tanks
23 20 00  HVAC Piping and Pumps

1. General
   1.1. Equipment and System Cleaning:
      1.1.A. After hydrostatic tests and prior to operating tests, equipment, including but not necessarily limited to chillers, cooling towers, boilers, heat exchangers and all piping shall be thoroughly flushed, cleaned, and disinfected.
      1.1.A.1. The contractor is responsible for removing and disposing of any cleaning water that cannot be discharged to the city sewer system.
      1.1.B. The A/E shall specify that a 3rd party water treatment firm will be hired by the contractor to oversee the flushing and cleaning process.
      1.1.C. The 3rd party water treatment firm will issue a report to the Owner that documents the cleaning and disinfecting chemicals used. The report will also document the water treatment chemicals used and the final state of the piping system water chemistry.
      1.1.D. All hydronic piping systems shall be cleaned and flushed until the following conditions are met:
         1.1.D.1. Turbidity < 1 NTU above domestic water source level
         1.1.D.2. Iron (Fe) < 1 PPM
      1.1.E. Prior to substantial completion, all hydronic piping systems shall be chemically treated for the application. Contact FM for the current requirements of each system type.

Owners Intent: A third party water treatment firm must verify that hydronic piping has been adequately flushed and cleaned. Contractors may use any qualified third party to perform this verification. Contractors may, but are not required to use any of the water treatment firms that currently have a contract with the University.

For independent closed loop systems (e.g. building heating hot water) the contractor is expected to provide the initial water treatment after the system has been flushed and cleaned. This initial treatment should be compatible with similar systems on campus. The contractor should contact Facilities Management for information about current water treatment plans for each system type.

For piping loops that will be connected to existing building systems (e.g. an extension of a hydronic heating system into a new addition or remodel) the expectation is that the final combined system will be properly treated at substantial completion. This will generally involve circulating water through the entire combined system for a period of time and then treating the entire system as needed to obtain the desired water chemistry.

For piping loops that will be connected to a district chilled water system the expectation is that the new piping will be flushed and cleaned and then refilled with city water. Because the district system is very large compared to most building systems it is acceptable to allow the district water to mix with the city water in the building system. The University manages the district
water chemistry and will make adjustments as needed to compensate for the introduction of city water.

23 21 00  Hydronic Piping and Pumps

23 21 13 Hydronic Piping

1. General
   1.1. **PROHIBITED**: Direct-buried steam and steam condensate pipe

2. Tie-ins to New or Existing Mains
   2.1. **Prohibited**: Stub-ins when connecting to new or existing mains.
   2.2. Branch lines up to and including 10 inches in diameter that are at least two sizes smaller than the mains may be tied-in using reducing tees or weld-o-lets.
   2.3. Branch sizes greater than 10 inches in diameter must be tied-in with tees.
   2.4. Connections to piping in University tunnels shall have appropriate offsets to maintain pipe stress within acceptable limits.

3. Steel Pipe
   3.1. General
       3.1.A. Galvanized steel pipe shall be at least minimum standard weight.
       3.1.B. Standard weight and extra heavy black steel pipe shall be A53B, A106B, A120 or A135 welded or seamless construction as indicated for specific applications.
       3.1.C. Steam pipe shall be minimum standard weight ASTM A53B seamless or A106B.
       3.1.D. Steam condensate pipe shall be minimum Schedule 80 ASTM A53B seamless or A106B.

4. Copper Pipe
   4.1. **Prohibited**: Soft annealed copper.
   4.2. Type ‘K’ for gas and HWS&R under slabs serving around entrance ways. Type ‘L’ copper pipe for all piping within the building.

5. Plastic Pipe
   5.1. **Prohibited**: Plastic piping is not allowed in the hydronic systems.
   5.2. HDPE: is approved for underground chilled water systems.
   5.3. PEX: PEX piping is not allowed.

6. Glass Pipe:
   6.1. Glass piping should be used only with the express approval of the Owner.
   6.2. Existing glass pipe within the project area should be removed and replaced with an appropriate plastic pipe alternative.

23 21 13.13 Underground Hydronic Piping
23 21 13.23 Aboveground Hydronic Piping
23 21 13.33 Ground-Loop Heat-Pump Piping
23 21 16 Hydronic Piping Specialties

1. Pipe Fittings
   1.1. General Requirement
1.1.A. **Prohibited:** Couplings normally furnished with lengths of pipe used to install threaded piping.

1.1.B. Standard weight steel, malleable or drainage couplings shall be used according to application.

1.1.C. Specify extruded or wrought copper fittings in copper piping systems.

1.1.D. Specify 300# black or galvanized steel unions for steel piping systems.

1.1.E. Specify butt-weld or socket-weld fittings consistent with the piping system. For example, specify standard weight fittings with standard weight pipe. Welding flanges shall be weld neck or slip-on with pressure to match the system as required.

1.1.F. For takeoffs from black steel piping mains and headers 2-1/2 inches and larger, where pipe reduction is two sizes or more, specify weld-o-lets or sock-o-lets in lieu of reducing weld tees subject to field inspection prior to connection to branch lines. Manifolds must use reducing weld tees.

1.1.G. Specify isolating/dielectric unions or isolating/dielectric flanges wherever iron and copper or iron and brass piping and equipment are used together in a water piping system. The A/E shall clearly show on drawings all locations for isolating/dielectric unions.

1.2. **Low Pressure Steam Condensate**

1.2.A. Fittings that are 2 inches and smaller shall be ANSI Class 150, black malleable iron threaded. Fittings more than 2 inches shall be butt weld.

1.2.B. Unions that are 2 inches and smaller shall be ANSI Class 150, black malleable iron threaded.

1.2.C. Flanges shall be ANSI Class 150, forged steel weld neck with B7 studs and A194 extra heavy hex nuts.

1.3. **High Pressure Steam Condensate**

1.3.A. Fittings that are 2 inches and smaller shall be ANSI Class 3000, forged steel, socket weld. Fittings more than 2 inches shall be butt or socket weld.

1.3.B. Unions that are 2 inches and smaller shall be ANSI Class 3000, forged steel, socket weld.

1.3.C. Flanges shall be ANSI Class 300, forged steel weld neck with B7 studs and A194 extra heavy nuts.

1.4. **Strainers/Steam and Hydronic Systems**

1.4.A. “Y” type strainers with screens shall be installed ahead of all traps (except radiator traps), control valves, pressure-reducing valves and other devices where debris may cause malfunction.

1.4.B. Strainers shall be installed so the equipment isolating valves also isolate the strainers.

1.4.C. Strainers for low-pressure steam shall be ANSI Class 150, and shall have brass screen.

   1.4.C.1. Strainers for low-pressure steam smaller than 3 inches shall have blow down plugs installed with Teflon pipe dope.

   1.4.C.2. Strainers for low-pressure steam 3 inches and larger shall be complete with valve, nipple and pipe cup on blow down.

1.4.D. Strainers for high-pressure steam above 15 psig shall have 16-gauge mesh, stainless steel screen with forged steel bodies, ANSI Class 300 with blow down valves.

2. **Hot Water Relief Valves**
2.1. The A/E shall provide BTU-rated, ASME-approved hot water relief valves where necessary.

2.2. Relief valves on hot water systems shall be sized to the pressure of the system and the head of the pump. The valves also shall have a sufficient margin of safety in accordance with ASME code.

23 21 23 Hydronic Pumps

1. General Requirements for Chilled Water Pumping Systems
   1.1. Each condenser water-pumping system shall be designed with a stand-by pump.
   1.2. Each primary and secondary system shall have a stand-by pump.

2. Chilled Water Pumping System Control Sequence
   2.1. Secondary Chilled Water Pump Control: The chiller controls shall regulate when the secondary chilled water pumps start and stop. The chiller plant controls shall modulate the VFDs for the secondary pumps to maintain the pressure differential between the secondary supply and return mains. The chiller controls shall monitor the secondary differential pressure sensors where the secondary/tertiary connects at each building. The chiller controls shall select the pressure sensor with the lowest reading and modulate the VFD to maintain the differential pressure set point.

2.2. Tertiary Chilled Water Pump Control
   2.2.A. The building control system, rather than the chiller cluster controls, shall start and stop the tertiary chilled water pumps. The building control system also shall modulate the VFD to maintain a differential between the building supply and return mains. The differential pressure sensors shall be located where it is most difficult hydraulically to get water to chilled water coils. Some buildings may require more than one differential pressure sensor depending on the piping layout.

3. Condenser Water Pumping System Control Sequence:
   3.1. The chiller panel shall start the condenser water pumping system and run as long as the chiller panel is energized.

23 21 23.13 In-Line Centrifugal Hydronic Pumps
23 21 23.16 Base-Mounted, Centrifugal Hydronic Pumps
23 21 23.19 Vertical-Mounted, Double-Suction Centrifugal Hydronic Pumps
23 21 23.23 Vertical-Turbine Hydronic Pumps
23 21 29 Automatic Condensate Pump Units

23 22 00 Steam and Condensate Piping and Pumps

1. Steam Piping Systems
   1.1. This section pertains to standards for designing and testing campus steam distribution and steam condensate piping systems, and connecting to University buildings. The campus steam distribution system extends from the district meters located near the heating plants up to and including the gate valves immediately upstream of the building steam pressure reducing stations. The campus steam condensate piping system extends from the district meters located near the heating plants up to the building condensate meters.
1.2. The methods of design and construction shall be in accordance with the State of Minnesota Code for High Pressure Piping, Chapter 5230, and ANSI B31.1 for high-pressure piping, and shall be in accordance with the Minnesota Department of Administration State Building Code, Mechanical Systems, Chapter 1345 for low-pressure piping.

1.3. Whenever University Standards differ from applicable codes, the more stringent requirement shall be followed. In case of dispute, the authority having jurisdiction is the high-pressure piping inspector, who is employed by the Minnesota Department of Labor and Industry for high-pressure steam. The University Building Code official is the authority having jurisdiction for low-pressure steam condensate.

1.4. High-pressure steam systems and components shall be designed for 250 psig at 500 degrees F for Minneapolis and St. Paul.

1.5. A sample of high-pressure steam system welds shall be x-rayed before hydrostatic testing. The engineer and owner shall determine the sample number. The contractor shall notify the University and any legal officers at least 24 hours prior to hydrostatic testing. The university shall inspect the piping systems prior to testing, and shall forward a punch list of items to be corrected, if necessary, to the contractor. The contractor shall address the punch list items, forward a written report to the university that indicates that all items on the punch list have been satisfied and request permission from the university to proceed with the hydrostatic testing. Upon receiving permission, the contractor shall test the system. A hydrostatic test shall be conducted on campus steam condensate return piping at 1-1/2 times the design pressure or 150 psig, whichever is greater, prior to the installation of any insulating material. Design pressure for high-pressure steam distribution systems shall be considered to be 250 psig. Upon passing the hydrostatic test, the piping insulation shall be applied. The contractor shall remove any temporary drains and/or vents.

1.6. Startup: When the contractor is finished with construction, testing and completing the punch list, university personnel shall start the system. The contractor shall have one or more pipefitters in attendance during system startup. Once the system is up to full pressure and flow, the university and the contractor’s pipefitters shall inspect the system for leaks, excessive movement and proper support. If required, the university shall shut down the system for the contractor to repair/revise the system. Then the startup procedure shall be repeated until the university accepts the system as-built.

1.7. Documentation: The design specifications shall call for the contractor to furnish the proper documentation to Steam Utilities on engineered items such as pumps, valves and piping expansion/contraction parts that include expansion joints, controls and meters. Documentation shall include assembly drawings, parts lists, calibration certificates, wiring diagrams, maintenance instructions and recommended spare parts lists.

2. Flash Tanks

2.1. Typical flash tank installation shall be per the sketch in Figure 1.
3. Steam Pressure Reducing Station
   3.1. Steam pressure-reducing stations shall have duplex pressure reducing valves (PRV) in parallel with a globe valve by-pass.
   3.1.A. One PRV shall be sized for 1/3 of the maximum load. The other PRV shall be sized for 2/3 of the maximum load.
   3.1.B. The by-pass shall be designed to facilitate inspection of the pressure regulator without interrupting service.
   3.1.C. The control valve shall be single-seated.
   3.1.D. Pressure-reducing valves shall be pilot-operated, Spence ED or the U of M approved equal.
   3.1.D.1. Provide an isolation valve on each pilot line.
   3.2. The pressure-reducing station shall be vented to the outside through a pressure-relief valve.
   3.2.A. Follow B31.1 design requirements with non-mandatory appendix II for the design of safety valve installations.
   3.3. The A/E shall specify a strainer ahead of each pressure-reducing valve. Each pressure-reducing valve shall be isolated by gate valves at both ends, and be rated for the higher pressure. Isolation valves shall be the same size as the pipe connected to header.
   3.4. The A/E shall provide a detail showing piping and valve arrangement, and including headroom above the regulator and clearance under the regulator for maintenance and replacement.
   3.5. Each header shall have a drip leg with valve and trap to be gravity drained to condensate system.
   3.6. Typical steam PRV station installation shall be per Figure 2.
   3.7. Steam pipes that require welding shall be accomplished in the same method as identified in the following ASME welding procedure specification.
4. Steam Traps
   4.1. Typical steam trap installations shall be per the sketch shown in Figure 3. High-pressure steam traps shall be Plenty Velan Model 250 or university-approved equal.

4.2. Traps
   4.2.A. All traps shall have tags showing the model number and orifice size.
   4.2.B. Prohibited: Cast-iron traps on high-pressure steam systems.
   4.2.C. Thread O Let connections to steam mains on high-pressure steam systems.
   4.2.D. All steam mains shall have properly designed and detailed drip trap assemblies shown with a maximum spacing between drip trap assemblies to be 200 linear feet. Steam mains shall be dripped whenever the piping makes elevation changes. Consideration shall be given to looped mains because flow may be bi-directional.
   4.2.E. Maintain 4 inches minimum clearance between threaded dirt leg cap and any obstruction.
   4.2.F. Low Pressure Steam Systems
   4.2.F.1. Specify Armstrong Series 880 or university-approved equal inverted bucket traps or F & T traps with integral strainers and thermic vent (in all cases) such as drip lines, unit heaters and heating coils where radiator
thermostatic traps are too small. Install in all instances except radiation. A safety factor of two shall be used when determining trap size.

4.2.F.2. Radiator traps shall be thermostatic, siphon multiple bellows type with replaceable stainless steel seats and discs. The traps shall close upon failure.

4.2.G. High Pressure Steam Systems
4.2.G.1. Traps shall be stacked bimetallic thermostatic with a minimum orifice size of 3/8 inches. Specify Plenty Velan type TS thermostatic steam trap or university-approved equal.

4.2.G.2. Every trap assembly shall be designed for ease of trap testing by including a test valve after the check valve

**Figure 3. Typical Steam Trap Piping**

---

23 22 13 Steam and Condensate Heating Piping
### Table 4. Steam Condensate Piping Standard

**System:** Low Pressure Condensate Piping  
**Area of Use:** Low pressure condensate in building and district energy distribution systems within the rated design pressure and temperature.  
**Design Pressure:** 30 PSIG  
**Design Temperature:** 250°F

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<th>Piping and Components</th>
<th>Item</th>
<th>Size</th>
<th>Ends</th>
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<th>Grade</th>
<th>Sched/Rating</th>
<th>Spec</th>
<th>Description</th>
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<td>XS</td>
<td>B36.10</td>
<td>Type S</td>
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<td>Over 2”</td>
<td>Butt Weld</td>
<td>A106 or A53</td>
<td>B</td>
<td>XS</td>
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<td>Type S</td>
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23 22 13.13 Underground Steam and Condensate Heating Piping
23 22 13.23 Aboveground Steam and Condensate Heating Piping
23 22 16 Steam and Condensate Heating Piping Specialties
23 22 23 Steam Condensate Pumps
23 22 23.13 Electric-Driven Steam Condensate Pumps
23 22 23.23 Pressure-Powered Steam Condensate Pumps

23 23 00 Refrigerant Piping
23 23 13 Refrigerant Piping Valves
23 23 16 Refrigerant Piping Specialties
23 23 19 Refrigerant Safety Relief Valve Discharge Piping
23 23 23 Refrigerants

23 24 00 Internal-Combustion Engine Piping
23 24 13 Internal-Combustion Engine Remote-Radiator Coolant Piping
23 24 16 Internal-Combustion Engine Exhaust Piping

23 25 00 HVAC Water Treatment
1. Chemical Treatment for Open Loop Systems
   1.1. **Prohibited:** Chemicals with powder and pellets.
   1.2. The A/E shall specify a chemical water treatment system for each open loop. The system specified shall include equipment, piping, tubing, inter-connecting components and electrical controls as detailed in this section.
   1.3. The minimum system requirements for open loops shall include all controls, tanks, pumps, sensors, probes, analyzers, and valves necessary to perform and service the following water treatment functions:
      1.3.A. Automatic control of cooling tower bleed off
      1.3.B. Automatic control of chemical treatment for scale and corrosion
      1.3.C. Automatic control of biocide treatment
   1.4. The A/E shall specify a water meter with a contacting head in the make up line and a solenoid valve to measure water usage and control chemical feed in the cooling tower. Provide a Y strainer upstream from water meter and solenoid valve. It shall be supplied and positioned so water reading can be done remotely. Local authorities shall approve the water meter. Specify Master Meters or university-approved equal.
   1.5. The A/E shall specify a water meter with a solenoid valve in the cooling tower blow down line to measure water discharge. The specified meter shall comply with local minimum code requirements. Provide a Y strainer upstream from the water meter and solenoid valve. The meter must be in a position and location so it can be easily read from the floor. It also shall be supplied so water reading can be done remotely. Local authorities shall approve the water meter. Specify Master Meters or university-approved equal.
   1.6. The A/E shall specify a microprocessor-based conductivity controller that controls bleed off, feeds the corrosion and scale inhibitor via a water meter in the make-up water line that activates a pulse timer, alternates with a dual 28-day biocide program
and handles two water meters. The recommended water meter manufacturer is Pulsatrol Plus Series Model MCT210BCF or university-approved equal.

1.7. The A/E shall specify the liquid diaphragm metering pumps with adjustable stroke and speed to feed biocides and the corrosion and scale inhibitor. The pumps must be able to handle the design pressure and gpm for the specified system. The recommended manufacturer is LMI or university-approved equal.

1.8. A corporation stop injector shall be provided at each point of injection in the system.

1.9. The rack shall include a strainer, shut-off valves and a flow-regulating orifice that are designed to produce 5 gpm.

1.10. The A/E shall specify that once the cooling tower is turned over to the university, the university is responsible for the chemical treatment of the system. No chemical treatment contract with the contractor or with an outside vendor is to be specified for the warranty period. The university shall purchase all chemicals necessary for the chemical treatment of the system.

1.11. The A/E shall specify that the water treatment supplier at the university is responsible for cleaning and disinfecting open loop systems. The supplier shall clean and disinfect them before they become operational. The supplier shall meet the minimum requirements that DEHS defines for disinfecting. This specification shall be included in the contractor's bid, and this activity must be coordinated with the applicable zone.

2. Chemical Treatment for Closed Loop Systems

2.1. The A/E shall specify the necessary equipment for the chemical treatment of the closed loop systems based on the following requirements:

2.1.A. The university shall purchase all chemicals necessary for the chemical treatment of the system.

2.1.B. Each heating and cooling closed loop system shall be provided with a one-shot feeder with an air-release valve, sized for the system to be served and rated for a pressure of 300 psig. The minimum size of the feeder shall be 5 gallons.

2.1.C. Propylene or ethylene glycol can be used where systems are susceptible to freezing, provided the toxicity of the solution is consistent with safety regulations. The minimum concentration of any glycol solution shall be 20 percent. There can be no connections between systems with a glycol/water mixture and systems with only water, which includes systems used as stand by. All glycol provided for the system shall be HVAC grade, Dowtherm, Dowfrost or university-approved equal.
Figure 4. ASME Welding Procedure Specification (Page 1)
### Figure 5. ASME Welding Procedure Specification (Page 2)

#### QW-403 Procedure Qualification Record (PQR)

**Company Name:** UNIVERSITY OF MINNESOTA  
**Procedure Qualification Record No.:** 1-1  
**Weld No.:** 1  
**Welding Procedure:** SMAW  
**Type:** Manual, Automatic, Semi-Automatic  
**Welding Process:** Manual

#### JOINTS (QW-402)

**Single V Butt Joint**  
**Groove Design of Test Coupon**

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<td></td>
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<td>other</td>
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Owner’s Intent Narrative

Overview
Air distribution systems should be designed to support high ventilation effectiveness, reduce energy consumption, reduce noise, provide adequate filtration for occupied spaces, and maintain the proper outdoor air ventilation rates under all operating conditions. Final design choices are highly dependent on the application and the system type.

The preferred air distribution concept is a fully pressure independent system. Airflow should be controlled directly and maintained at setpoint regardless of duct pressure variations. Airflow setpoints may be held constant or may vary, depending on the application, but the system will operate with pressure independent airflow control. Pressure independent airflow control applies to supply, return, and exhaust applications.

Distribution Systems
Where a pressure independent control device (e.g. VAV box) serves multiple spaces the system can be balanced with fixed dampers (hard balanced) downstream of the control device. The number of separate spaces that can be served by a single air control device will depend on the application. The Owner will provide project specific guidance regarding the number of spaces that can be combined into a single ventilation zone.

Return air systems shall be pressure independent and shall control the return airflow dynamically based on the supply and exhaust airflows and pressure requirements of a particular air zone. Return air systems may be fully or partially ducted. For partially ducted systems it is acceptable to transfer air out of spaces to areas where it can enter the return air system if space pressure control requirements can be met. The return air system shall be configured with a sufficient number of zones to allow for proper space pressure control but at a minimum each floor shall have at least one zone.

For example. In an office application where multiple supply VAV boxes serve multiple rooms, it is acceptable to allow the return air to transfer out of the rooms to a plenum or other location where a return air VAV box removes the air and returns it to the AHU. The transfer method will depend on the application but could include transfer via doors, transfer openings in the ceiling (e.g. grills open to the plenum) or ducted transfers (e.g. lined transfer duct for sound mitigation). The return VAV could have a screened inlet above the ceiling or it could be ducted to a grill located in a hallway or wherever the office air transfers to. The return VAV setpoint would be the sum of the supply flows in that zone, less any local exhaust (restroom, etc.), and plus or minus any space pressurization air. Generally, the minimum number of return zones per floor will be the same as the number of smoke partitions on that floor. Additional zones may be needed for space pressure control depending on the application.
The goal of the return system is to facilitate the free movement of ventilation air into and out of the various spaces. Not all return air schemes will be appropriate for all supply system types. Of particular concern are systems that operate at low duct static pressure levels where changes in room pressures can significantly impact the flow of supply, return, or exhaust air.

For example. Exfiltration schemes work best when the supply system operates with relatively high duct static pressures. Rooms with dedicated VAV boxes or spaces served by active chilled beams (ACB) usually need duct static pressures that exceed 0.5” w.c. to operate. At this level of duct pressure small changes in room pressure will not significantly impact the amount of supply air that enters the space. For these applications it is possible to use a wide variety of transfer methods including reasonably sized door undercuts.

Systems operating with lower duct static pressures are more susceptible to the effects of room pressure. Large constant volume systems or VAV systems where VAV boxes serve extensive downstream distribution ductwork may operate with supply duct pressures that are as low as 0.1” w.c. For these types of systems a small change in room pressure can change the amount of supply air by a significant amount. For these types of applications the return system must be sized to prevent high or low room pressures and may require a partial or even fully ducted configuration.

For pressure independent return air systems, the return fans in AHUs should control to duct static pressure. Flow tracking, speed tracking, or building pressure control schemes are not needed or desired for return fan control when connected to a pressure independent system. Building pressure control is accomplished by adjusting the return flow setpoints at the room or floor level. Single zone systems or simple VAV systems that serve a single floor may be allowed to use airflow tracking or building pressure to control return and relief fans if approved by the Owner.

1. General
   1.1. Design supply and return air systems to minimize short-circuiting supply air to the return air system. The A/E shall include a schedule of ventilation efficiency on the contract documents for rooms occupied by more than five people. Ventilation efficiency shall be no less than 75 percent. Ventilation efficiency shall be calculated in accordance with the most recent edition of ASHRAE 62.1. Refer to Program Information/Requirements, Basic Design Requirements to determine proper design in regards to air regulations and emissions.
   1.2. Specify and witness duct leakage tests on supply and exhaust systems. The design engineer and the university shall determine the frequency and extent of testing.
      1.2.A. All concealed ductwork shall be tested. Tests shall be completed and approved prior to concealing the ductwork.
      1.2.B. All fume hood exhaust ductwork shall be tested.
   1.3. To improve rigidity and tightness of construction, fabricate ductwork in accordance with the most recent edition of the SMACNA standards.
1.4. The A/E shall coordinate the location, size and type of louvers, roof intake and relief hoods. The size of each intake shall be based upon the manufacturer's criteria for eliminating rain, snow or carry over into the air-handling system.

2. Laboratory Ventilation Systems

2.1. Exhaust Systems

2.1.A. Laboratory exhaust systems shall be designed for variable flow. Constant speed fans and manual (hard) balanced designs are prohibited.

2.1.B. **Prohibited:** Modulating fume hood flows to provide capacity control for heating and cooling. Fume hood flows shall be controlled solely based on the needs of the hood. If additional ventilation, heating, or cooling airflow is required the designer shall include general exhaust for that purpose.

2.1.C. **Prohibited:** Positive pressure ductwork for class 4 exhaust air installed inside the building.

2.1.D. **Prohibited:** Fume exhaust fan installation indoors. Contact DEHS and Energy Management for existing facilities or prior to submitting an exception request for new construction.

2.1.E. **Prohibited:** Square-to-round fabric transitions.

2.1.F. **Prohibited:** Radial blade and paddlewheel type centrifugal fans for fume exhaust applications.

2.1.G. Fans for fume exhaust applications shall be specified with chemical resistant materials and/or coatings. Designers shall submit the proposed fan material specification to the Owner for approval.

2.1.H. If flammable gas, vapor, or combustible dust is anticipated to be present in exhaust in concentrations above 20% of the lower flammable limit, exhaust fans shall be constructed as recommended by Air Movement and Control Association International (AMCA) 99-0401, “Classification for Spark Resistant Construction.”

2.1.I. Exhaust stack design shall be submitted to DEHS and Energy Management for review no later than the end of schematic design. Stack design shall consider:

2.1.I.1. Stack discharge velocity shall be minimized to reduce energy consumption and noise generation. Stack location, height, and discharge velocity will be selected on a project specific basis using currently accepted Code and industry best practices.

2.1.J. Prior to modeling (wind tunnel or CFD) or site specific calculations, the designers shall assume the following exhaust stack requirements:

2.1.J.1. Stack-design and discharge velocity shall distribute contaminants outside the eddy current envelope of the building.

2.1.J.2. On structures with roof areas at more than one level, discharge ducts within 30 feet of a higher level shall terminate at a point at least 10 feet above the elevation of the higher level and any air intakes.

2.1.J.3. Cluster discharge ductwork when designing exhaust ductwork in close proximity in new and existing buildings.

2.1.J.4. Maintain the maximum distance from fresh air intakes on the building and on adjacent buildings. Maintain at least 100 feet between fume hood exhausts and fresh air intakes.

2.2. Fume Hoods
2.2.A. Fume hoods in research laboratories much comply with ANSI/AIHA Z9.5 Class A performance standards.

2.2.B. Fume hoods shall be variable flow type and must be controlled via pressure independent devices (e.g. air valves). Each hood shall have its own flow control device.

2.2.C. Fume hoods shall use sash position and measured airflow to maintain face velocity or minimum hood flows. Pressure based flow monitoring is not allowed for variable volume applications.

2.2.D. Fume hood controls shall include an emergency override mode that can be initiated from the front of the hood. When active, the emergency override will produce an audible alert and the hood exhaust flow will operate at full design flow regardless of sash position.

2.2.E. Fume hood controls shall include a local audible alarm. The alarm shall be configured for the following alarms:

   2.2.E.1. Low face velocity. The alarm will sound if the face velocity is 20% below the design face velocity for the hood. Alarm time delay is 20 seconds.

   2.2.E.2. High face velocity. The alarm will sound if the face velocity is 20% above the design face velocity for the hood. Alarm time delay is 20 seconds.

   2.2.E.2.a. When the hood is operating at minimum flow (sash closed) the high face velocity alarm will be disabled.

   2.2.E.3. Minimum flow. The alarm will sound when the hood flow falls more than 20% below the design minimum flow. Alarm time delay is 20 seconds.

2.2.F. Face velocity shall be chosen by the designer based on the application. Face velocities shall not be less than 80 fpm and not more than 150 fpm.

   2.2.F.1. The designer will submit a narrative prior to schematic design describing the basis for the face velocity selection.

2.2.G. Hoods and BSCs shall be located in distal corners of the laboratory space when possible and away from doors or other high traffic areas. The intent is to isolate the hoods and BSCs from the turbulence caused by people and material movement in the space and to avoid blocking or restricting egress pathways in the event of a spill in or adjacent to a hood or BSC.

2.3. Radioisotope Fume Hoods

   2.3.A. An exhaust filter enclosure with a pre-filter and a HEPA and/or charcoal filter usually is not required for radioisotope hoods. If required, however, the enclosure must meet the following specifications:

      2.3.A.1. PROHIBITED: Proprietary or custom-sized filters and pre-filters.

      2.3.A.2. The filter enclosure must be airtight and constructed of stainless steel.

      2.3.A.3. The filter enclosure shall be easily accessible from the outside of the hood. The filter enclosure shall provide bag-in/bag-out of filters, so the maintenance staff is not exposed to collected material.

      2.3.A.4. Provide an indicator on hoods with a filter enclosure that is clearly visible and indicates when the pressure drops across the filter.

      2.3.A.5. Use a standard-size pre-filter and charcoal and/or HEPA filter on the filter enclosure.

2.3.A.7. Fume hoods provided with filter enclosures always shall be individually ducted.

2.4. Ducted Biological Safety Cabinets (BSCs)
   2.4.A. **Prohibited**: Pressurized gas, including natural gas, must not be piped to a BSC.
   2.4.B. Layouts for BSCs in lab spaces shall follow the requirements for fume hoods to avoid cross drafts and turbulence.
   2.4.C. BSCs require a manually actuated bubble-tight damper in the exhaust to allow for complete exhaust isolation for gas-phase decontamination.
   2.4.D. Laminar flow clean air devices such as clean benches shall comply with Institute of Environmental Sciences (IES) Standard IES-RP-CC002.

2.5. Laboratory Supply Air System
   2.5.A. **Prohibited**: Fume hoods with auxiliary supply air.
   2.5.B. Laboratory supply air shall track the exhaust air (supply tracks exhaust) to maintain the required airflow differentials.
   2.5.C. Supply air distribution shall be designed to avoid excessive cross drafts and turbulence in the vicinity of all hoods and workbench spaces. The intent is to manage supply air turbulence via placement of the supply diffusers before relying on laminar diffusers or similar products.
**HVAC Ducts and Casings**

1. **Minimum Supply Duct Size:** Ducts shall be minimum 6 inches by 6 inches or 6 inches round unless University-approved.
2. **Maximum aspect ratio for rectangular or oval duct is 2:1 unless approved by Owner.**
3. **Prohibited:** Pipe or any other type of obstruction passing through a duct.
4. **Duct Hangers and Supports**
   - **4.1.** All ventilation ducts and related piping shall be independently supported from the building structure. Cable hanging systems are approved as long as these are used per manufacturer’s installation recommendations.
   - **4.2.** Horizontal ducts 48 inches or wider shall be rigidly and securely supported with angle-iron trapeze hangers under the duct, according to SMACNA standards.
   - **4.3.** Structural members shall support all vertical ductwork at each floor.
   - **4.4.** All fastenings and hardware for galvanized ductwork and sheet metal shall be cadmium-plated.

**23 31 13 Metal Ducts**

1. **General use ductwork shall be fabricated from G-90 coated galvanized steel.**
2. **Fully welded duct is required for all positive pressure hazardous exhaust applications (e.g. fume hoods).**

*Positive pressure hazardous exhaust ductwork should not be located within the occupied portions of the building or the shafts and chases that adjoin the occupied spaces. Hazardous exhaust fans should be located on the roof or, if necessary, within a ventilated mechanical penthouse.*

3. **Ductwork for applications where internal condensation is expected (e.g. cage wash exhaust, dish room exhaust, etc.) shall be fully welded stainless steel. A condensate management plan shall be developed. The plan shall be reviewed and approved by the Owner.**
4. **Non-welded stainless steel ductwork may be used for negative pressure exhaust applications provided it is compatible with the building fire/smoke separation strategy. Confirm with Owner which applications will require welded ductwork.**
5. **Gauge stickers or stamps shall be provided on each section of duct. In lieu of stickers, gauge can be printed on the ductwork.**
6. **Fire-stopping/sealant shall be installed in accordance with the requirements of Division 7 - Thermal and Moisture Protection.**
7. **The A/E shall coordinate the sealing of floor and wall penetrations.**

**23 31 13.13 Rectangular Metal Ducts**

**23 31 13.16 Round and Flat-Oval Spiral Ducts**

**23 31 13.19 Metal Duct Fittings**

1. **Duct connections shall be made with 30-degree to 45-degree takeoffs in the direction of airflow.**
2. Provide a minimum of three duct diameters from fan inlet or discharge before transition or elbows.

23 31 16 Nonmetal Ducts
23 31 16.13 Fibrous-Glass Ducts
23 31 16.16 Thermoset Fiberglass-Reinforced Plastic Ducts
23 31 16.19 PVC Ducts
23 31 16.26 Concrete Ducts
23 31 19 HVAC Casings

23 32 00 Air Plenums and Chases
23 32 13 Fabricated, Metal Air Plenums

1. Each intake air plenum shall be sized based on the manufacturer’s criteria for eliminating rain and snow from penetrating or carrying over into the air-handling system.

23 32 33 Air-Distribution Ceiling Plenums
23 32 36 Air-Distribution Floor Plenums
23 32 39 Air-Distribution Wall Plenums
23 32 43 Air-Distribution Chases Formed by General Construction
23 32 48 Acoustical Air Plenums

23 33 00 Air Duct Accessories
23 33 13 Dampers
23 33 13.13 Volume-Control Dampers

1. General
   1.1. Damper construction shall be per most current SMACNA standards and shall comply with the maximum leakage per MN Energy Code.

2. Manual Balance Dampers
   2.1. Specify and show all dampers required for proper balance of air on drawings.
   2.2. Balance dampers are not allowed prior to a pressure independent flow control device (e.g. VAV box).
       2.2.A. A/E shall specify the removal of all existing manual dampers in ducts that serve new pressure independent flow control devices.
   2.3. Dampers come with a locking quadrant that is set, marked and locked in position at the time of final balancing.

3. Motorized Dampers:
   3.1. Outside Air Dampers
       3.1.A. All outside air dampers shall be ultra-low leak, thermally insulated steel airfoil blade design with flexible extruded silicone side seals and blade gaskets.
3.1.B. Dampers shall be AMCA classification 1 or shall comply with current MN Energy Code, whichever results in a lower leakage rate in the closed position.

23 33 13.16 Fire Dampers

1. All fire dampers shall be designed with access panels adjacent to the dampers. The dampers shall be sized and located to allow the fire dampers to be reset through the access panels.
   1.1. Access doors with 1/4-inch wire glass panels shall be installed so the damper position can be inspected without opening the access panel. Refer to 23 33 33 Duct-Mounting Access Doors for size and construction requirements.
   1.2. The A/E shall require field-testing of all smoke and fire damper installations in the presence of the contractor.
   1.3. Ducts shall be increased in size to accommodate fire and smoke dampers that are a minimum size of 12 inches by 8 inches.

23 33 13.19 Smoke-Control Dampers

1. Smoke dampers or combination smoke/fire dampers shall have electric actuators, and of multiple-blade type that meets the requirements of UL555 and UL555S.
   1.1. Damper operation shall be a controlled-closure type that closes in no less than seven seconds and no more than 15 seconds.
2. All smoke dampers shall be designed with access panels adjacent to the dampers. The dampers shall be sized and located to allow the dampers to be reset through the access panels.
   2.1. Access doors with 1/4-inch wire glass panels shall be installed so the damper position can be inspected without opening the access panel. Refer to 23 33 33 Duct-Mounting Access Doors for size and construction requirements.
   2.2. The A/E shall require field-testing of all smoke and fire damper installations in the presence of the contractor.
   2.3. Ducts shall be increased in size to accommodate fire and smoke dampers that are a minimum size of 12 inches by 8 inches.

23 33 13.23 Backdraft Dampers
23 33 19 Duct Silencers
23 33 23 Turning Vanes
23 33 33 Duct-Mounting Access Doors

1. Install access doors on mechanical and electrical devices such as coils, motorized and manual dampers, and humidifiers.
2. Access doors shall be installed in sides or bottom of duct.
   2.1. The minimum size for access doors shall be 18 inches by 16 inches. For smaller ducts, door width shall be 2 inches narrower than the ducts by 16 inches long.
   2.2. Refer to Division 13 00 30 - Food Service Construction Guide for more information regarding access doors in kitchen hood exhaust ducts.
3. Fire and smoke access doors shall be removable, have as many gaskets as necessary, and have a minimum of four cam lock closures that can be latched. 
   3.1. The doors shall be a minimum 10 inches by 16 inches.
4. Access door construction shall be per latest edition of SMACNA.
5. Coordinate mechanical access doors with architectural access panels.

23 33 38 Duct Security Bars
23 33 43 Flexible Connectors
23 33 46 Flexible Ducts

1. Flexible duct length shall not exceed 6 feet. Limit total sag to less than 1/2-inch per foot. Minimize bends in flexible duct. Limit total bends on one branch to 180 degrees. Between takeoff and termination, provide a minimum 6-inch overlap where flexible duct connects to sheet metal duct or an air distribution device. Minimum flexible duct size shall be 6 inches.

23 33 53 Duct Liners

23 34 00 HVAC Fans

23 34 13 Axial HVAC Fans
23 34 16 Centrifugal HVAC Fans
23 34 23 HVAC Power Ventilators
23 34 33 Air Curtains
23 34 39 High-Volume, Low-Speed Propeller Fans

23 35 00 Special Exhaust Systems


23 35 13 Dust Collection Systems
23 35 13.13 Sawdust Collection Systems
23 35 16 Engine Exhaust Systems
23 35 16.13 Positive-Pressure Engine Exhaust Systems
23 35 16.16 Mechanical Engine Exhaust Systems
23 35 33 Listed Kitchen Ventilation Exhaust System

1. Refer to Division 13 00 30 - Food Service Construction Guide.
23 36 00  Air Terminal Units

23 36 13 Constant-Air-Volume Units
23 36 16 Variable-Air-Volume Units

1. VAV box size shall be minimum of 6”.
2. Single duct VAV air valve/terminal units shall be compatible with the temperature controls. Refer to Division 25.

23 37 00  Air Outlets and Inlets

23 37 13 Diffusers, Registers, and Grilles

1. **Prohibited:** Combination of supply and exhaust registers or diffusers.
2. Supply air registers shall have opposed blade dampers and horizontal and vertical adjustable louvers.
3. Adjustable pattern ceiling diffusers shall be used.
   3.1. Balance dampers should be located at the branch takeoff to reduce noise. If the balance damper must be located at the diffuser the damper shall be screwdriver operated.
4. Where diffusers are located near fume hoods, canopy hoods, biological safety cabinets, or other devices which are sensitive to air turbulence, install diffuser to direct airflow parallel to the front face of the device (i.e. not directed at device).

23 37 13.43 Security Registers and Grilles
23 37 16 Fabric Air Distribution Devices
23 37 23 HVAC Gravity Ventilators
23 37 23.13 HVAC Gravity Dome Ventilators
23 37 23.16 HVAC Gravity Louvered-Penthouse Ventilators
23 37 23.19 HVAC Gravity Upblast Ventilators

23 38 00  Ventilation Hoods

23 38 13 Commercial-Kitchen Hoods
23 38 13.13 Listed Commercial-Kitchen Hoods
23 38 13.16 Standard Commercial-Kitchen Hoods
23 38 16 Fume Hoods
23 40 00  HVAC Air Cleaning Devices
23 41 00  Particulate Air Filtration

1. Provide air-handlers with a MERV 8 pre-filter and MERV 13 final filter. Filters shall be located upstream from the first coil
2. Provide cartridge-style filters.
3. The A/E shall specify a MERV 8 pre-filter on the upstream side of all exhaust heat recovery coils.
4. To maintain cleanliness of the coils, conserve energy and extend filter life, the selection of the filter area shall be based on a maximum face velocity of:
   4.1. 350 fpm for constant volume systems
   4.2. 500 fpm for variable volume systems
5. Air-handling units in the same mechanical room shall use no more than two sizes of filters.
6. A ‘Magnehelic’ pressure gauge with an adjustable indicator needle shall be installed across the filter bank to indicate the filter bank pressure loss.

23 41 13 Panel Air Filters
23 41 16 Renewable-Media Air Filters

1. **Prohibited:** Roll filters.

23 41 19 Washable Air Filters
23 41 23 Extended Surface Filters
23 41 33 High-Efficiency Particulate Filtration
23 41 43 Ultra-Low Penetration Filtration
23 41 46 Super Ultra-Low Penetration Filtration

23 42 00  Gas-Phase Air Filtration

23 42 13 Activated-Carbon Air Filtration
23 42 16 Chemically-Impregnated Adsorption Air Filtration
23 42 19 Catalytic-Adsorption Air Filtration

23 43 00  Electronic Air Cleaners

23 43 13 Washable Electronic Air Cleaners
23 43 16 Agglomerator Electronic Air Cleaners
23 43 23 Self-Contained Electronic Air Cleaners
23 50 00  Central Heating Equipment
23 51 00  Breechings, Chimneys, and Stacks
  23 51 13 Draft Control Devices
  23 51 13.11 Draft Control Fans
  23 51 13.13 Draft-Induction Fans
  23 51 13.16 Vent Dampers
  23 51 13.19 Barometric Dampers
  23 51 16 Fabricated Breechings and Accessories
  23 51 19 Fabricated Stacks
  23 51 23 Gas Vents
  23 51 33 Insulated Sectional Chimneys
  23 51 43 Flue-Gas Filtration Equipment
  23 51 43.13 Gaseous Filtration
  23 51 43.16 Particulate Filtration

23 52 00  Heating Boilers
  23 52 13 Electric Boilers
  23 52 16 Condensing Boilers
  23 52 16.13 Stainless-Steel Condensing Boilers
  23 52 16.16 Aluminum Condensing Boilers
  23 52 17 Low Mass Boilers
  23 52 19 Pulse Combustion Boilers
  23 52 23 Cast-Iron Boilers
  23 52 33 Water-Tube Boilers
  23 52 33.13 Finned Water-Tube Boilers
  23 52 33.14 Flexible Water-Tube Boilers
  23 52 33.16 Steel Water-Tube Boilers
  23 52 33.19 Copper Water-Tube Boilers
  23 52 39 Fire-Tube Boilers
  23 52 39.13 Scotch Marine Boilers
  23 52 39.16 Steel Fire-Tube Boilers
  23 52 83 Boiler Blowdown Systems

23 53 00  Heating Boiler Feedwater Equipment
  23 53 13 Boiler Feedwater Pumps
  23 53 16 Deaerators

23 54 00  Furnaces
  23 54 13 Electric-Resistance Furnaces
  23 54 16 Fuel-Fired Furnaces
23 54 16.13 Gas-Fired Furnaces
23 54 16.16 Oil-Fired Furnaces

23 55 00 Fuel-Fired Heaters
23 55 13 Fuel-Fired Duct Heaters
23 55 13.13 Oil-Fired Duct Heaters
23 55 13.16 Gas-Fired Duct Heaters
23 55 23 Gas-Fired Radiant Heaters
23 55 23.13 Low-Intensity Gas-Fired Radiant Heaters
23 55 23.16 High-Intensity Gas-Fired Radiant Heaters
23 55 33 Fuel-Fired Unit Heaters
23 55 33.13 Oil-Fired Unit Heaters
23 55 33.16 Gas-Fired Unit Heaters

23 56 00 Solar Energy Heating Equipment
23 56 13 Heating Solar Collectors
23 56 13.13 Heating Solar Flat-Plate Collectors
23 56 13.16 Heating Solar Concentrating Collectors
23 56 13.19 Heating Solar Vacuum-Tube Collectors
23 56 16 Packaged Solar Heating Equipment
23 56 23 Solar Air-Heating Panels

23 57 00 Heat Exchangers for HVAC

1. Documentation
   1.1. Indicate dimensions, description of materials and finishes, general construction, specific modifications, component connections, anchorage methods, hardware, and installation procedures, including specific requirements.

2. Design Guidelines:
   2.1. For buildings that use Steam for heating:
      2.1.A. The steam shall be supplied to the converters through two control valves that are equipped with a three-valve bypass.
      2.1.B. The control valves shall be piped so that both valves can serve either one of the converters. Each valve shall be sized for 50 percent of the load.
      2.1.C. The outside temperature shall cause the operation and sequence of the valves to be reset.

   2.2. The hot water system shall have two pumps; each rated at 100 percent design capacity. Each pump shall be fed from a different electric branch circuit or feeder.

   2.3. Arrange service valves around the control valves and pumps so that those components may be serviced while the other components are in operation.

3. Hot Water Piping Systems
   3.1. **Prohibited:** Victaulic type mechanical fittings with rubber insert,
   3.2. Specify standard weight black steel pipe, ASTM A53 or A120 continuous weld and Type L copper up to 2 inches.
3.3. Piping systems up to and including 2 inches in size shall be screwed construction with standard weight cast iron fittings or lead-free soldered or brazed copper. Larger systems shall be welded, 150# class weld neck or slip-on flanges.

3.4. A hydrostatic test shall be conducted on completed piping at no less than 100 psi gauge pressure or one and a half times the maximum working pressure, whichever is greater. The pressure shall be maintained for two hours.

4. Chilled and Condenser Water Piping Systems

4.1. Mechanical fittings such as Victaulic, Goovelock are acceptable for chilled water and condenser water.

4.2. Aboveground chilled and condenser water piping systems shall be standard weight black steel pipe, ASTM A53 or A120 continuous weld.

4.3. Copper type ‘L’ up to 2-1/2 inches may be used for pipe branches to connect the main line to the cooling coils in air-handling units.

4.4. Risers and mains shall have valve drains.

4.5. All chilled water loops and condenser water loops shall be chemically treated. The A/E shall specify the necessary equipment for treatment. Refer to 23 25 00 HVAC Water Treatment.

4.6. The makeup water line that feeds the chilled water and condenser water loops shall be equipped with a backflow preventer as required by code.

4.7. The A/E shall design and specify two types of piping systems for underground chilled water pipe applications, one as an alternate bid:

4.7.A. Main Bid Option: Underground chilled water piping shall be coated Schedule 40 black steel that conforms to ASTM A53 with passive cathodic protection. The coating shall be polyethylene on the exterior surface with setbacks for butt-welding that conforms to AWWA C105.


4.8. A hydrostatic test shall be conducted on completed piping at no less than 100 psi gauge pressure or one and a half times the maximum working pressure, whichever is greater. The pressure shall be maintained for two hours.

5. Steam Supply and Return Piping System

5.1. Prohibited: Bypassed traps.

5.2. Prohibited: Condensate from pure or clean steam that is connected to a central condensate return due to the incompatibility with iron piping.

5.3. Traps shall be designed to have a test valve that discharges to the atmosphere located between the trap and the discharge shutoff valve.

5.4. Piping: Steam distribution piping shall be black steel pipe; ASTM A120 welded through 4 inches; A53 welded for larger pipe.

5.5. Extra heavy steel shall be used for condensate return piping. The piping shall comply with ASTM A53 or A120 requirements, and be of continuous weld.

5.6. Steam condensate piping shall be of welded construction, except at valves, traps and similar devices. Exception: Low-pressure (15 psig and less) steam and low-pressure condensate return piping 2 inches and smaller may be screwed using standard weight malleable or cast iron fittings.
5.7. Piping larger than 2 inches shall be fabricated using butt or socket-weld fittings. Flanges may be welded neck or slip-on type 150# class (up to and including 75 psig) or 300# class (greater than 75 psig).

5.8. Drip piping shall be welded, except for connection to screwed strainers and traps. Screwed unions shall be 300# AAR or black steel.

5.9. Drip and trap assemblies for steam mains and headers shall be fabricated using 2-inch extra heavy steel nipples with screwed caps for mains greater than 2 inches line size. Lines smaller than 2 inches shall have a full-sized gate valve (NO) between the main and the take-off to the trap.

5.10. Steam and return piping, valve fittings and accessories shall be accessible for maintenance.

5.11. Branch steam mains shall have valves at the main.

5.12. Flanges or unions shall be provided, and valves arranged so removable equipment may be easily dismantled for maintenance without disruption of service.

5.13. High-pressure condensate shall be discharged to a flash tank before draining to a low-pressure condensate return line. The flash tank shall be vented to the outside. The A/E shall include a detail of the flash tank installation, including piping arrangement. The design of the flash tank installation and its sizing shall comply with all the requirements in the Minnesota High Pressure Steam Code. Use the flash steam to the greatest extent that is economically possible.

6. Specialties

6.1. Provide details that show valves, unions and controls on all converter and expansion tank systems. Properly size relief valves for the system designed.

6.2. The A/E shall detail the piping connection to show valves, unions, control valves, flow-metering devices and gauges for all types of coils.

6.3. Expansion tank and makeup: Specify expansion tanks with butyl rubber bladders, Wessels NLA or university-approved equal. Connect the make-up water line at the expansion tank. Provide a code-approved backflow preventer to protect the domestic water supply at the make-up water line.

6.4. Heating coils shall be provided with an approved vacuum breaker and air vent.

6.5. Service Valves: Provide supply and return mains and risers with isolation valves for service, as well as valves and capped drains at low points to facilitate complete drainage of the hydronic system.

6.6. Vent all high points of the system with air vents that prevent air from entering the system under vacuum conditions.

6.7. To minimize water-hammering, makeup water lines to steam generators shall have slow-close solenoid valves.

7. Coils: All coils shall be designed to maintain a minimum of 3 FPS water flow at full flow design conditions.

7.1. All preheat coils shall be hot water with coil circulating pumps for freeze avoidance.

7.2. Where necessary, steam reheat coils shall distribute steam with sufficient pitch to completely clear the coils if the trap fails.

7.3. All heating coils shall be provided with an approved vacuum breaker and air vent.

7.4. Chilled water coils shall be able to be completely drained through individual headers. Acceptable models are Trane Type D or university-approved equal. Specify EWT and LWT to the cooling coil of 40 degrees F and 58 degrees F respectively, or appropriate...
temperature range to be consistent with the existing chilled water equipment. Chilled water coils shall be a maximum of eight rows.

7.5. Hot water coils shall be able to be completely drained through individual headers.
7.6. The A/E shall detail the piping connection to show valves, unions, control valves, flow-metering devices and gauges.
7.7. The A/E shall consider whether freeze protection is required using constant circulation pumps in cases where water coils are installed in air-handlers below 35 degrees F EAT.

8. Baseboard Units
8.1. For general-purpose use, fin tube radiation shall have 18-gauge sloping to steel covers, with 20-gauge solid backs.
8.2. Provide modulating valves to control the temperature of radiation units. When used in conjunction with reheat coils, valves shall be sequenced from the same control.
8.3. Provide an adequately sized access panel on radiation units at valves and air vents for maintenance.
8.4. Radiation shall be detailed and installed so the radiation element can be removed without draining risers that serve the element.
8.5. Radiation elements shall be fabricated from 1-1/4 inch standard weight steel pipe or pressure tubing and 20-gauge aluminum fins at 32 fins per foot. Supply and return connections shall include an eccentric reducer and threaded nipples for connection to screwed valves or unions.
8.6. Provide details for venting fin tube radiation.
8.7. Provide a clearance of 6 inches under the radiator, radiation enclosure and piping for sweeping with a broom.

9. Unit Heaters
   Exception: Food, fiber or fur animal housing at research and outreach centers may be heated with direct fired-unit heaters.
9.2. A thermostat-controlled unit heater shall heat the vestibule.
9.3. Motors and belt drives shall be located out of the air-stream.

10. Humidifiers
10.1. Direct steam injection (plant steam) is allowed.
10.2. Where indirect steam humidification is required, (a.k.a “clean steam”) plant steam may be used to generate steam using a building water source. The clean steam may be pressurized or atmospheric.
10.3. The A/E shall specify a slow closing, make-up water valve.

11. Process Heating (Constant Steam)
11.1. Process heating shall be shown distributed throughout the building in a system separate from the steam required for space heating.
11.2. The A/E shall consult with the end-user regarding water quality that is to be used for steam generation. Typical applications of constant steam include humidifiers, laboratory steam baths, stills, sterilizers, autoclaves and kitchen equipment.
11.3. The A/E shall specify a slow-closing make-up water valve on any steam-generating equipment.

12. Water Treatment
12.1. All re-circulating water systems shall be chemically treated.
12.2. The A/E shall specify the necessary equipment for treatment and the initial cleaning and treatment of the system.
12.3. Do not specify a supply of chemicals for the first year.
12.4. The university shall take over treatment of the system at the Substantial Completion Phase.

23 57 13 Steam-to-Steam Heat Exchangers
23 57 16 Steam-to-Water Heat Exchangers

1. Shell and Tube Heat Exchangers Design Requirements
   1.1. Specify instantaneous, counterflow, steam in shell and water in tubes with a maximum water velocity of 6 feet/second and a removable tube bundle.
   1.2. Specify a permanently attached ASME certification nameplate to the shell exterior.
   1.3. Each shell and tube heat exchanger system shall have redundant converters that are sized to handle 100 percent of the load. For larger systems, a 50/50 split is recommended.
2. Acceptable Shell and Tube Heat Exchanger Manufacturers: Bell & Gossett, Taco or university-approved equal.

23 57 19 Liquid-to-Liquid Heat Exchangers
23 57 19.13 Plate-Type, Liquid-to-Liquid Heat Exchangers

1. Design Requirements for Plate and Frame Heat Exchangers
   1.1. Specify a counter-flow exchanger designed to prevent fluid from intermixing when it leaks and flows outside of the unit.
   1.2. Provide type 304 stainless steel plates with a carbon steel frame that is coated with baked epoxy enamel, and has stainless steel guide bars, galvanized nuts and bolts.
   1.3. Review the gasket specification with the Project Manager to confirm the appropriateness of the application.
   1.4. Design the plate and frame heat exchanger with two exchangers; each sized for 67 percent of the design load.
   1.5. Specify steel flanged pipe connections and shroud.

23 57 19.16 Shell-Type, Liquid-to-Liquid Heat Exchangers
23 57 33 Direct Geoexchange Heat Exchangers
23 60 00  Central Cooling Equipment

The University of Minnesota standard cooling source for campus facilities is a district system. Chilled water piping is extended from an existing district system to the building. See Division 33 for design standards associated with district cooling system connections.

Where a district system is not available, a chilled water cluster may be created where one or more stand-alone chiller plants in adjacent buildings are connected and extended to serve the new chilled water loads.

Stand-alone chilled water plants serving single facilities are allowed only with the express approval of the Owner via the Standards Exception Process.

1. Refrigerants
   1.1. Acceptable refrigerants for all chillers and systems shall be approved per latest EPA governing codes and regulations.
   1.2. All refrigeration mechanical space must follow the University of Minnesota Emergency Spill Response to CFC Release. Mechanical spaces that have the potential for hazardous release of CFC shall meet the requirements of the latest edition of ASHRAE 15, and be equipped with the following:
      1.2.A. A multi-port monitoring system.
      1.2.B. A direct readout device located outside the entrance to the mechanical room and/or each entrance of the mechanical room. The device shall be equipped with a yellow alarm light at 30 ppm and a red alarm light and audio alarm at 500 ppm. The monitoring system shall have two alarm points. The first alarm point (yellow) shall be set at or below the AEL of 30 ppm. The second alarm (red) shall be set at 10 times the AEL of 500 ppm. Recommended manufacturers of the CFC monitor include Trane, TruSense MGRMWE infrared photoacoustic refrigerant, Chillgard RT or university-approved equal.
      1.2.C. The monitoring system shall be connected to the BAS and shall report alarms to PSECC.
      1.2.D. The A/E shall specify the sequence of operation as follows:
         1.2.D.1. When the yellow alarm is activated, the mechanical room ventilation system automatically ramps up to high speed and PSECC is notified.
         1.2.D.2. When the red alarm is activated, the system that controls the operation of the compressors is immediately shut down.
   1.3. All contractors shall carry appropriate EPA certification for their on-site technicians and shall provide copies of these certifications as requested by the Project Manager. University contractors and their subcontractors shall follow requirements as defined in 40 CFR 82, which includes using EPA-approved recovery equipment and providing written certification to the university of refrigerant removal prior to final disposal of refrigerant containing equipment. The university has the first right of refusal of any claimed refrigerants.
   1.4. Refrigerant Piping and Vent Tests
1.4.A. Leak tests shall be made before insulation is installed on piping. Tests shall be conducted using nitrogen, R-22 or a mixture of both, at 250 psi on the high side and 160 psi on the low side of the system.

1.4.B. After completion of the above tests, apply a 28-inch vacuum to the entire system. No more than a 5-inch change shall be accepted after 24 hours.

1.4.C. Test the refrigerant vents at 25 psi or one and a half times the operating pressure, whichever is greater. Isolate the pipe from the chiller-rupture disk/relief valve assembly during the test. Type of test: pneumatic.

2. Kitchen Refrigeration Equipment: Refer to Division 130030 - Food Service Construction Guide.

23 61 00 Refrigerant Compressors

23 61 13 Centrifugal Refrigerant Compressors
23 61 13.13 Non-Condensable Gas Purge Equipment
23 61 16 Reciprocating Refrigerant Compressors
23 61 19 Scroll Refrigerant Compressors
23 61 23 Rotary-Screw Refrigerant Compressors

23 62 00 Packaged Compressor and Condenser Units

23 62 13 Packaged Air-Cooled Refrigerant Compressor and Condenser Units
23 62 23 Packaged Water-Cooled Refrigerant Compressor and Condenser Units
23 62 46 Packaged Variable-Refrigerant-Flow Air-Conditioning Systems

23 63 00 Refrigerant Condensers

23 63 13 Air-Cooled Refrigerant Condensers
23 63 23 Water-Cooled Refrigerant Condensers
23 63 33 Evaporative Refrigerant Condensers

23 64 00 Packaged Water Chillers

1. General Requirements
   1.1.A. Each project shall be evaluated with Energy Management prior to selecting the chiller size and type.
   1.1.B. Chillers shall be of energy efficient design, and shall comply with requirements for Excel Energy rebate programs. In areas where other programs are available, the equipment also shall comply with requirements for those programs.
1.2. All chillers shall have specified chiller and safety controls, including high-pressure and low-pressure safety controls, crank case heaters and low ambient controls.

1.3. Centrifugal chillers shall be designed for 40 degrees F LWT and 58 degrees F EWT at the evaporator of the chiller or absorber. High-pressure steam absorption chillers shall be designed for 42 degrees F LWT and 60 degrees F EWT.

1.4. High-pressure centrifugal chillers shall have a condenser receiver and a relief valve that can be resealed as standard equipment.

1.5. Low-pressure centrifugal chillers shall have a condenser receiver, non-fragmenting rupture disk and relief valve, and automatic environmental purge as standard equipment.

1.6. The decision on which chiller equipment to use in a given application shall be based on several factors such as economic (lifecycle costing), noise, vibration, energy efficiency and capacity. The decision also shall be based on the need at the university for steam used for co-generation. The A/E shall consider all of these factors in the final selection of the chiller.

1.6.A. The A/E shall specify acceptable noise levels to be met by the manufacturer of the equipment. The A/E shall select an acceptable noise criteria level in consultation with the Project Manager and zone personnel. Confirm the need for factory testing for verification of performance with the Project Manager.

1.6.B. The A/E shall specify an acceptable noise level for the manufacturer of the equipment with a penalty clause in the specifications if those levels are not met. The manufacturer shall perform a noise test in the presence of a university representative.

1.6.C. The acceptable noise level in chiller rooms or cluster areas is 85dBA for an 8 hour Time Weighted Average (TWA).

2. Year Round Cooling: Special year round cooling systems that are not connected to a central chilled water plant with year round cooling shall be stand-alone air-conditioning units. These units shall be capable of operating at an outside temperature as cold as -20 degrees F and shall be separated from the General Comfort Cooling System in the building. These special systems shall be equipped with an economizer cycle if feasible and/or humidifier controls as required. Examples of these special cooling systems are research spaces, telecommunication rooms, computer rooms, dry rooms and instrumentation rooms.

3. Control Sequence

3.1. The standard sequence of operation for water-cooled chillers shall be as follows:

   3.1.A. BAS starts and stops the chilled water pumps.

   3.1.B. The chiller panel is enabled upon receiving proof of flow from the chilled water flow switch.

   3.1.C. Upon call for cooling, the chiller panel shall start chiller and associated equipment. The sequence of operation is per the manufacturer.

   3.1.D. The chiller panel enables cooling tower fan control.

   3.1.E. The chiller controls prove water flow interlocks have a:

       3.1.E.1. Evaporator chilled water flow switch

       3.1.E.2. Condenser water flow switch

   3.1.F. The chiller panel controls the cooling tower fan based on condenser water temperature.

3.2. Building controls shall regulate systems with tertiary loop and variable speed pumping in the buildings (not a part of the chiller control system).
3.3. University Energy Management shall approve any proposed modification to this sequence.
3.4. For a multiple chiller system, the chiller manufacturer shall supply the hardware/software system to control the sequence of the chillers and the optimum start/stop operations (not the BAS). In such a case, the function of the BAS is to energize the multiple chiller system central panel.

4. Control Panels
4.1. Specify a dedicated factory-mounted and tested microprocessor-based chiller control panel for each chiller that will monitor and control the chiller. The control panel shall contain a microprocessor-based control system with non-volatile memory that maintains all programming data even when power is off. The internal controller shall provide a PID algorithm to control the chilled water temperature within +/- 0.5 degrees F. The control panel will have a face-mounted keypad and alphanumeric display for service/diagnostic functions. The panel shall be operable in different modes that allow keypad and remote control, programming and service/diagnostic capabilities.
4.2. Specify a central chiller plant controller that is capable of controlling a chiller or chillers as applicable and their related systems, which is the cooling tower and pumps.

5. BAS Interface
5.1. Specify a central chiller plant controller that is capable of interfacing with BAS.
5.2. The chiller supplier shall furnish all hardware, wiring, modems and software necessary to fully integrate the architecture of the chiller control system into the Johnson Controls Unity front-end or other integrating system in the Donhowe Building. This interface shall allow the BAS to issue commands to the chiller control system and monitor chiller information. Refer to Section 230900 - Controls and Instrumentation.

23 64 13 Absorption Water Chillers
23 64 13.13 Direct-Fired Absorption Water Chillers
23 64 13.16 Indirect-Fired Absorption Water Chillers
23 64 16 Centrifugal Water Chillers
23 64 16.13 Air-Cooled Centrifugal Water Chillers
23 64 16.16 Water-Cooled Centrifugal Water Chillers
23 64 19 Reciprocating Water Chillers
23 64 23 Scroll Water Chillers
23 64 23.13 Air-Cooled Scroll Water Chillers
23 64 23.16 Water-Cooled Scroll Water Chillers
23 64 26 Rotary-Screw Water Chillers
23 64 26.13 Air-Cooled, Rotary-Screw Water Chillers
23 64 26.16 Water-Cooled, Rotary-Screw Water Chillers
23 64 33 Modular Water Chillers
23 64 33.13 Air-Cooled, Modular Water Chillers
23 64 33.16 Water-Cooled, Modular Water Chillers
1. General Requirements
   1.1. The A/E shall specify that the Cooling Tower Institute shall certify the performance of
        the cooling tower in accordance with CTI Certification Standard STD-201.
   1.2. The A/E shall specify single-cell cooling towers with a single-speed, single-motor
        system and a variable frequency drive.
   1.3. Multiple-cell cooling towers shall be specified with equal-sized cells each with a
        single-speed motor. Variable frequency drives for all cells shall be specified.
   1.4. Each cooling tower system also shall be equipped with a three-way diversion valve and
        bypass system for startup and low-load conditions.
   1.5. Cooling towers shall be induced draft, except as follows: Forced draft towers shall be
        used for year-round cooling applications. Forced draft towers may be considered when
        space is limited.
   1.6. The A/E shall only specify direct or gear driven fans.
   1.7. The A/E shall locate towers preferably on roofs, away from fresh air intakes and
        hidden from view. Towers on roofs shall rest on a steel frame with at least 3 feet of
        clearance between the roof and the bottom of the frame. The A/E shall consider the
        plume or drift to minimize the effect on other adjacent buildings.
   1.8. The A/E shall specify installation of pressure gauges, temperature gauges, and isolation
        valves on the condenser water supply and return lines.
   1.9. The A/E shall specify the make up water meters and blow down deduct meters. Water
        meter specifications shall meet the requirements of the local agency having jurisdiction
        and the requirements of chemical treatment. Refer to Section 23 25 00 - Water
        Treatment for Open and Closed Loops.
   1.10. The A/E shall specify that the drain, the overflow and bleed-off water from the tower
        shall discharge into a sanitary sewer line and not into a storm sewer line.
   1.11. The A/E shall specify that the condenser water loop shall be equipped with a backflow
        preventer if an air gap cannot be provided. Refer to Minnesota Department of Health
        Plumbing Code.
   1.12. The A/E shall specify each tower cell with a single water inlet connection, complete
        with a pre-strainer assembly and means to balance the flow rates to the distribution
        basins. A blow down connection extended to the exterior of the casing shall be
        specified. If the manufacturer of the tower does not include a pre-strainer assembly, the
        A/E shall specify an in-line Y strainer with a blow down connection at the cooling
        tower inlet, so as to handle the blow down flow for installation.
   1.13. The A/E shall specify that an open gravity type hot water distribution basin is preferred
        to a pressurized spray system.
   1.14. The A/E shall specify that a ladder, perimeter handrails and a landing platform be
        provided at the cooling tower for access.
   1.15. The A/E shall locate the cooling tower in an area that adheres to the manufacturer-
        recommended clearance for service and access maintenance. It also shall meet the
        applicable OSHA and University Building Code Office requirements for safe access.
2. Controls: The chiller control panel shall control the tower fans and bypass valve. The A/E
   shall specify the proposed sequence of operation as follows:
2.1. On a rise in condenser water temperature above set point, the bypass valve shall modulate to allow water to enter the tower.

2.2. After there is full flow to the tower and a call for additional cooling, the VFD on the first cell will energize and modulate to maintain set point.

2.3. If the drive reaches 90 percent speed (adjustable) for three minutes adjustable, the second cell fan will be energized and the VFD will modulate to maintain set point.

2.4. When the drive has been below 30 percent (adjustable) for three minutes adjustable, the second cell fan will de-energize and the VFD will modulate to maintain set point.

2.5. With only the VFD running, if the temperature drops 3 degrees F adjustable below set point, the VFD will be de-energized.

2.6. The set point for the bypass valve will be 5 degrees F adjustable lower than the fan set point to ensure that if a fan is running there is full flow to the tower.
23 70 00 Central HVAC Equipment

1. General System Design
   1.1. To serve as a guide for the review of mechanical construction documents, a design intent report for the HVAC systems shall be included with the plans and specifications submitted to the university at the completion of each design phase. Include fan and system characteristic curves, noise criteria and sequence of operation for each ventilating system. Include an air distribution concept per requirements of Section 233000 - HVAC Air Distribution for each system.
   1.2. For each 100 percent exhaust make-up air system that operates 24 hours a day, and has total outdoor air requirements exceeding 5,000 cfm, include energy recovery hardware. Ensure that the hardware is capable of recovering at least 50 percent of the potential cooling or heating effect of the exhaust air whenever the temperature difference between the exhaust and outside air exceeds 10 degrees F.
   1.3. Heat recovery systems shall be controlled to prevent overheating. If other opportunities exist for heat recovery not covered in 1.2, the A/E shall provide a lifecycle cost analysis for the proposed system.
   1.4. On remodeling projects, the A/E shall be responsible for verifying the actual operating conditions of ventilating systems that require changes due to the proposed remodeling.
   1.5. Minimum design requirements for controlling air-handling units with cooling and/or heating coils and delivering 5,000 cfm or more are:
      1.5.A. Mixed air reset
      1.5.B. Discharge air reset
      1.5.C. Mixed air economizer
      1.5.D. Freezestat
   1.6. Air-handling units with more than 5,000 cfm and all 100 percent outside air ventilating units shall have the following features:
      1.6.A. Off the shelf air handling units are acceptable
      1.6.B. Double wall construction. The interior shall be galvanized
         1.6.B.1. Minimum wall thickness of 2” and a minimum insulation R= 12. The insulation shall be closed cell, hydrophobic and injected in the panels with thermal breaks.
         1.6.B.2. Less than 1 percent leakage per section at operating conditions. Provide testing procedure or certificate. This is the rated maximum total air flow at rated cabinet negative pressure with all piping and electrical penetrations in place.
      1.6.C. Coils supported on racks to allow the coils to be removed individually
      1.6.D. All drip pans to be stainless steel, each coil or section of coil shall have its own drip pan. Drain pans to be designed per ASHRAE standards. Drain pans shall have built-in pitch of at least 1/8” per foot towards the drain pan outlet. All drain pans shall have a built-in overflow protection by secondary piping. Where secondary piping is not possible, it shall have a UL 508 compliant electronic means of equipment shut off.
      1.6.E. Stainless steel drain pan below each coil.
      1.6.F. All drives shall be synchronous belts, premium high efficiency TEFC motors. See table 10.8, ASHRAE 90.1-2004 for motor efficiency requirements.
1.6.G. No exposed insulation in the air stream.

1.6.H. Both internal and external construction to be UV proof. All internal and external joints shall be caulked with UV inert 30+ year caulking.

1.6.I. Totally sealed pillow block bearings with minimum contact between the lubricant and the air stream. Extended life L10 bearing.

1.6.J. Economizer dampers shall be low leakage type, less than 4 cfm/sq. ft at 1" wc pressure difference per ASHRAE 90.1-2004.

1.7. The A/E shall specify appropriate noise criteria. Labs must not exceed an average of NC 45 and the space immediately in front of the fume hood must not exceed NC 55.

1.8. Re-circulating units up to 5,000 cfm capacity may be packaged ventilating units manufactured by Carrier, Trane, York or a university-approved equal.

1.9. All ventilating units shall be designed, detailed and specified to blend the outside air with the return air to prevent stratification.

1.10. Air-handling units shall have door access to filters, heating and cooling coils, dampers, humidifiers, fans and burners. The A/E shall include the manufacturer-recommended clearances for maintenance and repair work in the plans. The contract documents shall show the service space around all equipment.

2. Filter Section
   2.1. Filter racks shall be designed to eliminate air bypass.
   2.2. Filter sections shall allow for complete and total access for replacement of all filters.

3. Equipment Spaces
   3.1. Equipment rooms with refrigeration equipment shall comply with ASHRAE Standard 15.
   3.2. Provide adequate ventilation for all equipment rooms, including a filtered outdoor air and exhaust system, complete with thermostatic control. The temperature in equipment rooms shall not exceed 100 degrees on a design day.
   3.3. Ventilation fans shall be installed within the building or in a penthouse.
   3.4. Penthouses that contain fume hood exhaust stacks shall be provided with a minimum of four air changes per hour continuously.
   3.5. Coordinate with Division 26 - Electrical for design of generator room HVAC.
   3.6. Locate light switches at the entrance to equipment rooms.

4. Location of Intake
   4.1. **Prohibited:** Activated carbon filters to protect poorly located outside air intakes.
   4.2. The A/E shall be responsible for locating the outside air intake away from sources of exhaust fumes. Examples include loading docks, parking areas, heavy traffic areas, cooling towers, incinerator stacks, fume hood stacks and other stacks that emit toxic or radioactive materials, nuisance odors, plumbing vents, emergency generator exhausts and engine-driven fire pumps exhausts. The A/E also shall consider a wind study.
   4.3. Ensure that noise levels meet local requirements at 20 feet from the building face.
   4.4. Intakes shall be at least 24 inches above the roof and at least 30 feet above grade.
   4.5. Each intake shall be sized based on the manufacturer’s criteria for eliminating rain and snow penetration or carry over into the air-handling system.
   4.6. Provide a minimum 24-inch by 24-inch, insulated access panel with a gasket at all intakes for cleaning and maintenance.

5. Exhaust and Relief
   5.1. The A/E is responsible for locating building exhausting away from air intakes. Consider intakes on adjacent existing buildings.
5.2. Provide a minimum 24-inch by 24-inch, insulated access panel with a gasket at all exhaust and relief valves for cleaning and maintenance.

6. Duct Drainage
   6.1. Outside air intake chambers, relief hoods and power roof ventilators shall be furnished with watertight drain pans that have a minimum depth of 2 inches. An open waste drain line shall be designed to carry rain or melting snow to a nearby floor drain. Install an access door large enough to service the drain. Metal pans shall be stainless steel.
   6.2. At duct humidifiers, solder ductwork watertight, 5 feet upstream and 25 feet downstream of the ductwork. Pitch ductwork to a drain located at the humidifier.
   6.3. All ducts exposed to weather shall be watertight.

7. Areas Generating Noxious Odors
   7.1. All areas within buildings where noxious and nuisance odors are generated shall be under negative pressure at all times and exhausted directly to the outdoors. The A/E shall be responsible for locating building exhausts (including laboratory vacuum discharges) away from air intakes on adjacent existing buildings.
   7.2. The A/E shall provide calculations that confirm that noxious and nuisance odors are not entrained.

8. Fan Identification: All fan units shall be permanently marked to clearly identify the area served.


10. Fan Bearings
    10.1. Fans shall be equipped with frictionless self-aligning, resilient-mounted, pillow block type bearings with a minimum average life of 80,000 hours on shafts 2” and smaller. Shafts 2.125” and up shall have bearings with L10 life of 200,000 hours.
    10.2. Fan shafts shall not have to be removed to replace the bearings. Provide adequate space for removing the shaft. Indicate space on coordination drawing.

11. Fan Drives shall be synchronous belts with a minimum life of 3 years between replacements
    11.1. Belt drives shall be selected for loading at least 150 percent of the brake horsepower indicated by the fan manufacturer at the specified operating conditions.
    11.2. All sheaves shall be fixed pitch.
    11.3. Drive belt guards shall be made with expanded metal and have hinged access so the belts can be easily examined.
    11.4. Provide shaft guards per OSHA standards.

12. Fan Access Panels: Fans shall be equipped with a drain and cap at the low point of the scroll access panels so the blade and scroll interior can be cleaned and repaired. Panels shall have gaskets and be airtight.

13. Fan Vibration
    13.1. Isolate fans to meet the specified vibration requirements of the project.
    13.2. Provide a minimum 1/16-inch-thick flexible connection between ducts and inlets and outlets of all supply and exhaust fans and units. Joints shall be lapped and airtight, and not be located at corners of ducts. Provide a minimum separation of two inches between joints on flexible canvas connections with a minimum overlap of two inches.
    13.3. Vane axial fans with greater than 5 inches of static pressure shall have thrust restraints.
    13.4. Fans must meet Air Movement and Control Association (AMCA) 204, Balance Quality and Vibration Levels for Fans.

14. Lights:
14.1. Air-handling units with more than 5,000 cfm shall be provided with interior service and inspection lighting at each access door.

14.2. Lamps shall be LED

14.3. Lights shall be controlled with a mechanical or digital timer switch and will automatically turn off when the timer expires.

15. Trap for Cooling Coil Drain Pan: The trap for cooling coil drain pans shall be designed to handle the maximum static pressure of the system. The water shall flow out of the pan at the specified maximum static pressure without the pan overflowing.

16. Motors and Drives

16.1. **Prohibited:**

16.1.A. Design E motors due to the effects of high inrush currents.

16.1.B. Variable frequency drives with bypasses, manual or electronic.

16.2. Variable frequency drives shall conform to the requirements of Division 26 - Electrical.

16.3. Coordinate mechanical and electrical documents to clearly indicate and not duplicate the responsibility for providing starters and wiring of equipment, motors and controls.

16.4. Start motors to determine the largest motor that can be started at full voltage within industry standards for an acceptable dip in voltage. Specify the appropriate methods for starting large motors with less voltage.

16.5. Specify inverter-duty motors with integral grounding rings for VFD applications. Specifications shall clearly state that the contractor or a specific equipment supplier is responsible for VFD and motor compatibility. If VFDs using IGBT output devices or high-carrier frequency are permitted by specifications, address requirements for motor over-voltage and surge protection in the design.

16.6. Specify that all motors be mounted so that the nameplate can be read without removing the motor from its mounting.

16.7. Specify that bearings that require lubrication have readily accessible, approved grease fittings for easy service.

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**23 71 00 Thermal Storage**

- 23 71 13 Thermal Heat Storage
- 23 71 13.13 Room Storage Heaters for Thermal Storage
- 23 71 13.16 Heat-Pump Boosters for Thermal Storage
- 23 71 13.19 Central Furnace Heat-Storage Units
- 23 71 13.23 Pressurized-Water Thermal Storage Tanks
- 23 71 16 Chilled-Water Thermal Storage
- 23 71 19 Ice Storage
- 23 71 19.13 Internal Ice-on-Coil Thermal Storage
- 23 71 19.16 External Ice-on-Coil Thermal Storage
- 23 71 19.19 Encapsulated-Ice Thermal Storage
- 23 71 19.23 Ice-Harvesting Thermal Storage
- 23 71 19.26 Ice-Slurry Thermal Storage
23 72 00  Air-to-Air Energy Recovery Equipment

23 72 13 Heat-Wheel Air-to-Air Energy-Recovery Equipment

1. All wheel-type energy recovery devices shall be specified with bypass dampers.
   1.1. Bypass dampers shall be installed across both the supply and exhaust sides of the wheel.
   1.2. Bypass dampers shall be designed to allow a minimum of 50% of the design wheel airflow to pass through the open damper at 25% of the design wheel pressure drop.
   1.3. Bypass damper actuators are to be modulating type controlled with an analog output (0-10V, 4-20mA, etc.).
       1.3.A. Modulating actuators are required even if the control sequence operates the dampers as 2-position open/close dampers.

Owner’s Intent Narrative

There are three reasons for the bypass dampers across the energy recovery wheel. The first is to reduce energy consumption by reducing the airside pressure drop when the wheel is not in use. This is particularly important for systems that operate at constant volume and for VAV systems that operate at or near full load for long periods.

The second reason for the dampers is to allow for better temperature control, particularly at low loads. Energy wheels typically have a minimum rotation rate that is determined by the wheel drive system. Most wheels have significant capacity even at minimum speed. This capacity is often more than required during the shoulder seasons when the outdoor conditions are mild which can result in temperature control instability. The bypass dampers allow the wheel capacity to be reduced during low load times, which improves temperature control stability.

The third reason is wheel frost control.

23 72 16 Heat-Pipe Air-to-Air Energy-Recovery Equipment
23 72 19 Fixed-Plate Air-to-Air Energy-Recovery Equipment
23 72 23 Packaged Air-to-Air Energy-Recovery Units
23 73 00       Indoor Central-Station Air-Handling Units

Owner’s Intent Narrative

Indoor AHUs will typically use hot water for heating and chilled water for cooling. Steam coils may be appropriate for some applications but are generally not preferred. Glycol for heating and cooling coils in indoor AHUs is generally discouraged.

Hot water coils used for preheat or mixed air applications are normally equipped with a circulating pump that maintains coil tube velocity when the entering air conditions are below freezing. Auto-resetting freeze stats and control sequences that enhance freeze protection are employed for hydronic heating coils exposed to below freezing conditions.

Chilled water coils that are served by district chilled water plants or any other system that functions year round are not drained but are left wet during the winter. Chilled water coils may be equipped with coil circulating pumps for freeze protection depending on the application. Pumps are often omitted when the preheat coil is hot water. Pumps are usually required if the preheat coil is steam or any form of face and bypass control is used. Heat recovery wheels general produce highly temperature stratified airstreams and this should be taken into account when deciding whether a freeze protection pump is required.

23 73 13 Modular Indoor Central-Station Air-Handling Units
23 73 23 Custom Indoor Central-Station Air-Handling Units
23 73 33 Indoor Indirect Fuel-Fired Heating and Ventilating Units
23 73 33.13 Indoor Indirect Oil-Fired Heating and Ventilating Units
23 73 33.16 Indoor Indirect Gas-Fired Heating and Ventilating Units
23 73 39 Indoor, Direct Gas-Fired Heating and Ventilating Units

23 74 00       Packaged Outdoor HVAC Equipment

Owner’s Intent Narrative

Outdoor equipment tends to have shorter lifespans and increased maintenance costs compared to indoor equipment so the University prefers indoor air handling equipment. However, outdoor air handlers are appropriate in some applications. The Owner may approve the use of outdoor air handlers when space constraints or other issues make indoor equipment impractical.
1. Rooftop AHUs may be considered with the express permission of the Owner.

2. Location:
   2.1. The A/E shall locate the unit to minimize the adverse effects to the building aesthetics.
   2.2. The A/E shall select the unit and location to minimize noise impact in occupied areas.
       2.2.A. The A/E shall submit the noise criteria that will be used for the selection of equipment.

3. When required by application, condensing equipment shall be capable of starting and operating at low ambient temperatures.

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23 74 13 Packaged, Outdoor, Central-Station Air-Handling Units
23 74 16 Packaged Rooftop Air-Conditioning Units

23 74 16.11 Packaged, Small-Capacity, Rooftop Air-Conditioning Units
23 74 16.12 Packaged, Intermediate-Capacity, Rooftop Air-Conditioning Units
23 74 16.13 Packaged, Large-Capacity, Rooftop Air-Conditioning Units
23 74 23 Packaged, Outdoor, Heating-Only Makeup-Air Units
23 74 23.13 Packaged, Direct-Fired, Outdoor, Heating-Only Makeup-Air Units
23 74 23.16 Packaged, Indirect-Fired, Outdoor, Heating-Only Makeup-Air Units
23 74 33 Dedicated Outdoor-Air Units

---

23 75 00 Custom-Packaged Outdoor HVAC Equipment

23 75 13 Custom-Packaged, Outdoor, Central-Station Air-Handling Units
23 75 16 Custom-Packaged, Rooftop Air-Conditioning Units
23 75 23 Custom-Packaged, Outdoor, Heating and Ventilating Makeup-Air Units
23 75 33 Custom-Packaged, Outdoor, Heating and Cooling Makeup Air-Conditioners

---

23 76 00 Evaporative Air-Cooling Equipment

23 76 13 Direct Evaporative Air Coolers
23 76 16 Indirect Evaporative Air Coolers
23 76 19 Combined Direct and Indirect Evaporative Air Coolers
23 80 00 Decentralized HVAC Equipment

23 81 00 Decentralized Unitary HVAC Equipment
23 81 13 Packaged Terminal Air-Conditioners
23 81 13.11 Packaged Terminal Air-Conditioners, Through-Wall Units
23 81 13.12 Packaged Terminal Air-Conditioners, Freestanding Units
23 81 13.13 Packaged Terminal Air-Conditioners, Outdoor, Wall-Mounted Units
23 81 16 Room Air-Conditioners
23 81 19 Self-Contained Air-Conditioners
23 81 19.13 Small-Capacity Self-Contained Air-Conditioners
23 81 19.16 Large-Capacity Self-Contained Air-Conditioners
23 81 23 Computer-Room Air-Conditioners
23 81 23.11 Small-Capacity, Computer-Room Air-Conditioners, Floor Mounted Units
23 81 23.12 Large-Capacity, Computer-Room Air-Conditioners, Floor-Mounted Units
23 81 23.13 Computer-Room Air-Conditioners, Ceiling Mounted Units
23 81 23.14 Computer-Room Air-Conditioners, Console Units
23 81 23.16 Computer-Room Air-Conditioners, Rack Mounted, Space-Cooling Units
23 81 23.18 Computer-Room, Rack-Cooling Equipment
23 81 26 Split-System Air-Conditioners
23 81 26.13 Small-Capacity Split-System Air-Conditioners
23 81 26.16 Large-Capacity Split-System Air-Conditioners
23 81 29 Variable Refrigerant Flow HVAC Systems
23 81 43 Air-Source Unitary Heat Pumps
23 81 46 Water-Source Unitary Heat Pumps
23 81 49 Ground-Source Unitary Heat Pumps

23 82 00 Convection Heating and Cooling Units
1. Use hot water for radiation and reheat applications.
23 82 13 Valance Heating and Cooling Units
23 82 14 Chilled Beams
23 82 16 Air Coils
23 82 16.11 Hydronic Air Coils
23 82 16.12 Steam Air Coils
23 82 16.13 Refrigerant Air Coils
23 82 16.14 Electric-Resistance Air Coils
23 82 19 Fan Coil Units

---

**Owner’s Intent Narrative**

*Fan coil units (FCU) shall be part of the building control system, no different from VAV boxes or other terminal units.*

*When FCUs are used in residence rooms or other residential applications the control sequences shall set back the space setpoints based on local occupancy (occupancy sensor) and scheduled occupancy (occupancy command from the BAS). Variable speed fans are preferred for all applications and especially cooling applications with latent loads.*

*For applications where the FCU is serving unoccupied spaces (MDF/IFD, electrical, mechanical, etc.) the control sequence should prioritize reducing energy consumption over space temperature control. For constant speed fan applications this usually means having temperature deadbands and controlling the FCU in an on/off fashion. Tight temperature control is not required in these types of applications.*

*For applications where the FCU serves occupied spaces (non-residential) the temperature control is expected to be similar to VAV box control.*

---

1. Fan Coil Units (FCU) shall include direct digital controls (DDC).
   1.1. FCU controls shall be integrated with the building BAS.
2. FCUs used for mechanical, electrical, telecom, or other unoccupied applications shall be configured to minimize fan power consumption.
   2.1. FCUs in unoccupied applications will cycle the fan to maintain the space temperature at setpoint. The FCUs will deliver full cooling or heating capacity when the space temperature rises above the cooling setpoint or falls below the heating setpoint. The FCU will shut off when the space temperature is satisfied.
3. FCUs used for occupied applications will modulate capacity to satisfy the space heating or cooling demand.
   3.1. Variable speed control of fans shall be the first stage of control.
   3.2. Once the fan speed is at the design minimum then heating or cooling coil valve modulation shall be the second stage of control.
3.3. Discharge air temperature control shall be used to prevent excessive hydronic flow at low fan speeds.

4. FCUs that have the potential to create condensate shall include condensate pan overflow sensors
   4.1. Overflow sensors can be either electronic or float type
   4.2. Overflow sensors will be used to turn off the FCU fan and close the cooling valve
   4.3. When overflow sensors cannot be used in the primary containment pan, the MN Mechanical Code provides several options for compliance. The Owner must approve any condensate overflow safety option if the primary containment pan sensor is not used.

23 82 23 Unit Ventilators
23 82 26 Induction Units
23 82 29 Radiators
23 82 33 Convector
23 82 36 Finned-Tube Radiation Heaters
23 82 39 Unit Heaters
23 82 39.13 Cabinet Unit Heaters
23 82 39.16 Propeller Unit Heaters
23 82 39.19 Wall and Ceiling Unit Heaters
23 82 41 Water-to-Water Heat Pumps

23 83 00 Radiant Heating Units

23 83 13 Radiant-Heating Electric Cables
23 83 13.16 Radiant-Heating Electric Mats
23 83 16 Radiant-Heating Hydronic Piping
23 83 23 Radiant-Heating Electric Panels
23 83 33 Electric Radiant Heaters
23 84 00  Humidity Control Equipment

23 84 13 Humidifiers
23 84 13.13 Heated-Pan Humidifiers
23 84 13.16 Wetted-Element Humidifiers
23 84 13.19 Atomizing Humidifiers
23 84 13.23 Direct-Steam-Injection Humidifiers
23 84 13.26 Jacketed, Steam Humidifiers
23 84 13.29 Self-Contained Steam Humidifiers
23 84 13.33 Portable Humidifiers
23 84 16 Mechanical Dehumidification Units
23 84 16.13 Outdoor, Mechanical Dehumidification Units
23 84 16.16 Indoor, Mechanical Dehumidification Units
23 84 16.33 Portable Dehumidifiers
23 84 19 Desiccant Dehumidification Units
## Appendix 23-A Utility Meter Systems

### Table 5. Pre-Approved Mag Liquid Flow Meters

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>1 150</td>
<td>316L SS</td>
<td>250</td>
<td>PTFE or PFA</td>
<td>4-20 mA</td>
<td>pulse</td>
<td>HART</td>
<td>Integral - With Display</td>
<td>0.5% of Reading</td>
<td>8705TSA010C1M0B3</td>
<td>AXR025C-J1AL1-BA11-21B/FF1</td>
<td>AXG025-CAFF2BA1AH212B-1JA11/GRL/MC</td>
<td>VN03-44A5440B11000600000000</td>
<td>VN31-4NAS460010100003</td>
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<td>1.5 150</td>
<td>316L SS</td>
<td>250</td>
<td>PTFE or PFA</td>
<td>4-20 mA</td>
<td>pulse</td>
<td>HART</td>
<td>Integral - With Display</td>
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<td>VN31-4NAS460010100003</td>
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<td></td>
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<tr>
<td>2 150</td>
<td>316L SS</td>
<td>250</td>
<td>PTFE or PFA</td>
<td>4-20 mA</td>
<td>pulse</td>
<td>HART</td>
<td>Integral - With Display</td>
<td>0.5% of Reading</td>
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<tr>
<td>3 150</td>
<td>316L SS</td>
<td>250</td>
<td>PTFE or PFA</td>
<td>4-20 mA</td>
<td>pulse</td>
<td>HART</td>
<td>Integral - With Display</td>
<td>0.5% of Reading</td>
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<td>AXR080C-J1AL1-BA11-21B/FF1</td>
<td>AXG080-CAFF2CA1AH212B-1JA11/GRL/MC</td>
<td>VN03-44A5440B11000600000000</td>
<td>VN31-4NAS460010100003</td>
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<td></td>
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<tr>
<td>4 150</td>
<td>316L SS</td>
<td>250</td>
<td>PTFE or PFA</td>
<td>4-20 mA</td>
<td>pulse</td>
<td>HART</td>
<td>Integral - With Display</td>
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<td>PTFE or PFA</td>
<td>4-20 mA</td>
<td>pulse</td>
<td>HART</td>
<td>Integral - With Display</td>
<td>0.5% of Reading</td>
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<td>PTFE or PFA</td>
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<td>PTFE or PFA</td>
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<td>PTFE or PFA</td>
<td>4-20 mA</td>
<td>pulse</td>
<td>HART</td>
<td>Integral - With Display</td>
<td>0.5% of Reading</td>
<td>8705TSA120C1M0B3</td>
<td>AXG300-CAFF2CA1AH212B-1JA11/GRL/MC</td>
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<td>VN31-4NAS460010100003</td>
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### Pre-Approved Vortex Steam Flow Meters

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<td>316L SS</td>
<td>400</td>
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<td>pulse</td>
<td>HART</td>
<td>Remote - With Display</td>
<td>1% of Reading</td>
<td>8800DF010SA3N1D1K5MSHR7</td>
<td>84F-T01Y2SSTJF</td>
<td>DY025-EBMBA2-2D/FF1</td>
<td>* OEM approved, model # contingent upon Energy Management Approval</td>
<td></td>
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<td>300</td>
<td>316L SS</td>
<td>400</td>
<td>4-20 mA</td>
<td>pulse</td>
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<td>2</td>
<td>300</td>
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<td>400</td>
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<td>HART</td>
<td>Remote - With Display</td>
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<td>pulse</td>
<td>HART</td>
<td>Remote - With Display</td>
<td>1% of Reading</td>
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<td>84F-T04Y2SSTJF</td>
<td>DY100-EBMBA2-2D/FF1</td>
<td>* OEM approved, model # contingent upon Energy Management Approval</td>
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<td>6</td>
<td>300</td>
<td>316L SS</td>
<td>400</td>
<td>4-20 mA</td>
<td>pulse</td>
<td>HART</td>
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<td>DY250-EBLBA2-2D/FF1</td>
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<td>4-20 mA</td>
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<td>HART</td>
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<td>84F-T12R2SSTJF</td>
<td>DY300-EBLBA2-2D/FF1</td>
<td>* OEM approved, model # contingent upon Energy Management Approval</td>
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### Table 7: Pre-Approved Condensate Flow Meters: Turbine

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<tr>
<td>0.75 MNPT</td>
<td>Noryl</td>
<td>250</td>
<td>200</td>
<td>Reed Switch</td>
<td>None</td>
<td>5 x D</td>
<td>3 x D</td>
<td>1</td>
<td>20.0</td>
<td>7.1</td>
<td>1.0% of Reading</td>
<td>Niagara</td>
<td>MTX 60480P014</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 MNPT</td>
<td>Noryl</td>
<td>250</td>
<td>200</td>
<td>Reed Switch</td>
<td>None</td>
<td>5 x D</td>
<td>3 x D</td>
<td>2</td>
<td>50.0</td>
<td>13.0</td>
<td>1.0% of Reading</td>
<td>Niagara</td>
<td>MTX 60480P016</td>
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<td>1.5 MNPT</td>
<td>Noryl</td>
<td>250</td>
<td>200</td>
<td>Reed Switch</td>
<td>None</td>
<td>5 x D</td>
<td>3 x D</td>
<td>3</td>
<td>85.0</td>
<td>12.5</td>
<td>1.0% of Reading</td>
<td>Niagara</td>
<td>MTX 60480P018</td>
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<tr>
<td>2 Flange</td>
<td>Noryl</td>
<td>250</td>
<td>200</td>
<td>Reed Switch</td>
<td>None</td>
<td>5 x D</td>
<td>3 x D</td>
<td>4</td>
<td>130.0</td>
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<tr>
<td>2 Flange</td>
<td>Polyethersulfone</td>
<td>250</td>
<td>200</td>
<td>Reed Switch</td>
<td>None</td>
<td>5 x D</td>
<td>3 x D</td>
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<td>WPX 60480P060</td>
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<td>200</td>
<td>Reed Switch</td>
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<td>5 x D</td>
<td>3 x D</td>
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<td>600.0</td>
<td>2.9</td>
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<td>Niagara</td>
<td>WPX 60480P061</td>
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### Table 8: Pre-Approved Condensate Flow Meters: Drum

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<tr>
<th>Inlet Line Size (OD in)</th>
<th>Outlet Line Size</th>
<th>Meter Size</th>
<th>Min Capacity (lbs/hr)</th>
<th>Max Capacity (lbs/hr)</th>
<th>Max Capacity (lbs/revolution)</th>
<th>Max Capacity (lbs/pulse)</th>
<th>Output Type</th>
<th>Output Circuit Max Voltage Rating</th>
<th>Output Circuit Max Amperage Rating</th>
<th>Upstream Liquid Head Height Requirement</th>
<th>Accuracy (+/-)</th>
<th>Make</th>
<th>Flow Meter Model</th>
<th>Output Module Model</th>
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<tbody>
<tr>
<td>0.5</td>
<td>1.25 A</td>
<td>0</td>
<td>250</td>
<td>2.5</td>
<td>0.4167</td>
<td>Reed switch</td>
<td>140 VAC</td>
<td>0.5A</td>
<td>12&quot; to CL of inlet</td>
<td>1.0% of Reading</td>
<td>EA140</td>
<td>Cadillac</td>
<td>CGALRCS</td>
<td></td>
</tr>
<tr>
<td>0.5</td>
<td>1.5 B</td>
<td>0</td>
<td>500</td>
<td>5</td>
<td>0.8333</td>
<td>Reed switch</td>
<td>140 VAC</td>
<td>0.5A</td>
<td>12&quot; to CL of inlet</td>
<td>1.0% of Reading</td>
<td>EB140</td>
<td>Cadillac</td>
<td>CGBLRCS</td>
<td></td>
</tr>
<tr>
<td>0.5</td>
<td>1.5 C</td>
<td>0</td>
<td>750</td>
<td>7.5</td>
<td>1.2500</td>
<td>Reed switch</td>
<td>140 VAC</td>
<td>0.5A</td>
<td>12&quot; to CL of inlet</td>
<td>1.0% of Reading</td>
<td>EC140</td>
<td>Cadillac</td>
<td>CGCLRCS</td>
<td></td>
</tr>
<tr>
<td>0.75</td>
<td>2 D</td>
<td>0</td>
<td>1500</td>
<td>15</td>
<td>2.5000</td>
<td>Reed switch</td>
<td>140 VAC</td>
<td>0.5A</td>
<td>12&quot; to CL of inlet</td>
<td>1.0% of Reading</td>
<td>ED140</td>
<td>Cadillac</td>
<td>CGDLRCS</td>
<td></td>
</tr>
<tr>
<td>0.75</td>
<td>2.5 E</td>
<td>0</td>
<td>3000</td>
<td>30</td>
<td>5.0000</td>
<td>Reed switch</td>
<td>140 VAC</td>
<td>0.5A</td>
<td>18&quot; to CL of inlet</td>
<td>1.0% of Reading</td>
<td>EE140</td>
<td>Cadillac</td>
<td>CGELRCS</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>3 F</td>
<td>0</td>
<td>6500</td>
<td>65</td>
<td>10.8333</td>
<td>Reed switch</td>
<td>140 VAC</td>
<td>0.5A</td>
<td>18&quot; to CL of inlet</td>
<td>1.0% of Reading</td>
<td>EF140</td>
<td>Cadillac</td>
<td>CGFLRCS</td>
<td></td>
</tr>
<tr>
<td>1.25</td>
<td>3 G</td>
<td>0</td>
<td>12000</td>
<td>120</td>
<td>20.0000</td>
<td>Reed switch</td>
<td>140 VAC</td>
<td>0.5A</td>
<td>18&quot; to CL of inlet</td>
<td>1.0% of Reading</td>
<td>EG140</td>
<td>Cadillac</td>
<td>CGGLRCS</td>
<td></td>
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Table 9. Pre-Approved Resistance Temperature Devices (RTDs)

<table>
<thead>
<tr>
<th>Pipe Size OD</th>
<th>MFG.</th>
<th>App.</th>
<th>Series</th>
<th>Tolerance</th>
<th>Base Resist.</th>
<th>Temp Coeff (alpha, deg C^-1)</th>
<th>OD</th>
<th>Type</th>
<th>RTD Immersion Length</th>
<th>Matching T. Well Included?</th>
<th>T. well Lag Length (in)</th>
<th>4-20 mA Trans. Range (deg F)</th>
<th>RTD Part Number</th>
<th>T. well Part Number</th>
<th>Transmitter Part Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>3&quot;</td>
<td>JMS Southeast</td>
<td>CHW/HW</td>
<td>Platinum</td>
<td>+/- 0.03 C</td>
<td>100 Ohm</td>
<td>0.00385 1/4&quot; 3-Wire</td>
<td>1.625</td>
<td>Yes</td>
<td>1/2&quot;</td>
<td>30-530</td>
<td>RST185L483-S4C008T7-SL-BHN31-T.440-385U-S(30-230F)</td>
<td>Included</td>
<td>Included</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4-6&quot;</td>
<td>JMS Southeast</td>
<td>CHW/HW</td>
<td>Platinum</td>
<td>+/- 0.03 C</td>
<td>100 Ohm</td>
<td>0.00385 1/4&quot; 3-Wire</td>
<td>2.5</td>
<td>Yes</td>
<td>1/2&quot;</td>
<td>30-530</td>
<td>RST185L483-S4C008T7-SL-BHN31-T.440-385U-S(30-230F)</td>
<td>Included</td>
<td>Included</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8-10&quot;</td>
<td>JMS Southeast</td>
<td>CHW/HW</td>
<td>Platinum</td>
<td>+/- 0.03 C</td>
<td>100 Ohm</td>
<td>0.00385 1/4&quot; 3-Wire</td>
<td>4.5</td>
<td>Yes</td>
<td>1/2&quot;</td>
<td>30-230</td>
<td>RST185L483-S4C008T7-SL-BHN31-T.440-385U-S(30-230F)</td>
<td>Included</td>
<td>Included</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12&quot;</td>
<td>JMS Southeast</td>
<td>CHW/HW</td>
<td>Platinum</td>
<td>+/- 0.03 C</td>
<td>100 Ohm</td>
<td>0.00385 1/4&quot; 3-Wire</td>
<td>6</td>
<td>Yes</td>
<td>1/2&quot;</td>
<td>30-230</td>
<td>RST185L483-S4C008T7-SL-BHN31-T.440-385U-S(30-230F)</td>
<td>Included</td>
<td>Included</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14-16&quot;</td>
<td>JMS Southeast</td>
<td>CHW/HW</td>
<td>Platinum</td>
<td>+/- 0.03 C</td>
<td>100 Ohm</td>
<td>0.00385 1/4&quot; 3-Wire</td>
<td>7.5</td>
<td>Yes</td>
<td>1/2&quot;</td>
<td>30-230</td>
<td>RST185L483-S4C100T8-SL-BHN31-T.440-385U-S(30-230F)</td>
<td>Included</td>
<td>Included</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18-24&quot;</td>
<td>JMS Southeast</td>
<td>CHW/HW</td>
<td>Platinum</td>
<td>+/- 0.03 C</td>
<td>100 Ohm</td>
<td>0.00385 1/4&quot; 3-Wire</td>
<td>10.5</td>
<td>Yes</td>
<td>1/2&quot;</td>
<td>30-230</td>
<td>RST185L483-S4C100T8-SL-BHN31-T.440-385U-S(30-230F)</td>
<td>Included</td>
<td>Included</td>
<td></td>
<td></td>
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<tr>
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<td>100 Ohm</td>
<td>0.00385 1/4&quot; 3-Wire</td>
<td>1.625</td>
<td>Yes</td>
<td>1/2&quot;</td>
<td>30-530</td>
<td>3SSBNK128SP2ZYYZI</td>
<td>STA12X</td>
<td>8N30-230F2Z</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4-6&quot;</td>
<td>JMS Southeast</td>
<td>CHW/HW</td>
<td>Platinum</td>
<td>+/- 0.03 C</td>
<td>100 Ohm</td>
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<td>2.5</td>
<td>Yes</td>
<td>1/2&quot;</td>
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<td>STA12X</td>
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<tr>
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<tr>
<td>3&quot;</td>
<td>JMS Southeast</td>
<td>Steam</td>
<td>Platinum</td>
<td>+/- 0.03 C</td>
<td>100 Ohm</td>
<td>0.00385 1/4&quot; 3-Wire</td>
<td>1.625</td>
<td>Yes</td>
<td>1/2&quot;</td>
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<td>Included</td>
<td></td>
<td></td>
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<tr>
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<td>Steam</td>
<td>Platinum</td>
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<td>100 Ohm</td>
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<td>6</td>
<td>Yes</td>
<td>1/2&quot;</td>
<td>30-530</td>
<td>RST185L483-S4C008T7-SL-BHN31-T.440-385U-S(30-530F)</td>
<td>Included</td>
<td>Included</td>
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<tr>
<td>14-16&quot;</td>
<td>JMS Southeast</td>
<td>Steam</td>
<td>Platinum</td>
<td>+/- 0.03 C</td>
<td>100 Ohm</td>
<td>0.00385 1/4&quot; 3-Wire</td>
<td>7.5</td>
<td>Yes</td>
<td>1/2&quot;</td>
<td>30-530</td>
<td>RST185L483-S4C008T7-SL-BHN31-T.440-385U-S(30-530F)</td>
<td>Included</td>
<td>Included</td>
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<tr>
<td>18-24&quot;</td>
<td>JMS Southeast</td>
<td>Steam</td>
<td>Platinum</td>
<td>+/- 0.03 C</td>
<td>100 Ohm</td>
<td>0.00385 1/4&quot; 3-Wire</td>
<td>10.5</td>
<td>Yes</td>
<td>1/2&quot;</td>
<td>30-530</td>
<td>RST185L483-S4C008T7-SL-BHN31-T.440-385U-S(30-530F)</td>
<td>Included</td>
<td>Included</td>
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NOTE: FOR ALL JMS SOUTHEAST RTDS SHOWN BELOW, THERMOWELL AND TRANSMITTERS ARE NOT NORMALLY INCLUDED WITH RTDS, SO ENGINEER MUST SPECIFY EACH PART NUMBER INDIVIDUALLY.
### Table 10. Pre-Approved Pressure Transmitters

<table>
<thead>
<tr>
<th>Connection Size</th>
<th>Manufacturer</th>
<th>Model</th>
<th>Output</th>
<th>Configuration</th>
<th>Span (psi)</th>
<th>Min Accuracy</th>
<th>Housing Material</th>
<th>Display</th>
<th>Sensor Part Number</th>
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</thead>
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<tr>
<td>1/2&quot; FNPT</td>
<td>Yokogawa</td>
<td>EJA530E</td>
<td>4-20 mA</td>
<td>HART 5/7</td>
<td>0-250</td>
<td>0.25% of span</td>
<td>Aluminum</td>
<td>None</td>
<td>EJA530E-JBS4N-01ZNN</td>
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<tr>
<td>1/2&quot; NPT</td>
<td>Siemens</td>
<td>P300</td>
<td>4-20 mA</td>
<td>HART</td>
<td>0-250</td>
<td>0.25% of span</td>
<td>Stainless Steel</td>
<td>None</td>
<td>7MF8023-1EA14-1AJ1-Z-B21+Y01+Y16</td>
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<tr>
<td>1/2&quot; NPT</td>
<td>Foxboro</td>
<td>IGP10</td>
<td>4-20 mA</td>
<td>HART</td>
<td>0-250</td>
<td>0.25% of span</td>
<td>Aluminum</td>
<td>None</td>
<td>IGP10-T22D1F</td>
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### Table 11. Pre-Approved BTU Computer

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Series</th>
<th>Display</th>
<th>Input Power</th>
<th>Description</th>
<th>Mounting</th>
<th>Options</th>
<th>Model Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kessler Ellis Products</td>
<td>ST2</td>
<td>LCD</td>
<td>120 VAC</td>
<td>KEP BTU Computer electronic module only.</td>
<td>NEMA 4, Panel</td>
<td>Include Internal Modbus TCP/IP Card (CAT5e connection) and RS485 Terminal Block</td>
<td>ES74L1(3MOD/IP)P</td>
</tr>
<tr>
<td>Kessler Ellis Products</td>
<td>Enclosure</td>
<td>N/A</td>
<td>N/A</td>
<td>KEP Enclosure for Supertrol II</td>
<td>NEMA 4x/IP65, Wall</td>
<td>Windowed front, hinged panel left</td>
<td>MS811; NEMAST4X1H1L</td>
</tr>
</tbody>
</table>
Figure 6. Typical Pumped Condensate Meter Installation (DWG M01)
Figure 7. Typical Gravity Return Electromagnetic Condensate Meter Installation (DWG M02.1)
Figure 8. Typical Gravity Return Condensate Meter Installation (DWG M02.2)
Figure 9. Typical Steam Meter Installation (DWG M03)
Figure 10. Typical Cone DP Steam Meter Installation (DWG M03.1)
Figure 11. Typical Chilled Water Meter Installation (DWG M04.1)
Figure 12. Typical Bi-Directional Chilled Water Meter Installation (DWG M04.2)

NOTES:

* INSTALL ELECTROMAGNETIC FLOWMETER SUCH THAT ELECTRONICS ARE POSITIONED AT THE 12 O'CLOCK OR 6 O'CLOCK POSITION
* FOLLOW ALL OEM INSTALLATION INSTRUCTIONS INCLUDING ANY GROUNDING REQUIREMENTS

KEY

- Pressure Boundary
- Electrical
- UMN Meter Technician (Programming)
- OIT
Figure 13. Typical Condensate BTU Computer Wiring Diagram (DWG E01)
Figure 15. Typical Chilled Water BTU Computer Wiring Diagram (DWG E03.1)
Figure 16. Typical Bi-Directional Chilled Water BTU Computer Wiring Diagram (DWG E03.2)
Figure 17: Typical Communication and PLC Wiring Diagram (DWG E04)