TABLE OF CONTENTS

MECHANICAL

Table of Contents
Page Verification Sheet

15A  General Requirements
15B  Plumbing
   15B1  Potable and Nonpotable Water
         Drawing – Water Filter Header
         Drawing – Typical Building Water Header
   15B2  Waste and Drains
   15B3  Laboratory Wastes
   15B4  Compressed Air, Vacuum, Natural Gas & Nitrogen
   15B5  RO/DI
   15B6  Plumbing Pressure Testing
15C  Heating Ventilation and Air Conditioning
   15C1  Process and Environmental Chilled Water
   15C2  Central Cooling Water
         Drawing – Central Cooling Water Building Header & Coil Connection
   15C3  Steam and Condensate
         Drawing – Steam Trap Assembly
   15C4  Hydronic Heating
   15C5  Refrigeration
   15C6  Air Handlers and Ventilation Fans
   15C7  Filters
   15C8  Coils
   15C9  Ductwork and Duct Accessories
   15C10 HVAC and HVAC Piping Pressure Testing
15D  Piping, Valves & Accessories
15E  Hangers and Supports
15F  Pumps
15G  Motors and VFDs
15H  Metering and Gauges
15J  Nonstructural Component Seismic Design
15K  Identification
15L  Insulation
15M  Water Treatment and Flushing
15N  Noise and Vibration Control
15P  Cold/Environmental Rooms
15Q  Computer Server Rooms
<table>
<thead>
<tr>
<th>15R</th>
<th>Environmental Control Systems</th>
</tr>
</thead>
<tbody>
<tr>
<td>15T</td>
<td>Testing, Adjusting and Balancing</td>
</tr>
<tr>
<td>15U</td>
<td>Commissioning</td>
</tr>
<tr>
<td>Title</td>
<td>Pages</td>
</tr>
<tr>
<td>------------------------------------------------------</td>
<td>-------</td>
</tr>
<tr>
<td>Table of Contents</td>
<td>1-2</td>
</tr>
<tr>
<td>Page Verification Sheet</td>
<td>1</td>
</tr>
<tr>
<td>15A General Requirements</td>
<td>1-4</td>
</tr>
<tr>
<td>15B Plumbing</td>
<td></td>
</tr>
<tr>
<td>15B1 Potable and Nonpotable Water</td>
<td>1-4</td>
</tr>
<tr>
<td>15B3 Acid and Laboratory Wastes</td>
<td>1-1</td>
</tr>
<tr>
<td>15B5 RO/DI</td>
<td>1-2</td>
</tr>
<tr>
<td>15B6 Plumbing Pressure Testing</td>
<td>1-2</td>
</tr>
<tr>
<td>15C Heating, Ventilating and Air Conditioning</td>
<td></td>
</tr>
<tr>
<td>15C1 Process and Environmental Chilled Water</td>
<td>1-3</td>
</tr>
<tr>
<td>15C2 Central Cooling Water</td>
<td>1-3</td>
</tr>
<tr>
<td>15C3 Steam and Condensate</td>
<td>1-3</td>
</tr>
<tr>
<td>15C4 Hydronic Heating</td>
<td>1-2</td>
</tr>
<tr>
<td>15C5 Refrigeration</td>
<td>1-2</td>
</tr>
<tr>
<td>15C6 Air Handlers and Ventilation Fans</td>
<td>1-5</td>
</tr>
<tr>
<td>15C7 Filters</td>
<td>1-1</td>
</tr>
<tr>
<td>15C8 Coils</td>
<td>1-1</td>
</tr>
<tr>
<td>15C9 Ductwork and Duct Accessories</td>
<td>1-7</td>
</tr>
<tr>
<td>15C10 HVAC and HVAC Piping Pressure Testing</td>
<td>1-3</td>
</tr>
<tr>
<td>15D Piping, Valves, &amp; Accessories</td>
<td>1-9</td>
</tr>
<tr>
<td>15E Hangers and Supports</td>
<td>1-1</td>
</tr>
<tr>
<td>15F Pumps</td>
<td>1-2</td>
</tr>
<tr>
<td>15G Motors and VFDs</td>
<td>1-3</td>
</tr>
<tr>
<td>15H Metering and Gauges</td>
<td>1-4</td>
</tr>
<tr>
<td>15J Nonstructural Component Seismic Design</td>
<td>1-1</td>
</tr>
<tr>
<td>15K Identification</td>
<td>1-3</td>
</tr>
<tr>
<td>15L Insulation</td>
<td>1-2</td>
</tr>
<tr>
<td>15M Water Treatment and Flushing</td>
<td>1-3</td>
</tr>
<tr>
<td>15N Noise and Vibration Control</td>
<td>1-2</td>
</tr>
<tr>
<td>15P Cold/Environmental Rooms</td>
<td>1-2</td>
</tr>
<tr>
<td>15Q Computer Server Rooms</td>
<td>1-1</td>
</tr>
<tr>
<td>15R Environmental Controls System</td>
<td>1-30</td>
</tr>
<tr>
<td>15T Testing, Adjusting and Balancing</td>
<td>1-1</td>
</tr>
<tr>
<td>15U Commissioning</td>
<td>1-3</td>
</tr>
</tbody>
</table>
Basis of Design

This section applies to the general mechanical requirements for all Division 15 work.

Background

- This section is intended to assist the Mechanical Engineer and other design team members during the design process by answering questions about how the University builds, operates, and maintains mechanical systems in buildings. If there are questions about this information or proposals of alternate solutions, discuss them with the Project Manager and Campus Engineering.

Programming

- Design facilities to minimize annual operating costs and future repair and replacement costs.
- This document is written primarily for the Seattle campus. Facility design standards can vary for the Tacoma campus, Bothell campus and off-site facilities. Review each project with the Project Manager and Campus Engineering to determine modifications to the Facilities Services Design Guide as appropriate. State these modifications clearly in the Technical Program.
- The Central Power Plant (CPP) is located on the east side of the Seattle campus and provides utilities to the buildings adjacent to the utility tunnel system. This includes all buildings on the central, south, and southwest campuses and most of the buildings on the east campus and along Campus Parkway. Mechanical utilities from the CPP include steam, condensate return, central cooling water and compressed air. Due to the capacity and hydraulics limitations of these system, verify the addition of new loads onto these systems with Campus Engineering.
- Mechanical rooms need to be large enough to house the equipment and provide adequately sized access pathways for the repair, maintenance, and eventual replacement of the equipment. Equipment access pathways shall be large enough to allow for the removal of coils and other large pieces of equipment. Identify these areas on the design document drawing.
- Include an evaluation for building system renovation projects which describes the condition of the building systems, variances from present codes, and identifies spare system capacity or system deficiencies and opportunities for improving energy efficiency. The design team’s mechanical, electrical, civil, structural, and architectural disciplines should participate jointly in this evaluation.
- The mechanical infrastructure shall consist of the mechanical rooms, penthouses, shafts and plenum areas. Extra attention should be given to the plenum areas above the corridor ceiling, as they often become the critical space for mechanical and electrical distribution.

Design Criteria

- Important mechanical areas of coordination with Campus Engineering:
  1) Connection to existing utility distribution systems, including capacity and location,
  2) Temporary construction water and sewer point of service,
  3) Distribution concepts including piping and ductwork,
  4) Load calculations for campus utilities,
  5) Noise criteria levels for all spaces,
  6) Seismic bracing,
7) Special systems design (research and diagnostic equipment, and other equipment and designs not specifically covered by the Facilities Services Design Guide),
8) Control systems and indoor environmental monitoring,

- Provide Basis of Design Narrative including the design conditions for each space as follows:
  1) Indoor dry bulb temperature,
  2) Indoor relative humidity,
  3) Outdoor dry bulb temperature,
  4) Outdoor wet bulb temperature,
  5) Occupancy, hours, and degree of activity,
  6) Lighting and miscellaneous power,
  7) Ventilation – recirculation and outside air,
  8) Internal loads,
  9) Special loads,
  10) Insulating R-values for roof, wall, glass, etc.,
  11) Percentage of glass – fenestration,
  12) Type of glass, including coatings and solar coefficients,
  13) Building pressurization and infiltration,
  14) Building mass,
  15) Code requirements and impact on criteria,
  16) Air quality design criteria, i.e. ASHRAE 62-2007,
  17) Noise criteria,
  18) Fire and life safety,
  19) Energy efficiency and cost,
  20) Sustainability,
  21) Maintainability.

- Design systems and components with maximum reliability, maximum flexibility, and minimum operation and maintenance cost. Give full consideration for future system alterations with a minimum of system shutdowns. Accomplish preventive maintenance without a major building shutdown. Maintenance accessibility is very important. Meet current regulations for worker safety, including fall protection.

- Since laboratory buildings will need periodic renovation to keep up with changing technology, the building will be divided up into lab modules. These lab modules are a basis for HVAC and plumbing zoning.

- Provide isolation valves and devices for each utility serving each lab. Down feed all mechanical systems except the waste lines to minimize the number of floor penetrations.

- Coordinate mechanical equipment located on the roof with the Architect. Minimize the number of roof penetrations.

- Provide access with platform for shafts that contain systems that require periodic maintenance, repair, or replacement, e.g. valves, dampers etc. Accessibility will also be required if space is provided for future mechanical equipment. Provide access through access doors or removable walls and space within the shafts. Sheet rock walls are
considered removable. Accessible shafts are preferred over removable walls. Coordinate access method and platform requirements with Architect.

- Route utilities supplied by the Central Power Plant through a tunnel system. See details Utility Tunnel Section, Utility Trench Section, Utility Tunnel Manhole Plan, Mechanical Pipe Support Details 1 and Mechanical Pipe Support Details 2 in the Civil – Utility Tunnels and Trenches.
- Provide adequate access to all equipment requiring periodic maintenance. Show building access doors on both the mechanical and architectural drawings so they are properly located for maintenance and appearance. Provide equipment access doors with a minimum size of 18” x 18” unless discussed with Campus Engineering. Lifts or removable ladders shall not be relied upon for access unless approved by Campus Engineering. Permanent platforms may be required to access equipment.
- Mount equipment, e.g. fans and pumps, on a 4-inch thick concrete pad secured to structural slab. Size concrete pads larger than equipment. Pad shall extend at least ten times the diameter of the mounting bolts past the equipment. Coordinate with Structural Engineer for final design.
- See Architectural 9B-Finishes section for coating over entire mechanical room floor, including over housekeeping pads under air handling units, etc.
- Provide pipe sleeves for all piping penetrations through concrete and masonry. Provide galvanized schedule 40 pipe sleeves. Coordinate with architectural and structural for location and installation.
- Protect sharp edges in accessible areas requiring maintenance, for example, add screw protectors within accessible duct plenums.

Inter-discipline Coordination

- Coordinate the mechanical work with other disciplines to define the work and responsibilities of the Mechanical Contractor. Because of the space taken up by the mechanical equipment, the Mechanical Engineer will need to work very closely with the Architect, Structural, and Electrical Engineers to coordinate the required infrastructure with all elements of the building. In many cases, the mechanical and electrical system space requirements will necessitate changes to the floor plans, building sections, and exterior elevations, if not properly included at the onset.
- Coordinate between the Mechanical Engineer and Electrical Engineer for equipment motors, motor starters, disconnect switches, thermal overload switches, variable frequency drives, and mechanical controls for all mechanical equipment including AHUs, exhaust fans, and pumps.
- Classrooms Services establishes additional University standards that may affect the design of specific mechanical systems. Refer to Classroom Services requirements.
- UW Technology establishes additional University standards. Entrance rooms and communications rooms have specific continuous air conditioning loads that must be accommodated by the mechanical system. Refer to UW Technology Design Guide requirements.
- Environmental Health and Safety establishes University Life, Health, and Safety standards that may affect the design of specific mechanical systems. Refer to EH&S Laboratory Safety Design Guide.
- Coordinate with the electrical consultant to insure that the mechanical equipment installed has a short circuit current rating in accordance with the short circuit study.

Plans and Specifications
**General Requirements**

- Extensive drawings of existing building mechanical and utility systems are available from the records vault.

**Operational Constraints**

- Sustainability, operability and maintainability are key elements in the evaluation of the Technical Program and Schematic Design. General use buildings are operated to match occupancy and are normally shut down during nights (10pm to 6am), weekends and holidays. Libraries usually have extended schedules. Laboratory buildings normally run continuously to maintain a safe working environment 24 hours per day. Evaluate on a building-by-building basis; to allow a more efficient operation.

- In remodel or renovation projects, shutdowns of existing utilities and services may be necessary. These shutdowns may have to occur after normal working hours to prevent interruption of critical operations. Temporary utilities may be necessary to maintain service to critical loads in laboratories and hospital health care areas and to refrigeration equipment.

- Locate equipment, valves, and accessories above ceilings such that they can be readily accessed within arms reach by a person standing no higher than the second highest step on a stepladder with ladder height that fits below the ceiling. Coordinate ladder placement to avoid interference from casework, lab benches, sinks, adjacent walls, or lab equipment. Give consideration to ceiling tiles immovable due to sprinkler heads, light fixtures, or other ceiling mounted devices.

**Construction Requirements**

- Include a statement in the specifications that all components of the ventilation system (e.g. fan, duct, insulation, sound attenuators, terminal boxes, etc.) must be kept clean and dry as manufactured, delivered, stored and installed before operating the HVAC system. At the University of Washington Medical Center and specific animal care facilities confirm if isopropyl alcohol wipe-down is required at all air handling equipment prior to installation.

**Renovation and Demolition**

- The abandonment of existing equipment and material in place is not acceptable. Conserve space as much as possible. Abandoned systems become a serious liability since it can not easily be determined what is active and what is not. The correction of existing mechanical problems and removal of abandoned mechanical equipment, while maintaining the operation of the building, all need to be addressed in the contract documents. Disposal of materials can be a problem with limited on-site areas for temporary storage. Define reuse of equipment where appropriate.

**Design Evaluation**

The following information is required to evaluate the design:

- **Programming Phase:** Identify mechanical system requirements and any exceptions to the Facilities Services Design Guide. Submit Basis of Design Narrative.

- **Schematic Design Phase:** Refer to requirements specified in the individual Mechanical sections.

- **Design Development Phase:** Refer to requirements specified in the individual Mechanical sections.

- **Construction Document Phase:** Refer to requirements specified in the individual Mechanical sections.
Basis of Design

This section applies to the design and installation of potable and nonpotable water systems.

Design Criteria

- Most University of Washington buildings will include laboratories, vivariums or other areas that require a non potable laboratory water system. Each potable and non potable system will require a water header, separate semi-instantaneous hot water heaters, and a hot water circulation system.

- When incoming water pressure exceeds 80 psig, provide a pressure reducing station with two parallel PRVs (each sized at 2/3 of total flow, each valved to operate independently.)
  1) A minimum pressure of 25 psig should be provided at the highest point of the building.
  2) The assembly shall include appropriate valves, strainers, gauges, drains, etc. and include a bypass.

- See Metering section for metering and monitoring requirements.

- Separate water systems into potable and non-potable by installing reduced pressure backflow preventers (RP devices). Separate the incoming water header from all lines supplying water to non-domestic uses, including laboratory, circulating heating and cooling, and industrial process water, e.g., to boilers, air conditioners and cooling towers.

- Provide the laboratory non potable water system with parallel RP devices each sized 2/3 of the laboratory supply pipe capacity to prevent need for shutdown to test and repair. Protect the laboratory water system by installing faucets with built-in and unremovable vacuum breakers.

- Locate irrigation system backflow preventers inside the building mechanical room rather than outside if feasible.

- Provide potable water to hallways, kitchenettes and conference rooms in laboratory areas to offer safe drinking water. Do not provide potable water to laboratories except to emergency showers and eye washes. Equip all drinking fountains in laboratory buildings with cup filler spouts to meet the safe drinking water requirement.

- Divide water system into smaller systems with isolation valves separating them. This will allow a section of the building to be worked on without affecting the remainder of the building. Provide isolation valves for each floor, for each laboratory, each restroom and each plumbing fixture.

- Design the restroom plumbing systems of buildings with large classroom areas using the Hunter stadium curve. This alternate pipe sizing criteria was developed for sports stadiums where restroom use is confined to a short time period. A similar problem exists during the class break period. The maximum flow velocity should not exceed 4 feet per second.

- Design the potable and laboratory hot water systems to heat water to 125°F and 145°F respectively. The initial operating set points should be set at 105°F and 125°F respectively.

- Provide booster heaters for dishwashers and other equipment requiring higher hot water temperatures than previously listed. Do not raise the temperature of the building system.

- Do not install water piping below slabs on grade except for trap priming lines. Protect copper trap primer lines from contact with concrete.

- Provide electronic sensor faucets for all lavatories. Do not use electronic sensor flushometers for toilets and urinals.
For emergency safety shower and eyewash fountain requirements, refer to EH&S Laboratory Safety Guide.

- Provide 0.5 gallon per flush urinals.
- Avoid dual flush toilets.
- See UW Standard Drawings:
  1) Water Filter Header
  2) Typical Building Water Header

Design Evaluation

The following information is required to evaluate the design:

- **Schematic Design Phase**: Provide locations of water headers, pipe chases, plumbing equipment, and plumbing fixtures. Provide design calculations and a plumbing legend.

- **Design Development Phase**: Provide a preliminary system riser diagram showing all fixtures, valves, recirculation lines, pipe sizing, etc. Provide piping plans, design calculations, and a detail of each water header. Provide preliminary water service point of connection location and elevation.

- **Construction Document Phase**: Provide detailed potable and non-potable plumbing system riser diagrams, design calculations, water heater piping details, a water header diagram, and pipe sizes. Provide final water service point of connection location and elevation.

Construction Submittals

- Submittal information shall include catalog cuts of all fixtures, valves, fittings, pipe, hangers, solder, etc.

Products, Material and Equipment

- For potable and laboratory piping materials see Piping, Valves & Accessories section.
- Fittings on copper piping shall be wrought copper or cast brass, solder pattern.
- Solder shall be 95-5 tin antimony or approved substitution. No lead-type solders shall be allowed on the job site.
- Use dielectric nipples between copper and other dissimilar materials.

Installation, Fabrication and Construction

- Slope all piping to allow the system to be drained. Provide a drain valve at the low point of the system along with a drain to take the water away.

END OF DESIGN GUIDE SECTION
NOTES:

1. THE 100 MICRON FILTERS ARE USED TO EXTEND THE FILTER LIFE.

2. DUAL UNITS ARE PROVIDED TO ALLOW ONE TO BE CHANGED WITHOUT SHUTTING DOWN THE SYSTEM.

3. FOR USE WITH DELICATE EQUIPMENT ONLY, NOT FOR THE BUILDING WATER SUPPLY.
**Typical Building Water Header**

**LEGEND**

* RPBP REQUIRED ONLY ON BUILDING WITH HAZARDOUS PROCESSES.
DCVA REQUIRED FOR ANY BUILDING OVER 30’ HIGH
RPBP REDUCED PRESSURE BACKFLOW PREVENTER
DCVA DOUBLE CHECK VALVE ASSEMBLY.
** REQUIRED ONLY FOR SYSTEMS WITH GLYCOL CONCENTRATION.

© University of Washington – Campus Engineering 2015
Basis of Design

This section applies to waste and storm drain piping located inside and within five feet of the building envelope.

**Design Criteria**

- Provide minimum 6-inches diameter side sewers.
- Provide gravity waste drains. Do not incorporate sump pumps and sewage pumps into the design without specific approval from Campus Engineering.
- Provide lead-lag sump pumps. Discuss if alarms are required with Campus Engineering.
- Indicate slope of piping on design drawings.
- Provide accessible clean-outs. Provide access doors, wall caps, removable panels, or other approved methods for access for clean-outs recessed in wall cavities.
- Independently collect waste and storm water within the building and convey separately to respective sanitary sewer and storm drains outside the building. If no storm drain exists within 200 feet of the building, connect storm water (with required storm retention) to sanitary sewers outside of the building. Design the systems to accommodate future system separation and consult with Campus Engineering.
- Connect all footing drains to the storm drainage system. If connection to the storm drainage system is not practical, the footing drain may be connected to the tunnel drainage system. Do not connect footing drains to an interior sump pump.
- Connect all area drains, yard drains, roof drains, window well drains, etc. to the storm drainage system.
- Provide invert elevations and routing of sanitary sewer and storm pipes leaving the buildings. This allows future connection of waste lines from any point in the basement area.
- Connect drains from transformer vaults with oil-filled transformers and shop areas where oil is present to a City of Seattle-approved oil interceptor, discharging to a sanitary sewer.
- Limit the number of garbage disposals. When garbage disposals are necessary, connect garbage disposal waste piping to a major waste pipe with as few bends as possible. Provide accessible clean-outs in this waste pipe.
- Provide 6-inch diameter drains with 36 inch high standpipe for the fire sprinkler system drain.
- Provide mechanical rooms, pipe trenches, and tunnels with floor drains.
- Provide electronic timer-type trap primers for floor and funnel drains.
- Do not connect flammable or hazardous chemical/liquid storage room floor drains to the sewer systems. Design an alternate drainage system in coordination with the Fire Code or contain in place if allowed.
- Refer to Facilities Services Design Guide – Civil – Earthwork for pipe bedding located under floor slabs.
- Due to the unstable nature of the soils East of Montlake Boulevard NE, it is recommended that all piping below slab on grade be hung from the slab rather than supported by the soil. In addition, coordinate details for pipe installation with the structural engineer on each project because the slab on grade may be a structural slab.
- Show the location of cleanouts on the mechanical and architectural drawings.
Design Evaluation

The following information is required to evaluate the design:

- **Programming Phase:** Provide utility connection locations.
- **Schematic Design Phase:** Provide description of fixture and pipe chases. Preliminary calculations and plumbing legend.
- **Design Development Phase:** Provide piping plans, design calculations, preliminary inverts and point of connections.
- **Construction Document Phase:** Provide riser diagrams, pipe sizes, and invert elevations of all sanitary drain lines leaving the building.

Installation, Fabrication and Construction

- Do not install crosses into waste piping systems.
- Connect to top of pipe and use a $\frac{1}{8}$ bend located for branch connections to food service area waste piping.
- Support waste and drainage piping crossing excavated areas on pre-cast concrete beams. Support concrete beams by the building structure and undisturbed earth.
- Specify full size clean-outs for up to 4 inches. Use 4-inch clean-outs for all piping larger than 4 inches.
- Floor drains: Specify block-outs twice the size of the drain body and infill with non-shrink grout to prevent perimeter cracking at concrete.

END OF DESIGN GUIDE SECTION
Basis of Design

This information includes supplementary requirements for waste and drain lines for corrosive and chemical wastes.

Design Criteria

- Provide corrosion-resistant material for waste piping and vents servicing laboratories.
- In existing buildings, extend new corrosion-resistant piping to the nearest existing corrosion-resistant waste pipe of adequate size. If no such waste pipe exists, extend waste piping to the nearest existing cast iron waste pipe at least two pipe sizes larger and consult with Campus Engineering.
- Do not connect laboratory waste piping to steel or copper piping.
- In new buildings, do not connect sanitary and lab waste piping systems to each other inside the building. Collect laboratory waste lines independently and carry separately out of the building to a sanitary sewer manhole.
- Radioactive wastes and hazardous chemical wastes are disposed of by a collection service provided by the Owner.

Design Evaluation

The following information is required to evaluate the design:

- **Programming Phase**: Provide utility connection locations.
- **Schematic Design Phase**: Provide description of fixture and pipe chases. Preliminary calculations and plumbing legend.
- **Design Development Phase**: Provide piping plans, design calculations, preliminary inverts and point of connections.
- **Construction Document Phase**: Provide riser diagrams, pipe sizes, invert elevations of all acid resistant waste drain lines leaving the building, and final calculations.
Basis of Design

This section applies to the design and installation of compressed air, vacuum, natural gas, and nitrogen systems.

**Design Criteria**

- Compressed air at 100 psig is available as a central piped utility in the tunnel distribution system. Determine the availability of compressed air central piped utility. Compressed air must be reduced to 30 psig before distribution to the laboratory compressed air system within buildings. Occasionally there is a requirement for 60 psig air, which should be served separately.

- Consider the use of an air dryer at the building compressed air service entrance because the dew point of the utility compressed air service is in the range of 60ºF to 70ºF.

- Size laboratory compressed air piping based on 0.5 scfm per outlet (unless actual flow is known) plus any known flow required for specific pieces of lab equipment. Apply reasonable diversity factors to the compressed air outlets based on the size of the system.

- In addition to laboratory use, compressed air will likely be used to serve the environmental control system pneumatic actuators and dry fire protection sprinkler systems. Provide a separate valved branch to serve each of the connections to the environmental control air system and the fire protection system at the building service entrance.

- Provide central building laboratory vacuum systems with an ASME receiver where practical. Duplex liquid ring pumps are the preferred type. Consider water conservation options for vacuum pump unit selections. Air cooled vacuum pumps are acceptable if cooling water is not available, check with Campus Engineering.

- Size laboratory vacuum piping based on 0.5 scfm per inlet (unless actual flow is known) plus any known flow required for specific pieces of lab equipment. Apply reasonable diversity factors to system inlets based on the size of the system.

- Vacuum pumps will be controlled by a pressure switch in the receiver set to operate between 22 and 25 inches of mercury vacuum.

- Branch vacuum shall be connected to the top of the main vacuum piping and pitched in the direction of air flow.

- Natural gas is available as a direct buried utility throughout the campus. Determine the natural gas anticipated usage for the project. Coordinate with the civil consultant on the project team regarding the availability of natural gas utility piping near new project sites.

- Natural gas piping in new buildings should be flared off near the most remote outlets to eliminate “odor fade” upon occupancy.

- Nitrogen storage for central systems should be from vendor provided cryogenic storage tanks located outside of the building.

- Provide isolation valves at each floor and for each laboratory and equipment connection.

- Laboratory nitrogen gas piping shall be sized based on 0.5 scfm per outlet (unless actual flow is known) plus any known flow required for specific pieces of lab equipment. Apply reasonable diversity factors to the nitrogen gas outlets based on the size of the system.

**Design Evaluation**

The following information is required to evaluate the design:
Programming Phase: Provide a narrative description of compressed air, vacuum, natural gas and nitrogen systems to include maximum anticipated usage volume. Define known future increases in anticipated usage volume if any. Describe each system's major components. Describe the flexibility of each system to accommodate future addition or renovation. Provide an estimate of energy and water usage for vacuum pumps and air compressors. Describe system reliability based on equipment selection to minimize downtime.

Schematic Design Phase: Provide a block layout of the central equipment, pressure reducing stations, and pipe headers. Locate pipe risers, horizontal pie runs, and the concept of outlet connections.

Design Development Phase: Provide a preliminary layout of the central equipment, pressure reducing stations, and pipe headers. Identify the locations of outlets and equipment utilizing each service. Provide a preliminary layout of the horizontal pipe runs and risers. Provide preliminary one line system diagrams including the central equipment and the distribution piping. Provide a preliminary equipment schedule. Provide an outline of specifications and design calculations.

Construction Document Phase: Provide a final layout of the central equipment, pressure reducing stations, service entrance, and pipe headers. Provide a final layout of the horizontal pipe runs, risers, and all outlet locations. Provide a final one line system diagram including the central equipment and the distribution piping. Provide a final equipment schedule. Provide final specifications and design calculations.

Construction Submittals

- Provide layouts and diagrams of vendor provided equipment.

Installation, Fabrication and Construction

- Natural gas or natural gas vent piping must never be installed in the campus utility tunnel system.
- Natural gas service entrance piping must be protected from accidental damage by vehicles, foundation settlement, or vibration. Where practical, the natural gas service entrance pipe should be above grade and provided with a self tightening swing joint prior to entering the building.
- Natural gas meters must be installed outside the building to avoid leakage concerns.

END OF DESIGN GUIDE SECTION
Basis of Design

This section applies to the design and installation of reverse osmosis/deionized high purity water systems.

Programming

- Determine the anticipated current and future usage volume in gallons per day and the minimum water purity requirements required by the client during the programming phase of the project. Based on the quantity and quality of water required for the project determine the most appropriate system.
- Provide a flexible design to accommodate future renovation and modification.
- Provide systems that minimize energy and water usage.
- Provide equipment arrangements that minimize downtime in the event of a failure.

Design Criteria

- The minimum water purity for most central equipment RO/DI systems on the Seattle campus is College of American Pathologists (CAP) Type II. These requirements shall be met at each outlet.
- If higher purity water than CAP Type II is required in some individual labs in the building provide Point-of-Use polishing equipment at those locations.
- Typical central equipment shall consist of flushable prefilters, multi-media filters, reverse osmosis unit(s), deionizers, carbon filters, ultraviolet lights, storage tank, and distribution loop pumps.
- A water heater may be required upstream of the RO unit because they are most efficient when operated at an inlet water temperatures of 77°F.
- High purity water must be circulated continuously in a closed series loop layout from the central equipment to lab outlets throughout the building. The distribution loop piping must be sized to circulate the water at a velocity in the range of 4 to 6 feet per second under no demand conditions.
- The RO/DI system storage tank shall be sized to provide storage for 24 hours of estimated usage. Coordinate the weight of the storage tank with the structural engineer on the consultant team.
- Provide access to sanitize the storage tank.

Design Evaluation

The following information is required to evaluate the design:

- Programming Phase: Provide a narrative description of the RO/DI system to include maximum anticipated usage volume in gallons per day and minimum water purity criteria. Define known future increases in anticipated usage volume if any. Describe the system major components. Describe the flexibility of the system to accommodate future addition or renovation. Provide an estimate of energy and City water usage. Describe system reliability based on equipment selection to minimize downtime.
• **Schematic Design Phase:** Provide a block layout of the central equipment. Locate pipe risers, horizontal pipe runs, and the concept of outlet and equipment like glass washer connections.

• **Design Development Phase:** Provide a preliminary layout of the central equipment. Identify the locations of outlets and equipment such as glass washers. Provide a preliminary layout of the series distribution loop including risers. Provide a preliminary one line system diagram including the central equipment and the distribution loop. Provide a preliminary equipment schedule. Provide an outline of specifications and design calculations.

• **Construction Document Phase:** Provide a final layout of the central equipment. Provide a final layout of the series distribution loop including riser locations. Provide a final one line system diagram including the central equipment and the distribution loop that includes a control sequence of operation. Provide a final equipment schedule. Provide final specifications and design calculations.

**Construction Submittals**

• Submittal information shall include catalog cuts of all equipment, valves, fittings, pipe, pipe supporting methods, and the DDC control interface.

**Products, Material and Equipment**

• For RO/DI piping materials, see Piping, Valves and Accessories section.

• For RO/DI equipment, provide materials suitable for use with high purity water systems.

**Installation, Fabrication and Construction**

• Provide a means to periodically sanitize the entire system.

• Slope all horizontal piping to be free draining with a minimum slope of 1/8 inch per foot.

• The distribution loop piping shall drop to each outlet or piece of equipment to minimize dead end pipe sections to less than six branch line pipe diameters. Each pipe termination shall be outfitted with a diaphragm valve.

END OF DESIGN GUIDE SECTION
Basis of Design
This section applies to pressure testing of plumbing piping systems.

Design Evaluation
The following information is required to evaluate the design:

- **Design Development Phase:** Provide an outline specification of plumbing pipe pressure testing.
- **Construction Document Phase:** Provide a final specification of plumbing pipe pressure testing.

Products, Material and Equipment
- Provide industry standard test apparatus.

Installation, Fabrication and Construction

General
- Pressure test all piping.
- Demonstrate to an Owner witness that the piping passes the following pressure tests before it is insulated or covered by walls or ceilings. Test piping after all fittings and valves for that portion of the piping have been installed.
- All pressure testing shall be witnessed and documented with results approved and signed off by a University representative.
- Repair leaks discovered during pressure testing. Retest failed sections of piping to demonstrate satisfactory results.
- Maintain a set of drawings for recording and sign-off of each tested section.
- After each day of testing, submit to the Owner a copy of the paperwork recording the raw test data, designating the piping system and Pipe Code, and comparing the allowable and actual results.

Pipe Testing Methods
- Hydrostatic pressure testing: Use clean, fresh city water for test. On compressed gas piping, remove water from piping systems after testing and dry by blowing dry, oil-free air or nitrogen through lines.
- Pneumatic pressure testing: Perform testing with dry, oil-free air or nitrogen on piping systems.
- The following table lists typical piping systems and the corresponding recommended test method and test pressure.
<table>
<thead>
<tr>
<th>Piping System</th>
<th>Pipe Code</th>
<th>Test Method</th>
<th>Test Pressure, lb/in² gage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acid Resistant Vent</td>
<td>P-3</td>
<td>Hydrostatic</td>
<td>(1)</td>
</tr>
<tr>
<td>Acid Resistant Waste</td>
<td>P-3</td>
<td>Hydrostatic</td>
<td>(1)</td>
</tr>
<tr>
<td>Carbon Dioxide</td>
<td>P-1</td>
<td>Pneumatic</td>
<td>1.5 x max. (2)</td>
</tr>
<tr>
<td>Coil Condensate</td>
<td>P-1</td>
<td>Hydrostatic</td>
<td>60</td>
</tr>
<tr>
<td>Compressed Air (Laboratory)</td>
<td>P-1</td>
<td>Pneumatic</td>
<td>150</td>
</tr>
<tr>
<td>Compressed Air (Pneumatic)</td>
<td>P-1</td>
<td>Pneumatic</td>
<td>150</td>
</tr>
<tr>
<td>Fire Protection</td>
<td>P-10</td>
<td></td>
<td>(3)</td>
</tr>
<tr>
<td>Helium Recovery</td>
<td>P-1</td>
<td>Pneumatic</td>
<td>1.5 x max. (2)</td>
</tr>
<tr>
<td>Irrigation</td>
<td>P-1</td>
<td>Hydrostatic</td>
<td>150</td>
</tr>
<tr>
<td>Laboratory Cold Water</td>
<td>P-1</td>
<td>Hydrostatic</td>
<td>150</td>
</tr>
<tr>
<td>Laboratory Hot Water</td>
<td>P-1</td>
<td>Hydrostatic</td>
<td>150</td>
</tr>
<tr>
<td>Laboratory Hot Water Circulation</td>
<td>P-1</td>
<td>Hydrostatic</td>
<td>150</td>
</tr>
<tr>
<td>Laboratory Vacuum</td>
<td>P-1</td>
<td>Pneumatic</td>
<td>100</td>
</tr>
<tr>
<td>Lake Water</td>
<td>P-9</td>
<td>Hydrostatic</td>
<td>1.5 x max. (2)</td>
</tr>
<tr>
<td>Medical Gas</td>
<td>P-8</td>
<td>Pneumatic</td>
<td>(4)</td>
</tr>
<tr>
<td>Medical Vacuum</td>
<td>P-8</td>
<td>Pneumatic</td>
<td>(4)</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>P-5</td>
<td>Pneumatic</td>
<td>8</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>P-1</td>
<td>Pneumatic</td>
<td>1.5 x max. (2)</td>
</tr>
<tr>
<td>Oxygen</td>
<td>P-8</td>
<td>Pneumatic</td>
<td>(4)</td>
</tr>
<tr>
<td>Potable Cold Water</td>
<td>P-1</td>
<td>Hydrostatic</td>
<td>150</td>
</tr>
<tr>
<td>Potable Hot Water</td>
<td>P-1</td>
<td>Hydrostatic</td>
<td>150</td>
</tr>
<tr>
<td>Potable Hot Water Circulation</td>
<td>P-1</td>
<td>Hydrostatic</td>
<td>150</td>
</tr>
<tr>
<td>Propane</td>
<td>P-5</td>
<td>Pneumatic</td>
<td>8</td>
</tr>
<tr>
<td>Reverse Osmosis/De-ionized Water (High Purity)</td>
<td>P-6</td>
<td>Hydrostatic</td>
<td>150</td>
</tr>
<tr>
<td>Roof Drain</td>
<td>P-2</td>
<td>Hydrostatic</td>
<td>(1)</td>
</tr>
<tr>
<td>Sanitary Vent</td>
<td>P-2</td>
<td>Hydrostatic</td>
<td>(1)</td>
</tr>
<tr>
<td>Sanitary Sewer</td>
<td>P-2</td>
<td>Hydrostatic</td>
<td>(1)</td>
</tr>
<tr>
<td>Sea Water</td>
<td>P-9</td>
<td>Hydrostatic</td>
<td>1.5 x max. (2)</td>
</tr>
<tr>
<td>Storm Drain</td>
<td>P-2</td>
<td>Hydrostatic</td>
<td>(1)</td>
</tr>
<tr>
<td>Tempered Water (Safety Shower/Eyewash)</td>
<td>P-1</td>
<td>Hydrostatic</td>
<td>150</td>
</tr>
<tr>
<td>Trap Primer</td>
<td>P-1</td>
<td>Hydrostatic</td>
<td>150</td>
</tr>
<tr>
<td>Well Water</td>
<td>P-9</td>
<td>Hydrostatic</td>
<td>1.5 x max. (2)</td>
</tr>
</tbody>
</table>

Notes:
(1) In accordance with UPC – Min. 10 ft. head.
(2) 1.5 x Maximum Operating Pressure.
(3) Refer to NFPA and Environmental, Health & Safety - Fire Protection System section for information.
(4) Refer to NFPA for additional information.

END OF DESIGN GUIDE SECTION
Basis of Design

This section applies to the design and installation of environmental and process chilled water systems.

Programming

- Do not use City water to cool equipment. Once-through domestic water-cooled process chillers are prohibited except for emergency back-up. Use air-cooled condensers or cooling towers in lieu of City water-cooled condensers.
- Some lab equipment may require a decoupled primary/secondary loop to accommodate high pressure drops and internal condensation.
- Give special consideration to the location of cooling towers with respect to contamination of the building fresh air intake, intakes of nearby buildings and noise to the occupants and local residential areas.
- If a central building is to be connected to the Central Cooling Water (CCW) system, provide infrastructure—piping risers, stub outs, etc—to support one ton of process cooling for each lab module (approximately 250 ft²). Add additional capacity for specific equipment that would exceed the one ton per lab module density.
- Size the chiller(s) with sufficient capacity to accommodate estimated future loads. Incorporate capacity control strategies to limit short-cycling and provide efficient operation during present and future loading.
- Provide redundant capacity for the system where a shutdown is not tolerable. For example, if the initial load were 40 tons, the installation of three 20 ton machines would be reasonable.
- If scroll compressors are considered, then discuss providing chilled water storage with Campus Engineering.
- As a general practice, mechanical cooling will not be provided in general use buildings, except for libraries and large auditoria. Other exceptions will be considered. Discuss with Campus Engineering and the Project Manager. General use buildings, including libraries that are provided with mechanical cooling will be cooled to 78° F unless further restricted by the City or State Energy Codes.
- Buildings may need ambient and/or process cooling. Provide ambient cooling to maintain the ventilation air temperature. Provide process cooling to meet equipment loads imposed by electron microscopes, computers, lasers, and other equipment with a process chilled water system located in the building.
- Use independent cooling systems for applications requiring year-round control of temperature or humidity such as animal quarters, computer installations, patient care, rare books, art galleries, or research areas.

Design Criteria

- Establish project design criteria in writing at a meeting attended by the Department (client), Mechanical Design Engineer, Refrigeration Shop Supervisor, Campus Engineering and Environmental Health & Safety. Criteria for discussion shall include the following items:
  1) Chiller type,
  2) Chiller refrigerant; see Refrigeration section,
  3) Cooling tower type,
4) Cooling tower air intake and discharge locations,
5) Cooling tower chemical treatment system,
6) Equipment location,
7) Reliability of the system, i.e. quantity of equipment for maintenance and repair work,
8) Humidity requirements,
9) Future system expansion provisions,
10) Special equipment cooling requirements, e.g. lasers,
11) Chiller room alarm monitoring and ventilation,
12) Carbon footprint.

- Provide equipment with weatherproof enclosures and screening if roof mounting is required.
- Size the chilled water distribution piping for the ultimate load. Size piping using a minimum velocity of 2 feet/second and a maximum velocity of 7 feet/second.
- Use a design supply water temperature of 42º F. The return water temperature should take into account the initial load but should be a minimum of 12º F higher than the supply.
- Use a system differential pressure of 20 psi. Locate the differential pressure controller two thirds of the distance to the most distant point of the system. For pipe sizing, calculate the piping loss using the ultimate flow values.
- Depending on the level of reliability required for the system, the following equipment may need to be on the emergency power for non-life safety systems. Coordinate with UW Project Manager.
  1) Chilled water circulating pumps,
  2) Chillers,
  3) Tower fan and condenser water circulating pumps,
  4) Controls.

All additions to the emergency power for non-life safety systems must be discussed with Campus Engineering. Emergency power for non-life safety systems is limited.

- Locate chillers in the basement mechanical room for the best vibration isolation situation.
- Provide lead lag pumps for both the chilled water and condenser water systems.
- Use glycol to prevent freezing of condenser or chilled water coils exposed to freezing outside air.
- Provide an expansion tank fitted with automatic fill and drain for the chilled water system.
- Provide controls that prevent the chiller from operating unless chilled water pump, condenser water pump, condenser fan, etc. are operating.
- Flow/No-Flow switches to verify pump operation shall have no moving parts and use heat dissipation of the chilled water or condenser water to sense flow.
- Provide a refrigerant sensing/measuring device and adequate ventilation for chiller rooms. Vent the refrigerant safety valve outside the building. Discuss details with Campus Engineering.
• Provide access platforms as required for cooling tower maintenance.
• The central equipment for ambient cooling is located in the power plant and includes both steam absorption and electrical centrifugal chillers to meet the load.
• Provide a refrigerant leak detection system that is compatible with the building Fire Alarm System. Refrigerant leak alarm devices (lights and horns) shall be driven by the Fire Alarm System. The Fire Alarm System shall monitor the following functions: a refrigerant leak, a refrigerant leak detection panel fault condition, failure of the supply and/or exhaust fan for the refrigeration machinery room. Discuss details with Campus Engineering.
• Each chilled water system shall have a pot feeder, coupon rack and make-up water meter. Cooling towers shall have make-up water and blowdown meters. See Metering and Gages section for meter information.
• Chemical treatment systems for cooling towers are preferred over non-chemical water treatment systems. Please discuss with Campus Engineering if a non-chemical treatment system is being considered.
• Cooling tower chemical storage shall include secondary containment and a safety eyewash/shower.

Design Evaluation

The following information is required to evaluate the design:

• Programming Phase: Provide programming requirements here.
• Schematic Design Phase: Provide project design criteria, location of cooling tower exhaust relative to the building outside air intake, location of header, location of pipe chase, preliminary one-line system diagram and energy balance; identify all special occupancy zones and systems.
• Design Development Phase: Provide outline specifications, process chilled water system diagram, refrigeration piping schematics (if not standard system), and piping plans.
• Construction Document Phase: Provide final one-line system diagram, pipe sizes, coil detail, and design calculations.

Products, Material and Equipment

• See Piping, Valves and Accessories section for pipe and fitting material.
• Fluorocarbon refrigerant R-22 is not acceptable. Reduce and aim to eliminate all CFCs from existing facilities. Provide EPA approved HFC refrigerant for new equipment (if not available, discuss with Campus Engineering). CFC and HCFC are not acceptable.

Installation, Fabrication and Construction

• Demonstrate coordination of chiller controls with the DDC system.
• Locate the chilled water loop for each floor in the corridor, easily accessible to all spaces. Isolation valves for each space should be located in the most accessible area (either in the corridor ceiling space or inside the room.)
• Subject completed systems to an operating test as stipulated in the Mechanical Refrigeration Ordinance, Field Test Section, 14.1-3 and instructions, 15.1-7. The University's Representative shall witness this test.

• Provide isolation valves at all air vents.

• Locate expansion tanks at the highest point possible, and fit with gauge glass, drain, vent, and shut-off valve.

• The basic system is shown on detail Building Process Chilled Water System at the end of this section.

END OF DESIGN GUIDE SECTION
Basis of Design

This section applies to the utilization and interface requirements of the University’s Central Cooling Water (CCW) system.

Background

- CCW is the terminology used for the campus distribution system, which consists of five 2,000 ton centrifugal chillers, one 1,000 ton centrifugal chiller, one 1,000 ton absorption chiller and the associated cooling towers and pumps. The chillers are located at the Central Power Plant (CPP) and generate and distribute chilled water for summer cooling from early May through early October. The distribution piping is located in the utility tunnels and currently serves the central and south portions of campus. See civil section Utility Trenches and Tunnel for utility tunnel piping details.

Programming

- Discuss the intent of using CCW with Campus Engineering before design begins. Due to limitations in CCW capacity and distribution, the CCW system may not have adequate capacity to serve new loads, particularly in South Campus.
- Provide other cooling systems for projects that are located outside the CCW System. See section Process and Environmental Chilled Water.
- Provide a supply air temperature of 60°F for buildings cooled by the CCW System.

Design Criteria

- The CCW System is operated as a primary pumping system with the pressure differential manually controlled at the CPP. Additional controls located at the building control the building differential pressure.
- At each building CCW cooling coil or heat exchanger provide a two way, pressure independent control, DeltaP Valve as manufactured by Flow Control Industries, Inc.
- The CCW System temperature and pressure varies during the operating season. Use the following for design conditions:
  1) Supply Temperature 42°F (at CPP)
  2) Return Temperature 56°F (at CPP)
- A typical building header and coil connection is shown in the Central Cooling Water Building Header and Coil Connection detail at the end of this section. Provide the appurtenances such as bypass relief valves, pressure gauges, thermometers and isolation valves shown on this detail.
- Pipe the bypass relief valves to relieve pressure from the building side of the isolation valve to the CPP side of the isolation valve. The valves shall relieve water when the differential across the relief valves exceeds 15 psig.
- See Metering and Gauges section for CCW meters.
- During the winter months a nominal flow of water is maintained through the CCW System. Provide each building with a winter/summer control switch as noted in detail Central Cooling Water Building Header and Coil Connection.
- As a general practice, mechanical cooling will not be provided in general use buildings, except for libraries and large auditoria. Other exceptions will be considered. Discuss with Campus Engineering and the Project Manager. General use buildings, including libraries that
are provided with mechanical cooling will be cooled to 78° F unless further restricted by the City or State Energy Codes.

Design Evaluation

The following information is required to evaluate the design:

- **Programming**: Description of proposed system.
- **Schematic Design Phase**: Provide location of header and preliminary one-line system diagrams.
- **Design Development Phase**: Provide a CCW header diagram and preliminary calculations.
- **Construction Document Phase**: Provide pipe sizes, final CCW header diagram, final one-line system diagram, and design calculations, tunnel pipe supports design and calculations.

Products, Material and Equipment

**Piping**

- See Piping, Valves and Accessories section.
- All piping and fittings shall be rated at 200 psig working pressure when located below elevation 150 feet (City of Seattle Datum).
- Insulate piping in accordance with Insulation section.

**Bypass Relief Valve**

- Provide initial setpoint of 15 psig.
- Shall be rated to function with a back pressure (pressure on the tunnel side) of up to 150 psig.
- Metal nameplate with manufacturer, model and spring range shall be fastened to valve.
- Cash Acme, Kunkel or approved substitution.

Installation, Fabrication and Construction

- Comply with the University’s shutdown procedures for all connections to the CCW System.
- Locate the CCW header along a wall adjacent to the tunnel entrance at a convenient height for maintenance and repair access.
- If two-way control valves are used, provide a 1-inch bypass line with globe valve for throttling at the most remote coil to allow continuous flow through the building piping.
- Perform the system pressure test and flushing in the presence of Campus Engineering, who will then provide written approval to allow the system to become operational after all required repairs have been made. Flush with water at a velocity of 5 to 6 feet per second in the pipes. Since CCW cannot be used for flushing, provide temporary pumps. Piping shall be filled with clean water after flush and prior to opening valves. University personnel will open the valves to the main CCW system after approval by Campus Engineering.
- Provide testing and balancing in accordance with Testing, Adjusting and Balancing section. The University will set the differential pressure of the system to perform the required tests.
- Perform flow tests during both the winter and summer modes. Temperature tests can only be made on a design day. The Commissioning Agent shall be responsible to return to the site on a design day to complete these tests.
END OF DESIGN GUIDE SECTION
Basis of Design

This section applies to the design and installation of steam and condensate systems.

Design Criteria

- Heat all buildings adjacent to the utility tunnel by steam from the power plant. Steam is available at 185 psig and/or 10 psig. Check with Campus Engineering on the availability of steam service. Use 10 psig steam when ever possible because it benefits the operation of the power plant turbine generator. The 185 psig steam is reserved for use in buildings distant from the power plant (i.e., Campus Parkway and South Campus) and laboratory buildings that need the higher pressure steam for laboratory or process use. Provide local building two-stage pressure reducing stations to reduce the 185 psig steam down to 15 psig for use on all building heating systems. Return the steam condensate to the Power Plant whenever possible. Steam radiant heating is not acceptable except for special applications approved by Campus Engineering.

- Convert Power Plant steam to hot water at all buildings to meet all heating requirements except one-way air (100% outside air) system preheat coils. Use steam in one-way air system preheat coils to prevent freeze damage to the system. Provide two-position control valves on preheat coils in one-way air systems. Use low pressure steam, no greater than 15 psig; size the preheat coil based on 7 psig steam to the valve.

- See Metering section for steam/condensate meter and monitoring requirements.

- Recommended AHU coil arrangement in order from the outside air intake to the supply fan on a draw thru system is (heat recovery, steam preheat, heating water, and cooling coil). Discuss with Campus Engineering if different.

Design Evaluation

The following information is required to evaluate the design:

Schematic Design Phase: Identify all systems, and include single line system flow diagrams, shaft locations, design calculations, and energy balances. Special occupancy zone requirements must be called out and systems identified.

Design Development Phase: Provide updated single line system flow diagrams, equipment schedules, design calculations, and an outline of specifications.

Construction Document Phase: Provide equipment access indications, final single line system flow diagrams, tunnel pipe supports design and calculations, equipment schedules, design calculations, and specifications.

Products, Material and Equipment

- For steam and condensate piping, see Piping, Valves & Accessories section.

- Provide inverted bucket-type traps at the end of high pressure steam mains. Provide float and thermostatic type traps for low pressure steam mains.

- Provide pneumatic rather than self-contained steam control valves on hot water converters.

- Hand valves for radiators or convectors should be packed type suitable for servicing.
• Converters must be ASME approved, stamped, and State Boiler Inspector's certificate forwarded to University. Use low pressure steam only (15 psig maximum) with capacity based on 7 psig steam to the control valve.
• See Steam Trap Assembly detail at the end of this section.

Installation, Fabrication, and Construction

• Steam headers shall have valved branches to each specific load, hot water, storage heater, converter, heating coil, etc.
• Pressure reducing stations shall include at least two valves sized for \( \frac{1}{3} \) - \( \frac{2}{3} \) of total load. Show loads on drawings.
• Flash high pressure steam (185 psig) condensate in a flash tank to the low pressure steam system.
• Drip and trap all low and medium pressure steam (1 - 110 psig) supply main branches over 12 feet long.
• Provide strainers ahead of traps on coils, converters, or other heat exchangers. Provide adequate static head (minimum 12") above traps to insure proper operation.
• Do not attempt to lift condensate by steam pressure.
• Do not install steam or condensate piping below slabs on grade.
• If steam is intended to be used for temporary heat, discuss with Campus Engineering. In most cases, condensate shall be wasted by tempering to below 140F then dumped to sewer drain.

END OF DESIGN GUIDE SECTION
Basis of Design

This section applies to the design and installation of hot water heating systems to appropriately interface with existing resource utilities / systems.

Programming

- Design temperatures shall be as established by the City and State Energy Codes. Design temperatures for remote off campus areas will be set by the local code authority or the State code. Consider energy conservation in all aspects of building design at the UW. It must be a goal of the mechanical design to minimize annual operating costs. Mechanical systems must operate efficiently at partial and full load, both at the time of building occupancy and into the future.
- Establish laboratory and research space temperatures as part of the technical programming process. Design unoccupied spaces, including mechanical and electrical rooms, to be heated to 40° F for freeze protection. List all space temperatures differing from the 68° F set point in the final programming document.

Design Criteria

- New hot water converters shall be on a reset schedule. Confirm existing reset schedule. Reset converter and radiation water temperatures by the outside air temperature. The normal reset schedule for a converter is to reset the water temperature from 180° F to 140° F as the outside air temperature changes from 20° F to 70° F respectively. The normal reset schedule for a radiation system is to reset the water temperature from 180° F to 100° F as the outside air temperature changes from 20° F to 70° F respectively.
- Provide hot water heating radiation systems in areas where people are located adjacent to the outside wall. Examples of this type of occupancy are perimeter office areas and study carrels in libraries. Radiation systems will not be required in lab areas, auditoria, or other areas where people will not be seated along the exterior wall. Size radiation systems for 80% of transmission losses. Select finned pipe radiation to extend for the entire length of each glass area. If the perimeter heat loss does not exceed 250 BTUH/LF, radiation may be omitted.
- Provide separate pumps and decoupled distribution systems for radiation systems and reheat coils. Discuss with Campus Engineering if the systems are too small to justify separate systems. Stand-by pumps are required for critical systems. Please discuss standby requirements with Campus Engineering and the Project Manager.
- Reheat coil hot water is normally set at 140° F. If the air temperature to the coil is constant and the skin loss is taken care of by the radiation system, then this temperature does not need to be reset.
- Night setback temperature control is required to protect the building and the equipment inside. Buildings with wood floors or equipment that would be affected by humidity (wood expands) should not be allowed to drop below 55° F. Temperatures below 55° F have caused wood floors to buckle and pianos to go out of tune. For some buildings, a night setback temperature of 40° F, for freeze protection only, will be acceptable. Discuss with Campus Engineering and the Project Manager.
- Provide two-pipe down feed design on hot water heating systems.
- Buildings off campus, including remote sites, should be heated with boilers or furnaces. Availability of fuels will need to be investigated. Discuss fuel options with Campus Engineering.
• Provide pipe test ports/wells to measure pressures and temperatures at each piece of equipment.
• Indicate all systems diversities that the balancer must account for in the completion of the work.
• Each hydronic heating system shall have a pot feeder, coupon rack and make-up water meter. See Metering and Gages section for meter information.

Design Evaluation

The following information is required to evaluate the design:

Programming Phase: Provide a narrative to describe room temperature setpoints as outlined in the Basis of Design – Programming section.

Schematic Design Phase: Identify all systems, and include single line system flow diagrams, shaft locations, design calculations, and energy balances. Special occupancy zones must be called out and systems identified.

Design Development Phase: Provide updated single line system flow diagrams, equipment layout and access requirements, equipment schedules, design calculations, and an outline of specifications.

Construction Document Phase: Provide final single line system flow diagrams, equipment layout and access indications, equipment schedules, design calculations, and specifications.

Products, Material and Equipment

• For heating water piping, see Piping, Valves and Accessories section.
• For systems that require freeze protection, provide Dowtherm SR-1, or an approved equal. Approved equals must have been approved by the city for disposal in the sanitary sewer system and must have comparable levels of corrosion inhibitors, heat transfer efficiency, and viscosity.
• Hot water converter selection should include a 0.001 waterside fouling factor.
• At the high points in the water systems provide automatic air vents with a cast iron body, copper ball float and needle, or ball-type air valve. Provide manual air vents on zone heating coils. Provide automatic air vents on pre-heat heating coils. Provide low point drains on hydronic systems.
• Surface mounted convectors must have sloping top to prevent materials from being placed/stored on top of the enclosure and blocking airflow. Avoid custom enclosures.

Installation, Fabrication and Construction

• Provide sectionalized down-fed hot water piping systems with isolating and drain valves to simplify servicing without draining large volumes of water during maintenance and repair.
• Allow space for tube removal on each hot water converter.
• Provide relief valves on each hot water converter in compliance with the Boiler and Pressure Vessel code.
• Do not install cast iron radiation, finned radiation, and air heating coils on the same pumped circuit.
• Provide a hose end drain valve on each hot water coil.
- Provide isolation valves at all air vents.
- Locate expansion tanks at the highest point possible, and fit with gauge glass, drain, vent, and shut-off valve.
- Provide control valves on convectors and radiation; dampers will not be accepted.
- Provide isolation valves with rising stems at the inlet and outlet of each AHU or supply fan coil, or other major component. Locate valves so that each unit, and its control valve, can be serviced without draining an entire system or riser.

END OF DESIGN GUIDE SECTION
Basis of Design

This section applies to refrigeration equipment.

Design Criteria

- Design air-cooled condensing units using an ambient temperature of 95 °F. Design to operate at a low ambient temperature of 0° F.
- Do not use city water-cooled condensing units without prior approval from Campus Engineering.
- To avoid short-cycling, incorporate a compressor capacity-control scheme (i.e. hot gas bypass) whenever the range of the minimum and maximum refrigeration load differs by 25% or less.
- With the exception of refrigeration systems that incorporate heat recovery, use outside air as the heat sink for air-cooled condensing systems.
- Regulate condensing unit fan speed to control the condensing system operating pressure. For multiple fan units, the speed of at least one fan shall be regulated and operated on a "first on/last off" basis.
- Provide compressors located remotely from evaporators with oil separators. Design oil circulation piping to ensure adequate oil circulation.
- Install refrigeration compressors, condensers, and condensing units in a mechanical room or in a weather-protected enclosure. Provide a minimum of 24 inches horizontal clearance between units to allow future maintenance.
- Incorporate refrigeration equipment with vibration isolation to reduce sound transmission and prevent piping or tubing damage.
- Provide evaporator condensation drains from evaporators with a trap and route to funnel or floor drains. Provide condensate pan and piping with insulation, and equip with electric heater cable/tape where temperatures are expected to be below 32°F.
- Implement the "pump down" method to control compressors. Provide compressor controls with a low-pressure switch (primary control and a high-pressure limit with manual reset.) Provide compressors designed with pressurized oil lubrication which have an oil pressure safety switch with timer and manual reset.
- Provide a refrigerant sensing/measuring device and adequate ventilation for refrigerant Machinery rooms. Vent the refrigerant safety valve outside the building.
- Provide a minimum of 400 cfm per ton.
- Fluorocarbon refrigerant R-22 is not acceptable. Reduce and aim to eliminate all CFCs from existing facilities. Provide EPA approved HFC refrigerant for new equipment (if not available, discuss with Campus Engineering). CFC and HCFC are not acceptable.
- For refrigeration leak detection system requirements see Mechanical – Process and Environmental Chilled Water section.

Design Evaluation

The following information is required to evaluate the design:

- **Schematic Design Phase:** Provide equipment locations; system definition and design criteria developed by the users, names of responsible Mechanical Design Engineer, Refrigeration Shop Supervisor, and Campus Engineering representative.
Design Development Phase: Provide design calculations, equipment sizing criteria, equipment lists, operation sequence, control diagram and piping plans.

Construction Document Phase: Provide one-line diagrams, pipe sizing, descriptive literature with capacities for each piece of equipment and appropriate selections marked. Capacity balance curves shall be included to show operating balance conditions for matching components.

Construction Submittals

- Provide control schematics, sequence of operation, and location of controls.
- Provide standard industry submittal requirements.

Products, Material and Equipment

- Specify scroll-type hermetic compressors.
- Specify maximum warranty option for compressors.

Installation, Fabrication and Construction

- Braze all pipe joints under a nitrogen purge. No mechanical couplings allowed. No Flare connections.
- All work shall be performed by a contractor with a valid City of Seattle Refrigeration Mechanics license. The contractor shall also have an A & B Refrigeration Handlers Certificate with a Universal Rating as required by 40CFR part 82-F of EPA Regulations.
- Subject completed systems to the field test as stipulated in the latest edition of the Seattle Mechanical Code. The University’s Representative shall witness this test.
- Complete Refrigeration Compliance Forms. The University can provide these forms or download from https://www.washington.edu/facilities/fstech/node/609.

END OF DESIGN GUIDE SECTION
Basis of Design

This section applies to the selection and installation of air handling units and ventilation fans.

Design Criteria

- Ensuring that efficiency is not compromised, specify fan speeds less than 1,000 rpm to reduce noise levels and increase equipment life. Review with Campus Engineering any applications where fan speeds greater than 1000 rpm are intended for use.
- Provide weather protected fans installed near the building roof. Fan installation in penthouses is preferred. The fan should be the last element of the exhaust system to assure that the ductwork throughout the building is under negative pressure.
- Install fans to be readily accessible for maintenance and inspection without entering the plenum. If exhaust fans are located inside a penthouse, consider the ventilation needs of maintenance workers.
- Discuss laboratory ventilation interlocks and standby power requirements with EH&S and Campus Engineering.
- Coordinate the mechanical design with fume hood selection and location to achieve design performance criteria listed in the EH&S Laboratory Safety Design Guide.
- Mechanical and electrical rooms will be ventilated for temperature control. Usually the temperature will be controlled to 90˚F unless there are specific equipment temperature requirements. Ventilation can be controlled by a thermostat, as long as an override is provided for Physical Plant use. Provide outside air to all mechanical and electrical rooms as part of the ventilation system.
- General use storage rooms may eventually become offices and must have provisions for future ventilation. The ductwork and piping systems shall be sized for this eventual conversion. Storage rooms are not considered unoccupied areas.
- To maintain the best possible indoor air quality, the location of the air intake(s) is very important and must be discussed with Campus Engineering and EH&S. Locate the intakes to avoid contamination from streets, exhaust vents, loading docks, and other sources of contamination. For air intake requirements see EH&S Laboratory Safety Design Guide.
- To protect the air intake locate all building exhausts as remotely as possible from the intake. All fume exhaust systems must be located on the roof and discharge vertically.
- Provide the air intake area with easily cleaned screens and drains to allow for the delivery of clean dry air to the ventilation system. Provide bird screen to keep birds, leaves and other material out of the system.
- For airflow simulation study requirements for all buildings see EH&S Laboratory Safety Design Guide.
- Most building systems will be large units, in the 20,000 to 75,000 CFM range. The use of multiple small package units is discouraged.
- Separate ventilation systems or zones may be required for separate occupancy uses, such as libraries and auditoria. The occupancy schedule of these areas will not always be the same. Make provisions to run these areas when the remainder of the building is not in operation.
- Provide building copy/duplicating rooms and other rooms that contain several personal computer printers with exhaust systems to eliminate the migration of dust and chemicals. To maintain adequate indoor air quality, do not recirculate the air from these rooms.
Do not use fan rooms and mechanical rooms as supply or relief/exhaust air plenums. Duct all outside air and relief/exhaust air ducts to outdoors.

For fume exhaust, see Ductwork and Duct Accessories section and EH&S Laboratory Guide Manual.

Minimize return air plenums. Provide ducted return air system. Discuss with Campus Engineering if plenum returns are proposed.

For separate snorkel exhaust system requirements see EH&S Laboratory Safety Design Guide.

When connecting to existing systems, use the actual operating conditions (temperatures, air flow volumes, and pressures), not the design values shown on the as-built drawings. As an example, the as-built drawings show a cold deck temperature of 55°F, whereas the actual operating conditions can only maintain a cold duct temperature of 60°F.

Provide weatherproof enclosures for roof mounted equipment. Roof mounted supply air systems should be blow through design to eliminate negative pressure plenums exposed to the weather.

Indicate all systems diversities that the balancer must account for in the completion of the work.

For naturally ventilated spaces specify the space temperatures to be maintained and provide supporting calculations.

**Design Evaluation**

The following information is required to evaluate the design:

- **Schematic Design Phase**: Identify all system fans, and include single line system flow diagrams, outside air intake and exhaust outlet locations and design calculations. Special occupancy zones must be called out and fan systems identified.

- **Design Development Phase**: Provide single line duct layouts, updated single line system flow diagrams, equipment layout and access indications, outside air intake calculations, equipment schedules, design calculations, and an outline of specifications.

- **Construction Document Phase**: Provide double line duct layouts, equipment layout and access indications, final single line system flow diagrams, equipment schedules, design calculations, and specifications.

**Fume Exhaust Fans**

- Provide fans with the following:
  1) Outboard "split" bearings,
  2) Shaft seal,
  3) An access door,
  4) Multiple 150 percent rated belts, or direct drive. In designing for explosion and fire control, the fan shall be of the non-sparking construction and the V-belt drive shall be non-conductive.

- Provide chemical resistant fan system.
• Weld or permanently seal fan housing to avoid air leakage from the wheel shaft and discharge.

• Fume exhaust fans shall be arrangement 1 or 9, overhung wheel type with bearings outside air stream. Fans shall have two bearings; split-case with split inner and outer races and cage.

• Choose fan type as follows:
  1) Use straight-radial fans for systems handling moderate to heavy quantities of particulate matter in air.
  2) Use backward-inclined fans for systems handling relatively clean (low particulate) air.
  3) Provide perchloric acid hood with an induction type fan.

• Manifold fume exhaust systems shall use constant volume fans with make-up air/outside air bypass.

Installation, Fabrication and Construction

General

• During storage, transport, and installation prior to start-up, cover the air handlers with plywood and/or plastic as necessary to keep them dry, clean, and protected from damage. Provide heaters and/or dehumidifiers if necessary to prevent condensation inside air handlers prior to start-up. Provide temperature/humidity data loggers in units in transit and during storage. Air handlers with insulation that has been wet are unacceptable.

• Thoroughly clean equipment casings of debris and small particles of rubbish and dust before installing and making final duct connections.

• Do not start the fans until the Owner has approved the level of cleanliness of the air distribution system. Provide full access to the system for the inspection of cleanliness prior to start-up.

• The preferred fan design is single inlet, single width centrifugal type with backward inclined airfoil blades; however, utilization of airfoils, propellers, and duct axial flow fans is acceptable where appropriate.

• Do not provide VFDs on manifolded fume exhaust systems unless a minimum of 2500 fpm exit stack velocity can be maintained. Refer to section Mechanical – Testing, Adjusting, and Balancing for balancing information related to VFDs.

• Provide rigid structural steel base for both fan and motor with slide rails for drive adjustment. Hinged motor bases are not acceptable.

• Provide ball-type fan bearings (selected for extended life), lubricated with grease fittings extended through fan casing for easy access.

• Provide each fan drive with an easily removable guard assembly protecting drive belts and shaft, with access for tachometer use.

Air Handlers

• Air handler walls shall be double-walled panels with a minimum of 2 inches of fiberglass insulation, 16 gauge exterior galvanized steel; and 22 gauge internal galvanized steel perforated except downstream of cooling coils and in outside air intakes.
  1) Floor: non-skid floor that extends up the walls to prevent leakage in the event of water accumulation.
2) For access doors, use the same metal gauges and insulation levels as are specified for the rest of unit.
3) Downstream from cooling coils, double-walled internal duct insulation with a solid metal surface exposed to the air stream is required.
   - Angle iron bracing inside plenums shall be galvanized.
   - Provide access doors to each area between the coils, filters and fan. The access between the coils, filters and fan must be a minimum of 18 inches (preferably 24 to 36 inches).

Fume Hood Fans
   - Provide access for fan maintenance.
   - Mount the fan with vibration isolators.
   - Provide weather protected fans installed near the building roof. Fan installation in penthouses is preferred. The fan should be the last element of the system to assure that the ductwork throughout the building is under negative pressure.
   - Install fans to be readily accessible for maintenance and inspection without entering the plenum. If exhaust fans are located inside a penthouse, consider the ventilation needs of maintenance workers.
   - Discuss fire alarm interlocks to fume exhaust fans and standby power requirements with EH&S and Campus Engineering.
   - Coordinate Fume Hood selection and location with architectural to achieve design performance criteria listed in the EH&S Laboratory Safety Design Guide.
   - Specify fume exhaust fans with minimum two belt sheaves.
   - Specify all belt guards to allow visual inspection.
   - Provide perchloric acid systems, including duct fans and hood, with an internal wash-down system that meets the following requirements:
     1) Design the perchloric acid fume hood system to provide as complete a wash-down with all ductwork at 45 degrees or less from vertical to drain back to the fume hood.
     2) Provide fan casings and hood bottoms with continuous gravity drainage to the acid resistant waste.
     3) The wash down system shall be activated by a manual valve located adjacent to the fume hood.
     4) Prior to substantial completion, testing of the wash-down system must be witnessed and approved by Owner’s witness and EH&S.

END OF DESIGN GUIDE SECTION
Basis of Design
This section applies to the selection and installation of filters.

Design Evaluation
The following information is required to evaluate the design:

- **Schematic Design Phase:** Describe all system filters.
- **Design Development Phase:** Identify filter locations, access, preliminary design calculations with catalog cut sheets, and an outline of specifications.
- **Construction Document Phase:** Identify filter locations, access, final design calculations with catalog cut sheets, and specifications. Provide a filter schedule and drawing details.

Products, Material and Equipment

- Provide pre-filters (MERV 8) and final filters (MERV13).
- All filters should be 24 inch by 24 inch face size if possible.
- Consider specific project filter applications (absolute, grease).
- Final filters shall have 85% efficiency (dust spot method using atmospheric dust) at 500 feet per minute face velocity.
- Locate and arrange HVAC equipment for reasonable filter removal and replacement.

Installation, Fabrication and Construction

- Avoid operating HVAC systems prior to the completion of construction except where flushing of the building is necessary to comply with LEED requirements. Specify temporary filters for fans, air terminal units, and primary return/exhaust inlets that are operated prior to completion of construction.
- After construction dirt has been removed from the building, provide new filters for permanent locations.
- Indicate the required filter removal and equipment access space on the contract documents.

END OF DESIGN GUIDE SECTION
Basis of Design

This section applies to the selection and installation of coils.

**Design Criteria**

- Provide detail drawings of cooling coil drain pan traps. For AHUs, assure that the height of the drip pan connection is sufficient for a trap of the specified depth to clear the floor.
- Use condensate drain pan dimensions sufficient to catch all condensate off coil. Provide pan under coil and extend downstream of coil far enough to catch all condensate.

**Design Evaluation**

The following information is required to evaluate the design:

- **Schematic Design Phase:** Identify all system coils, and include coils in single line system flow diagrams, design calculations, and energy balances. Special occupancy zones must be called out and system coils identified.
- **Design Development Phase:** Provide updated single line system flow diagrams, equipment schedules, design calculations, and an outline of specifications.
- **Construction Document Phase:** Provide coil access and removal indications, final single line system flow diagrams, equipment schedules, design calculations, and specifications.

**Products, Material and Equipment**

- Provide non-freeze type steam coils with perforated inner distribution tubes with vertical tubes; each section should be individually trapped. Tube wall thickness must be 0.035 inches (minimum).
- For systems that require freeze protection, provide Dowfrost HD, propylene glycol or an approved equal. Approved equals must have been approved by the city for disposal in the sanitary sewer system and must have comparable levels of corrosion inhibitors, heat transfer efficiency, and viscosity.
- At the high points in the water systems provide automatic air vents with a cast iron body, copper ball float and needle, or ball-type air valve. Provide manual air vents on zone heating coils. Provide low point drains on hydronic systems.
- Provide a maximum fin density for coils of 10 fins per inch and tube wall thickness of 0.035 inches (minimum).
- Locate and arrange air conditioning equipment for reasonable motor, filter, and coil/tube removal.

**Installation, Fabrication and Construction**

- Provide a hose end drain valve on each water coil.
- Locate all air heating and cooling coils so that water jet or steam cleaning may be employed on each side of each coil. Provide ductwork access panels on each side of each coil.
- Provide a balancing valve in the return piping from each individual coil.
- Provide isolation valves with rising stems or quarter turn valves at the inlet and outlet of each AHU or supply fan coil, or other major component. Locate valves so that each unit, and its control valve, can be serviced without draining an entire system or riser.
• Provide access panels in ceilings or partitions for servicing concealed coils.
• Provide a flow-measuring device such as a venturi in the coil piping of each supply fan.
• Indicate the required coil equipment access and removal space on the contract documents.

END OF DESIGN GUIDE SECTION
Basis of Design

This section applies to the design and installation of ductwork, air terminal boxes, air outlets and inlets, volume dampers, pressure relief dampers, smoke/fire dampers, and smoke/fire damper actuators.

Design Criteria

- Select duct velocities to meet N.C. requirements of each occupied space. NC level requirements shall be identified in the Basis of Design narrative. Coordinate required NC levels with University Project Manager and users.

Supply, Return and Non Fume Exhaust Ductwork

- Provide a 6-inch pressure rating for supply ductwork and plenums between the supply fan and the zone terminal boxes; for ductwork downstream of the terminal box, provide a 2-inch pressure rating. If pressure classes less than those given above are considered sufficient for a specific application, review with Campus Engineering before specifying a lower rating.
- Use the ASHRAE Handbook of Fundamentals chapter on duct design to determine the allowable leakage rate (cfm/100 sq.ft.) at the specified test pressure for each type of ductwork on the project other than fume exhaust ductwork. Specify for each type of ductwork the duct pressure rating, the pressure to apply during the duct leakage test, and the allowable cfm/100 sq.ft. leakage rate at the test pressure.
- Minimize use of square elbows. Provide turning vanes in square elbows of supply ductwork. Do not use turning vanes in return or exhaust ductwork.
- To minimize noise levels in the space, avoid substitution of registers for balancing dampers.
- Provide a balancing damper for each outlet and each inlet. Locate those balancing dampers adjacent to the connection to the main branch to minimize noise levels in the space.
- Do not use perforated plate ceiling diffusers in office or classroom applications. They cause dumping.
- Specify laminar flow diffusers in laboratory applications when required.
- Do not use nonmetal ductwork (i.e. fiberboard) without the approval of Campus Engineering.
- Design ductwork to and from the HVAC equipment carefully so that stratified air will be mixed properly before entering branch ducts or downstream equipment.
- Limit flexible duct to no more than 6 feet and one elbow.
- On renovation and remodel projects, obtain the latest existing supply and exhaust air quantity information from the Owner and incorporate into the design. It may be necessary to procure the services of a balancer if existing information is not available.
- On renovation and remodel projects investigate the condition of existing ductliner, in particular at cooling coils, test for mold and replace the ductliner if warranted.

Dampers

- Install manually operated, opposed blade or single blade, quadrant-type volume dampers on all branch main and branch duct takeoffs from the main duct to control the amount of air entering or leaving the branch.
- Avoid register or diffuser-mounted dampers because they cannot reduce large volumes of air without causing objectionable air noise levels.
- Do not locate single blade volume dampers immediately behind diffusers and grilles. This application does not allow uniform airflow across the outlet face.
To minimize generated duct noise, locate volume dampers at least two duct diameters from a fitting and as far away as possible from the outlet or inlet.

Provide the necessary access space around components to allow the TAB technician to take proper readings. Allow adequate straight duct sections from fan outlets, elbows, or open duct ends to provide accurate duct traverse readings.

Pressure Relief Doors or Panels

Smoke/fire dampers have the potential to damage ductwork if they close by accident, or even if they close when the fan is shut off but wheeling down during a power outage, fire test, or fire. Risk of damage to the ductwork is particularly serious if a single smoke/fire damper will arrest the full supply of air into or out of a large fan. Design the air distribution system so that the ducts won't be damaged if the fans are run with the smoke fire dampers closed.

The preferred means for protecting the ductwork against over-pressurization during smoke/fire damper closure is to select a duct pressure classification so the ducts will withstand sudden exposure to the maximum fan pressure. Provide accessible, well-sealed pressure relief doors or panels that can be closed after they open.

Use pressure relief doors rather than pressure relief backdraft dampers.

Mounting

For exterior ductwork, fans and air handlers, see the Facilities Services Design Guide architectural standard drawing titled Mechanical Equipment Mounting, for minimum mounting height. Coordinate with Architect to specify rooftop mounting under Architectural.

Renovation and Expansion Projects

When adding or removing ductwork on an existing air distribution system, show on the mechanical drawings all existing ductwork and flow rates that will need to be rebalanced after construction.

Review manufacturer's fan data for existing fans to ensure these fans can operate at the new operating conditions. Review existing motor amperage and motor nameplate to determine whether a new fan motor should be specified.

In the fan schedules, provide the existing and proposed fan airflows, fan static pressures, motor amperages and motor horsepower requirements for existing fans serving systems altered in renovation projects. The existing actual flows are needed for the design. Arrange with the University of Washington Project Manager for flow measurements as needed.

On floor plans, show any new balancing dampers that should be added to the existing branch ductwork to facilitate balancing.

Require measurements, prior to demolition, of any unknown airflows or static pressures that will need to be reestablished as part of testing, adjusting and balancing.

If a small portion of an existing system is to be changed, avoid creating a new high pressure drop critical path to an existing system. Larger components should be selected to avoid significant increases in the fan discharge pressure requirements.

Provide temporary means as necessary for dust control and lab safety while ductwork and fans are being removed and installed.

Fan-powered Zone Air Terminal Boxes

For VAV air terminal box fans, specify the method of speed adjustment (e.g., continuous or 3-speed fan control) to be used during testing, adjusting and balancing. In reviewing manufacturer’s literature during design and during contractor equipment submittals, make
sure the selected air terminal boxes will operate at a speed range that doesn’t create excess noise or motor problems. Specify “extra-quiet” fan-powered VAV boxes.

- Specify maximum sound ratings (db level) for the air terminal boxes.
- To control sound transmission out of the secondary (plenum) air intake, include a lined intake boot that has at least one 90 degree elbow.
- On mechanical floor plans, indicate with dotted lines the horizontal access clearance requirements for maintenance of air terminal boxes.
- Connect fan powered air terminal boxes to the ductwork with flex connections.
- Connect fan powered air terminal boxes to structure with vibration isolators unless the fans are internally isolated.

Smoke/Fire Dampers

- The smoke/fire dampers and their actuators are to be covered under the ductwork specialties section of the project specifications (not under controls or the fire alarm system). Exception: The EP switch for smoke/fire damper pneumatic actuators will be specified under the fire alarm system. Coordinate with electrical and refer to Environmental Health & Safety Design Guide – Fire Alarm System section.
- The University strongly discourages use of engineered smoke control systems. Consult EH&S before designing one.
- Work with the Architect and EH&S to minimize the number of smoke/fire dampers through (1) coordination of duct layout with suite configuration, and (2) close attention to code “exceptions” to standard smoke/fire damper placement requirements.
- Use pneumatic actuators. Electric smoke/fire dampers shall only be used in retrofit projects where electric smoke/fire dampers are already installed.
- If electric smoke/fire dampers are to be used, discuss actuator application including noise with Campus Engineering.
- Dampers shall be Class II, 250° F, with a minimum closure time of 7 seconds and a maximum closure time of 15 seconds.
- Fire damper actuating device shall be approximately 50° F above normal operating temperature within duct system. Rate for 286° F for smoke control systems.
- Do not use fire dampers in laboratory hood exhaust systems.
- Provide end switch for position verification.

Access Doors and Panels

- Coordinate with Architect to ensure there are access doors through walls and hard ceilings wherever necessary to reach access doors in the HVAC equipment.
- Access doors and panels should be a minimum of 24" x 24" unless the duct is too small to accommodate a larger door or the necessary access can be handled easily with a smaller door.
- Coordinate with Architect so that all access doors and panels in the ductwork are accessible in a manner that meets applicable safety standards. This includes access doors and panels located at the smoke/fire dampers.

Hospitals, Labs, and Animal Holding Facilities Pressure Relationships

- On hospital, lab, and animal holding facilities projects, discuss with EH&S and Campus Engineering whether there are any special requirements for documentation and review of room pressure relationships.
Design Evaluation

The following information is required to evaluate the design:

- **Programming Phase:** On retrofit projects, descriptions of existing systems to be altered. For all projects, provide design criteria for ventilation, heating and cooling and noise levels. Basic strategy for zoning air distribution system.

- **Schematic Design Phase:** Identify all systems; include single line system flow diagrams, outside air and exhaust outlet locations, shaft locations, and design calculations.

- **Design Development Phase:** Provide single line duct layouts, outside air intake calculations, updated single line flow diagrams, equipment schedules, design calculations, and outline specifications.

- **Construction Document Phase:** Provide fan curves that demonstrate the duct rating is high enough to withstand the deadhead fan pressure for the basis-of-design fan selections. Provide double line duct layouts, final single line system flow diagrams (Supply air, return air, and exhaust air), equipment schedules, design calculations, and final specifications.

Construction Submittals

- For smoke/fire damper submittals: Include the number of damper actuators in each damper bank, and an equipment list showing the manufacturer, model number, and amperage draw for the actuators in each damper bank (whether composed of a single or multiple dampers).

- Include manufacturer’s literature on the smoke/fire damper actuators.

- For projects with electric smoke/fire dampers, provide shop drawings that show electrical and mechanical coordination of smoke/fire dampers.

Products, Material and Equipment

**Accessories**

- Provide insulated drip pans for cooling coils.

- Damper position switches that contain mercury are not acceptable. Use cam action, lever, or proximity type damper position switches.

**Ductwork – Non Fume Exhaust**

- Provide an easily accessible lockable, handle for each balancing damper. Orient the handle parallel to the damper blade(s).

- Use aluminum sheet metal with watertight joints for exhaust ductwork from high humidity areas such as shower rooms. Slope ductwork back toward inlet.

**Fan-powered Zone Air Terminal Boxes**

- Internally isolate the fans in air terminal boxes.

- Line the air terminal boxes with at least 1 inch of fiberglass batt insulation. Cover liner with aluminum foil at least 0.001 inch thick to prevent entrainment of fibers into the air stream.

- Damper shafts shall have at least one flat facet at the point of connection to the actuator.

**Damper Shafts**
- Provide a grooved scribe running parallel to the blades on the end of each damper shaft, including but not limited to shafts on balancing, and smoke/fire dampers.

**Fume Exhaust Ductwork**

- Provide ducts that are round, non-combustible, inert to agents to be used, non-absorbent, and free of any organic impregnation.
- Provide liquid and airtight joints.
  - Provide smooth, non-porous lining surfaces free of cracks, joints, or ledges.
- Use flexible connection sections of ductwork, such as hypalon or neoprene-coated glass fiber cloth, between the fan and its intake duct when such material is compatible with hood chemical use factors. Provide the transition joint from duct to fan of a seamless, constant diameter, inert, corrosion and ultraviolet-resistant material as approved by Owner. Provide the duct alignment within ½ inch at the hood collar and fan.
- Choose duct material based on the compatibility with the materials handled in the hood.
- On projects where general exhaust is combined with fume exhaust the all ductwork shall be the same material as the fume exhaust.

**Smoke/Fire Damper Actuators**

- Provide pneumatic actuators for the smoke/fire dampers unless the building doesn’t have other pneumatic controls. (The Facilities Services Design Guide requires pneumatic actuators for HVAC controls in mechanical rooms. See the Environmental Control Systems section.)
- Serve pneumatic actuators for smoke/fire dampers with pneumatic lines made out of hard drawn copper tubing that meets copper tubing specifications under Environmental Control Systems.
- Electric actuators shall have an end-switch or clutch to reduce force on the damper when it is being held open. Electric actuators shall not use stall-motors.

**Access Doors**

- Access doors shall be hinged, latched, and gasketed. Where located in insulated ductwork, access door shall be double walled and insulated to same level as duct in which they are located.
- Access panels shall open and close easily without damage to duct insulation, and reseal tightly on re-closure.

**Installation, Fabrication and Construction**

**General**

- Expose no raw fiberglass fibers to the air distribution system air stream or to occupied space.
- During storage, transport, and installation prior to start-up, cover the ductwork and air terminal boxes with plywood and/or plastic as necessary to keep them dry, clean, and protected from damage.
- At no extra cost to the Owner:
  1) Replace metal that is dented or has a damaged finish.
  2) Replace duct liner that is torn or wet.

**Ductwork**
- Specify to cover the ends of ductwork while they are in storage and after installation prior to start-up, so they are protected from accumulation of dirt.
- Thoroughly clean ductwork and plenums of debris and small particles of rubbish and dust before installing and making final duct connections.
- Locate plenums at least 4 inches AFF to protect them from water in case of mechanical room flooding. Provide adequate support.
- Provide each plenum area with a light. Include an "ON" pilot light on switch.

**Fume Hood Ductwork**

- Slope all horizontal ductwork down towards the fume hood. Low points or “bellies” in the ductwork run are unacceptable.
- Some retrofits may require to tie-into existing glazed ceramic ducts and vitrified clay tile ducts. Provide appropriate transition detail.
- Decontaminate fume hood ducts being removed as part of the project.
- Provide a flanged removable spool piece (minimum of 12 inches long) at each fume hood connection. Use spool sections for leak tests, inspection, and to facilitate removal of equipment. Install suitable gaskets at flanged joint connections.
- Provide adequate space and easy access to facilitate inspection, repair, or replacement of exhaust ducts.
- The target design velocity in each duct shall be in the range of 1200 to 1500 feet per minute (fpm) to prevent condensed fumes or particulates from adhering to the walls of the ducts, settling out onto horizontal surfaces, and to address acoustical issues. The actuated exhaust terminal unit needs to consider noise and prevention of product deposition in the ducts.

**Fume Hood Exhaust Stacks**

- See Environmental Health & Safety Laboratory Safety Design Guide for air flow study requirement.
- Terminate fume hood exhaust stacks at whichever is the greatest of the following: At least ten feet above the roof for workers safety or stack height as determined by the air flow study.
- Design discharge stack velocity to be at least 3000 fpm.
- Do not provide exhaust stacks with weather protection, such as weather caps or louvers, which require the air to change direction or cause turbulence upon discharge.

**Zone Fan-Powered Air Terminal Boxes**

- Cover air inlet and discharge openings for air terminal boxes while they are in storage and after installation prior to start-up to prevent accumulation of dirt.
- Coordinate location of filters for easy access and replacement.
- Orient secondary air inlets either down or sideways, not toward the ceiling.
- Provide enough clearance between the secondary air inlet and the nearest surfaces to avoid restriction of air flow.

**Access Doors**

- Provide hinged access doors on rectangular ductwork, air handlers and plenums. On round and oval ductwork provide removable access panels.
- Provide access doors for all plenum areas. Provide latches operative from both inside and outside the plenum.
• Provide access doors that open against pressure, and are self-closing due to the direction of airflow and by pressure differential. No exceptions.

• Provide access panels upstream of all fire dampers, smoke/fire dampers, and coils, and elsewhere where occasional access is required. Provide access panels to both sides of turning vanes.

Smoke/Fire Damper Tests

• The Contractor shall demonstrate to an Owner’s witness the full functionality of each smoke/fire damper by visual observation of the blades as it strokes “full open” and “full closed.” All of the smoke/fire dampers shall pass the Owner-witnessed test before tests are witnessed by the Fire Department. To allow observation of the damper blades, access doors shall be opened by the Contractor before the test begins.

Fire Damper Tests

• Demonstrate to an Owner’s witness that the fire dampers drop from the “full open” to the “full closed” position by gravity when the fusible link is removed. Perform tests for the Fire Department only after fire dampers have passed the Owner-witnessed test before tests are witnessed by the Fire Department. Open access doors to allow observation of the damper blades by the Contractor before the test begins.

END OF DESIGN GUIDE SECTION
Basis of Design
This section applies to the pressure testing of ductwork and HVAC piping systems.

Design Evaluation
The following information is required to evaluate the design:

- **Design Development Phase**: Provide an outline specification of HVAC duct and piping pressure testing.
- **Construction Document Phase**: Provide a final specification of HVAC duct and piping pressure testing.

Products, Material and Equipment

- Duct test apparatus consists of portable high pressure blower with volume adjustment; flow measuring assembly consisting of a calibrated orifice mounted in a straight tube with straightening vane and pressure taps; U-tube manometer; and calibration curve for orifice assembly.

Installation, Fabrication and Construction

Duct Pressure Tests

- Pressure test all ductwork in shafts, all plenums, fume exhaust ductwork, snorkel exhaust ductwork and all ductwork with a pressure rating of more than 2 inches (negative or positive). For ductwork with a pressure rating of 2 inches or less (negative or positive), two selected supply ducts shall be tested on each floor, and one selected exhaust or return duct. Specify Owner will select the ducts.
- Demonstrate to an Owner witness that the ductwork passes the following pressure tests before it is insulated or covered by walls or ceilings. Test ductwork after all smoke/fire dampers, fire dampers, pressure relief doors, and access doors for that portion of the ductwork have been installed.
- Discuss test pressures applied to each system with Campus Engineering.
- All pressure testing shall be witnessed and documented with results approved and signed off by a University representative.
- Before testing, provide the Owner with the table or curve of pressure drop versus flow for the orifice being used to measure leakage. Provide data that is certified and an orifice that is clearly labeled so that a correlation between the orifice and table can be established.
- Maintain a set of drawings for recording and sign-off of each tested section.
- After each day of testing, submit to the Owner a copy of the paperwork recording the raw test data, calculating the duct areas, designating the duct category, and comparing the allowable and actual results.
- Maintain pressure testing records on site. Provide a copy of current pressure test results if requested by an Owner Representative.
- Complete test reports.

Test Procedure – General Environmental Supply, Return, Exhaust, and Outside Air Ductwork
Close off and seal openings in the duct section to be tested. Connect the test apparatus to the duct by means of a section of flexible duct.

Test for leaks as follows:
1) Start blower with its control damper closed.
2) Gradually open the control damper until the duct pressure reaches 2 inches W.G. in excess of designed duct-operating pressure.
3) Survey joints and seams for leaks. Mark each leak and repair after shutting down blower. Do not apply a retest until sealants have set.
4) After leaks have been sealed, retest failed sections of ductwork until satisfactory results are obtained. Contact the Construction Coordinator to schedule an Owner’s Representative to witness re-tests.

Test Procedure – Fume Exhaust Ductwork
- Connect a blower to the duct specimen through a shutoff valve. Provide a magnehelic gage or inclined manometer with 0 inches to 10 inches W.G. range on the duct side of the shutoff valve.
- Provide temporary seals at all open ends of the ductwork.
- Average test pressure shall be 6 inches w.g. Initial pressure shall be 7 inches w.g.
- All fume duct joints from the fume hood collar to the fan inlet flex connection, not inclusive, shall be tested.
- To prevent over-pressurizing the ducts, start the blower with the variable inlet damper closed. Controlling pressure carefully, pressurize the duct section to the required level. When the pressure of the duct reaches 7 inches W.G., close the shutoff valve.
- Using a stopwatch, measure the time elapsed from when the duct is at 7 inches w.g. to 5 inches w.g. Use the formula \( t = 6.23D \) to determine if the duct passes the test. (\( D \) is the nominal duct diameter, measured in inches; \( t \) is the MINIMUM allowable elapsed time, measured in seconds.)
- Complete test reports.

Pressure Relief Doors or Panels
- With an Owner witness, demonstrate that the ductwork is not damaged during a fire alarm test.

Piping Pressure Tests
- Pressure test all piping.
- Demonstrate to an Owner witness that the piping passes the following pressure tests before it is insulated or covered by walls or ceilings. Test piping after all fittings, and valves for that portion of the piping have been installed.
- All pressure testing shall be witnessed and documented with results approved and signed off by a University representative.
- Repair leaks discovered during pressure testing. Retest failed sections of piping until satisfactory results are obtained. Contact the Construction Coordinator to schedule an Owner’s Representative witness the test.
- Maintain a set of drawings for recording and sign-off of each tested section.
After each day of testing, submit to the Owner a copy of the paperwork recording the raw test data, designating the piping system and Pipe Code, and comparing the allowable and actual results.

- Complete test reports.

Pipe Testing Methods

- Hydrostatic pressure testing: Use clean, fresh city water for test. On compressed gas piping remove water from piping systems after testing and dry by blowing dry, oil-free air or nitrogen through lines.

- Pneumatic pressure testing: Perform testing with dry, oil-free air or nitrogen on piping systems.

- The following table lists typical piping systems and the corresponding recommended test method and test pressure.

<table>
<thead>
<tr>
<th>Piping System</th>
<th>Pipe Code</th>
<th>Test Method</th>
<th>Test Pressure, lb/in² gage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central Cooling Water</td>
<td>P-4</td>
<td>Hydrostatic</td>
<td>250</td>
</tr>
<tr>
<td>Condenser Water</td>
<td>P-1</td>
<td>Hydrostatic</td>
<td>60</td>
</tr>
<tr>
<td>Heating Hot Water</td>
<td>P-1</td>
<td>Hydrostatic</td>
<td>1.5 x max.</td>
</tr>
<tr>
<td>Process Chilled Water</td>
<td>P-1</td>
<td>Hydrostatic</td>
<td>1.5 x max.</td>
</tr>
<tr>
<td>Refrigerant Liquid</td>
<td>P-7</td>
<td>Pneumatic</td>
<td>350</td>
</tr>
<tr>
<td>Refrigerant Suction</td>
<td>P-7</td>
<td>Pneumatic</td>
<td>125</td>
</tr>
<tr>
<td>Steam (Low Pressure)</td>
<td>P-4</td>
<td>Hydrostatic</td>
<td>25</td>
</tr>
<tr>
<td>Steam (Medium Pressure)</td>
<td>P-4</td>
<td>Hydrostatic</td>
<td>90</td>
</tr>
<tr>
<td>Steam (High Pressure)</td>
<td>P-4</td>
<td>Hydrostatic</td>
<td>280</td>
</tr>
<tr>
<td>Steam Condensate</td>
<td>P-4</td>
<td>Hydrostatic</td>
<td>1.5 x max.</td>
</tr>
</tbody>
</table>
Basis of Design

This section applies to the design and installation of pipe, pipe fittings, valves, piping accessories and equipment for plumbing and HVAC systems including potable and laboratory hot and cold water, heating water, cooling water, steam and condensate, HVAC equipment, sanitary and storm drains, rainwater leaders, compressed air, vacuum and gases.

Design Criteria

- Generally, use the following systems for all piping installations. Other systems may be used with coordination and approval by Campus Engineering. Piping installation referenced shall be inside of building to five feet exterior of the building envelope. Outside piping: Refer to Civil sections for utilities.
- Design piping to allow for ample movement and flexibility for expansion and contraction due to temperature changes.
- Provide a service header for every service entering a building. Provide a shutoff valve in the service header piping immediately upon entry into the building. Install all meters, strainers, pressure reducing valves, backflow preventers, major branch connections, etc. at the service header. Provide bypass connections at the service header so that service to the building is continuous when maintenance is performed on the various components.
- Provide valves to permit isolation of portions of the building piping systems for maintenance, alterations, and repair work without shutting down entire systems.
- Provide individual shutoff valves to isolate all equipment from the piping system including pumps, coils, fixtures, fume hoods, bio-safety cabinets, and autoclaves.
- The following table lists typical piping systems with its corresponding symbol, and pipe codes to reference subsequent Products, Materials and Equipment tables. See also Facilities Services Design Guide – Mechanical sections - Water Treatment and Flushing, Plumbing Pressure Testing and HVAC and HVAC Piping Pressure Testing.
- Provide pipe expansion loops wherever possible. If required, manufactured expansion joints or flexible connections may be used. Pipe expansion compensation must be designed and shown on the drawings.
- Example: Potable Cold Water; symbol CW, and pipe code P-1
  1) Pipe code table P-1 lists a maximum operating pressure of 100 lb/in² and maximum operating temperature of 70º F.

<table>
<thead>
<tr>
<th>Piping System</th>
<th>Symbol</th>
<th>Pipe Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acid Resistant Vent</td>
<td>ARV</td>
<td>P-3</td>
</tr>
<tr>
<td>Acid Resistant Waste</td>
<td>ARW</td>
<td>P-3</td>
</tr>
<tr>
<td>Carbon Dioxide</td>
<td>CO2</td>
<td>P-1</td>
</tr>
<tr>
<td>Central Cooling Water</td>
<td>CCW</td>
<td>P-4</td>
</tr>
<tr>
<td>Coil Condensate</td>
<td>CD</td>
<td>P-1</td>
</tr>
<tr>
<td>Piping System</td>
<td>Symbol</td>
<td>Pipe Code</td>
</tr>
<tr>
<td>---------------------------------------------------</td>
<td>--------</td>
<td>-----------</td>
</tr>
<tr>
<td>Compressed Air (Laboratory)</td>
<td>A</td>
<td>P-1</td>
</tr>
<tr>
<td>Compressed Air (Pneumatic)</td>
<td>CA</td>
<td>P-1</td>
</tr>
<tr>
<td>Condenser Water</td>
<td>CNDW</td>
<td>P-1</td>
</tr>
<tr>
<td>Fire Protection</td>
<td>F</td>
<td>P-10</td>
</tr>
<tr>
<td>Heating Hot Water</td>
<td>HHW</td>
<td>P-1</td>
</tr>
<tr>
<td>Helium Recovery</td>
<td>HR</td>
<td>P-1</td>
</tr>
<tr>
<td>Irrigation, Inside Building</td>
<td>I</td>
<td>P-1</td>
</tr>
<tr>
<td>Irrigation, Outside Building</td>
<td>I</td>
<td>P-9</td>
</tr>
<tr>
<td>Laboratory Cold Water</td>
<td>LFW</td>
<td>P-1</td>
</tr>
<tr>
<td>Laboratory Hot Water</td>
<td>LHFW</td>
<td>P-1</td>
</tr>
<tr>
<td>Laboratory Hot Water Circulation</td>
<td>LHWC</td>
<td>P-1</td>
</tr>
<tr>
<td>Laboratory Vacuum</td>
<td>LV</td>
<td>P-1</td>
</tr>
<tr>
<td>Lake Water</td>
<td>LW</td>
<td>P-9</td>
</tr>
<tr>
<td>Medical Gas</td>
<td>MG</td>
<td>P-8</td>
</tr>
<tr>
<td>Medical Vacuum</td>
<td>MV</td>
<td>P-8</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>G</td>
<td>P-5</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>N</td>
<td>P-1</td>
</tr>
<tr>
<td>Oxygen</td>
<td>O</td>
<td>P-8</td>
</tr>
<tr>
<td>Potable Cold Water</td>
<td>CW</td>
<td>P-1</td>
</tr>
<tr>
<td>Potable Hot Water</td>
<td>HW</td>
<td>P-1</td>
</tr>
<tr>
<td>Potable Hot Water Circulation</td>
<td>HWC</td>
<td>P-1</td>
</tr>
<tr>
<td>Process Chilled Water</td>
<td>CHW</td>
<td>P-1</td>
</tr>
<tr>
<td>Propane</td>
<td>P</td>
<td>P-5</td>
</tr>
<tr>
<td>Refrigerant Liquid</td>
<td>RL</td>
<td>P-7</td>
</tr>
<tr>
<td>Refrigerant Suction</td>
<td>RS</td>
<td>P-7</td>
</tr>
<tr>
<td>Reverse Osmosis/De-ionized Water (High Purity)</td>
<td>DI</td>
<td>P-6</td>
</tr>
<tr>
<td>Roof Drain (Rain Leader)</td>
<td>RD</td>
<td>P-2</td>
</tr>
<tr>
<td>Sanitary Vent</td>
<td>V</td>
<td>P-2</td>
</tr>
<tr>
<td>Sanitary Sewer</td>
<td>SS</td>
<td>P-2</td>
</tr>
<tr>
<td>Sea Water</td>
<td>SW</td>
<td>P-9</td>
</tr>
<tr>
<td>Steam (Low Pressure)</td>
<td>LPS</td>
<td>P-4</td>
</tr>
<tr>
<td>Steam (Medium Pressure)</td>
<td>MPS</td>
<td>P-4</td>
</tr>
<tr>
<td>Steam (High Pressure)</td>
<td>HPS</td>
<td>P-4</td>
</tr>
<tr>
<td>Steam Condensate</td>
<td>CNDS</td>
<td>P-4</td>
</tr>
<tr>
<td>Storm Drain</td>
<td>SD</td>
<td>P-2</td>
</tr>
<tr>
<td>Tempered Potable Water (Safety Shower/Eyewash)</td>
<td>TW</td>
<td>P-1</td>
</tr>
<tr>
<td>Trap Primer</td>
<td>TP</td>
<td>P-1</td>
</tr>
<tr>
<td>Well Water</td>
<td>WW</td>
<td>P-9</td>
</tr>
</tbody>
</table>
Design Evaluation

The following information is required to evaluate the design:

- **Programming Phase**: Provide a statement of design intent describing piping systems to be used.
- **Schematic Design Phase**: Provide a basis of design narrative. Provide preliminary location of utility connection(s), header(s), pipe chase(s), fixture(s), pipe legend, and outline specifications. See Mechanical: Commissioning section for items to be included in the basis of design.
- **Design Development Phase**: Provide piping layout plans, controller and header locations, header diagrams, utility connection locations and sizes, and outline specifications.
- **Construction Document Phase**: Provide complete pipe layout and sizes, valve and accessory locations and sizes, utility points of connection and invert elevations, individual riser diagrams for all piping systems (Chilled Water, Central Cooling Water, Condenser Water, Heating Hot Water, Potable and Nonpotable Water, Wastes and Acid Resistant Wastes, Rainleaders, RO/DI, etc.), piping diagrams and details, water header diagram, enlarged mechanical plans where necessary, section drawings detailing underground piping and congested areas showing coordination with equipment from other trades (e.g. above corridors), details for special applications, design calculations, final basis of design (to be used by Test Engineer for Commissioning), and final specifications. If a specification is stated as a function of the “operating pressure”, the operating pressure for that system must be given in the specifications.

Products, Material and Equipment

**Pipe**

- Use industry standards for piping systems specified and comply with the following additional requirements:
- The following tables list the typical service piping, standard operating pressures and temperatures, recommended testing pressures.

<table>
<thead>
<tr>
<th>PIPE CODE P-1</th>
<th>Max Operating Pressure</th>
<th>Max Operating Temp</th>
</tr>
</thead>
<tbody>
<tr>
<td>Service</td>
<td>lb/in2 gage</td>
<td>Deg F</td>
</tr>
<tr>
<td>Carbon Dioxide (CO)</td>
<td>Varies</td>
<td>-</td>
</tr>
<tr>
<td>Coil Condensate (CD)</td>
<td>40</td>
<td>60</td>
</tr>
<tr>
<td>Compressed Air – Laboratory (A)</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Compressed Air – Pneumatic (CA)</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Condenser Water (CNDW)</td>
<td>40</td>
<td>85</td>
</tr>
<tr>
<td>Heating Hot Water (HHW)</td>
<td>Varies</td>
<td>190</td>
</tr>
<tr>
<td>Helium Recovery (HR)</td>
<td>Varies</td>
<td>-</td>
</tr>
<tr>
<td>Irrigation, Inside Building (I)</td>
<td>100</td>
<td>70</td>
</tr>
<tr>
<td>Laboratory Cold Water (LCW)</td>
<td>100</td>
<td>70</td>
</tr>
<tr>
<td>Laboratory Hot Water (LHW)</td>
<td>100</td>
<td>160</td>
</tr>
</tbody>
</table>
### Laboratory Hot Water Circulation (LHWC)

<table>
<thead>
<tr>
<th>Service</th>
<th>Max Operating Pressure</th>
<th>Max Operating Temp</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>lb/in² gage</td>
<td>Deg F</td>
</tr>
<tr>
<td>Laboratory Hot Water Circulation (LHWC)</td>
<td>100</td>
<td>160</td>
</tr>
<tr>
<td>Laboratory Vacuum (LV)</td>
<td>-29 in-Hg</td>
<td>100</td>
</tr>
<tr>
<td>Nitrogen (N)</td>
<td>Varies</td>
<td></td>
</tr>
<tr>
<td>Potable Cold Water (CW)</td>
<td>100</td>
<td>70</td>
</tr>
<tr>
<td>Potable Hot Water (HW)</td>
<td>100</td>
<td>160</td>
</tr>
<tr>
<td>Potable Hot Water Circulation (HWC)</td>
<td>100</td>
<td>160</td>
</tr>
<tr>
<td>Process Chilled Water (CHW)</td>
<td>Varies</td>
<td>60</td>
</tr>
<tr>
<td>Tempered Potable Water (TW)</td>
<td>100</td>
<td>80</td>
</tr>
<tr>
<td>Trap Primer (TP)</td>
<td>100</td>
<td>70</td>
</tr>
</tbody>
</table>

**Sizes**

1/2-inch and larger

---

### Pipe

- Above grade: Copper Type L; Below grade: Copper Type K or ductile iron; CHW & HHW above grade: 2½-inch and larger, black steel. Schedule 40
- Compressed air piping in the tunnels shall be schedule 40, black steel, welded, for larger than 2 inch pipe size and schedule 80, black steel, threaded for 2 inch and smaller pipe size.
- Irrigation outside: See remarks.
- Irrigation piping: All fittings/joints shall be cleaned as for medical gas service (NFPA 99); piping shall be cleaned and capped ACR type.
- Mechanical joints are OK for copper and stainless steel water service piping.

**Wall Thickness**

Standard Weight

**Valves**

Single piece, full flow ball style. Valves should have a packing nut independent of the handle.

**Remarks**

- Irrigation: Refer to Civil – Irrigation section.
- LV: Branch piping section outlet shall connect to top of main.
- Nitrogen piping system shall be brazed under a nitrogen purge.
- Mechanical joints ok only for 2-1/2” and larger CW, LCW, CHW, HHW, CNDW and F piping

---

### PIPE CODE P-2

<table>
<thead>
<tr>
<th>Service</th>
<th>Max Operating Pressure</th>
<th>Max Operating Temp</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>lb/in² gage</td>
<td>Deg F</td>
</tr>
<tr>
<td>Roof Drain (RD)</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Sanitary Vent (V)</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Sanitary Sewer (SS)</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Storm Drain (SD)</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Sizes</td>
<td>All</td>
<td></td>
</tr>
<tr>
<td>Pipe</td>
<td>Above grade: Cast Iron CISPI 301, no hub; Below grade: Cast Iron CISPI 301, hub &amp; spigot. Roof drains shall be cast iron.</td>
<td></td>
</tr>
<tr>
<td>Wall Thickness</td>
<td>Standard Weight</td>
<td></td>
</tr>
</tbody>
</table>
Remarks

Below grade: Refer to Civil sections for utilities.

### PIPE CODE P-3

<table>
<thead>
<tr>
<th>Service</th>
<th>Max Operating Pressure</th>
<th>Max Operating Temp</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>lb/in2 gage</td>
<td>Deg F</td>
</tr>
<tr>
<td>Acid Resistant Vent (ARV)</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Acid Resistant Waste (ARW)</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Sizes All

Pipe

Above grade: Polypropylene; pigmented, flame retardant
Below grade: Polypropylene; pigmented, non-flame retardant

Wall Thickness Schedule 40

Remarks

Above grade: Fusion joints.
Below grade: Fusion joints.
Within laboratory casework (accessible):
Mechanical joints allowed at the connection to the plumbing fixture.

### PIPE CODE P-4

<table>
<thead>
<tr>
<th>Service</th>
<th>Max Operating Pressure</th>
<th>Max Operating Temp</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>lb/in2 gage</td>
<td>Deg F</td>
</tr>
<tr>
<td>Central Cooling Water (CCW)</td>
<td>180</td>
<td>60</td>
</tr>
<tr>
<td>Steam (LPS)</td>
<td>15</td>
<td>259</td>
</tr>
<tr>
<td>Steam (MPS)</td>
<td>60</td>
<td>338</td>
</tr>
<tr>
<td>Steam (HPS)</td>
<td>185</td>
<td>388</td>
</tr>
<tr>
<td>Steam Condensate (CNDS)</td>
<td>Varies</td>
<td>-</td>
</tr>
</tbody>
</table>

Sizes All

Pipe Black steel

Wall Thickness LPS and CCW, larger than 12 inch Standard Weight;
LPS, MPS, HPS and CCW, 2-1/2 inch to 12 inch Schedule 40;
LPS, MPS, HPS and CCW 2 inch and smaller Schedule 80;
CNDS, Schedule 80.

Valves

Campus utility building isolation valves 2 1/2 -inch and larger for CCW, HPS, MPS and LPS service shall be high performance butterfly valves, see remarks.
Inside the building CCW 2-1/2 inch and larger shall be Class 150 or Class 300 butterfly valves. CCW 2 inch and smaller shall be Class 150 or Class 300 ball valves or rising stem gate valves. HPS, MPS,
LPS and CNDS shall be Class 150 or Class 300 rising stem gate valves.

Remarks
2-inch and smaller: Threaded forged fittings; 2½-inch and larger: Butt weld type forged fittings; All steam raised faced flanges, with spiral wound gasket. High performance butterfly valves shall be Class 150 or Class 300, triple offset, steel, lugged style, and gear operated by TYCO, Vanessa; WEIR, Tricentric; or QUADAX VALVES, Inc., no substitutions. Specify 300# or higher rated fittings where Schedule 80 piping is used.

---

### PIPE CODE P-5

<table>
<thead>
<tr>
<th>Service</th>
<th>Max Operating Pressure lb/in² gage</th>
<th>Max Operating Temp Deg F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural Gas (G)</td>
<td>5</td>
<td>-</td>
</tr>
<tr>
<td>Propane (P)</td>
<td>5</td>
<td>-</td>
</tr>
</tbody>
</table>

Sizes All
Pipe Black steel
Wall Thickness Schedule 40
Remarks Above grade: 2-inch and larger butt-welded fittings; 2-inch and smaller threaded fittings allowed. Below grade: Refer to Civil sections for utilities. See EH&S Laboratory Safety Design Guide regarding lab emergency gas shut-off valves.

---

### PIPE CODE P-6

<table>
<thead>
<tr>
<th>Service</th>
<th>Max Operating Pressure lb/in² gage</th>
<th>Max Operating Temp Deg F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reverse Osmosis/De-ionized Water (DI)</td>
<td>100</td>
<td>70</td>
</tr>
</tbody>
</table>

Sizes All
Pipe Polypropylene – non-pigmented
Wall Thickness Schedule 40
Valves Union body, full port, ball style
Remarks Electric fusion joints. Piping shall be continuously supported.

---

### PIPE CODE P-7
## Service

<table>
<thead>
<tr>
<th>Service</th>
<th>Max Operating Pressure</th>
<th>Max Operating Temp</th>
</tr>
</thead>
<tbody>
<tr>
<td>Refrigerant Suction (RS)</td>
<td>High Side: 250</td>
<td>150 Deg F</td>
</tr>
<tr>
<td>Refrigerant Liquid (RL)</td>
<td>Low Side: 90</td>
<td>70 Deg F</td>
</tr>
</tbody>
</table>

### Sizes

| Sizes      | ½-inch and larger |

### Pipe

| Pipe            | Copper, ACR type |

### Wall Thickness

| Wall Thickness | Standard Weight |

### Remarks

<table>
<thead>
<tr>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>No flared connections and fittings.</td>
</tr>
<tr>
<td>Braze piping under nitrogen purge.</td>
</tr>
</tbody>
</table>
### PIPE CODE P-8

<table>
<thead>
<tr>
<th>Service</th>
<th>Max Operating Pressure lb/in² gage</th>
<th>Max Operating Temp Deg F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medical Gas (MG)</td>
<td>Varies</td>
<td>150</td>
</tr>
<tr>
<td>Medical Vacuum (MV)</td>
<td>Varies</td>
<td>70</td>
</tr>
<tr>
<td>Oxygen (O)</td>
<td>Varies</td>
<td>-</td>
</tr>
</tbody>
</table>

Sizes ½ inch and larger

Pipe
Medical Gas and Oxygen: Copper, wall thickness per Code,
Medical Vacuum: Copper Type L,
Piping shall be specially prepared and labeled for medical service, oxygen and vacuum.

Wall Thickness Standard Weight
Remarks

### PIPE CODE P-9

<table>
<thead>
<tr>
<th>Service</th>
<th>Max Operating Pressure lb/in² gage</th>
<th>Max Operating Temp Deg F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Irrigation, Outside Building (I)</td>
<td>100</td>
<td>70</td>
</tr>
<tr>
<td>Lake Water (LW)</td>
<td>Varies</td>
<td>70</td>
</tr>
<tr>
<td>Sea Water (SW)</td>
<td>Varies</td>
<td>70</td>
</tr>
<tr>
<td>Well Water (WW)</td>
<td>Varies</td>
<td>70</td>
</tr>
</tbody>
</table>

Sizes ½-inch and larger

Pipe
Polypropylene or CPVC or PVC if not exposed.
Sea water, outside: HDPE

Wall Thickness Schedule 40
Remarks

### PIPE CODE P-10

<table>
<thead>
<tr>
<th>Service</th>
<th>Max Operating Pressure lb/in² gage</th>
<th>Max Operating Temp Deg F</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Fire Protection (F)</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

Sizes See remarks.
Pipe See remarks.
Wall Thickness See remarks.
Remarks Refer to NFPA and Environmental Health & Safety Design Guide – Sprinkler Protection & Standpipes section.

### Valves
- Provide valves with flanged, grooved or threaded ends. Valves may have solder ends for 2-inch and smaller copper piping. See Mechanical - Piping section.
- Provide gate valves with rising stem and union bonnet for 2-inch and smaller.
- Provide ball valves for 2-inch and smaller pipe and butterfly valves for 2½-inch and larger pipe.
Balancing valves shall be globe type with ports and graduated scale. Balancing valve shall not be used as an isolation valve. All balancing valves shall be sized based on the appropriate flow within the range of the valve not the service pipe size.

Plug valves larger than 2-inch size shall be lubricated type.

Provide check valves on each individual closed loop makeup water system.

Strainers

- Provide wye type strainers in 2-inch and smaller piping.
- Provide basket type strainers in piping larger than 2-inch, except for steam piping.
- Provide wye type strainers in steam piping.
- Strainer body material shall match the piping material.
- Provide strainer screens with a free area not less than three times the free area of the pipe line. Perforations should be 1/16-inch size. Provide stainless steel screens in steam strainers. Provide brass screens in all other strainers.

Installation, Fabrication and Construction

Pipe and Fittings

- Do not install piping below slabs on grade, except for waste and vent piping and associated trap primer piping.
- Provide a minimum of two 90 degree changes in direction at each branch connection, particularly in heating systems, with reasonable pipe lengths to allow for pipe movements.
- Provide unions or flanged connections at equipment for maintenance and repair.
- Provide insulating nipples or flanges between copper and galvanized connections.
- Provide welding outlets where branch piping is smaller than the main. Provide welding tees for all other cases.
- Welders must be certified by the National Certified Pipe Welding Bureau.
- Patch wall/floor openings to match adjacent material after removal of pipe and ductwork.
- Do not provide flexible connections without Campus Engineering approval. Rubber flexible connectors are not acceptable.
- All piping and tubing shall be reamed and all burrs removed.

Pipe Sleeves

- Provide sleeves large enough to allow insulated piping pass through without disrupting the insulation.
- Provide Link Seal, or approved substitution, on all sleeves through exterior walls below grade.
- Provide UL Listed fire-stopping material on all sleeves through fire rated floors and walls.
Valves

- Install valves with the stem vertical. When this is not possible, they may be installed rotated but never less than horizontal under any circumstance.
- Provide isolation valves at each floor.
- Install isolation valves staggered where they come out from a pipe shaft so they are completely and conveniently accessible.
- Install valves with adequate room to permit removal of the bonnet, disk, and trim without removing the valve from the line.
- Provide globe valves where throttling is required, except for balancing valves.
- Provide balancing valves at all pumps, main pipe branches, and all system coils.
- Triple Duty valves are not allowed.
- Discuss the sizing of balancing valves for small coils (less than 1 gpm) with Campus Engineering.

Strainers

- Provide a ball valve and hose-end adapter for blow-down on all wye strainers, except use gate valve on steam and condensate strainers.
- Provide strainers ahead of automatic control valves, steam traps, and in main service piping to buildings. Those steam traps provided for a device having an automatic control valve do not require strainers.

Headers

- Space components apart by at least two pipe diameters between flanges.
- Locate header assemblies approximately 4 feet above the floor.

END OF DESIGN GUIDE SECTION
Basis of Design

This section applies to the design and installation of hangers and supports for HVAC and plumbing equipment, piping and ductwork.

Design Evaluation

The following information is required to evaluate the design:

- **Schematic Design Phase:** Provide a preliminary basis of design narrative.
- **Design Development Phase:** Provide pipe anchor locations, pipe guide locations, pipe roller locations, equipment housekeeping pads size and location, and outline specifications.
- **Construction Document Phase:** Provide pipe anchor locations and details, pipe guide locations and details, pipe roller locations and details, equipment housekeeping pad sizes, locations and details, maximum support spacing, and final specifications.

Products, Material and Equipment

**Hangers**

- Provide hangers rods with a minimum diameter of 3/8-inch.
- Expansion shells are not allowed in new construction. Discuss the use of these devices in existing construction with Campus Engineering.
- Prevent contact between dissimilar metals, such as copper tubing and steel, by use of copper-plated or plastic-coated supports. Use copper-plated supports where supports contact copper tubing. Use electroplated or galvanized steel supports where supports contact steel piping.

**Inserts**

- Provide cast, not stamped, metal concrete inserts in new construction.

Installation, Fabrication and Construction

- Support all equipment, ductwork and piping from the building structure. Do not support material from adjacent equipment, ductwork, piping, or light fixtures.
- Install floor-mounted heat-producing equipment on a non-combustible pad.
- Adjust hangers and supports to provide proper alignment and slope of ducts or pipes.
- At a minimum, provide pipe support at the following locations:
  - As required on straight runs to maintain alignment and slope,
  - Adjacent to fitting at each offset or change of direction,
  - End of branch over five feet long,
  - At each floor penetration,
  - At each valve.
- Do not use perforated strap to hang or support material.

END OF DESIGN GUIDE SECTION
Basis of Design

This section applies to the selection and installation of pumps for hot and chilled water circulation, sump and steam condensate return systems. Not included are vacuum pumps, sewage lift stations, ejectors, air pumps, or piston pumps.

Design Criteria

- Locate pumps where they provide easy service accessibility and isolate them to prevent pumping or vibration source noise from disturbing the surrounding occupied areas. Locate pumps in mechanical rooms wherever possible.
- Provide pumps based on the highest efficiency, nonproprietary products available.
- Provide pumps that allow installation of a larger impeller to meet future requirements whenever possible.
- Provide stand-by pumps when shutdowns can not be tolerated for repairs and maintenance. For example, condensate pump stations, sewer lift stations, and primary pumping loops.
- Provide pumps that operate at 1800 rpm.
- Provide centrifugal-type pumps where the shutoff head is not more than 25% greater than the operating head.
- Provide motors that are not overloaded at any point on the pump’s operating curve.
- Refer to Motors and VFDs and Testing, Adjusting and Balancing sections for additional requirements on systems with variable frequency drives.
- Provide check valves in the pump discharge piping when pumps are operating in parallel, standby, or whenever a reverse flow may occur.
- Provide "lead-lag" start controls for sump and condensate pumps. Provide the ability to manually alternate the pumps on a "lead" start.
- Obtain discharge head information for condensate pumps from the UW Project Manager. There are locations on campus at an elevation lower than the Power Plant. Other locations are gravity return to the Power Plant hot well.
- Condensate pumps stations and sewer lift stations shall have dual pumps with standby power.

Design Evaluation

The following information is required to evaluate the design:

- **Schematic Design Phase**: Provide pump design criteria and location.
- **Design Development Phase**: Provide outline specifications, preliminary pump head calculations, and equipment layout plans.
- **Construction Document Phase**: Provide pump installation details and design calculations which shall include data showing pump impeller diameter and curve. For variable speed pumps include data of pumps at maximum and minimum rpm.

Construction Submittals

- Provide industry standard construction submittals, including pump curve(s) with design conditions plotted.
• Insure that a copy of each pump curve with design conditions plotted is included in the Operations and Maintenance manual.

Products, Material and Equipment

• Provide a pump that is a complete, integrated unit consisting of pump, motor, shaft, coupling, frame and base as manufactured at the factory.
• Pumps: Centrifugal, end suction or horizontal split case type.
• Provide close-coupled pumps up to 1 hp; otherwise provide a frame-mounted type.
• In-line circulators may be used when they can be adequately supported and are easily accessible.
• Provide frame-mounted, not close coupled, chilled water pumps, so that the entire casing and connections may be completely insulated.
• Provide mechanical seals on all pumps, suitable for the intended service.
• Provide certification from the pump manufacturer that the mechanical seals for pumps are suitable for the maximum expected temperature and chemical treatment used.
• Provide pressure gauges upstream and downstream of pump between pump and isolation valves.
• Provide an air vent in the casing of 1 HP and larger pumps.
• Provide vertical shaft-type sump pumps with the motor located above the sump. Do not use submersible pumps.
• Condensate pumps: Preferred is floor mounted, cast iron casing type. Select pump and pump seals for 210°F water without flashing for large condensate applications.
• Provide hot well type pumps with a cast iron or concrete sump.

Installation, Fabrication and Construction

• Specify each pump with separate balancing valves in the discharge piping so the design flow rate may be set.
• Provide each pump with check valves, isolating valves and unions or flanges for easy service removal.
• Provide all pumps with inlet strainers as part of the piping or pump inlet accessories.
• Grout pump base to the concrete equipment pad or inertia base for floor mounted pumps.
• For floor mounted condensate pumps, provide a sight glass and vent. The vent shall terminate outdoors. If an outdoor termination is not convenient, pipe the vent a minimum of 4 feet vertically and terminate at a drain.
• Provide isolation valves between condensate pumps and condensate receiver.
• Minimize pipe/pump flexible connections.
• Verify pump alignment and submit alignment data.

END OF DESIGN GUIDE SECTION
Basis of Design

This section applies to the design and installation of motors and variable frequency drives for HVAC and plumbing systems.

Design Criteria

- The University wants motor driven systems that use "off the shelf" premium efficiency motors so if the motor fails, an appropriate replacement can be located in stock in Seattle. If the Consultant creates a need for an unusual motor (inverter rated, 900 RPM, metric, etc.) it may not be replaced in kind when it fails.

Design Evaluation

The following information is required to evaluate the design:

- **Schematic Design Phase:** Provide a basis of design narrative describing HVAC and/or plumbing systems to be equipped with variable speed drives and any unusual motors.
- **Design Development Phase:** Provide preliminary motor schedule, motor service clearances, VFD locations and service clearances, and outline specifications.
- **Construction Document Phase:** Provide final motor and VFD schedule, motor service clearances, VFD locations and service clearances, and final specifications.

Products, Material and Equipment

**Electric Motors**

- Endeavor to use NEMA rated 1800 RPM motors with Class F insulation when appropriately matched to the driven equipment. Do not select motor speeds requiring V-belt drive reduction ratios greater than 6 to 1.
- Identify the type of control for every motor within the scope of the project.
- Motor bearings shall be factory lubricated for motors less than 1/3 HP. Sleeve bearings will only be permitted for fractional HP motors and where specifically recommended by the equipment manufacturer as the better type of bearing for the application.
- Vertical shaft motors shall be equipped with suitable thrust bearings.
- Shaded pole-type motors ≥ 1/8 HP are not acceptable.
- Motors shall typically be open drip-proof construction. Totally enclosed or explosion proof types shall be provided where conditions dictate.
- Motors shall be sized to operate between 70% and 95% of full motor load when running at full 60 Hz speed. If a larger future load is anticipated, size the motor mounting pad to accommodate the larger anticipated motor frame size.
- Motors that are controlled by VFDs shall have shaft grounding. Approved: AEGIS.

**Variable Frequency Drives**

- Specify VFD manufacturers limited to Allen Bradley, Danfoss, and Yaskawa.
- Most HVAC motors larger than 5 HP will use VFDs for modulation of flow and pressure. Compressors and vacuum pumps may be the only typical exception to this expectation. VFDs, motors and Environmental Controls are all within the Mechanical section to facilitate proper coordination. The Electrical section provides all electric supply equipment and wiring.
to the input of the VFD and the connecting wiring for the VFD, Environmental Control System and motor.

- **By-pass starter**: A manual by-pass starter is typically required when there is no redundancy. The use of a By-pass starter should be discussed with Campus Engineering. Critical-need applications require an automatic bypass feature. In some critical applications, a backup fan or pump and VFD is provided, in which case by-pass starters may not be necessary. The by-pass feature shall be fully isolated. All safeties shall operate in by-pass mode. Manual Start Operation shall operate VFD or bypass starter. A soft start is required for motor 50 hp and greater.

- **Amperage interrupt capacity**: Requirements can vary depending on the electrical system design. The nominal requirement is a 65,000 RMS symmetrical ampere interrupting capacity. Some electric services require less capacity, so the mechanical should coordinate with the electrical designer and comply with the protective device study to determine the appropriate specification.

- **Radio frequency sensitive applications**: A VFD may be installed in the vicinity of highly sensitive research or medical equipment. Radio microphones and sound reinforcement equipment may also be susceptible to RF generated by a VFD. An appropriate FCC rating may be necessary in these applications, and this requirement may result in the use of 6-step or 12-step technology VFDs. Review with Campus Engineering if control and interface requirements in the guide specification cannot be met.

- **Interface with Environmental Control System**: The guide specification requires both hardwire and digital connection to the environmental control system. These requirements should be carefully reviewed and coordinated with the environmental control system specifications.

- **Interface with the Fire/Life safety Systems**: Ensure the Fire/Life Safety system operation sequence is met in Manual, Off, Auto, and Bypass Modes. Verify the correct speed is maintained in all Modes.

- **Sheaves and impellers**: Motor Speed should be used as the adjustment mechanism for balancing critical paths in air and water systems. After testing and balancing is complete, adjust sheaves, impellers and motor sizes as necessary so that the motor operates above 55 Hz and between 70% and 95% of full load amperage when the maximum desired system pressures and flows are produced. When the motor operates in VFD bypass at 60 Hz, system pressures and flows shall not cause problems and the motor current shall not exceed full load amperage. It may be necessary to install pressure protection switches and/or duct blowout panels to protect variable air volume systems from over-pressure. Coordinate these requirements with the Testing and Balancing requirements.

- **Line reactance**: Provide a minimum of 3% input line reactance. This may be provided in the form of separate line reactors at the input of the VFD, reactors included as part of the DC bus or a combination of the two totaling 3% to 5%.

- **Total Harmonic Distortion (THD)**: Specify in the documents that the THD at the point of common coupling for all VFDs connected, shall be less than 5% and to provide required filtering equipment in conjunction with line reactors.

- **Output rate of rise, peak output voltage and wire length**: A primary purpose of the guide specification is to purchase and install VFDs that will not damage typical premium efficiency motors. Implementing the following three requirements will essentially eliminate motor insulation and bearing failures associated with VFD use.
  1. Use output filtering to keep the rate of rise, for each pulse in the output, below 1,000 volts/microsecond.
2) Use output circuitry, which prevents the peak output voltage from reaching 1,000 volts to ground at the motor.

3) Limit wire length to less than 50 feet between the motor and VFD. Demonstrate the 50 foot distance in the contract documents.

- Provide damper control accessory.

Installation, Fabrication and Construction

Electric Motors

- Do not expose motors to the weather. Install motors within the building or in suitable enclosures. If motors are not housed within the building structure, specify totally enclosed type motors, even though a weatherproof enclosure is provided. Provide motor heaters in outdoor enclosures.

Variable Frequency Drives

- Mount the VFD close enough to the motor to keep the wire length below 50 feet (shorter is better). Coordinate with the electrical designer to ensure that this requirement is met. It is also necessary that the VFD be solidly mounted to structural members.
  
  1) Unistrut type structures can be used in most mounting circumstances.
  
  2) Do not mount VFDs directly to the flexible sides of air handling units, plenums or ductwork.
  
  3) Avoid mounting VFDs outdoors, inside plenums, or adjacent to piping that could spray a leak onto the VFD housing. Discuss VFD location with Campus Engineering.

- Verify working clearances within air handling unit service areas. Special manufacturing may be required.
Basis of Design

This section applies to the design and installation of metering and gauges for distributed and building mechanical utilities.

Design Criteria

- Provide shutoff valves and a bypass connection as necessary to allow continuous service when maintenance is performed on the meters.
- Provide monitored meters (connected to building DDC system) on all building domestic water, reclaimed water (if used) and rain water (if used).
- Provide monitored meters on central cooling water, building environmental chilled water, building process chilled water, cooling tower make-up water (deduct) and cooling tower blow-down water.
- Provide monitored meters on natural gas.
- Provide monitored meters on steam/condensate systems.
- Provide monitored meters on all irrigation deduct meters.
- Consult with Campus Engineering for meters and monitored meters of other utilities that are not specifically mentioned above.
- Provide thermometers and "pete's plugs" at all locations where fluid mixing or heat transfer occurs.
- Provide pressure gages at all services entering the building, at pressure-reducing valve outlets, pump inlets and outlets, and on other equipment where required for confirming satisfactory operation.

Design Evaluation

The following information is required to evaluate the design:

- **Programming Phase**: Provide a narrative of the intended metered utilities.
- **Schematic Design Phase**: Provide location of meters. See Mechanical: Commissioning section for items to be included in the basis of design. Provide anticipated use of resources, e.g. water, steam, etc. for comparison in our future reporting.
- **Design Development Phase**: Provide outline specifications and anticipated flow rates for meter size verification.
- **Construction Document Phase**: Provide DDC points list for monitored meters (to be used by Test Engineer for verifying the remote output reading matches the local display).

Construction Submittals

- Submittal data should clearly indicate the meter is suitable for the anticipated operating temperature and flow range.

Products, Material and Equipment
Domestic Water Meters

- Connect meter to the building DDC system. DDC vendor shall verify meter compatibility with their system. The meter shall be sized for the anticipated flow rates.
- Provide a magmeter for all pipe sizes.
- Meter shall be capable of measuring cumulative water consumption measured in cubic feet and be equipped with a local display.
- The meter shall have the ability to be trended and logged in 15 minute increments through the DDC system.

Reclaimed Water and Rain Water Meters

- Connect meter to the building DDC system. DDC vendor shall verify meter compatibility with their system. The meter shall be sized for the anticipated flow rates.
- Provide a meter that is suitable for the water system. A magmeter is the preferred type but other styles will be considered depending on the water quality.
- Meter shall be capable of measuring cumulative water consumption measured in cubic feet and be equipped with a local display.
- The meter shall have the ability to be trended and logged in 15 minute increments through the DDC system.

Central Cooling Water BTU Meters

- Connect meter to the building DDC system. DDC vendor shall verify meter compatibility with their system. The meter shall be sized for the anticipated flow rates.
- Meter shall be an Onicon System-10 BTU Meter, which consists of an insertion flow meter, two temperature sensors and local display panel. The insertion flow meter shall be an Onicon dual turbine Model F-1200.
- Meter shall be capable of measuring supply water temperature, return water temperature, instantaneous flow (gallons per minute), cumulative chilled water use (gallons), instantaneous energy flow (Btu/hr) and cumulative energy use (Btu). All of these points shall have the ability to be trended and logged in 15 minute increments through the building DDC system.

Building Environmental and Process Chilled Water BTU Meters

- The metering for these systems could be similar to the Central Cooling Water BTU meters listed above. Additionally, a cumulative kWh value could be measured for the chiller. This information shall have the ability to be trended and logged in 15 minute increments through the DDC system (or cumulative kWh through the main UW building electrical meter system).

Cooling Tower Make-Up and Blow-Down/Drain Water Meters

- Connect meter to the building DDC system. DDC vendor shall verify meter compatibility with their system. The meter shall be sized for the anticipated flow rates.
- On make-up water pipes, provide a disc, compound or turbine meter for pipe sizes smaller than 3-inches.
- On blowdown/drain pipes, provide a magmeter for all pipe sizes.
• Meter shall be capable of measuring cumulative water consumption measured in cubic feet and be equipped with a local display.

• The meter shall have the ability to be trended and logged in 15 minute increments through the DDC system.

Natural Gas Meters

• Connect meter to either the building DDC system or the main UW building electrical meter system. DDC vendor or UW building electrical meter vendor shall verify meter compatibility with their system. The meter shall be sized for the anticipated flow rates.

• Provide an ultrasonic type flow meter. The meter shall be equipped with a Form A pulse output.

• Meter shall be capable of measuring cumulative gas consumption measured in cubic feet and be equipped with a local display.

• The meter shall have the ability to be trended and logged in 15 minute increments through the DDC or UW building electrical meter.

Steam/Condensate Meters

• Connect meter to the building DDC system. DDC vendor shall verify meter compatibility with their system.

• Where condensate is pumped the meter shall be suitable for hot water temperatures up to 250 degrees F. The meter shall have a local display with output measured in gallons. The meter shall have the ability to be trended and logged in 15 minute increments through the DDC system.

• Where condensate is returned by gravity a temperature compensating steam mass flow meter shall be provided. The meter shall be provided with a local display with output measured in pounds. The meter shall have the ability to be trended and logged in 15 minute increments through the DDC system.

• If a steam mass flow meter can’t be installed a drum type condensate meter (Cadillac) shall be provided. The meter shall be provided with a local display with output measured in pounds. The meter shall have the ability to be trended and logged in 15 minute increments through the DDC system.

Irrigation Deduct Water Meters

• Connect meter to the building DDC system. DDC vendor shall verify meter compatibility with their system. The meter shall be sized for the anticipated flow rates.

• Provide a magmeter for pipe sizes 3-inches and larger.

• Provide a disc, compound or turbine meter for pipe sizes smaller than 3-inches.

• Meter shall be capable of measuring cumulative water consumption measured in cubic feet and be equipped with a local display.

• The meter shall have the ability to be trended and logged in 15 minute increments through the DDC System.

Closed Loop Chilled, Heating Hot Water, and Heat Recovery Systems

• Provide manual meter with local display.
Pipe Accessories

- Provide industrial quality thermometers with thermowell and 9-inch scale length. Provide a scale range of 30º to 240º F in hot water piping, or 0º to 100º F in central cooling water or chilled water piping.
- Provide pressure gages with a 4-inch minimum size and a scale range approximately twice the operating pressure. Show units of measure on the face plate.

Power Monitoring

- Log total runtime and kW/hr energy consumption in 15 minute increments for variable frequency drives and chillers through the DDC system.

Installation, Fabrication and Construction

Meter Local Display

- Verify that remote output reading matches the local display.
- Install the meter local display at a height that allows it to be read while standing on the floor.
- Provide the necessary upstream and downstream pipe diameters lengths for proper operation of the meters.

Pipe and Fittings

- Install thermometers where they can be read from the floor.
- Mount pressure gages on ½-inch size pipe extensions with ½-inch shut off valves.

Duct Accessories

- In fume exhaust ductwork, install two Pete’s Plugs made of non-corrosive material in the exhaust duct at 90º to each other around the circumference for the purpose of pitot tube insertion.
- Provide dedicated adjustable inclined manometer or magnahelic gauge on each air filter installed to indicate filter pressure drop.

END OF DESIGN GUIDE SECTION
Basis of Design

This section establishes minimum seismic design and installation criteria for mechanical components that are permanently attached to the structure and for their supports and attachments.

Design Criteria

- Mechanical nonstructural component seismic design may be specified to be contractor designed.
- The seismic design shall comply with the “Seismic Design Requirements for Nonstructural Components” of the latest edition of American Society of Civil Engineers Standard ASCE/SEI 7, “Minimum Design Loads for Buildings and Other Structures”.
- The design team shall review and approve the contractor-designed seismic system.
- Provide a schedule that lists all equipment, piping, and ductwork that requires seismic restraint.

Design Evaluation

The following information is required to evaluate the design:

Preliminary Design Phase: Provide a description of the project specific seismic restraint system in the design intent narrative.

Design Development Phase: Provide outline specifications. Provide a preliminary schedule that lists all project equipment, piping, and ductwork that requires seismic restraint.

Construction Document Phase: Provide final specifications. Provide a final schedule that lists all equipment, piping, and ductwork that requires seismic restraint.

Construction Submittals

- Submit all seismic structural calculations and shop drawings. Structural calculations and shop drawings shall be stamped and signed by a structural engineer licensed in the State of Washington.
- The mechanical nonstructural component seismic design shall be reviewed and approved by the design team prior to installation.

Quality Assurance

- Provide inspection of all installation by an independent testing lab.

Installation, Fabrication and Construction

- All steel exposed to the weather shall be hot dipped galvanized unless an acceptable alternate coating is specified.
- Powder driven fasteners are not allowable for use to resist seismic loads.

END OF DESIGN GUIDE SECTION
Basis of Design

This section applies to identification of piping, plumbing, ductwork, and equipment. For exterior piping and equipment and any piping exposed to special conditions, the Consultant should go beyond the following requirements.

Design Evaluation

The following information is required to evaluate the design:

- Design Development Phase: Provide outline specifications.
- Construction Document Phase: Provide final specifications.

Products, Material and Equipment

Piping

- Coordinate selection of piping and ductwork labels with selection of insulation jackets for compatibility.
- Piping and ductwork labels shall be made of rugged plastic with permanent adhesive.
- Use lettering large enough to be read from the floor (unless the pipe is too small to accommodate that size of lettering, in which case the size of the lettering will be the largest feasible for the pipe size.)
- Asbestos-free labeling shall read “asbestos free” and shall have white lettering on a blue background. All other piping labels shall have black lettering on a white background unless regulated; the color of the labeling is regulated by safety codes.
- Adhesive arrow bands shall have a background color that is coded in accordance with the following table. If the stated background color is not commercially available, incorporate arrows into the label and provide color coded bands without arrows.

<table>
<thead>
<tr>
<th>Service</th>
<th>Background Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steam</td>
<td>Aluminum</td>
</tr>
<tr>
<td>Condensate</td>
<td>Orange</td>
</tr>
<tr>
<td>Hot Water Heating</td>
<td>Tan</td>
</tr>
<tr>
<td>Central Cooling Water</td>
<td>White</td>
</tr>
<tr>
<td>Potable Cold Water</td>
<td>Dark Blue</td>
</tr>
<tr>
<td>Lab Cold Water</td>
<td>Light Blue</td>
</tr>
<tr>
<td>Potable Hot Water</td>
<td>Bright Yellow</td>
</tr>
<tr>
<td>Lab Hot Water</td>
<td>Dark Yellow</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>Green</td>
</tr>
<tr>
<td>Compressed Air</td>
<td>Black</td>
</tr>
<tr>
<td>Fire Service</td>
<td>Red</td>
</tr>
<tr>
<td>Waste, Soil Vent, Rain Leader, Grey Water</td>
<td>Brown</td>
</tr>
<tr>
<td>Duct</td>
<td>Grey</td>
</tr>
</tbody>
</table>

- For loop piping systems, indicate on the labels whether they are supply or return pipes.
For cooling water pipes connected to the campus tunnel system, state “Central Cooling Water” on the labels. For chilled water pipes connected to a chiller within the building, state “Chilled Water” or “Process Chilled Water” on the labels.

Indicate pressures on labels for steam lines with pressure greater than 20 psig and on all gas lines (such as nitrogen, compressed air, etc.) over 30 psig.

### Plumbing Fixtures

- Labels for non-potable fixtures shall have black ½-inch lettering and yellow background on either self-adhesive waterproof paper, plastic, or vinyl.
- Labels for potable fixtures shall have white ½-inch lettering and sky blue background on either self-adhesive waterproof paper, plastic, or vinyl.

### Valves

- On each valve tag, indicate the size and service.
- Provide bronze valve tags that are 1” x 2½” with lettering 1/4” minimum height. Tags lettering shall be stamped or engraved.

### Equipment

- Give the equipment name and I.D. on each equipment label. Use the identifiers given in the contract drawings.
- Provide laminated black plastic equipment labels with lettering cut through to white background.

### Installation, Fabrication and Construction

#### Piping

- Throughout the project, indicate direction of flow and service at least once in each space, at least once every 20 feet, and at all wall penetrations for all piping.
- Attach piping labels at each end with adhesive arrow bands around the full circumference of the pipe and overlapping at the ends.
- Orient adhesive labels parallel to the pipe, and locate labels where they can be read from the floor or the most likely approach for access.
- On all piping, apply labels stating “asbestos free” at least once in each space, at least once every 20 feet, and within 6 inches of each point of connection with existing piping insulation. Mark the circumference of the new insulation with a black marking pen at each point of connection with existing insulation and draw an arrow from the nearest “asbestos free” to the black line. On the arrow, write with the black marker “terminates here.”

#### Plumbing Fixtures

- Non-potable: Identify all fixtures dispensing laboratory water (intended for research, processing, or other non-domestic uses) in laboratories with cautionary signage placed above or behind the fixture as follows:

```
LABORATORY WATER
DO NOT DRINK
```
- Potable: All fixtures dispensing potable water except restroom sinks, eye washes, drinking fountains and their associated cup/pot fillers, shall be identified by placement of advisory signage as follows:

  POTABLE WATER

Valves
- Tag each valve.

Equipment
- Provide an equipment label for each major piece of equipment. This category includes but is not limited to air handlers, chillers, pumps, fan coil units, and heat exchangers and fans located outside ductwork.
- Information provided on nameplates doesn’t substitute for the equipment labeling requirements of this section.
- Prior to testing, adjusting and balancing, air terminal boxes shall be identified neatly with equipment labels or a permanent black marking pen. Air terminal box identification shall be readable from the floor.
Basis of Design

This section applies to the thermal insulation of piping, ductwork and associated mechanical equipment. Duct liner, AHU insulation, and air terminal box lining are covered under 15C Heating, Ventilation and Air Conditioning.

Design Criteria

- In project scope of work, include re-insulation of any remaining pipes that will be uncovered during asbestos abatement.
- Address any insulation of exterior ductwork or piping thoroughly in the specifications to offer permanent protection from weather. Address any exterior duct and piping insulation explicitly in the specifications.
- Make clear at an early phase in the design which portions of the ductwork are to be lined, so that this information can be reviewed by Campus Engineering.
- Minimize use of fiberglass insulation exposed to airstream. Fiberglass duct liner use should be minimized, and air velocity should be kept to a maximum of 1000 fpm. Ensure insulation specified includes a coating exposed to the airstream such that fiberglass fibers will not degrade and enter the airstream.
- Specify insulation that does not promote or provide a source for mold growth in areas of high humidity (i.e. Outdoor air intakes, shower rooms, etc.)

Design Evaluation

The following information is required to evaluate the design:

- Construction Document Phase: Provide standard industry submittal requirements.

Products, Material and Equipment

Ducts and Piping

- Insulation of ducts and pipes within an outside air plenum or air handler: Use only materials that will not support mold growth in the presence of moisture. This restriction applies to insulation, jackets, adhesives, and any other components of the insulation system. Discuss with Campus Engineering.

Piping

- Removable insulation pads: Provide woven fiberglass jacketing around fiberglass batt insulation, to be attached by stainless steel wire and lacing hooks or Velcro. Use insulation no less than 2 inches thick in removal insulation pads. (The term “pad” is used here because the term “jacket” already has another meaning with regard to insulation systems.)
- Coordinate selection of insulation and insulation jacket for compatibility with mechanical identification products.
- Pipe insulation metal jackets: Provide uniformly ribbed, 0.01-inch minimum-thickness metallic casing with a vapor barrier lining.
- Insulation for steam and condensate piping in tunnels shall be suitable for the temperature with no off-gassing or binder oxidation occurring near the pipe’s operating temperature. Fiberglass insulation shall not be used on tunnel steam and condensate piping.
- Insulation for CCW piping in tunnels shall be cellular glass.
Insulation on refrigerant piping shall be closed cell foam.

Installation, Fabrication and Construction

- Do not insulate ducts and pipes until the corresponding system has passed the required static pressure tests.
- Do not insulate over valve handles, test ports, etc.
- At no extra cost to the Owner, remove and replace any piping or duct insulation that gets wet, dirty, or moldy before the system is turned over to the Owner.
- Remove ripped or otherwise damaged insulation and replace at no extra cost to the Owner. Dented jackets shall be repaired or replaced.
- Do not leave any raw fiberglass fibers exposed.
- Coordinate with other trades to assure there is adequate clearance for uncompressed insulation to the levels specified for pipes and ductwork.

Piping

- Provide continuous piping and plumbing insulation through all types of hangers. Insulate around piping anchors and supports.
- Provide high-density inserts or saddles for pipes through hangers. Provide shields to protect insulation at all hangers. Do not use "Foamglas" for high pressure steam.
- Provide insulation and a vapor barrier jacket on all components of refrigerant suction piping, chilled water distribution systems, rainwater leaders inside the building, domestic and lab cold water pipes, chilled water coil condensate piping, make-up water piping, and any other water distribution system carrying water at less than 55º F.
- Fully insulate chilled water pumps with removable insulation pads.
- Provide insulation at valves and fittings that is of equal thickness to insulation on the pipes.
- In mechanical rooms, provide removable insulation pads for all valves on systems with insulated piping. On actuated valves outside the mechanical rooms, provide either removable insulation pads or removable insulation enclosed in the transport packing by the valve manufacturer to serve also as insulation.
- Provide metal jackets for all new piping insulation in the campus utility tunnels, any piping insulation located in outside air intakes, building plenums, and on all piping insulation less than 8 feet above the finished floor in mechanical rooms.

Ductwork

- Conform to the current “SMACNA Duct Construction Standards”.

END OF DESIGN GUIDE SECTION
Basis of Design

This section applies to the water treatment and flushing of piping and associated accessories and equipment for plumbing and HVAC systems, including potable and laboratory hot and cold water, heating water, cooling water, steam and condensate, HVAC equipment, compressed air, vacuum, gases, and make up water connections to mechanical systems.

Design Evaluation

The following information is required to evaluate the design:

- **Design Development Phase**: Provide an outline specification of the water treatment and flushing program for all required piping systems.
- **Construction Document Phase**: Provide specifications of the water treatment and flushing program for all required piping systems.

Construction Submittals

- Provide industry standard construction submittals. Provide catalog cut sheets including SDS data sheets for chemicals used. List the name and chemical content of all additives, the amount to be added to each piping system, the total volume of each system and schedule of chemical feed.
- Submit a flushing and water treatment plan for each system. Include data sheets for equipment to be provided and parameters set for the procedure; such as media used for flushing, pressure, velocity, temperature, and duration.
- Conduct and submit initial water quality analysis to ensure the onsite water supply is within reasonable expected conditions and as a basis for the overall chemical treatment program.
- For antifreeze systems, provide a report of the manufacturer and specific chemical contents of all additives, the amounts added, the total volume of the system, and the rated freezing temperature for the specified concentration.
- Provide a schedule indicating total volume of each system and targeted tolerable range of test results.
- Provide a list of piping systems requiring chemical treatment and specify treatment.
- Chemical treatment report to include pipe volume for each hydronic system. In addition, the report is to include the total bacteria, corrosion rates and meter readings.

Products, Material and Equipment

- Use industry standard water treatment and flushing products, material and equipment.

Installation, Fabrication and Construction

General

- Water treatment supplier, mechanical subcontractor and the general contractor shall coordinate to execute the flushing and water treatment plan. Integrate the tentative flushing and water treatment schedule in the construction outlook plan.
- Demonstrate to Campus Engineering that flushing and water treatment of the systems meets specifications.
- Maintain a set of drawings on-site for recording and sign-off of each flushed and/or treated section or system. All flushing/cleaning and treatment shall be witnessed and documented with results approved and signed off by an Owner representative.
- After each day of flushing/cleaning and treatment, submit to the Owner a copy of the paperwork recording the raw data, designating the piping system and Pipe Code, and comparing the allowable and actual results.
- Central Cooling Water is treated by the University at the Power Plant. For CCW treatment, fill the CCW system with clean water and notify Campus Engineering and the Power Plant of the system startup date and total system volume.

**Flushing/Cleaning and Treatment Methods**

- Special procedures or temporary modifications may be required to ensure all parts of the system are flushed and receive chemical treatment. Pay particular attention to piping dead legs and back-up equipment (back-up chiller, back-up pumps, etc.). Return all systems to intended operating conditions after successful completion of the procedure.
- Hydrostatic or water flush: Use clean, fresh city water. On gas piping, remove water from the entire systems after flushing and use the following pneumatic cleaning method to dry the system.
- Pneumatic cleaning: Blow clean, dry and oil-free air or nitrogen through the system.
- Water flush: Flush piping with water until effluent is clean and contains no visible particulate matter. Flushing pressure shall not exceed maximum operating pressure specified in pipe codes. Flushing water supply shall have sufficient capacity to produce a flow velocity of 6 ft/s in largest pipe size with pipe full. Provide flow measurement in flushing water supply line to be used as basis for verification of flow velocities in piping system. Clean all strainers after flushing.
- When required, piping and tubing shall be disinfected. Example systems are CW, HW, HWR, LCW, LHW, and LHWR.
- Extension of water treatment program: Contractor shall be responsible for the continuation of a water treatment program for a period of one year following the date when the system is put into intended normal operation. The extended program shall include monthly water quality tests, reports, and scheduled chemical feed to maintain water quality within tolerable ranges.
- The following table lists the typical piping system, pipe code and corresponding recommended cleaning method.

<table>
<thead>
<tr>
<th>Piping System</th>
<th>Pipe Code</th>
<th>Cleaning Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acid Resistant Waste</td>
<td>P-3</td>
<td>-</td>
</tr>
<tr>
<td>Carbon Dioxide</td>
<td>P-1</td>
<td>Pneumatic</td>
</tr>
<tr>
<td>Central Cooling Water</td>
<td>P-4</td>
<td>Water Flush</td>
</tr>
<tr>
<td>Coil Condensate</td>
<td>P-1</td>
<td>Water Flush</td>
</tr>
<tr>
<td>Compressed Air (Laboratory)</td>
<td>P-1</td>
<td>Pneumatic</td>
</tr>
<tr>
<td>Compressed Air (Pneumatic)</td>
<td>P-1</td>
<td>Pneumatic</td>
</tr>
<tr>
<td>Condenser Water</td>
<td>P-1</td>
<td>Water Flush</td>
</tr>
<tr>
<td>Fire Protection</td>
<td>P-10</td>
<td>(1)</td>
</tr>
<tr>
<td>Heating Hot Water</td>
<td>P-1</td>
<td>Water Flush</td>
</tr>
</tbody>
</table>

© University of Washington – Campus Engineering 2015
<table>
<thead>
<tr>
<th>Piping System</th>
<th>Pipe Code</th>
<th>Cleaning Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Helium Recovery</td>
<td>P-1</td>
<td>Pneumatic</td>
</tr>
<tr>
<td>Irrigation</td>
<td>P-9</td>
<td>Water Flush</td>
</tr>
<tr>
<td>Laboratory Cold Water</td>
<td>P-1</td>
<td>Water Flush (3)</td>
</tr>
<tr>
<td>Laboratory Hot Water</td>
<td>P-1</td>
<td>Water Flush (3)</td>
</tr>
<tr>
<td>Laboratory Hot Water Circulation</td>
<td>P-1</td>
<td>Water Flush (3)</td>
</tr>
<tr>
<td>Laboratory Vacuum</td>
<td>P-1</td>
<td>Pneumatic</td>
</tr>
<tr>
<td>Lake Water</td>
<td>P-9</td>
<td>Water Flush</td>
</tr>
<tr>
<td>Medical Gas</td>
<td>P-8</td>
<td>Pneumatic (2)</td>
</tr>
<tr>
<td>Medical Vacuum</td>
<td>P-8</td>
<td>Pneumatic (2)</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>P-5</td>
<td>Pneumatic (2)</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>P-1</td>
<td>Pneumatic</td>
</tr>
<tr>
<td>Oxygen</td>
<td>P-8</td>
<td>Pneumatic (2)</td>
</tr>
<tr>
<td>Potable Cold Water</td>
<td>P-1</td>
<td>Water Flush (3)</td>
</tr>
<tr>
<td>Potable Hot Water</td>
<td>P-1</td>
<td>Water Flush (3)</td>
</tr>
<tr>
<td>Potable Hot Water Circulation</td>
<td>P-1</td>
<td>Water Flush (3)</td>
</tr>
<tr>
<td>Process Chilled Water</td>
<td>P-1</td>
<td>Water Flush</td>
</tr>
<tr>
<td>Propane</td>
<td>P-5</td>
<td>Pneumatic</td>
</tr>
<tr>
<td>Refrigerant Liquid</td>
<td>P-7</td>
<td>Pneumatic</td>
</tr>
<tr>
<td>Refrigerant Suction</td>
<td>P-7</td>
<td>Pneumatic</td>
</tr>
<tr>
<td>Reverse Osmosis/De-ionized Water (High Purity)</td>
<td>P-6</td>
<td>Water Flush</td>
</tr>
<tr>
<td>Sea Water</td>
<td>P-9</td>
<td>Water Flush</td>
</tr>
<tr>
<td>Steam (Low Pressure)</td>
<td>P-4</td>
<td>Water Flush</td>
</tr>
<tr>
<td>Steam (Medium Pressure)</td>
<td>P-4</td>
<td>Water Flush</td>
</tr>
<tr>
<td>Steam (High Pressure)</td>
<td>P-4</td>
<td>Water Flush</td>
</tr>
<tr>
<td>Steam Condensate</td>
<td>P-4</td>
<td>Water Flush</td>
</tr>
<tr>
<td>Tempered Water (Safety Shower/Eyewash)</td>
<td>P-1</td>
<td>Water Flush</td>
</tr>
<tr>
<td>Trap Primer</td>
<td>P-1</td>
<td>Water Flush</td>
</tr>
<tr>
<td>Well Water</td>
<td>P-9</td>
<td>Water Flush</td>
</tr>
</tbody>
</table>

(1) Refer to NFPA and Environmental, Health & Safety - Fire Protection System section for information.
(2) Refer to NFPA for additional information.
(3) Refer to City/County Department of Public Health for cleaning, disinfection, bacteriological testing, and additional information. Contact Owner prior to testing.

END OF DESIGN GUIDE SECTION
Basis of Design

This section applies to the design and installation of noise and vibration control components for HVAC and plumbing systems.

Design Criteria

- Select duct velocities to meet N.C. requirements of each occupied space. NC level requirements shall be identified in the Basis of Design narrative. Coordinate required NC levels with University Project Manager and users.

- Noise criteria should be the following: Office space: NC level 35, Laboratory space: See EH&S Laboratory Safety Design Guide, Classroom: See Classroom Services section. Identify NC levels for spaces on the design documents.

- Many campus buildings have vibration-sensitive equipment such as electron microscopes. Establish acceptable vibration criteria early in the technical program so that equipment, piping, and ductwork that require vibration isolation can be identified. Provide a table in the design documents which lists the vibration isolation requirements for piping, equipment, and ductwork.

- Analyze mechanical system equipment sound levels to control noise transmission. Select all mechanical equipment to meet the noise criteria (NC) requirement of each occupied space. Identify NC level requirements in Contract Documents. Coordinate required NC levels with University Project Manager and users.

  1) Minimize the use of fiberglass liner inside ventilation ducts. Do not install liner between the supply fan cooling coil and the terminal unit. Do not install liner on outside air intake ductwork. Minimize liner in the return air duct. Do See Ductwork and Duct Accessories section. Consult with Campus Engineering if noise control is a concern.

  2) Reduce fan and air noise by the use of sound attenuators, round or oval ducts, where feasible, instead of rectangular, as well as larger ducts and fans at lower RPM.

  3) Duct liner downstream of the terminal box is acceptable to mitigate cross-talk noise between rooms.

  4) Insulate fan powered boxes with fiberglass and a hard, cleanable surface exposed to the air stream.

  5) Existing HVAC systems with fiberglass liner in good condition may be left in place until the entire building is renovated.

  6) Identify when floating slab are required for acoustical isolation and review options with Campus Engineering.

- At University of Washington Medical Center projects, ductwork sound lining is not acceptable.

- Provide acoustic treatment in mechanical room walls and ceilings if adjacent areas will be affected by noises generated in the mechanical room. Coordinate interior finishes with Architect.

- Avoid “Floating Slabs” i.e., slabs that are acoustically isolated from the structural slab with insulation between the two slabs. These slabs are usually constructed before the building is “closed in” or protected from rain. Consequentially they are exposed to rain which saturates the insulation, making the acoustical performance ineffective and providing a breeding place for mold and mildew. Consult with Campus Engineering if floating slabs are considered.

Design Evaluation
The following information is required to evaluate the design:

- **Programming Phase:** Establish acceptable vibration criteria for vibration sensitive equipment.
- **Schematic Design Phase:** Provide a preliminary basis of design narrative and identify noise criteria levels for each occupied space.
- **Design Development Phase:** Provide a schedule listing vibration isolation requirements, including isolator type and model number, isolator loading and deflection. Provide a schedule listing equipment sound power levels. Provide outline specifications.
- **Construction Document Phase:** Provide a schedule listing vibration isolation requirements for equipment, piping and ductwork, including isolator type and model number, isolator loading and deflection. Provide a schedule listing equipment sound power levels. Provide final specifications.

**Construction Submittals**

- Provide catalog cut sheets of all noise and vibration control components, including rubber-in-shear isolators, spring isolators, neoprene pads, inertia bases, flexible connectors, and sound attenuators. Identify isolator mounting deflections, spring diameters, compressed spring heights at rated load, and equipment operating speed.
- Coordinated shop drawings provide by the contractor shall be reviewed by the design team, specifically the acoustical consultant, to verify systems shown on the shop drawings will meet noise/vibration criteria set by the consultant during design. Any revisions to systems and equipment causing variance from the approved shop drawing noise/vibration design shall be reviewed and approved by the acoustical consultant.

**Products, Material and Equipment**

**Vibration Control**
- Provide spring-type or rubber-in-shear vibration isolators for rotating equipment on grade.
- Provide spring-type vibration isolators and inertia bases for rotating equipment in areas not on grade.
- Provide springs that are large diameter, stable type which do not require guides or snubbers.

**Noise Control/Acoustic Treatment**
- If sound attenuators are used, pack-less types are strongly recommended.
- Fan powered boxes that have lining exposed to the air stream shall have a cleanable surface.

**Installation, Fabrication and Construction**

**Vibration Control**
- Do not make rigid connections between rotating equipment and the building structure that short-circuit vibration isolation systems.
- Provide slack electrical circuit connections to isolated equipment.
- Verify mounting systems are not resonant with supported equipment forcing frequencies.
- Level vibration-isolated equipment while equipment is under full operational load.
- Do not use vibration isolation components to correct misaligned sections of pipe.
END OF DESIGN GUIDE SECTION
Basis of Design
This section applies to the design and installation of refrigerated walk-in coolers, walk-in freezers, environmental rooms and cold rooms.

Programming
- How will the cold/environmental room be used? The future users of the cold/environmental room must explain, in detail, how the room will be utilized. Include current and future expectations. Consider long-range goals during design.
- What is the required size of the cold/environmental room? When determining room dimensions, consider the wall thickness required to maintain cold room temperatures. Do not locate mechanical and electrical systems above the cold/environmental room.
- If a cold/environmental floor height is 4 to 6 inches higher than the building floor, provide a ramp or depressed slab.
- What are the cold/environmental room temperature requirements? What are the maximum and minimum temperatures required? How quickly must operating temperatures be achieved? What is the temperature control range? For instance, a ± 2°F control range requires the installation of a specific type of control system.
- What are the cold/environmental room humidity requirements? If cold/environmental room operating temperature is approximately 32°F, humidity is difficult to control.
- What will the refrigeration loading be? If refrigeration load is constant, the refrigeration equipment is sized for wall and infiltration losses. If large objects are to be cooled or frozen, will a larger-capacity refrigeration system be required? Consider the frequency of door opening/closure as part of the system design.
- How important is cold/environmental room reliability? Refrigeration equipment will eventually fail and leave the cold/environmental room without temperature control. Can this be tolerated or is standby equipment required? If reliability is extremely important, provide standby power.
- Is constant monitoring of cold/environmental room required? Is a contract with ADT or Sonatrol necessary? Who is the contact when the unit does fail?
- Where will the compressor be located? Do not locate compressors on top of pre-fabricated cold/environmental rooms. Provide an equipment space immediately adjacent to the cold/environmental room. The compressor may then be mounted on the wall, providing usable floor area. Consider sound level requirement with the compressor location.
- Will people be working in the cold room? Must the cold/environmental room be ventilated? Will air need to be exhausted from the room? Contact Campus Engineering and EH&S.
- What are the limitations on air velocities?
- Is the evaporator positioned to direct air at the door (Reduces incoming air)?
- What utilities are required inside the cold room? Interior water and waste utilities may require freeze protection.
- How is the access to equipment/piping/ductwork above the cold room/environmental room ceiling provided?

Design Criteria
- See Refrigeration section for design criteria.
• Provide environmental control chambers/refrigerated rooms with frost/fog-free viewing windows, an internally actuated panic alarm system for personnel protection, a temperature limit alarm (automatic) with audible and visual signals, and two contacts for remote monitoring.

• Provide positive pressure ventilation for environmental rooms to avoid condensation. If exhaust is required, provide neutral pressure.

Design Evaluation

The following information is required to evaluate the design:

• Schematic Design Phase: Provide equipment locations; system definition and design criteria developed by the users, names of responsible Mechanical Design Engineer, Refrigeration Shop Supervisor, and Campus Engineering representative.

• Design Development Phase: Provide design calculations, equipment sizing criteria, room dimensions, insulation type and thickness, equipment lists, operation sequence, control diagram and piping plans.

• Construction Document Phase: Provide one-line diagrams, pipe sizing, descriptive literature with capacities for each piece of equipment and appropriate selections marked. Capacity balance curves shall be included to show operating balance conditions for matching components.

Construction Submittals

• Provide equipment product data.

• Provide control schematics, sequence of operation, and location of controls.

• Provide standard industry submittal requirements.

Installation, Fabrication and Construction

• See Refrigeration section for installation, fabrication and construction.

END OF DESIGN GUIDE SECTION
Basis of Design

This section applies to mechanical cooling systems for Computer Server Rooms.

In support of the UW's efforts to meet its climate goals and objectives, no new server rooms or upgrades are to be designed into new or existing buildings on any of the campuses of the University of Washington. A server room is defined as a separate or shared space used to store, power, and operate computer servers and their associated components in support of business functions. Business functions are all of the activities that support the work of the University, whether academic, administrative, research, or clinical in nature.

This policy is effective immediately and applies to all University campuses, schools, colleges, and departments, including those in partnership with the University through affiliations, and third-party entities operating in University facilities. Campuses, schools, colleges, and departments are henceforth directed to work with the UW Information Technology (UW-IT) unit on solutions for meeting technology requirements.

University policies, standards, guidelines, and procedures institute controls that are used to protect and operate University assets and resources efficiently and effectively. While every exception to a policy or standard weakens the overall efficiency goals and intent of the policy, occasional exceptions may be necessary. See UW Administrative Policy Statement 17.1 which defines the process for the review, approval, and time limit of exceptions to this policy statement.

If the exception is granted, please contact Campus Engineering to obtain FSDG section that outlines design criteria for computer server room design.

END OF DESIGN GUIDE SECTION
Basis of Design

University of Washington Specific Controls Features

The following items are specific to the University of Washington:

- The goal is to move from pneumatic to DDC controls. This goal shall be evaluated by the consultant against limitations in project budget and schedule. Work with Campus Engineering on a project-by-project basis to determine how these goals are to be balanced on a given project.
- Hard-wired fan high-limit pressure switches and low-limit freeze stats provided as back-up to software-based freeze-protection algorithms.
- Control system return to normal operation unmanned in stages after a power outage or fire alarm.
- Access to control system provided from both local and remote sites.
- On new construction, coordinate with Architect to provide a dedicated, ventilated, well-lit, and secure control room to house the environmental control system's main terminal, operating manuals, and mechanical drawings.
- On retrofit projects, work with Campus Engineering to decide what type of space and front-end equipment the control shop will need to operate the system.
- Coordinate with electrical to provide appropriate power to the Local Operators Station (LOS), an Ethernet connection for remote communication on the UW Facility Network, and phone for remote access by the control shop.
- On remodels and expansion projects, consult with Campus Engineering on how to coordinate new and existing controls.
- In project specifications, coordinate with piping specialties to assure there is a test port at each piping sensor.
- Much of the labor required for commissioning is provided by the Control Contractor. Coordinate control specifications with commissioning requirements in other specification sections so that the control system is operated by the Control Contractor for all commissioning tests that require the control system.

Interfacing the DDC with Equipment Built-In Controls

- Indicate the relationship between the environmental control system and the dedicated (built-in) controls for specific HVAC equipment such as chillers, heat pumps, furnaces, and boilers.
- Use built-in controls provided under other sections of the project specifications to handle staging and coordination of parts within each major piece of equipment. This provides a sole source of responsibility for the equipment's performance to avoid damage to the equipment, to increase safety, and to increase Contractor and manufacturer responsiveness during problem solving.
- The building’s environmental control system may offer monitoring and enable the local controls for “on/off.” Review with Campus Engineering which parameters should be monitored by the environmental control system.
- Operation of multiple supply terminal boxes in a single zone presents special problems. Discuss with Campus Engineering.
• Make sure any equipment submittals and on-site testing cover the interface between built-in controls and the building’s environmental control system.

Interfacing the DDC with Fire Alarm

• Only the fire alarm system should control life safety fans such as those serving atrium, elevator shaft, and dedicated smoke control. Likewise, only the fire alarm system should control the smoke dampers at air handler inlet and discharge. Fire smoke damper position is not monitored by the environmental controls so the fire alarm system should not release the fans to run until those dampers are open. The fire alarm system should directly shut down all environmental fans over 2,000 cfm and that shut down authority should be effective for all positions of the local HOA or VFD controls. The environmental control system shall not control fans after shutdown by the fire alarm system until after reset of the fire alarm system. Toilet and other non-recirculating exhaust fans shall remain on unless this creates a problem of excessive pressure on exit doors. Fume hood fans shall remain operating. Consult with EH&S for further information.

• Smoke/fire dampers and smoke/fire damper actuators are to be specified under the air distribution system, not under control specifications. The University of Washington promotes use of pneumatic actuators and copper pneumatic lines for smoke/fire dampers. Coordinate control specifications to provide pneumatic lines to any pneumatic smoke/fire damper actuators specified under other sections.

• Specify provision for a current switch for fire alarm system "run status."

Interfacing the DDC with Emergency Power

• In buildings where mechanical systems operate under DDC control in emergency power conditions, the environmental control system shall monitor the fire alarm panel to determine when the building is under a fire alarm condition. The Environmental Control System shall monitor the appropriate emergency power transfer switch to determine when there is loss of normal power and restoration of normal power.

• Specify a restart schedule indicating equipment start-up priority.

PART 1 - INSTALLATION, FABRICATION AND CONSTRUCTION

1.01 SCOPE

Specify provision for an operational, distributed processing control system, including all software, licensing, and equipment necessary for stand-alone operation of each system. Specify provision for all software, licensing, and hardware necessary for communication among controllers and Local Operator’s Stations (LOS) via local building LAN provided by the DDC vendor. Specify provision for all software, licensing, and hardware necessary for communication between building and Remote Operator’s Stations (vendor’s central campus server) via campus Ethernet. Vendor is required to provide all parts and labor required in establishing a complete and workable system.

1.02 GENERAL

This section includes controls for heating, ventilation, air conditioning systems, laboratory ventilation systems, metering and interfaces to other systems such as fire alarm systems, as well as other
interfaces to other mechanical systems, plumbing systems, electrical systems, etc. for miscellaneous control and monitoring. All materials and equipment used shall be new, standard components, regularly manufactured and not custom-designed or fabricated specifically for this project. All components and software shall have been previously tested and proven in regular use. The HVAC control system shall possess a modular architecture, permitting expansion through the addition of more distributed processing units, input/output units, sensors, actuators and operator stations. Vendor shall submit and receive approval for all submittals including materials, floor plan, schematics, programming, and mechanical equipment/systems graphics prior to installation.

1.03 APPROVED MANUFACTURERS

Specify provision for an HVAC control system by Siemens Industry Building Technologies Issaquah Branch, Johnson Controls Bothell Branch or Alerton by ATS Automation (no substitutions). New equipment and software shall be selected for compatibility with systems presently installed on campus. Specify that the controls vendor shall provide all software, hardware, and licensing upgrades to allow new controls to work with both old and new control systems. Design, component selection, installation, project specific programming, technical checkout/startup documentation, testing, training and warranty service shall be the direct responsibility of the controls vendor. These services shall be provided from a business address located within 50 miles of the project site. HVAC control system components purchased and installed by a third-party contractor, that is not the selected controls vendor for the project as chosen from the three allowable control vendors, shall not be allowed. When providing additional controls in a building that has an existing DDC system, specify that the additional controls shall be the same as the existing DDC system. More than one control vendor in the same building is not acceptable.

1.04 SUBMITTALS

Schedule of Prerequisite Submittals: Specify provision for the submittal of the proposed graphics, the point-to-point (PTP) and sequence-of-operation verification test plans at least 90 days prior to the scheduled beginning of testing. PTP testing shall be part of the construction schedule.

- Resubmit all materials which, in the Owner’s opinion, have become substantially changed as a result of the review process.

Programming Code: Specify provision for a print-out of the programming code (Algorithm).
- Show initial setpoints.
- Specify provision for all documentation and software necessary to interpret programming related submittals.

Sequences of Operation: Specify provision for project specific highly detailed prose sequences of operation detailing all control strategies, including initial setpoints and referencing all points by the point name used in the DDC controls programming. (These sequences of operation will also be provided in the construction and record drawings.)

Controls Drawings: Specify provision for a complete set of reproducible control drawings using computer aided design and drafting (CADD) technology. Include the following information:
- Show general physical arrangement of component devices installed in the panels. Indicate applicable detailed drawing reference.
- Specify provision for a typical schematic drawing of each control circuit.
Identify equipment and devices by the reference designations shown on the drawings and by unique point identification used in system software. Provide material list with or on each drawing.

Supply block diagrams and schematics showing riser diagrams, the layout of equipment, communication cabling, and wire type.

Specify provision for electric ladder diagrams that coordinate with each system’s sequence of operation and systems diagram.

Specify provision for schematics showing the general mechanical system layout with all sensors/devices of each mechanical system.

Specify provision for floor plan drawings showing the general location of all controlled equipment and devices used for sensing and control.

Specify provision for a schematic drawing of each control circuit, complete with individual wire identifications. Typical drawings are acceptable.

Specify provision for all graphic display designs for Owner’s approval.

Specify provision for LAN trunk riser diagram showing cable routing and location of all repeaters.

Equipment List, Cutsheets, Damper and Valve Schedules: Specify provision for a complete list of equipment to be furnished, which includes a manufacturer’s catalog sheet for each item on the material list. Care shall be taken in the preparation of catalog cut sheets. Digital format is preferred.

Catalog cut sheets shall be digital and indicate item being submitted.

Supplement catalog sheets as necessary to fully describe the device being furnished. Include information to aid the Owner in judging the suitability of each device.

Specify provision for a damper schedule with one line per damper. Provide for each damper: The project TAG, the size, the model of the damper, the model of the actuator, and whether the damper fails open, closed, or in place. Indicate whether the actuator is electronic or pneumatic.

Specify provision for a valve schedule with one line per valve. Provide for each valve: The project TAG, the size, the model of the valve, the pressure rating, the model of the actuator, the valve Cv, and whether the damper fails open, closed, or in place. Indicate whether the actuator is electronic or pneumatic.

Submit sizing calculation data for pneumatic air dryer for approval, if used.

Testing Plan: Specify provision for a detailed test plan describing the specific procedures used to complete and document the “Owner-witnessed Testing” described in the Final Acceptance requirement.

Test plans shall include a complete schedule for tracking each phase of the testing, e.g. zone testing by floor, fan testing by system, chiller interface testing, heating system testing, etc.

The vendor is required to supplement the planned work effort to meet the progress dates given in the schedule.
As part of the submittal process, the vendors including the engineer assigned to programming the system shall meet with representatives of the Owner’s engineering and operations divisions, giving them a thorough briefing on the DDC programming design. This briefing shall describe in detail the methods the control programmer has used to meet the requirements of the sequence of operations.

1.05 SYSTEM STARTUP AND COMMISSIONING

**Startup:** Specify that the controls vendor shall provide complete and documented startup services for the controls systems, including verification of interfaces to other equipment and systems as specified.

- The Contractor shall provide complete startup services of the DDC controls systems to provide a fully functioning system to meet the design requirements. The Contractor shall then demonstrate compliance of the system installation, setup, operation, stability, and documentation via the Owner-Witnessed point to point testing and then through the commissioning process as demonstrated to the Owner and the Commissioning Authority for the project.

- Specify that controls vendor shall provide staff and materials to conduct the point-to-point testing, also referred to as Owner-Witnessed Testing and then for the commissioning process.

- The Contractor shall perform their own preliminary point-to-point, and commissioning functional performance “pretests” before the witnessed tests, and shall fill out data sheets during pretests, as a prerequisite, to demonstrate successful performance prior to witnessed tests.

**Owner-Witnessed Point to Point Testing Demonstration:** Demonstration of the point to point testing shall be conducted by commanding system points via the graphics screens and witnessing that the actual component, in the field, responds appropriately to the command and the actual state of the point is accurately reflected in the controls system. Physical verification or commanding from other software tools shall be allowed as a substitute verification method only where the control point is not available on the graphics or where the test function cannot be completed through the graphics.

- Verify operation, location and identification of power sources, including circuit breakers and control power transformers.

- Start/stop points: Issue start and stop commands. Verify that controlled equipment responds appropriately and that the start/stop status is indicated.

- Analog points: Analog inputs and outputs shall be verified at both extremes of their ranges and at the midpoint. Verify tight shutoff and full opening of dampers and valves.

- Binary points: Verify that both commanded conditions (on/off, open/closed, etc.) are achieved.

- Fan and pump run status points: Test fan and pump run status feedback by turning off the motor at the HOA switch and observing the run-state indication at the operator station. For motors controlled by variable frequency drives, verify that the motor speed matches the speed signal sent from the controls system, and that minimum speed is coordinated between the controls signal and the VFD’s minimum speed setpoint, such that the “%” speed signal from the controls system matches the “%” speed signal displayed at the VFD throughout the entire speed range.

- Temperature points: Verify accuracy of sensors by comparing displayed temperature values with the reading of an independent measuring device located in the same flow. Test liquid temperature sensors as installed in piping thermowells to verify effectiveness of heat conducting compound. [NOTE: Specify within the piping specialties section the requirement for self-healing-type pressure/temperature test ports to be located near all pipe sensors for the purpose of verifying the controls system temperature sensor calibration].
• Relative humidity points: Verify accuracy of sensors by comparing displayed RH with the reading of an independent measuring device located in the same flow stream.

• Gas concentration points: Verify accuracy of sensors by comparing displayed gas concentration level; (CO2, CO, NOx, etc.) with the reading of an independent measuring device located in the same flow stream. Alternately, the reading through the controls system can be compared to the known, pre-mixed gas concentration of a calibration bottle kit, made specifically for calibration verification of that sensor model when hooked up to that sensor.

• Pressure points: Verify accuracy of sensors by comparing displayed pressure with the reading of an independent measuring device located in the same flow stream. Retain the services of the balancer as required to confirm readings. [NOTE: Specify within the piping specialties section the requirement for self-healing-type pressure/temperature test ports to be located near all pipe sensors for the purpose of verifying the controls system pressure sensor calibration]

• Flow points: Verify that the sensor meets at least the manufacturer’s minimum installation direction requirements to ensure proper and accurate operation. Verify accuracy of sensors by comparing displayed flow with the reading of an independent measuring device located in the same flow stream. Confirm that the flow units are displayed correctly through the controls system. Retain the services of the balancer as required to confirm readings.

• Control valves and dampers: Verify that the controlled device operates in the direction per the command (open and close), has full range of commanded stroke, and has tight shutoff. For control valves, verify tight shutoff by comparing water or air temperatures entering and leaving the heat transfer device. For pneumatic actuators used in modulating applications, verify that the pilot positioners are set up to achieve the full range of commanded positions with tight shutoff. Ensure that the position of multiple operators provides simultaneous modulation of damper or valve assemblies.

• Safety switches: Safety switches, such as freezestats and pressure limit switches, shall be tested by simulating fault condition at the sensor (i.e. – applying pressure to the high pressure port of a high pressure limit switch using a hand squeeze bulb and manehelic pressure gauge, or dipping the last 24” of a freezestat bulb into an ice water bath). Confirm that the switch makes as expected and that it is properly interlocked to the associated equipment to shut it down whether the equipment is in its HAND, OFF, OR AUTO operating mode. Also verify that the status of the switch is correctly identified through the controls system.

Commissioning Functional Performance Testing: Specify that the controls vendor shall provide assistance, staff, and materials to support all of the commissioning activities, including functional performance testing.

• This includes all testing apparatus in use by the vendor to test and calibrate or verify calibration of the control system and all other apparatus for which the vendor has control or calibration responsibility.

• Assistance includes but is not limited to reviewing test procedures and providing software enhancements to accommodate testing methods.

• Controls vendor shall operate the control system for any commissioning tests specified in other specification sections. Testing shall be performed by the manufacturer or its local representative, witnessed by the Owner and demonstrated to the Commissioning Authority.

• The procedure for the test must provide a format for documenting the results, comments, vendor repair activity, vendor’s initials, and retest witnessing. Specify provision for data sheets with one
line for each physical point on the system, and columns to record the results, dates, and initials of witnesses for both pretests and witness tests.

- The complete local operator station, including all controls software and programming development, shall be installed and made available to support the point-to-point testing and commissioning activities.

- Demonstrate the capability of the controls system to execute the complete sequence of operation as given in the mechanical design documents, including all modes of operation, all alarm and failure responses, all interfaces to other equipment and building systems, and all enhancements necessary, as found during the functional performance testing, to make the systems function properly and to meet the design intent.

- Control signal stability, general: Demonstrate that control loops are tuned so that the output does not change until the controlled system has had time to respond to the last output signal.

- Control signal stability, response to step input: Demonstrate that control loops are tuned so that they are stable without excessive hunting following a step input of not less than 20% of the operating/reset range of the controlled variable.

- Control signal stability, floating point devices: Verify that minimum pulse output duration is no less than the value required to assure repositioning of the controlled device. For each floating point actuator, ensure that the control system parameters are set up to conduct “command/position synchronization” routines on a regular basis, or as needed to meet the sequence of operation and without losing control of the basic HVAC functions, such as zone temperature control, pressurization control, or causing the central fan or pump equipment to operate at a falsely-loaded capacity.

- LOS Point override test: Verify manual override capability for start/stop and modulated point types.

- Control logic test: Exercise all control logic packages. Check response to upset, change in setpoint.

- Supervisory functions: Verify content and operation of time clock schedules. Also, verify alarm’s reporting capabilities and setup.

- Failure modes: Verify all stand-alone operation by disconnecting communication lines between stand-alone control units and verifying continued operation. Disconnect and reapply 120 VAC Local Operator Station (LOS) power to confirm proper recovery from power failure. Disconnect and reconnect controller power to confirm proper recovery from power failure.

- Remote server tests: Verify communication with each field device installed. Verify transmission and reporting of alarms. Verify acquisition of data. Verify trend logging functions. Verify report generation functions. Verify remote access to the server through the campus Facnet internet gateway and also from the vendor’s other local operator stations on campus

- Test the ability of the control system to automatically restart all the connected systems which are scheduled to run following a power restoration and fire alarm recovery.


1.06 FINAL ACCEPTANCE REQUIREMENTS
As Built Documentation: Specify that controls vendor is required to provide corrected documentation to show changes made to correct deficiencies discovered during commissioning tests. Vendor shall reassemble manuals and drawing packages to reflect corrected documentation records.

- Submit shop drawings reflecting final “as-built” condition.
- Specify provision for 3 copies of drawings and programming database.
- Specify provision for 1 copies of reproducible record drawings and 1 on computer disk for the latest edition of AutoCAD as well as .pdf file format.
- These record drawings shall accurately depict the final as-built conditions and the floor plan portions shall be on Architectural/Mechanical backgrounds provided by the A/E.
- These drawings shall include accurate depiction of location of sensors and controlled equipment (motor starters, valves, chillers, dampers, AHUs, etc.)
- Insert one copy of applicable shop drawings, panel layout drawing, and points list at each enclosure’s documentation holder.
- Furnish one original set of application software on original media as well as printed and .pdf file media. Disks shall bear the manufacturer’s label. Field copies are not acceptable. Application software includes operating system, controls application generation, graphic support, maintenance support and all other utilities provided in support of the installed system.

Operation and Maintenance (O&M) Manuals: Specify provision for three paper copies. Also, refer to section— “O&M Documentation” for submittal schedule as well as requirements for electronic O&M formats. Describe operation, maintenance and servicing requirements of the HVAC control system and associated equipment. Specify provision for the following information with an index.

- Technical literature for all equipment, including catalog sheets, calibration, adjustments and operation instructions, and installation instructions.
- Hardware and software manuals, including information supplied by the original product developer, on the application programs and on the computers and controllers provided by vendor.
- System description and complete sequence of operation.
- Reduced size (11” x 17”) copies of record drawings.
- Input/output (I/O) summary forms for the system, listing all connected analog and binary input and output functions and the number and types of points. Indicate spare input/output capacity control programs specific to this system.
- Integrated points summary forms, listing all integrated points by equipment/system. Where the purpose of the point is not obvious, include a description for the point. For each integrated equipment, specify the network address and version of the firmware file for the integrated equipment.
- Completed point-to-point checkout plan used in Owner-witnessed testing, and the completed data sheets showing the results of the point-to-point testing.

- One copy of the preliminary as-builts (site drawings) shall be provided to support the point to point testing.
Owner Demonstration and Training: Specify provisions for Owner training and demonstration within the specification section—"Demonstration and Training". The requirements for that specification, relating to controls system training, are noted here for reference.

Specify provision for a minimum of 32 hours of classroom and on-site training in the operation and maintenance of the installed system. For the first training session, hold eight hours of this training prior to point to point testing. This shall be an introductory session. Provide each trainee with a copy of the sequence of operations and the graphics during each training session. Training shall address the following subjects:

- System log-on procedures
- Review of sequence of operations
- System troubleshooting
- Emergency service support
- Fire alarm interface
- System restart after power failure
- System backup and restoration procedures
- Replacement procedures of each system component
- Calibration and initialization procedures
- Regeneration procedures on all installed programming at operator’s control stations
- Operation of maintenance service programs
- Any building systems interface
- Conduct site walk-thru to familiarize the staff with locations of major controllers and components as well as the equipment controlled by the system.

Specify provision for an additional 4 hour training session just prior to turnover of the facility for Owner operation. The subjects from the initial training session shall be reviewed and the trainer will also emphasize system characteristics that would be helpful for the staff in managing and operating the systems. Many of these characteristics will be learned from the startup and commissioning processes.

Specify provision for on-site training in system operation and programming for the Owner’s staff on 4 separate occasions during the year following final system acceptance.

- The combined total of this training shall be no less than 20 hours.
- This training shall focus on preparing new personnel in the basic operation of the system.

Specify provision for the standard manufacturer’s training (at minimum, 80 classroom hours) to prepare the Owner’s staff to write and maintain the control system programming.
• This training shall be provided for 2 employees of the Owner at the manufacturing facility or (at the Owner’s option) by the manufacturer’s regularly employed trainer(s) at the Owner’s location for up to 4 employees of the Owner.

• Included are all travel and lodging expenses for trainer and Owner’s employees.

• Training shall prepare the Owner’s maintenance staff to generate and maintain the control system programming logic.

• Personnel shall be capable of making changes to the control system, transferring programming between controllers and server, understanding how backups are secured in the system as well as how programming and parameters are automatically downloaded by controllers, expanding the control system by adding logic and hardware devices, performing troubleshooting, and how to obtain technical support.

Specify provision for one set of the special tools, reference materials (manuals), test instruments, and software manufactured or modified by the manufacturer for use in the installation, troubleshooting, and repair of installed devices. Include portable test terminal, test boxes, circuit card extenders, and calibration modules. Specify provision for software for the portable operator’s station as required to perform system maintenance and operation functions.

Owner will provide computer support for the generation of backup database records. Actual use of computer support is during Owner training for generation of backup database records.

1.07 SERVICE AND GUARANTEE

The complete control system shall be warranted to be free of defects in manufacturing, workmanship and materials for one year. Temperature sensor accuracy shall be warranted for 3 years. Software and documentation shall be revised to reflect system changes required to meet warranty obligations.

During the warranty period, specify provision for a 24-hour emergency service telephone number where a qualified service technician, familiar with the installed system, may be reached.

• This technician shall have the capability of remote communication with the control system for troubleshooting and program alterations.

• The vendor shall pay all costs to provide communications for remote access via owner provided static IP address.

• A fully equipped, qualified repair technician shall be at the job site within 4 hours of a request for emergency service.

Specify provision for free of charge during the warranty period 2 DDC software sequence modifications as instructed by the Owner. Modification shall be in software only.

PART 2 - SYSTEM DESCRIPTION

2.01 GENERAL

Specify provision for all software, licensing, hardware, input/output devices, wiring and control power not shown in electrical bid documents, actuated dampers, actuated valves, actuators, operation and maintenance training, special maintenance tools and aids, supervision of labor, and warranty.
The system shall be built only of standard components kept in stock by the supplier.

- All replacement parts shall be available on site within 48 hours.
- The components shall not require customizing other than setting jumpers and switches, or adding firmware or software modules, or on-site software programming to do required functions.

System display should meet the following requirements:

- All system titles, prompts, and instructions are to be in the English language.
- All values shall be in actual control unit, i.e., a setpoint such as 74°F.

The primary means of information display, mechanical systems management and monitoring functions shall be by graphic display.

- System shall be controlled and monitored through a color Graphical User Interface (GUI).
- Graphical presentation shall group all elements of a system in a clear and logical manner and present on-screen display of system status.
- Each display will contain comment sections to indicate building area served (if area-specific) and also contain a graphical presentation for all other interlocked systems.

The system shall include all standard software applications needed to fully service, edit, set up, configure, manage, trend, and troubleshoot all of the controls systems software, network, components, and controllers. The software required to manipulate the graphics overlays, backgrounds, and active components shall also be included, along with the associated licensing. Control system management shall generally occur at a dedicated computer, the local operator station. However, the system shall also be managed through the remote connection to the vendor’s campus server as well as connection of a laptop (portable operator’s station) to individual controllers. Provide all software, special cables, and interface modules necessary to perform all direct-controller interface troubleshooting, setup, and monitoring from the portable operator station.

2.02 SYSTEM ARCHITECTURE

The environmental control system shall consist of a distributed network of controllers providing full stand-alone operation of the building. The controllers shall contain the necessary programming to accomplish the sequence of operations for building control.

Controllers shall normally execute the control strategy to use peer-to-peer communication capabilities. Upon loss of communication, the stand-alone control unit shall be able to execute its own stand-alone programming. This distribution of control authority is mandated so that the lost communications capability shall not cause a complete loss of control for affected systems. All points required to implement the sequence of operation for a particular equipment or system shall be connected to a common controller to allow for stand-alone operation in the event of communication failure to the rest of the control system. Exceptions will be made for global points that are passed to all of the controllers, such as outside air temperature, changes to occupancy schedules from the server, etc. or for programming that is required to interlock operation of equipment/system, each of which has their own, stand-alone controller already. Remote sensors, for example duct static pressure sensors mounted 2/3 down the main trunk, shall be hard-wired back to the controller for the associated air handling unit. All programming for a particular system shall reside within that common controller and shall not require programming from a different
controller, with communications over the system networks, in order to implement the full sequence of operation for that system. The vendor shall utilize controllers with sufficient programming capabilities and capacity to accomplish this requirement.

Specify provision for all equipment and hardware necessary for communication among the main distributed processing units within the facility using TCP/IP or BacNet over IP. Specify provision for a single point of connection per building from the DDC system to the campus Ethernet for communication to remote operator's stations and the vendor’s server for the campus. The port for the campus Ethernet connection shall be installed inside a 12x12x6 inch, lockable enclosure similar to Milbank series 12126-LC1. The Ethernet port shall allow the operators to connect to the UW Facility Network subnet (“FACNET”). Coordinate communication and power requirements with the electrical consultant. The owner will provide the static IP address for all the Ethernet-connected controllers and operator stations.

Operator station shall not be necessary to sustain building operation.

2.03 SPECIFIC SYSTEM FEATURES

Zone-by-zone control of space temperature, usage scheduling, and equipment failure reporting (A zone is the area served by one HVAC terminal unit, fan coil, heat pump, air terminal, etc.)

Specify provision for UPS (Un-interruptible Power Supply) having 5 year battery life and battery hot swappable capability for all cabinets containing controllers. Discuss the requirement for UPS backup power with Campus Engineering. These cabinets shall be provided with a fused duplex receptacle to be used as a source for UPS power. Cabinet shall draw power from the UPS. Specify provision for a shelf for the UPS. Where a UPS is used, the UPS shall have an output contact that shall be monitored by the BAS as a summary alarm point for the UPS. The contact should be normally closed so that if the point is disconnected, the BAS will indicate an alarm for it. The purpose of this summary alarm is to notify the operator of malfunctions of the UPS and more importantly, to monitor battery life and impending need for battery replacement.

Totally tamper-proof room sensors installed with Allen, Bristol or similar hardware with no local setpoints. All temperatures are to be set from an operator’s station or portable terminal. (Note to Consultant: Modify this statement when it is appropriate to include a limited adjustment capability by the occupant.)

Specify individually assignable priority password security system to prevent unauthorized use. Specify provision for at least 4 levels including the following: Information only, change of setpoint & ON/OFF, programmer, and a fourth master level for assigning appropriate local access.

Auto-restart, without operator intervention, the operator stations and all controlled equipment to the control state that would be in effect if the power failure or fire alarm event had not occurred. Start/stop outputs shall continue to command the affected device while motor power is unavailable and allow for equipment restart, as previously commanded or scheduled, upon restoration of motor power.

Equipment run-time totalization of motor driven equipment.

Interactive displays of all input and output points: As a minimum, each of the screens on the display monitor shall be able to display all of the interactive points and custom text for that screen.

Operator may, through keyboard interface, disable any control logic for any output or setpoint, temporarily substitute the value for any input/output, and introduce a different value or state for all inputs, outputs and setpoints.
Individual controllers will be programmed with nonvolatile stand-alone control logic necessary to maintain appropriate HVAC equipment operation. While in temporary stand-alone mode, energy efficiency can be sacrificed to maintain temperature control and operational conditions that will not damage equipment or compromise health and safety.

The control system shall only control equipment while the HOA switch is in the Auto position. Where equipment is controlled by both the fire alarm system and DDC controls, the fire alarm system shall provide separate start/stop relays. The fire alarm system shall always override the DDC controls. The controls contractor shall engineer and provide the integrated wiring diagram to coordinate this priority of controls as well as indicate how the wiring is terminated to the equipment to provide positive start and positive stop from the fire alarm commands regardless of the motor starter HAND, AUTO, OFF, or BYPASS positions. The fire alarm commands shall not override electrical disconnect functions.

Controllers shall, upon loss of valid programming, be capable of requesting and receiving a programming download of all required program code from the local operator control station. The controllers shall not automatically download programming upon loss of power or cold start of panel in order to prevent inadvertent override of controller programming or parameter setup to earlier versions of the backups on the server.

UW personnel shall be able to create and modify control software with an MS Windows (current version in use by UW) compatible computer utilizing menu-driven programming. UW personnel shall be able to store the programming on a removable computer disk and preprogram a nonvolatile, transportable memory storage device, which can be used for replacement of the programming in system controllers.

2.04 OPERATOR STATIONS

Operator stations shall be Microsoft Windows® based personal computers or servers selected to meet the specification requirements of the vendor-provided control system software.

All operator station hardware and software shall be provided, installed and made operational by the control vendor.

Stations will provide complete facilities for local printing on laser type printers.

Stations will provide complete facilities for loading and archival storage of computer software as well as provide CD/DVD Drive.

Specification for processor type, speed and memory shall be consistent with those recommended by the software manufacturer.

Station will provide all hardware and software to communicate with remote operator stations over the campus Ethernet system using TCP/IP protocol.

Remote Operator Station (ROS). The contractor shall provide all hardware, software, and licensing to provide secure communication, over the campus FACNET using TCP/IP, from the LOS or POS within the facility to the vendor’s campus server for their system (ROS).

Local Operator Station (LOS): Specify provision for a computer selected to meet all specifications for operation of control system software and provide additional unused disk store space for operational requirements such as trending and totalization. Disk storage space shall be no more than 20% utilized by the initial installation.
Portable Operator Station (POS): Specify provision for one “lap top” computer capable of operating all vendor-supplied field maintenance programs. Provide all special cables and interface devices required to interface directly with all controllers to the POS.

2.05 CONTROLLERS

Each controller shall operate as part of the building-wide control system and as an independent unit when not in communication with other controllers or an operator station. Global controllers shall be able to share Global information on a peer-to-peer basis without relying on an operator station.

It shall be possible to define control strategies at each controller from any operator station. Each controller shall be able to interface directly with an operator station.

Each controller shall include its own microprocessor, power supply, and, if necessary, battery with automatic charger. Upon loss of system power, the controller memory shall be maintained for a minimum of 60 hours with no external source of power. Upon restoration of system power, the control unit shall resume full operation without operator intervention.

Specify provision for control programming logic at each controller for proportional and/or proportional plus integral control capabilities as necessary to assure complete and stable control of each controlled variable.

Controllers shall be either BACNET IP or BACNET MSTP based communication compatible.

2.06 CONTROLLER FUNCTIONALITY

Each controller shall maintain and perform its own stand-alone control strategy upon communications failure. The controller stand-alone control program shall be adequate to maintain the basic control function and specify provision for protection from inappropriate equipment operation. The controller shall retain its programming during a power failure and resume operation without program reloading from another device.

The controllers shall be powered by 24 VAC, one grounded leg.

Each controller shall be isolated (optically or by other means) from communication trunk and have fuse or overload protection.

The controller point monitoring and control capabilities shall include but not be limited to the following:

- Binary inputs (contact closures)
- Analog inputs (use only resistive, 0-10 volt, and 4-20 ma. inputs; provide A/D conversion of 10 bits, minimum)
- Binary output (start/stop or latching and momentary contacts)
- Floating point control
- Analog outputs (must include 4-20 ma. @ 10 VDC minimum, 0 -10 VDC; provide A/D conversion of 12 bits, minimum)

2.07 FAILURE MODE
Upon failure of any global controller, the operator station shall display off-line occurrence for each affected point, and provide communication verification to each controller for each I/O channel.

In the event of communication failure, controller shall continue to operate equipment using appropriate backup values for missing global information. If sensor information is necessary for proper stand-alone function, then that sensor shall be attached directly to the appropriate controller. Specify provision for failure mode programming to accomplish safe operation of equipment in case of communications failure on local trunk.

Upon return of primary power after a power failure of up to 72 hours, the system shall automatically return to completely normal operation with no action required from operating personnel.

Unless otherwise indicated in the design documents, provide the following failure modes, (that is, the position that the controlled device attains under failure due to loss of power, loss of air pressure, or loss of communications) for valves and dampers:

- All heating converter steam valves shall fail closed.
- All fan preheat steam valves shall fail open (when this is specified, the temperature rating of sprinkler heads within the AHU that houses the steam coil shall be selected to prevent nuisance head operation in the event that the steam coil fails open when the unit is isolated and no airflow passes through the AHU).
- All fan and unit heating hot water heating valves shall fail open.
- All fan cooling water valves shall fail closed.
- All central cooling water differential pressure control valves shall fail closed.
- All fan exhaust air and outside air dampers shall fail closed.
- All fan recirculation dampers shall fail open.
- All fume exhaust control and fan isolation dampers shall fail open.
- Zone-level air terminal unit hot water valves and dampers, unit heater hot water valves, and perimeter hot water heater valves may fail in place.

EP transducers shall be selected so that valves and dampers go to the above-listed failure positions on loss of power.

### 2.08 ENERGY REDUCTION AND MONITORING AND SPECIAL OPERATION SOFTWARE

The system shall be designed to control energy-consuming loads. Specify provision for engineering, consulting, and programming to develop and set up the following energy reduction software:

- Time schedules: Software should provide at least 16 time schedules. Each schedule is to be on 7-day type, capable of 6 entries minimum per day. Time program shall provide ON/OFF commands, and reset SETPOINT capabilities.
- Holiday time programs: Specify provision for a holiday time schedule capability.
- Optimal start warmup and cool-down modes: Specify provision for the ability to optimize start times to attain and maintain temperature setpoint only during occupied times. The system shall
be self-tuning, based on the system’s historic ability to achieve the target occupied temperature by occupied start time as well as outside air temperature and average zone temperature, with compensation for weekends and holidays.

- **Setpoint reset:** Specify provision for a means of automatically resetting heating water supply air temperature, chilled water supply temperature, condenser water supply temperature, and outside air ventilation air inflows (demand-based ventilation), fan static pressure setpoints, and pump differential pressure setpoints, based on demand.

- **Specify provision for a program to automatically restart all DDC controlled equipment upon the resumption of power or return from fire alarm condition.** Equipment shall be restarted according to a prearranged, prioritized and staggered restart schedule.

- **For loads that have been turned off at the MCC controller, local motor starter, or VFD motor starter, either by positioning of the HOA switch or the line disconnect; provide a restart strategy that automatically restarts load upon the reset of switches to their normal on-line positions.**

- **Specify provision for global command software to support balancing and commissioning work including, as a minimum, single command authority to command hydronic control valves, for each system independently (including all terminal units and zone reheat valves), to their full open position.** For air systems, provide a single command authority to command all terminal units to their maximum airflow setpoints, for each air handling unit system independently. Provide single command authority for return to normal operation. Provide pre-configured reports to indicate valve and damper position reports, independently by system that can be run at any time by single command.

- **Specify provision for capability to adjust the setpoints of all mechanical systems from the operator station using simple ‘point and click’ command windows.**

### 2.09 ALARM PROGRAMMING

For each analog input point, assign operator high and low alarm limits according to design data or as Owner requests.

For each alarm input, provide the following assignable alarm responses:

- **Display English language point description in addition to system point identification.**

- **Print out alarm description and operator-created alarm message.**

- **Require acknowledgment by operator and print occurrence if directed by Owner.**

Specify provision for equipment monitoring and alarm function including information for diagnosing equipment problems.

- **All system points shall be programmed to report alarm conditions by fully expanded point names that are tailored and specific to this project.**

- **The consultant shall include a matrix of all expected alarms for the control system and shall include this matrix within the design document sequence of operation.** The matrix shall be coordinated with the U.W. Campus Engineering, U.W. controls shops, and, where facilities have critical environmental requirements (for example: critical temperature labs, critical relative humidity for museum archive storage, etc.), those alarms for the critical parameters shall also be coordinated with the users for those spaces. The matrix shall also indicate alarm points that are
intended to be remotely annunciated via text message, email, phone, or other method, as well as the distribution network and escalation responses.

- Interlock all alarm points to system status so as to lock out alarms when the system is not operational by schedule or operator command.

### 2.10 LOGS AND TRENDS

As a minimum, specify provision for capacity for 500 trend logs. Store time segments. Allow for review of data on monitor, printer, or exported file. Each trend log shall have assignable individual start/stop times/dates. Trends shall be displayed in tabular format and graphical chart format. Chart trend logs shall have the ability to graph multiple trended points on a common trend chart, including the ability to use two separate value axis. This allows comparison of trended points that have significantly different range values.

Current alarm log: Display all points currently in alarm.

Operator activity log: Record a running log of operator activity by operator account identification and work performed.

### 2.11 SPECIFIC SENSOR FEATURES

**General**

- All devices shall be mounted within enclosures. Cable trays and external cabinet services shall not be used as mounting services.

**Temperature sensors**

- Sensors shall be completely pre-calibrated with no electrical adjustments or calibration required for standard installation conditions, but shall have provisions to adjust sensor output to adjust “calibration” if needed.

- The temperature displayed at an operator terminal shall be accurate to within 1º F. This accuracy shall be warranted (parts and labor) for a minimum of 3 years. Temperature sensors, including room “thermostats” shall read within ±1.5ºF of an independent instrument that is rated with an accuracy of ±0.5ºF or better. Point-type discharge air sensors from terminal units shall be accurate to within ±2ºF. Temperature sensors that do not comply shall be adjusted through the controls system or replaced until compliance with this requirement is achieved.

- Wall sensors shall be housed in tamperproof enclosures installed with Allen, Bristol or similar mounting hardware. Wall sensors for zone controls shall provide jack for operations laptop connection. That connection shall allow communication with system for monitoring and adjusting at least the zone-level equipment serving that zone. Wall-mounted sensors shall be mounted on electrical boxes, not mud rings, and the boxes and electrical penetrations shall be sealed to prevent thermal convection from the inside of the wall from influencing the sensor readings. The wall sensor shall be air tight from the interior wall cavity. Provide thermal blocking back-plates where sensors are mounted to an exterior wall.
Thermowells shall be bronze, brass, or stainless steel with 1-inch NPT threads. Use heat-conducting compound. Thermowells shall be sized with a length sufficient to ensure that the sensor is within the flow path of the sensed medium in order to achieve the fastest response time and accurate reading of the parameter.

Specify provisions within the piping specialties specification section to require self-healing type pressure/temperature port fittings (Pete’s Plugs®) within 6’’ of every controls system temperature and pressure sensor tap in piping systems. These shall be used to verify calibration of these control system sensors by directly inserting an independent, calibrated testing instrument in the same location as the controls system sensor.

Terminal unit discharge air temperature sensors shall not be mounted within 36” of the discharge point of the unit reheat coil.

Mount and shield outside air sensors so as to avoid solar influence.

Outside air sensors shall be a waterproof assembly protected from solar radiation. Span shall cover the range of – 30º F to 100º F or better and not exceed a 150º F span.

Provide averaging-type temperature sensors within air handling units on the discharge side of each heat transfer coil. The averaging sensors shall cover the entire cross-sectional area of the coil to provide a true average temperature output from the coil. Averaging elements shall be mounted so as to cross a minimum of 80% of the plenum width and shall be located so as to provide an indication of temperature within +/- 1º F. Specify provision for support at 36 inches maximum. Where coils are made up of multiple coil sections, a separate averaging sensor shall be used for each coil section and then an average of those sensors shall be written to a common virtual point for real time monitoring and display of one temperature on the system graphics.

Space Air Pressure and Differential Pressure Sensors:

Mount outside pressure reference sensors with an outdoor sensing port device so as to eliminate wind effect.

Provide finished terminations for indoor air pressure reference ports. The open end of a controls tube shall not be an acceptable termination method.

Air Velocity and Flow Transmitters:

Shall provide air velocity information independent of the effects of static pressure. Transmitter shall operate at rated accuracy from 0º F to 120º F. The minimum accuracy of displayed value at an operator terminal shall be within ±3% through the range of 20% to 100% of sensed airflow, with a drift rate no greater than 1% per year. The proportional output shall be 4 to 20 ma.

Flow transmitters shall be installed per all the manufacturer’s installation instructions to achieve the rated measurement accuracy, including minimum required straight ductwork lengths ahead of and following the sensor to achieve a uniform airflow pattern across the face of the transmitter sensor(s). The Contractor shall work with the balancing contractor to
ensure that the output of the transmitter is spanned properly and reads accurately by the controls system.

Relative Humidity Transmitter:

- Sensors shall be of the solid state type using a hygroscopic or thin-film capacitive technology sensing element. The sensor shall operate from 40°F to 100°F. The minimum accuracy, as displayed at an operator terminal, shall be within ±2% RH through the range of 10% to 95% RH, with a drift rate no greater than 1% per year. The proportional output shall be 4 to 20 ma.

Differential and static pressure transmitters:

- Transmitter shall operate from 50% of minimum to 150% of maximum anticipated pressure. The maximum error of displayed value at an operator terminal shall be ±2% through the range of 20% to 150% of the intended maximum setpoint. Minimum pressure tolerance shall be 150% of the maximum pressure expected in normal operation. The maximum drift rate shall be no greater than 1% per year. The proportional output shall be 4 to 20 ma. Specify designed pressure pitot sensor.

Freeze protection thermostats:

- Freezestats shall be mounted upstream of the coil they are intended to protect, typically the cooling coil.

- Specify provision for freeze protection thermostats with DPDT contacts. One set of contacts shall be wired directly to controlled mechanical equipment contactor/VFD in order to affect both automatic and manual (HOA) switch positions. The second set of contacts will be wired to a digital input for annunciation of freeze protection alarm condition. Both contacts shall actuate simultaneously. Differential actuation of the contacts shall not be allowed.

- Manual reset type freeze protection thermostats are required.

- Freezestats used for fan shutdown control shall be wired to stop the fan in both HAND and AUTO positions of the motor starter (including the BYPASS position for VFD’s). Fire alarm controls shall have priority control over freezestat control.

- Averaging bulb freezestats shall not be allowed. The freezestats shall make when any 12” section of its sensing bulb falls to below the setpoint of the device.

- Locate the reset head outside the plenum wall and at the highest point of the assembly. The sensing bub shall be sloped continuously downward from the reset head.

- Freezestats’ capillary length shall provide 1 foot of capillary length for each 4 square feet of coil face area (provide multiple freezestat units if necessary to meet this requirement). In all cases the coil face shall be completely crossed from corner to corner.

- Freezestats shall be installed with capillaries supported by non-metallic stand-offs. No part of the capillary shall otherwise touch the coil or frame. Specify mounting support at least every 36” and within 6” of the capillary end.
Electrical current transmitters:

- Current sensors shall convert AC to proportional DC (4 to 20 ma). Response time: 300 milliseconds to 99% of final value.

Current sensing relay switches:

- Current switch (AC relay) shall indicate the presence of current flow. Device to be powered by induction from the line being monitored. Use for fire alarm system “run status” monitoring.

- Current sensing relays shall be used to provide positive run status feedback of equipment and motorized fans and pumps.

- Current sensing relays shall be adjusted to ensure reliable operation at the lowest operating loads for the equipment as well as the lowest run speed settings for VFD’s.

2.12 CONTROLLED DEVICES

Actuators

- Actuators for steam valves and actuators located in mechanical rooms shall be pneumatic type. Air distribution system air terminal (zone) box damper and valve actuators and perimeter hot water heater valve actuators may be electronic.

- Specify pneumatic actuators selected from the standard vendor catalog.

- Specify in sufficient size, quantity and type to assure reliable operation throughout the normal aging process of valves and dampers.

- Full stroke actuation of pneumatic actuators shall not be more than 30 seconds unless there are more stringent requirements.

- Large damper assemblies shall be made of individually driven segments that are small enough to ensure reliable operation and uniform closure across the entire damper assembly. The actuators shall be operated independently so that if one damper segment or actuator becomes inoperable, the others remain operable. The use of jackshafts shall not be permitted unless the damper sections can be synchronized to maintain position within 5% stroke of each other through their entire modulation range while at the same time achieve 100% tight shutoff for all damper sections.

- See the failure mode section above for actuator responses under failure due to loss of power, loss of control air, or loss of communication. Where an actuator is to fail open or fail closed, provide spring return. Actuators shall not be dependent on batteries or capacitors to stroke to the power fail position upon loss of power.

- Permanently stamp or scribe position indication on the end of driven shaft unless damper is visible from same location as end of shaft. Use of permanent ink markers shall not be an allowable permanent substitute for stamping or scribing.

- Select electronic actuators from the vendor standard product line.

- All electronic actuators shall be 24 VAC. The use of any other actuator must be approved by the Owner.
Proportional electronic actuators shall use 0 to 10 VDC, 4 to 20 ma. or floating point control. Floating point actuators shall not be allowed for air terminal units serving spaces that have pressurization direction requirements (i.e. – labs, operating rooms, etc.) unless they have special provisions in their controllers and are provided with accessories to prevent the need to fully open or close the primary air damper for the purpose of airflow sensor calibration (“autozero”) or damper position/command synchronization and these provisions prevent disruption of pressurization direction control while conducting those functions.

Multiple electronic actuators may be powered by one separately fused 24 VAC transformer, providing the transformer size does not exceed 100 VA.

Do not stack electronic actuators.

Valve actuators shall be installed directly above the controlled valve whenever possible (with the exception of steam control valves where the actuator is rotated approximately 30 degrees to avoid hot zone directly above valve) unless rotation is needed to permit maintenance access. However, in no case shall the operator be rotated to or beyond horizontal.

All electronic valve actuators shall have field manual positioning capability to allow manual positioning of valve in absence of control power.

Actuated dampers

Outside air and exhaust air dampers that continue the thermal envelope of the building shall be provided with insulated damper blades.

Specify provision for low leakage control dampers where not furnished with packaged units.

Damper leakage rate shall not exceed 6 CFM/sq. ft. at 4-inch wg. and 1% of full flow rate.

Dampers shall have blade seals and stops.

Specify American Warming and Ventilation, Ruskin, Greenheck or approved equal dampers.

Install actuators in the orientation recommended, or stated as preferred, in manufacturer’s literature.

For actuator selection, see “Failure Mode” requirements above.

Actuated valves

Valves shall be selected to meet CV and pressure requirements.

Valve body and actuator selection shall be sufficient to handle system pressure, and shall close against the system differential pressures.

Valve service rating shall be 125 psig. or greater (except that valves in the central cooling water piping shall be rated at 250 psig. or greater.)

The shafts to which the actuators are coupled shall be square or hexagonal or round with one side flattened to permit secure coupling.

Install valves in the orientation recommended, or stated as preferred, in manufacturer’s literature.
• Use valves and actuators directly marketed and warranted by the controls vendor. Third party and after-market devices will not be accepted where the vendor’s catalog shows appropriate devices.

• Zone valves: Valves shall be constructed with a cast brass body. The valve shall provide for 100% shut-off and silent operation.

• AHU valves: Valves shall be constructed with cast brass or iron body and screwed or flanged ends. Specify the valve Cv so that the valve pressure drop at full open position is equal to the pressure drop through the coil’s branch circuit pressure loss, where branch circuit is defined as the branch lines going to the coil, all of the piping specialties, including the balancing valves, and the coil itself. For CCW coils refer to section Steam valves

• Shall have similar construction as AHU valve but with temperature and pressure ratings to match the steam application. Specify the valve Cv so that the valve pressure drop at full open position is equal to the pressure drop through the coil’s branch circuit pressure loss, where branch circuit is defined as the branch lines going to the coil, all of the piping specialties, including the balancing valves, and the coil itself.

• Butterfly valves may only be used for two position applications.

• Butterfly valves with plates attached to the stem with screws, bolts or rivets are not acceptable.

Control relays

• Panel relays shall be plug-in type with contacts rated at twice the amperage rating of circuit requirements: Minimum temperature range –25º C to +70º C.

• Enclosure: Clear dust cover and shock resistant, rated for minimum of 2.5 million mechanical operations and 100,000 electrical operations at full load.

Remote/interposing relays shall be used for all remote switched loads.

• They shall be housed in a NEMA-rated enclosure. Where two or more relays are mounted in the same enclosure, provide a hinged cover.

• Besides meeting panel relay requirements, they shall have 24 VAC coils and form C dry contacts with a minimum rating of 5 amps @ 240 VAC.

• Relays controlling inductive loads shall be equipped with coil transient suppression devices to limit transients to 150% of rated coil voltage.

2.13 ENCLOSURES

All enclosures to be NEMA 1, unless otherwise required for intended service. All controls and instruments shall be logically assembled at one or more panels, have hinged doors and be marked with engraved melamine labels. All enclosures used as a mounting site for control devices shall also contain a documentation holder located on the inside of the door. All enclosures shall be provided with locks with the vendor’s standard core. Label each equipment panel furnished with 120 VAC power with power source label showing identification of power panel and breaker.

Provide weather-proof enclosures for control components located outdoors.
2.14 WIRING AND CONDUIT

All wiring shall be stranded. Exceptions will be made for wiring used in preassembled factory crimped cables, 20 ga. and smaller, where connectors provide support to the insulated cable jacket at the point of connection.

Junction box covers shall be labeled “DDC” or show the vendor logo. Splicing shall not be allowed between the controller and the controlled device.

Conduit shall be cleaned of foreign material just before pulling the wire or cable. Lubricants shall be compounds specifically prepared for cable pulling and shall not contain petroleum or other products that will affect cable insulation.

All wire shall be new and brought on the jobsite in original packages bearing Underwriter’s label and the date of manufacture. Wire that has scrapes, nicks, gouges, or crushed insulation shall not be used and shall be removed when present.

Groups of conductors, where installed in cabinets and wire trays, shall be neatly grouped with wire ties or equal. All wiring contained in metal wireways shall be in wireways dedicated to low voltage service.

Low voltage energy-limited wiring shall not be run in the same wireways with, or closely parallel to, high voltage or switched power wiring. Interposing relays shall be used for all switched power loads and shall be located so that the switched power conductors do not run in the same wireway as the interposing relay coil power or any other energy-limited low voltage conductors.

Aluminum wire is prohibited.

No conduit shall be filled so that the maximum bundled cross sectional dimension exceeds 40 % of conduit inside diameter. No raceway shall be filled to more than 40% and maximum fill for “wiremold” (surface raceway) shall be 20%. No wire run or circuit shall be longer than 80% of the maximum allowable length or power consumption for the wire size and application.

No output circuit shall exceed 80% of the maximum load capacity specified by the manufacturer. The basic wiring method shall be in conduit unless otherwise permitted in this section. Where conduit direct connection is not possible, all permitted open wiring shall be plenum rated.

Permitted open wiring is limited to the following applications:

- Wiring from a zone airflow control unit to a nearby temperature sensor not to exceed 50 feet
- Wiring from a zone airflow terminal control unit to a nearby water control valve not to exceed 6 feet

Open wiring, when permitted, shall be installed in compliance with WAC 296-46B-300 and shall also be installed as follows:

- All open wiring that penetrates through walls and crosses structural ceilings shall do so within 18 inches of the structural ceiling surface.
- Wiring shall be attached to vertical supports at attachment points prepared by a protective wrap of electrical tape around the support. This wrap shall create a surface free of sharp edges.
- Absolutely no wire is to be attached to pipe work or conduit of any kind.
Wire ties, if used, shall be trimmed so as to reduce sharp edges.

The vendor shall provide required cabling attachment points for control’s use if the ceiling structure does not provide acceptable attachment points.

Wiring from any controller to a device which has otherwise been approved for installation and cannot accept conduit connection shall meet the following requirements:

- Conduit shall be used to within 12 inches of the device.
- Install in wireway all trunk communication wiring between the operator station and the controllers, and between controllers. Open wiring is not otherwise permitted.

Conduits shall be provided with appropriate bushings and end fittings to protect cabling from sharp conduit edges. Conduit size shall be 1/2-inch minimum. For all wiring groups consisting of 6 or more conductors, conduits shall be 3/4-inch minimum. NEC requirements shall apply as though conductors were used to their full current carrying and thermal capacity.

Wireway runs shall be parallel or perpendicular to walls, pipes and sides of openings. Passageways for access and servicing shall not be blocked.

All trunk or LAN cables shall be in conduit or wireway and 100% backed up with spare conductors.

All conductors that become bundled or pass from an enclosure or into an enclosure shall be identified with typed or machine lettered labels. Tag numbers shall agree with wire numbers assigned on wiring diagrams and the installation drawings as well as the point name. Wires shall be labeled with mechanically prepared labels at their connection point to each apparatus point of connection.

2.15 SPECIAL DESIGN STANDARDS

VAV terminal boxes used in configurations of multiple supply and/or multiple exhaust units need to have their flow rates synchronized to ensure airflow rates are appropriate and repeatable. Control vendor shall accomplish synchronization through positive feedback of the damper position or by commanding the damper position with an analog signal (or other appropriate means).

If alternation of lead-lag motors or services is made possible by design requirements, lead-lag scheduling shall be by operator command.

Specify provision for a minimum 1¼-inch pressure gauge at the output of each I/P and E/P transducer.

2.16 GRAPHIC DISPLAY REQUIREMENTS

Specify provision for a Microsoft Windows-based software package, including necessary licensing, for the preparation of system graphics, including backgrounds, overlays, and dynamic graphics.

Include with this software a library of HVAC symbols such as fans, pumps, chillers, etc.

All graphics screens shall be submitted and approved before implementation.

Graphics shall be arranged and organized to make them as intuitive as possible to read and understand.

This section establishes standards for graphic displays as follows:
• The graphics shall be a set of separate graphics pages with navigation links and a home page. The main graphic page will have links to the major system and equipment graphic screens as well as links to floor plan graphics, miscellaneous systems, and monitoring functions. Each major graphic screen shall have links back to the home page and links to sub screens to navigate to subsystem graphics. The system will allow navigation backwards and forwards through the navigation history.

• All non-portable operator stations shall be programmed to display dynamic color graphic representations of the mechanical systems and floor areas for which this system has control. All operator stations shall have the ability to access the graphs from the vendor’s campus server through remote connection. Representations of equipment does not need to be exact representations of the actual equipment installed but, at a minimum, be representative of the type of equipment installed so that it accurately represents that equipment. For example, a small condensing hydronic boiler shall not be used on the graphics to represent a large fire tube boiler that is actually installed. Some equipment, such as large air handling units, are typically represented in diagram form, in order to show all of the controlled components and sensors installed in such a complex unit.

• All controlled and monitored equipment shall be displayed within the graphics screens.

• Show the following components (if included on a project) on a single graphic: Hydronic systems (for example, include chilled and condenser water pumps, cooling towers, chillers, etc. for a chilled water system and then provide sub graphics for the individual equipment) air handling units, hot water heating systems, central cooling water (CCW) differential pressure control valves (header), heat exchangers between the CCW system and the condenser water, and the status indicator for whether the two systems are in their “summer” or “winter” mode of operation.

• Displays shall automatically update with current real time data.

• Floor plan displays are required and shall indicate the approximate positions of controlled mechanical system elements as well as zone sensor locations (temperature, RH, CO2, etc.). Each temperature control zone shall be represented by an outline, filled in with a different color to distinguish it from adjacent, neighboring temperature zones. Thermostat shall be linked “jump-point” to detailed terminal unit information graphic. Room floor plan displays are required if rooms are served from more than one terminal unit. All displays shall show real time data to include temperatures, actuator positions, and motor run status.

• All displays shall show real time data updates. For each graphic page, indicate all controlled devices as well as all sensors and monitored points relating to that system or equipment. Where the graphic has sub-graphics, some of those points may be indicated on the sub-graphics in order to better organize the screens as well as prevent overcrowding of information. For each control loop, the graphic shall indicate the setpoint and update it dynamically if it is reset. For each reset function, the graphic shall indicate pertinent information relating to that reset so that the operator can understand and troubleshoot the current reset setpoint value as appropriate for the current conditions (for example, an outside air reset sequence for AHU discharge temperature setpoint reset shall indicate on the graphics the limit variables for the reset table, but not necessarily allow adjustment of those setpoints form the graphics).

• Where setpoint or parameter values can be adjusted through the graphics screens, the suggested value for that setpoint or parameter shall be noted next to that graphic field.

• For each air handling unit system, include a graphics zone summary page that indicates, in tabular form, each temperature control zone with room parameter setpoints, room parameter real-time values, reheat coil valve position, primary air damper positions, fan status (for fan-powered
For each major system, provide a sub-graphic that includes the sequence of operation, including setpoint values (dynamically updated).

Provide dynamic graphics that indicate animations for fans, pumps, dampers, and compressors such that it is intuitive when they are running or when they are stopped. Additionally, show these components in a different color when they are operating (such as green) than when they are stopped. When a component is in alarm, indicate that component with a color change to flashing red so that it is very obvious when observing that graphic screen.

2.17 SMALL PROJECTS

The requirement for a dedicated computer (as indicated in section Operators Stations), as the point for system management does not apply. It shall be possible to attach a portable computer to the main system controller for the purpose of system management.

Requirements for operator stations do not apply except for the specification on portable operator stations.

Alarm log requirements do not apply except for the current alarm log and a reduced trending requirement of 10 trend logs.

Section POST INSTALLATION INSTRUCTIONS AND MATERIALS - TRAINING is modified as follows:

- Training requirement of 32 hours is reduced to 8 hours.
- Training requirement of 16 hours is reduced from 16 hours on a total of 4 occasions to 4 hours on a single occasion.
- Training requirement for 2 employees is reduced to 1 employee, and the use of a local trainer at the local facility or project is permitted.

Section FINAL ACCEPTANCE REQUIREMENTS makes reference to a Local Operator Station. This reference is amended to be the existing Remote Operator Station.

Section SYSTEM DESCRIPTION, GENERAL is amended to require remote communications to a remote site via campus Ethernet, which can act as a communications relay device. If an existing relay site is used, vendor shall pay all costs to upgrade and configure such site for support of this project.

On small projects building system graphics shall be updated appropriately to indicate the modifications of the project.

2.18 PNEUMATIC AIR SYSTEMS

Pneumatic air piping shall conform to the following:

- Copper tubing: ASTM B88, hard drawn deoxidized copper tubing, type L, with wrought copper solder joint fittings conforming to ANSI B16.22. Copper tubing used to support life safety functions, such as pneumatic actuators on combination fire/smoke dampers, shall be joined with brazed joints, and using a nitrogen purge.
• Plastic tubing: Virgin polyethylene tubing, FR rated, tested in accordance with ASTM D-1693 standards with minimum burst pressure of 600 psig and minimum working pressure of 100 psi at 75º F.

• Plastic tubing is only permitted inside panels and for final connection (not to exceed 6 inches) to devices that are designed with barbed fittings.

• Pneumatic copper tubing shall be run parallel to building lines. Create tubing bends with formed pieces or with the use of a tubing bender.

• Tubing shall be attached to the building structure at no greater than 4-foot intervals (No adhesive type mounts allowed)

• Copper tubing shall be ¼ inch o.d. minimum in all locations. Take special care in sizing pneumatic lines for applications serving pneumatic actuators on fire dampers and fire/smoke dampers. These need to be sized sufficiently large in order to allow the actuators to bleed down fast enough to meet the code-required closing time limits for these devices.

• Specify provision for soldered end caps at all terminations of existing and new copper tubing. Crimped or taped tubing ends or other means are not permitted.

• The pneumatic operator's air supply system shall be sized and piped to operate the driven load with full stroke time not to exceed 30 seconds unless there is a more stringent requirement.

• The campus tunnel pneumatic control air supply distribution shall be used as the primary source for pneumatic control air. Provide a refrigerated air dryer, sized for the maximum calculated control air load, a filter unit, and a coalescing water separator after the dryer.

PART 3 - SEQUENCE OF OPERATION AND POINTS DESCRIPTION

3.01 DESIGN STATEMENTS

Design Sequence of Operation appears on the mechanical design drawings. Supplement in controls sequence of operation statements to explain how the control system programming and architecture accomplishes the design intent.

3.02 GENERAL

Program as a minimum the following:

• Control of equipment as described in the design sequence of operations

• Time and holiday schedules

• Alarm limits and histories

• Summary of data for each zone

• Trend logs (for every control loop including commanded components, controlled variable(s), and setpoint(s))and historical data

• All setpoints
3.03 SPECIFIC REQUIREMENTS

The following Points Descriptions and Sequences of Operation shall be enhanced as necessary and included as part of the control drawings to expand and clarify information shown in the drawings.

- Point’s information shall be displayed and organized by system in dynamic graphic form at the operator stations.
- The energy reduction software and miscellaneous functions shall manage all points.
- It shall be possible to “disconnect” any output or setpoint from the AUTOMATIC control logic and enter a MANUAL value or state from any Operator Station.
- It shall be possible to replace any input with a MANUAL value from any Operator Station.
- All control loop parameters for each loop shall be displayed on one display.

3.04 SPECIFIC DISPLAY AND PROGRAMMING REQUIREMENTS

The following commands, displays and data shall be available at the operator terminal:

- Air handling unit
- Fan status (current sensor proof)
- Outside air temperature
- Mixed air temperature
- Supply air temperature
- Return air temperature
- Coldest and warmest zone, all zones sampled
- Duct and space static pressures
- Freeze protection status
- Alarms (temperature, airflow, pressure)
- VFD (Output)

The following points, numbered 1 through 3, are only required if needed by control strategy:

- Directly measured total supply airflow (CFM)
- Directly measured total return airflow (CFM)
- Directly measured minimum outside airflow (CFM)
The following points shall be displayed using calculated values based upon commanded position unless exact values, as indicated by a feedback signal, are required by control strategy:

- Fan speed (per cent of full speed)
- Damper positions (per cent of full open)
- Heating and cooling valve position (per cent of full open)

**Hot water steam converters and pumps**

- Status of pumps (current sensor proof)
- Supply and return temperature
- VFD (Output)
- Valve positions (per cent of full open) (A calculated value not requiring feedback)
- Differential pressure (if used)

**Air terminals**

- Current space temperature
- Discharge air temperature
- Occupied heating/ventilating setpoint
- Unoccupied heating/ventilating setpoints
- Current status (heating/ventilating)
- Current mode (day/night)
- Minimum and maximum airflow setting (CFM)
- Current primary airflow reading (CFM)
- Current primary airflow calculation
- Valve position (per cent of full open) (Water - a calculated value not requiring feedback)
- High/low temperature alarm
- Input and software capacity to add local temperature adjustment and push button timed override from the space temperature sensor

**Chilled Water System**

- Supply and return temperatures
- Entering and leaving temperatures (if different from above)
- Supply temperature reset
- Pump status (current sensor proof)
• Pump command status
• Chiller status
• High/low temperature alarms
• VFD (Output)

Central Cooling Water (CCW) System

Consultant should refer to the standard drawing under Mechanical - Central Cooling Water for more detail about control of that system.

• Temperature and pressure of CCW supply water coming into the building at the header
• Temperature and pressure of CCW return water leaving the building at the header
• CCW supply pressure at the CCW header discharge
• Summer/winter mode status
• Entering and leaving water temperatures for the heat exchanger between the condenser water to CCW

Metering:
• See Metering section for utilities with meter outputs connected to DDC.

Special monitoring and control: Specify provision for the following DDC I/O points:

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fire alarm status</td>
<td>Binary Input</td>
</tr>
<tr>
<td>Cascade Lighting Control</td>
<td>Binary Output</td>
</tr>
<tr>
<td>Emergency Power Switch Position</td>
<td>Binary Output</td>
</tr>
</tbody>
</table>

Note: Review on a project-by-project basis whether it is desirable to monitor the lighting controls.

3.05 SEQUENCE OF OPERATION

Refer to mechanical design drawings. Control vendor shall develop a controls version of the sequence to show how the controls programming and contractor-engineered system implements the framework and intent of the sequence provided in the mechanical design. Include controls sequence of operations written in project specific highly detailed prose in submittals.

PART 4 – INTERFACE WITH OTHER SYSTEMS AND EQUIPMENT

4.01 INTERFACING TO FIRE ALARM SYSTEMS
The building fire alarm system shall shut down fan systems as required by Code. The control system shall monitor a relay from the fire alarm system for the purpose of determining when the fire alarm system has initiated a fire alarm event. The controls contractor shall coordinate with the fire alarm vendor to provide a coordinated shutdown and subsequent restart of fan systems that are shut down by the fire alarm system. Where the fire alarm system has priority control over the control systems for fan start or stop, the control system shall monitor the fire alarm system to determine which fans it has shut down. This can be accomplished by several methods. For instance, if there is a duct detector associated with a fan for smoke control shutdown purposes, that duct detector will report to the fire alarm system that the detector has activated and the fire alarm system will respond by sending a signal to that fan's motor starter to force it to stop (and possibly other actions as well). The control system shall have a means of monitoring that the fire alarm system has shut down that particular fan so that the control system can release its run signal to that fan. Otherwise, the control system will see that event as a fan failure and annunciate a nuisance fan failure alarm. Instead, the control system shall monitor that fire alarm action (either by monitoring a discrete relay from the fire alarm system or monitoring a secondary contact from the smoke detector, or monitoring integrated communications point between the fire alarm system and the control system), and respond by initiating its own "complementary shutdown" of the fan system in a manner that prevents nuisance alarms in the control system. The control system shall initiate an alarm event that relays the activation of the fire alarm system action only (such as an alarm for the duct smoke detector point being active). If, for example, a general fire alarm event for the building causes the fire alarm system to shut down all or a group of fan systems in the building, the controls system shall likewise initiate a complimentary shutdown for those same fan systems. After the fire alarm event has cleared, the controls system shall automatically restart the affected fan systems in an orderly manner without the need for operator intervention.

Shaft pressurization fans and their associated dampers shall be started and stopped by the building fire alarm system via interposing relays to the fan motor starter. The controls contractor shall be responsible for the interconnection wiring from the fire alarm start (and stop) relay to the motor starter terminations. The control system shall monitor the fan for run status only.

Where the fire alarm system controls a fan under fire alarm response and the control system controls the fan under normal building operation, the fire alarm system shall have priority control over the building control system. This also applies to situations where the two systems control the same damper. The order of priority of controls, from greatest priority to least priority, shall be as follows:

- Electrical disconnect switch
- Ductwork high static pressure safety limit switch
- Manual fan override switches at the fire alarm panel
- Supply fan ductwork smoke detectors (for pressurization fans that are associated with that fan, not the duct detectors tied to smoke or combination fire/smoke dampers in the distribution ductwork)
- Automatic active smoke control sequence of operation (for engineered smoke control systems only)
- Building automation system controls hard-wired safety devices (freezestats typically)
- Motor start HOA or VFD bypass starter controls
- Building automation system controls in AUTO

The controls contractor shall engineer and install the controls interface wiring for all fire alarm interfaces to fan motor starters in a manner to allow for the correct sequence of operation to occur as well as maintain the order of priority for the controls as required by the Codes.
4.02 INTERFACING TO EMERGENCY POWER SYSTEMS

- The control system shall monitor the emergency electrical system automatic transfer switches (ATS’s) that serve equipment that is controlled by the building control systems.

- For each ATS monitored, the control system shall monitor the “ATS transferred to Emergency Power Source” and “ATS transferred to Normal Power Source” points. The exact points will vary between ATS manufacturers.

- When the ATS has transferred to emergency power source, the DDC shall initiate a complementary shutdown of the affected equipment in order to prevent nuisance alarms such as fan failure, etc. When the ATS transfers back to the normal power source, the DDC shall conduct an orderly restart of the affected equipment, after appropriate delay has expired, and clear any nuisance alarms that are a result of the power loss and restart event.

- The controls contractor shall test the effectiveness of the controllers under power loss and restart conditions to ensure that the controllers retain their programming and parameter setups.

END OF DESIGN SECTION
Basis of Design

- This section applies to testing, adjusting, and balancing (TAB) of building mechanical systems. The following are design requirements.

Design Criteria

- Generally, for large projects with $3 million Maximum Allowable Construction Cost (MACC) or greater, TAB services are provided by the Contractor as part of the construction contract commissioning service.
  1) For small projects with less than $3 million MACC, the UW will hire the balancer directly under a separate contract.
  2) For projects that do not include full scope commissioning, the UW contracts separately for the testing, adjusting, and balancing (TAB) firm.

- The designer must give special consideration to the TAB process during the design. The TAB technician must be able to test and analyze the particular installation so that he can properly balance the system to obtain the greatest system efficiency and comfort level. It is important that balancing capability be designed into the system.

- On systems with variable frequency drives (VFD) the fan and pump design performance shall be accomplished with the VFD operating at 55 to 58 HZ.

- Specify that Testing Adjusting and Balancing will be performed in accordance with current NEBB or AABC requirements. Balancers must be affiliated by qualification with NEBB or AABC.

Design Evaluation

The following information is required to evaluate the design:

- Programming Phase: Provide a description of the scope of balancing activities to include new and existing systems. Describe any balancing activity required prior to demolition/renovation of existing systems.

- Schematic Design Phase: Indicate primary duct traverse locations where airflow measurements are required for pre-demolition.

- Design Development Phase: Provide an outline of specifications to include a preliminary description of the scope of balancing activities.

- Construction Document Phase: Provide a final specification to include a final description of the scope of balancing activities.

Construction Submittals

Balance Report submittals

Preliminary submittal

- Draft report for review by the A/E, Commissioning Agent, and UW Campus Engineering that includes the following:
  a) A list of items which will prevent the balancer from providing a full and complete balance.
  b) Narratives that describe all problem areas that may require major construction or design changes.
c) Narratives that describe the building systems and control systems to demonstrate comprehension of system operation, including system diversity.

d) The balancing agenda which reiterates the scope of the balancing work and the intended order of activity.

e) Sample balancing data sheets

Final submittal

- Certified Testing Adjusting and Balancing report that includes the following:
  a) Completed balancing data sheets.
  b) Drawings annotated to indicate inlet and outlet numbering that corresponds to the balancing data sheets.
  c) Narratives that describe the building systems and control systems including system diversity.
  d) Narrative description of those items not conforming to the contract requirements.

**Installation, Fabrication and Construction**

- On projects where the UW hires the balancer under a separate contract, the Design Consultant must specify the scope of Testing, Adjusting, and Balancing in the project contract documents. Specify the Contractor’s responsibility to provide construction support for the UW-hired balancer.
- On projects where the TAB is part of Commissioning and/or otherwise provided by the Contractor, the Design Consultant must specify the scope of Testing, Adjusting, and Balancing in the project contract documents.
Basis of Design

This section applies to commissioning of building mechanical systems.

Background

- The purpose of commissioning is to assure the Owner that the facilities are operating at optimum performance levels according to building-program established parameters.
- New facilities have become much more complex, requiring that new methods of start-up and operation be employed to assure that each facility will function as intended.
- There are many critical participants involved with a comprehensive building commissioning program. The obvious participants are the Contractors, Consultants, and the Owner. Additional specialists include a third party Commissioning Agent who is engaged directly by the Owner, and the Test Engineer who will be a member of the prime Contractor's team. Whereas, by contract, each will have clearly defined individual responsibilities, overall both become the essence of the final quality assurance program. The underlying objective is to deliver a fully operational facility that operates in accordance with the design intent.

Design Criteria

- Generally, for projects with a maximum allowable construction cost (MACC) exceeding $3 million, the UW will hire a Commissioning Agent. This will be a firm skilled in commissioning facilities of the type represented by the specific project. In this situation, the firm will be referred to as the Commissioning Agent. The Commissioning Agent will be hired prior to construction to be available to work with the Design Team and Contractor. In some cases the Commissioning Agent may be hired during design to contribute expert advice before the project is bid. UW Environmental Health and Safety shall serve as the commissioning agent for fire sprinkler systems. Commissioning of the life safety systems shall be coordinated with and approved by the UW Environmental Health and Safety.
- The specific duties of the Commissioning Agent are:
  1) Review the Contractor's systems start-up plans.
  2) Review the Contractor's equipment and component test procedures.
  3) Review the Contractor's systems and inter-systems functional performance test procedures.
  4) Witness, verify and approve satisfactory completion of equipment and component tests and systems and inter-systems functional performance tests.
  5) Review and approve specified documentation.
  6) When testing, adjusting and balancing (TAB) work is contracted separately by the Owner, coordinate the TAB firm's participation in the project.
  7) When commissioning has been successfully completed, recommend final acceptance to the Owner.
  8) Work with design consultant on developing FPT criteria to be implemented in the design document. Test Engineer will develop final FPT based on the criteria outlined in the design document.
- Generally, for projects with a MACC exceeding $3 million, the contract documents will require the prime Contractor to engage a Test Engineer to organize, schedule, and conduct all equipment and apparatus tests and prepare and perform all system functional performance tests. This organizing, scheduling and testing will be presented to the Commissioning Agent and UW Environmental Health and Safety for fire/life safety projects for review and approval.
The primary roles of the Test Engineer are to develop appropriate test procedures for all equipment/systems being tested, complying with the manufacturer’s standards and procedures, and to ensure that all is successfully completed within the contract completion period.

The specific duties of the Test Engineer are as follows:

1) Develop test procedures and forms for documentation of all equipment tests, system functional tests, and cross system functional tests. Test procedures shall be in accordance with equipment manufacturer's recommendations, where applicable. Test procedures shall fully describe system configuration and steps required for each test; appropriately documented so that another party can repeat the tests with virtually identical results.

2) Develop schedules for all testing; integrate testing into the master construction activity schedule; and coordinate all subcontractor testing.

3) Review and approve all other functional performance tests, results, and documentation required by the contract documents; for all equipment and systems, as performed by subcontractors, vendors, and manufacturer's representatives.

4) Submit test procedure schedule, procedures, forms, and other documentation to the Commissioning Agent and Owner for approval in accordance with the Commissioning Plan.

5) Coordinate directly with each subcontractor on the project specific to their responsibilities and contractual obligations.

6) Provide qualified personnel for participation in commissioning tests, including seasonal testing required after the initial commissioning.

7) Provide engineering and technical expertise to oversee and direct the correction of deficiencies found during the commissioning process.

8) Observe the start-up and initial testing of equipment by the Contractor and subcontractors, and then all final tests of equipment and systems.

9) Manage all cross system testing such as HVAC, building automation, fire alarm, emergency power, life safety, elevators, etc.

10) Note any inconsistencies or deficiencies in system operations and enforce system compliance or recommend to the Architect modifications to system design which will enhance system performance.

11) Coordinate the required A/E, Commissioning Agent, and Owner testing participation and approval procedures, after verifying that pretests have been satisfactorily conducted and final tests are ready to be performed.

12) In the event that a functional test fails, the cause of failure shall be determined and rectified as soon as possible, and then retested. If more than three functional tests of the same system(s) are required, the Contractor shall reimburse all associated costs for the extraordinary participation of the A/E, Commissioning Agent, and Owner's staff, as required by the particular test being performed.

13) Review operation and maintenance information and as-built drawings provided by the various subcontractors and vendors for verification, organization, and distribution.

14) Obtain all documentation from tests and assemble a final test report to be submitted to the Architect and the Commissioning Agent for approval.

15) Oversee and/or provide training for the systems specified in the division with coordination by the Divisions 15 and 16 subcontractors.

16) Update Basis of Design by Owners representative.
For projects with a MACC less than $3 million the UW will hire a Commissioning Agent to perform the duties that would be performed by the Test Engineer. The Commissioning Agent may be hired prior to construction to be available to work with the Design Team and Contractor (Please consult with Campus Engineering at early design phases). The Commissioning Agent can contribute expert advice before the project is bid.

For projects with a MACC less than $3 million, it may not be necessary to require the prime Contractor to engage a Test Engineer. The scope of commissioning and the extent of commissioning requirements may be reduced as may be appropriate to the complexity and sophistication of the specific project. These decisions must be made by the Consultant and the University, via specific discussion of the commissioning program, and all related decisions and commitments made prior to the end of the design development phase.

Even though a Test Engineer may not be required on projects with a MACC less than $3 million, commissioning requirements for the project will still be incorporated into the contract documents. It shall also be required that the prime Contractor designate, in writing, a member of the construction team to be responsible for the commissioning program.

For all projects a critical requirement for the prime and subcontractors is development of the comprehensive test procedures for equipment and systems. This test is based on the operating criteria, test parameters, and acceptable results required. Many contractors have not had experience in this area. Therefore, someone who specializes (or has had experience) in development of test procedures is required.

The University has developed a library of test procedures for the range of equipment and systems it has commissioned. To a degree, there is a somewhat generic quality regarding test procedures for common equipment and systems. However, in every instance, such procedures must be carefully reviewed and adapted to the unique characteristics and design conditions of the project.

The University will make this material available to consultants and contractors for reference during design and construction. Doing so will help to reduce the time required for such development, develop more consistent testing/commissioning, and gradually improve the quality of the program.

Design Evaluation

The following information is required to evaluate the design:

- **Schematic Design Phase:** Provide a list of systems and equipment to be commissioned.
- **Design Development Phase:** Provide a preliminary scope of work description for systems and equipment to be commissioned.
- **Construction Document Phase:** Provide a final scope of work description for systems and equipment to be commissioned. Provide final design commissioning documents.

Construction Submittals

- **Preliminary submittal**
  a) Commissioning plan
  b) Basis of Design documentation
  c) Sample installation audit forms
  d) Draft startup plan
  e) Draft commissioning schedule
  f) Draft functional performance test procedures

- **Final submittal**
a) Commissioning plan  
b) Basis of Design documentation  
c) Installation audit forms  
d) Startup plan and startup forms  
e) Functional performance tests  
f) Commissioning progress reports  
g) Commissioning issues matrix  
h) Commissioning meeting minutes  
i) O&M preliminary review  
j) Owner Training Plan  
k) Final Commissioning Report

END OF DESIGN GUIDE SECTION