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

23 00 01 General: 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.

23 00 02 Scope: This division covers the following mechanical systems:
   a. Heating, Ventilating, and air-conditioning (HVAC), including, all ducting, air handling equipment, all supply, return, and exhaust fans, all heat recovery equipment and any other air flow equipment for buildings environmental controls
   b. All HVAC equipment piping
   c. All ventilation for research related equipment
   d. All bio-tech related piping
   e. Steam distribution and individual applications
   f. Chilled water and glycol distribution and individual applications
   g. Hydronic heating distribution and individual applications
   h. Compressed air generation and distribution for the laboratory applications
   i. All process piping for all research related equipment
   j. All piping in utilities tunnels and shafts.
   k. All direct buried piping for all utilities, including the factory insulated steam and condensate piping.
   l. 23 00 02 Prohibited materials and practices:
      Where applicable, individual sub sections include the prohibited materials and installation practices.

23 00 03 Codes: All work shall meet all applicable U of M, local, state and national codes and standards.

23 00 04 Design Intent Report/Basis of Design:
   Architect/Engineer (A/E) shall provide a design intent report at the preliminary design phase that documents the following:
   a. Energy conservation measures and energy requirements for the proposed facility.
   b. Noise criteria
   c. Choice of equipment with life cycle cost analysis
   d. Variances to the codes and standards
   e. B3, SB-2030 and/or LEED compliance measures when required.
   f. 50 year design considerations and its impact on mechanical equipment selection. Most mechanical equipment has a 25 years life.
   g. Alternates and proposed value engineered construction materials and construction methods.

23 00 05 Coordination with University of Minnesota departments.
05.1. The architectural and engineering consulting firm (A/E) shall coordinate with the following departments to ensure that the users needs are satisfied:
1. Facilities Management (FM)
2. Board of Regents
3. U of M Building Code Office
4. Capital Project Management (CPM)
5. Office of Classroom Management (OCM)
6. Department of Environmental Health and Safety (DEHS)
7. Disability Services
8. Facility Support
9. Food Service
10. Parking and Transportation Services (PTS)
11. Central Security
12. Office of Information Technology (OIT)
13. University of Minnesota Policy Department (UMPD)
15. Operations and Maintenance
16. District offices

The A/E shall also coordinate with the University Utility Group to determine availability of steam, chilled water, compressed air, and 13.8 KV electrical feed for connection to campus utility systems.

05.2. The architect shall work with the mechanical engineer to ensure that the equipment installation meets the architectural requirements of the building. All mechanical equipment shall be located inside the building except cooling towers and rooftop air handling equipment.

05.3. Building air intakes shall be located a minimum of 30 feet above the grade or on the roof. On buildings less than three stories high, location on the roofs shall be allowed. All ground level air intakes shall be reviewed and approved by the Facilities Management.

### 23 00 06 Access for maintenance

06.1. Location of equipment shall be determined by its service need, so it can be easily maintained. 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. The A/E shall provide sectional drawings of the mechanical rooms and shall meet with the district (Facilities Management) early in the design phase. For all equipment on flat and pitched roofs, access, safety and service platforms shall be provided per MN OSHA and MN building codes.

06.2. The A/E shall coordinate the mechanical design with other disciplines to provide adequately sized and properly located access panels.

06.3. If below ground pits are required, these shall be minimum 6’x6’ with permanent ladders, gratings, and railings, a minimum 20 A GFI outlet, and a floor drain. These shall be reviewed with the DEHS for the confined spaces and properly labeled.
23 00 07  **Mechanical Standards:** 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.

23 00 08  **Mechanical Drawings:** Mechanical drawings shall be clearly delineated at
appropriate scale to accurately define piping, ductwork and equipment. The A/E shall provide
coordination drawings when necessary. These are different than the construction coordination
drawings, normally in 3d format.

23 00 09  **Coordination with other trades**

09.1. 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.

23 00 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 limited to welding and
pressure piping.

23 00 11  **Equipment Bases:** Concrete bases with a 4-inch minimum height shall be
provided under all floor-mounted mechanical equipment. The concrete base height shall be
adequate to accommodate condensate ‘P’ traps and proper condensate flow. Base size and
location shall be coordinated with the equipment specified and shall be shown on the
architectural and structural drawings. Mechanical equipment shall be installed using vibration
isolators. The vibration isolators shall be per equipment manufacturer’s recommendations. No
isolation to the floor is needed for slab on grade.

Concrete bases for equipment requiring isolation pads shall be designed, reviewed and approved
by the final user of the equipment.

23 00 12  **Painting**

12.1. All piping, ducts, radiation, grills, diffusers and other equipment that is exposed in finished
and unfinished spaces shall be painted in accordance with Division 09 91 00 under finishes.

12.2. 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.

23 00 13  **Existing Facilities:** For remodeling projects, the University of Minnesota shall
provide openings in walls and ceilings where required and where the A/E requests to permit verification of existing piping, ductwork and equipment.

**23 00 14 Building Service Outages:** The A/E shall coordinate this requirement with the Preconstruction Meeting Agenda form located in the Forms Section.

14.1. Service Outage Request: The contractor shall request all building service outages through the Project Manager. All outages shall be accommodated Monday thru Thursday unless otherwise requested by the Project Manager. The contractor shall give 2 week notice to the Project Manager for any planned service outages.

14.2. 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.

14.3. Fire Safety Precautions

14.3.1. 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.

14.3.1.1. 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.

14.3.1.2. 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.

14.3.1.3. 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.

14.3.1.4. 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 fires.

14.3.1.5. Before grinding, cutting, brazing, sweating or welding, consult with the A/E as to particular safety precautions.

14.3.1.6. 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 the Standard Operating Procedures for Hot Works form located in the Forms Section.

23 00 15  Mechanical Equipment Rooms, Penthouse Access

15.1. All equipment rooms shall be properly ventilated to maintain proper operating temperatures as required by the proper equipment operation.

15.2. Mechanical equipment shall be located, sized and arranged in a space that provides easy access for maintenance, repair and future replacement. The equipment also shall be enclosed to separate it from other building functions.

15.3. Where heat-generating equipment is situated adjacent to or above occupied spaces, the equipment shall be ventilated. In addition, the floors, walls and ceilings shall be insulated with permanently attached, durable, and fire-resistant insulation to provide a “U” (overall heat transfer coefficient) value through the wall or ceiling not to exceed 0.15 BTU/hr. sq. ft. °F. The insulating materials shall be reviewed and approved by the U of M designated representative.

15.4. Adequate provisions shall be made in mechanical space to support equipment, piping and ductwork.

15.5. Equipment, piping and ductwork in such 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.

15.6. No mechanical equipment of any type shall be placed in building areaways or tunnels without prior approval from the appropriate parties. No piping shall run into or through fresh air plenums and/or air ducts.

23 00 16  Operating Instructions

16.1. 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.

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

16.3. 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.

23 00 17  Energy Information

17.1. The Uof M operates its own central steam, chilled water, central compressed air, and primary electric distribution systems. For utility services to new buildings or existing buildings
being remodeled, contact the University Energy Management Utility section for information on utility services availability and installation requirements to connect to the central systems.

17.2. Specification for new university buildings shall include a section that identifies the peak and monthly energy and utility requirements of the buildings. The requirements shall include electrical, chilled water, gas, steam, compressed air, and water services. Provide both design load and estimated load.

17.2.1. Electricity

A. Design Load: kWh/month for a 12-month period
B. Design Demand: Peak kW/month for a 12-month period
C. Estimated Load Profile: kWh/month for a 12-month period
D. Estimated Demand: Peak kW/month for a 12-month period

17.2.2. Chilled Water

A. Design Load: Tons of cooling required/chiller size recommended
B. Installed Capacity: Chiller size in tons if a stand alone chiller is required.
C. Design cooling load calculations in tons on a design day
D. Estimated Load Profile: Ton hours/month for a 12-month period

17.2.3. Gas

A. Estimated Load Profile: Therms/month for a 12-month period
B. Design Demand: Peak usage, cubic ft./hr. on a design day

17.2.4. Steam

A. Estimated Load Profile: Steam pounds per month for a 12-month period
B. Design Demand: Peak steam demand in pounds per hour on a design day

17.2.5. Water

A. Estimated Load Profile: Water gallons per month for a 12-month period
B. Design Demand: Gallons/hour maximum

17.2.6 Compressed Air

A. Estimated use in SCFM
B. Designed load in SCFM

23 00 18 Energy Conservation and Sustainability

Refer to the Sustainable Design Standards section (General Information) for energy conservation design requirements.
**23 00 19 Industry Standards**

In addition to the requirements of the regulatory agencies listed in Division 01 00 00 - General Requirements, Division 01 41 13 - Building Code Regulatory Requirements, the design and construction shall conform to the latest edition of the following standards where applicable:

- a. American Concrete Institute
- b. American Conference of Governmental Industrial Hygienists
- c. American Institute of Steel Construction
- d. American Society of Heating, Refrigeration and Air Conditioning Engineering
- e. American Society of Mechanical Engineers
- f. American Society for Testing Materials
- g. American Water Works Association
- h. American Welding Society
- i. ANSI Code for Power Piping B31.1
- j. Associated Air Balance Council
- k. Hydraulic Institute Standards for Centrifugal, Rotary and Reciprocating Pumps
- l. Institute of Electrical and Electronic Engineers
- m. National Association of Sheet Metal and Air Conditioning Contractors
- n. National Board of Boiler and Pressure Vessel Inspectors
- o. National Bureau of Standards
- p. National Commercial and Industrial Insulation standards
- q. National Environmental Balancing Bureau
- r. National Fire Protection Association
- s. National Safety Code for Mechanical Refrigeration
- t. International Institute of Ammonia Refrigeration
- u. ASME BioProcessing Equipment and Piping

**23 00 20 Welding and Brazing**

20.1. Certified and licensed trades persons shall perform all mechanical welding and brazing. 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.

20.2. 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.

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

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

**23 00 21 Electrical Requirements**
21.1. 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.

21.2. 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.

21.3. 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.

23 00 22 Excavation and Backfill for Underground Mechanical Work

22.1. 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.

22.2. Fill at manholes shall be placed in 6-inch lifts and compacted to the standards specified in Division 31 - Earth Work.

23 00 23 Equipment Isolation

23.1. The specifications shall include isolation valves. All equipment must be installed with isolation valves for shutoff service. The valves must have flanged or screwed ends. If screwed, provide a union between equipment and valve.

23.2. All systems such as potable water, heating systems and cooling systems must have a minimum of one isolation valve per building level.

23 00 24 Equipment and System Cleaning

24.1. The specifications shall include system-cleaning requirements. After hydrostatic tests and prior to operating tests, equipment, including and not necessarily limited to the chiller, cooling tower, boilers, heat exchangers and all piping shall be thoroughly flushed and cleaned.

24.2. All piping systems, including open and closed loops, shall be cleaned and disinfected before they become operational. Exception: Sanitary and storm sewers are not required to be disinfected. The A/E shall specify that cleaning and disinfecting the system be done by the university water treatment supplier. Coordination of the activity with the District is required. Disinfecting shall be done to meet the minimum requirements that DEHS defines.

24.3. After the solution has cleaned the system, the solution shall be drained and thoroughly flushed with fresh water from the system. After initial cleaning, the Project Manager or designee shall sign and certify that the system has been thoroughly cleaned. Any cleaning water that cannot be drained to the city sewer system shall be removed from the site by the contractor.

23 00 25 Basic tunnel requirements.
General: These services and equipment are provided by appropriate contractors.

25.1. Lighting must be equivalent to equipment rooms. Two-lamp fluorescent, surface-mounted, low profile fixtures that are free from sharp edges are preferred. Pay careful attention to location to ensure that lighting fixtures do not pose a hazard for head injuries.

25.2. Four-way convenience outlets shall be no farther than 100 feet apart.

25.3. Welding outlets that match existing standard welding outlets shall be no farther than 200 feet apart.

25.4. Provide ventilation. Fresh air sources shall be controlled with manual dampers.

25.5. Surface and groundwater must be drained to the nearest storm sewer. Drainage pipes and trenches must be designed so that trash, sand, mineral deposits and other debris can be easily removed.

25.6. Secure all access points by padlock or key lock or electronic card entry. Full-sized doors require panic hardware. Dampers may be provided on doors for ventilation.

25.7. Designers shall contact University Energy Management Utility Section personnel regarding specific design requirements for equipment that detects intrusion into tunnels and steam system sensors.

23 00 26 Tunnel Communication Cable Installation.

1. General: 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.

2. Planning

2.1. 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 detail precisely where the cable is to be routed. Drawings shall clearly point out locations where headroom or other safety compromises cannot be avoided.

2.2. 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.
3. Installation

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

3.2. Cable installation shall be done in as safe and professional manner as possible.

3.3. New installation shall not create unnecessary safety hazards.

3.4. Headroom shall be maintained at all times in all locations.

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

3.6. Cable installation shall be free of sharp edges.

3.7. Remove unused cable at the earliest possible time.

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

23 01 30 Operation and Maintenance of HVAC Air Distribution

30.51 HVAC Duct Cleaning
When duct cleaning is necessary, refer to Appendix II - HVAC System Decontamination: Duct Cleaning.

For all new construction, all HVAC ducts shall be cleaned prior to the commissioning of HVAC equipment and acceptance of the mechanical work.

For all remodeling, all ductwork shall be cleaned as required and as directed by the A/E and the District’s personnel.

23 01 60 Operation and Maintenance of Central Cooling Equipment

60.71 Refrigerant Recovery/Recycling
For all new and remodeling work, special attention shall be provided to eliminate any leaks and accidental discharge of any refrigerant to the atmosphere. All refrigerants shall be recovered and recycled per local and national standards and codes. The recovered refrigerant are the property of the U of M. These shall be saved or discarded by the contractor as directed by the U of M authorized personnel.

23 05 13 Common Motor Requirements for HVAC Equipment
Design ‘E’ motors are prohibited
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.

All electrical motors shall be of high efficiency, 1.1 service factor.

All motors located inside the air handling equipment shall be TEFC.

All motors located in the ambient shall be protected from rain.

All motors shall meet the minimum requirements of all applicable Energy codes, and standards.

23 05 16 Expansion Fittings and Loops for HVAC Equipment

1. Wherever practical, show details for properly designed expansion loops or piping offsets to compensate for thermal expansion in the piping system. A structural engineer shall design anchors and guides for expansion loops and joints as required. Show details for the anchors and guides on the drawings. A structural registered engineer’s signed design calculations shall be submitted for review.

2. 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.

3. Where loops cannot be used, the following expansion joints shall be specified:

   3.1. Low Pressure Steam Lines (15 psig and less)

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

      3.1.2. 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.

      3.1.3. 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.

      3.1.4. 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.

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

   3.2. High Pressure Steam Lines (greater than 15 psig)
3.2.1. High-pressure steam lines greater than 15 psi: 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.

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

3.2.3. 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 with 100 degree F superheat.

3.2.4. 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.

3.2.5. 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.

3.2.6. Specify Advanced Thermal Systems Inc. or university-approved equal.

23 05 19 Meters and Gages for HVAC Piping

1. General

1.1. 1/8” NPT connection and dry pressure gages are prohibited

1.2. The designer shall obtain information and assistance that relates to the location(s) and design of all meters by contacting University Energy Management. Initial contact shall be made at the earliest possible stage of design. Steam condensate and chilled water meters shall have a local readout and be capable of interfacing with the local Building Automation System and BSAC to enable remote reading and data logging.

1.3. The A/E shall provide University Energy Management with utility and energy consumption and demand estimates. These estimates shall be calculated in accordance with the ASHRAE bin method described in the handbook of fundamentals. Include estimated building or system design requirements, demand peak, minimum usage and hourly consumption for electricity, steam, chilled water, domestic water and sanitary sewer.

1.4. Verify with University Energy Management if sub-metering is needed.
1.5. University Energy Management shall use the estimates that the A/E provides to analyze existing utility infrastructure systems and determine if adequate capacity exists. University Energy Management and the A/E shall work together to determine the location of utility tie-ins and meter requirements.

1.6. The A/E shall include a copy of the utility meter report form in the specifications for the contractor to complete prior to receiving utility services. The A/E shall submit the form to University Energy Management.

1.7. Chilled water and steam condensate water meters shall be connected to the building automation center. Chilled water and condensate meters shall be sized and specified by the Energy Management and procured and installed by the mechanical contractor.

1.8. Water meters used for potable water, including cooling towers, shall be installed with an electronic radio transmitter (ERT) device for remote reading. The ERT shall be located on the outside perimeter wall of the building. Empty conduit is required from the meter to the ERT. Wiring is provided by the local water utility provider.

1.9. The A/E shall develop a sub-metering plan with the Project Manager as required.

1.10. Provide a local disconnect switch inside a lockable box for all meters.

1.11. The A/E shall design a metering system that includes a scaled piping drawing and electrical wiring diagram in sufficient detail so that accuracy and maintainability are not compromised.

1.12. The design specifications shall call for the contractor to furnish the proper documentation on all meters, including assembly drawings, parts lists, calibration certificates, wiring diagrams, maintenance instructions and recommended spare parts lists to University Energy Management.

2. Steam Meters

2.1. 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. Steam meters shall be sized and specified by the Energy Management and procured and installed by the mechanical contractor.

2.2. Steam supply systems in buildings that will be occupied by more than one university department or shared between non-university and university entities shall be designed to incorporate separate metering.

2.3. Using the data identified in item 1.3 of this section, and any other relevant design information, the A/E shall design a metering system accurate to +/- 2 percent of actual flow over the top 90 percent of the building steam demand. It shall have a minimum turndown of 40:1. The metering system shall be temperature-compensated and pressure-compensated.

2.4. All steam meters shall be provided with remote surface-mount electronic totalizers with two clearly identified terminals that allow for the remote readout of consumption. One terminal shall
have local readout and the other shall be capable of interfacing with the Building Automation System and BSAC to enable remote reading and data logging.

2.5. One remote readout terminal shall be a dry contact type, normally closed, and shall open to indicate a unit of measure. The contact shall be rated for at least two amps at 120 volts. The contact shall remain open for at least 40 milliseconds. The other remote readout terminal shall be 4 mA to 20 mA that is proportional to the flow rate. The totalizers shall be of a backlit LCD type, indicating steam flow and total, as manufactured by Kessler Ellis or university-approved equal.

2.6. Steam metering systems shall incorporate electronic "peak pickers" that can be reset and store monthly peak flow.

3. Chilled Water Meters

3.1. Chilled water meters shall be incorporated into the design of the chilled water distribution systems for all new buildings that consume steam supplied by a central heating plant.

3.2. Chilled water supply systems in buildings that will be occupied by more than one university department or shared between non-university and university entities, shall be designed to incorporate separate metering.

3.3. Chilled water meters shall be incorporated into the design of chilled water systems to measure the water flow and BTUs of the chilled water. Meters shall be manufactured by EMCO, model MAGFLO 3100 or university-approved equal.

3.4. Totalizers shall be designed to read tons and ton/hours. Totalizers shall be manufactured by EMCO, model FP-100 or university-approved equal.

3.5. The designer shall analyze the range of flow that chilled water systems operate. The designer also shall design a metering system that is accurate at all anticipated flow to a maximum error of +3 percent of actual flow over the top 90 percent of the building chilled water demand.

3.6. Chilled water meters shall be able to measure flow bi-directionally using magnetic or ultrasonic transducers. Chilled water meters also shall measure temperature differences of at least 1 degree F using matched RTD sensors.

3.7. Chilled water meters shall be provided with local readout and with two clearly identified terminals that allow for the remote readout of consumption. One remote readout shall be connected to the chiller control panel and the other remote readout to BSAC.

4. Steam Condensate Meters

4.1. 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.
4.2. Steam condensate return systems in buildings that will be occupied by more than one university department or shared between non-university and university entities shall be designed to incorporate separate metering.

4.3. When the building design includes a condensate pump, a turbine hot water meter, Niagara WPX series turbine flowmeter or university-approved equal shall be used.

4.4. If the building design does not require a condensate pump, the meter shall be a low-head positive displacement drum meter as manufactured by Lincoln Meter Co. or university-approved equal.

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

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

5.1. 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).

5.2. Specify pressure gauges at all inlets and outlets of pumps and 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.

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

5.4. 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.

5.5. 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.

5.6. 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

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

1.2 Valves

1.2.1. General
1.2.1.1. Valves shall use chain operators when necessary.

1.2.1.2. Valve material must be compatible with system fluid.

1.2.1.3. Valves in accessible areas shall be secured.

1.2.1.4. The majority of valves for all major piping systems, except steam service, shall be ball valves unless noted otherwise on the drawings.

1.2.1.5. Provide a by-pass on all actuated valves unless noted otherwise.

1.2.1.6. PVC valves shall be true union type.

1.2.1.7. Use threaded connections for pipes that are 2 inches and smaller, except for a high-pressure steam system that is welded or concealed gas piping, which is to be welded. Use flanged connections for pipes 2-1/2 inches and larger unless noted otherwise. PVC/thermoplastic valves that are 3 inches and smaller shall have sockets. PVC/thermoplastic valves that are 4 inches and larger shall be flanged.

1.2.1.8. The minimum rating for valves shall be one and a half times the maximum system pressure, except high-pressure steam shall be ANSI Class 300 and low-pressure steam shall be ANSI Class 150.

1.2.2. Balancing Valves: Ball valves with memory stops shall be specified for balancing hydronic systems. Triple duty hydronic valves are acceptable, however, butterfly valves with butterfly check valve combination is preferred.

1.2.3. Gate Valves

1.2.3.1. Valves used for compressed air, chilled water, heating water, and condenser water shall be the following:

   1.2.3.1.1. Valves up to 2 inches in size shall be bronze body, ANSI Class 150 minimum, union bonnet, rising stem, solid wedge gate, screwed type, Milwaukee No. 1151 or the U of M approved equal.

   1.2.3.1.2. Valves 2-1/2 inches in size and larger shall have flanged ends, cast steel body, ANSI Class 150 minimum, rising stem, outside stem and yoke, renewable seat and solid wedge, Milwaukee No. 1550 or the U of M approved equal.

1.2.3.2. Valves used for low-pressure steam 15 psi and below shall be the following:

   1.2.3.2.1. 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 steel seat rings, solid wedge, welded bonnet, Bonney Forge W-11-T or the U of M approved equal.
1.2.3.2.2. 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.

1.2.3.3. Valves used for high-pressure steam more than 15 psi shall be the following:

1.2.3.3.1. 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.

1.2.3.3.2. 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. Valves in main service required for warm-ups shall have externally tapped by-pass and be so noted on drawings.

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

1.2.4. Butterfly Valves

1.2.4.1. Valves used for compressed air, chilled water, condenser water, and heating water service up to 150 degrees F. They also shall be of a threaded lug style or a flanged style with extended necks, cast iron body, ANSI Class 125 or ANSI Class 150 compatible flanges, 316 stainless steel shaft and disc, hand lever with 10 position notch plate, EPDM seat. Valves must be rated for a minimum of one and half times the design pressure.

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

1.2.4.3. For high-pressure steam service 3 inches and larger, all isolation valves must be Vanessa series 30,000 or the U of M approved equal.

1.2.4.4. Butterfly valves used for isolation shall be bubble-tight.

1.2.5. Ball Valves: Prohibited on steam and condensate

1.2.5.2. All ball valves shall be full port.

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

1.2.5.4. Ball valves specified for insulated piping systems shall have extended stems. Stems shall be of sufficient length to allow free operation of handle.
1.2.5.5. Ball valves that are 2 inches and smaller shall be screwed valve, bronze body, stainless steel stem and ball, with Teflon seat or the U of M approved equal.

1.2.5.6. Ball valves that are 2-1/2 inches and larger and used for water service shall be American Valve model 4000, flanged end or the U of M approved equal.

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

1.2.6. Globe Valves

1.2.6.1. Globe valves used for low-pressure steam up to 15 psig shall be the following:

   1.2.6.1.1. 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.

   1.2.6.1.2. 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.

1.2.6.2. Valves used for high-pressure steam more than 15 psig shall be the following:

   1.2.6.2.1. 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.

   1.2.6.2.2. 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.

1.2.6.3. Valves for water service shall be ANSI Class 150 minimum, made of brass body with stainless steel trim and have a rising stem.

1.2.7. Hydrants: Provide frost-proof sill cocks on all sides of new buildings. Each sill cock shall be equipped with a non-pressure type vacuum breaker and interior shut-off valve

   1.2.7.1. Hydrants may be provided with integral vacuum breakers. Hydrants without integral vacuum breakers shall be provided with a field-testable dual check valve backflow preventor, ASSE 1052-approved and as approved by the State of Minnesota, similar to Woodford Model 67. Indicate all exterior hydrants to have loose key operating handle.

1.2.8. Check Valves: Spring loaded check valves are prohibited on steam and condensate.
1.2.8.1. Check valves for compressed air, a low-pressure steam condensate system up to 15 psig, chilled water, condenser water, potable and non-potable water and heating water service shall be as follows:

1.2.8.1.1. Valves 2 inches and smaller shall be screwed end, bronze body, 300 pound, WOG, with replaceable disc. Swing checks shall be Milwaukee 510 or the U of M approved equal. Spring checks shall be Symmons model 506 SB or the U of M approved equal.

1.2.8.1.2. Valves 2-1/2 inches and larger shall be flanged end, cast steel body, ANSI Class 150, with replaceable disc: Milwaukee No. 1570 or the U of M approved equal.

1.2.8.2. Valves for high-pressure steam more than 15 psig shall be as follows:

1.2.8.2.1. Check valves 2 inches and smaller shall be ANSI Class 800 screwed forged steel body. Swing check shall be Bonney H-60-SW.

1.2.8.2.2. 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.

1.2.9. Gas Valves

1.2.9.1. Valves on gas systems 2 inches and smaller shall be iron body or brass body, rated at 200 pounds, WOG, with screwed ends.
1.2.9.2. Valves on gas systems 2-1/2 inches and larger shall be iron body, rated at 200 pounds, WOG, with flanged ends.
1.2.9.3. Medical gas and medical vacuum valves shall comply with the current edition of NFPA 99, Standard for Health Care Facilities.

1.2.10. Oxygen Valves: Valves on oxygen main piping shall be National Cylinder Gas 2500 Series valves or the U of M approved equal. Valves shall be brass, diaphragm type globe valves of leak-proof construction.

1.2.11. Mixing Valves: All mixing valves for photo processing, emergency showers and personal use shall be Symmons or the U of M approved equal and contain integral check stops.

1.2.12. Pressure Regulating Valves

1.2.12.2. Steam pressure-reducing stations shall have duplex valves in parallel with a globe valve by-pass. One valve shall be sized to handle one-third of the maximum load, while the other shall be sized to handle the remaining load. The by-pass shall be designed to facilitate inspection of the pressure regulator without interrupting service. The control valve shall be single-seated. Pressure-reducing valves shall be pilot-operated, Spence ED or the U of M approved equal. Provide an isolation valve on each pilot line.
1.2.12.3. The pressure-reducing station shall be vented to the outside through a pressure-relief valve.

1.2.12.4. 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.

1.2.12.5. 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.

1.2.12.6. Each header shall have a drip leg with valve and trap to be gravity drained to condensate system.

1.2.13. Pressure Relief Valves

1.2.13.1. Pressure relief valves for the steam pressure-reducing station shall be sized for the total steam capacity of the steam station. 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.

1.2.13.2. All safety valves for steam shall be vented to the outside of the building away from pedestrian traffic. Maximum pressure drop in the discharge piping shall not exceed 10% of the operating pressure. The pressure relief piping shall be pitched upward and designed with proper drains. 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.

1.2.13.3. The A/E shall provide BTU-rated, ASME-approved hot water relief valves where necessary. Relief valves shall be sized to be less than the maximum allowable BTU rating for converters and boilers.

1.2.13.4. Relief valves on hot water systems shall be properly 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.

1.2.13.5. All safety valves shall be ASME-approved. All valves shall be flanged on lines that are 2-1/2 inches or larger.

1.2.13.6. Steam pressure relief valves that are 2 inches or larger shall be connected to a drip pan elbow.

23 05 29 Hangers and Supports for HVAC Piping and Equipment

1.1 Torch cut hanger rods and support members in trapeze hangers are prohibited
Clevis hangers for hanging any steam pipes are prohibited

1.2. Suitable trapeze hangers, Clevis hangers, approved Phillips shields or heavy line hangers shall support piping. Piping also shall be supported from concrete inserts or the U of M approved concrete anchors.

1.3. Hanger rods for piping supports shall comply with the following chart:

<table>
<thead>
<tr>
<th>Pipe Size</th>
<th>Hanger Rod Diameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to 2 inches</td>
<td>3/8 inch</td>
</tr>
<tr>
<td>2 ½ to 3 ½ inches</td>
<td>1/2 inch</td>
</tr>
<tr>
<td>4 to 5 inches</td>
<td>5/8 inch</td>
</tr>
<tr>
<td>6 inches</td>
<td>3/4 inch</td>
</tr>
<tr>
<td>8 to 12 inches</td>
<td>7/8 inch</td>
</tr>
</tbody>
</table>

1.4. Hangers for insulated piping shall be large enough to encompass the insulation and the metal saddle.

1.5. Specify riser clamps to support vertical risers at every floor.

1.6 Sleeves

1.6.1. 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.

1.6.2. Space between the piping/insulation and sleeve shall be sealed with an approved fire-rated caulking material on all fire-rated walls. Space between the piping/insulation and sleeve shall be sealed with an approved waterproof caulking at wet walls and through floor slabs. Sleeves through exterior walls shall be provided 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. 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.

1.6.3. Sleeves through Walls

Division 23 - Heating, Ventilation and Air Conditioning
University of Minnesota Standards and Procedures for Design
December 2012
9.3.1. 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.

9.3.2. 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.

1.6.4. Sleeves through Slabs

1.6.4.1. Generally, no sleeves are required through slabs on grade.

1.6.4.2. Sleeves through roof slabs shall be made of minimum 16-gauge galvanized steel.

1.6.4.3. 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.

1.6.4.4. 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.

1.6.4.5. 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.

1.6.4.6. Sleeves for heating piping shall be anchored midway with three anchors, 120 degrees apart.

1.6.4.7. 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.

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

23 05 53 Identification of HVAC Piping and Equipment

1.1 Magic marker or permanent pen written markings are prohibited

1.2 Identification Labels
   Ducting: Mark supply or return or exhaust every 20 feet with minimum 2” high white letters on black background
Chilled and Hot Water: Supply and return pipes shall be marked using ASME, ANSI standards and follow NFPA54 and NFPA58 guidelines. All piping shall be labeled every 20 feet and every change of direction as to type of service and direction of flow.

Natural Gas: ASME and ANSI standards

Refrigerant: ASME and ANSI standards

Steam: ASME and ANSI standards

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. Tags shall be stamped with an identifying number. 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.

Traps: Each steam trap shall be tagged with a triangular steel tag that contains the number of trap, and its orifice size. The U of M shall provide the contractor with a sequence of numbers to be used in numbering the traps. The A/E shall specify the necessary clearance for the maintenance, repair and replacement of valves and traps and other fittings.

Fume Hoods: All fume hoods, special exhaust systems and supply and return exhaust mains shall be labeled every 20 feet, including change of direction.

23 05 93 Testing, Adjusting, and Balancing

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. The contractor shall perform the fume hood evaluation procedures outlined in this section. The Class A Performance Standard requires that capture efficiency for fume hoods as used and installed must be at least 4AU0.1 as measured by the ASHRAE 110 tracer gas test. To meet the Class A standard, less than 0.1 ppm of gas shall be detected in the breathing zone when 4 l/min of test gas is released inside the hood. Performance is determined when the fume hood sash is located at the sash lock, the safety sash is moved to one side and the test mannequin is positioned in the center of the fume hood open area. Note that ASHRAE 110 is a quantitative test of capture efficiency that involves the release of a gas inside the hood and detection of escaped gas in the breathing zone of a test mannequin. The university shall check some hoods to verify the contractor's work.

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

2.1.1. Equipment List
A. A properly calibrated anemometer with a velocity grid
B. A supply of 30-second to 60-second smoke candles or a theater fog generator
C. A bottle of titanium tetrachloride and supply of cotton swabs or another smoke-producing device such as a MSA tube

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

2.1.3. Room Conditions

2.1.3.1. Verify that the cross draft velocity does not exceed 20 fpm.

2.1.3.2. 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.

2.1.3.3. Correct conditions causing cross drafts that exceed 20 fpm before performing fume hood testing.

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

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

2.1.5.1. The average face velocity for each fume hood shall be 100 (or less as approved by the DEHS) fpm (+/- 10 fpm) 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 airflow at the sash lock with the horizontal sashes closed must be 100 fpm (+/- 10 fpm) and second, airflow with the vertical sash at its lowest position and the horizontal sashes fully open must be 100 fpm (+/- 10 fpm).

2.1.5.2. The average face velocity shall be determined by taking at least six velocity readings at evenly distributed points across the open fume hood face.

2.1.6. Sash Operation

2.1.6.1. Sashes shall function smoothly through their full range of motion. Vertical rising sashes shall hold at any height without creeping up or down.

2.1.6.2. Qualitative Verification of Proper Air Flow and Patterns Using Smoke

2.1.6.2.1. 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.
2.1.6.2.2. 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.

2.1.6.2.3. 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.

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

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

2.1.6.2.6. When a hood fails a test, the contractor shall adjust the system and retest until the hood passes.

2.1.7. Disputes

2.1.7.1. The university typically will accept a hood that passes a qualitative verification of proper airflow and patterns using smoke.

2.1.7.2. 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.

2.1.8. Evaluate the Low Airflow Monitor

2.1.8.1. Verify that the monitor sounds a local audible alarm when the face velocity is less than 80 fpm or as directed by the DEHS

2.1.8.2. Ensure that alarms do not sound when the sash is open to the sash lock.

2.1.9. Reports: 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: The A/E shall specify testing and balancing procedures based on NEBB or AABC specification. The use of NEBB or AABC forms in the balancing report is required. The TAB contractor shall be NEBB or AABC certified. Each ductwork shall be tested for leaks using the maximum allowable class pressure. Follow MN Mechanical codes and nationally recognized standards.
5. Testing and Balancing of Hydronic System: Each hydronic system shall be balanced following NEBB or AABC specification. The A/E shall specify the use of NEBB or AABC forms for the balancing report. The TAB contractor shall be NEBB or AABC certified.

23 06 00 Schedules for HVAC
   All HVAC equipment schedules shall be shown on drawings.
   All Chilled water equipment schedules shall be shown on drawings.
   All Heating water equipment schedules shall be shown on drawings.
   All Steam heating equipment schedules shall be shown on drawings.
   All Refrigerant equipment schedules shall be shown on drawings.

23 07 00 HVAC Insulation

23 07 13 Duct Insulation
   1.1. Interior thermal insulation of air ducts is prohibited.
   1.2. Sound attenuation for each individual project must be reviewed and is subject to approval before design is completed.
   1.3. Duct insulation thickness and vapor jacket perm rating are in accordance with the latest MN Mechanical Code.
   1.4. 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.
   1.5. 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.
   1.6. Insulation shall be suitably framed at all access panels.
   1.7. Class I kitchen ventilation systems must be insulated as specified in NFPA 96.

23 07 16 Equipment Insulation
   1.1. Prohibited: Insulated steam traps, hot water and condensate return pumps, and hot water expansion tanks. Hog rings and staples are also prohibited.
   1.2. Pieces of 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.
1.3. Equipment condensate drain pans shall be insulated. The type and thickness of insulation shall be as specified for piping.

1.4. Specify factory insulation of autoclaves and sterilizers.

1.5. 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.

1.6 Blankets

1.6.1. 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.

1.6.2. Each removable cover shall have a close contour fit for appearance and proper thermal performance.

1.6.3. Blanket material shall be as follows:

A. Inner and outer jacketing and gussets: 17-ounce, Teflon-coated Nomex cloth
B. Insulation: 2-inch, high-density fiberglass insulation, Temp-mat or university-approved equal
C. Sewing thread: Teflon-coated Nomex
D. Seam fasteners: 17-ounce, Teflon-coated fiberglass cloth belts with stainless steel double D-rings and Velcro tabs
E. ID Tags: stainless steel
F. Terminal ends: 17-ounce, Teflon-coated fiberglass cloth flaps with Nomex drawcord
G. All hardware: stainless steel

1.6.4. 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.

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

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

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

1.6.8. Covers shall be constructed and installed so that the end flaps can be tightened securely over adjacent pipe insulation.
1.6.9. Covers shall be as manufactured by Advance Thermal Corp or university-approved equal.

23 07 19 **Piping Insulation.** Minimum thickness per MN mechanical codes and energy codes.

1.1. Prohibited: Insulated steam traps and steam condensate return pumps.

Steam:
1.1. Insulate low-pressure steam condensate piping systems 15 psi and less that are located in tunnels, tunnel shafts and manholes with calcium silicate, mineral wool, or university-approved equal.

1.2. Insulate low-pressure steam condensate piping systems outside of tunnels, tunnel shafts and manholes with fiberglass, pre-molded pipe covering or a factory-applied jacket.

1.3. 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.

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

1.5 Steam traps and steam condensate return pumps shall not be insulated.

Pipe and Fittings Insulation for Chilled Water Supply and Return Systems, and Condensate Drain Lines

1.1 Chilled water supply and return pipes shall be insulated with fiberglass, foamed plastic or flexible elastomeric material.

1.2. Below grade chilled water piping shall have no insulation.

Piping and Fitting Insulation for Hot Water Heating Systems

1.1 Prohibited: Foamed plastic or flexible elastomeric material. No insulation is required on hot water recirculating pumps and hot water expansion tanks.

1.2 Hot water heating supply and return pipes shall be insulated with fiberglass. See MN Mechanical code for insulation thickness

Materials
1.1 Insulation containing any asbestos is prohibited

1.2. 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.

1.2.1. Minimum insulation thickness shall comply with the latest Minnesota Energy Code.

2. Jacket

2.1. Stapling pipe covering is prohibited. Paper jacket on high-pressure steam condensate return systems is prohibited.

2.3. PVC jacket: On piping 3 inches and larger, install 30-mil thick PVC covering over insulation of all piping located in shafts, manholes and tunnels. In addition, install PVC covering for outside applications that are subject to exposure to water. On piping smaller than 3 inches, install 20-mil thick PVC covering. Stop PVC jacket 2 inches from exposed metal on valves, traps and unions, and finish with CP-11.

2.4. Canvas jacket: Except for tunnels and tunnel shafts, 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. Coat canvas with waterproof mastic, CP11 or the U of M approved equal. Paint the canvas pink. 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.

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

2.6. All jacketing shall be continuous with vapor seal throughout system.

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

3. Protection at Hangers

3.1. Wood block inserts on all steam condensate return systems is prohibited.

3.2. 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.

3.3. 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.
4. Pipe and Fittings Insulation

4.1. General Requirements

4.1.1. Insulate the following piping:

A. Steam lines
B. Domestic hot and recirculating water lines
C. Steam condensate lines
D. Chilled water lines, except for buried lines
E. Refrigerant lines, where necessary
F. Fuel oil lines, where necessary or exposed to low temperature
G. Heating water lines
I. Other piping systems above and below ambient temperature

4.1.2. 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.

4.1.3. 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.

4.1.4. 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.

4.1.5. The A/E shall specify the type and thickness of the insulation based on the pipe size and the exposure. Minimum insulation thickness shall comply with the latest Minnesota State Energy Code. 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 90A-1980 for energy conservation.

5. Piping and Fitting Insulation for Refrigerant Lines

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

5.2. 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.
5.3. Provide refrigerant lines and equipment warmer than 32 degrees F with fiberglass, foam plastic or flexible elastomeric material.

5.4. 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

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PART 1. General

1.1 General

A. Provide all labor, materials, equipment, installation, service and training necessary for a complete, operational, and fully commissioned direct digital control (DDC) system for the facilities identified on the contract drawings. The system shall use the BACnet protocol at the TCP/IP level of the architecture.

B. Provide all labor, materials, equipment, service, and training necessary to integrate the new DDC systems into the existing University DDC network. The communications protocol used by the University is BACnet/IP.

C. 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.

D. The controls contractor shall include minor items, which are obviously and reasonably necessary to complete the installation and usually included in similar work even though not specifically mentioned in the Contract Documents.

E. Expansion of Existing Systems: Furnish all labor, materials, equipment, service and training necessary to integrate the existing DDC systems in the facility into the new DDC system. Alternately, the existing DDC system can be removed and replaced with a BACnet-based DDC system meeting the requirements of this specification.

F. Temperature control panels and/or enclosures in equipment rooms shall be located at readily accessible walkup locations approved by the University’s Owner Representative.

G. Building Systems Automation Center (BSAC)

1. The University owns and operates BSAC, which provides central monitoring of HVAC systems, fire and life safety systems, and other building systems on the Twin Cities campus. Each addition and/or alteration to a building control system shall be designed to work with the BSAC systems. BSAC uses the MultiLiant workstation (MLWS) as the primary DDC alarm monitoring device.

2. BSAC is presently located in the Donhowe Building on the East Bank Campus.

H. University DDC Network

1. The University owns and operates a dedicated mixed-mode network (fiber and copper) for building-to-building and building-to-BSAC communications. Energy Management is responsible for network design and network device maintenance. The DDC network is a private LAN with no Internet connections.
2. The University DDC system uses Distributed Process Architecture to monitor, control and integrate pneumatic, electric, and DDC systems. The controls contractor shall consider the DDC network an existing University utility system to which the specific building control system will be connected.

3. All building level devices must communicate using BACnet/IP and must support the objects and services listed in this specification. The University of Minnesota is committed to integration so that point status and automatic control can be channeled into a common protocol. The University has established BACnet as the common protocol.

I. University DDC System Functions

1. The general categories of the automated capabilities of the University DDC system are:
   a. Monitoring and Scheduling: Includes starting, stopping, observing, and reporting the operating status of the equipment, systems, and subsystems.
   b. Intervention: The ability to automatically or manually shift to an alternate operating mode from a remote location when weather or other conditions warrant it.
   c. Integration: The ability to coordinate the operation of several systems within a building, or several subsystems within a system, to ensure most efficient operation.
   d. Management Information: The ability to provide cumulative operating data such as system run time, units of energy consumed, and preventive maintenance schedules.

2. All vendor DDC systems must be capable of functioning in the following modes:
   a. All life safety and building systems points can be monitored and commanded, including equipment scheduling, by the MLWS and the vendor workstation 24 Hrs/Day, 7 Days/Wk.
   b. System alarms shall be displayed and acknowledged at the vendor’s workstation, and MLWS 24 Hrs/Day, 7 Days/Wk.

3. University personnel can make control set point, alarm limit and time schedule program modifications from the vendor’s workstation or through any third party BACnet workstation.

J. BACnet Integration:

1. Due to the complexity and size of the University BACnet system, integration requires stringent cooperation between the Energy Management department and the selected temperature Controls contractor. The University requires direct communication with the manufacturer's highest level of customer support, and may need to converse with the manufacturer's BACnet development team during project design, implementation, commissioning, and warranty phases.
2. The University of Minnesota is committed to integrating different manufacturer’s temperature control systems on a common LAN using a master workstation for all existing and future temperature control systems that may be installed. U of M BACnet required conformance is limited to B-Side or BACnet building controllers, only. The temperature Controls contractor must provide labor, software, materials, wiring, fiber coordination and expertise to install the BACnet Building Controller.

3. Bidding Controls contractor must indicate Readable, Writable or Not Supported under Proposed Temperature Control Panel Conformance column in Appendix A for all standard objects shown and return this information with their proposal.

4. BACnet communication shall be via the private DDC LAN directly from the building level controllers without having to route or convert it from a proprietary source. When building level network controllers are used for core BACnet communications, the field level panels on its sub LAN, such as VAVs and unitary level controllers, can utilize BACnet MS/TP, or LON. Building level network controllers shall support the requirements of Appendix A.

5. BACnet conformance disputes that may arise in the temperature control contractors installed BACnet Building Controller will be resolved by U of M engineers working directly with the temperature Controls contractor’s factory. Cost of translation between non-English speaking testers, developers and customer support personal whether overseas or in the USA will be the responsibility of the controls contractor. On site device testing will be conducted using the BACnet Manufacturers Association / BACnet Testing Laboratories (BMA/BTL) Virtual Test Shell 3.5.0 (VTS) program. Virtual Test Shell (VTS) is an application for testing the BACnet functionality of various devices used in building automation systems. It is available at http://sourceforge.net/projects/vts/. Conformance issue fault will be agreed on and resolved using ANSI/ASHRAE Standards 135-2004 publication.

1.2 Related Sections
A. 230913 Instrumentation and Control Devices for HVAC
B. 230933 Electric and Electronic Controls System for HVAC
C. 230943 Pneumatic Controls System for HVAC
D. 230953 Pneumatic and Electric Control System for HVAC
E. 230993 Sequence of Operations for HVAC Controls
F. 250000 Integrated Automation

1.3 Related Documents

B. University DDC Point Naming Convention. Energy Management maintains the point naming conventions for DDC systems. Contact Energy Management for the latest version of the conventions.

1.4 Definition Of Terms/Acronyms/Abbreviations

A. Additional definitions of terms or acronyms are included on the contract drawings and in other sections of this specification.

B. In the preparation of submittals and reports, the contractor shall use these definitions and abbreviations. Any terms or abbreviations used by the contractor in submittals and reports that have not been defined in this section shall be defined by the contractor in the first section of the submittal or report prior to their use.

C. The following definitions serve as a guide for industry acronyms in the coming sections:

1. ANSI - American National Standards Institute
2. ASHRAE - American Society of Heating Refrigeration and Air Conditioning Engineers
3. BACnet - Building Automation and Controls Network
4. BAC/IP – BACnet communications protocol via IP
5. BACnet/MSTP – BACnet communications using master/slave token passing on a field bus.
6. BIBBs - BACnet Interoperability Building Blocks
7. BMA – BACnet Manufacturers Association
8. BTL – BACnet Testing Laboratories
9. CSV – Comma Separated Value
10. DDC - Direct Digital Controls
11. EIA - Electronic Industries Association
12. Field Bus – Communications link between unit level controllers (RS485 or LON)
13. IP – Internet Protocol
14. ISO - International Standards Organization
15. LAN - Local Area Network
16. LON – LONTalk communications protocol
17. LONTalk - Open, published protocol
18. LONWorks - A set of tools and components
19. NIST - National Institute of Standards and Technology
20. PIC - Protocol Implementation Conformance Statement
21. Point Expansion Modules – Devices that are connected to unit controllers via dedicated communication links that are intended to increase the physical point count for the unit controller.
22. VAV - Variable Air Volume

1.5 References

A. The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

1. AIR MOVEMENT AND CONTROL ASSOCIATION (AMCA)
2. AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)
3. AMERICAN SOCIETY OF HEATING, REFRIGERATION AND AIR-CONDITIONING ENGINEERS (ASHRAE)
   a. ASHRAE 135-2004 BACnet Standard
4. FEDERAL COMMUNICATIONS COMMISSION (FCC)
5. INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)
6. INTERNATIONAL ORGANIZATION FOR STANDARDIZATION (ISO)
7. NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)
8. NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)
9. UNDERWRITERS’ LABORATORIES (UL)
   a. UL 864

1.6 Products Furnished, But Not Installed Under This Section

A. None.

1.7 Products Installed, But Not Furnished Under This Section

A. None

1.8 Products Integrated With The Work Of This Section

A. None

1.9 Submittals
A. Upon receipt of order, the controls contractor will submit drawings for approval prior to ordering or installing any equipment.

B. Copies of all required software shall be submitted to the Owner prior to the start of construction. No pay applications will be approved until all required software has been received.

C. Shop drawings shall be 11 inch by 17 inch, landscape, bound on the left edge. They shall be produced with Microsoft Visio or Autodesk AutoCAD software. Organize the packages by building. All documents shall be submitted electronically in portable document format (PDF). At the request of the Owner, shop drawings will also be submitted in the native CAD format.

D. All text based documents and product data sheets shall be 8 ½ inch by 11 inch format bound on the left edge. All documents shall be submitted electronically in portable document format (PDF).

E. Software files shall be submitted on fully labeled CDs that shall include a table of contents file in PDF format that provides a description of all of the files on the CD.

F. Submittals Prior To Construction

1. Shop Drawings
   a. System Architecture Design Diagram
      1) A riser diagram that shall show the IP layer and all of the field bus layers.
      2) It shall show each computer, printer, router, repeater, controller, and protocol translator that is connected to either the IP layer or any of the field busses.
      3) Where applicable, this diagram shall include the existing control system that is to be integrated into the new system.
      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.
      5) The physical relationship of one component to another component shall reflect the proposed installation.
      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.
      7) This diagram shall not include power supplies, sensors or end devices.
   b. System Flow Design Diagram for each controlled system.
      1) A two dimensional cross sectional diagram showing key components such as fans, coils, dampers, valves, pump, etc.
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 landed.

3) Where pneumatic devices are monitored or controlled by the DDC systems, a pneumatic piping diagram for all components must be included.

4) A legend shall be provided for all symbols used.

c. Sequence of Control: A sequence of control for each system being controlled. Include the following as a minimum.

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:
   a) Local (stand alone) control sequences.
   b) Supervisory logic sequence of control (e.g. dynamic setpoint resets from the network controller(s), smoke mode initiation, demand limit control, etc.).

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.

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.).

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

d. Installation Design Detail for each I/O device.

1) A drawing of the wiring details for each sensor and/or end device.

2) For devices with multiple quantities, a standard detail may be submitted.

2. Data

a. BACnet Compliance Documentation:

1) BACnet Interoperability Building Blocks (BIBBs) and PICs Statement: The Contractor will submit up-to-date PICS and BIBBs Statements for each controller and workstation showing ANSI/ASHRAE 135-2004 BACnet communication protocol standards that identifies all of the portions of BACnet that the vendor adheres to. The PIC statement must show conformance to the BACnet devices the vendor proposes to use. See Appendix A for additional PIC information. The vendor PICS statement will contain the following:
   a) BACnet protocol revision
   b) Applications software and firmware revision
c) Vendor and BACnet object description

d) BIBBs supported by the device

e) The standardized BACnet device profile to which the device conforms

f) The non-standardized BACnet device application services

g) A list of all standard and proprietary object types that are supported

h) For each object type that is supported, the University requires the following:
   (1) Optional properties that are supported with the device or BACnet server
   (2) A list of properties that can be written using BACnet services
   (3) Any object that can be dynamically created or deleted using BACnet services
   (4) Any restrictions in the data value range for properties

i) Data link layer options supported

j) Device address binding (necessary for two-way communication with MS/TP devices)

k) Networking options (BBMD, MS/TP)

l) Character sets supported

m) Segmented requests or responses supported

b. Direct Digital Control System Hardware Technical Data.

   1) A complete bill of materials of equipment to be used indicating quantity, manufacturer, and model number.

   2) Manufacturer’s description and technical data for each unique device to include performance curves, product specification sheets, and installation instructions. When a manufacturer’s data sheet refers to a series of devices rather than a specific model, the data specifically applicable to the project shall be highlighted or clearly indicated by other means.

   3) This requirement applies to:
      a) Controllers
      b) Transducers/Transmitters
      c) Sensors
      d) Actuators
      e) Valves
      f) Relays and Switches
      g) Control Panels
      h) Power Supplies
      i) Batteries
      j) Operator Interface Equipment

   c. An Instrumentation List for each controlled system.
      1) The list shall be in a table format.
2) Include name, type of device, manufacturer, model number, and product data sheet number.

d. Binding Map
1) A list of the device-to-device (peer-to-peer) data flow. This shall not include the flow of data from devices to the OWS.
2) Include:
   a) Description of the variable.
   b) Sending device.
   c) Receiving device.

G. Submittals During Construction

1. Training Plan
   a. Submit the following six weeks in advance of the training:
      1) Outline of the training with time allocations per topic.
      2) Training presentation material (slides, word documents, etc.).
      3) Copy of training reference material (product manuals to be used, etc.).
      4) Instructor’s name and resume with an emphasis on experience in presenting training programs.

2. Startup Testing Plan
   a. Submit a startup testing plan for each unique system at least two weeks prior to equipment startup.
   b. The purpose of a startup test is to demonstrate the completeness of the system and the performance of the components.
   c. For each task on the startup test checklist, the plan shall require the technician to enter his or her initials and the date the test was completed along with any recorded data such as voltages, offsets, or tuning parameters. Any deviations from the submitted installation plan shall also be recorded.
   d. Required elements of the startup testing include:
      1) Measurement of voltage sources, primary and secondary.
      2) Verification of proper controller power wiring.
      3) Verification of component inventory when compared to the submittals.
      4) Verification of labeling on components and wiring.
      5) Verification of connection integrity and quality (loose strands and tight connections).
      6) Verification of bus topology, grounding of shields and installation of termination devices.
      7) Verification of point checkout.
         a) All I/O device wiring is landed per the submittals and functions per the sequence of control.
         b) Analog sensors are properly scaled and a value is reported.
         c) Binary sensors have the correct normal position and the state is correctly reported.
d) Devices controlled by analog outputs have the correct normal position and move full stroke when so commanded.

e) Devices controlled by binary outputs have the correct normal state and respond appropriately to energize/de-energize commands.

8) Documentation of analog sensor calibration (measured value, reported value and calculated offset).

   a. Startup testing reports shall be submitted on a per system basis.
   b. Startup testing reports shall be the documented results of the executed startup testing plans.

4. Graphic Pages: Submit a sample graphic page for each type of page described in the specification section on graphic pages.

H. Submittals After Construction

1. The following is a list of post construction submittals that shall be updated to reflect any changes during construction and re-submitted as “As-Built”. As-Built drawings will each be stamped “As-Built” and have the as-built date on them. The As-Built drawings will contain at a minimum:
   a. System architecture drawing.
   b. Detailed drawings for each piece of controlled and monitored equipment
      1) Layout drawing for each control panel.
      2) Wiring Design Diagram for each control panel.
         a) The control voltage wiring diagram shall clearly designate devices powered by each control transformer. The diagram shall clearly show the consistent grounding of the appropriate power connection. All wire identification numbers shall be annotated on the diagram.
         b) If shielded communication wiring is used, the grounding of the shield shall be shown.
         c) The terminal strip wiring diagram shall identify all connections on both sides of the terminal strip. Wiring label numbers for all wiring leaving the control panel shall be annotated on the diagram.
         d) Where pneumatic devices are monitored or controlled by the DDC systems, the control panel wiring diagrams shall include pneumatic piping diagrams for all components.
      3) Wiring diagram for individual components.
      4) Point lists
      5) Room Schedules
      6) Sequence of operation
      7) Hardware with part number information
      8) System flow diagram for each controlled system.
c. Detailed routing of all communication trunk wires (building-to-building and within building), locations of all network and integration devices, front-end workstations, UPS and campus network/LAN connections.

d. Binding map.

2. Operation and Maintenance Manuals
   a. The controls contractor shall provide one electronic (PDF) copy and three (3) bound copies of Operation and Maintenance Manuals.
   b. Deliver manuals to the University project manager.
   c. Manuals shall be bound in heavy-duty, vinyl-covered, three-post, loose-leaf binders, permanently labeled on front and spine of each binder.
   d. Arrange the manuals according to specification section numbers used in the Project Manual; include a table of contents that identifies the responsible installing contractor, contact person, and telephone number with area code and thumb tab index sheets.
   e. Provide pocket folders for folded sheet information.
   f. Maintenance and Operating Manual shall include the following type of information:
      1) One copy of the executed Certificate(s) of Substantial Completion. This document will be used to communicate to all necessary University personnel the starting date of the one-year Warranty period.
      2) Signed record copy of bonds, guarantees, and warranties required by the Contract Documents.
      3) Manufacturer’s required preventative maintenance inspections, testing, service, lubrication, maintenance instructions, and schedules.
      4) Parts lists and local service organization.
      5) As-built wiring and piping diagrams.
      6) System architecture diagram for components within the building annotated with specific location information.
      7) As-built drawing for each control panel.
      8) As-built wiring design diagram for each control panel.
      9) As-built wiring design diagram for all components.
     10) Installation design details for each I/O device.
     11) As-built system flow diagram for each system.
     12) Sequence of control for each system.
     13) Room schedules.
     14) Binding map for the building.
     15) Product data sheet for each component.
     16) Installation data sheet for each component.
     17) Other information required by the Specifications.
   g. The Contractor shall instruct University personnel in the use of Maintenance and Operating Manuals.
3. Software
   a. Submit a copy of all software installed on the servers and workstations.
   b. Submit all licensing information for all software installed on the servers and workstations.
   c. Submit two copies of all software used to execute the project even if the software was not installed on the servers and workstations. This includes all programs used to configure, program, and troubleshoot both unit-level and system-level controllers. If the controllers require proprietary cabling to use the software this cabling must also be provided.
   d. Submit all licensing information for all of the software used to execute the project.
   e. All software revisions shall be as installed at the time of the system acceptance.

4. Firmware Files
   a. Submit a copy of all firmware files that were downloaded to or pre-installed on any devices installed as part of this project.
   b. This does not apply to firmware that is permanently burned on a chip at the factory and can only be replaced by replacing the chip.
   c. Submit a copy of all application files that were created during the execution of the project.
   d. Submit a copy of all graphic page files created during the execution of the project.
   e. Submit a copy of all secondary graphic files such as bitmaps, jpegs, etc. that were used in the creation of the graphic pages.

I. Project Closeout Submittals:

1. The controls contractor shall advise the Owner throughout the duration of construction as to the status of the contract closeout submittals including, but not limited to, the ongoing development of the maintenance and operations manuals and record documents.

2. The Contractor shall assemble and submit as one package the following before making application for final payment.
   a. Consent of Surety.
   b. Documentation that Contractor returned University keys.
   c. Documentation that Contractor returned signs reading, “Construction Staging Area, Vehicle Permit Required, Violators Will be Tagged and Towed.”
   d. Documentation that the Punch list is complete.
   e. Executed Certificate of Occupancy (if required).
   f. Executed TGB Total Payment Affidavit (if required).
   g. Executed TGB Verification of Completed Work Affidavit (if required).
   h. Executed Prevailing Wage Payment Affidavit (if required).
i. Evidence of Completed Operations Liability insurance coverage during the one-year correction period (if required).

j. Waste manifests, TCLP (Toxicity Characteristic Leachate Procedure), and OSHA monitoring results for asbestos or lead, as required by the Contract Documents (if required).

1.10 Project Record Documents

A. General Requirements:

1. The Contractor shall maintain a set of Contract Documents at the site, on which variations shall be accurately marked with red erasable pencil on a daily basis. All changes, whether resulting from change orders, Architect’s supplementary instructions, Contractor change directives, or other job noted changes, shall be recorded. The controls contractor shall periodically verify that this is being done satisfactorily.

B. Contract Drawings

1. Maintain a clean, undamaged set of blue or black line prints of Contract Drawings to use as the Project record documents.

2. Mark the drawing sets to show the actual installation where the installation varies substantially from the work as originally shown.

3. Give particular attention to recording concealed elements that will be difficult to measure and record at a later date. Also record new information that is important to the Owner but is not shown on Contract Drawings.

4. Note the related change order number where applicable.

5. Organize the record drawing sheets into manageable sets. Bind sets with durable-paper cover sheets; print the University Project Number and Name, and drawing numbers and titles on the cover sheet.

C. Record Project Manual

1. Maintain a clean, undamaged, complete set of the Project Manual to use as the Project record documents.

2. Include one copy of the addenda and other written documents issued during the construction period (Change Orders, RFIs, PRs, etc.) with the record Project Manual.

3. Contractor shall submit the Project record documents to the University for final inspection and comment at the completion of the job.

4. The final payment will not be made to the Contractor until the record documents and the Maintenance and Operating Manuals are received and approved in writing by the University.

5. Two months before expiration of the one-year correction period the controls contractor shall conduct a walk through and provide a written summary of findings and recommendations.

6. Submit electronic versions of all CAD drawings, points lists, and operating sequences. The electronic copies shall be stored on CDs and shall be saved in an editable format. Acceptable formats include
Microsoft Office program formats (i.e. Word, Excel, Access, etc.), Visio, and AutoCAD. Other formats must be approved by the University at time of project award.

1.11 Warranty

A. Warrant all work as follows:

1. The warranty period for labor and material for the control system, including all subcontractor work, shall be 12 months after acceptance by Owner. The Owner’s written acceptance will be given after verification testing demonstrates that the equipment is operating in accord with the contract documents. Minor deficiencies identified during testing that do not affect the functional performance of the equipment will not be used to deny acceptance for the purposes of determining the start of the warranty period.

2. During the warranty period, the Contractor shall respond to the Owner’s request for warranty service within 24 hours during normal business hours.

3. For systems designated at critical, the Contractor shall respond to warranty service requests within 4 hours.

4. The Contractor shall correct all warranty repairs at no cost to the Owner.

5. The Contractor shall make all reasonable efforts to minimize the Owner’s business disruption and loss associated with warranty repairs. This includes expedited shipping of materials, overtime work, night/weekend work, etc.

6. Software upgrades and service patches shall be made available and installed by the Contractor at no cost to the University during the warranty period.

7. The Contractor shall maintain a copy of the project database through the warranty period.

1.12 Ownership Of Proprietary Material
A. The Owner shall retain all rights to software for this project.

B. The Owner shall sign a copy of the manufacturer’s standard software and firmware licensing agreement as a condition of this contract. Such license shall grant use of all programs and application software to the Owner as defined by the manufacturer’s license agreement, but shall protect the manufacturer’s rights to disclosure of Trade Secrets contained within such software.

C. The licensing agreement shall not preclude the use of the software by individuals under contract to the owner for commissioning, servicing, or altering the system in the future. Use of the software by individuals under contract to the owner shall be restricted to use on the owner’s computers and only for the purpose of commissioning, servicing, or altering the installed system.

D. All project developed software, files and documentation shall become the property of the Owner. These include but are not limited to:

1. Server and Workstation software
2. Application Programming Tools
3. Configuration Tools
4. Addressing Tools
5. Application Files
6. Configuration Files
7. Graphic Files
8. Report Files
9. Graphic Symbol Libraries
10. All Documentation.

1.13 Permits And Inspections

A. In accordance with Minnesota statute, the University of Minnesota enforces the Minnesota State Building Code and other applicable codes and regulations in University owned facilities. The University carries out this responsibility through a University Building Official appointed by the Regents of the University of Minnesota.

B. A building permit is required for all new construction, alterations, demolition, remodeling, additions, electrical work, wiring, mechanical, plumbing work, and temporary work that is conducted on University of Minnesota property. The controls contractor shall obtain and pay for all permits and inspections required for the electrical and mechanical work, arrange for inspections to be performed, and furnish a certificate of final inspection and approval by enforcement authorities. Contact University Code Office at 612.625.3318.

C. University Building, Electrical, Mechanical, Plumbing, or Fire Inspectors shall inspect construction work conducted on University of Minnesota property. Contractor shall request an inspection from the University Building
D. As provided for in state law, the Contractor may be required to uncover work that was covered prior to being inspected.

E. The controls contractor is to retain on the job site a signed copy of the building permit, a copy of the inspection sign off card, requests for mechanical/electrical inspections, and the University Building Code signed and stamped approved plans and specifications.

F. When required, the Contractor shall obtain permits other than those issued by the University Building Official, which include, but are not limited to, high-pressure steam, elevators, and city and/or county utilities.

1.14 Hazardous Waste Management

A. The University will identify areas in the facility where asbestos or other hazardous materials are known to exist.

B. Controls contractor shall identify all locations where the proposed construction may disturb hazardous material in before performing any work and notify the Owner. Owner shall coordinate all work with the University of Minnesota hazardous abatement department to remove the asbestos material as deemed necessary for the safety and well being of building occupants and construction workers. All costs related to the removal of the hazardous material shall be the responsibility of the University.

C. The Contractor or any of the subcontractors shall not remove asbestos containing materials of any kind. Any trades working around any asbestos containing materials shall take extra caution not to disturb those materials. If this does not appear to be possible, the materials shall be requested to be removed. Such requests shall be made to the Owner in a timely fashion so as not to delay the project.

1.15 Solid Waste Management Plan

A. Provide for the management of construction and demolition waste through reuse, recycling and reduction methods. Typical designated waste streams are: land clearing debris, concrete and masonry, metals, dimensional wood & lumber, wooden pallets, gypsum wallboard, paper and cardboard. Depending on the project, other large volume wastes may be included (e.g., bricks, asphalt, carpeting).

1. A specified percentage of the waste should be specially collected, segregated and sent for recycling or reuse. Documented waste reduction strategies will be credited against the goal.

2. Specification will include standard instructions for handling designated wastes, stressing the need for not contaminating the recyclable wastes.

3. The Contractor is encouraged to work with the University’s Waste Management Division to evaluate recycling options. The Waste
Management Division will also provide no cost service for recycling properly segregated and uncontaminated cardboard and scrap metals.

4. Reduction: Reduction includes eliminating excess material use or waste. Examples of reduction include ordering materials to fit the module of the design, such as eliminating cut-off waste from lumber, drywall or carpeting; working with suppliers to eliminate or reduce packaging.

5. Reuse: Reuse includes salvaging components from remodeling or demolition projects for resale or transfer to salvage businesses, non-profits, material exchange networks, or for use in new construction at the same site or elsewhere. Reusable items include plumbing and mechanical equipment, doors, windows, fixtures, trim, etc. Other reuse strategies include returning unused products or shipping containers (pallets) to vendors.

6. Recycling: Recycling includes the recovery of materials that have existing and stable markets. These materials can be used as raw materials for the manufacturing of new products. Examples include cardboard, metals and concrete.

B. Submittals:

1. Contractor shall submit the Construction Solid Waste Management Plan to Project Manager 10 days prior to start of construction. The plan should include the following elements:
   a. Whether construction waste will be recycled or reused by source separation, time-based separation, or commingled for delivery to an off-site separation facility.
   b. The types of materials to be targeted for recycling and reuse, the projected volumes and fate of the materials. Identify materials that are recyclable or otherwise recoverable that must be disposed of in a landfill.
   c. The diversion goal indicates the percentage of waste to be diverted from land filling or incineration.
   d. The facilities to be used, both landfills and recycling facilities, indicating which of the targeted wastes are to be received, projected volumes, and documentation of their permit status.
   e. Maintenance of a Construction Waste Log (dates, facility, transporter, weights) and a file of waste receipts for all wastes shipped off-site.

C. Implementation:

1. Contractor shall conduct a Pre-Construction Waste Management Conference to discuss the Plan requirements, schedules and procedures with Contractor personnel associated with waste management, the Architect, suppliers (where appropriate), and Project Manager.

2. Contractor shall designate the on-site party responsible for implementing the plan and instructing workers, distributing plan to site foremen and each subcontractor, including the plan in worker orientation and safety meetings, and providing site instruction on separation, handling, and recovery methods.
PART 2. Products

2.1 Manufacturers

A. Approved Manufacturers
   1. Johnson Controls
   2. Siemens
   3. University Approved Alternate

B. Acceptable Installation Contractors
   1. Branch offices and independent representatives for the above manufacturers must have a full staff of project managers, project engineers, system application engineers, application engineers and technicians. Branch offices and independent representatives must have a separate fully staffed service department to be an acceptable bidder.
   2. Approved Installation Contractors
      a. Johnson Controls Branch Office – Minneapolis
      b. Siemens Building Technologies Branch Office – Minneapolis
      c. Trane Branch Office – Minneapolis
      d. University Approved Alternate
   3. Installation contractors not currently on the approved list may be considered if they meet the requirements of this specification. Financial stability and prior experience on University (or similar) projects will be considered by the Owner when selecting an installation contractor.

2.2 System Architecture

A. The DDC system architecture shall consist of two layers, the TCP/IP layer and the field bus layer.

B. The TCP/IP layer connects all of the buildings on a single dedicated and isolated network. Fixed IP addresses for connections to the University private DDC network shall be used for each device.

C. BACnet Building Controllers (B-BC) shall be used to connect each field bus to the TCP/IP layer.

2.3 Networking

A. IP Network: All devices that connect to the WAN shall be capable of operating at 100 megabits per second.

B. IP-to-Field Bus Routing Devices
   1. BACnet Building Controller shall be used to provide this functionality.
   2. These devices shall be configurable locally with RS232 or IP crossover cable and configurable via the IP network.
   3. The routing configuration shall be such that only data packets from the field bus devices that need to travel over the IP level of the architecture are forwarded.
C. Field Bus
   1. The wiring of components shall use a bus or daisy chain concept with no tees, stubs, or free topology.

D. Repeaters
   1. Where repeaters are required to connect two segments, repeaters shall be installed in an enclosure mounted in an accessible area.

2.4 Building Level Controllers (B-BC)

A. Building level DDC controllers shall be microprocessor-based, multi-tasking, multi-user, real-time digital control processors fully capable of being integrated with the selected vendor’s master work station, or any third party BACnet workstation.

B. Building level DDC controllers shall utilize BACnet open standard communication protocol. All building level controllers shall communicate using BACnet/IP.

C. A BACnet Building Controller (B-BC) as defined by ASHRAE Annex L is a general purpose, field programmable device capable of carrying out a variety of building automation and control tasks. It enables the specification of the following:

1. Data Sharing
   a. Ability to provide the values of any of its BACnet objects
   b. Ability to retrieve the values of BACnet objects from other devices
   c. Ability to allow modifications such as scheduling and present value of some or all of its BACnet objects by another device as shown in U of M required object table (see Appendix A).

2. Alarm and Event Management
   a. Generation of alarms / events notifications and the ability to direct them to recipients using the BACnet intrinsic alarming method
   b. Maintain a list of unacknowledged alarms / events retrievable using standard BACnet Services
   c. Maintain a list of alarms / events retrievable using standard BACnet Services
   d. Notifying other recipients that the acknowledgment has been received
   e. Adjustment of alarm / event parameters

3. Scheduling
   a. Ability to schedule output actions, both in the local device and in other devices, both binary and analog, based on date and time

4. Trending
   a. Collection and delivery of (time, value) pairs

5. Device and Network Management
   a. Ability to respond to information about its status
   b. Ability to respond to requests for information about any of its objects
   c. Ability to respond to communication control messages
d. Ability to synchronize its internal clock upon request. (not required by U of M)
e. Ability to perform re-initialize upon request (not required by U of M)
f. Ability to upload its configuration and allow it to be subsequently restored
g. Ability to command half routers to establish and terminate connections (not required by U of M)

D. If Building Controllers have embedded I/O, all of the requirements for I/O that are described under Unit Level Controllers shall apply.

E. The temperature controls contractor's B-BC device(s) shall support all ANSI/ASHRAE 135-2004 standard object required and optional properties as listed in Appendix A. **BACnet intrinsic alarming is required.** All objects and object properties shall be supported so that alarms are sent from the temperature controls contractor's BACnet device without having to be solicited from the University BACnet Operators Workstation (BOWS) or U of M Master History PC.

F. DDC panels and devices must utilize ANSI/ASHRAE 135-2004 BACnet Communications Protocol on a single building level network. BACnet communications must not cause derogated communications on the sites existing temperature control network. Derogation includes router, switch, or hub lockups, BACnet building controller lockups, excessive site network slowdowns, unnecessary and repeated ‘who is’ messages. Refer to ASHRAE BACnet standard for definition of unnecessary Who-is messages.

G. U of M BACnet Required Protocol Services supported:
1. Acknowledge Alarm
2. Confirmed Event Notify
3. Get Alarm Summary
4. Get Enrollment Sum
5. Add List Element (for the purpose of allowing the addition of a recipient to the BB-C)
6. Remove List Element (for the purpose of allowing the deletion of a recipient to the BB-C)
7. Read Property
8. Read Property Multiple
9. Write Property
10. Write Property Multiple
11. Confirm Private Xfer
12. I AM
13. I Have
14. Unconfirmed COV Notify
15. Unconfirmed Event Notify
16. Time Synchronization
17. Who Has
18. Who Is
19. UTC Time Sync
20. Get Event Info
H. All building controllers must be capable of having their databases uploaded, downloaded and viewed from the vendor’s master workstation.

I. All building level controllers shall have a local port that can connect to a laptop PC or other hand-held tool for local service work, troubleshooting, etc. Each controller shall include the capability to store, retrieve and print alarm summaries, trends and other critical point summaries or reports.

J. Memory: Each DDC controller shall have sufficient memory to support its own operating system and databases and continuous trending on all analog points for that controller (AV, AI, AO) based on 300 sample intervals.

K. Integrated On-line Diagnostics: Each DDC controller shall continuously perform self-diagnostics and communication diagnosis of all associated unit level equipment. The DDC controller shall provide both local and remote annunciation of any detected component failures, or repeated failure to establish communication. Indication of the diagnostic results shall be provided at each DDC controller and shall not require the connection of an auxiliary I/O device.

L. Power Fail Restart: In the event of the loss of normal power, there shall be an orderly shutdown of all DDC controllers to prevent the loss of database or operating system software. Non-volatile memory shall be incorporated for all critical controller configuration data, and battery back up shall be provided to support the real-time clock and all volatile memory for a minimum of seventy-two (72) hours. Upon restoration of normal power, the DDC controller shall automatically resume full operation without manual intervention. Should a DDC controller memory be lost for any reason, the user shall have the capability of reloading the DDC controller via the local area network or via the local interface port.

M. System architectural design shall eliminate dependence upon any single device, front-end or higher level of controller for alarm reporting and control execution. Each DDC controller shall operate independently by performing its own specified control, alarm management, operator I/O, and historical data collection. The failure of any single component or network connection shall not interrupt the execution of control strategies at other operational devices.

N. Building level DDC controllers shall be able to access any data from, or send control commands and alarm reports directly to any other building level controller or combination of controllers on the IP network without dependence upon a central processing device. Building level DDC controllers shall also be able to send alarm reports to multiple operator workstations without dependence upon a central processing device.

O. All Ethernet network communications will use 100 MPS communication rates.

2.5 Unit Level Controllers

A. Each Unit Level DDC controller shall consist of modular hardware with plug-in enclosed processors, communication controllers, power supplies, input and
output (DI, DO, AI, AO) capabilities. A sufficient number of controllers shall be supplied to fully meet the requirements of this specification, the project drawings, and the point lists.

B. Unit level DDC controllers shall utilize BACnet/MSTP or LON open standard communication protocol.

C. All unit level controllers, including VAV controllers, must be able to have their databases uploaded, downloaded and viewed from the vendor’s master workstation.

D. Power Fail Restart: In the event of the loss of normal power, there shall be an orderly shutdown of all DDC controllers to prevent the loss of database or operating system software. Non-volatile memory shall be incorporated for all critical controller configuration data, and battery back up shall be provided to support the real-time clock and all volatile memory for a minimum of seventy-two (72) hours. Upon restoration of normal power, the DDC controller shall automatically resume full operation without manual intervention. Should a DDC controller memory be lost for any reason, the user shall have the capability of reloading the DDC controller via the local area network or via the local interface port.

E. Each controller will be programmed such that each controlled device will have a default value in which to be commanded to in the event of a control sensor failure. The acceptable default values are, last command, full open, or full closed.

F. Controller I/O Requirements

1. Analog Input Circuits
   a. The resolution of the A/D chip shall not be greater than 0.01 Volts per increment. For an A/D converter that has a measurement range of 0 to 10 VDC and is 10 bit, the resolution is 10/1024 or 0.00976 Volts per increment.
   b. For non-flow sensors, the control logic shall support a calibration offset such that the raw measured value is added to the (+/-) offset to create a calibration value to be used by the control logic and reported to the Operator Workstation (OWS).
   c. For flow sensors, the control logic shall provide support for the use of an adjustable gain and an adjustable offset such that a two point calibration concept can be executed (both a low range value and a high range value are adjusted to match values determined by a calibration instrument).
   d. For non-linear sensors such as thermistors and flow sensors the controller shall provide software support for the linearization of the input signal.

2. Binary Input Circuits
   a. Dry contact sensors shall wire to the controller with two wires.
   b. An external power supply in the sensor circuit shall not be required.
3. Pulse Input Circuits  
   a. Pulse input sensors shall wire to the controller with two wires.  
   b. An external power supply in the sensor circuit shall not be required.  
   c. The pulse input circuit shall be able to process up to 20 pulses per second.  
4. True Analog Output Circuits  
   a. The logical commands shall be processed by a digital to analog (D/A) converter chip. The 0% to 100% control signal shall be scalable to the full output range which shall be either 0 to 10 VDC, 4 to 20 milliamps or 0 to 20 milliamps or to ranges within the full output range.  
   b. The resolution of the D/A chip shall not be less than 0.04 Volts per increment or 0.08 milliamps per increment.  
5. Binary Output Circuits  
   a. Single pole, single throw or single pole, double throw relays.  
   b. Voltage sourcing or externally powered triacs with support for up to 30 VAC and 0.5 amps at 24 VAC.  
6. Program Execution  
   a. Process control loops shall operate in parallel and not in sequence unless specifically required to operate in sequence by the sequence of control.  
   b. The sample rate for a process control loop shall be adjustable and shall support a maximum sample rate of 1 second.  
   c. The sample rate for process variables shall be adjustable and shall support a maximum sample rate of 1 second.  
   d. The sample rate for algorithm updates shall be adjustable and shall support a maximum sample rate of 1 second.  
   e. The application shall have the ability to determine if a power cycle to the controller has occurred and the application programmer shall be able to use the indication of a power cycle to modify the sequence of controller immediately following a power cycle.  
7. Local Interface: The controller shall support the connection of a portable interface device such as a laptop computer or vendor specific hand-held device. Via this local interface, an operator shall be able to:  
   a. Adjust application parameters.  
   b. Execute manual control of input and output points.  
   c. View dynamic data.  
G. Unit level controllers shall not be dependent upon any other controller (unit or building level) to maintain safe operation of the controlled equipment.  
H. All unit level controllers and/or enclosures shall be clearly labeled with their Node address. Tag all wiring on the DDC side of the interface panel identifying the associated point.  
I. **PROHIBITED:** Using a single unit level controller (or building level controller that is serving as a unit level controller) to control more than one major mechanical system without the express permission of the Owner. The
intent is to minimize disruptions to multiple systems if a single controller fails or must be serviced/programmed. A voluntary deduct may be provided with the proposal stating which systems will be controlled by a common controller and the associated price reduction. Major mechanical system is defined as:

1. Air handling units
2. Heating systems (multiple pumps and heat exchangers that are part of the same overall heating loop can be combined).
3. Cooling systems (multiple pumps, chillers, towers, etc. associated with the same cooling loop can be combined).
4. Building exhaust systems.
5. Other building systems where a failure of multiple devices will cause significant disruption to building operations.

J. **PROHIBITED**: Transmitting process variable data via the IP network or field bus for use in PID control loops. Data transmitted from point expansion modules to unit controllers via a dedicated point expansion communication bus is allowed.

K. **PROHIBITED**: Splitting mechanical systems between more than one Unit Level controller without prior approval from Owner.

### 2.6 Operator Workstation (OWS)

A. The Operator Interface Workstations will comprise a Personal Computer (PC) together with operator terminals. The PC will be a fully integrated node on the management level network and shall provide the operator with a graphical interface into the entire network. The monitoring and control functions of the BMCS shall be totally independent of the PC such that if the PC is not operational there shall be no impact on the building control systems except for the reduced operator interface capability at that location.

B. Provide OWS meeting, at minimum, the following requirements:

1. Intel motherboard with single Intel Core 2 Duo processor with a minimum speed of 3.0 GHz and 4 MB L2 Cache.
2. 2 Gigabyte of memory.
3. One 160 Gigabyte SATA hard drive.
4. Tower or desktop style case.
5. 4 USB ports.
6. 48x32xCDRW and 16xDVD+-RW.
7. Auto sensing full duplex 10/100/1000 Ethernet network interface card (NIC).
8. USB style connectors for keyboard and mouse.
9. 256 Megabyte video RAM.
10. All necessary mounting hardware and cables for all components.
11. Integral power supplies which shall be suitably rated for the service.
12. Real time software or hardware clock.
13. 1.44 Floppy disk drive
C. Provide a Video Display Unit (VDU) meeting, at minimum, the following requirements:

1. Flat panel LCD display with screen diagonal measurement of no less than 19 inches.
2. Resolution of .28 pitch, 1280 by 1024 pixels with 85Hz minimum refresh rate.
3. Capable of displaying both schematic and alphanumeric data at the same time.
4. 16 million discrete colors.
5. Manufactured by NEC, Viewsonic, Sony, Samsung, or approved equal.

2.7 DDC System Software

A. BACnet Operator Workstations

1. Hardware Communication Function
   a. The OWS shall extract data from the hardware environment and move the data to the data server and/or present the data to the presentation system.
   b. The OWS shall extract data from the data server and present the data to the data presentation system.
   c. The OWS shall track operator actions at the presentation system and write a record of activities to the data server.

2. BACnet Compliance
   a. The OWS shall be able to initiate a “Who Is” request to the network.
   b. The OWS shall respond to a “Who Is” request from another BACnet device with an “I Am” response.
   c. The OWS shall be able to read binary and analog data from BACnet devices that support the reading of data.
   d. The OWS shall be able to write binary and analog data to BACnet devices that support the writing of data from a BACnet OWS.
   e. The OWS shall be able to receive alarm messages from BACnet devices that export alarm messages.
   f. The OWS shall be able to acknowledge alarms from BACnet devices.
   g. The OWS shall be able to edit time schedule parameters in BACnet devices that support the editing of time schedule parameters from a BACnet OWS.
   h. The OWS shall be able to retrieve a collection of trend samples from a BACnet device that stores the data and permits the export of that data to a BACnet OWS.
   i. The OWS shall be able to initiate time synchronization commands to all BACnet devices that support the receipt of time synchronization commands from a BACnet OWS.

3. Data Presentation: Data shall be presented in the following formats.
   a. Points lists with dynamic presentation of data. The operator shall be able to create custom point lists with data that originates from multiple
devices. A point may be dynamic data from a controller or a configuration parameter to be written to a controller by the operator.

b. Graphic pages with dynamic presentation of data on a visual diagram that represents a building, a floor plan, a cross section of a mechanical system or a table of data.

c. Graphical presentation of historical trend log data plotted against time.

d. Graphical presentation of real time trend data plotted against time.

e. Alarm Presentation
   1) Unless restricted by a reduction in viewing authority, an operator shall be able to view alarms for all systems in a single alarm list.
   2) Custom alarm views configured for select categories of alarms shall present only the alarms specified.
   3) Alarm messages shall include identifying information and the signal value or state at the time of the alarm.

f. Event Presentation
   1) Unless restricted by a reduction in viewing authority, an operator shall be able to view an event log that chronologically captures all activity created by the system and operator actions.
   2) Custom event views for select categories of events shall present only the events specified.

g. Time Schedules
   1) Each time schedule shall have the ability to issue a minimum of 10 start and 10 stop commands for the week. The requirements for start and stop commands may be different for each day of the week.
   2) Each time schedule shall also include a holiday component where a holiday is identified by the date and duration (one day, two days, etc.). The time schedule shall support a unique set of start and stop commands for each holiday. The time schedule shall support a minimum of 20 holidays per year. Holiday schedules shall take precedence over standard schedules during the holiday period. Holidays that are date specific shall roll over from year to year without operator programming action.
   3) There shall be a mechanism to link a master time schedule editor at an OWS to multiple time schedules in various Building Controllers. Once linked, whenever the master time schedule is changed at an OWS, the new time schedule parameters shall be downloaded to all of the linked time schedules. This concept shall apply to both standard schedules and holiday schedules.

h. The system shall support a configuration that:
   1) Causes the system to go into standby mode (user is logged out but the current screen is still displayed) after a specific period of inactivity.
   2) Automatic system logout after a specific period of inactivity.

4. Data Source
a. An operator workstation shall present data from the entire hardware environment.

b. The system architecture shall provide for a minimum of 25 concurrent operator workstations per system.

5. Operator Access And Privileges

a. There shall be a minimum of four privilege levels.
   1) System Administrator
      a) No limitations
      b) Only level that can assign or delete users and assign or modify privileges.
   2) Engineer
      a) View data in any format.
      b) Acknowledge alarms.
      c) Inhibit alarms.
      d) Exercise control actions.
      e) Edit the presentation of data.
      f) Modify the system.
   3) Operator
      a) View data in any format.
      b) Acknowledge alarms.
      c) Exercise control actions.
   4) Viewer
      a) View data in any format.

b. The level assigned to a specific user shall be the maximum level that can be used anywhere in the system. The software shall provide the capability to reduce a user’s level from his or her maximum level to a lower level on a per building or system basis. This may be accomplished on a per object basis within the database or by the application of additional security levels beyond the basic four levels.

c. Signing on to the system shall require a user name and password. When the password is typed in, it shall not be shown on the screen.

d. The software shall provide the capability to establish groups of users with the same privileges. Once assigned to the group, the user shall automatically have the maximum privileges and the selectively reduced privileges assigned to the group.

e. The software shall provide the capability to set user profiles that enable assigning a specific home graphic page, alarm view, and event view.

6. Operator Actions

a. Given the appropriate authority, an operator from an operator workstation shall be able to:
   1) View all data that is presented in the forms described previously.
   2) Acknowledge alarms.
   3) Manually control both physical input and physical output points.
4) Edit both independent and master time schedules.
5) Initiate real time trend logging.
6) Manually initiate reports.
7) Initiate system backups for the database and trend log data.
8) Customize the layout of the operator workstation presentation which shall then be the default for that user.

b. The operator shall be able to execute the above tasks on data from any of the operator workstations.

c. The system shall support the use of Electronic Signature system wide or on a per user basis.

d. All of the operator workstations shall be operable simultaneously.

7. Engineering Actions

a. The software shall, as a minimum, enable the following engineering functions from each of the operator workstations:

1) Create graphic pages for the presentation of dynamic data on visual images of buildings or equipment.

2) Create reports for the presentation of historical data in an organized format.

3) Create time schedules.

4) Create trend logs in any of the field level devices and assign a dynamic variable from a field bus device to be trended.

5) Setup long term storage of trend log data on the data server computer and the automatic transfer of the trend log data to the data storage tables in the long-term database.

6) Create alarm objects in any of the field level devices, assign an alarm variable from a field bus device to initiate the alarm and set up the alarm routing.

7) Configure and bring on-line a newly installed Building Controller in support of an initial or incrementally added building control system.

8) Configure and bring on-line a newly installed field level devices in support of an initial or incrementally added building control system.

9) Create and download applications for programmable devices.

10) Download firmware updates to field level devices.

11) Import all field level devices into the system so that all input network variables, output network variables and adjustable application parameters can be accessed from any of the operator workstations.

12) Establish data flow from one field level device to a second field level device.

13) Establish data flow from a field bus device under one IP connection to a field bus device under a different IP connection.

14) Configure the system to create backups of the database and all application and supporting databases on a scheduled basis.
15) Setup user groups and individual users and establish authority levels for each group and individual user.

16) Any additional tasks defined later in this document or required to deliver a fully functional system.

B. Graphic Page Creation And Editing

1. The Graphics Editor portion of the Engineering Software shall provide the following minimum capabilities:
   a. Create and save symbols.
   b. Create and save pages.
   c. Group and ungroup symbols.
   d. Modify an existing symbol.
   e. Modify an existing graphic page.
   f. Rotate and mirror a symbol.
   g. Place a symbol on a page.
   h. Place analog dynamic data in decimal format on a page.
   i. Place binary dynamic data using state descriptors on a page.
   j. Create motion through the use of gif, jpeg, bmp or svg files.
   k. Place test mode indication on a page.
   l. Place manual mode indication on a page.
   m. Place links using a fixed symbol or flyover on a page.
      1) Links to other graphics.
      2) Links to web sites.
      3) Links to notes.
      4) Links to time schedules.
      5) Links to trends.
   n. Assign a background color.
   o. Assign a foreground color.
   p. Place alarm indicators on a page.
   q. Change a symbol color as a function of an analog variable.
   r. Change a symbol color as a function of a binary state.
   s. Change symbols as a function of a binary state.
   t. All symbols used by the contractor in the creation of graphic pages shall be saved to a library file for use by the owner.

C. Event Logging

1. The system shall maintain a log of all operator activity, system messages, alarms, and alarm acknowledgments.

2. Operator activity is defined as any action by an operator such as changing the value of an application parameter, modifying a program, acknowledging an alarm, logging on, logging off, etc. Any change in the system caused by operator action shall be part of the log. The log shall include the event, the time of the event, the part of the system affected, and an identification of the operator and the OWS from which the change was made.
3. When the event deals with a value change, both the original and new values shall be part of the event record.
4. The Event Log shall be exportable to a report format that is printable.
5. The System Administrator shall be able to archive the event log.
6. The event data shall comply with 21 CFR Part 11 requirements for data integrity.
7. The Event Log shall have a search function with assignable criteria to identify subsets of the event log such as all points placed under manual control, etc.

D. Alarm Generation And Processing

1. Alarm creation is a two part process. The creation of a binary alarm indication is accomplished in a field level device where a binary state of zero shall indicate a normal condition and a binary state of one shall indicate an alarm condition. The binary alarm condition is read within a B-AAC, or Building Controller. The B-AAC or Building Controller shall assign a descriptive message, a category or priority number and a date and time stamp to the alarm and forward the information to the OWS in accordance with an alarm routing table.
2. Alarm parameters such as high limits, low limits, time to state, binary alarm conditions are setup within the programming of the field level devices. These parameters shall be viewable and editable in point lists and on configuration graphic pages.
3. The alarm message shall be descriptive.
   a. Building identification
   b. System identification
   c. Device identification
   d. Date
   e. Time to the second
   f. Nature of the alarm
      1) High value
      2) Low value
      3) Fail to start
   g. Value or state at the time of the alarm.
4. When the operator acknowledges the alarm, there shall be an opportunity to enter a message that becomes a permanent part of the alarm record recorded in the event log.
5. The system shall support the association of graphic pages, trend charts, reports and text documents with specific alarms.
   a. The operator shall have the ability to configure the system to auto-launch a specific graphic page when the alarm occurs.
   b. The system shall support the assignment of wav files to alarm signals on graphic pages.
   c. The operator shall have the ability to launch a specific trend chart from the alarm window when the alarm occurs.
d. The operator shall have the ability to launch a specific text document when the alarm occurs.

e. An associated report shall automatically execute and write to the hard disk on the OWS when the alarm occurs. Configurations options shall include overwriting the previous report or creating a new file.

6. The system shall use selectable multiple colors on alarm messages for each of the following conditions:
   a. Alarm condition exists and has not been acknowledged
   b. Alarm condition has returned to normal but was never acknowledged
   c. Alarm condition exists and has been acknowledged

7. When an alarm condition no longer exists and has been acknowledged, it shall no longer be displayed in the alarm viewer but it shall be permanently recorded in the event list.

8. The Alarm Routing Table shall support the following:
   a. Multiple workstations at any time.
   b. Specific workstations at particular times (to include all of the time as one choice).
   c. Pagers
   d. Email addresses via simple mail transfer protocol (SMTP; RFC 821)
   e. Permanent comprehensive system wide alarm file
   f. Specific alarm file based on a building or equipment identification
   g. One or more alarm printers at any time
   h. Specific alarm printers at specific times
   i. Rerouting of alarms to a backup receiver when an acknowledgement has not been entered into the system within a specified time.

9. The system shall have a default audible indicator generated by the computer when an alarm is received.

10. Once an alarm is acknowledged at one OWS, it shall display as acknowledged at all operator workstations.

11. An operator shall be able to select multiple alarms for single action acknowledgement.

12. There shall be the ability to disable alarms.

13. The OWS alarm viewer shall be able to display the last 100 active alarms. If there are more than 100 active alarms, as alarms are acknowledged and removed from the viewer, older alarms shall be viewable to keep the viewer showing the last 100 active alarms until there are less than 100 active alarms.

E. Trends

1. Real Time Trends:
   a. At each OWS the operator shall be able to initiate a real time trending instance of up to 10 variables simultaneously.
   b. The polling interval setting shall be adjustable down to a rate of every second.
c. The data for each instance shall be presented on a single graphical display that automatically updates with each new data collection cycle.
d. The graphical presentation shall plot the variables on the Y axis and time on the X axis.
e. A minimum of two Y axis scales shall be available.
f. The operator shall have the ability to set the range on each Y axis scale or let the scales auto range to cover the range of the values being trended.
g. Each element of data on the graphical display must be labeled by name or by a unique color. If color is used, a color legend must be included on the graph.
h. The operator shall be able to open up to five instances simultaneously for a total of 100 points being trended at one time.
i. An operator shall be able to print an instance of real time data.
j. The system shall be capable of trending any variable in the system.
k. The operator shall be able to save pre-configured instances of real time trending that can be initiated with simple point and click actions.

2. Historical Data Collection:
a. Historical trend data shall be collected by field level devices and periodically uploaded to the data server.
b. The trend log objects in the field level devices shall have the capacity to store 300 samples per variable. When the 301st sample is collected, the 1st sample shall be discarded.
c. The field level devices shall be configured to request an upload of data when the number of samples is not greater than 180. Uploads may be configured to occur at a greater frequency.
d. Initiation of historical data collection shall be configurable.
   1) By manual operator intervention in a point and click manner.
   2) By a user adjustable time schedule or date.
   3) Triggered by a binary status variable (when the fan status is on, start the trend of the mixed air temperature).
   4) The system shall be capable of trending any variable in the system.
e. The status and capacity of the trend logs in the field devices shall be viewable from the operator workstation.

3. Historical Data Presentation:
a. An OWS shall have the capability to present the historical data for a variable in a tabular presentation of the values along with the date and time of the sample. The time period for the values to be presented shall be user adjustable.
b. An OWS shall have the capability to present the historical data for a variable in a graphical presentation of the values plotted against time and date.
c. The graphical presentation capabilities for historical trends shall equal those described above for real time trends.
d. The operator shall be able to save pre-configured instances of historical trending that can be initiated with simple point and click actions.

e. The operator shall be able to print the tabular presentations and graphical presentations of historical trend data.

4. The data collection, storage, retrieval and presentation system shall provide the features necessary for the owner to achieve certification under 21 CFR Part 11. The key issue is the integrity of the data, the ability to verify that the data has not been modified after collection by the system.

F. Application Programming

1. The application programming tool may be based on Line Programming or Graphical Programming concepts.

2. If the application programming is object based and graphical:
   a. There shall be an off-line simulation capability.
   b. There shall be the ability to view dynamic data displayed on the object diagram in real time.

3. There shall be self checking for errors in programming to be used by the programmer.

4. Key functions that must be supported are:
   a. Timer functions to include Delay Off, Delay On and Sample Rate Support
   b. Interval timer
   c. Math functions to include Addition, Subtraction, Multiplication, Division, Exponentiation, Trigonometric Functions and Logarithmic Functions (base 2 and base 10)
   d. If-Then-Else Instructions (also referred to as switching logic)
   e. Look up tables with a minimum of 100 entries, with and without extrapolation
   f. Bit Wise Logic
   g. Sample and hold binary
   h. Sample and hold analog
   i. Latch on and latch off functions with resets
   j. Input network variable definition
   k. Output network variable definition
   l. Sensor measurement definition
   m. End device control definition
   n. Logic functions to include And, Or, Not and Exclusive Or
   o. Detection of a power cycle
   p. Common function support (standard objects in graphical programs and subroutines in line programs). As a minimum the common functions shall include:
      1) PID with analog output
      2) PID with tri-state outputs
      3) Enthalpy from temperature and relative humidity
4) Optimum start stop based on occupancy schedule, temperature, set point and outside air temperature.

5) Polynomial equation

G. Report Creation

1. The operators shall be able to extract historical data from the data collection files and present the data in a Microsoft Excel format. All of the data in the log shall be exportable to include the date, time and values.

2. The number of trend logs that can be inserted into a single Excel Workbook shall not be limited by the OWS software.

3. The operators shall be able to pre-configure reports for manual execution or automated execution.

4. The OWS shall be able to auto execute any report based on:
   a. A time schedule
   b. An alarm trigger
   c. The status of a binary point (state=1, execute the report)

5. The operators shall be able to pre-configure the destination of the report:
   a. OWS screen
   b. Write to file on the hard drive
   c. Send to a printer.

6. The generation of a report shall not interrupt the use of the OWS by the operator, that is, it shall execute in the background.

2.8 Enclosures And Weather Shields

A. Enclosures shall meet the following minimum requirements:

1. Outdoors: Enclosures located outdoors shall meet NEMA Type 4 requirements.

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.

3. Wet Locations: Enclosures shall meet NEMA 250 Type 4 requirements.

4. All Other Dry Locations: Enclosures shall meet NEMA 250 Type 1 requirements.

5. All panels shall be self-supporting enclosures with keyed lock

6. Each panel shall be UL/ETL listed and stamped.

B. Weather shields shall meet the following minimum requirements:

1. They shall prevent the sun from directly striking the sensor.

2. They shall provide sufficient ventilation so that the sensing element measures the ambient conditions of the surroundings.

3. They shall prevent rain from directly striking or dripping onto the sensor.

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.
5. They shall be unpainted aluminum or they shall be white galvanized steel aluminum or PVC.

2.9 WIRE, CABLE, AND TRANSFORMERS

A. Refer to Division 26 for conduits and conductors, except as noted.

B. All wire and cable shall meet the requirements of NFPA 70 and NFPA 90A.

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.

D. Control wiring for binary sensors shall be 18 AWG copper and shall be rated for 300-volt service.

E. Wiring for 120-volt circuits shall be 18 AWG or thicker stranded copper and shall be rated for 600-volt service.

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.

G. IP Network cable shall meet or exceed all requirements of Category 5 cable as specified in ANSI/TIA/EAI 568-A.

H. 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.

2.10 OTHER EQUIPMENT REQUIREMENTS
A. At a minimum, building level controllers and unit level controllers monitoring and/or transmitting fire alarm points shall have UL 864 UOJZ listing with Underwriters Laboratories. The controls contractor shall provide a copy of the UL certificate for their controllers.

B. All controllers used for smoke control shall be UL 864 UUKL listed.

C. 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.

D. 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 four-hour UPS is required. If a generator does not support the electrical circuit, then 24-hour UPS is required. The University must approve any deviations from this requirement in writing prior to bidding.

E. Operating system for the building level network controller shall be Windows XP Professional or the most recent release of Windows.

2.11 Hvac Control Hardware Identification

A. Automatic Control Valve Tags
   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.
   2. For lubrication instructions, use linen or a heavy duty shipping tag.
   3. Tag the valves with identifying number and system.
   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.

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

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.

D. Panels and Control Devices
   1. Control Panels (Enclosures) shall be labeled.
   2. All sensors, controllers, and controlled devices shall also be labeled.
   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.
4. Identification on the labels or tags shall match the identification documented on the submittals/as-builts.

PART 3. Execution

3.1 Examination

A. Verify existing conditions before starting work. The beginning of installation implies that the contractor accepts the existing conditions.

B. The contractor shall thoroughly examine the project plans for control device and equipment locations, and any discrepancies, conflicts, or omissions shall be reported to the Engineer for resolution before rough-in work is started.

C. The contractor shall inspect the site to verify that equipment is installable as shown, and any discrepancies, conflicts, or omissions shall be reported to the Engineer for resolution before rough-in work is started.

D. The contractor shall examine the drawings and specifications and if head room or space conditions appear inadequate or if any discrepancies occur between the plans for work under this contract and the plans for the work of others, the discrepancies shall be reported to the Engineer and the contractor shall obtain written instructions for any changes necessary to accommodate the work under this contract with the work of others.

E. For Retrofit Projects:

1. Where required, verify that conditioned power supply (UPS) is available to the control units and to the operator work station.
2. Verify that existing equipment to be reused such as field end devices, wiring, and pneumatic tubing is installed and in working condition prior to installation proceeding.

3.2 Protection

A. The contractor shall protect against and be liable for damage to work and to material caused by the contractor’s work or employees.

B. The contractor shall be responsible for work and equipment until inspected, tested, and accepted.

C. The contractor shall be responsible for protecting materials awaiting installation.

D. The contractor shall close open ends of work with temporary covers or plugs during storage and construction to prevent entry of foreign objects.

3.3 Coordination

A. Site

1. The contractor shall assist in coordinating space conditions to accommodate the work of each trade where work will be installed near or will possibly interfere with work of other trades. If installation with
coordination causes interference with work of other trades, the contractor shall correct conditions without extra charge.
a. Coordinate and schedule work with work in the same area and with work that is dependent upon other work to facilitate mutual progress.

B. Submittals: See Part 1

C. Test and Balance

1. The contractor shall provide the Test and Balance Contractor a single set of necessary tools to interface with the control system for testing and balancing.
2. The contractor shall provide a minimum of 4 hours of training on the use of the interface tools.
3. The contractor shall provide a qualified technician to assist with the testing and balancing of one system controlled by a programmable controller and the first twenty terminal units.
4. The Test and Balance contractor is obligated to return the interface tools undamaged and in working condition at completion of the testing and balancing.

D. Network

1. The contractor shall allocate space in each Building Controller control panel for the installation of a network switch. The size of the network switch shall be selected such that a minimum of one spare port is available at each control panel at the completion of the project.

E. Life Safety

1. Duct smoke detectors required for air handler shutdown are provided under Division 16. The contractor shall interlock the smoke detectors to the air handlers for shutdown as required by the sequence of control.
2. Smoke dampers and actuators required for duct smoke isolation are provided under Division 15. The contractor shall interlock the smoke dampers to the air handlers as required by the sequence of control.
3. Fire and smoke dampers and actuators required for fire-rated walls are provided under Division 15. Fire and smoke damper control is provided under Division 16.

F. Coordination with other controls specified in other sections or divisions: Other sections and/or division of this specification include controls and control devices that are to be part of or interfaced to the control system specified in this section. The contractor shall coordinate his integration of these devices as follows.

1. All communication media and equipment shall be provided as specified in Section XXXXX.
2. Each supplier of a controls product is responsible for the configuration, programming, start-up and testing of that product to meet the sequence of control.
3. The contractor shall coordinate and resolve any incompatibility issues that arise between the control products provided under this section and those provided under other sections or divisions of this specification.

4. The contractor is responsible for providing all controls described in the contract documents regardless of where within the contract documents these controls are described.

5. The contractor is responsible for the interface of control products provided by multiple suppliers regardless of where this interface is described within the contract documents.

G. Site Meetings

1. The project manager shall attend and lead the progress meetings as scheduled (see section 1.12).

2. The contractor shall allocate at least 2 hours for each meeting.

H. Verify building posting requirements with the Owner, before starting work.

3.4 General Workmanship

A. The contractor shall install equipment, piping, and wiring/raceway parallel to building lines (i.e., horizontal, vertical, and parallel to walls) wherever possible.

B. The contractor shall provide sufficient slack and flexible connections to allow for vibration of piping and equipment.

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

D. The contractor shall verify the integrity of all wiring to ensure continuity and freedom from shorts and grounds.

E. All equipment, installation, and wiring shall comply with acceptable industry specifications and standards for performance, reliability, and compatibility and be executed in strict adherence to local codes and standard practices.

F. Penetrations for raceway, piping, sleeves, or other equipment shall be sealed in a manner consistent with existing building conditions and current building code requirements.

G. Limit dust and dirt dispersal to lowest practicable level. Comply with governing regulations regarding environmental hazards and general dust control. Notify the Project Manager of possible exposure to harmful dusts and vapors, flammable or explosive materials, and other potential hazards. See Appendix B - Dust, Contaminant and Odor Control Options. Patch to match existing adjacent materials. When identical patching materials are not available, review alternatives with Project Manager.

3.5 Field Quality Control
A. All work, materials, and equipment shall comply with the rules and regulations of applicable local, state, and federal codes and ordinances as identified in Part 1 of this specification.

B. The contractor shall continually monitor the field installation for code compliance and quality of workmanship.

C. The Contractor shall have work inspected by local and/or state authorities having jurisdiction over the work.

3.6 Existing Equipment
A. Interconnecting control wiring shall be removed by the contractor and become the property of the contractor unless specifically noted or shown to be reused.

B. Interconnecting pneumatic tubing shall be removed by the contractor and become the property of the contractor, unless specifically noted or shown to be reused.

C. The contractor shall remove existing control panels and deliver to the owner.

D. Unless otherwise directed, the contractor is not responsible for the repairs or replacement of existing energy equipment and systems, valves, dampers or actuators. Should the contractor find existing equipment that requires maintenance, the Owner is to be notified immediately.

E. The contractor may re-use any existing temperature sensor wells in piping for temperature sensors. These wells shall be modified as required for proper fit of the new sensors. The contractor is responsible for inspecting all wells that are reused. Any leaks or other deficiencies are to be reported to the engineer immediately.

F. Where indicator gauges remain and are not removed, they must be made operational and recalibrated to ensure reasonable accuracy. Replace defective gauges as necessary.

G. Where existing thermostats are to be replaced, remove existing room thermostats and deliver them to the owner unless otherwise noted. Patch and finish holes and marks left by the removal process to match existing walls.

H. Where existing electronic sensors and transmitters are no longer required, remove, and deliver them to the owner unless otherwise noted.

I. Where existing controllers and auxiliary electronic devices are no longer required, remove, and deliver them to the owner unless otherwise noted.

J. Remove existing pneumatic controllers and auxiliary devices and deliver them to the owner unless otherwise noted.

K. Where existing damper actuators, linkages and appurtenances are replaced or no longer required, remove, and deliver them to the owner unless otherwise noted.

L. Where existing control valves are replaced or no longer required, remove, and deliver them to the owner unless otherwise noted.

M. Patch all existing surfaces of walls, cabinets, insulation, etc. when the surfaces have been disturbed by the removed of existing equipment. Painting will be performed by others.

N. At the owner’s request, items to be delivered to the owner shall be properly disposed of. Hazardous materials shall be disposed of as required by Division 02.
O. Interconnecting control wiring shall be removed by the contractor and become the property of the contractor unless specifically noted or shown to be reused.

P. Interconnecting pneumatic tubing shall be removed by the contractor and become the property of the contractor, unless specifically noted or shown to be reused.

Q. The contractor shall remove existing control panels and deliver to the owner.

R. Unless otherwise directed, the contractor is not responsible for the repairs or replacement of existing energy equipment and systems, valves, dampers or actuators. Should the contractor find existing equipment that requires maintenance, the Owner is to be notified immediately.

S. The contractor may re-use any existing temperature sensor wells in piping for temperature sensors. These wells shall be modified as required for proper fit of the new sensors. The contractor is responsible for inspecting all wells that are reused. Any leaks or other deficiencies are to be reported to the engineer immediately.

T. Where indicator gauges remain and are not removed, they must be made operational and recalibrated to ensure reasonable accuracy. Replace defective gauges as necessary.

U. Where existing thermostats are to be replaced, remove existing room thermostats and deliver them to the owner unless otherwise noted. Patch and finish holes and marks left by the removal process to match existing walls.

V. Where existing electronic sensors and transmitters are no longer required, remove, and deliver them to the owner unless otherwise noted.

W. Where existing controllers and auxiliary electronic devices are no longer required, remove, and deliver them to the owner unless otherwise noted.

X. Remove existing pneumatic controllers and auxiliary devices and deliver them to the owner unless otherwise noted.

Y. Where existing damper actuators, linkages and appurtenances are replaced or no longer required, remove, and deliver them to the owner unless otherwise noted.

Z. Where existing control valves are replaced or no longer required, remove, and deliver them to the owner unless otherwise noted.

AA. Patch all existing surfaces of walls, cabinets, insulation, etc. when the surfaces have been disturbed by the removed of existing equipment. Painting will be performed by others.

BB. At the owner’s request, items to be delivered to the owner shall be properly disposed of. Hazardous materials shall be disposed of as required by Division 02.
3.7 Continuity Of Existing System Operation

A. The contractor shall make all reasonable efforts to mitigate the impact of this work on the operation of existing systems, building occupants, and research equipment.

B. Notify the owner prior to commencing work that could or will disrupt the functions of any building or network systems. The contractor and owner will plan the detailed implementation of the contractor’s work plan submitted with the proposal.

C. The contractor shall make provisions to maintain adequate continuous system operation for equipment that serves critical research areas and all research animal holding areas.

D. Where building DDC systems are used for fire alarm signaling, the contractor shall make provisions to maintain this function during construction. The fire alarm signaling can be disabled for construction during first shift if:
   1. Approved by the owner.
   2. BSAC fire system outage notification procedures are followed.
   3. Proper fire watch procedures are followed.
   4. The system is back online before the contractor leaves the jobsite each day.

E. The contractor shall notify BSAC and the FM maintenance district prior to disrupting the operation of any existing equipment or system. Notification will also be made when the affected systems are back in operation.

3.8 Exposed Work

A. The controls contractor shall not run any conduit or wiring exposed below the finished ceiling or on any finished walls, unless approved by the Owner. The controls contractor shall be responsible for all cutting and patching required in connection with his work. The Owner shall approve all cutting and patching.

3.9 Enclosures

A. Unless otherwise noted, all existing control panels (including pneumatic) shall be reused.

B. All building controllers and/or enclosures shall be clearly labeled with their device ID and IP address.

C. Mark all DDC panels with circuit number and electrical panel number.

3.10 Wiring

A. Licensed union electricians, experienced in this type of work shall perform all electrical work. The Contractor shall be responsible for all control wiring required for the proper installation of the system.

B. All power, control, and interlock wiring shall comply with national, state and local electrical codes and Division 16 of this specification. Where the
requirements of this section differ from those in Division 16, the requirements of this section shall take precedence.

C. All components/devices used in wiring shall be UL/ETL approved, listed and stamped. All cable material and installation shall comply with State of Minnesota Fire Code requirements.

D. Surge transient protection shall be incorporated in design of system to protect electrical components in field panels.

E. Pathway/Raceway Construction

1. All raceway construction shall be in accordance with the latest revision of the NEC and Division 16 requirements. The pathway shall be minimum EMT with a flexible section for connection to devices, or PVC (polyvinyl chloride) where corrosion is expected to be a problem. Pathway which has been crushed or deformed in any way shall not be installed.

2. Bends of pathway system shall be made such that the pathway shall not be injured and that the internal diameter of the conduit will not be effectively reduced. The radius of the curve shall not be less that that recommended by either the NEC or manufacturer of the wires or cable to be contained within the pathway. Wherever possible, the maximum angle of bends between pulls shall not total more than 270 degrees including the entrance to and from the pull box.

3. The maximum allowable distance between pull points shall be 300 feet. When the distance between the two pull points contains bends, the maximum allowable distance shall be 75 feet. A lubricating agent compatible with the wire insulation shall be used. The pull boxes shall be sized to allow for an adequate bending radius for the wire or cable being pulled.

4. The combined cross-sectional area of all conductors and cables shall not exceed 40% of the total cross-sectional area of the pathway. The minimum size of pathway is ¾ inches in diameter. Pathway on equipment to end devices minimum size will be ½ inches and no longer than 3 feet.

5. Pathway shall be firmly supported within one meter or 3 feet of each pull box, junction box or termination point. The pathway shall be sufficiently supported elsewhere in accordance with NEC requirements. Pathway runs shall be solidly connected to assure the ground continuity of the entire length. Ground jumpers shall be installed where the possibility of losing continuity exists.

6. Pathway runs shall be provided with condensation drains at low points. Pathway runs shall be parallel or perpendicular to building walls.

7. Conduit Supports
   a. Single runs: Galvanized conduit straps or ring bolt type hangers with specialty spring clips. Do not use plumber’s perforated straps.
   b. Multiple runs: Conduit rack with 25 percent spare capacity.
   c. Vertical runs: Channel support with conduit fittings.
   d. Anchor Methods
1) Hollow masonry: Toggle bolts or spider type expansion anchors.
2) Solid masonry: Lead expansion anchors or present inserts.
3) Metal surfaces: Machine screws, bolts, or welded studs.
4) Wood surfaces: Wood screws.
5) Concrete surfaces: Self drilling anchors or power driver studs.

8. The size of raceway and size and type of wire shall be the responsibility of the contractor, in keeping with the manufacturer’s recommendations and NEC requirements, except as noted elsewhere.

9. EMT and rigid conduit size shall be ¾” or greater.

10. Covers for J-Boxes used with DDC system wiring shall be painted green and/or stenciled with “DDC”.

11. Include one pull string in each raceway that is 1 inch in diameter or larger.

12. Conceal all raceways, except within mechanical, electrical, or service rooms. Install raceway to maintain a minimum clearance of 6 inches from high-temperature equipment such as steam pipes or flues.

13. Secure raceways with raceway clamps fastened to the structure and spaced according to code requirements. Raceways and pull boxes may not be hung on flexible duct strap or tie rods. Raceways may not be run on or attached to ductwork.

14. Adhere to Division 16 requirement where raceway crosses building expansion joints.

15. Install insulated bushings on all raceway ends and openings to enclosures. Seal top end of all vertical raceways.

16. Flexible metal raceways and liquid-tight, flexible metal raceways shall not exceed 3 feet in length and shall be supported at each end. Flexible metal raceway less than ½ inch electrical trade size shall not be used. In areas exposed to moisture, including chiller and boiler rooms, liquid-tight, flexible metal raceways shall be used.

17. Raceway must be rigidly installed, adequately supported, properly reamed at both ends, and left clean and free of obstructions. Raceway sections shall be joined with coupling according to code. Terminations must be made with fittings at boxes and ends not terminating in boxes shall have bushings installed.

F. Class 1 Wiring

1. All NEC Class 1 (line voltage) wiring shall be UL Listed in approved raceway according to NEC and Division 16 requirements.

2. Maximum allowable voltage for control wiring shall be 120 Volts. If only higher voltages are available, the contractor shall provide step-down transformers.

G. Low Voltage (Class 2) Wiring

1. Low voltage wiring shall meet NEC Class 2 requirements. Sub-fuse low voltage power circuits as required to meet Class 2 current limits. Maximum control transformer size is 100VA without prior approval form Owner.
2. Class 2 wiring installed above hard ceilings or other inaccessible locations shall be run in approved raceway.
3. All exposed Class 2 wiring shall be enclosed in metallic conduit or raceway.
4. All wiring in mechanical, electrical, or service rooms, or where subject to mechanical damage, shall be installed in raceway at levels below 10 feet.
5. Low voltage wiring installed above lay-in or other accessible ceilings shall be in conduit unless specifically allowed by the University. If allowed, open cable installations will adhere to the requirements of this section.
6. 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.
7. Install plenum wiring in sleeves where it passes through walls and floors. Maintain the fire rating at all penetrations.
8. Where Class 2 wiring is run without raceways:
   a. Wiring is to be run parallel along a surface or perpendicular to it
   b. Wiring will be neatly tied at 10 foot intervals or less as required to prevent excessive sagging.
   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.
9. The contractor shall not install Class 2 wiring 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).
10. The contractor shall not install wiring in raceway containing pneumatic tubing.
11. 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.
12. All wiring within enclosures shall be neatly bundled and anchored to permit access and prevent restriction to devices and terminals.
13. All wiring shall be installed as continuous lengths, with no splices permitted between termination points.
14. Use coded conductors throughout with conductors of different colors.

H. Other Requirements

1. 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.
2. The contractor shall terminate all control and/or interlock wiring and shall maintain updated as-built wiring diagrams with terminations identified at the job site.
3. 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. On a fan
system with VFDs, wire the safeties so the fan shuts down if the VFD is in
hand or bypass mode of operation.

3.11 Communication Wiring

A. The contractor shall adhere to the items listed in the previous section on
WIRING.

B. The contractor shall install all cabling in a neat and workmanlike manner.
Follow manufacturer’s installation recommendations for all communication
cabling.

C. The contractor shall not install communication wiring in raceway and
enclosures containing Class 1 wiring.

D. When a cable enters or exits a building, the contractor shall install a lightning
arrester between the lines and ground. The lightning arrester shall be installed
according to the manufacturer’s instructions.

E. The contractor shall install all runs of communication wiring with un-spliced
lengths when that length is commercially available.

F. The contractor shall label all communication wiring to indicate origination
and destination data.

G. The contractor shall ground coaxial cable in accordance with NEC regulations
on “Communications Circuits, Cable, and Protector Grounding.”

H. When shielded wiring is use, the contractor shall ground the shield only once
for each continuous segment of cable. The grounding location shall be at the
end of the segment that is most readily accessible.

3.12 Network Communication Trunk And Terminations
A. A backbone communication trunk will be provided and installed by the University of Minnesota. All network fiber shall be 62.5 micron FDDI grade. The University will provide the fiber connection in one location in the building. The controls contractor is responsible for all DDC network wiring within the building.

B. The controls contractor shall tag all fiber or copper cable with a tag indicating “BSAC Fiber or BSAC Cable.” All lower level panel-to-panel networking and fiber patch cords shall be the responsibility of the controls contractor.

C. The controls contractor shall connect the new system to the dedicated fiber communication trunk and provide all components necessary (hubs, switches, links, modems, connectors, cables, interface equipment, software, labor, etc.) for communication on the dedicated University DDC network to the vendor’s master work station. Hub and switch locations shall be supported by a four hour UPS, provided by the University, and emergency power.

D. The controls contractor shall provide a network riser for all locations as part of construction, submittals and as-built documents. All fiber and network devices shall be clearly marked.

3.13 Ip Interface Devices

A. Install Building Controllers for each required connection to the dedicated DDC TCP/IP network.

B. The Building Controllers shall be configured and commissioned to ensure that the only data traffic on the TCP/IP is data that is essential for operation of the system. Messages between field devices on the same field bus shall not be allowed to pass onto the TCP/IP network.

3.14 Control Piping And Tubing And Wiring

A. GENERAL

1. Pneumatic lines shall be installed such that they are not exposed to outside air temperatures.
2. Pneumatic lines shall be concealed except in mechanical rooms and other areas where other tubing and piping is exposed.
3. All tubes and tube bundles exposed to view shall be installed neatly in lines parallel to the lines of the building.
4. Tubing in mechanical/electrical spaces shall be routed so that the lines are easily traceable.
5. All lines shall be purged of dirt, impurities and moisture before connecting to the control equipment.
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.
7. Piping shall be hard-drawn, seamless copper tubing with extruded or wrought copper fittings joined with 95-5 solder.
8. Polyethylene tubing and approved fittings may be specified and used subject to the following conditions:
9. All polyethylene control air tubing shall be installed in rigid conduit or metallic raceways that run parallel to the building structure.
10. Conduit or raceways may terminate 12 inches from individual controllers. A flexible metal sheath shall protect tubing from conduit to controller.
11. Low pressure control piping systems (nominal 20 psig) shall be tested with air at not less than 50 psig. Maintain this pressure for two hours. Use brush-on soap solution to detect leaks. If 5 psig is lost, the test has failed.

B. PNEUMATIC LINES IN MECHANICAL/ELECTRICAL SPACES
1. In mechanical/electrical spaces, pneumatic lines shall be plastic or copper tubing.
2. Horizontal and vertical runs of plastic tubing or soft copper tubing shall be installed in raceways or rigid conduit dedicated to tubing.
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.

C. PNEUMATIC LINES EXTERNAL TO MECHANICAL/ELECTRICAL SPACES
1. Shall be soft copper with sweat fittings or plastic tubing in raceways not containing power wiring.
2. Raceways and tubing not in raceways shall be supported every 8 feet.
3. Pneumatic lines concealed in walls shall be hard-drawn copper tubing or plastic tubing in rigid conduit.
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.

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

E. CONNECTION TO LIQUID AND STEAM LINES
1. Tubing for connection of sensing elements and transmitters to liquid and steam lines shall be copper or series 300 stainless steel.
2. Fittings shall be brass or stainless steel compression type fittings compatible with the tubing material.
3. CONNECTION TO DUCTWORK: Tubing shall be plastic.

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

G. CONNECTIONS TO ACTUATORS:
1. Final connections to actuators shall be plastic tubing, 12 inches long and unsupported at the actuator.
H. COMPRESSED AIR STATIONS:

1. The air line shall be connected to the tank with a flexible pipe connector.

3.15 Sensors

A. The contractor shall install sensors in accordance with the manufacturer’s recommendations.

B. The contractor shall mount sensors rigidly and adequately for the environment within which the sensor operates.

C. The contractor shall install all sensors in accessible locations.

D. Room temperature sensors shall be installed on concealed junction boxes properly supported by the wall framing.

E. 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.

F. Sensors used in mixing plenums and hot and cold decks shall be of the averaging type. Averaging sensors shall be installed in a serpentine manner vertically across the duct. Each bend shall be supported with a capillary clip.

G. 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.

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

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

J. Differential air static pressure sensors:

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.

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.

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. The piping to the pressure ports on all pressure transducers shall contain a capped test port located adjacent to the transducer.

5. Mount transducers in a location accessible for service without the use of ladders or special equipment to the maximum extent possible.
K. 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.

L. 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.

3.16 Flow Switches

A. Airflow Switches
   1. Install in horizontal duct runs whenever possible.
   2. If a vertical duct run is the only option, then install in a location with an upward airflow.

B. Hydronic Switches
   1. Use the correct paddle type for the pipe diameter as described by the switch manufacturer.
   2. Adjust the flow switch in accordance with the manufacturer’s instructions.

3.17 Actuators

A. Damper actuators shall be provided with all mounting hardware and linkages.

B. Mount and link control damper actuators according to manufacturer’s instructions.

C. When spring return actuators are used on normally closed dampers, the seals shall be compressed when the dampers have been closed by the actuator.

D. Damper/actuator combinations shall modulate smoothly from fully closed to fully open and return.

E. Actuator Selection
   1. Size damper actuators to operate the related control damper(s) with sufficient reserve power to provide smooth modulating action or two-position action.
   2. Actuators shall also be sized for proper speed of response at the velocity and pressure conditions to which the control damper is subject.
   3. Shall produce sufficient torque to close off against the maximum system pressures encountered.
   4. Shall produce sufficient torque to close off against the fan shutoff pressure as a minimum.
   5. 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.
   6. Use line shafting or shaft couplings (jackshafting) in lieu of blade-to-blade linkages or shaft coupling when driving axially aligned damper sections.
F. Electric/Electronic Damper Actuators
   1. Shall be direct-mounted on the damper shaft or jackshaft unless shown as a linkage installation.
   2. Shall be mounted following the actuator manufacturer’s recommendations.

G. Electric/Electronic Valve Actuators
   1. Shall be connected to the valve with adapters approved by the actuator manufacturer.
   2. Shall be mounted following the actuator manufacturer’s recommendations.

H. Pneumatic Actuators
   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.

3.18 Control Dampers
   A. Install dampers in accordance with the manufacturer’s instructions to operate and to obtain leakage rates specified herein. Adjust the damper linkage such that the damper closes before the actuator is fully closed to assure tight shut-off of the damper.
   B. Blank-off and seal around dampers and between dampers and sleeves or frames to eliminate air by-pass.
   C. For outdoor air damper assemblies, stage the opening of each section to prevent stratification and poor mixing of outside and return air.

3.19 Control Valves
   A. Install in an accessible location, with room for actuator removal and service. Adjust the actuator to provide tight shutoff. Provide valve stem indicator and adjust to indicate proper travel.
   B. Where butterfly valves are used, permanently mark the end of the valve shaft to indicate the valve position.

3.20 Warning Labels
   A. The contractor shall affix permanent warning labels to all equipment that can be automatically started by the DDC system.
      1. Labels shall use white lettering, 12 point type or larger, on a red background.
      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.”
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. Labels shall use white lettering, 12 point type or larger, on a red background.
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.”

3.21 Identification Of Hardware And Wiring

A. The contractor shall 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.

B. The contractor shall label all pneumatic tubing at each end within 2 inches of the end with a descriptive identifier.

C. The contractor shall label all control panels with minimum ½ inch letters on laminated plastic nameplates.

D. The contractor shall identify all other control components with permanent labels. 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.

E. The contractor shall label room sensors relating to terminal box or valves with nameplates.

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

G. All identifiers shall match the as-built documents.

3.22 Programming For Programmable Devices

A. These requirements apply to Building Controllers and Unit Level Controllers.

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

1. Air handling units.
2. Packaged chillers.
3. Chillers, excluding pumps and tower.
C. To the maximum extent possible, all process control loops for built up systems shall reside in a single controller. An example is a chiller with its associated chilled water and condenser water pumping systems or a boiler system with steam to hot water heat exchangers. The objective of this requirement is that the contractor shall use large point count primary controllers in lieu of multiple secondary controllers.

D. Supervisory logic for integral and built up systems may reside in building controllers with the output commands to the process control loops traversing the field bus to the controllers executing the process control.

E. The contractor shall create and download application programs that meet the requirements of the sequence of operations, time scheduling requirements, trend logging requirements, alarm handling requirements and data visibility requirements at the OWS.
   1. The contractor shall use the University point naming convention throughout the project.
   2. All time schedules shall be fully configured with weekly schedules and all of the holidays identified by the owner.
   3. All trend logs identified in the sequence of control shall be fully configured and operational.
   4. All alarm handling shall be consistent with University alarming standards. See Appendix B for current standards.
   5. All application parameters identified as (adj) in the sequence of control shall be exposed as viewable parameters and appropriate initial values shall be set.
   6. Manual control of all external points shall be configured with BACnet command priority eight (8) unless otherwise specified in the sequence of control.
   7. For all variables broadcast onto the field bus, event driven communication shall be used to avoid data storms. As a minimum the program shall provide for the send on delta parameter and minimum send time parameter for each output variable.
   8. The contractor shall embed into the programs sufficient comment statements to clearly describe each section of the program. This applies to both line programming and graphical programming systems.
   9. If graphical programming systems with multiple layers for the functional block diagrams are used, no more than two layers shall be used.

F. All device-to-device (peer-to-peer) data flow shall be in place and configured to meet the sequence of control.

G. The programmed applications for a single integrated system shall not be distributed over more than one field bus. Examples:
   1. A chiller is controlled by a controller on field bus number 1. The controllers that control the pumps and tower shall also be on field bus number 1 as these systems are integrated in their control requirements.
2. Multiple air handling units are controlled by controllers on field bus number 1. The chiller system is controlled by controllers on field bus number 2. The chiller control logic requires the chilled water valve positions from each of the air handling unit controllers. It is acceptable that these related but non-integral systems are controlled by controllers on different field busses.

3.23 Servers And Workstations
   A. The contractor shall install a data server and operator work stations as shown on the contract drawings.
   B. All required software for fully functional systems shall be installed and configured. The owner shall provide the IP connections and identify the specific rooms where the computers shall be installed.

3.24 Cleaning And Finishing
   A. The controls contractor shall maintain good housekeeping at all times. Keep the premises free from accumulations of waste materials or rubbish caused by execution of the work. At completion of the work the Contractor shall leave all work locations in a first class clean condition. In case of dispute, the Owner may remove the rubbish and charge the cost to the Contractor. The controls contractor shall be responsible for removing and reinstalling any ceiling tiles necessary to perform the work. Damaged tiles will be replaced at the Contractor's expense.
   B. The entire project area shall be cleaned immediately prior to final inspection.
   C. Each surface or unit shall be cleaned to the condition expected in a normal, commercial building cleaning and maintenance program.
   D. Cleaning shall include the interior of cabinets and casework, converters, unit heaters, radiation, electric panels, and similar items, and such accessible spaces as tunnels, shafts, pipe spaces, plenums, crawl spaces and similar areas.
   E. When punch-list work generates dust and debris, an additional cleaning will be needed prior to occupancy.

3.25 Systems Integration
   A. The controls contractor shall be fully responsible for the installation and commissioning of the integrated system.
   B. Controls contractor shall be responsible for all on-site and off-site programming as required to provide a fully operational integrated system. Contractor shall coordinate all programming and point mapping requirements with University personnel. If the Contractor deems changes to the Contract Documents necessary, submit details in writing, to the Owner for approval.
   C. The controls contractor shall provide all engineering and analysis work necessary to determine the method of network connectivity. The Contractor shall furnish, install and program hardware, wiring, network devices, cabling, software and graphics to connect the new DDC controls system to the
University DDC network. The interface will allow, at a minimum, the following:

1. Alarm annunciation in BSAC
2. Output control
3. Analog and digital commands
4. Reset commands
5. Point enable and disable
6. Set point adjustments
7. Time Of Day Scheduling
8. Dynamic Alarm Synchronization

3.26 Building Systems Automation Network Performance Requirements

A. The temperature controls contractor will supply all hardware software labor, material and expertise necessary to tie the BACnet building controller(s) to the University private DDC control network. BACnet integration must conform to Data Link Layer Option BACnet/IP shown in BACnet ANSI/ASHRAE 135-2004 publication Annex J.

B. The controls contractor must install all new building level controllers such that BACnet communications on the existing temperature control network are not derogated. Derogation includes router, switch, hub lockups, BACnet building controller lockups, site network excessive slowdowns, unnecessary and repeated ‘who is’ messages. Refer to ASHRAE BACnet standard for definition of unnecessary Who-is messages.

C. All BACnet read property requests from the U of M Master BACnet Operator Workstation must not take more then 5 seconds to process once the BACnet Building Controller receives the read request. Object properties that are read requested that require multiple segmented packets must not take more than 5 seconds to process the request. All information that is received from a read property multiple or single read property must not be older that 10 seconds.

3.27 Training:

A. The Control Contractor shall schedule twenty four (24) hours of system training with a minimum of two weeks notice.

1. All training must be held on-site.
2. An outline of the proposed agenda shall be submitted to Energy Management for review.
3. Training shall be performed during normal working hours with project personnel who are familiar with the full scope of the integration project and the vendor’s front-end workstation.
4. The training shall consist of instructions in the proper operation, programming, and maintenance of the selected vendors system.
5. The Contractor shall instruct the Owner's personnel so that they can troubleshoot and maintain integration hardware and databases, program,
reprogram, and/or reenter the desired schedules, values, settings, and strategies.

3.28 Documentation

A. The controls contractor shall provide three (3) bound copies of Owner's Manuals (i.e. equipment Data drawings with sequence of operations, Operational Manuals, As-built drawings, etc.)

B. The controls contractor will include control equipment drawings for each building. Submittal drawings will include network diagrams, panel layout drawings, detailed equipment drawings, description of operation, wiring diagrams, termination details, point schedules, trunk layouts including power supplies at all bus levels, and room schedules. Drawings shall be “B” sized 11 inches x 17 inches. Submittal brochures will include detailed product data sheets on all integration devices.

C. The controls contractor will include in the submittals a detailed point list for each integrated building. The point list shall detail the point descriptor, the type of input or output (i.e., DI, DO, AI, AO) and software points. The point list must be submitted to the Project Manager for review and approval.

D. As-built drawings will each be stamped “As-Built” and have the as-built date on them. Copies of as-built drawings shall include the following at a minimum: Detailed drawings for each piece of controlled and monitored equipment, point lists, sequence of operations, hardware with part information, logic tables, room schedules, and O & M manuals. As part of the as-built drawings, the Contractor will provide a drawing that shows the detailed routing of all communication trunk wires (building-to-building and within building), locations of all network and integration devices, front-end workstations, UPS and campus network/LAN connections.

E. The controls contractor shall provide electronic copies of all as-built documentation to the University. The electronic copies shall be stored on CDs and shall be saved in an editable format. Acceptable formats include Microsoft Office program formats (i.e. Word, Excel, Access, etc.), Visio, and AutoCAD. Other formats must be approved by the University at time of project award.

3.29 Control System Checkout

A. The contractor shall furnish all labor and test apparatus required to execute the start up testing plan. Key tasks to be executed and documented in the start up testing report include:

1. Verification of all primary and secondary voltages.
2. Verification that power wiring for all devices conforms to manufacturer’s instructions.
3. Verification that all labeling is in place.
4. Inspection of wiring for loose strands and tight connections.
5. Verification of field bus topology, grounding of shields (if used) and installation of termination devices.

6. Verification that each I/O device is landed per the submittals and functions per the sequence of control.
   a. Analog sensors shall be properly scaled and a value reported to the OWS.
   b. Binary sensors shall have the specified normal position and the state is reporting properly to the OWS.
   c. Analog outputs have the specified normal position and move full stroke when so commanded.
   d. Binary outputs have the specified normal state and respond to energize/de-energize commands.

7. Analog sensors calibrated with high quality instrumentation suitable for the sensor being calibrated.
   a. The instruments shall display a current (12 month) NIST traceable calibration sticker. Associated instrument calibration certificates shall be made available within 24 hours of a request.
   b. The measured value, reported value, and the calculated offset that was entered into the database shall be recorded.
   c. The calibration criteria shall be:
      1) Space Temperature: +/- 0.5 degrees F
      2) Air Temperature: +/- 0.5 degrees F
      3) Fluid Temperature: +/- 0.5 degrees F
      4) Air Flow Rate: +/- 5 %
      5) Liquid Flow Rate: +/- 5 %
      6) Differential Pressure: +/- 3 %
      7) Gauge Pressure: +/- 5%
      8) Relative Humidity: +/- 3 % relative humidity
      9) CO2: +/- 2 %

8. Loop Tuning
   a. The contractor shall tune all P, PI and PID control loops.
   b. The loop tuning criteria shall be a stable control loop where the average error over 15 minutes and 30 samples shall be less than:
      1) Space Temperature: +/- 0.75 degrees F
      2) Air Temperature: +/- 1.50 degrees F
      3) Air Humidity: +/- 5 % relative humidity
      4) Chilled Water Temp: +/- 1.00 degrees F
      5) Hot Water Temp: +/- 1.00 degrees F
      6) Duct Pressure: +/- 0.2 inches w.g.

3.30 Testing And Commissioning

A. The HVAC and control systems shall be commissioned in accordance with the project Commissioning Plan. If no Commissioning Plan has been prepared, the systems shall be commissioning in accordance with ASHRAE Guideline
The controls contractor shall provide assistance, staff and materials to support the commissioning activities.

B. All buildings transmitting fire alarm signals will be tested in accordance with the 2002 EDITION of NFPA 72; 4.5 Documentation, 4.5.1; Approval and Acceptance, sub-section 4.5.1.2, 4.5.2; Completion Documents and 4.5.3 Records. Test transmission of fire, trouble and supervisory signals. University of Minnesota staff and Code Officials are available for consultation and testing support.

C. The controls contractor shall provide assistance, staff and materials to support the commissioning activities in the presence of a designated University Representative, which shall include the following tests:

1. When installation is complete, verify and document communication transmission between each building, the vendor’s master workstation, and any third party BACnet work station. The controls contractor is responsible for all final adjustments and testing. Submit test report to the Owners Representative as part of the final operational test.
2. Field test the accuracy of all points and verify that the vendor’s front end and third party BACnet work station receives the change of states. Field point status must be in sync with the present alarm conditions, values, and status of points that are mapped into the third party BACnet work station. Any device out of the specified range shall be identified in the checkout report. All field controller information for analog, digital, software points, etc, received at the integrated front end, shall not be more than 10 seconds old.
3. All analog inputs shall be verified for accuracy according to the specifications for the device. Any device out of the specified range shall be replaced. The devices shall be tested against the calibrated instrument used in the initial setup of the device.
4. Switch the status of all digital inputs from the final field device. Verify that BSAC received the change of state.
5. The building control system shall provide commands to all outputs. Proper operation shall be verified in the field.
6. All DDC panels shall be tested for panel alarm condition and communication trunk will be tested for panel no response alarm conditions at the vendor’s master workstation and at the MLWS.

D. All points shall be in the automatic mode when the project is turned over to the University.

E. Verification Testing.
1. The University will perform verification tests on all equipment installed as part of this project.
2. The University will develop verification test plans for each system.
3. The controls contractor is responsible for providing materials and labor to assist the University with verification testing. A University representative will witness all verification testing.
4. The University will compile a log of open and deficient items observed during the testing.
   a. The controls contractor shall complete all required repairs, test the system, and inform the University that the open and deficient items have been resolved within one week after receipt of the log.
   b. The University will retest the corrected items to confirm they are complete. It is expected that the controls contractor will correct all deficiencies in a timely manner and that multiple retesting by University staff will not be required.
   c. If more than one retest on the same system is required, the University may back charge the controls contractor for all additional retests at a rate of $100/hr per person.

3.31 Service And Spare Parts
   A. During the warranty period, the controls contractor shall provide service on hardware and software components with technical staff located in the Minneapolis/St. Paul Metropolitan Area.
   B. All service items and spare parts shall be available from the manufacturer or Contractor’s stock for a minimum of 5 years following the expiration of the warranty period.

3.32 Alarms
   A. Contractor shall configure alarms as required by the latest University DDC alarm guidelines.
   B. All alarmed points must be properly named and must have a complete and correct descriptor before the intrinsic alarm is enabled.
   C. The completed system must be capable of transmitting all fire alarms, emergency signals and building control points from the selected vendors systems to the MLWS. A panel failure alarm must be transmitted to the third party BACnet system when a DDC controller or network fails. Alarm conditions shall be printed and stored in an electronic text format for immediate and future reference.
   D. All binary alarm points shall be Normally Open contacts (closed contact mean alarm).
   E. The controls contractor shall discuss with Energy Management the software procedures for specific types of alarm lockouts. If different limits are needed, the controls contractor shall get approval from Energy Management before programming alarm limits. The controls contractor is responsible for high and low alarm limits for analog input points. All critical digital input points shall be programmed as alarmable points. All analog and digital points for process equipment need to be reviewed with the process equipment owner or building occupant for alarm conditions.
   F. The vendor’s system and integrated system shall have the capability to recognize alarm point limits and alarm point lockouts from field panels for
Dynamic Alarm Synchronization. On systems that are seasonal in operation or have alarm limits controlled based on control logic, the alarm reporting will be automatically overridden when the equipment is shut off and the alarm condition shall read normal if the limits are within the alarm range.

G. All analog temperature, pressure, and other process variables shown in the alarm guidelines that are actively controlled by the DDC system shall be configured with dynamically resetting alarm limits linked to the control setpoint. The point shall be in alarm whenever the present value of the point is away from setpoint by more than the programmable deviation limit, subject to the alarm delays shown in the guidelines. The default deviation limits for analog points are as follows:

1. Discharge Air Temperature: +/- 5°F
2. Other AHU Temperatures: +/- 5°F
3. Duct Static Pressure: +/- 0.2 in w.c.
4. Room Temperature: +/- 5°F
5. Space Humidity: +/- 10%
6. Discharge Air Humidity: +/- 10%
7. Hot Water System Temperatures: +/- 5°F
8. Chilled Water System Temperatures: +/- 3°F
9. Hydronic System Pressures: +/- 10% of setpoint or 1 psi whichever is greater

H. All alarms must be routed to a BACnet notification class capable of routing BACnet alarms to a third party BACnet device. If applicable, alarmed points should be set to BACnet intrinsic. Proprietary alarming methods requiring use of vendor specific software to view alarms are prohibited. Alarmable points must be routed to the proper BSAC console operator terminal via a recipient entry into a BACnet notification class object. Routing for Console 1 operator position includes the East Bank & Northwest District and University of Minnesota – Duluth (UMD). Console 3 operator position includes the Saint Paul District & Academic Health District. All intrinsic reporting must also be routed to the BSAC Master Alarm History Recorder which is located in the B30 Donowe Building at BACnet device ID 123456. A BACnet Broadcast Management Device has been initiated on each subnet. Additional BBMD support, when needed, is the control contractor’s responsibility. BBMD must fully support foreign device registration.

### 3.33 Trends

A. All DDC points associated with unit controllers shall have trends installed by the controls contractor.

1. Exception: Points that are not needed for troubleshooting system performance issues provided the contractor received approval from Energy Management.

B. Analog input and output points and analog programming points shall have trends that store a minimum of 24 hours of data with a maximum sampling
period of 30 minutes. Trends shall be configured to store the most recent 24 hours of data with older data being discarded as new data is stored.

1. Exception: Analog points that do not change frequently (e.g. setpoints) can be treated as binary points when configuring trends.

C. Binary input and output points and binary programming points shall have trends that record at least the last 10 changes of state.

D. Trends for multistate points (multiple discreet values) shall be configured like binary point trends.

3.34 Fire Alarm Monitoring

A. **PROHIBITED:** Using DDC equipment to transmit fire alarm data to the Central Station monitoring facility (BSAC).

B. In facilities where the fire alarm signaling is transmitted via the private DDC IP network the network media converter and all networking equipment between the converter and the fire alarm signaling device(s) shall be connected to emergency power and backed up with a 4 hour UPS.

C. The DDC system shall monitor all UPS required under this section and report an alarm to BSAC whenever the UPS senses a loss of primary power or indicates a fault of any kind.

D. The DDC system will monitor the status of the fire alarm system only as required by the system sequences of operation. The fire alarm contractor shall provide relay outputs for the DDC system to monitor. These outputs will be used by the DDC system to trigger control system responses to fire alarm events (e.g. duct smoke detectors shutting down AHUs).

3.35 Critical System Monitoring
A. The system point list defines which alarm points are considered critical

B. In facilities where critical system monitoring is performed by DDC equipment, the controls contractor shall be responsible for all required material and labor to connect the Owner’s critical equipment to the DDC system.

C. All critical system monitoring binary inputs shall be configured as normally closed (open contact indicates an alarm condition).

D. In buildings with emergency generators, all DDC devices and networking equipment that monitor and/or transmit critical system monitoring points shall be connected to emergency power.

E. The controls contractor shall provide UPS power supplies for all DDC and networking devices that monitor and/or transmit critical system monitoring points. UPS shall be capable of maintaining full operation for a period no less than 4 hours.

F. The DDC system shall monitor all UPS required under this section and report an alarm to BSAC whenever the UPS senses a loss of primary power or indicates a fault of any kind.

3.36 Software And Graphics
A. The controls contractor shall provide all necessary non-disclosure and license agreements for required software. Energy Management shall receive all software licenses, the original copies of all software loaded into the system, and back-ups of all system databases and programs on CDs. All original software and documentation shall be delivered to Energy Management in the Donhowe Building. During the project, the controls contractor shall maintain disk or CD copies of all data files, application programs, and system software.

B. Two copies of all software and/or hardware needed to configure all control devices shall be provided to the Owner at the completion of the project. This includes any software tools, cabling, disks, etc. needed to program, configure, and maintain building and unit level DDC devices along with all networking hardware provided as part of the project.

C. The controls contractor shall update all DDC controllers to the latest released version of firmware at the completion of the project. Identical controllers shall all have the same software revision number when the project is complete.

D. The controls contractor shall make available and install DDC system and configuration software fix packs and patches at no cost to the University during the warranty period.

E. The controls contractor shall make available and install DDC system and configuration software version upgrades released during the warranty period at no cost to the University.

F. When the controls contractor integrates the selected vendors system into the vendor’s master workstation or third party BACnet system, all workstations shall be updated with the new system software, databases, graphics, etc.

G. In coordination with the requirements, specifications, and existing operating conditions the controls contractor shall program all schedules, parameters, high/low limits, control strategies, alarm values, descriptor, engineering units, map all physical and software points into the vendor’s DDC panels/workstations or third party BACnet system for a complete operational system.

H. The DDC operator interface shall include all software programming required to add the new building DDC databases and graphics to the existing DDC network in the Donhowe Building. The programmer for the DDC system shall map all physical and software points necessary for the operator to monitor and command all physical points and adjust all set points from the operator’s PC without requiring any additional program modifications. The controls contractor shall verify and remove all points from the database that are not used in the program. The controls contractor also shall be responsible for all point mapping and input/output object creation. A minimum of eight points shall be mapped from all VAV controllers to the vendor’s master workstation and/or integrated system.

I. The addition of the vendors DDC points to the new subsystem shall not cause that subsystem or any other subsystem to stop functioning (crash) or slow
down the request for point information. Subsystem start up synchronization between field panels and or vendor workstations and any subsystem shall not cause that subsystem or any other subsystem to stop functioning (crash) or slow down the request for point information.

J. All database programs shall be complied and/or de-compiled for errors before saving to the master front-end hard drive. Follow the specific procedures for directory, path and file names.

K. The controls contractor shall upload all DDC controller databases, including network controller level DDC programs, to the vendors master workstation front end PC located in BSAC. Primary and secondary bus controllers, including VAV box controllers, shall be uploaded and saved separately to the vendor’s master workstation.

L. The University shall have the capability to add, modify and delete time of day schedules, holiday schedules, weekday schedules, weekend schedules, temporary schedules, etc. from the vendor’s front end.

3.37 Graphic Standards For Building Systems

A. Graphics shall be generated from the vendor’s template library. New graphics shall be created at the vendor’s workstation. System graphics shall be developed for the vendors DDC system or at the integrated operator’s workstations, not both. Discuss graphic development as part of the bid and design process. Vendor’s workstation graphics shall follow all existing U of M graphic standards including ‘Fan Served Area served and ‘Quick Reference’ text table sections. The University will provide the ‘Fan Served Area’ in Auto-Cad version 14.

1. All hardware points shall have graphic(s) assigned
2. All user adjustable software points shall have graphic(s) assigned
3. Starting graphic for University campus with zones 1 through 5.
4. Each new building shall belong to one of the five zones.
5. Create graphic for outside conditions (Outside air, humidity, enthalpy, etc.)
6. The graphics shall note the analog output range and normal position.

B. Each piece of equipment shall have one or more graphics to include the following:

1. All hardware points
2. All user adjustable set points
3. All safety alarm points for the system (Fan, pump, static, freezestat, etc)
4. Heating/cooling switchover points
5. Occupancy/unoccupancy points
6. Summer/Winter mode points
7. Create graphic(s) for fire systems and other life and safety system alarms (Fire system, carbon monoxide, oxygen depletion, etc).
8. Create graphic(s) for all other critical points (Elevator, control air, phase outage, generator, city water, etc.).
9. Create graphic for steam points (Steam pressures, flow meters, etc.).
10. Create separate graphic(s) when more than 5 identical type of alarm points are monitored (Six cold rooms, ten incubators, etc.).
11. Create miscellaneous graphic(s) for other non-critical points (roof drain, sump pump, etc.).
12. Create graphic(s) for building layout and network system configuration with identifying the bus layout.
13. Verify that all programmed points on each graphic are referencing the correct software/hardware point at the controller level.

C. Other graphic criteria:

1. All graphics systems shall use standard templates and colors.
2. Type of font and font sizes shall be identical when appropriate.
3. All text and controller points shall be aligned properly.
4. All points shall flash red when points are in alarm condition.
5. When screens have minimal information, maximize the usage of the screen by enlarging the graphic.
6. Use building equipment numbers when possible for all equipment.
7. Points and descriptors shall not overlap.

3.38 Point Naming/Point Logical Grouping And Graphics

A. The programmer shall meet with Energy Management personnel before proceeding with programming to review point naming, system layout, point logical grouping, graphics, graphical display response time, and tree structure.

1. The controls contractor shall contact Energy Management personnel before deviating from University Standards.
2. Failure to work within the University Standards may result in the on Contractor being required to redo their work without being compensated.
3. Point descriptors must also follow the University conventions.

B. Supervisory controllers must be named with their corresponding building number & panel number. Before database generation is started, controls contractors are advised to contact Energy Management for questions regarding naming. Energy Management reserves the right to require changes to point naming if the controls contractor does not clarify naming before start of the controller database(s).

C. BACnet Object Identification numbers must also include building number and panel number. Controls contractors must coordinate Object IDs & IP address information with Energy Management prior to the start of database generation.
APPENDIX A: U of M BACnet Object Support Requirements

Controls contractor shall complete and return Appendix A with their proposal. Controls contractors must indicate Readable, Writable or Not Supported under Proposed Temperature Control Panel Conformance column below for all object standards shown.

Standards Required Column Definition:

**Optional:** Indicates that the property is optional and is not required by U of M BSAC

**Readable:** Indicates that the property is required by the University to be present and readable using BACnet services. This property will be read by the BSAC Master Operator Workstation.

**Writable:** Indicates that the property is required by the University to be present, readable, and writable using BACnet services. This property will be read from and written to by the BSAC Master Operator Workstation.

**Not Req:** Indicates that the property is not required by the University to be present

**Alarm and Event Services:**
BACnet intrinsic to device alarming method is required by U of M BSAC. All standard object properties and services that are required by ANSI/ASHRAE BACnet Standard 135-2004 for use with intrinsic reporting are required by U of M BSAC. Standard U of M required objects that support intrinsic reporting:

If Present_Value changes to a new state for longer that Time_Delay AND the new transition is enabled in Event_Enable an intrinsic alarm shall be sent for the following standard BACnet objects:

- Binary Input
- Binary Value
- Multi-state Input
- Multi-state Value

If Present_Value exceeds range between High_Limit and Low_Limit for longer than Time_Delay AND the new transition is enabled in Event_Enable and Limit_Enable an intrinsic alarm shall be sent for the following standard BACnet objects:

- Analog Input
- Analog Output
- Analog Value
If Present_Value returns within the High_Limit - Deadband to Low_Limit + Deadband range for longer than Time_Delay AND the new transition is enabled in Event_Enable and Limit_Enable an intrinsic return to normal shall be sent for the following standard BACnet objects:

- Analog Input
- Analog Output
- Analog Value

If Present_Value differs from Feedback_Value for longer than Time_Delay AND the new transition is enabled in Event_Enable an intrinsic alarm shall be sent for the following standard BACnet objects:

- BACnet standard object type Binary Output
- BACnet standard object type Multi-state Output

All BACnet Object definitions are standard types as defined by the ANSI/ASHRAE BACnet Standard 135-2004. Custom or nonstandard BACnet objects supported by the Vendor must support the Object-Identifier, Object_Name and Object_Type properties as required by ASHRAE 135-2004. All Object properties required by ASHRAE for intrinsic reporting are required by U of M. If a standard BACnet object is not listed in this construction standard then it is not required. U of M requires support for 13 of the 23 ASHRAE 135-2004 standard objects. The U of M requires Confirmed Event Notification Service. All alarms sent to the U of M Master Operator Console Workstation and Master Alarm History PC via Notification Class Object recipient list must be set to ‘Confirmed’.

The U of M requires foreign device registration support at control contractors BACnet Broadcast Management Device (BBMD). The control contractor must support BBMD capabilities for each individual subnet.

**Controls contractors that are unable to comply with BACnet schedule Object:**

If the controls contractor does not support the required schedule object including associated properties and services than the controls contractor will be required to submit a technical document that includes the following:

A. Custom and proprietary schedule objects and properties which will include complete datatype and ANSI data definitions. Controls contractor will be required submit, during the job submittal phase, all information that is necessary to properly read and write schedule data into controls contractor proprietary schedule at a building panel level.

B. Submitted proprietary schedule object data must include:

- Internal schedule ID, name, and description information
• Date range information when schedule is active (only if vendor supports this function)
• Weekly schedule information
• Holiday schedule information
• Exception or temporary schedule information that would take precedence over normal day’s behavior
• List of references including points information that are connected to the schedule
• Command priority for writing schedules information
# Analog Input

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<tr>
<th>Property Identifier</th>
<th>Analog Input Property Datatype</th>
<th>Standards Required</th>
<th>Proposed Temperature Control Panel Conformance</th>
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1. This property is required to be writable when Out_Of_Service is TRUE.
2. This property is required if the object supports COV reporting. (Not Required by the U of M)
3. These properties are required if the object supports intrinsic reporting. (Required by the U of M)
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<tr>
<th>Analog Output Property Identifier</th>
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1 This property is required if the object supports COV reporting. (Not Required by the U of M)
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<tr>
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</table>

1 If Present_Value is commandable, then both of these properties shall be present.
2 This property is required if the object supports COV reporting. (Not Required by the U of M)
3 These properties are required if the object supports intrinsic reporting. (Required by the U of M)
4 If Present_Value is commandable, then it is required to be writable. This property is required to be writable when Out_Of_Service is TRUE.
<table>
<thead>
<tr>
<th>Property Identifier</th>
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<tr>
<td>Polarity</td>
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<tr>
<td>Time_Of_State_Count_Reset</td>
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<tr>
<td>Alarm_Value</td>
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<td>Optional-5</td>
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<td>BACnetEventTransitionBits</td>
<td>Optional-5</td>
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<tr>
<td>Notify_Type</td>
<td>BACnet NotifyType</td>
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<tr>
<td>Event_Time_Stamp</td>
<td>BACnetARRAY (3) of BACnetTime Stamp</td>
<td>Optional-5</td>
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<tr>
<td>Profile_Name</td>
<td>CharacterString</td>
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</table>

1 This property is required to be writable when Out_Of_Service is TRUE.
2 If one of the optional properties Inactive_Text or Active_Text is present, then both of these properties shall be present.
3 If one of the optional properties Change_Of_State_Time, Change_Of_State_Count, or Time_Of_State_Count_Reset is present, then all of these properties shall be present.
4 If one of the optional properties Elapsed_Active_Time or Time_Of_Active_Time_Reset is present, then both of these properties shall be present.
5 These properties are required if the object supports intrinsic reporting.
(Required by the U of M)
<table>
<thead>
<tr>
<th><strong>Binary Output Property Identifier</strong></th>
<th><strong>Binary Output Property Datatype</strong></th>
<th><strong>Standards Required</strong></th>
<th><strong>Proposed Temperature Control Panel Conformance</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Object_Identifier</td>
<td>BACnetObject Identifier</td>
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<td>Description</td>
<td>CharacterString</td>
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<td>Reliability</td>
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<tr>
<td>Time_Of_State_Count_Reset</td>
<td>BACnetDateTime</td>
<td>Optional-2</td>
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<td>Time_Of_Active_Time_Reset</td>
<td>BACnetDateTime</td>
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<tr>
<td>Minimum_Off_Time</td>
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</tr>
<tr>
<td>Minimum_On_Time</td>
<td>Unsigned 32</td>
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<tr>
<td>Priority_Array</td>
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<td>Relinquish_Default</td>
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<td>Time_Delay</td>
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<td>Feedback_Value</td>
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<tr>
<td>Event_Enable</td>
<td>BACnetEventTransitionBits</td>
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</tr>
</tbody>
</table>
1 If one of the optional properties Inactive_Text or Active_Text is present, then both of these properties shall be present.
2 If one of the optional properties Change_Of_State_Time, Change_Of_State_Count, or Time_Of_State_Count_Reset is present then all of these properties shall be present.
3 If one of the optional properties Elapsed_Active_Time or Time_Of_Active_Time_Reset is present, then both of these properties shall be present.
4 These properties are required if the object supports intrinsic reporting. (Required by the U of M)
<table>
<thead>
<tr>
<th>Binary Value Property Identifier</th>
<th>Binary Value Property Datatype</th>
<th>Standards Required</th>
<th>Proposed Temperature Control Panel Conformance</th>
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<tbody>
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<td>Status Flags</td>
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<td>Event_State</td>
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<td>Time_of State_Count_Reset</td>
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<td>Time_of_Active_Time_Reset</td>
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<td>Priority_Array</td>
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<td>Acked_Transitions</td>
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<td>-------------------</td>
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<tr>
<td>Profile_Name</td>
<td>CharacterString</td>
<td>Not Req</td>
<td></td>
</tr>
</tbody>
</table>

1. If Present_Value is commandable, then it is required to be writable. This property is required to be writable when Out_Of_Service is TRUE.
2. If one of the optional properties Inactive_Text or Active_Text is present, then both of these properties shall be present.
3. If one of the optional properties Change_Of_State_Time, Change_Of_State_Count, or Time_Of_State_Count_Reset is present, then all of these properties shall be present.
4. If one of the optional properties Elapsed_Active_Time or Time_Of_Active_Time_Reset is present, then both of these properties shall be present.
5. If present_Value is commandable, then both of these properties shall be present.
6. These properties are required if the object supports intrinsic reporting.
(Required by the U of M)
<table>
<thead>
<tr>
<th>Calendar Property Identifier</th>
<th>Calendar Property Datatype</th>
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<td>Object_Type</td>
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<td>Date List</td>
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<td>Device Property Identifier</td>
<td>Device Property Datatype</td>
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<td>Proposed Temperature Control Panel Conformance</td>
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<td>Object_Identifier</td>
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<td>Object_Name</td>
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<td>Application_Software_Version</td>
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<td>Protocol_Object_Types_Supported</td>
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<td>Object_List</td>
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<td>Max_Segments_Accepted</td>
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<td>VT_Classes_Supported</td>
<td>List of BACnet VTClass</td>
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<td>Active_VT_Sessions</td>
<td>List of BACnetVTSession</td>
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<td>Local_Time</td>
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<td>List of BACnetSessionKey</td>
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<td>Time_Synchronization_Recipients</td>
<td>List of BACnetRecipient</td>
<td>Optional-5</td>
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Max_Master | Unsigned (1..127) | Optional-6
Max_Info_Frames | Unsigned | Optional-6
Device_Address_Binding | List of BACnetAddressBinding | Readable
Database_Revision | Unsigned | Readable
Configuration_Files | BACnetARRAY (N) of BACnet Object Identifier | Optional-7
Last_Restore_Time | BACnetDateTime | Optional-7
Backup_Failure_Timeout | Unsigned 16 | Optional-8
Active_COV_Subscriptions | List of BACnetCOVSubscriptions | Optional-9
Profile_Name | CharacterString | Not Req

1 Required if segmentation of any kind is supported.
2 If one of the properties VT_Classes_Supported or Active_VT_Sessions is present, then both of these properties shall be present. Both properties are required if support for VT Services is indicated in the PICS.
3 If the device supports the execution of the TimeSynchronization service, then these properties shall be present.
4 If the device supports the execution of the UTCTimeSynchronization service, then these properties shall be present.
5 Required if PICS indicates that this device is a Time Master. If present, this property shall be writable.
6 These properties are required if the device is an MS/TP master node. (The U of M allows MS/TP at the building subLAN only)
7 These properties are required if the device supports the backup and restore procedures.
8 This property must be present and writable if the device supports the backup and restore procedures.
9 This property is required if the device supports execution of either the SubscribeCOV or SubscribeCOV Property service.
# Multi-state Input Property Identifier

<table>
<thead>
<tr>
<th>Multi-state Input Property Identifier</th>
<th>Multi-state Input Property Datatype</th>
<th>Standards Required</th>
<th>Proposed Temperature Control Panel Conformance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Object_Identifier BACnetObjectIdentifier</td>
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</tr>
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<td>Object_Type BACnetObjectType</td>
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<tr>
<td>Present_Value Unsigned</td>
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<tr>
<td>Description CharacterString</td>
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<tr>
<td>Device_Type CharacterString</td>
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</tr>
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<tr>
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<td>Alarm_Values List of Unsigned</td>
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<tr>
<td>Profile_Name CharacterString</td>
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</table>

1 This property is required to be writable when Out_Of_Service is TRUE.
2 This property shall be required if Fault_Values is present.
3 These properties are required if the object supports intrinsic reporting (Required by the U of M)
<table>
<thead>
<tr>
<th>Multi-state Output Property Identifier</th>
<th>Multi-state Output Property Datatype</th>
<th>Standards Required</th>
<th>Proposed Temperature Control Panel Conformance</th>
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<tbody>
<tr>
<td>Object_Identifier</td>
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<td></td>
</tr>
<tr>
<td>Object_Name</td>
<td>CharacterString</td>
<td>Readable</td>
<td></td>
</tr>
<tr>
<td>Object_Type</td>
<td>BACnetObjectType</td>
<td>Readable</td>
<td></td>
</tr>
<tr>
<td>Present_Value</td>
<td>Unsigned</td>
<td>Writable</td>
<td></td>
</tr>
<tr>
<td>Description</td>
<td>CharacterString</td>
<td>Not Req</td>
<td></td>
</tr>
<tr>
<td>Device_Type</td>
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</tr>
<tr>
<td>Status_Flags</td>
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<tr>
<td>Event_State</td>
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<td></td>
</tr>
<tr>
<td>Reliability</td>
<td>BACnetReliability</td>
<td>Not Req</td>
<td></td>
</tr>
<tr>
<td>Out_Of_Service</td>
<td>BOOLEAN</td>
<td>Readable</td>
<td></td>
</tr>
<tr>
<td>Number_Of_States</td>
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<td>Readable</td>
<td></td>
</tr>
<tr>
<td>State_Text</td>
<td>BACnetARRAY(N) of CharacterString</td>
<td>Not Req</td>
<td></td>
</tr>
<tr>
<td>Priority_Array</td>
<td>BACnetPriorityArray</td>
<td>Readable</td>
<td></td>
</tr>
<tr>
<td>Relinquish_Default</td>
<td>Unsigned</td>
<td>Readable</td>
<td></td>
</tr>
<tr>
<td>Time_Delay</td>
<td>Unsigned</td>
<td>Optional-1</td>
<td></td>
</tr>
<tr>
<td>Notification_Class</td>
<td>Unsigned</td>
<td>Optional-1</td>
<td></td>
</tr>
<tr>
<td>Feedback_Value</td>
<td>Unsigned</td>
<td>Optional-1</td>
<td></td>
</tr>
<tr>
<td>Event_Enable</td>
<td>BACnetEventTransitionBits</td>
<td>Optional-1</td>
<td></td>
</tr>
<tr>
<td>Acked_Transitions</td>
<td>BACnetEventTransitionBits</td>
<td>Optional-1</td>
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<tr>
<td>Notify_Type</td>
<td>BACnetNotifyType</td>
<td>Optional-1</td>
<td></td>
</tr>
<tr>
<td>Event_Time_Stamps</td>
<td>BACnetARRAY(3) of BACnetTimeStamps</td>
<td>Optional-1</td>
<td></td>
</tr>
<tr>
<td>Profile_Name</td>
<td>CharacterString</td>
<td>Not Req</td>
<td></td>
</tr>
</tbody>
</table>

1 These properties are required if the object supports intrinsic reporting.
(Required by the U of M)
<table>
<thead>
<tr>
<th>Multi-state Value Property Identifier</th>
<th>Multi-state Value Property Datatype</th>
<th>Standards Required</th>
<th>Proposed Temperature Control Panel Conformance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Object_Identifer</td>
<td>BACnetObjectIdentifier</td>
<td>Readable</td>
<td></td>
</tr>
<tr>
<td>Object_Name</td>
<td>CharacterString</td>
<td>Readable</td>
<td></td>
</tr>
<tr>
<td>Object_Type</td>
<td>BACnetObjectType</td>
<td>Readable</td>
<td></td>
</tr>
<tr>
<td>Present_Value</td>
<td>Unsigned</td>
<td>Readable-1</td>
<td></td>
</tr>
<tr>
<td>Description</td>
<td>CharacterString</td>
<td>Not Req</td>
<td></td>
</tr>
<tr>
<td>Status_Flags</td>
<td>BACnetStatusFlags</td>
<td>Readable</td>
<td></td>
</tr>
<tr>
<td>Event_State</td>
<td>BACnetEventState</td>
<td>Readable</td>
<td></td>
</tr>
<tr>
<td>Reliability</td>
<td>BACnetReliability</td>
<td>Optional-2</td>
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</tr>
<tr>
<td>Out_Of_Service</td>
<td>BOOLEAN</td>
<td>Readable</td>
<td></td>
</tr>
<tr>
<td>Number_Of_States</td>
<td>Unsigned</td>
<td>Readable</td>
<td></td>
</tr>
<tr>
<td>State_Text</td>
<td>BACnetARRAY(N) of CharacterString</td>
<td>Not Req</td>
<td></td>
</tr>
<tr>
<td>Priority_Array</td>
<td>BACnetPriorityArray</td>
<td>Optional-3</td>
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</tr>
<tr>
<td>Relinquish_Default</td>
<td>Unsigned</td>
<td>Optional-3</td>
<td></td>
</tr>
<tr>
<td>Time_Delay</td>
<td>Unsigned</td>
<td>Optional-4</td>
<td></td>
</tr>
<tr>
<td>Notification_Class</td>
<td>Unsigned</td>
<td>Optional-4</td>
<td></td>
</tr>
<tr>
<td>Alarm_Values</td>
<td>List of Unsigned</td>
<td>Optional-4</td>
<td></td>
</tr>
<tr>
<td>Fault_Values</td>
<td>List of Unsigned</td>
<td>Optional-4</td>
<td></td>
</tr>
<tr>
<td>Event_Enable</td>
<td>BACnetEventTransitionBits</td>
<td>Optional-4</td>
<td></td>
</tr>
<tr>
<td>Acked_Transitions</td>
<td>BACnetEventTransitionBits</td>
<td>Optional-4</td>
<td></td>
</tr>
<tr>
<td>Notify_Type</td>
<td>BACnetNotifyType</td>
<td>Optional-4</td>
<td></td>
</tr>
<tr>
<td>Event_Time_Stamps</td>
<td>BACnetARRAY(3) of BACnetTimeStamps</td>
<td>Optional-4</td>
<td></td>
</tr>
<tr>
<td>Profile_Name</td>
<td>CharacterString</td>
<td>Not Req</td>
<td></td>
</tr>
</tbody>
</table>

1. If Present_Value is commandable, then it is required to also be writable. This property is required to be writable when Out_Of_Service is TRUE.
2. This property shall be required if Fault_Values is present
3 If Present_Value is commandable, then both of these properties shall be present.
4 These properties are required if the object supports intrinsic reporting. (Required by the U of M)
<table>
<thead>
<tr>
<th>Notification Class Property Identifier</th>
<th>Notification Class Property Datatype</th>
<th>Standard Required</th>
<th>Proposed Temperature Control Panel Conformance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Object_Identifier</td>
<td>BACnetObjectIdentifier</td>
<td>Readable</td>
<td></td>
</tr>
<tr>
<td>Object_Name</td>
<td>CharacterString</td>
<td>Readable</td>
<td></td>
</tr>
<tr>
<td>Object_Type</td>
<td>BACnetObjectType</td>
<td>Readable</td>
<td></td>
</tr>
<tr>
<td>Description</td>
<td>CharacterString</td>
<td>Not Req</td>
<td></td>
</tr>
<tr>
<td>Notification_Class</td>
<td>Unsigned</td>
<td>Readable</td>
<td></td>
</tr>
<tr>
<td>Priority</td>
<td>BACnetARRAY(3)of Unsigned</td>
<td>Readable</td>
<td></td>
</tr>
<tr>
<td>Ack_Required</td>
<td>BACnetEventTransitionBits</td>
<td>Readable</td>
<td></td>
</tr>
<tr>
<td>Recipient List</td>
<td>List of BACnetDestination</td>
<td>Readable</td>
<td></td>
</tr>
<tr>
<td>Profile Name</td>
<td>CharacterString</td>
<td>Not Req</td>
<td></td>
</tr>
<tr>
<td>Schedule Property Identifier</td>
<td>Schedule Property Datatype</td>
<td>Standards Required</td>
<td>Proposed Temperature Control Panel Conformance</td>
</tr>
<tr>
<td>-----------------------------</td>
<td>---------------------------</td>
<td>--------------------</td>
<td>-----------------------------------------------</td>
</tr>
<tr>
<td>Object Identifier</td>
<td>BACnetObjectIdentifier</td>
<td>Readable</td>
<td></td>
</tr>
<tr>
<td>Object_Name</td>
<td>CharacterString</td>
<td>Readable</td>
<td></td>
</tr>
<tr>
<td>Object_Type</td>
<td>BACnetObjectType</td>
<td>Readable</td>
<td></td>
</tr>
<tr>
<td>Present_Value</td>
<td>Any</td>
<td>Readable</td>
<td></td>
</tr>
<tr>
<td>Description</td>
<td>CharacterString</td>
<td>Not Req</td>
<td></td>
</tr>
<tr>
<td>Effective_Period</td>
<td>BACnetDateRange</td>
<td>Writable-1</td>
<td></td>
</tr>
<tr>
<td>Weekly_Schedule</td>
<td>BACnetARRAY(7)of BACnetDailySchedule</td>
<td>Writable-1</td>
<td></td>
</tr>
<tr>
<td>Exception_Schedule</td>
<td>BACnetARRAY(N)of BACnetSpecialEvent</td>
<td>Writable-1</td>
<td></td>
</tr>
<tr>
<td>List_Of_Object_Property_References</td>
<td>List of BACnetDeviceObjectPropertyReference</td>
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<td></td>
</tr>
<tr>
<td>Priority_For_Writing</td>
<td>Unsigned (1..16)</td>
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</tr>
<tr>
<td>Profile_Name</td>
<td>CharacterString</td>
<td>Not Req</td>
<td></td>
</tr>
</tbody>
</table>

1- Writable indicates a requirement of the U of M which is over and above BACnet conformance requirements.
<table>
<thead>
<tr>
<th><strong>Trend Property Identifier</strong></th>
<th><strong>Trend Property Datatype</strong></th>
<th><strong>Standards Required</strong></th>
<th><strong>Proposed Temperature Control Panel Conformance</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Object_IDEntifier</td>
<td>BACnetObjectIdentifier</td>
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</tr>
<tr>
<td>Object_Name</td>
<td>CharacterString</td>
<td>Readable</td>
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</tr>
<tr>
<td>Object_Type</td>
<td>BACnetObjectType</td>
<td>Readable</td>
<td></td>
</tr>
<tr>
<td>Description</td>
<td>CharacterString</td>
<td>Not Req</td>
<td></td>
</tr>
<tr>
<td>Log_Enable</td>
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</tr>
<tr>
<td>Start_Time</td>
<td>BACnetDateTime</td>
<td>Optional-1,2</td>
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</tr>
<tr>
<td>Stop_Time</td>
<td>BACnetDateTime</td>
<td>Optional-1,2</td>
<td></td>
</tr>
<tr>
<td>Log_DeviceObjectProperty</td>
<td>BACnetDeviceObjectPropertyReference</td>
<td>Optional-1,2</td>
<td></td>
</tr>
<tr>
<td>Log_Interval</td>
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<td>Optional-1,2</td>
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</tr>
<tr>
<td>COV_Resubscription_Interval</td>
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<tr>
<td>Client_COV_Increment</td>
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</tr>
<tr>
<td>Stop_When_Full</td>
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</tr>
<tr>
<td>Log_Buffer</td>
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</tr>
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</tr>
<tr>
<td>Total_Record_Count</td>
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<td>Notification_Threshold</td>
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<td>Records_Since_Notification</td>
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<tr>
<td>Last_Notify_Record</td>
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</tr>
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<td>Event_State</td>
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</tr>
<tr>
<td>Notification_Class</td>
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<td>Readable-3</td>
<td></td>
</tr>
<tr>
<td>Event_Enable</td>
<td>BACnetEventTransitionBits</td>
<td>Readable-3</td>
<td></td>
</tr>
<tr>
<td>Acked_Transitions</td>
<td>BACnetEventTransitionBits</td>
<td>Readable-3</td>
<td></td>
</tr>
<tr>
<td>Notify_Type</td>
<td>BACnetNotifyType</td>
<td>Readable-3</td>
<td></td>
</tr>
<tr>
<td>Profile_Name</td>
<td>CharacterString</td>
<td>Not Req</td>
<td></td>
</tr>
</tbody>
</table>

1 These properties are required to be present if the monitored property is a BACnet property.
2 If present, these properties are required to be writable.
3 These properties are required if the object supports intrinsic reporting. (Required by U of M)

U of M Minimum Protocol Implementation Conformance (PIC) for BACnet Building Controller

This PIC is used to describe what parts of the BACnet standard need to be implemented at U of M in order to achieve interoperability. It is the intention of the U of M to require temperature control products to conform to select BACnet standards in order to utilize a single Master Operator Workstation.

**BACnet Protocol Implementation Conformance Statement**

**Date:**  
April 1<sup>st</sup> 2005

**BACnet Standardized Device Profile (Annex L):**

All proposed devices show must meet all U of M BACnet requirements:
- BACnet Building Controller (B-BC)
- BACnet Advanced Application Controller (B-AAC)
- BACnet Application Specific Controller (B-ASC)
- BACnet Smart Sensor (B-SS)
- BACnet Smart Actuator (B-SA)

**BACnet Interoperability Building Blocks Supported (Annex K):**

**Segmentation Capability:**

*Segmented requests supported*

The U of M does not require segmentation capability. Some vendors use this for larger messages. If the vendor segments requests then it must conform to the BACnet standard.

*Segmented responses supported window Size*

Varies depending on usage. Not stipulated by the U of M.

**Standard Object Types Supported:**

The U of M will require support for the following Standard ANSI/ASHRAE 135-2004 BACnet objects. See the object tables above for Individual Object property requirements.

<table>
<thead>
<tr>
<th>BACnet Object 2004 Standard</th>
<th>Vendor required to support object</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analog Input</td>
<td>Vendor required to support object</td>
</tr>
<tr>
<td>Analog Output</td>
<td>Vendor required to support object</td>
</tr>
<tr>
<td>Analog Value</td>
<td>Vendor required to support object</td>
</tr>
<tr>
<td>Average</td>
<td>Not required</td>
</tr>
</tbody>
</table>
Binary Input | Vendor required to support object
---|---
Binary Output | Vendor required to support object
Binary Value | Vendor required to support object
Calendar | Vendor required to support object
Command | Not required
Device | Vendor required to support object
Event Enrollment | Vendor required to support object for command failure
File | Not required
Group | Not required
Life Safety Point | Not required
Life Safety Zone | Not required
Loop | Not required
Multistate Input | Vendor required to support object
Multistate Output | Vendor required to support object
Multistate Value | Vendor required to support object
Notification Class | Vendor required to support object
Program | Not required
Schedule | Vendor required to support object
Trend Log | Vendor required to support object

**Data Link Layer Options:**

- **X** BACnet IP, (Annex J)
- BACnet IP, (Annex J), Foreign Device
- ISO 8802-3, Ethernet (Clause 7)
- ANSI/ATA 878.1, 2.5 Mb. ARCNET (Clause 8)
- ANSI/ATA 878.1, RS-485 ARCNET (Clause 8), baud rate(s) __________
- MS/TP master (Clause 9), baud rate(s): __________
- MS/TP slave (Clause 9), baud rate(s): __________
- Point-To-Point, EIA 232 (Clause 10), baud rate(s):__________
- Point-To-Point, modem, (Clause 10), baud rate(s):__________
- LonTalk, (Clause 11), medium: __________
- Other: ______________

The U of M will utilize BACnet on the temperature control network LAN.  BACnet/IP will be deemed acceptable.  BACnet integration methods must conform to Data Link Layer Option BACnet/IP shown in BACnet ANSI/AHWRAE 135-2004 publication Annex J.  The BACnet device must act as a full-fledged IP node, complete with its own IP address and IP protocol stack.  BACnet tunneling will not be acceptable.

**Networking Options:**

- Router, Clause 6 - List all routing configurations, e.g., ARCNET-Ethernet, Ethernet-MS/TP, etc.
Annex H, BACnet Tunneling Router over IP (This protocol is not acceptable for any U of M application)

BACnet/IP Broadcast Management Device (BBMD)

BBMD support registrations by Foreign Devices?  X Yes  ☐ No

The U of M requires Foreign Device Registration. If the BACnet Building Controller proposed by the temperature controls contractor does not support registrations by Foreign Device than the temperature controls contractor is required to supply a 3rd party device (BACnet router) or equivalent to perform this task.

BBMD (BACnet Broadcast Management Device) receives broadcast messages on one subnet and forwards them to another subnet.

The U of M requires BBMD support

Character Sets Supported:

Indicating support for multiple character sets does not imply that they can all be supported simultaneously.

X ANSI X3.4  ☐ IBM ™ /Microsoft ™ DBCS  ☐ ISO 8859-1
☐ ISO 10646 (UCS-2)  ☐ ISO 10646 (UCS-4)  ☐ JIS C 6226

The U of M requires ANSI X3.4 Support

All ANSI/ASHRA 135-2004 required standard object properties will be supported by the temperature controls contractor BACnet device(s). Standard object optional properties will be supported if they are a requirement of any object listed above. Unsolicited change-of-value notification is required. All objects and object properties will be supported so that alarms are sent from the temperature control contractors BACnet building controller without having to be solicited from the U of M Master BACnet Operators Workstation (B-OWS) or Master History PC.

End of 23 09 00 Instrumentation and Control for HVAC

23 21 13 Hydronic Piping and Heating Piping

Pipe

1.1. PROHIBITED: Direct-buried steam and steam condensate pipe.

1.2. Tie-ins to New or Existing Mains

   1.2.1. Prohibited: Stub-ins when connecting to new or existing mains.

   1.2.2. 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 qeldolets.
1.2.3. Branch sizes greater than 10 inches in diameter must be tied-in with tees.

1.2.4. Connections to piping in university tunnels shall have appropriate offsets to maintain pipe stress within acceptable limits.

1.3. Steel Pipe

1.3.1. General

1.3.1.1. Galvanized steel pipe shall be at least minimum standard weight.

1.3.1.2. Standard weight and extra heavy black steel pipe shall be A53B, A106B, A120 or A135 welded or seamless construction as indicated for specific applications.

1.3.2. Steam pipe shall be minimum standard weight ASTM A53B seamless or A106B.

1.3.3. Steam condensate pipe shall be minimum Schedule 80 ASTM A53B seamless or A106B.

1.4. Copper Pipe

1.4.1. Prohibited: Soft annealed copper.

1.4.2. Type ‘K’ for gas and HWS&R under slabs serving around entrance ways. Type ‘L’ copper pipe for all piping within the building.

1.5. Plastic Pipe

1.5.1 Prohibited: Plastic piping is not allowed in the hydronic systems.

1.5.2 HDPE: is approved for underground chilled water systems.

1.5.3 Pex: Pex piping is not allowed.

1.6. Glass Pipe: Borosilicate glass drain line shall be specified for use in corrosive waste systems and corrosive vent systems.

Pipe Fittings

1.1. General Requirements
1.1.1. Prohibited: Couplings normally furnished with lengths of pipe used to install threaded piping.

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

1.1.3. Specify extruded or wrought copper fittings in copper piping systems.

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

1.2.1. 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.

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

1.2.3. 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.

1.3. Low Pressure Steam Condensate

1.3.1. 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.

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

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

1.4. High Pressure Steam Condensate

3.4.1. 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.

3.4.2. Unions that are 2 inches and smaller shall be ANSI Class 3000, forged steel, socket weld.
3.4.3. Flanges shall be ANSI Class 300, forged steel weld neck with B7 studs and A194 extra heavy nuts.

Strainers/Steam and Hydronic Systems

1.1. “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.

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

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

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

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

1.4. 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.

23 21 23 Hydronic Pumps
Pumping Systems for Chilled Water Plants

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. The basic chilled water pumping system shall consist of a primary system with constant flow pumps that only serve the chiller. A secondary system that consists of pumps with VFD shall supply chilled water to the building.

   1.3. The A/E shall determine if a tertiary pumping system is optional based upon the pumping needed for the cluster of buildings.

   1.4. 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

2.2.1. 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.

2.2.2. The building controls shall monitor the chilled water return temperature that leaves the building and modulate a two-way control valve on the return water piping to maintain the chilled water return set point of 58 degrees F.

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

23 22 00 Steam and Condensate Piping and Pumps
   Utility Heating Piping Systems

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.

1.8. Typical flash tank installation shall be per the sketch on the following page.
1.9. Typical steam trap installations shall be per the sketch on the following page. High-pressure steam traps shall be Plenty Velan Model 250 or university-approved equal.

1.10. Typical steam PRV station installation shall be per the sketch on the following page.

1.11. Steam pipes that require welding shall be accomplished in the same method as identified in the following ASME welding procedure specification.

1.12 Traps:

All traps shall have tags showing the model number and orifice size.

1.12.1 Prohibited: Cast-iron traps on high-pressure steam systems.

Thread O Let connections to steam mains on high-pressure steam systems.

1.12.2. 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.

1.12.3. Maintain 4 inches minimum clearance between threaded dirt leg cap and any obstruction.

1.12.4. Low Pressure Steam Systems

1.12.4.1. 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.

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

1.12.5 High Pressure Steam Systems

1.12.5.1. 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.

1.12.5.2. Every trap assembly shall be designed for ease of trap testing by including a test valve after the check valve.
Note: Use vertical ASME 300# tank
Note: Traps with or without strainers shall have an inline strainer upstream of the trap.
Typical Steam PRV Station

Note: Globe bypass valve shall be Klinger/Piston type or equal 3” and under and Vanessa triple offset butterfly valve for 4” and above.
**ASME Welding Procedure Specification (Page 1)**

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**QW-482 WELDING PROCEDURE SPECIFICATION (WPS)**
(See QW-201.1, Section IX, ASME Boiler and Pressure Vessel Code)

<table>
<thead>
<tr>
<th>JOINTS (QW-402)</th>
<th>Details</th>
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<tr>
<td>Joint Design</td>
<td>Single V Butt</td>
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<tr>
<td>Backing (Yes)</td>
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<tr>
<td>Backing Material Type</td>
<td>Metal or Weld Metal</td>
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- Metal
- Nonfusing Metal
- Nonmetallic
- Other

Sketches, Production Drawing, Weld Symbols or Written Description should show the general arrangement of the parts to be welded. Where applicable, the root spacing and the details of weld groove may be specified.

(At the option of the Mgr., sketches may be attached to illustrate joint design, weld layers and bead sequence, e.g., for notch toughness procedures, for multiple process procedures, etc.)

**BASE METALS (QW-403)**

| P-No. 1 Group No. 1 to P-No. 1, 2 Group No. 1, 2 |
|-----------------|---------|

OR

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<tr>
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<tr>
<td>to Chem. Analysis and Mech. Prop.</td>
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**Thickness Range:**

- Base Metal: Groove 0.062" to 0.688"
- Fillet Unlimited
- Pipe Dia. Range: Groove 1" and over
- Fillet Unlimited

**FILLER METALS (QW-404)**

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Division 23 - Heating, Ventilation and Air Conditioning
University of Minnesota Standards and Procedures for Design
December 2012
ASME Welding Procedure Specification (Page 2)
23 25 00 HVAC Water Treatment

Water Treatment for Open and Closed Loops

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:

   A. Automatic control of cooling tower bleed off
   B. Automatic control of chemical treatment for scale and corrosion
   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:

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

2.1.2. 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.

2.1.3. 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.

23 30 00 HVAC Air Distribution

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 62-92. Refer to Program Information/Requirements, Basic Design Requirements to determine proper design in regards to air regulations and emissions.

1.2. To distribute outdoor air to people in the occupied spaces, supply and return air shall be fully ducted.

1.3. 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.

1.4. To improve rigidity and tightness of construction, fabricate ductwork in accordance with the most recent edition of the SMACNA standards.

1.5. 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. Ductwork Material

2.1. Prohibited: Fiberglass ductwork.

2.2. Fabricate ductwork from G-90 coated galvanized steel. Spunglass fiberglass ductwork may be used underground. Stainless steel ducts may be required for exhaust applications based on the use.

2.3. Gauge stickers or stamps shall be provided on each section of duct. In lieu of stickers, gauge can be printed on the ductwork.

2.4. Supply and return air shall be fully ducted. Exceptions are special applications such as in computer rooms, clean air rooms and dry rooms.

3. Minimum Supply Duct Size: Ducts shall be minimum 6 inches by 6 inches or 6 inches round unless university-approved.

4. Ductwork Construction

4.1. Prohibited: Pipe or any other type of obstruction passing through a duct.

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

4.4. 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.

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

5. Sealing at Floors and Walls

5.1. Fire-stopping/sealant shall be installed in accordance with the requirements of Division 7 - Thermal and Moisture Protection.

5.2. The A/E shall coordinate the sealing of floor and wall penetrations.

6. Special Exhaust System


6.2. Refer to Division 13 00 30 - Food Service Construction Guide.

7. Duct Hangers and Supports

7.1. 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.

7.2. Horizontal ducts 48 inches or wider shall be rigidly and securely supported with angle-iron trapeze hangers under the duct, according to SMACNA standards.

7.3. Structural members shall support all vertical ductwork at each floor.

7.4. All fastenings and hardware for galvanized ductwork and sheet metal shall be cadmium-plated.

8. Manual Dampers

8.1. Specify and show all dampers required for proper balance of air on drawings.
8.2. Dampers come with a locking quadrant that is set, marked and locked in position at the time of final balancing.

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

9. Motorized Dampers: All outside air dampers shall be ultra-low leak, thermally insulated steel airfoil blade design with flexible extruded silicone side seals and blade gaskets. Damper leakage rates in closed position shall not exceed 6 cfm/sq. ft. at 4 inches WC.

10. Smoke and Fire Dampers

10.1. Smoke dampers or combination smoke/fire dampers shall have electric actuators, and of multiple-blade type that meets the requirements of UL555 and UL555S.

10.2. Damper operation shall be a controlled-closure type that closes in no less than seven seconds and no more than 15 seconds.

10.3. All smoke and fire dampers shall be designed with access panels adjacent to the dampers. The dampers shall be the right size to allow them to be reset through the access panels.

10.4. Access doors with 1/4-inch wire glass panels shall be installed after each fire damper is installed, so the damper position can be inspected from the floor. Refer to 11. Duct Access Doors for size and construction requirements.

10.5. The A/E shall require field-testing of all smoke and fire damper installations in the presence of the contractor.

10.6. Ducts shall be increased in size to accommodate fire and smoke dampers that are a minimum size of 12 inches by 8 inches.

11. Duct Access Doors

11.1. Install access doors on mechanical and electrical devices such as coils, motorized and manual dampers, and humidifiers.

11.2. Access doors shall be installed in sides or bottom of duct. 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. Refer to Division 13 00 30 - Food Service Construction Guide for more information regarding access doors in kitchen hood exhaust ducts.

11.3. 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. The
doors shall be a minimum 10 inches by 16 inches. Access door construction shall be per latest edition of SMACNA.

11.4. Coordinate mechanical access doors with architectural access panels.

12. Registers and Diffusers

12.1. Prohibited: Combination of supply and exhaust registers or diffusers.

12.2. Supply air registers shall have opposed blade dampers and horizontal and vertical adjustable louvers.

12.3. Adjustable pattern ceiling diffusers shall be used. Linear diffusers with clamshell pattern controllers shall be used for variable volume applications unless the university approves otherwise.

13. Air Cleaning


13.2. Provide air-handlers with a MERV 8 pre-filter and MERV 13 final filter. Filters shall be located upstream from the first coil.

13.3. Provide cartridge-style filters.

13.4. The A/E shall specify a MERV 8 pre-filter on the upstream side of all exhaust heat recovery coils.

13.5. 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 in constant volume units of 350 fpm. In variable volume units, the maximum design velocity at the filters shall be 500 fpm.

13.6. Air-handling units in the same mechanical room shall use no more than two sizes of filters.

13.7. A ‘Magnehelic’ pressure gauge with an adjustable indicator needle shall be installed across the filter bank to indicate a drop in static pressure, at which time the filters must be replaced.

2. Heat Exchangers

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

2.2. Shell and Tube Heat Exchangers Design Requirements

2.2.1. Specify instantaneous, counterflow, steam in shell and water in tubes with a maximum water velocity of 6 feet/second and a removable tube bundle.

2.2.2. Specify a permanently attached ASME certification nameplate to the shell exterior.

2.2.3. Each shell and tube heat exchanger system shall have redundant converters that are sized to handle 100 percent of the load. For very large systems, a 50/50 split is recommended.

2.2.4. The A/E shall consider using separate radiation and duct reheating systems.

2.3. Acceptable Shell and Tube Heat Exchanger Manufacturers: Bell & Gossett, Taco or university-approved equal.

2.4. Design Requirements for Plate and Frame Heat Exchangers

2.4.1. Specify a counter-flow exchanger that is designed to prevent fluid from intermixing when it leaks and flows outside of the unit.

2.4.2. Require 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.

2.4.3. Review the gasket specification with the Project Manager to confirm the appropriateness of the application.

2.4.4. Design the plate and frame heat exchanger with two exchangers; each sized for 67 percent of the design load.

2.4.5. Specify steel flanged pipe connections and shroud.
2.5. Acceptable Plate and Frame Heat Exchanger Manufacturers: Alfa-Laval, Bell and Gossett, Taco, or university-approved equal.

3. Installation and Valves

3.1. Use steam to heat hot water in buildings.

3.2. The steam shall be supplied to the converters through two control valves that are equipped with a three-valve bypass.

3.3. 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.

3.4. The outside temperature shall cause the operation and sequence of the valves to be reset.

3.5. 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.

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

4. Hot Water Piping Systems

4.1. Prohibited: Victaulic type mechanical fittings with rubber inserts

4.2. Specify standard weight black steel pipe, ASTM A53 or A120 continuous weld and Type L copper up to 2 inches.

4.3. 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.

4.4. 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.

5. Chilled and Condenser Water Piping Systems

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

5.1. Aboveground chilled and condenser water piping systems shall be standard weight black steel pipe, ASTM A53 or A120 continuous weld.
5.2. 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.

5.3. Risers and mains shall have valve drains.

5.4. All chilled water loops and condenser water loops shall be chemically treated. The A/E shall specify the necessary equipment for treatment. Refer to Section 23 25 00 - Water Treatment for Open and Closed Loops.

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

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

5.6.1. 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.


5.7. 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.

6. Steam Supply and Return Piping System


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

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

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

6.5. 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.
6.6. 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.

6.7. 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).

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

6.9. 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.

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

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

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

6.13. 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.

7. Specialties

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

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

7.3. 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.
7.4. Heating coils shall be provided with an approved vacuum breaker and air vent.

7.5. 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.

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

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

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

8.1. All preheat coils shall be integral face and bypass, and constructed of 150# WSP. Acceptable manufacturers are Flo-con, Wing or university-approved equal.

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

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

8.4. 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.

8.5. Hot water coils shall be able to be completely drained through individual headers. Specify EWT to the heating coil of 180 degrees F.

8.6. The A/E shall detail the piping connection to show valves, unions, control valves, flow-metering devices and gauges.

8.7. The A/E shall consider whether freeze protection is required using constant circulation pumps in cases where hot water coils are installed in air-handlers below 35 degrees F EAT.

9. Baseboard Units

9.1. For general-purpose use, fin tube radiation shall have 18-gauge sloping to steel covers, with 20-gauge solid backs.
9.2. 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.

9.3. Provide an adequately sized access panel on radiation units at valves and air vents for maintenance.

9.4. Radiation shall be detailed and installed so the radiation element can be removed without draining risers that serve the element.

9.5. 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.


9.7. Provide a clearance of 6 inches under the radiator, radiation enclosure and piping for sweeping with a broom.

10. Unit Heaters

10.1. Prohibited: Direct fuel-fired heaters in places intended for human habitation. Exception: Food, fiber or fur animal housing at research and outreach centers may be heated with direct fired-unit heaters.

10.2. A thermostat-controlled unit heater shall heat the vestibule.

10.3. Motors and belt drives shall be located out of the air-stream.

10.4. If possible, provide steam to vestibule unit heaters. If such units are subject to freezing, traps shall be remotely located in a heated area.

11. Humidifiers

11.1. Prohibited: Supplying steam-to-steam humidifiers from the steam plant due to chemical treatment of water for the steam plant.

11.2. Provide indirect clean steam humidity.

11.3. The A/E shall specify a slow closing, make-up water valve.

12. Process Heating (Constant Steam)
12.1. Process heating shall be shown distributed throughout the building in a system separate from the steam required for space heating.

12.2. 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.

12.3. The A/E shall specify a slow-closing make-up water valve on any steam-generating equipment.

13. Water Treatment

13.1. All re-circulating water systems shall be chemically treated.

13.2. The A/E shall specify the necessary equipment for treatment and the initial cleaning and treatment of the system.

13.3. Do not specify a supply of chemicals for the first year.

13.4. The university shall take over treatment of the system at the Substantial Completion Phase.

23 60 00 Central Cooling Equipment

1. Refrigerants

1.1. All comfort cooling refrigeration equipment shall be charged with a non-flammable, low toxicity, hydrochlorofluorocarbon (HCFC) or hydrofluorocarbon (HFC), having an ozone depletion factor (ODF) of 0.05 or less. Acceptable refrigerants for centrifugal chiller shall be approved per latest governing codes and regulations.

1.2. Refrigerant piping arrangement, equipment room and purge system ventilation shall consider the allowable exposure limit for the refrigerant specified. Provide a corresponding complete purge system.

1.3. 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:

1.3.1. A multi-port CFC monitoring system.

1.3.2. 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.

1.3.3. The monitoring system shall be connected to BSAC.

1.3.4. The A/E shall specify the sequence of operation as follows:

1.3.4.1. When the yellow alarm is activated, the mechanical room ventilation system automatically ramps up to high speed and BSAC is notified.

1.3.4.2. When the red alarm is activated, the system that controls the operation of the compressors is immediately shut down.

1.4. 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.

1.5. Refrigerant Piping and Vent Tests

1.5.1. 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.

1.5.2. 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.

1.5.3. 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 64 00 Packaged Water Chillers**

Chillers
1. General Requirements

1.1. The university advocates providing chilled water for air-conditioning needs from central chilled water plants. Chilled water plants shall be designed to provide year-round cooling.

1.2. The size of the central plants will grow over time because the number of chiller locations is being reduced. Further, consolidating capacity in pre-agreed central configurations is causing the plants to grow. The plants shall be planned to accommodate expected loads in a predetermined cluster of buildings served by a common piping distribution system.

1.3. Prior to proceeding, the A/E shall contact University Energy Management to obtain current status and availability of capacity, and to determine practicality of connecting to a central system.

1.4. 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. When the campus chilled water utilities are not available, use the following guidelines to select chillers:

1.4.1. For cooling loads less than 100 tons, a reciprocating or scroll compressor chiller with an air-cooled condensing unit is recommended. Recommended manufacturers are Carrier, Trane, York or university-approved equal.

1.4.2. For cooling loads more than 100 tons but less than 250 tons, a water-cooled screw compressor chiller or a centrifugal compressor chiller shall be used. Recommended manufacturers are Carrier, Trane, York or university-approved equal.

1.4.3. For cooling loads more than 250 tons, the use of a water-cooled centrifugal chiller or a high-pressure steam absorption chiller is recommended. The decision to use a high-pressure steam absorption chiller or electric chiller shall be based on a lifecycle cost analysis, and shall be approved by the university. Recommended manufacturers are Carrier, Trane, York or university-approved equal.

1.5. All chillers shall have specified chiller and safety controls, including high-pressure and low-pressure safety controls, crank case heaters and low ambient controls.
1.6. 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.

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

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

1.9. 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.

   1.9.1. 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.

   1.9.2. 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.

   1.9.3. 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:
3.1.1. BSAC starts and stops the chilled water pumps.

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

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

3.1.4. The chiller panel enables cooling tower fan control.

3.1.5. The chiller controls prove water flow interlocks have a:

   A. Evaporator chilled water flow switch
   B. Condenser water flow switch

3.1.6. 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 BSAC or any other building DDC system). In such a case, the function of BSAC or the DDC system 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. BSAC Interface

5.1. Specify a central chiller plant controller that is capable of interfacing with BSAC.

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 BSAC to issue commands to the chiller control system and monitor chiller information. Refer to Section 230900 - Controls and Instrumentation.

23 65 00 Cooling Towers

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 at least 50 percent of the system capacity 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 specified 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 belt driven fans to reduce maintenance, inventory costs and downtime.

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 easy 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 73 00 Indoor Central-Station Air-Handling Units
Air Handling

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. Run around coils shall be used in all instances except high latent loads, where desiccant wheels may be used. 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:

   A. Mixed air reset
   B. Discharge air reset
   C. Mixed air economizer
   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:

A. Off the shelf air handling units are acceptable
B. Double wall construction. The interior shall be galvanized
B. 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.
C. 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.
D. Coils supported on racks to allow the coils to be removed individually
E. 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.
F. Stainless steel drain pan below each coil.
G. All drives shall be synchronous belts, premium high efficiency TEFC motors. See table 10.8, ASHRAE 90.1-2004 for motor efficiency requirements.
H. No exposed insulation in the air stream.
I. Both internal and external construction to be UV proof. All internal and external joints shall be caulked with UV inert 30+ year caulking
J. Totally sealed pillow block bearings with minimum contact between the lubricant and the air stream. Extended life L10 bearing.
K. 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 exhausts 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 $L_{10}$ 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: Air-handling units with more than 5,000 cfm shall be provided with interior service and inspection lighting at each access door.

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

16.2. Variable frequency drives shall conform to the requirements of Division 16 - 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.

23 74 00 Packaged Outdoor HVAC Equipment
Rooftop Air Conditioners

1. When other viable options are not available, rooftop equipment may be considered.

2. The A/E shall locate the unit to minimize the adverse effects to the building aesthetics.

3. The A/E shall select the unit and location to minimize noise impact in occupied areas. The A/E shall submit to the University for review what noise criteria level will be used for the selection of equipment.

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

23 75 00 Compressed-Air System:
1. Prohibited: Non-metallic material (unless specifically designed for compressed air usage and approved by the U of M).

2. Mechanical grooved fittings such as Victaulic, Grinnell or as approved by the U of M are allowed in the compressed air systems.

3. Welded piping, and brazed copper or soldered copper are allowed in the compressed air system.

4. Copper; K, L, M, schedule 40 galvanized steel and schedule 10-40 stainless steel are acceptable piping materials.

5. Compressed air piping systems shall be tested with air at 125 psi gauge pressure for two hours or one and a half times the maximum working pressure, whichever is greater. Use soap test on all joints.

End of Division 23 – Heating Ventilation and Air Conditioning