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FOREWORD

The Facilities Criteria (FC) provide functional requirements (i.e., defined by users and operational needs of a particular facility type), and are intended for use with the International Code Council (ICC) and American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE).

Because the FC are coordinated with the ICC and ASHRAE technical requirements, they form an element of the JHU requirements applicable to specific facility types.

The FC are living documents and will be periodically reviewed, updated, and made available to users as part of the Services’ responsibility for providing criteria for design and construction.

Recommended changes or variance with supporting rationale shall be sent to the respective service proponent office by the form in Appendix C.

FC are effective upon issuance and are distributed only in electronic media from the following source:

- Johns Hopkins University – Department of Facilities and Real Estate

Hard copies of FC printed from electronic media should be checked against the current electronic version prior to use to ensure that they are current.
Document: Johns Hopkins University (JHU) Mechanical Engineering Design Guide

Superseding: Initial Issue

Description: This FC provides mechanical engineering requirements for the design, development and revision of project documents, including drawings, specifications, and Requests for Proposal, for facilities under the jurisdiction of JHU. This FC is the initial issue and will reviewed periodically and revised as needed.

Reasons for Document:
This FC provides JHU specific mechanical engineering requirements that are more stringent than the referenced standards and codes.

Impact:

- Improve the consistency and clarity of the mechanical engineering requirements
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CHAPTER 1 - INTRODUCTION

1-1 BACKGROUND.

The Facilities Criteria (FC) were created to facilitate consistency and to set minimum design criteria across all aspects of the design and execution of projects to include facilities infrastructure improvements, renovation efforts, re-capitalization efforts, and new work on JHU occupied facilities. Chapter 2 of this FC further expands upon mechanical specific design requirements while Chapter 3 expands upon plumbing specific design requirements.

1-2 PURPOSE AND SCOPE.

This FC document provides the mechanical engineering requirements for new and existing facilities owned or occupied by JHU. This information shall be used to generate design deliverables such as Calculations, Specifications, Drawings, and Request for Proposals.

1-3 APPLICABILITY.

This FC document applies to all planning, design, and construction of JHU owned or occupied facilities as stated within the project contract. Mechanical design shall be in accordance with all referenced documents as this FC document. Conflicts between this FC and the project contract shall be brought to the attention of the Project Manager or Engineering Group.

1-4 GENERAL BUILDING REQUIREMENTS.

Comply with the International Building Code (IBC) for general building requirements. The IBC provides applicability of model building codes and criteria for typical design disciplines and building systems, as well as for accessibility, security, high-performance and sustainability requirements, and safety. Use this FC in addition to the ICC and ASHRAE and criteria referenced therein.

1-5 REFERENCES.

Appendix A contains a list of references used in this document. The publication date of the code or standard is not included in this document. In general, the latest available issuance of the reference is used.

1-6 GLOSSARY.

Appendix B contains acronyms, abbreviations, and terms.
CHAPTER 2 - HEATING, VENTILATION AND AIR CONDITIONING SYSTEMS

2-1 HVAC SYSTEM SELECTION AND LIFE CYCLE COST ANALYSIS (LCCA) CONSIDERATIONS

The designer must prepare a LCCA to determine the heating and cooling systems, fuel sources and major system components. The analysis must conform to the life cycle cost and energy criteria specified in Chapter 6 of ASHRAE 90.1.

In general, water-cooled equipment shall be provided for energy efficiency. Air-cooled equipment shall be utilized where project requirements show air-cooled equipment is a more effective solution. In areas without a reliable make-up water source, air-cooled chiller equipment shall be evaluated in coordination with the project manager/engineering department.

2-2 VENTILATION AIR

Ventilation shall be provided per ASHRAE 62.1.

System performance for critical health, energy and security concerns, such as proper indoor air quality, minimization of ventilation conditioning and avoidance of infiltration exposures, depend upon close attention being paid to the proper design and operation of the building ventilation systems, relief/exhaust systems and their effect on building pressurization.

Create an understanding of ventilation, exhaust and pressurization requirements derived from code and other associated standards as defined in this document. Within the design, define the expected operational modes, such as air side economizer, small and large conference room control strategies (including flexibility to add in the future) and general demand control ventilation. For the design of new and/or modifications of existing systems; evaluate and apply one or more of the following operational approaches as appropriate:

- Fixed Flow: Building ventilation and exhaust, under non-economizer operation, remains fixed. Suitable modulating control relief shall be provided for economizer operations.

- Variable Flow: Where systems need to support large variable ventilation loads, such as large conference rooms or have a requirement for close control of local pressurization, then a variable flow system having VAV and/or CAV terminals shall be used in the ventilation and relief/exhaust systems. A Decoupled AHU Concept using a 100% outside air shall be used for variable flow ventilation applications in conjunction with local conditioning terminals for highly variable distributed ventilation loads, such as for conference centers.
2-2.1 Relief Air

Relief air systems are part of the overall HVAC systems and are required to assist in maintaining proper building pressurization. The outdoor air introduced into the building shall be tracked through METASYS to maintain proper building pressurization. When the building pressure exceeds a pre-determined set point as sensed by static pressure sensors located throughout the building, return/relief fans or separate exhaust fans shall be energized to relieve air from the building to the outdoors. Relief fans can be provided as part of the air handling unit system or as a separate exhaust system. The building pressure shall not exceed 0.05 inches water column (w.g.). The relief air duct velocity shall not exceed 1800 fpm.

2-2.2 Convenience Purge

Provide an operational mode for non-occupancy periods, which is operator selectable, for concentrated ventilation air and matching relief capacity to serve purge operations of any or all controllable zones within each air handling unit’s service area. Areas subject to process fumes, smoke or odors, such as mechanical rooms, shall have a manual purge operation.

2-3 HEATING AND COOLING LOAD CALCULATIONS

HVAC design analysis for new facilities or renovation of existing facilities shall include a psychometric analysis documenting that the system meets the design criteria. The analysis must provide calculations of system cooling load, energy/mass transfer through conditioning equipment and fan and a system schematic indicating state point dry bulb and wet bulb temperatures (or humidity ratios) of return air, outside air, mixed air and supply air flow streams. The system must provide the capability to condition ventilation air and maintain space relative humidity over the full range of cooling load.

2-3.1 Load Calculations

Heating and cooling system design loads shall be determined in accordance with the calculation procedures described in ASHRAE Standard 183 unless otherwise specified.

Provide a 1.15 safety factor for cooling equipment and distribution sizing, to include piping mains, to account for potential growth or change in occupancy/use. Provide a 1.10 safety factor for heating equipment and distribution sizing, to include piping mains, to account for potential growth or change in occupancy/use.

Acquire the actual space load conditions based on the actual equipment load in the spaces. The Project Manager/engineering department will assist to determine the appropriate method for sizing cooling equipment depending on specific project requirements. The A/E shall be responsible for collecting existing drawings and, if necessary, for measuring the current space loads should the equipment information be
Consult equipment manufacturers for specific heat gain requirements for documentation of design criteria. Note that often a design calls for anticipated or future loads (for example, 750-30,000 watts per rack, and 1,000 watts per square foot). This equipment load terminology does not include cooling loads derived from lights, building envelope or people, which must be included on a project-by-project basis. For example, if the equipment loads are not easily discernible in the early stages of a project, a requirement may be for the equipment load to be within the range of 5 to 1,000 watts per square foot depending on application, while the cooling load from the lights, building envelope and people are determined through the design.

Request, from the Project Manager/Engineering Department, the occupancy requirements to determine the cooling load required due to occupancy. If unknown, derive from standard industry guidelines. The Project Manager/Engineering Department will provide actual equipment loads and occupancy requirements. In addition, ensure the greater of the actual space load or the anticipated/future load governs the design. Acquire the actual space load conditions based on the actual equipment load in the spaces. Apply caution when utilizing ASHRAE guidelines regarding sizing for this equipment compared to actual specification heat output. The Project Manager/Engineering Department shall assist to determine the appropriate method for sizing cooling equipment depending on specific project requirements.

2-3.2 Outdoor Design Conditions

2-3.2.1 Site Specific Criteria

The following outdoor design conditions shall be used to design all mechanical systems in compliance with ASHRAE Climatic Design Information unless otherwise noted:

- Summer Design: 0.4% - 95/78 F (Baltimore/Washington metro area)
- Winter Design: 99.6% - 0 F (Baltimore/Washington metro area)
- Cooling Tower: ASHRAE 0.4% Evaporation WB
- Air-Cooled Equipment: ASHRAE 0.4% Cooling DB + 15 degrees F

2-3.3 Indoor Design Conditions

2-3.3.1 Conditioned Spaces Specific to JHU

The A/E shall design all mechanical systems and complete all load calculations in compliance with Table 2-1 below. Use the listed temperatures for use in all load calculations (e.g. 72 °F in Office Areas). If a Noise Criteria (NC) level is not indicated, the NC shall comply with industry standards.

The specifications shall require the Testing and Balancing (TAB) agent to perform sound tests, or acquire the services of a sound consultant, and administer testing in
accordance with applicable American Society of Testing and Materials (ASTM) standards to verify the installation complies with the requirements of Table 2-1. There shall be no testing tolerance.

<table>
<thead>
<tr>
<th>Area</th>
<th>Temperature</th>
<th>Humidity</th>
<th>Sound NC (maximum)</th>
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<tr>
<td>Office Areas</td>
<td>72°F</td>
<td>50% +/- 10%</td>
<td>40</td>
</tr>
<tr>
<td>Conference Rooms</td>
<td>72°F</td>
<td>50% +/- 10%</td>
<td>30</td>
</tr>
<tr>
<td>Transport Closets/Comms Rooms</td>
<td>72°F</td>
<td>50% +/- 10%</td>
<td>55</td>
</tr>
<tr>
<td>Mechanical/Electrical Rooms/Elevator Machine Rooms</td>
<td>74°F</td>
<td>50% +/- 10%</td>
<td></td>
</tr>
<tr>
<td>Electrical Closets</td>
<td>85°F</td>
<td>50% +/- 10%</td>
<td></td>
</tr>
<tr>
<td>UPS Rooms</td>
<td>74°F</td>
<td>50% +/- 10%</td>
<td></td>
</tr>
<tr>
<td>Battery Rooms</td>
<td>77°F</td>
<td>N/A</td>
<td></td>
</tr>
</tbody>
</table>

Note: All people counts shall be actual seating not default based on ASHRAE 62.1

2-3.3.1.1 Data Center and Machine Rooms

For Data Centers and Machine Rooms the ambient space temperature, humidity and sound Noise Criteria (NC) levels shall be determined based on the operational requirements, to include the project specific IT equipment.

2-3.3.1.2 Special Areas

For special areas, such as clean rooms, printing areas, industrial processes and warehouse spaces, the ambient space temperature, humidity and sound Noise Criteria (NC) levels shall be determined based on the operational requirements, to include end-user specific criteria.

2-4 SPECIFIC FACILITY-TYPE HVAC REQUIREMENTS

2-4.1 Transport Closets and Communications Rooms

Provide fan coil units (FCU) as the primary cooling equipment while the house system functions as the redundant cooling system. If the house system is not available to serve as the redundant cooling system, the A/E shall provide an alternative solution to provide adequate redundancy for the primary cooling equipment.

The temperature sensor within the space shall modulate the FCU control valve to maintain space conditions as required in this FC. The A/E shall be aware that there is only a maximum humidity requirement and, to the maximum extent practical, induce
a modest ventilation air change from a house air handling unit or other means to avoid staleness.

It is acceptable for the required ventilation to be achieved by utilizing a door undercut to the space. The FCU design shall be as follows:

- Chilled water cooling capacity shall meet the calculated load plus an additional 25% capacity.
- Evaluate the need for and feasibility of floor-mounted CRAC units to satisfy cooling requirements for the space.

2-4.2 Office Areas

Evaluate and design all office areas in accordance with ASHRAE 62.1 and the IMC to provide cooling units to maintain space conditions as required in this FC. Office areas shall have a maximum NC rating of 40. The house air system shall be sized for typical office, people and skin loads with adequate airflow to ensure for proper conditioning and ventilation distribution.

Any chilled water system(s) shall be distributed under the raised access floor or located in the ceilings. The chilled water system shall be sized to accommodate any additional loads over and above the house air system.

2-4.3 Conference Rooms

Evaluate and design all conference rooms for intermittent usage per current ASHRAE 62.1 and the IMC guidelines. Conference rooms that contain audio or video conferencing equipment shall have a maximum NC rating of 30. Conference rooms that don’t contain audio or video conferencing equipment shall have a maximum NC rating of 35. Where the project allows, equip the AHU with heat recovery equipment and devices. For intermittent usage applications, it is acceptable to utilize the house system, where capacity allows, with VAV and reheat coils to compensate for high minimum primary air settings.

For conference center applications, containing multiple conference rooms located adjacent to each other, each conference room shall be served by two separate VAV boxes (one house and one 100% outside air) each with reheat coils. The outside air VAV box shall be controlled by a wall-mounted CO2 sensor in the space. The base building HVAC portion shall be controlled by a wall-mounted thermostat.

2-4.4 Electrical Rooms

Evaluate and design all electrical rooms in accordance with the IMC, NEC and ASHRAE 62.1. Provide N+1 cooling units to maintain space conditions as required in this FC. Locate units to achieve even conditioning of the space. Provide fresh air ventilation from the house air handling unit(s) to create a room air change which
avoids staleness.

2-4.5 Electrical Closets

Evaluate and design all electrical closets in accordance with the IMC, NEC and ASHRAE 62.1. Heat shall be dissipated using transfer air by one of the following scenarios without impacting Fire Protection or Security requirements.

- Undercut up to 1-inch
- Provide a door louver
- Transfer duct with appropriate protective measures and termination grille

Provide an exhaust fan and wall-mounted thermostat to control exhaust for maintaining space requirements.

Electrical Closets containing transformers larger than 100-kVA and/or panel boards rated for 1200A or larger shall be treated as Electrical Rooms.

2-4.6 Mechanical Rooms

Evaluate and design all mechanical rooms in accordance with the IMC and ASHRAE 62.1. Provide cooling units to maintain space conditions as required in this FC. Provide fresh air ventilation from the house air handling unit(s) to create a room air change which avoids staleness. Provide potable water service, associated floor drains with trap primer systems and compressed-air drop wall outlet(s) for maintenance operations. Provide unclassified phone equipment in Mechanical Rooms. Include the connections and infrastructure between communications closet and telephone such as conduit, routing, junction boxes and line connection locations.

A strategically placed permanent structural beam system (new construction) shall be installed overhead to allow hoist and trolley to operate in a continuous, unobstructed path to allow mechanical equipment and components (e.g. chiller, pumps, etc.) to be transported or removed into an aisle way for service from the space. Overhead hoists and beams/trolleys shall be capable of moving the heaviest installed component that would require replacement. Portable units, coordinated with the chiller manufacturer to comply with weight requirements, shall be provided for servicing chiller evaporator and condenser heads if permanent units are not feasible. Portable units shall be specified to become property of JHU upon project completion. In addition, include hand chain hoist with a geared trolley (w/ hand chain) for chiller and water pumps servicing, repair and replacement.

Mechanical Rooms housing chillers shall comply with all manufacturer’s recommendations and the requirements listed below for installation, operation, rigging and maintenance of chiller and water pumps, and shall allow for servicing of equipment, including but not limited to chiller motor, chiller compressor, chiller suction ell, pump motor, pump casing and pump impeller.
2-4.7  Elevator Machine Rooms

Evaluate and design all elevator machine rooms in accordance with the IMC, ASME 17.1 and ASHRAE 62.1 to provide cooling and humidity control. Conditioning shall be achieved through the use of a packaged Direct Expansion (DX) and shall not obstruct or violate elevator machinery access. Obtain performance requirements and conditioning loads from the Basis of Design elevator equipment manufacturer.

2-5  OTHER HVAC DESIGN CONSIDERATIONS

2-5.1 Sounds and Vibration Control

The design of HVAC systems to maintain noise levels below those recommended for the proposed occupancy in accordance with the ASHRAE Handbook and SMACNA guidelines. Preferably, locate sound sensitive rooms away from air handlers and mechanical equipment. Acoustical duct liner is not allowed. Use double wall acoustic duct where sound attenuation cannot be accomplished by other methods and the duct is not serving occupancies that are sensitive to particulates. Increase the outside duct dimensions as required to maintain adequate internal cross sections.

2-5.2 Commissioning requirements

After successful completion of Testing and Balancing and prior to the acceptance of the HVAC systems, provide a minimum of one week of trends measured with data loggers or from the Building Automation System (BAS) while the equipment is in full automatic mode to ensure that all systems are working properly under all conditions. Include the following trending requirements:

- Points to be trended shall match those in the contract documents
- Data points must be at the same time increments
- Provide trends in graphic format.
- Clearly identify all trend data

Commissioning shall be completed in accordance with all guidelines listed in the Code Reference Section and Division 01 Specification 01 91 13.00 50 - General Commissioning Requirements, Commissioning of Mechanical Systems 23 08 00.00 50, Commissioning of EMCS Systems 23 09 09.00 50, Commissioning of Plumbing Systems 22 08 00.00 50 and ASHRAE Guideline 0-2005, the Commissioning Process.

2-6  CHILLED AND CONDENSER WATER SYSTEMS

2-6.1 System Architecture

Evaluate and design all chilled and condenser water systems in accordance with the IMC and ASHRAE 90.1. The chilled and condenser water system(s) shall be flexible, reliable, easily expandable and readily maintainable. The system(s) shall be
designed for the 100% load (or demand) plus the safety factor indicated in this FC.

Piping mains shall be sized appropriately for this extra capacity unless stated otherwise by the Project Manager/Engineering Department. Extra equipment shall be used for redundancy only and shall not add additional capacity to the system. Where directed by the Project Manager/Engineering Department, space shall be allocated for future chillers, pumps and associated headers and piping systems, to include appropriate sizing; tap, valves and blind flange locations, taking into account minimal impact to existing operations.

The central chilled/condenser water plant and associated distribution system shall be primary/secondary and shall be configured using the N+1 redundancy where N is the number of equipment sized to handle 100% of the load or demand. The N+1 method shall be applied to chillers, primary chilled water pumps, secondary chilled water pumps, cooling towers and condenser water pumps. Variable flow primary systems and constant flow secondary systems shall be considered on a case-by-case basis through coordination with the Project Manager/Engineering Department.

If a single chiller is served by a multiple cell cooling tower, the N+1 redundancy shall require one additional multiple cell cooling tower, not just an extra cell.

2-6.1.2 Condenser and Primary and Secondary Chilled Water Pumps

Primary chilled or condenser water pumps shall be piped in Parallel Configurations to allow flexibility in case of failure so any condenser or primary pump can be operated with any chiller. This concept requires that chillers and cooling towers shall also be piped in parallel configurations. Secondary Pumps shall be equipped with Variable Frequency Drives (VFD) and associated controls to work in conjunction with terminal equipment two-way modulating valves.

To the maximum extent practical, condenser water pumps shall be installed indoors, however sump pump systems and vertical turbine pumps must be coordinated through the Project Manager based on an evaluation of factors such as operation efficiency, energy efficiency and/or life cycle cost.

2-6.1.3 Free Cooling

Plate-and-frame heat exchangers for use in Water-Side Free Cooling Applications shall be used where economically feasible, as determined in the Energy Evaluation. The free cooling configuration shall be designed for seamless switching from free cooling to mechanical cooling so that the chillers restart in mechanical cooling mode regardless of entering condenser water temperature. This may be accomplished utilizing either integral chiller head pressure control or by primary/secondary/condenser water pumping (with chillers on secondary loop to control chiller head pressure). Investigate the ability of simultaneous water side free cooling and chiller operation.
2-6.1.4 Make-Up Water Reliability

Chilled/condenser water systems shall be fed from two diverse sources for reliability in case of failures, additions and deletions of loads; and maintenance issues. The chilled/condenser water sources can range from two chilled/condenser water plants to two different piping main sources. Depending on the site location, existing conditions and project requirements, the water source may be either domestic or reclaimed water (where available). Coordinate with the Project Manager/Engineering Department to determine availability, practicality and effectiveness of the source(s).

2-6.1.5 Roll-Up Chiller

Provide one set of taps (with isolation valves, flanges, covering caps and labels) on chiller primary headers to allow for a temporary connection of a roll-up chiller in case of failure or to assist in future replacement projects. Identify the purpose and include the operating procedure for the taps on the drawings. Follow Project Manager/Engineering Department guidance for tap sizing.

For Leased Facilities, A/E shall evaluate the provisions of manufacturer’s packaged pump houses and chiller plants.

2-6.1.6 Small Applications

Unless otherwise directed by the Project Manager/Engineering Department, traditional packaged air cooled chillers shall be utilized for applications requiring less than or equal to 200 Tons of cooling and location is not feasibly connected to the campus central utilities. Where rigging, implementation space and or flexible redundancy/expansion are considerations that may prevent the use of traditional air-cooled chillers, modular type chillers shall be evaluated as an alternative selection. An analysis on the practicality and benefit to using a modular chiller approach shall be provided to the Project Manager for approval no later than the first design submission.

Chillers shall be configured in an N+1 arrangement which provide one full duty and one full standby chiller. In addition, a set of headers with valved connections shall be provided for an additional full size chiller.

The chilled water systems shall utilize a variable volume pumping strategy. Pumps shall be configured in an N+1 redundancy arrangement where N is the number of equipment sized to handle 100% of the load or demand.

The chilled water distribution shall be configured in a loop to provide a network that provides chilled water to the HVAC equipment branches to maintain reliability for maintenance, capacity and tie-in purposes. The piping mains shall be sized for the combined capacity of the duty and standby chiller.
2-6.2 Supply and Return Temperatures

2-6.2.1 Existing Systems

For existing systems, the chilled/condenser water supply temperature and Delta T (Return Temperature Outlet minus Supply Temperature Inlet) shall conform to the existing plant and existing coil design parameters (e.g. if the existing plan size and coil sizes have a 10°F delta T, the new chillers (if applicable) and/or new coils shall have a 10°F delta T). Coordinate with the Project Manager/Engineering Department and existing facility surveys and documentation to determine existing conditions.

2-6.2.2 New Systems

For new systems, provide a life cycle and engineering analysis to determine the value of increasing the design Delta T to a maximum of 12°F. The design chilled/condenser water supply temperature shall be based on the worst-case situation in the building that typically is the following project specific requirements:

- Dehumidification requirement
- System treatment of outside air in the site-specific location

The following critical factors should be considered and coordinated with the Project Manager/Engineering Department to design a cost-effective, flexible system:

- Increasing the design Delta T resulting in decreased pipe sizes.
- Ensuring that efficient heat exchange takes place through coils, even at partial loads (possibly non-turbulent) which may be a concern with large heat exchanger equipment.
- Integrating any customized water-cooled equipment for Data Centers into the system.
- Integrating any equipment with any unconventional Delta T coils into the system, such as equipment coils with 14°F or 16°F temperature differentials.

2-6.3 Distribution

All condenser water piping to the cooling tower shall be run as symmetrically as possible to ensure flow is evenly distributed to all cooling tower cells. The supply header shall be located below the cold water basin level to prevent flooding of the cooling tower basin upon pump shutdown. For the distribution piping leading from the water supply main to the hot water basin inlet, the upper section (from the automated control valve to the hot water basin) shall be constructed of Schedule 80 PVC to avoid any unwanted corrosion. Provide tower fill bypasses for winter operations (either at the tower or within condenser water mains).
All chilled water piping shall be run as symmetrically as possible as well.

2-6.3.1 Configurations

In areas of heavy cooling loads (e.g. data centers, watch centers, etc.), provide two chilled water pathways in one of the following distribution piping configurations:

- **Loop** – a circumferential distribution which provides for equalization of pressure through the system and has branch taps for equipment support.
- **Grid** – a branching network allowing for full reach of service to potential equipment loads.
- **Cross-Connected Loop** – a combination of an enhanced loop with cross-over grid to allow for better reach for future critical equipment, such as for chilled water serving data center computer room units, to achieve reliability and flexibility in maintenance, capacity expansion and ease of connection.

Coordinate with the Project Manager/Engineering Department if future flexibility requirements differ from the requirements of this FC. The Project Manager/Engineering Department will determine the quantity, size and spacing of chilled water taps to support the project requirements based on power density, future growth, etc.

2-6.3.2 General

The following are requirements of typical chilled water distribution systems.

a. Risers shall be located in room corners or adjacent to walls and have the clearances as stated in this FC.

b. Terminal equipment shall be equipped with Two-Way Modulating Control Valves to work in conjunction with the secondary pump variable frequency drive system and associated controls.

c. Manual Air Vents (no automatic air vents) shall be installed, without disruption to other systems service or operation, in all high points in the chilled/condenser water system, in pipe segments (with isolation valves) of loop or grid systems, at heat transfer coils and elsewhere as required to vent all air out of the chilled water system (including reverse traps due to pipe jogging).

d. Piping penetrating through walls and floors shall have black steel pipe sleeves with fire retardant in compliance with NFPA. Floor sleeves shall have a "sealed lip" pipe sleeve 2 inches above and flush below to prevent flooding from draining through the piping penetration. Wall penetrations shall have be flush on both sides of wall. Exterior wall
penetrations shall have a “Dry-Link” type of expanding sleevefill.

e. Drains shall be provided, without disruption to other systems service or operation, at all chilled/condenser water system low points, in pipe segments (with isolation valves) of loop or grid systems and at all heat transfer coils for draining system (including reverse traps due to pipe jogging).

2-6.3.3 Overhead Piping

New overhead piping containing water shall be prohibited to be designed to pass within or through electrical rooms/closets and telecommunication rooms/closets. Every effort shall be made to separate electrical/IT equipment and piping containing water. Fittings, valves, meters, and any other non-welded, non-soldered, non-brazed joints or penetrations in the pipe are not permitted above equipment and, to the maximum extent practical, should be located completely out of any electrical rooms/closets and telecommunication rooms/closets. Investigate and design protection schemes to ensure risks to electrical/IT equipment is minimized for any scenarios where water piping is not practical to be located outside of the room/closet.

For existing, overhead piping containing water within electrical rooms/closets and telecommunication rooms/closets, evaluate the feasibility of relocating the pipe with the Project Manager/Engineering Department. The feasibility evaluation shall include the following, at a minimum:

- Potential pathways for relocating the pipe. Define the technical and operational reasons which eliminate any possible alternate paths (e.g. clearances, access, system reliability, etc.)
- Potential risk mitigation strategies such as providing drip pans with drains
- Potential outages required to provide potential pathways for relocating the pipe.
- Cost of alternative pathways for relocating the pipe vs. risk mitigation strategies.
- Impacts to the construction schedule for installation of any alternative pathways and/or risk mitigation strategies.
- Drawings, sketches or slides to convey options, paths and impacts

If JHU agrees the conditions do not allow for separating the pipes, the A/E must provide the best mitigation possible given the restrictions of the site. The following methods for mitigation shall be considered when preparing the design:

1. Water piping shall not pass over medium voltage electrical equipment (>600v).
2. Piping, located above electrical equipment (<600v), shall pass by the shortest route possible, preferably perpendicular to the long side of the equipment.
3. Fittings, valves, meters, and any other non-welded, non-soldered, non-brazed joints or penetrations in the pipe are not permitted above equipment and, if possible, should be located completely out of the electrical room. Ultrasonic flow meters may be considered as alternatives to in-pipe meters if the flow meter cannot be moved out of the room.

4. Drip pans are required for any existing pipe that passes above equipment. The pan shall be equipped with a drain which is sized to one inch minimum for easy cleaning and routed to the nearest drain. Leak detectors shall be installed in all drip pans and be connected to an alarm to the building EMCS.

5. The following are options to provide shielding for electrical equipment. Each option requires that the product shall be installed on areas that are within 6'-0" horizontal distance of any electrical equipment. Either option is subject to Project Manager approval.
   a. Install a clear poly-carbon (e.g. Lexan or similar material) shield to deflect potential water leaks away from the electrical equipment. The shield shall extend a minimum 6" below the lowest level of the pipe on the equipment side of the pipe. The shield shall be transparent and shall not impede access to the pipe by maintenance personnel with tools. This may result in the shield being located 12"-18" from the side of the pipe.
   b. Install Teflon-coated fiberglass (Ramco or approved equal) at all connection in the piping system. Shielding shall meet the minimum temperature and pressure ratings of the system. The shield shall be attached to the pipe with boot clamps under the insulation. Pipe connections being protected will not be readily apparent nor visible as a result of the coverage with the insulation. Install a drain hose from each shield terminal at the leak detection cabling. Each drain line shall include a clear pigtail which shall be located as close as reasonably possible to the shield. A/E shall evaluate and provide details regarding the following grouping: together multiple drain lines, and securing and concealing drain piping along the vertical chilled water piping risers.

6. Any utilized piping shield shall be rated as Class A for interior wall and ceiling finish (flame spread 0-25, and smoke developed 0-50 when tested per NFPA 255, Standard Method of Test of Surface Burning Characteristics of Building Materials)

7. The A/E, on a drawing, shall show all dimensions/clearances from the equipment to the pipe or walls/ceiling, whichever is less. The intention is to show all critical dimensions within the space. Minimum clearances shall be 6'-0" vertical and 6'-0" horizontal clearance from the equipment. If these minimum clearances cannot be achieved, consideration shall be given to moving equipment, or downsizing it, as approved by the JHU.

8. Risers shall be located in room corners or adjacent to walls and have the clearances as stated herein.
2-6.3.4 Isolation Valves

Header Isolation Valves are critical for piping loop isolation and rerouting in case of repairs or terminal equipment additions. Isolation valves shall be provided at each header and branch takeoff. Provide isolation valves to accommodate maintenance and isolation functions to facilitate redundant units being taken out of service.

All valves shall be located to ensure accessibility for maintenance operations. When located above the ceiling or below the raised access floor, identification marker tags shall be provided to identify locations.

2-6.3.5 Differential Pressure Transmitters

Differential Pressure Transmitters controlling secondary pump speed shall be located so as not to be affected by loop isolation or closure.

2-7 REFRIGERANT SYSTEMS

Chillers shall not use HCFC based refrigerants.

Chillers shall be furnished with the necessary features to facilitate refrigerant recovery including recovery and transfer of entire refrigerant charge between self- contained isolation vessels, including with isolation valves in compressor discharge and condenser liquid lines.

2-7.1 Refrigerant Recovery Systems

Refrigerant recovery systems shall meet the requirements of 40 CFR 82 Protection of Stratospheric Ozone with respect to system capabilities and be certified per AHRI. Provide refrigerant recovery pump and storage tank(s) designed with storage capacity for a full chiller charge. The refrigerant recovery equipment may be remote from the chiller(s) with refrigerant recovery piping to and from the chillers(s). The system shall be designed to allow isolation and “push/pull” refrigerant recovery of individual chillers. All liquid refrigerants shall transfer through a three-core filter drier, with a moisture indicating sight glass in the transfer line at the storage vessel. The refrigerant recovery unit shall be cooled by the system condenser water, with an emergency domestic water back-up connection upon loss of condenser water. Waste water from the emergency back-up shall be discharged to the sanitary sewer system.

2-7.2 Refrigerant Monitoring System

A system for refrigerant exhaust which operates during a refrigerant leak shall be provided per code, with detectors (sensors) distributed/mounted at all likely points of refrigerant accumulation (such as near open drives, floor drains and ventilation points- refrigerant sensor shall be provided at all egress doors). In addition, this system shall include audible/strobe alarms within the space and a 3-light tower visual annunciator at each entry point (Red for refrigerant measurements of 100% OEL.
ppm, Yellow for refrigerant measurements of 50% OEL ppm, and Blue for refrigerant measurements of 5% OEL ppm where OEL is determined from each Refrigerant’s Safety Data Sheet). At a minimum, a 3 light tower and audible/strobe alarm shall be located on each interior wall of the mechanical room (for operating personnel safety) and on the outside wall of each entrance to the mechanical room (for responders). The refrigerant exhaust system shall be designed per ANSI/ASHRAE Standard 15: Safety Standard for Refrigeration Systems. Also the audible alarm’s DB rating for refrigerant room shall comply with NFPA Standards.

1. Refrigerant Signs: there shall be two separate signs that indicate the warning for a danger area which contains a large amount of refrigerant. The first shall be placed outside of doorways and the second will be inside. Both will be easily visible for the public and in close proximity to the alarm beacon.
   a. The signs shall be constructed of 0.060 Styrene Single-Sided with rounded corners per OSHA standard and mounting holes drilled in each corner.
   b. The outside sign shall be 11” high x 17” wide.
   c. The inside sign shall be 8.5” high x 11” wide.
   d. The signs shall be oriented landscape and have 9 rows of text. There is a bold black line that boarders all of the text, and the first row has a red background. All text is black unless otherwise noted.

2. The 11”x17” sign is as follows:
   a. First line: has a 2” danger sign (triangle exclamation point in the middle) followed by 1.5” DANGER centered.
   b. Second line: Centered 1” AUTHORIZED PERSONNEL ONLY.
   c. Third line: Centered 1” (Type of Refrigerant used i.e. R-134a) Refrigerant In Use.
   d. Fourth line: Centered 1” STAYOUT DURING ANY ALARM.
   e. Fifth line: Centered ¾” in parentheses- (Strobe Light Flashing and/or Audible Alarm).
   f. Sixth line: Adjusted left ½” ALARM/ STROBE INDICATOR.
   g. Seventh line: Adjusted left ½” RED (have word red in color red): DANGER- Refrigerant Leak.
   h. Eighth line: Adjusted left ½” AMBER (have word amber in color amber): WARNING- Refrigerant Leak.
i. Ninth line: Adjusted left ½” BLUE (have word blue in color blue):
   CAUTION- Refrigerant Leak or System Malfunction.

3. The 8.5”x11” sign is as follows:

   a. First line: has a 1” danger sign (triangle exclamation point in the middle)
      followed by 1” DANGER centered.

   b. Second line: Centered ½” AUTHORIZED PERSONNEL ONLY.

   c. Third line: Centered ½” (Type of Refrigerant used i.e. R-134a) Refrigerant In
      Use.

   d. Fourth line: Centered ½” EXIT ROOM DURING ANY ALARM.

   e. Fifth line: Centered ¼” in parentheses- (Strobe Light Flashing and/or
      Audible Alarm).

   f. Sixth line: Adjusted left ¼” ALARM/ STROBE INDICATOR.

   g. Seventh line: Adjusted left ¼” RED (have word red in color red):
      DANGER- Refrigerant Leak.

   h. Eighth line: Adjusted left ¼” AMBER (have word amber in color amber):
      WARNING- Refrigerant Leak.

   i. Ninth line: Adjusted left ¼” BLUE (have word blue in color blue):
      CAUTION- Refrigerant Leak or System Malfunction.

2-8 HEATING SYSTEMS

Coordinate with the Project Manager/Engineering Department to determine the
intended operational needs of heating systems. Investigate the feasibility of
cost savings opportunities where appropriate such as heat reclaim of exhaust
air or process conditioning; and demand control ventilation. Campus steam is
created in the South Utility Plant at 125 psi and distributed throughout campus
at approximately 70 psi. Where campus steam is not available, every effort shall
be made to implement fossil fuel driven technology, such as condensing type
boilers, unless specific engineering analyses or project requirements indicate
electric usage is more effective.

Provide natural gas fired equipment shall be used in instances where campus
steam is unavailable. Where directed by the Project Manager/Engineering
Department, space shall be allocated for future boilers, pumps, converters
and associated headers and piping systems taking into account minimal
impact to existing operations.
2-8.1 Steam Systems

Steam systems are extensive and serve a variety of equipment and systems such as HVAC systems, domestic hot-water, etc. The need for clean or pure steam shall be reviewed with the program user group for unique applications as justified by a unique programmatic need.

Single-pipe systems must not be used for comfort heating. For safety purposes, low-pressure steam 15 psig (100 kPa gage) and below must be used where terminal equipment is installed in occupied areas. High or medium-pressure above 15 psig (100 kPa gage) steam unit heaters may be used for space heating in areas such as garages, warehouses, and hangars where the discharge outlets are a minimum of 13 feet (4 meters) above floor level.

The steam supply and steam condensate return distribution system shall be sized conservatively with minimal line pressure losses at maximum design load plus allowances for warm-up and future growth. All valves, traps, equipment and specialties shall include warm-up factors and estimated inlet and outlet pressures. Steam condensate shall be collected and returned to the central plant.

Connection to the site distribution piping system shall be achieved by extending the existing utility tunnel to the building or by installing steam and condensate pipes in an accessible pipe trench between the utility tunnel and the building wall.

Steam traps shall be sized for the particular application. Trap bypass valves shall not be installed; if redundancy or additional capacity is required, dual traps shall be installed. All traps, except those on radiation heating equipment, shall be located a minimum 6-in below the equipment they serve.

2-8.2 Heating Hot Water

2-8.2.1 General Requirements

1. Above ground heating hot water piping shall not be permitted to be installed in or pass through main electrical equipment rooms/closets and telecommunication rooms/closets.

2. All terminal equipment shall be equipped with two-way modulating control valves.

3. Provide pressure and temperature gauges in primary and secondary mains.

2-8.2.2 System Architecture

Evaluate and design all heating hot water systems in accordance with the IMC and ASHRAE 90.1. The heating hot water system(s) shall be flexible, reliable, easily expandable and readily maintainable. The system(s) shall be designed for the 100% load (or demand) plus the safety factor indicated in this FC.
The plant and associated distribution system shall be Primary/Secondary and shall be configured using the N+1 redundancy where n is the number of equipment sized to handle 100% of the load or demand. The N+1 method shall be applied to boilers, primary heating hot water pumps; and secondary heating hot water pumps. Two-way valves shall be modulating type.

Piping mains shall be sized appropriately for extra capacity unless stated otherwise by the Project Manager/Engineer. Extra equipment shall be used for redundancy only and shall not add additional capacity to the system. In general, the heating equipment shall be of the highest energy efficiency in the class, determined by economic analysis.

2-8.2.3 Primary and Secondary Boiler/Converter Water Pumps

Primary boiler/converter water pumps shall be piped in parallel configurations to allow flexibility in case of failure so any primary pump can be operated with any boiler/converter. Secondary Pumps shall be equipped with VFD and associated controls to work in conjunction with terminal equipment modulating two-way valves.

2-8.2.4 Make-Up Water Reliability

The make-up water for the heating hot water shall be domestic water. Coordinate with the Project Manager/Engineering Department to determine availability, practicality and effectiveness of the source(s).

2-8.2.5 Supply and Return Temperatures

Low temperature hot water design should follow campus guidelines if they exist, but otherwise use a 20°F boiler differential for primary plant design across boilers, with supply upper temperature target of 180°F. Condensing boilers can take a much higher differential, but the design shall not design to the extremes of the boiler manufacturer’s allowable operating range. When using a condensing boiler, design for a 40°F delta T for reheat terminals.

2-8.3 Heating Terminals

2-8.3.1 Perimeter Occupied Spaces

For perimeter occupied spaces, such as offices, laboratories, operation spaces and public spaces, if the heating load calculations indicate a perimeter heat loss greater than or equal to 200 BTUs per linear foot or where there are windows, these areas shall be served by VAV \terminal units with hot water heating coils or steam radiators. Heating shall be served by a heating water system, a heating water system from a steam to hot water heat exchanger utilizing campus steam or low pressure steam depending on systems already in use in the building. Control valves shall be 2-way modulating for all units. Room Thermostat shall
be located within 10 ft. of the exterior wall. Provide radiant heating panels where the heating load cannot be met by terminal unit reheat coils, or where existing radiant heating panel systems are present.

2-8.3.2 Interior Occupied Spaces

All interior occupied spaces shall have heat provided, if they do not otherwise have warm-up capacity when conditioning rooms under roofs or above exposed floors. Control of supply valves shall be per room thermostat.

2-8.3.3 Utility or Other Non-Occupied Spaces

At a minimum, if any utility or other non-occupied space could be subjected to freezing conditions, provide heating terminals which are utility in nature such as suspended unit heaters or fan coils. Room Thermostat(s) shall be located within 10-feet of the exterior wall or at an appropriate location depending on the most critical point of freezing potential such as near ventilation opening(s).

2-8.3.4 Loading Docks

At a minimum, loading docks shall have air curtains with heating terminals and a remote thermostat.

2-8.3.5 Service or Testing Bays

Service or testing bays shall be provided with infrared heat.

2-9 PIPING

2-9.1 General Piping Requirements

Specify that all piping shall be stored in a clean and dry place, with ends capped, before installation. Black Steel (BS) pipe shall comply with ASME/ANSI B 36.10 and ASTM A53 except for seamless piping. Include ASTM A106 for seamless piping. For installations which require connection to an existing piping system, where the piping material differs from the below standards, coordinate with the Project Manager/Engineering Department.

2-9.2 Valves

Valve material shall be compatible with installed pipe system. For valves mounted 10 feet - 0 inches above finished floor (AFF) or higher, provide with chain operator.
2-9.2.1 Hydronic Valves

2-9.2.1.1 Size and Type

Valves 2-inches or smaller shall have screwed fittings or be copper sweat. For Isolation Applications (shutoff service) use ball valves.

Valves 2.5-inches or larger shall have flanged fittings. For Isolation Applications (shutoff service) use butterfly valves, of the lug body type.

2-9.2.1.2 Isolation

Provide isolation valves at all equipment and on branch pipes at connections to mains where branch pipes serve three or more pieces of equipment.

2-9.2.1.3 Throttling Service

For Throttling Service (balancing), use calibrated balancing valves wherever possible. Calibrated balancing valves shall be used for all equipment and shall evaluate the need for branch lines that serve 3 or more pieces of equipment. Ensure that locations have proper distances of upstream and downstream length per the valve manufacturers’ recommendations.

2-9.2.1.4 Triple Duty Valves

Triple duty valves shall be cast iron body, pump-discharge fitting, with drain plug and bronze-fitted shutoff, calibrated balancing and check valve features. The valve shall be equipped with brass readout valves with integral check valve to facilitate taking differential pressure readings across the orifice for accurate system balance. Cv rating shall be provided at every 10% increment opening and the manufacturer shall supply the Cv rating for read-out of flow and pressure drop. Triple duty valves are used on discharge chilled water, condenser water, and hearing hot water pumps. Pumps can be provided alternatively with balancing valves, check valves and isolation valves, but shall be evaluated and require approval from the Project Manager/Engineering Department.

2-9.3 HVAC Piping Requirements

Special circumstances should be submitted to the Project Manager/Engineering Department for approval. Connections (takeoffs) shall come off the sides of mains where possible. Isolation valves shall be provided in all branch piping connections at mains, in addition to shut off valves located at associated equipment. Specify that piping insulation shall not be installed until hydrostatic tests have been successfully completed, witnessed and accepted by the Project Manager/Engineering Department.

The following are prohibited:
- Mechanical grooved pipe and fittings.
- Extruded and press fittings.
- Automatic air vents.

2-9.4 Chilled, Condenser and Heating Hot Water

2-9.4.1 Above Grade

1. Piping 4-inches and larger shall be Schedule 40 black steel with welded fittings.

2. Piping 3-inches and smaller shall be copper Type L with brazed fittings for 2 ½-inches and 3 inches and soldered fittings for 2-inch and smaller. Brazing material shall be 80% Copper, 5% Phosphorus, and 15% Silver. Solder material shall be 95% Tin, 4-5% Copper, 0.04-0.20 % Selenium.

3. Chilled and condenser water piping shall be schedule 40 seamless for 10-inches and smaller and standard weight Electric Resistance Welded (ERW) for 12-inches and larger.

4. Heating hot water piping shall be schedule 40 seamless for 10-inches and smaller and standard weight ERW for 12-inches and larger.

5. For steel piping applications, flanges shall only be installed for joining valves with flanges. All other pipe shall be butt-welded.

2-9.4.2 Below Grade

For underground piping installations, specify corrosion resistant pre-insulated piping to eliminate the need for cathodic protection. Pre-insulated piping systems consist of a carrier pipe (see guidelines above) that is factory insulated and wrapped in a non-ferrous (FRP, PVC, or HDPE) jacket. Leak detection shall be provided within the outer jacket to identify the relative location of leaks along the entire length of buried pipe.

2-9.4.3 Existing Data Center Applications

For projects constructed within an existing, operational data center, the following piping sizes and materials apply:

1. Chilled water piping 6-inches and larger shall be black steel with welded fittings.

2. Chilled water piping 2 ½-inches to 4-inches shall be copper Type L with brazed fittings. Flanges shall only be installed for joining valves with flanges.

3. Use of oxy-acetylene tank/torch is required for brazing in lieu of acetylene tank/torch. Brazing material chemical composition shall
be comprised of 80% Copper, 5% Phosphorus, and 15% Silver.

4. In applications with 2½"-4" copper situations where a brass/bronze flange is required, soldering in lieu of brazing is acceptable but requires using the soldering material chemical composition of 96% tin and 4% silver. Soldering material chemical composition shall be 95% Tin, 4-5% Copper and 0.04-0.20% Selenium for copper piping 2-inches and smaller.

2-9.4.4 Piping Maximum Allowable Water Velocity

All piping shall be designed in accordance with Table 2-2 below. Piping shall meet the velocity requirements in Table 2.2 while not exceeding a piping friction loss 4.5 ft per 100 feet of piping.

<table>
<thead>
<tr>
<th>Pipe Sizes (inches)</th>
<th>Maximum Water Velocity (ft/sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>3</td>
<td>5</td>
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<td>5</td>
<td>7</td>
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<td>6</td>
<td>8</td>
</tr>
<tr>
<td>8</td>
<td>9</td>
</tr>
<tr>
<td>10 or larger</td>
<td>10</td>
</tr>
</tbody>
</table>

2-9.5 Refrigerant

Refrigerant and refrigerant vent piping shall be ACR Type K, except for small split system applications which may use ACR Type L with brazed fittings.

2-9.6 Steam and Condensate Return Piping

Steam and condensation return piping shall be Piping shall be designed and installed to allow for expansion and contraction without creating excessive stresses in the piping system. Expansion loops, offsets, pipe guides and anchors shall be shown on the contract documents. Expansion joints shall be provided as a last resort. Expansion joints shall not be installed above the ceiling within a critical space. Pipe anchors shall be designed for each location and sized to handle all forces with conservative safety factors. All anchors, guide loops and joints shall be readily accessible for maintenance and inspection.

Condensate Piping shall be gravity drained from the trap to the condensate receiver for all low pressure-steam applications. Traps on steam coils shall be
at least 14 inches below the coil’s discharge. Where the hydraulic head is not achievable a condensate pump shall be utilized. Under no circumstances shall condensate be lifted after a steam modulating device.

Drip legs shall be provided in all steam mains to accommodate condensate drainage at all locations. Drip connections shall be provided at the base of each low point in mains and just before all equipment connections. Drip legs shall be provided in steam piping prior to connecting to laboratory process equipment. Steam instrumentation sensors require a 20 foot long sensing line from header to sensor to protect it from extensive heat.

High-pressure drip lines on steam distribution mains shall be routed to a flash tank and not connected to pumped condensate return lines.

Flash tanks shall be provided for high-pressure and medium-pressure condensate and before connection to the condensate receiver. The flash tank shall be factory fabricated and ASME stamped and approved. A contractor shop-fabricated tank is not acceptable. Flash tanks shall be vented directly to the outside with a relief valve of the proper size. Flash steam is waste energy and can be recovered either by installing a heat exchanger (vent condenser) to provide preheat for domestic hot water application or by connecting the steam vent to an active low pressure steam main through an appropriate pressure regulating valve. In this case a check valve must be installed to prevent backflow if the flash tank pressure should drop. A back pressure valve shall also be installed to control the maximum pressure in the tank and relief valve to protect the system.

Steam control valves shall be fully proportional with a modulating equal-percentage plug (Exception - steam control valves serving integrated face and bypass damper steam coil shall be non-modulating). A steam control valve shall have stainless steel trim and be suitable for the pressure condition, additionally it shall operate with the differential pressure required. Steam control valves shall be provided with a one-third/two-third control valve arrangement to provide better controllability.

Steam valves and specialties shall be of the industrial high-performance type. Positive shut-off and isolation of mains are critical to the safety of maintenance personnel. Stainless steel seats and disks are required. A shut-off gate valve shall be used in all steam and condensate lines; gate valves shall be OS&Y 300# ANSI for high, medium and low-pressure systems. Bronze stemmed gate valves are recommended for use throughout the JHU campus. All insulated stems shall be extended as required to permit sufficient clearance for proper operation without damaging the insulation.

Steam safety-relief valves shall be piped individually and discharged to less than 7 feet above the building roof. Care shall be taken not to locate discharge
close to outdoor air intake or where they could be a hazard to maintenance personnel. Relief valves shall not be connected to other steam vents. All valves, drip pan elbows and relief lines shall meet ASME requirements.

A warmup valve shall be provided to bypass shut-off valves on each building main shut-off valve larger than 3 inches.

A steam strainer shall be positioned horizontally (flat) to prevent condensate from collecting in the bottom of the strainer and reducing its life.

Steam vacuum breakers, not check valves, shall be used on coil and heat exchangers to eliminate any vacuum. Vacuum breakers shall be located external to AHU casings.

Steam pressure gauges shall be liquid filled with a range consistent with operating pressure. Stainless Steel ball valves shall be used for gauge cock.

2-9.6.1 Piping Maximum Allowable Flow Rates

All piping shall be designed in accordance with Table 2-3 below.

**Table 2-3 Piping Maximum Allowable Flow Rates**

<table>
<thead>
<tr>
<th>Pipe Size (inches)</th>
<th>Low Pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lbs/hr flow @ 1psig</td>
</tr>
<tr>
<td></td>
<td>0.25 psi/100 ft loss</td>
</tr>
<tr>
<td>Steam</td>
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2-9.6.2 Condensate Return Pumps

Steam condensate receivers shall serve steam condensate low-pressure mains. The receiver shall not be used as a flash tank or have high or medium-pressure condensate directly piped, regardless of capacity. High and medium-pressure steam condensate return shall be piped to separate flash tanks. Condensate return units (CRUs) shall be duplex electric or steam powered. A CRU will have the following design requirements:

1. Pump shall have Viton seals and stainless steel shaft.
2. Each pump shall have isolation valves on both the inlet and discharge lines to allow each pump to be taken out of service without removing the CRU from service.
3. Each condensate return unit shall be piped with a full size bypass line to drain. The bypass shall serve as emergency manual drainage for condensate if the return unit is offline. The bypass shall be indirectly piped to the sanitary system and have a cooling trap to temper condensate down to a suitable temperature prior to discharge.
4. The condensate receiver shall be vented outdoor and independent of other steam relief vents. The CRU shall have fully packaged controls, starter, alternator, disconnect and high-level alarm. The high-level alarm shall be tied to the METASYS system.
5. Pump motor starter shall be clearly identified, and where practical, shall be mounted on a common panel.
6. If a duplex condensate pump is installed in a pit, the starter, disconnect switch and alternator shall be located above the pit where it is easily accessible. Locating any serviceable equipment in a confined space shall be avoided.

2-9.6.3 Pressure Reducing Stations

Steam pressure-reducing valves (PRV) stations shall be provided near the steam service entrance into the building. Secondary and/or remote PRVs within the building shall be avoided. Second-stage PRVs may be installed in mechanical penthouses/rooms or other easily accessible mechanical spaces. PRV stations shall be sized for the calculated peak demand. For process equipment load, the PRV shall be sized, as a minimum, for 100% steam consumption of the largest single user plus 25% steam consumption of all other users.

Where a PRV would exceed 3-in in size or the turndown (maximum load/minimum load) is greater than 10:1, two (2) PRVs shall be provided in parallel, on for approximately 0-33% for low-load conditions and one for 33-100% for high-load conditions, with a single full pipe size bypass. In no case shall high pressure steam
be reduces in a single stage to 40 psi or less.

For a large PRV, where the valve size would exceed 6-in in size, three PRVs shall be provided in parallel. Each PRV shall be designed for a third of the load with a single fill pipe size bypass.

Bypass globe valves shall be provided around the PRV station and modulate pressure if the PRV is out of service. Ball valves are not appropriate for steam service. Isolation gate valves will be provided for isolation. Each branch of the PRV station shall have a single shut-off valve capable of securing steam without approaching the station.

Where the steam service includes capacity for future expansion, all PRV station piping and components except the PRVs shall be sized for the future load. The PRV shall be sized for the present load. An eccentric reducer before the PRC and a concentric reducer after the valve shall be installed to prevent condensate from collecting in the station. Each PRV shall be fitted with a removable custom fabric insulation jacket to further reduce noise and heat gain to the space. The insulation jacket shall be equipped with straps and buckles to allow frequent removal and reinstallation without damaging the insulation.

2-10 AIR SYSTEMS

2-10.1 Conditioning

Evaluate and design conditioning systems appropriate to the space to be served considering energy management and maintaining space conditions as required in this FC. For most installations, especially office areas, the house system shall consist of a VAV AHU distributing conditioned air to single duct and series fan powered VAV terminals equipped with reheat coils. House system AHUs shall use static pressure control and/or airflow measuring stations for control of the supply and return fan VFDs. Systems greater than 10,000 CFM supply air velocity flow shall use airflow measuring stations in lieu of “static pressure only” control.

To the maximum extent practical, each VAV terminal shall be sized to serve a maximum of 1,200 square feet or 2,000 cfm. In scenarios where more efficient solutions can be provided based on the project requirements, coordinate with the Project Manager/Engineering Department during the design.

A space thermostat shall sequence the VAV damper and 2-way modulating control valve for terminal heating coils or radiant panels to maintain space temperature.

Constant Air Volume (CAV) house systems may be used for special situations such as totally dedicated computer areas, conference rooms or special
ventilation applications as appropriate. Typically these units provide "neutral" air to the spaces that has already been dehumidified, cooled and/or heated and mixed with the appropriate amount of outside air. Some applications may call for a 100% outside air unit distributing "neutral" air to the spaces.

2-10.1.1 Distributed Conditioning Terminals

Distributed conditioning terminals, such as radiant panels or fan coils, are to be considered as a substitute for the conditioning AHU approach where common return mixing is not desired or where space is unavailable for conditioning ductwork. Provide documentation to the Project Manager/Engineering Department to show this is the best solution and for approval.

2-10.1.2 Economizers

Provide full airside economizer(s) into the AHU design, to the maximum extent practical, unless waterside economizers are equipped in a central plant.

2-10.1.3 Return Air

Provide return fans where pressure loss exceeds 0.5 inches water column (w.g.) in return duct runs.

House systems’ Return Air shall use the ceiling plenum concept unless special conditions are required. Spaces requiring acoustical isolation may require ducted return and/or Z transfer ducts and shall be considered in the design. Ducted return may also be required to attenuate excessive fan noises if the mechanical room is located adjacent to the spaces.

2-10.1.4 Discharge Temperature Resets

Discharge temperature reset strategies for a unique area at the expense of the entire system is not acceptable.

2-10.2 Ductwork

2-10.2.1 General Requirements

All heating, ventilating and air conditioning systems including basic standard manufactured duct fittings, hangers, supports, casings and exterior components shall be constructed and installed in accordance with the latest edition of SMACNA and ASHRAE standards, to include the following provisions:

- All duct systems, devices and components shall comply with the indicated NC within this FC.
- Bullhead duct fittings and tees or non-standard fittings are prohibited.
• Rigid ductwork designed for the purpose of environmental conditioning shall be zinc-coated sheet steel to conform to specific pressure-velocity classifications as defined by SMACNA Duct Construction Standards.

• Provide aluminum sheet metal with watertight joints for exhaust ductwork in high humidity areas such as shower rooms.

• Slope ductwork back towards inlets.

• Specify that all ductwork shall be delivered onsite with plastic wrap on both ends to protect from dust and debris prior to installation.

• Specify that all ductwork shall be stored in a clean and dry place, indoors and out of the elements prior to installation.

• Optimum air device design incorporating both effective room comfort air distribution and sound considerations.

2-10.2.2 Air System Performance

Every effort shall be made to design the fans and associated ductwork and accessories for optimal performance. Ensure proper outlet conditions and uniform airflow for the full flow potential of the fan.

2-10.2.3 Sizing Requirements

Supply, return, relief and exhaust ductwork shall be sized depending on the application and pressure classification using the SMACNA guidelines, to include the following:

• Pressure Class +/- 0.5-inch w.g (Transfer): Max. 600-FPM & 0.05-inch PD/100-feet.

• Pressure Class +/- 0.5-inch w.g (Branch): Max. 875-FPM & 0.10-inch PD/100-feet.

• Pressure Class +/- 1-inch w.g. (Main): Max.1200-FPM & 0.10-inch PD/100-feet.

• Pressure Class +/- 2 inch w.g. or greater (Main): Max. 2,500-FPM & 0.25-inch PD/100-feet.

All duct systems shall comply maximum airflow velocities as indicated in the following latest ASHRAE Applications Handbook Chapter entitled "Sound and Vibration Control". Include the requirements stated in the Tables entitled "Maximum Recommended Duct Airflow Velocities Needed to Achieve Specified Acoustic Design Criteria" and "Maximum Recommended Free Supply Outlet and Return Air Opening Velocities Needed to Achieve Specified Acoustic Design Criteria." In addition, include the following sizing provisions within the design:

• Ducts shall not have an aspect ratio greater than 4:1.
• Provide a minimum of 4 duct diameters upstream and downstream of any elbows for branch duct connections.

• Increase or decrease duct sizes when duct changes by 4 inches or greater in one or two dimensions.

• To the maximum extent practical, limit duct transitions to only one duct dimension at a time.

• Duct-taps shall be 2 inches smaller than duct size to allow for proper sealing and connection.

2-10.2.4 System Requirements

2-10.2.4.1 Flexible Connections

Flexible connections of neoprene-coated flameproof fabric shall be utilized wherever ductwork is connected to any rotating pieces of equipment such as fans or air handling units which may induce thermal, axial transverse or torsional movement.

2-10.2.4.2 Duct Access Doors

Provide access doors for fire and smoke dampers, sound attenuators, control dampers, volume dampers, outside air and exhaust air louvers, duct mounted coils (including steam preheat coils for 100% outdoor air units), waveguides and any other device requiring maintenance. Include duct access doors to allow for inspecting, adjusting and maintaining air distribution accessories. Access panels are prohibited.

Coordinate access door locations with wall and/or ceiling access to the duct access door. Access doors for duct mounted coils shall be located upstream of the coil to facilitate cleaning. In addition, provide access doors in the first three duct transitions on the supply and return side of an AHU and in the straight lengths of duct evenly spaced, but at no more than 100 feet intervals for future inspection and cleaning. In addition, provide access doors in the fresh air ductwork of AHUs to facilitate inspection and cleaning of the outside air duct prior to entering the equipment.

Access doors shall be an appropriately sized manufactured product with a locking mechanism and hinges which allow for the removal of the door. Ensure access doors are insulated in compatibility with ductwork.

Access doors shall be sized for the largest of the following:

• The largest component removal from the duct system.

• The minimum of 24”x24” to provide adequate space to allow for personnel to access and clean the duct.

Refer to the latest National Air Duct Cleaners Association (NADCA) Guidelines
for further details concerning the location and construction of service openings in HVAC Systems.

2-10.2.4.3 Flexible Duct

Flexible duct shall not exceed a maximum length of 5 feet. Specify that the installation of flex duct shall avoid creating a situation where a large misalignment may occur in the flex duct compared to both connection points per ASHRAE.

2-10.2.4.4 Air Terminal Devices (Registers, Grilles and Diffusers)

Devices shall be selected for proper air distribution as required for the area being served with a maximum pressure drop of 0.10 inch static pressure. Volume dampers shall not be placed closer than 5-feet from an air outlet to avoid unwanted noise.

Locate volume dampers at the branch take-off. The duct connection shall match the neck size of the air device. Consider the usage of equalizing grids on direct diffuser connections.

Supply Air Diffusers shall generally be sized to serve a maximum of 400 square feet each. However, the A/E shall determine the best design given the design requirements.

2-10.2.4.5 Airflow Measuring Stations

Specify that all airflow measuring stations shall be installed per manufacturer's recommendations.

2-10.2.4.6 Duct Silencers

Duct silencers shall only be provided if acoustical requirements cannot be met with conventional duct design. Where silences are provided to achieve the necessary NC ratings for the space in which the duct passes through or resides, detail as necessary and specify to be installed as required per the manufacturer.

Duct silencers shall be dissipative type that conforms to the latest ASTM E477 and the following provisions:

- Double-wall construction with perforated surface that contains an acoustical fill which complies with LEED requirements
- Encase with an EPA-registered, anti-microbial agent to mitigate chance of fungal or bacterial growth.
- Specify to be installed vertically wherever possible for maximum structural integrity. If vertical installation is not possible, specify to provide structural reinforcement for silencers wider than 24 inches.
Acoustical duct lining shall not be used in projects unless approved by the Project Manager/Engineering Department in special cases.

2-10.2.4.7 Fire and Smoke Dampers

Fire and Smoke Dampers shall be implemented as per IBC/IMC and NFPA 90A. All fire dampers shall be out of airstream type. Dampers with blades located in the airstream are only acceptable if the commercially available sizes of the dampers do not allow the use of dampers with blades located outside of the airstream. Such dampers shall be fitted with an indicator showing whether the damper is in the opened or closed position. The indicator shall be visible from the floor. Dampers shall be sized to give equivalent free area as connecting duct.

2-10.2.4.8 Louvers

All louvers shall be sized for an intake/exhaust velocity of 500 feet per minute or less through the free area of the louver at the face.

2-10.2.4.9 Filters

Filters shall comply with ASHRAE 52.2 and be provided with support frames and have gasket seals, including at all ends and access doors. Provide filters rated equivalent to MERV 8 for felt seals and a minimum of MERV 13 for liquid seals.

2-10.2.4.10 Cleaning

The Project Manager/Engineering Department shall evaluate existing conditions and determine if cleaning shall be incorporated into the project. JHU shall be consulted before initiation of any duct cleaning project and all work shall be performed in accordance with the latest National Air Duct Cleaner Association (NADCA) Standards.

2-11 HVAC EQUIPMENT

2-11.1 General Requirements

The following are general requirements for HVAC equipment:

- Flexible connections shall have stainless steel double braided exterior with stainless steel corrugated interior. Stainless steel shall be a minimum grade of 304SS or higher. Flexible connectors shall have restraining guide bolts to prevent excessive movement or loss of alignment. Provide flexible connectors at connections to all chillers, pumps, cooling towers, and other equipment that moves or vibrates.

- Where systems contain glycol, the glycol shall be propylene glycol (PG) type with inhibitors and the percentages shall be posted on the
protected equipment with a permanent nameplate to assist maintenance personnel with glycol monitoring since excessive addition immensely de-rates heat transfer performance.

- Glycol percentage mixture shall be based on a 10°F freeze protection temperature below ASHRAE 99.6% value for the location or at a minimum of 30% PG, whichever is more stringent.
- All heating and cooling coils shall conform to American Refrigeration Institute (AHRI) 410.
- Motors operating on 3-phase, 600 volts and less shall be NEMA Premium efficient rated in accordance with NEMA MG-1 with a service factor of 1.15.
- HVAC equipment fed by UPS power shall be provided with Variable Frequency Drive without bypass or shall have Electrically-Commutated (EC) motors.
- All HVAC equipment shall be provided with auto-restart capability, unless directed otherwise by the Project Manager/Engineer.

2-11.2 Variable Frequency Drives

Coordinate JHU’s Electrical Engineering Design Guide for additional requirements for Variable Frequency Drives (VFD). Motors used with VFDs shall be inverter duty rated. Specify that all VFDs shall be provided with a minimum two year manufacturer’s warranty, to include parts and labor.

2-11.3 Chillers

2-11.3.1 General Requirements

Specify all chillers shall meet or exceed minimum full load or IPLV, as determined in accordance with the requirements of ASHRAE 90.1, for energy use.

Verify the Chiller Restarts (both power outage and start-to-start), Lockout Times, Operations (both fully-automatic and manual-by-operator) and Overrides with the manufacture so that a minimum duration restart protocol can be accomplished. A maximum five minute restart cycle is expected unless otherwise approved by the Project Manager/Engineering Department. Provide Y-Delta Starters in all machines up to 100 Tons.

All chillers shall be furnished with such features as required to facilitate Refrigerant Recovery. All water-cooled chillers shall have isolation valves in the compressor discharge line and the condensed liquid line to facilitate isolation for transfer of refrigerant between the vessels of the same chiller to allow service to the high or low side without removing the refrigerant charge from the chiller.

For chillers up to 1000 ton capacity, water pressure drops should be less than 25
feet and for chillers above 1000 ton capacity, water pressure drop should be less than 30 feet.

2-11.3.2 Warranty

Specify that all chillers shall be provided with a minimum 6 year warranty (Manufacturer's standard 1 year warranty plus an extended warranty for an additional 5 years) which covers the entire chiller unit, including parts, labor, lubricants (excluding lubricants required for routine preventative maintenance), and refrigerant. Include the following additional requirements:

- Warranty shall be provided direct from the chiller manufacturer to JHU.
- Repair or replacement of any factory provided chiller component that becomes inoperative as a result of defects in material or workmanship within the warranty period.
- When the manufacturer determines that a chiller component requires replacement, the manufacturer shall furnish and install the new component at no additional cost to JHU.
- Upon notification that a chiller component has failed under the terms of the warranty, the manufacturer shall respond in no more than 24 hours. Response shall mean having a manufacturer qualified technician onsite to evaluate the extent of the needed repairs."

2-11.3.3 Water Cooled Chillers

All Water Cooled Chillers shall conform to American Refrigeration Institute (AHRI) 550/590. High Pressure, Open Drive chillers shall be provided to the maximum extent practical. Chillers shall use R-134a refrigerant.

If existing information is not available, design around HFC products to the maximum extent practical, however note that some larger manufacturers still provide equipment with R123 claiming their improved energy efficiency compared to HFC refrigerants outweigh the disadvantages of R123. Evaluate the use of refrigerants from all perspectives, including the capability and availability for the manufacturer's service technician in case of failures to ensure reliability is maintained.

All centrifugal chillers shall be provided with the Variable Frequency Drive feature. Design of hinged marine boxes shall be included in the chiller specification to allow easy access to the chiller tubes without major disruption to the piping arrangement. Provide additional chiller spacing to accommodate the marine box option. All piping connections to marine water boxes shall be flanged.
2-11.3.4 Air-Cooled Chillers

All Air-cooled chillers shall conform to AHRI 550/590. Air-cooled chillers shall be used for smaller installations or where project requirements justify usage compared to water cooled equipment. Energy efficient equipment shall be used as much as possible given the heavy and consistent loads experienced by JHU. Air-cooled chiller plants shall be isolated with factory furnished Acoustical Treatment packages to avoid noise problems to the space and adjacent areas. Where factory furnished acoustical treatments are not available or are inadequate, provide field erected acoustical treatments.

2-11.3.5 Modular Chillers

Modular chillers, for remote new facilities or existing building renovations where rigging, implementation space and/or flexibility/redundancy/expansion are considerations that prevent the use of traditional chillers, consist of a set of modules that operate as independently serviceable parallel chillers in a compact form. Operation shall be staged to optimize chiller efficiency at part loads.

All modular chillers shall be integrated with pumping packages for distribution. Each pump package shall have dual pumps (duty/standby) for 100% redundancy with automatic changeover controls. Pump packages shall be factory run tested. All system and pump requirements, such as controls for primary/secondary as well as all devices per standard details for example, shall apply. Each modular chiller shall be provided with the internal valve package option to allow any one module to be taken offline for service while the chiller remains online.

The optional acoustical package shall be specified to prevent sound levels from each individual module from exceeding 65 db.

If the total cooling load, including N+1 redundancy, exceeds the available capacity of a single modular chiller assembly, the load shall be split into two or more modular assemblies as needed. Therefore the chilled and condenser water distribution headers, where applicable for water or air-cooled chillers, shall be sized to accommodate the total flow of all the modular chiller assemblies required to allow for future expansion.

A master controller shall be provided by the unit manufacturer that is capable of staging compressors based on load, rotating lead compressor to equalize runtime, and transferring load to another compressor in the event of a compressor fault. Fault conditions shall be recorded and stored for easy recall and troubleshooting. Electrical and Mechanical connections shall be independent for servicing of modules without interrupting operation of other modules.

All other water-cooled and air-cooled chiller guidelines apply, to include modifications such as cleanable headers in lieu of marine water boxes, with any industry limitation exceptions such as the use of 407C refrigerant coordinated...
with the Project Manager/Engineering Department for approval.

2-11.4 Cooling Towers

Specify a cooling tower (crossflow, counter-flow, induced draft, etc.) suitable for the proposed application/project requirements. The total heat rejection, project budget, space limitations and noise restrictions associated with the application shall be considered. Note that forced draft cooling towers are to be used only as an exception and must be approved in advance by the Project Manager/Engineering Department. Cooling towers shall be CTI certified at the specified heat rejection capacity and ambient design conditions associated with the project. Each cooling tower cell shall be capable of independent operation and supplied with individual makeup, drain, and overflow connections.

2-11.4.1 Materials

Cooling towers and components such as casing panels and frames; welded collection basins, hot-water distribution basins (two per cell), basin partitions (weirs), drive shafts, oil fill, drain and vent lines; shall be constructed and assembled of Type 304 stainless steel to include fasteners. PVC fill material shall possess a maximum flame-spread index of 25 and shall be suitable for entering-water temperatures up to 120°F.

2-11.4.2 Cooling Tower Basins

Cold water collection basins shall include a removable strainer of matching material with openings smaller than the nozzle orifice. Each cell shall be provided with an adequately-sized equalizer connection. Basin covers shall be comprised of matching material and secured to the tower by stainless steel hardware. Basins shall have adequate depth to provide even distribution over the entire fill area throughout the full flow range indicated. Plastic nozzles shall be installed in the bottom of the hot water basin and must be easy to access and replace. Installation/extraction tools shall be supplied with the cooling tower if necessary for nozzle removal. Basin partitions (weirs) shall be provided if necessary to maintain adequate distribution.

2-11.4.3 Joints and Seams

All cooling tower joints and seams shall be sealed and watertight. All welded connections shall be continuous and watertight. Cooling tower inlet and outlet connections shall be Class 150 flange.

2-11.4.4 Fill, Drift Eliminator, and Intake Louver

PVC drift eliminators shall possess a maximum flame-spread index of 25 and shall limit drift losses to 0.005% or less of the design water flow rate.
Provide removable PVC air-intake louvers. PVC air-intake louvers shall contain UV inhibitors to protect against UV radiation and shall be designed to prevent water from splashing out of the tower during all modes of operation (including operation with fans off).

2-11.4.5 Air-intake Screens

Removable air-intake screens shall be constructed of stainless steel wire mesh and designed to prohibit large objects and debris from entering the tower.

2-11.4.6 Axial Fans

Axial fans shall be comprised of aluminum alloy blades and steel hubs. Fans shall ensure proper operation across entire variable speed range. The drive shaft shall be constructed of Type 304 stainless steel. A removable, stainless-steel, wire-mesh fan screen complying with OSHA regulations shall be provided.

2-11.4.7 Gear Drives

Cooling towers shall be provided with a right-angle gear drive coupled to a motor located outside of the air-stream. The gear drive housing shall be comprised of epoxy-coated cast iron and the internal gears shall be beveled high-strength steel, continuously bathed in oil across the entire range of operating speeds. The gear drive shall be able to operate in both forward and reverse with no minimum speed restrictions. Input and output bearings shall be selected for a minimum L10A service life of 100,000 hours or greater and shall employ a bearing isolator seal for extended service life. The gear drive sump shall be equipped with magnetic media to trap loose metal particles. Synthetic oil shall be provided with each unit and be rated for a minimum change interval of 5 years. Oil fill, drain, and vent lines shall be comprised of Type 304 stainless steel and extended to the outside of the cooling tower casing. An oil level sight glass or dipstick shall be provided to monitor oil levels from the cooling tower’s exterior. A low oil-level switch shall be wired to the cooling tower’s control panel to alarm the Metasys system in the event of low oil as well as to de-energize the fan motor. The gear drive and flexible couplings shall have a service factor of 2.0 based upon the motor nameplate horsepower.

2-11.4.8 Totally Enclosed Fan Cooled Motors

Totally Enclosed Fan cooled (TEFC) motors with a service factor of 1.15 shall be mounted outside of the cooling tower casing. Motors shall be provided with factory-installed AEGIS shaft grounding rings. Provide internal heaters for motor to prevent condensation.

2-11.4.9 Variable Frequency Drives

Each cooling tower fan shall be equipped with a dedicated variable frequency drive. Fan speed control shall be based upon the intended control approach (such as head pressure control or leaving water temperature). Variable frequency drives
and motors shall be capable of reversing operation for use in defrosting the cooling tower. The natural frequency of the cooling tower, cooling tower fan, gearbox, motor and driveshaft shall not prevent operation at any speed within the full speed range of the cooling tower fan motor. Skipped frequencies are prohibited.

Cooling towers installed without redundancy (<N+1) shall be specified with VFDs containing a manual three-contactor bypass circuit. Refer to JHU’s Electrical Engineering Design Guide for VFD bypass requirements. Full speed operation in bypass mode shall not overload the fan motor. Cooling tower fan motor service disconnects shall have line of sight to tower fan motors (between the motor and the VFD) and disconnects that are not within line of sight of the VFDs need to be electrically interlocked with the VFD so that the VFD cannot be energized when the service disconnect switch is open.

2-11.4.10 Defrost Systems

Cooling towers shall be equipped with defrost systems where the possibility of freezing exists. Cooling towers shall be capable of operating at low ambient temperatures (design point shall be 0°F or 5°F less than ASHRAE 99.6 condition) whichever is less.

2-11.4.11 Access Doors

Cooling towers shall be provided with access doors (one on each end) large enough for personnel to access cooling tower internal components. Doors shall be operable from both inside and outside of the cooling tower.

2-11.4.12 Access

Aluminum ladders (with safety gates) shall be provided for access to each end of the fan deck. Ladder extensions shall be provided if necessary to access the fan deck from the structural support platform below. Handrails shall be installed around the upper perimeter of the cooling tower. For multi-cell installations, provide field-erected platforms surrounding the upper tower perimeter on all sides, establishing an upper maintenance level. External platforms with ladders shall be provided for accessing motors outside of the airstream. An internal elevated service platform with handrails and a fixed vertical ladder shall also be provided for access to the fan drive assembly.

2-11.4.13 Maintenance Considerations

A galvanized steel davit crane assembly for each tower shall be provided to hoist equipment components from their operational location and place them on the roof (or grade) outside of the tower. This mechanism shall be capable of rigging, lifting, and replacing the single heaviest cooling tower component to include but not limited to the gear drive, motor, and fan blade assembly. The horizontal and vertical lift distances will vary based upon the cooling tower selected and the structural
support elevation. Specify that the contractor is responsible for coordinating with cooling tower manufacturers to ensure that a system meeting the above requirements is provided. If cooling tower manufacturers are unable to provide equipment that meets these requirements, a system of this nature shall be installed by the contractor in the field. Field-erected systems shall not physically inhibit the replacement of the towers they serve.

2-11.4.14 Immersion Heaters

Provide sump freeze protection and low temperature operation bypass (return water to the sump) and consult the cooling tower manufacturer for the control set-points.

Stainless steel electric immersion heaters shall be provided in each basin to prevent freezing and maintain a minimum water temperature of 40°F. Heaters shall be controlled by a NEMA 250, Type 4 control panel field mounted on the exterior of the cooling tower. Heaters shall automatically de-energize when the basin water-level reaches the low-level set point.

2-11.4.15 Vibration Detection Switches

A vibration detection switch (NEMA 250, Type 4 enclosure) with manual reset shall be supplied for each fan assembly and shall be field-wired to the tower’s control panel. The vibration switch shall have field-adjustable acceleration sensitivity (0 to 1g) and frequency range (0 to 3000 cycles). Upon sensing excessive vibration, the switch shall signal an alarm to Metasys and the fan motors shall be de-energized.

2-11.4.16 Valves

Heavy-duty, industrial grade balancing valves shall be provided for each hot water distribution basin. Valves shall be disc-type, with machined cast iron bodies and suitable for both balancing and isolation of each cooling tower cell.

Every tower needs to have a motorized isolation valve on the CWR and CWS lines. Additionally, a manual valve may be required if the motorized valve does not have a manual override.

2-11.4.17 Make-up Water

For cooling towers that have makeup water connections at each tower, use an electronic water-level controller (NEMA 250, Type 4 enclosure) with a slow-acting solenoid makeup valve shall be supplied for each collection basin. The water-level controller shall be installed in a stainless steel stilling chamber and be provided with both low and high-level auxiliary contacts. Bubbler water level sensors are preferred for cooling towers with concrete sumps. For cooling towers that utilize a makeup water source in the suction line of the condenser pumps or other common location, use a bubbler water level sensor. This sensor shall be located in
a standpipe on the common pipe of the cooling towers and shall be the makeup water controller for designs feeding CW makeup water to the suction of the CW pumps. The equalizer line shall have a manual isolation valve.

2-11.4.18 Miscellaneous Provisions

- A protected domestic water source shall be provided within 50 feet of each cooling tower for maintenance purposes. The protected domestic water source shall be lockable, drainable, freeze protected, adequately sized, and contain a manual valve-operated 1 1/2-inch threaded hose connection.

- Sufficient lighting shall be provided to perform all cooling tower maintenance. Convenience receptacles shall also be provided at the towers. Lighting and receptacle requirements shall be coordinated with the JHU Electrical Engineering Design Guide.

- All manual tower controls, switches, etc. shall be easily accessible from a permanent portion of the construction.

- Provide telephone equipment in weatherproof enclosures at the Cooling Tower in a location coordinated with the Project Manager/Engineering Department. Include all required infrastructure between the nearest communications closet and the telephone, such as ¾-inch EMT conduit, NEMA 3R junction box and wiring.

2-11.5 Heat Exchangers

2-11.5.1 Plate and Frame Heat Exchangers

For waterside economizer, a plate and frame heat exchanger shall be used. Using a counter flow application, the approach (i.e., LWT Hot Side – EWT Cold Side) of 2° F shall be designed. Pressure gauges shall be installed at each water port to track plate fouling. Performance rating shall be per AHRI 400.

2-11.5.2 General Requirements

All heat exchangers shall be provided with freestanding assembly consisting of frame support, fixed and movable end plates, tie rods, plates and one-piece gaskets. The plate material shall be type 304 stainless-steel. The gasket material shall be butyl. The piping connections shall be flanged. Install shutoff valves at heat exchanger inlets and outlet connections. Pressure drop shall be typically in the range of 10 to 15 psi, with up to 20 psi allowed for 2° F approach selections.

2-11.5.3 Shell and Tube Heat Exchanger

For steam to water conversion, a shell and tube heat exchanger shall be used. All
heat exchanger performance ratings shall be per AHRI 400. Provide two-pass, U-Tube for water. Provide steel shell and cast-iron head. For steam, the shell shall have flanged entry and threaded (or flanged for 2.5 inches and larger connection) exit. Provide seamless copper tubes with steel tube sheets.

2-11.5.4 Packaged Heat Transfer Systems

Where applicable (where space permits) a heat transfer packaged (HTP) system shall be used in lieu of a standard shell and tube exchanger for steam to hot water conversion. Heat exchanger shall be of shell and tube type and comply with requirements for shell and tube heat exchangers above.

The package heat transfer system shall be skid-mounted and include the following components at a minimum: controls, heat exchanger, air separation apparatus, expansion tank(s), pump(s), motor(s), triple duty valve(s), suction diffuser(s) with strainer, relief valve(s), reducing valve(s), temperature and pressure gauges, frame, interconnecting piping and motor starter(s). The frame of the heat transfer package shall be supported by a housekeeping pad. Provide vibration isolation of pumps, frame and piping connections within three pipe hangers from unit.

A single point of power connection is required. Air separation apparatus shall consist of an air separator, air vent and diaphragm tank. Specify the HTP shall be hydrostatically tested at the factory that includes a full flow and head test of which a test report shall be provided as part of the project record as part of the submittal. The University shall have the option of witnessing the factory test. In addition to the factory test, specify a field test shall be performed to confirm correct system operation.

Provide two pumps (one duty and one standby), each with VFDs, which shall be base- mounted, single- stage, end suction design with an integrally cast, foot mounted volute, capable of allowing the impeller and bearing assembly being serviced without disturbing piping connections, pump volute or motor. Each pump shall have full flow and head capabilities. Discharge side of each pump shall be fitted with an angle pattern combination calibrated balancing valve, center guided non-slam check valve and shut- off valve. Packages shall use triple duty valves where applicable.

The Pressure Reducing Valve shall be diaphragm operated and have a brass body, low inlet pressure check valve and inlet strainer. The strainer shall be easily removed without system shutdown. The valve seat, strainer and stem shall be removable and of non-corrosive material. Provide all devices, such as pressure and temperature gages, isolation valves and connections, per details associated with shell and tube heat exchanger and with pumps.

2-11.6 Boilers

Boilers are classed as to pressure/temperature (usually low pressure, up to 160
psig water or 15 psig steam and below 250°F water temperature), fuel (typically oil/gas dual fired, or condensing boiler is employed - unless otherwise directed by the Project Manager/Engineering Department), material (cast iron or steel), draft (natural or induced/forced draft), flue temperature (condensing or non-condensing) and output (steam or water). Piping installation, temperature differential and entering water temperatures shall conform to the manufacturers’ recommendations.

All boilers shall be tested and rated according to the Hydronics Institute's Testing and Rating Standard for Heating Boilers and include an emblem on the boiler nameplate indicating “I=B=R”. To the maximum extent practical, boilers shall be full modulating type, Low NOx with VFDs and O2 Trim control. Provide temperature control with manual-reset limits boiler water temperature and meters capable of recording fuel usage of natural gas and/or fuel oil. Specify that permits to construct fuel burning equipment shall be obtained through coordination with the JHU Facilities and Real Estate.

2-11.6.1 Sectional Cast Iron

Fuel-fired boilers with cast-iron sections set on an insulated steel base shall be factory-assembled and factory-packaged, commercial-type, sealed with high-temperature sealant and held together with tie rods with insulated extended jacket and vent connection. For water wall design, provide water-backed combustion area with water circulating around firebox, access to flue passages for cleaning and flame-observation ports. Refractory chamber or separate base are not required.

2-11.6.2 Condensing

For condensing, factory-assembled and factory-tested modules include combustion-air inlet chamber, pre-purge and post-purge blower assembly, air-gas fuel control valve, combustion chamber, heat exchanger and exhaust with insulated jacket around module and unit-mounted electrical control panel with operation sequence indicator lights. Provide air-supply and exhaust mufflers and vent terminal plates.

2-11.6.3 Fire Tube

Horizontal fire-tube design (two or more flue gas passes) shall be factory-assembled and factory-tested, central fluid-backed combustion chamber with insulated jacket around outer shell and unit-mounted electrical control panel with operation sequence indicator lights.

2-11.6.4 Water Tube

Header water-tube design shall be factory-assembled and factory-tested internal or external, with insulated jacket around outer shell (and header) and
unit-mounted electrical control panel with operation sequence indicator lights.

2-11.7 Pumps

All water transport pumps shall be of centrifugal type and Non-Overloading over the entire pump curve. Pump motor shall have the required capacity to prevent overloading with pump operating at any point on its characteristic curve. Select pump in the middle diameter range of the largest to the smallest of the impeller ranges for the selected pump. Bearings shall be replaceable without complete disassembly of the pump.

Pump motors shall conform to NEMA MG 1, and have sufficient wattage horsepower for the service required. Pumps shall be selected at or within 5 percent of peak efficiency. Pump speed shall not exceed 3,600 rpm, except where the pump head is less than 60 feet of water, the pump speed shall not exceed 1,750 rpm.

All pumps shall have drip pans, drain pans or troughs and shall have drain pipes installed to the nearest floor drain without being a tripping hazard. All pump performance curves shall be certified and comply with the Hydraulics Institute. Specify that the manufacturer’s guidelines shall be adhered to for installation and operations.

All pumps shall be installed with a VFD. VFDs shall not be used to balance the pump. Pumps installed without redundancy (<N+1) shall be specified with VFDs containing a manual three-contactor bypass circuit. Refer to JHU’s Electrical Engineering Design Guide for VFD bypass requirements. In the event where a VFD is absent, the pump motor shall be equipped with an across-the-line magnetic controller in a NEMA 250, Type 1 enclosure with “START-STOP” switch in the cover.

At a minimum, all pumps shall include the following:

- Motor.
- Individual Pressure Gauge Connections on each side of the pump using pump’s housing gauge taps, and pet cocks with snubbers. Pumps on open systems shall have compound gauges rated for suction and discharge pressure of the system.
- A replaceable bronze wear rings for pumps.
- Hangers or ground supports shall independently support the suction and discharge pipes.
- Pumps shall be mounted on a level plane.
- Pumps and associated piping within three horizontal pipe hangers of pumps shall have spring vibration isolation.
2-11.7.1 Suction Diffusers

Suction diffusers shall be provided with stainless steel basket strainer with 3/32 mesh openings. Only suction diffusers with cast in place flow straightening vanes shall be selected. Use a built-in stainless steel strainer to remove any foreign matter that may be harmful to the pump or other system components. All suction diffusers shall be provided with stainless steel 10 mesh opening construction start-up screens; coordinate size and usage of this screen with the cleaning, flushing, treating and testing piping system requirements indicated within this FC.

2-11.7.2 Base-mounted Pumps

Base mounted pumps shall have pump bearings that can be replaced without removing or disassembling the pump shaft seals. All base mounted pumps shall be coupled to their motor or prime mover with a maintenance-free rubber insert type coupling. At minimum, base mounted pump installations shall include the following:

- Inertia pad to meet pump manufacturer’s Installation, Operation, and Maintenance (IOM) guidelines for pump foundation requirements if it exceeds the 6-inch high requirement.
- Installed to allow manufacturer’s required clearances and access for inspection, maintenance and service.
- Where packaged duplex or triplex (parallel) pumps are used, to the maximum extent practical, provide triple duty valves for each pump.

2-11.7.3 In-line Pumps

In-line pumps are typically used when a base mounted pump is not practical due to flow characteristics (low flows and/or low head) or the lack of floor space (e.g., substitution of vertical height or wall space for floor space). At a minimum, in-line pump installations shall include the following:

- Where insulation boxes are employed, extend pressure gauges beyond box.
- In-Line pump shall be installed so that there is room for inspection, maintenance and service.

2-11.7.4 Condensate Pump

Where gravity drainage is not practical, provide a condensate pump with overhead pumped discharge to the nearest drain. Condensate pumps shall be corrosion-resistant construction with a covered plastic tank and automatic controls. Include a factory or field installed check valve. For condensate and sump pit pumps that have a field or factory installed check valve, install an isolation valve on the drain.
system (outlet) side of the check valve to allow servicing of the check valve without back draining pumped liquid from drain piping. Coordinate the condensate pump location with the condensate drainage requirements of this FC. Condensate pumps serving individual HVAC units shall be fed from the same electrical circuit as the unit.

2-11.8 Chilled Water Air Handling Units

2-11.8.1 General Requirements

AHU configurations depend on the requirements of the project design. Assemble the AHU sections and components to fulfill each particular application, to include the following requirements:

- All units shall be specified to be 100% bolted construction.
- Ensure that ease of maintenance is a strong consideration in the AHU configuration design. For example, on the drawings identify the manufacturer’s coil pull area as well as the perimeter and headroom required to perform maintenance on the equipment including filter changes, belt changes, motor replacements, controls repairs, coil cleanings, etc.
- Specify that Modular AHUs shall be completely factory assembled and tested prior to shipping. Whenever possible, AHUs shall be shipped as a single factory assembled piece. However, due to space and/or accessibility restraints or shipping size limitations, it may be required to disassemble the AHU at the factory and reassemble the modular AHU sections in the field. Include within the specifications that reassembly of modular units, installation training, and field inspection shall be conducted by the AHU manufacturer with a report submitted for Project Manager/Engineering Department approval. Reassembled AHU shall maintain factory leakage and performance integrity.
- Modular AHUs shall be specified to be furnished with sufficient gaskets and bolts for reassembly in the field by the contractor. Specifications shall require that a factory-trained service representative, who is knowledgeable in the manufacturing, servicing and maintenance of the equipment shall be contracted to supervise the lifting, rigging and field assembly process to ensure a quality installation.
- Specify that AHU manufacturers shall provide Certified Ratings conforming to the latest edition of the Air Movement and Control Association (AMCA) 210, 301-06, 310, 500-D, 500-L and AHRI 410 and 430. All electrical components and assemblies shall comply with National Electrical Manufacturer’s Association (NEMA) Standards. AHU internal insulation shall have a flame spread rating not over 25 and a smoke developed no higher than 50 complying
with NFPA 90A. AHUs shall comply with NFPA 70 and the National Electrical Code as applicable for installations and electrical connections of ancillary electrical components. AHUs shall be UL Listed.

- Specify that AHUs shall be supplied with one complete set of spare fan belts, filters and spare gaskets for each sectional joint of the unit.

2-11.8.2 Mixing Box Section

Provide dampers to modulate the volume of outdoor and return air that are rated for a maximum leakage rate of less than 0.10% of airflow at 1.0 inch static pressure. The mixing box section shall have an access door. The mixing box arrangement shall allow for adequate mixing of outdoor and return air to prevent stratification and nuisance tripping of the freeze-stats.

2-11.8.3 Dampers

All dampers shall be Low Leakage dampers with airfoil blades. Flat or formed blades are prohibited. The damper blade shall incorporate Silicon or Neoprene rubber edge seals, mechanically attached and zinc plated tubular steel shaft for non-slip operation. Shaft bearing holes shall be machine punched and fitted with 1 inch O.D. heavy duty nylon bearings to eliminate friction and any metal to metal contact. Damper jamb seals shall be stainless steel spring arcs designed for a minimum air leakage and smooth operation. Damper linkage shall be concealed within a 16 gauge galvanized steel frame.

2-11.8.4 Filter Section

AHU filter sections shall be angled to improve system efficiency. Coordinate with the Project Manager/Engineering Department if space constraints limit the use of angled filter sections to select an alternate approach, such as flat sections. Rigid Filter Media shall be 4 inches deep and shall have a minimum efficiency rating of MERV 13 (greater than 80% per dust spot test) as determined by ASHRAE Standard 52.2. Filters shall be of the mechanical type. The use of electro-mechanical (electrostatic) filters is prohibited. [Note: a 100% Outside Air Make-up filter section shall include a minimum efficiency reporting value (MERV) 8 (greater than 30% per dust spot test) pre-filters in addition to the MERV 13 final filters.]

Factory fabricated filter sections shall be of the same construction and finish as the unit. Face loaded pre and final filters shall have type 8 frames as manufactured by AAF, FARR or equal. Side service filter sections shall include hinged access doors on both sides of the unit. Internal blank-offs shall be provided by the air handling unit manufacturer as required to prevent air bypass around the filters. A Magnahelic, differential pressure gauge shall be factory installed and flush mounted on the drive side of the filters to measure the pressure drop across the filters. The gauge shall be permanently marked for proper operating range.
Specify the Contractor shall indicate the clean filter marking on the gauge or AHU to facilitate maintenance, timing filter changes and performing general evaluations.

2-11.8.5 Chilled and Heating Water Coil Sections

Coils shall be constructed of seamless copper tubing mechanically expanded into fin collars and mounted on a stainless steel support rack to permit coils to slide out individually from the unit. All fins shall be continuous within the coil casing to eliminate carryover inherent with a split fin design. If coil height exceeds 42 inches, or coil length exceeds 10 feet, or weight exceeds 600 pounds, then coils shall be selected of equal size sections to be smaller or lighter than these size/weight limitations to allow for ease of removal/replacement.

Include within the design analysis, an evaluation of whether coils experience adequate turbulence to perform effective heat transfer at the part load minimum design performance. All coils shall have a maximum face velocity of 500 fpm. Coils shall be provided with maintenance bypass sized for the full coil capacity. The maximum pressure drop through the coils at full flow shall not exceed 20 feet of water. At a minimum, include devices and connections as follows:

- Strategically placed flanges/unions for ease of maintenance and for damaged coil removal without affecting water flow through the remaining active coils, cutting pipes or moving headers.
- Coil isolation valves shall be located on the branch lines of each coil supply and return header on the header side of the union/flange so as to allow for isolation and removal of the damaged coil while leaving undamaged coils in operation throughout the removal and installation processes.
- All vents and drains shall be extended outside of the AHU casing.

2-11.8.6 Standard Steam Coils

Standard steam coils shall be constructed of seamless copper tubing mechanically expanded into fin collars. Fins shall be die formed plate type. Headers shall be seamless copper with die formed tube holes. Connections shall be male pipe thread (MPT) Schedule 40 Red Brass. Steam pressures above 50 psig will have opposite end connections. A maximum fin length of 120 inches shall have same end connections.

Intermediate tube supports shall be supplied on coils over 44 inches in length, with an additional support every 42 inches thereafter. Standard coils construction shall be suitable for 25 psig steam pressure.

2-11.8.7 Non-freeze Steam Coils

Non-freeze (NF) steam coils shall be constructed of 1 1/8-inch OD seamless
copper tubing mechanically expanded into collars. The 5/8-inch OD inner steam distributing tubes shall be centered in the outer condensing tube (1 1/8-inch). The inner tube shall have proportionally spaced directional steam jet orifices. These orifices direct the condensate flow to the outlet. Fins shall be die formed plate type. Headers shall be seamless copper with die formed tube holes. Connections shall be male pipe thread copper. Coils are to be pitched in the casing for drainage. Standard construction shall be suitable for 50 psig steam pressure.

2-11.8.8 Integral Face-and-Bypass Coils (100% Outdoor Air Units Only)

For 100% Outside Air (OA) Units only, provide an integral face-and-bypass coil for the outside air preheat process. This will prevent coil freeze-up, stratification and control problems since there is constant flow through the coil.

2-11.8.9 Electric Heating Coils

AHU electric heating coil sections shall be a factory installed, open coil type UL-listed assembly. The section shall include airflow switches and automatic-reset limits for protection against overheating. The electrical contractors used for energizing the coil shall be magnetic type. The operation of the heating coil shall be through a Silicon- Controlled Rectifier (SCR) type controller to ensure precise temperature control.

Include appropriate blank sections upstream and downstream of the coil to ensure proper separation and to prevent moisture carry-over.

2-11.8.10 Drain Pans

2-11.8.10.1 General

All sections of the AHU shall each have a full-width, sloped, drain pan that extends downstream enough to provide sufficient space to contain moisture carryover or condensation. With drain pans installed in all sections, there is easy access for maintenance and cleaning (sweeping and washing) of coils, filter sections and fan sections in order to maintain equipment efficiency and performance. Drain pans shall be IAQ type (double sloped) to assure positive condensate drainage. The pan shall have a double wall construction with a stainless steel liner and shall have a minimum of 2 inches of insulation (uncompressed). The pans shall have a minimum depth (free-board) of 4 inches. Drain pans shall be furnished with a drain connection on one side of the AHU. If clearance issues arise during the design process and adequate housekeeping pad dimensions cannot be achieved, it may be necessary to consider core drilling through the mechanical floor to install the traps in the room.
2-11.8.10.2 Connections

Minimum drain connection size for all sections shall match air handler manufacturer provided connection. Condensate traps shall be provided for the cooling coil and humidifier (if applicable) sections only.

Heating coil, access, filter, fan and mixing box sections shall be equipped with drain connections to assist in manual cleaning of interior of unit. Provide ball valve with hose end connection, cap and chain for these drain connections.

2-11.8.10.3 Intermediate Drain Pans

Coils sections are limited to a maximum of 42 inches in height. Provide an Intermediate Drain Pan between each vertical coil section, at the horizontal joint, extending the entire finned length of the coil section. The intermediate pans shall have drop tubes to guide condensate to the main drain.

2-11.8.11 Humidifiers

AHU humidifiers are only required for Special Area applications and are typically not used for Data Centers/Machine Rooms since space humidification is the University standard. However, the following general guidelines apply for determination of whether the application requires AHU Humidification. Review the basis of design manufacturer’s installation instructions and incorporate the requirements into the design.

2-11.8.11.1 Campus Steam Available

If campus steam is available at the project site, a Steam-to-Steam (or Steam Exchange) Humidifier is to be used. The Steam Exchange humidifier shall pass house steam through an internal stainless steel heat exchanger producing clean steam vapor at atmospheric pressure with modulating control. The humidifier shall be provided with stainless steel steam distribution components and an internal 1-inch air gap and vacuum breaker to prevent siphoning.

2-11.8.11.2 Campus Steam Not Available

If campus steam is not available, an Ultrasonic humidifier with a complete water treatment system shall be utilized. The ultrasonic humidifier shall be a self-contained unit with modulating control. The humidifier shall be provided with an AHU system vertical mounting rack (for multiple units).

2-11.8.12 Heat Wheel (100% OA Units only)

Heat recovery wheels shall be designed for total energy recovery (both latent and sensible) and ensure laminar flow. Heat wheels shall be constructed of lightweight polymer media with a desiccant coating to minimize cross-contamination. The polymer media shall be mounted on a stainless steel rotor for corrosion resistance.
Wheel design shall consist of removable segments for ease of replacement and/or cleaning. Heat recovery drive belt material shall be high strength urethane and shall be factory installed in a pre-stretched state eliminating the need for field belt tension adjustment. Link style belts are prohibited. If carry-over contamination is a concern (other than non-process related relief air, all other heat reclaim exhaust air is a contamination concern), provide a purge section to clear exhaust gases.

2-11.8.13 Fan Sections

Fan sections shall be equipped with access doors on both sides of the section. The fan and motor assembly shall be internally isolated from the unit casing with deflection spring isolators depending on the equipment size. The isolation system shall be designed to resist loads produced by external forces in compliance with the IBC. Bearings requiring lubrication shall have grease lines extended to the fan support bracket on the drive side.

VAV Fans shall use VFDs instead of inlet vanes. AHUs installed without redundancy (<N+1) shall be specified with VFDs containing a manual three-contactor bypass circuit. Refer to the Electrical Design Guide for VFD bypass requirements. VFDs shall lock-out natural frequencies of the fan assembly, but otherwise allow for full modulation range from full to minimum rotational speed without exceeding fan stall or surge conditions.

Fan Motors shall be mounted inside the AHU casing on an adjustable base to permit adjustment of drive-belt tension. Direct drive fans with its own dedicated VFDs shall be considered and if specified shall be provided with a spare unit.

Air flow measuring stations shall be provided in the supply, return outside air ductwork. In the event that the ductwork configuration will not allow the installation of duct mounted air flow measuring stations, the A/E shall specify that supply and return fans (if applicable) shall be equipped with an Inlet-Bell Airflow Measuring Station. The transducer shall be an Ebtron Model GTx116-PC or approved equal to ensure accuracy when tied into the Metasys System.

For belt driven fans, include within the specifications, the Contractor shall, after Testing and Balancing has been completed and accepted by the University, replace the factory-supplied variable pitch sheaves with fixed pitch sheaves.

2-11.8.14 Access Sections

If space is available, provide minimum 18-inch wide access sections, for ease of maintenance. All access sections shall have access doors on both sides. Access sections provide space to work on coils, filters, fan sections and also provide adequate space to mount control devices such as freeze stats and temperature sensors.
2-11.8.15 Housekeeping Pads

Coordinate the size and location of housekeeping pads to ensure proper operation of the condensate drain system. At a minimum the housekeeping pad shall be 6 inches in all directions larger than the unit and have ample height to accommodate condensate trap depth.

2-11.8.16 Casings

Exterior panels shall be fabricated from 16 gauge galvanized steel. The casing shall be of the no-through-metal design. The casing structure shall incorporate insulating thermal breaks as required so that, when fully assembled, there is no path of continuous, unbroken, metal-to-metal conduction from inner-to-outer surfaces. Provide necessary support to limit casing deflection to 1/200 of the narrowest panel dimension.

All panel seams shall be caulked and sealed for an airtight unit. Leakage rates shall be less than 1% at design static pressure or 8 inches whichever is greater. Exterior units shall have rain gutters for access doors and factory applied epoxy coating suitable for expected exposures.

2-11.8.17 Access Doors

Full height access doors shall be provided on each side of the applicable sections: mixing box, filter, coil access, and fan sections, large enough to accommodate the largest equipment for easy access. Doors in the mixing box, filter, access and fan sections shall be complete with a 10 inches by 10 inches dual thermal pane safety glass view window reinforced with steel mesh. The view windows shall be mounted on both sides of the AHU.

Access doors shall be the same thickness and construction as the wall panels. A bulb- type gasket shall be provided around the entire door perimeter. Industrial style hinges shall permit a complete 180 degree door swing. The AHU shall be equipped with solid double wall insulated, hinged doors as shown on the AHU configuration detail. The door frame shall have a thermal break barrier and full perimeter gasket. The door hinge assembly shall be die cast zinc with stainless steel pivot mechanism, completely adjustable.

2-11.8.18 Interior Lighting

Factory-supplied (enclosed and gasketed), vapor tight, compact fluorescent light fixtures shall be provided for all access, mixing box and fan sections. There shall be a minimum of two fixtures per section, evenly spaced for each module. Fixtures shall be complete with junction box, globe, aluminum globe guard, bulb, conduit and switch (on exterior wall of unit), with one switch per unit module. Light switch shall be located on access door side of unit. Lights shall be field wired and will require a 115/1/60 power source separate from the main power to the unit, permitting operation during periods of unit shutdown. Provide a pilot light at the
switch to signify from the outside of the unit whether the interior lights are on or off. Coordinate power requirements with the Electrical Design Guide.

2-11.8.19 Rain Hoods

Rain hoods shall be fabricated from the same material as unit casing with 1/4-inch wire mesh inlet screen and sized to minimize moisture carryover.

2-11.8.20 Louvers

Provide louvers that are coordinated with the requirements of the IBC/IMC. Maximum louver velocity shall be 500 fpm.

2-11.8.21 Pipe Chases

All openings for piping shall be factory fabricated based on pipe sizes indicated in the design. Outdoor units shall be provided with an internal pipe chase. External pipe chases shall be internally insulated and shall include adequately sized hinged access door(s) for installation and maintenance to all valves and piping.

2-11.9 Other Air Handling Units

2-11.9.1 General

All units shall comply with AHRI, AMCA, ANSI, and NEMA, with unit performance certified per AHRI 340/360. All heating and cooling coils shall conform to AHRI 410. Chilled water for cooling coils is preferred. In direct expansion (DX) applications, digital scroll compressors are to be used. If digital scroll compressors are not available, then multiple compressors are required at a minimum, unless commercially unavailable for the desired equipment. The unit shall have a single point power connection with disconnect switch. The unit shall be sufficiently rigid and arranged to permit handling by a crane or other means.

Provide a separate air-cooled condenser for each compressor in multi-compressor installations. If compressors are paralleled, provide no less than two circuits. A common housing may be used, but each coil shall be provided with separate controls to operate individual fans for each coil. All coils shall have sub-coolers. The air-cooled condensing coil shall be extended-surface fin-and-tube type with seamless copper tubes and aluminum fins.

Heating options shall be determined by the design engineer on a case-by-case basis due to availability of heating source such as heating hot water, natural gas or electric resistance heat. Coordinate with the Project Manager/Engineering Department for consideration for the use of a heat pump.
2-11.9.2 Direct Expansion Rooftop Air Handling Units

Direct Expansion (DX) Rooftop Air Handling Units (RTUs) shall be a factory standard packaged or custom packaged, in compliance with the AHU requirements of this FC, combination heating and cooling unit suitable for mounting on the roof of buildings. The package shall consist of one or more refrigerant compressors with electric motors, cooling coils, heating coils (as required), condensers, supply fan(s), return fan(s), access doors, control wiring and piping assembled in a weatherproof enclosure (complete with ground fault current interrupter (GFCI) receptacle) mounted on a structural steel base ready for connections to utilities and ducts.

All filters shall have a minimum efficiency of MERV 13. All sections shall have hinged access doors with cam or door handle latches. Provide utilities through the base.

Unless VFDs are used, units are to be belt driven and provided with an extra set of belts. Casings are to be factory painted enamel, with double wall insulated (minimum 2 inches rigid) construction.

All roof mounted equipment installations shall be provided with vibration isolation. For units mounted on roof curbs, they shall be supported a minimum height of 24 inches above the roof. For units mounted on structural steel, the minimum height shall be 42 inches above the roof. Determine the appropriate height of mounting where weather conditions with considerable snowfall will cover the condensate drains and would prevent access doors from being opened on a project by project basis.

2-11.9.3 Direct Expansion Packaged Air Handling Units

Where chilled water is unavailable, a combination split system AHU and Condensing unit or a self-contained AHU may be used. AHU shall comply with the standard Air Handling Unit requirements, unless commercially unavailable, and shall be suitable for vertical or horizontal mounting.

Self-contained AHUs shall consist of one or more refrigerant compressors, contained within the AHU, with electric motors, cooling coils, heating coils (as required), condensers (contained within the AHU or remote), supply fan(s), return fan(s), access doors, control wiring and piping assembled on a structural steel base ready for connections to utilities and ducts. Split system units shall have a package AHU with matching condensing unit, with electric motors, cooling coils, heating coils (as required), condensers, supply fan(s), return fan(s), access doors, control wiring and piping assembled on a structural steel base ready for connections to utilities and ducts.

Refrigerant piping size and routing shall comply with manufacturer’s installation requirements, but in no case shall the length exceed 100 feet.
2-11.9.4 Make-up Air Units

Make-up Air Units normally work in conjunction with other systems to provide ventilation air (for make-up air supporting kitchen exhaust for example). These units shall be interlocked with associated exhaust systems to maintain proper building pressure.

Make-up Air Units shall comply with the AHU requirements where commercially available.

2-11.10 Computer Room Air Conditioners

CRAC units shall be configured for Down-flow Operation with EC Motor Technology (preferred, but shall be evaluated) for raised access floor systems and spaced properly per manufacturer's requirements, cooling load demands and engineering analysis.

Provide adequate clearance for servicing. The Up-flow Configuration shall be used for solid, non-raised floor applications such as electrical rooms and other areas or depending on the specific application.

For belt driven fans, Variable Speed Drives shall be provided for airflow adjustment and equipped with two belts for more reliability in case of a single belt failure. Include within the specifications, the Contractor shall, after Testing and Balancing has been completed and accepted by the University, replace the factory-supplied variable pitch sheaves with fixed pitch sheaves. Specify that units shall be furnished with one spare set of belts and filters or an EC motor/fan. Filters shall be MERV 8 efficient based on ASHRAE 52.2. Filters shall be easily accessible and removable.

Optional field mounted Turning Vane shall be provided where required. Provide factory installed condensate pumps to meet drainage requirements. Provide factory furnished Disconnect Switch (locking type). If required, coordinate Emergency Power-Off (EPO) Station operation requirements with NFPA. Fire-stat and Duct Detectors shall be factory furnished. Coordinate requirements with JHU's Electrical Engineering Design Guide and NFPA. CRAC units installed in occupied locations shall be provided with closed cell interior insulation (if available).

2-11.10.1 Humidification

For Data Center/Machine Room humidification applications a self-contained electrode steam humidifier shall be used in all locations where the water conductivity level meets the manufacturer equipment requirements for proper operations. Where low water conductivity exists a resistive element version of the self-contained humidifier shall be used.
The humidifier shall be capable of providing uncontaminated steam with modulating control. At a minimum, the humidifier shall be provided with stainless steel steam distribution and components; factory mounted blower pack, drain water tempering control, one spare canister for every four units. For resistive element applications, provide a scale tank.

Coordinate with the Project Manager if humidification is required in a particular application and the CRAC unit is the only practical generation source and specify a steam generating canister type. Humidifier shall be provided with supply and drain valves, electronic controls and steam distributor. The humidifier shall have an automatic flush cycle to lengthen service life.

2-11.10.2 Dehumidification

Dehumidification is typically taken care of by the house system to treat ventilation air and by the CRAC units for the area or equipment which they serve. Typically electric heat or hot water means is not required for dehumidification and is strongly discouraged unless required by a specific application.

2-11.11 Heat Pumps

Heat pump units shall be assembled with heavy gauge metal zinc coated cabinets with weather resistant baked enamel finish. Two compressors shall be provided, unless not commercially available. Each refrigeration circuit shall have a factory installed thermal expansion valve. All units shall be equipped with some means of capacity control such as hot gas bypass or compressor unloading.

Heat pumps shall be provided with the following safety controls: coil defrosts control, low-ambient operation, and head pressure control down to 0°F ambient. Heat pumps that control sequence(s) shall be configured to prevent simultaneous heating and cooling. During cooling mode the electric heating coil shall be locked-out. For all water-cooled units low-limit temperature sensors shall limit the incoming condenser water temperature (normally 65°F) during heating mode. If condenser water temperature falls below set-point, the water regulating valve shall close and electric heating coil shall energize. Provide factory supplied electrical disconnect. Unit performance shall comply with AHRI 310/380.

2-11.12 Condensing Units

Condensing units can be part of a package assembly or split-system where the condenser is located remote from the Air Conditioning unit it serves. Use digital scroll compressors if available in the size required. If digital scroll compressors are not available, then multiple compressors are required at a minimum, unless commercially unavailable for the desired equipment. Each condensing unit shall be provided with vibration isolation when located on the roof or connected to the facility structure. At a minimum, condensing units shall be provided with hot gas bypass circuit for capacity control, charging valve, suction line shut-off valve, liquid
line shut-off valve and unit mounted disconnect switch. Condensing unit shall be AHRI 350 rated.

2-11.13 Terminals

2-11.13.1 Fan Coil Units

Fan coil units shall be factory assembled complete with, at a minimum, coils, fans, filters, access panels, and stainless steel double-sloped drain pans for units with a cooling coil. Units are preferred to be provided with hot water heating coils, although electric (with SCR control) or steam heating coils may be considered.

All fans shall be internally isolated. Provide large access panels for ease of maintenance. To the maximum extent practical, units shall have the option of being shipped with or without pre-piped valve packages for coordination in the field with existing conditions. Fan coil units shall have single point power connections and unit mounted disconnect switch. Units shall be factory tested prior to shipping, and all fans shall be certified by the AMCA. All coils shall be AHRI 410 rated. Units shall be rated per AHRI 440.

Condensate Drain Pans shall be IAQ, non-corrosive, positively sloped in every plane for efficient draining. Also an auxiliary drain pan shall be included and extend beyond the equipment footprint to also contain the valve packages as well. Both drain pans shall be easily removable for cleaning. Field fabricated or equipment supplied secondary drain pans shall be provided for all fan coil units located above the ceiling. Filters shall be MERV 8 efficient based on ASHRAE 52.2. Filters shall be easily accessed and removable. Condensate pumps serving individual HVAC units shall be fed from the same electrical circuit as the unit.

A manual combination thermostat and three-speed fan switch shall be provided with Off-Hi-Med-Lo positions. Also include a cabinet-mounted, factory-wired disconnect switch. The fan motor assembly shall be easily removable.

2-11.13.2 Series Fan-Powered VAV Terminals

Series Fan-Powered VAV Terminals shall be pressure independent primary airflow control, equipped with multi-point inlet velocity sensor with center averaging. Flow controllers shall control minimum and maximum primary CFM. The temperature sensor signal shall reset the flow control device to control primary air CFM to match load requirements. The fan shall run continuously distributing mixed plenum and primary air to the space.

Terminals shall have enhanced sound attenuation, for example heavier insulation and flexible mountings for fan, to maintain room NC levels below 35 when rated in accordance with AHRI 885-90 at 0.5 inches inlet pressure.
Terminals shall be the "Low Profile" type and shall not exceed 11 inches in height and equipped with SCR fan speed controls with minimum voltage stop. Provide reheat coil if required, using heating hot water to the maximum extent practical. Electric coils, with SCR controls, shall be the alternative in applications where heating hot water is not practical.

Terminals with reheat coils shall be provided with MERV 4 Filter and frame to protect the coils from dirt. Terminals without reheat coils shall be provided with filter frames for future installation of filters if deemed necessary. Provide an air boot on the plenum inlet with 1 inch acoustical lining for each terminal to control sound coming from the terminal fan. Unit performance shall comply with AHRI 880.

2-11.13.3 Single Duct VAV Terminals

Terminals shall be pressure independent primary airflow control equipped with multi-point inlet velocity sensor with center averaging. Flow controller shall control minimum and maximum primary CFM. The temperature sensor signal shall reset the flow control device to control primary air CFM to match load requirements. Provide reheat coil if required, using heating hot water to the maximum extent practical. Electric coils, with SCR controls, shall be the alternative in applications where heating hot water is not practical. Unit performance shall comply with AHRI 880.

2-11.13.4 Radiant Heating Panels

Radiant heating panels shall be located around the perimeter for skin loads in lieu of a convection system. Consult the Project Manager if convection heat is determined to be more suitable to a particular application. Synchronizing the radiant heating panel operation with the area VAV terminal units(s) with a single space sensor shall be considered depending on application.

2-11.13.5 Fin Tube Radiation/Convector

The fin tube radiation/convector heating element shall have copper tube and aluminum fins. Each building exposure shall be a separate zone. Coordinate element enclosures with the Project Manager. All heating elements shall be manufactured by means of mechanical expansion.

2-11.13.6 Unit Heater

Unit Heaters are available in vertical or horizontal discharge configurations, and shall be employed where aesthetics are not a concern (e.g., mechanical rooms, warehouses, utility rooms, etc.). Units consist of heavy gauge metal enclosure, propeller fan and hot water or steam heating coil. Units shall be provided with built-in overload protection.
Optional integral thermostats are available or units may be controlled by a remote wall-mounted thermostat. Refer to manufacturer’s literature for recommended mounting heights and application considerations.

2-11.13.7 Package Through-Wall Air Conditioning

Package through-wall air conditioning (PTAC) units, either for cooling only or for heating and cooling (i.e., heat pump), may be used for utility facilities, small stand-alone facilities or for temporary duty so long as humidity control is not a concern and physical or contaminant concerns are not present (or protective measures are cleared by the Project Manager). Units are to have self-contained controls, condensate discharge and ventilation provisions. Unit performance shall comply with AHRI 310/380.

2-11.14 Fans and Power Ventilators

Select fan type and configuration based on static pressure and airflow requirements, location, available space, and maintenance access. Fan material shall be suitable to the application. Roof curb mounted fans shall have hinged covers or curbs to allow for access. Coordinate with JHU’s Electrical Design Guide to provide a convenience outlet per NEC. Provide for rain protection of exhaust openings as necessary. Fan shall be mounted so as to insulate the structure from vibrations in accordance with this FC.

For all fan types, optional features and layout arrangements shall require:

- Belt-driven fans shall be purchased with variable-pitch sheaves and shall be replaced with fixed-pitch sheaves after testing and balancing
- Unobstructed access to motor for removal
- Belt-driven fans shall be provided with a spare set of belts

2-11.15 Heat Tracing

For systems subject to freezing conditions, such as cooling tower piping, provide heat tracing along the full length of exposed piping including all valves, fittings and drains. The heat tracing system shall be a self-regulating heating cable that consists of (2) bus wires embedded in a parallel self-regulating polymer core that varies its power output to respond to the ambient temperature along its length. The cable shall be designed such that it can be crossed over itself and cut to length in the field.

Provide a controlling thermostat for circuit that energizes/de-energizes for circuit cycling. Provide heat-tracing manufacturers dedicated heat-tracing power distribution panels with controls, ground-fault protection, individual breaker monitoring and alarms, panel door disconnect and ambient sensing thermostat. Each panel shall be provided with one spare circuit for future use. Provide alarm to
Metasys when heat trace fails while commanded on.

In order to conserve energy and to prevent overheating, the heating cable shall have a self-regulating factor of 90%. Heating cables used for freeze-protection of metal pipes shall operate on line voltages of 120v, 208v, 220v, 240v, or 277v without the use of transformers. Refer to manufacturer’s selection criteria for required wattage based on pipe size and ambient temperature. All cabling shall be UL listed and/or Factory Mutual (FM) approved. Component enclosure shall be NEMA 4X rated to prevent water intrusion and corrosion.

2-11.16 Water System Accessories

All accessories 2 inches or smaller shall have screwed fittings and those that are 2.5 inches or larger shall have flanged fittings. Di-electric fittings shall be required for joining dissimilar metals. Ensure they are installed per the Manufacturer’s recommendations.

2-11.16.1 Y-Pattern Strainers

Provide cast iron or bronze body with perforated stainless-steel basket and bottom drain connection consisting of a blow down ball valve, hose end fitting, with cap and chain.

Provide finest mesh available with a clean strainer pressure drop not to exceed 5 foot, with a fouled strainer scheduled to be cleaned at a 10 foot water pressure drop.

Disposable construction mesh baskets shall be provided during construction.

2-11.16.2 Manual Air Vents

Use a 3/4-inch ball valve with hose end connections cap and chain.

2-11.16.3 Pipe Drain Valves

Use a 3/4-inch ball valve with hose end connections cap and chain.

2-11.16.4 Centrifugal Air Separators

In main plant, provide in-line centrifugal air separator at the point of expansion tank connection. Air separators shall be ideally placed in the system where the lowest pressure and highest temperature exists. Air separator shall have flanged connections, be of steel material constructed and designed per ASME Section VIII, Division I.

2-11.16.5 Expansion Tanks

Use bladder type expansion tank for each closed system, since they are not
susceptible to loss of expansion capacity due to air absorption. Expansion tanks shall have replaceable bladders. Initial charge shall reflect fill pressure and static system head.

Expansion tank sizing calculations shall indicate the fluid upon which the tank was selected.

2-11.16.6 Thermometers and Pressure Gauges

Gauges shall have a minimum of a 3-1/2-inch face plate with scale to be two times operating range with midpoint set for expected operation point. Provide stems with a minimum length of 2 1/2-inch immersion, which shall be increased in insertion length as necessary to reach the centerline of pipe to which it is installed.

2-11.16.7 Basket Strainers

Provide basket strainers as required or designated for water cooled rack systems. For steel pipe systems the strainers body shall be cast iron or bronze body for copper pipe systems. The strainer shall have a mesh basket constructed of 304 stainless steel or better, flanged ends, bolted cover and inlet/outlet gage taps for pressure differential measurements. The bottom drain connection shall consist of a blow down ball valve and hose end fitting, with cap and chain. Bodies shall be epoxy painted if available. Carbon steel bodies may be used but must be epoxy painted. At a minimum provide size 40 mesh or one size finer than the rack manufacturers’ requirements. The pressure drop across the strainer should not exceed 5 feet of water pressure drop, with a fouled to be cleaned not to exceed 10 feet of water pressure drop. Spare cover gaskets and O-rings shall be provided for each strainer. Where applications require larger than 2 inch piping, optional stand/legs shall be provided when piping cannot support the weight of the strainer. Disposable stainless steel mesh baskets shall be provided during construction.

Redundant basket strainers shall be provided to allow for cleaning, with only one being operational at a time. Basket strainers shall be provided for all data center water-cooled rack and in-row cooler applications, as directed by the lead mechanical engineer on the project. Strainers shall only be used in horizontal applications. If strainer is to be installed under raised access floor, flooring shall be marked with “Basket Strainer” and “IT Grid” numbering system to mark its location. A working clearance is to be provided above the basket strainer, to provide space for the baskets removal.

2-11.17 Leak Detection

All suspended units (e.g., fan coils, air handlers or spot coolers) shall have a secondary means of condensate containment should the primary condensate pan fail (e.g., drain blockage or pan leakage). A moisture sensitive sensor in the secondary containment shall be Darwell Technologies Model AT1-M2 and shall be supplied with water detector tape model AT1-xxM2. All computer room units shall
have looped water sensing cable around the perimeter of the unit under raised floor. Leak detection shall disable unit operation (unless the unit is of a critical operational nature, then unit shall continue in operation – the Project Manager/Engineering Department shall determine units or areas of critical operational nature) and alarm Metasys upon detection of water. Secondary containment pan shall be easily removable to allow for filter changes and component access. Provide quick connects for the removal of leak detection devices and cabling to accommodate secondary containment pan removal. Provide spare cables.

2-11.18 Cathodic Protection

Corrosion control shall be a primary consideration for any underground piping system. Determine the need for, and type of, cathodic protection based on the corrosion rate of the specified pipe material in the specific environment. Specify cathodic protection requirements for any buried metallic pipes or tanks. Buried pipe shall be externally coated to isolate the pipe from the environment and to reduce cathodic protection current requirements. External coating shall be an effective electrical insulator and moisture barrier. Cathodic protection shall be provided by producing a continuous flow of direct current from a sacrificial anode to the metal to be protected. Select anode material appropriate for the pipe and soil combination. The anode shall be of a size and quantity to protect the buried items for the life expectancy of the piping system.

Provide electrical isolation devices in the piping system where required to facilitate the application of external corrosion control. Provide test stations to facilitate cathodic protection testing. Criteria for determining the adequacy of protection on the buried items shall be in accordance with NACE RP0169. Coordinate requirements with civil and electrical disciplines.

2-11.19 Chilled Beams

The designer of record (DoR) shall consult the Project Manager/Engineering Department if they determine chilled beams are suitable for a particular application, new construction or renovation work. On renovation work, the DoR shall be knowledgeable of the existing facilities mechanical infrastructure and its impact of design requirements for Chilled Beam Technology.

Chilled beams shall meet the following requirements:

- Be of the active type, which rely on airflow from an air handling unit to induce airflow over the chilled beam.
- Passive type chilled beams to be assess for transient space (lobbies and corridors)
- Chilled beams usage shall be limited to open office space. Chilled beam maybe considered for small office
- Chilled beam length shall be consistent over the open floor plate (limited to
zone, column bay, and perimeter zone)

- Air flow to the chilled beams shall be Automatic air balancing/Variable Air Volume (VAV) box
- Chilled beams shall be limited to 2-pipe type – cooling only
- Reheat of the supply air shall be provided at the VAV box and not at the chilled beam
- Reheat perimeter/top floor
- Chilled beams shall be monitored and controlled by the Metasys, including space temperature, dew point, condensation on chilled water piping, and modulating control valve operation. Have valves as normally closed
- Chilled beams shall include boarder options, drain pans at U-Bends, internal insulation, chains and latches for the removable diffuser, and hard pipe connections at beams
- Chilled water plant shall have 2 chilled water loops; a 44 deg. F (with a 12 deg. Delta T) loop serving the building and the other loop for the chilled beams system.
- At zone supply/return piping provide same as the typical chilled water coil connection detail
- Provide supply isolation (ball) valve and a return calibrated positive shut-off isolation ball valve at each Chilled beam
- Provide detailed commissioning plan for review and approval by the Project Manager/Engineering Department

At startup or sustained power outage the chilled beam system shall be brought back online slowly and under manual control.

2-12 CLEANING, FLUSHING, TREATING AND TESTING PIPING SYSTEMS

2-12.1 General Requirements

In all cases, the University’s water treatment contractor shall be consulted during design and specified during construction to recommend the proper course of action and proper chemistry requirements based upon the system metallurgy on hand. The industry standard definition of clean is a surface free of mill scale, slag, grease, oil, dirt, and corrosion products. All new piping systems shall be specified to be chemically pre-treated using an agent in compliance with the University’s water treatment contractor standards.

Any new/old system shall be specified to be flushed with clean fresh makeup water until the water coming out of the system is identical in content to the water going into the system. This ensures that any chemical agents used are completely rinsed out of the system and any corrosion products, oils, greases, etc. are removed from the system.

The University’s water treatment contractor shall test the water to ensure that the contaminant levels coming out of the system in the effluent are identical to
that of the makeup water source, in accordance with AWWA-C651.

Treat means to chemically pre-treat and passivate the system to ensure that the mill scale, slag, grease, oil, dirt and corrosion products are emulsified and flushed from the system. Treat also means chemically treating to ensure that the system is properly protected against microbiological fouling, mineral scaling and corrosion.

All new piping shall be specified to be cleaned, flushed, treated and hydrostatically tested to ensure clean, flushed, treated and leak-free construction prior to University acceptance.

For University owned buildings the AHJ shall be the Project Manager. For leased facilities the AHJ shall be the local plumbing inspector and the requirements shall be adjusted as required to comply with the local jurisdiction.

2-12.2 HVAC Piping

The DoR shall provide the Contractor with detailed Specifications for treatment of the hydrostatic testing water (if necessary), cleaning, flushing, treating and testing HVAC piping.

The following shall be incorporated into the specifications at a minimum (23 64 26 CHILLED, CHILLED-HOT, AND CONDENSER WATER PIPING SYSTEMS):

Definitions:

Clean: The industry standard definition of clean is a surface free of mill scale, slag, grease, oil, dirt, and corrosion products. It is necessary to hydrostatically test, flush, clean and chemically pre-treat all new systems using an agent specified by the Agency water treatment contractor on record.

Flush: Any new/old system shall be flushed with clean fresh makeup water until the water coming out of the system is identical in content to the water going into the system. This ensures that any chemical agents used are completely rinsed out of the system and any corrosion products, oils, greases, etc. are removed from the system. The University water treatment contractor shall test the water to ensure that the contaminant levels coming out of the system in the effluent are identical to that of the makeup water source. Discharge of flush activities to storm sewer or storm water management feature is prohibited without prior written approval from the Project Manager, after assurances that flush activities are compliant with Federal, state, and local environmental permit limitations.

Treat: Treat means to chemically pre-treat and passivate the system to ensure that the mill scale, slag, grease, oil, dirt and corrosion products are emulsified and flushed from the system. Treat also connotes chemically treating to ensure that the system is properly protected against microbiological fouling, mineral scaling
and corrosion.

Test: All new piping shall be hydrostatically tested to ensure leak-free construction. In some instances, system piping or components may be damaged by excessive pressures. The A/E is responsible for informing the Project Manager/Engineering Department of any instances in which the test pressures indicated below may result in harm to new or existing system components.

The Contractor shall work with the University water treatment contractor to prepare a script based upon these Specifications and submit to the University as a Shop Drawing for approval. All procedures must be approved and witnessed by the Project Manager, Operations personnel and the University water treatment contractor.

The following requirements shall be completed in following sequence:

1. Wash and wipe the exterior of all new piping to remove construction dirt, loose scale and flux before bringing the pipe indoors.
2. Each piece of installed or existing-to-remain (ETR) equipment (such as coils, evaporators, condensers or heat exchangers) shall have a valved bypass installed just prior to the equipment. Each piece of equipment shall be either valved or sealed off utilizing frying pan type blanks to prevent contaminated water, dirt, scale or debris from entering this equipment. Where bypasses are not installed, remove piping spool pieces between equipment isolation valves / blanks and provide temporary pipe bypasses, as required. Blowdowns on low points shall also be utilized.
3. Piping shall be tested at 150 psi, or 1.5 times highest design pressure with all piping and joints proven to be leak-free prior to approval by the Project Manager. For piping 4" and below, test for 4 hours. For piping 6" and above, test for 8 hours. Pressure testing tolerance shall be plus/minus zero psig. All air must be vented from the piping prior to the test. In addition, every isolatable section shall be separately tested to ensure the closed valves hold under the test conditions mentioned previously except with 1/2 hour intervals.
4. Fill water used during testing and final filling shall be supplied from an external water source (use of system water is not permitted). This water must be properly treated prior to being introduced to new or existing systems. The contractor must coordinate with the University water treatment contractor to ensure that the water is compatible with the system materials of construction and existing water treatment program. Air testing will not be acceptable as a documented test but may be used for pre-tests. Once hydro testing is complete, water is to be drained and flushing is to occur within 48 hours of hydro testing.
5. Clean the interior of all new closed water system (not open to atmosphere) piping using a neutral HEPD/polymer/sulfite based liquid compound with
emulsifying agents and detergents. Ensure that all chemicals are compatible with both the system materials of construction and the existing water treatment program.

6. Flush the system to remove any debris that either existed before or was caused by construction. To ensure that larger debris is removed from the system, minimum velocities as defined in Table 2-4 below must be achieved during the flushing procedure. Pipe velocities shall be measured in new piping segments using portable ultrasonic flow meters and verified by the Project Manager.

<table>
<thead>
<tr>
<th>Pipe Size (Inches)</th>
<th>Minimum Water Velocity (ft/sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td>8</td>
<td>9</td>
</tr>
<tr>
<td>10 or greater</td>
<td>10</td>
</tr>
</tbody>
</table>

The Contractor may employ the following methods to perform this work (in order of preference):

1. Provide temporary pumps to achieve the minimum flow requirements defined above. Stainless steel construction strainers (minimum 10 mesh to protect pump) shall be utilized during the procedure. Strainers must be designed to perform at pipe velocity listed in above chart. The A/E must ensure that the taps and by bypass of adequate sizing are included in new sections of pipe to facilitate these velocities.

2. If system design does not permit for use of temporary pumps, then new bearings, seals and gaskets will be transferred to owner for ALL pumps utilized for flushing.

3. If the system pump(s) are used to achieve the minimum flow requirements defined above, stainless steel construction strainers (minimum 3/32-inch mesh) shall be installed to protect the pump(s) during the procedure. The Contractor will be responsible for all costs (parts and labor) to repair pumps damaged as a result of this work.

During water circulation, remove foreign matter by draining at low points and equipment inlets. Ensure the desired drain flow does not exceed system water makeup capability. When the system appears to be free of
foreign matter (water runs clear), shut the pumps down, remove the construction strainers, and inspect and clean the strainers by removing any foreign matter before re-installing. Repeat this process until the system is determined by the Project Manager to be clean and free of debris. Duration of flushing and circulation shall be minimum 24 hours, or as required by the water treatment contractor.

a. The water treatment contractor shall test the water to ensure that the contaminant levels coming out of the system in the effluent are identical to that of the makeup water source, in accordance with AWWA-C651.

Once the system is determined to be clean, close the equipment bypass valves, remove any previously installed frying pan type blanks, remove any temporary bypasses, reinstall pipe spool pieces, and fill and vent emptied portions of the system, open equipment isolation valves and restart the pumps. Re-circulate water through the equipment strainers, evaporators, condensers, heat exchangers and cooling towers. Remove dead legs created by by-pass piping. After circulating water for four (4) hours, shut the system down, turn the valve off and drain the equipment. Remove all evaporator, condenser and heat exchanger water box covers for visual water box and tube inspection. Clean tubes found to be fouled or obstructed with new or existing debris. Repeat this process until strainers, evaporators, condensers and heat exchangers are determined to be clean by the Project Manager. When complete, replace the water box cover gaskets on all equipment. Flushing water shall be piped to the sanitary sewer system (discharge to the storm water system is not permitted).

2-12.3 Steam and Condensate Return Piping

Provide the Contractor with specifications for cleaning, flushing, treating and testing steam and condensate return piping. The following shall be incorporated into the specifications at a minimum:

- De-burr all pipe ends before installation, and once completed, flush total system with clean water.
- Strainers shall be cleaned before and after flushing.
- All joints, including welds, shall be left un-insulated and exposed for examination during testing.
- Subject piping to hydrostatic pressure that is not less than 1.5 times design pressure (which means that all system joints, pumps, valves or other component rated pressures shall not be exceeded).
- Verify that bottom of vertical runs does not exceed 90 percent of specified yield strength or 1.7 times SE value in Appendix A of ASME B31.9 - Building Services Piping.
- Hydrostatic test shall be at pressure a minimum of 2 hours before visibly examining joints and connections for leakage.
2-13 IDENTIFICATION LABELS

2-13.1.1 Equipment and Piping

Provide vinyl, adhesive type identification labels indicating flow direction, pipe size and service every 20-linear-feet for all piping both above ceiling and below raised access floor. All lettering sizes shall be per ANSI A13.1. Label all equipment above the suspended ceiling on the bottom side of the ceiling grid. Equipment designators shall be in accordance with Table 2-5 in this FC. Exterior piping shall use laminated labels and shall be fastened onto the piping with restraint ties. Coordinate with the Project Manager to obtain valve numbers to be incorporated into the design drawings.

Table 2-5 – Equipment Labeling

<table>
<thead>
<tr>
<th>Example</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>VAV 4 DD-10A</td>
<td>See below</td>
</tr>
<tr>
<td>VAV</td>
<td>Equipment Designator</td>
</tr>
<tr>
<td>4</td>
<td>Location designator using building floor</td>
</tr>
<tr>
<td>DD-10</td>
<td>Location designator using building column grid</td>
</tr>
<tr>
<td>A</td>
<td>Quantity designator sequential letter to indicate qty.</td>
</tr>
</tbody>
</table>

Table 2-5 – Equipment Designator Symbols

<table>
<thead>
<tr>
<th>VAV</th>
<th>Terminal VAV box</th>
<th>FPB</th>
<th>Fan Powered Box</th>
</tr>
</thead>
<tbody>
<tr>
<td>CRAC</td>
<td>Computer Room Air Conditioner</td>
<td>MAU</td>
<td>Make-up Air Unit</td>
</tr>
<tr>
<td>FPB-R</td>
<td>Fan Power box with Reheat</td>
<td>AHU</td>
<td>Air Handling unit</td>
</tr>
<tr>
<td>VAV-R</td>
<td>Terminal VAV Box with Reheat</td>
<td>CT</td>
<td>Cooling Tower</td>
</tr>
<tr>
<td>CWP</td>
<td>Condenser Water Pump</td>
<td>CH</td>
<td>Chiller</td>
</tr>
<tr>
<td>CHWP</td>
<td>Chilled Water Pump</td>
<td>FCU</td>
<td>Fan Cooling Unit</td>
</tr>
<tr>
<td>SCHWP</td>
<td>Secondary Chilled Water Pump</td>
<td>EF</td>
<td>Exhaust Fan</td>
</tr>
<tr>
<td>HWP</td>
<td>Heating Water Pump</td>
<td>HTP</td>
<td>Heat Transfer Package</td>
</tr>
</tbody>
</table>
2-13.1.2 Warranty Labels

Provide warranty labels for equipment described herein before under warranty. Labels shall be no greater than 8”x10” in size and shall include the following information:

1. Equipment number
2. Project Number
3. Project Name
4. Project Contract Number
5. Manufacturer
6. Model Number
7. Serial Number
8. General Contractor
9. General Manufacturer’s Warranty Expiration Date
10. Manufacturer’s local Representative
11. Manufacturer’s local representative’s number

Proposed warranty labels, along with mechanical attachment shall be submitted to the Project Manager during construction for review and acceptance prior to installation. If mechanical attachments are not practical, please submit an alternate fastening method for Project Manager approval.

2-14 INSULATION

Piping and ductwork minimum insulation requirements shall comply with ASHRAE 90.1 and as specified herein. Include within the specifications, the project specific Insulation Application Schedule. Capping and/or patching ductwork includes providing insulation as required.

2-14.1 General

Refrigerant suction and hot gas piping systems shall be insulated with flexible, elastomeric insulation. All other piping systems shall be insulated with rigid molded, non-combustible glass fiber with a thermal conductivity (K) value of 0.23 or less at 75°F. A white, kraft paper-reinforced, vapor retardant jacket shall be provided with glass fiber yarn and bonded to aluminum foil, secure with self-sealing longitudinal laps and butt strips for piping subjected to potential condensate conditions. Elastomeric piping insulation shall have UV protection/coating where exposed to the outdoors.

For heating hot water piping systems, a vapor retarder is not required if the piping is contained indoors. For refrigerant suction piping systems, liquid lines shall be insulated in all locations where condensation will occur. For refrigerant hot gas piping systems, hot gas lines shall be insulated where personal injury from incidental contact could occur. For condenser water piping systems, provide a vapor barrier for condenser water with an economizer operation if the facility has
humidification or if the system is exposed to untreated outside air.

Insulation thicknesses based on pipe sizing for various piping systems shall comply with Table 2-6 below. Domestic cold water piping systems referenced below include above-ground trap primer piping to and from the distribution unit.

**Table 2-6 Piping System Insulation Thicknesses**

<table>
<thead>
<tr>
<th>Piping System</th>
<th>Pipe Size (inches)</th>
<th>Insulation Thickness (inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chilled Water</td>
<td>≤ 3</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>4 to 10</td>
<td>1-½</td>
</tr>
<tr>
<td></td>
<td>≥ 12</td>
<td>2</td>
</tr>
<tr>
<td>Refrigerant Suction</td>
<td>≤ 1</td>
<td>1-½</td>
</tr>
<tr>
<td></td>
<td>1 ¼ to 6</td>
<td>2</td>
</tr>
<tr>
<td>Refrigerant Hot Gas</td>
<td>All Sizes</td>
<td>1</td>
</tr>
<tr>
<td>Condenser Water</td>
<td>≤ 6</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>≥ 8</td>
<td>1-½</td>
</tr>
<tr>
<td>Heating Hot Water</td>
<td>≤ 4</td>
<td>1-½</td>
</tr>
<tr>
<td></td>
<td>≥ 5</td>
<td>2</td>
</tr>
<tr>
<td>Low Pressure Steam and Condensate</td>
<td>≤ 2</td>
<td>1-½</td>
</tr>
<tr>
<td></td>
<td>2-½ to 6</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>≥ 8</td>
<td>3-½</td>
</tr>
<tr>
<td>Medium Pressure Steam</td>
<td>≤ 1</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>1 ¼ to 6</td>
<td>2-½</td>
</tr>
<tr>
<td></td>
<td>≥ 5</td>
<td>3-½</td>
</tr>
</tbody>
</table>

**2-14.2 Field-Applied Pipe Jacketing**

Provide full color-coded PVC jacket for all exposed piping within the mechanical rooms. Jacket shall be cut and curled for the appropriate pipe size (snap-on). PVC jackets for piping, fittings, valves and specialty devices shall be 20 mils thick and shall meet 25/50 fire/smoke spread ratings. The color-coding shall be as follows:

- Primary Chilled Water – Blue.
- Secondary Chilled Water – Light Blue.
- Condenser Water – Green.
- Hot Water – Orange.
- Steam – Gray.
- Steam Condensate – Gray.

For piping installed outdoors provide exterior jacketing of 0.016 inches thick, smooth finish aluminum jacket factory cut and rolled for the appropriate pipe size. For elbows, fittings, valves and specialties factory prefabricated fittings shall be used. No field fabricated fittings will be accepted. For joining sections of
jacketing, 3/4-inch wide type 304 stainless steel bands shall be used.

2-14.3 Piping at Hangers/Supports

Specify that the Contractor shall perform any and all re-adjustments of pipe hangers/supports following installation of the field-applied pipe jacketing after the pipe insulator has completed their work. Support locations for insulated pipe shall be protected with the appropriate saddle shield. Provide full circumference shields with clamps and U-bolts. The insulation insert of sufficient density shall be cellular glass and extend two inches beyond the end of the sheet metal saddle. The insert shall be a full section that totally encloses the pipe.

2-14.4 Duct Insulation

All external duct insulation shall comply with ASHRAE 90.1 and be either wrap or board type. Wrap type insulation shall be provided in areas where ductwork is concealed.

Board type insulation shall be provided in areas where insulation is susceptible to damage (utility or high traffic spaces). Acceptable types of external duct insulation are the following:

- Duct Wrap: Insulation shall be flexible glass fiber blanket, minimum of 3/4 lb. per cubic foot density with a thermal conductivity (K) value of 0.31 or less at 75°F. Insulation shall have a factory applied jacket of aluminum foil reinforced with glass fiber bonded to flame resistant kraft paper vapor barrier.

- Duct Board: Insulation shall be rigid glass fiber board, minimum of 6.0 lb. per cubic foot density with a thermal conductivity (K) value of 0.22 or less at 75°F. Insulation shall have a factory applied jacket of white, flame retardant vapor barrier jacket of aluminum foil reinforced with glass fibers bonded to flame resistant kraft paper.

Duct insulation thickness shall comply with Table 2-7 below:

<table>
<thead>
<tr>
<th>System</th>
<th>Installed Thickness (inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Return</td>
<td>-</td>
</tr>
<tr>
<td>Supply</td>
<td>1.5</td>
</tr>
<tr>
<td>Outside Air</td>
<td>1.5</td>
</tr>
<tr>
<td>General Exhaust and Relief</td>
<td>-</td>
</tr>
</tbody>
</table>

For return and general exhaust and relief duct passing through unconditioned spaces, provide minimum of 1-inch vapor proof insulation to prevent
condensation where applicable.

2-14.5 Field-Applied Duct Jacketing

For insulated duct installed outdoors provide exterior jacketing of 0.024 inch thick aluminum jacketing, with 2 inches overlap and stainless steel sheet metal screws 6 inches on centers. Jacketing shall have an integrally-bonded moisture barrier over the entire surface that is in contact with insulation and shall have end joints sealed with waterproof mastic.

2-15 HANGERS AND SUPPORTS

2-15.1 Hangers and Supports

Design all mechanical supports and hangers in compliance with IMC and IPC. Pipe hangers and supports systems for above grade applications, shall comply with Manufacturers Standardization Society for Valve and Fittings Industry (MSS). For existing installations, to the maximum extent practical, provide compatible designs that match existing conditions. Coordinate details with the Project Manager to avoid undesirable anchor locations to the extent practical.

Provide a minimum of A36 all-thread rods for hangers and supports with a minimum 0.5-inch diameter. Miscellaneous steel, such as plates, bars, angles, etc., shall be a minimum of A36. Provide floor stands for underfloor piping and infrastructure. Supporting from the RAF system is prohibited.

2-16 TESTING AND BALANCING

2-16.1 General Requirements

Communicate design assumptions, calculations, conditions (both environmental & systems' output), philosophies and assumptions about systems/equipment to the Testing, Adjusting and Balancing (TAB) Contractor through development of the specifications to perform the TAB. Balancing airflow and water flow within distribution systems, including sub-mains, branches and terminals, to indicated quantities according to specified tolerances listed below:

- AHUs and Fans: 0 to +10%.
- Air Terminal Devices: +/- 5%.
- Pumps: 0 to +10%.
- Water Terminal Devices: +/- 5%.

The specifications for TAB submittal processes shall follow this sequence:

Quality-Assurance Submittals: Require within 30 days from Contractor's Notice to Proceed, an electronic PDF submission of evidence that the Testing,
Adjusting and Balancing (TAB) Contractor and the Project's TAB team members meet qualifications specified in "Quality Assurance of Testing Personnel" as defined by the respective standard/authority selected for the testing approach.

Contract Documents Examination Report: Required within 45 days from Contractor's Notice to Proceed, a submission of 2 copies of Contract Documents review report.

Strategies and Procedures Plan: Required within 60 days from Contractor's Notice to Proceed, a submission of 2 copies of TAB strategies and step-by-step procedures as specified (including a complete set of report forms intended for use on the Project).

Certified TAB Reports: Require a submission of 2 copies of reports prepared, on approved forms certified by the TAB Contractor.

The TAB contractor shall notify the Project Manager during Testing and Balancing if systems are not within design parameters and are out of acceptable ranges as per TAB standards. Additionally, the Testing and Balancing contractor shall submit found deficiencies immediately (prior to completion of final report) to the A/E or the General Contractor for review and development of remedial action. The Contractor shall submit to the Project Manager the plan of remedial action and anticipated schedule of implementation within 3 working days after the initial notice of discovery.

2-16.2 Hydronic Systems

The specifications for TAB of hydronic systems shall include the following fundamental balancing procedures:

- If multiple chilled water sources are included within the design, specify that the Contractor shall verify that the required flow to the equipment can be achieved from either source. Coordinate with the Project Manager/Engineering Department to define the operational scenarios for testing in the specifications.
- Initial testing and balancing shall include all loads, current and future, both for performance capacity (i.e., as with adding load to fully test chillers) and for distribution performance (i.e., ensuring that adequate flow is available throughout the system). Specify to install any temporary bypasses and/or equipment required to enable testing and balancing at anticipated present and future maximum loading.
- Specify that test reports shall be prepared with pertinent design data and numbers in sequence starting at the pump to the end of the system, including checking the sum of branch-circuit flows against approved pump flow rate. Variations that exceed the specified tolerances shall be corrected.
• Provide schematic diagrams of systems' as-built piping layouts.
• Specify that all manual valves opened for maximum flow.
• Specify differential-pressure control valves set at specified differential pressure.
• Verify the pump-motor load is checked as the motor shall not be in an overloaded condition.

2-16.3 Air Systems

The specifications for TAB of air systems shall include the following fundamental balancing procedures:

• Specify that test reports shall be prepared for both fans and outlets, using the manufacturer's outlet factors and recommended testing procedures. The summation of required outlet volumes with required fan volumes shall be cross-checked. Variations that exceed the specified tolerances shall be corrected.
• Provide schematic diagrams of systems' as-built duct layouts shall be prepared.
• For variable-air-volume systems, provide a plan to simulated diversity.
CHAPTER 3 - PLUMBING SYSTEMS

3-1 DOMESTIC WATER SYSTEMS

A complete domestic cold, hot and circulation water distribution system shall be provided to all, but not be limited to, the following equipment and components: plumbing fixtures, plumbing equipment, water filtration, water softening, pressure booster systems, kitchen equipment and mechanical equipment.

3-1.1 Meters

Water service meters shall be located inside and furnished by the water utility or provider. Exterior water meter crocks or vaults are prohibited. The water service shall have a code, utility or provider compliant reduced pressure zone backflow prevention device (if required by local code or authority having jurisdiction) immediately downstream of the service water meter(s) prior to all other connections and branches.

Mechanical systems consuming domestic water, such as boiler systems (for blowdown) and open cooling tower systems (evaporation and blowdown) shall have a water sub-meter for tracking consumption (with bypass).

3-1.2 Pressure Maintenance

Either a packaged triplex (three pumps, for systems 300 gallons and above in total water demand) or duplex (two pumps, for systems less than 300 gallon water demand) booster pumping system with variable speed control shall be utilized where water flow and water utility or low Hydraulic Grade Line (Low HGL) water pressures do not provide required pressure demands at peak draw. Include the following at a minimum:

- The pumps will alternate operation (Lead/Lag) in startup mode and shall be equipped with VFDs.
- All sensing lines shall be copper tubing.
- All testing shall be performed by a factory-authorized service representative and witnessed by the Project Manager unless directed otherwise. Testing procedures shall be repeated until the Project Manager is satisfied with the results.
- The booster pump system shall be connected to the emergency generator power system.

When city pressure is insufficient to meet the Low HGL, water pressure boosting shall be provided only to those areas or floor elevations where insufficient water pressures may be experienced/expected utilizing the Low HGL. Outlets on floor elevations or areas that can be served with the required pressures provided at Low HGL shall not be from the pumped system. The entire water service shall not be pressure boosted if only portions of the building systems require pressure
maintenance boosting.

The water service supply source low hydraulic grade line (Low HGL - low head elevation of water source tank or pump, adjusted for friction and head losses/gains) shall be utilized for determining available water source pressure, pump suction calculations and selection. The water service supply source high hydraulic grade line (High HGL - high head elevation of utility service water supply source tank or pump, plus booster pump shut-off head for boosted systems), adjusted for static pressure head, shall be utilized for determining net system working pressures.

3-1.3 Piping and Fittings

3-1.3.1 Underground Applications

Underground domestic water piping 2 ½-inches and smaller shall be copper tube, ASTM, B88, Type K, water tube, annealed temper for underground piping. Fittings shall be wrought copper, solder-joint pressure fitting in accordance with ASME B16.22. Joining material shall be lead free solder and flux, 95% Tin, 4-5% Copper, 0.04-0.20% Selenium in accordance with ASTM B32.

Underground domestic water piping 3 inches and larger shall be ductile iron in accordance with ANSI/AWWA C151/A21.51, 250 psig minimum pressure rating with mechanical or push-on joint bell in accordance with ANSI/AWWA C111/A21.11, plain spigot end and ANSI/AWWA C104/A21.4 cement mortar lining. Fittings shall be ductile iron in accordance with ANSI/AWWA C153/A21.53 and ANSI/AWWA C110/A21.10 and mechanical joints in accordance with ANSI/AWWA C111/A21.11. Include AWWA C111 ductile iron gland, rubber gasket and steel bolts with mechanical fittings and AWWA C111 rubber gasket with push-on fittings.

Flanged piping is prohibited for underground applications.

3-1.3.2 Aboveground Applications

Aboveground domestic water piping shall be copper water tube, Type-L, drawn temper, in accordance with ASTM B88, 125 psig minimum working pressure rating. Fittings shall be wrought copper, solder-joint pressure fitting in accordance with ASME B16.22. Joining material shall be lead free solder and flux, 95% Tin, 4-5% Copper, 0.04-0.20 % Selenium, in accordance with ASTM B32.

3-1.4 Hot Water Service

Cold water temperatures supplied from the utility source vary in temperature by season and regional location. Obtain, from the water utility provider, seasonal cold water service temperatures (past three years preferred) supplied by the water utility purveyor if available. Low temperature (lowest of past three years) seasonal cold water
service temperatures shall be utilized in calculation and application of water heating, water heating energy source (steam, heating hot water, gas) and for make-up to the water heating energy source. Preheating of domestic cold water supply to the domestic water heater and cold water make-up to water heating energy source shall be considered utilizing steam condensate or heating hot water return if available.

Instantaneous tank-less water heaters are prohibited as a primary source. Instantaneous tank-less water heaters are permitted for incidental use, sporadic equipment demands, or remote individual fixtures (e.g., lavatory, sink, shower, service sink) and shall be approved by the Project Manager/Engineering Department. Point of use instantaneous water heaters are permitted for use at emergency fixtures to supply ANSI standard "tepid water" immediately at the emergency fixture or group of emergency fixtures.

There shall be no dead legs or capped spurs in excess of 4 feet within the domestic hot water plumbing system, without return circulation. Natural rubber fittings shall not be permitted within the potable domestic hot water or return systems, as they have been associated with persistent colonization of Legionella bacteria. For additional information on water temperature, control of Legionella bacteria and water safety, refer to the Center for Disease Control (CDC) Guidelines for Environmental Infection in Healthcare Facilities and ANSI Standard Z358.1 Emergency Eyewash and Shower Equipment.

Distribution system shall consist of a piping system that connects water heater(s) to all fixtures, equipment and outlet demands requiring potable domestic hot water.

Circulation return systems with circuit setters/balancing valves shall be provided for all branches in excess of 25 feet from the water heater or circulated distribution main.

Domestic hot water shall be available at each hot water outlet within 15 seconds of the time of operation. Domestic hot water return circuits of substantially varying pressures as result of pressure zoning or static head cannot successfully be joined to a single pressure zone water heater. Locate individual pressure zone water heater(s) within the pressure zone(s), where return pressures would vary substantially causing dead head on the lower pressure return circuits. Hot water return systems shall have circuit setters (balancing valves) and test plugs at each return circuit.

3-1.5 Supply Equipment

For new or retrofit applications where utility billing is involved, the water meters for domestic water service shall be furnished by the local water utility or provider. Each building shall have its own domestic water meter. For sub-metering, coordinate with the Project Manager/Engineering Department and Metasys specifications for meter type. Coordinate with the Project Manager/Engineering Department on Metasys specifications on interfacing requirements for all meters. All testing shall be performed by a factory-authorized service representative and witnessed by the Project Manager, unless directed otherwise. Procedures shall be repeated until the
Project Manager is satisfied with results.

3-1.5.1 Water Heaters

Water Heaters shall be provided with the following, at a minimum: external factory fabricated connections of materials compatible with tank for piping connections, relief valve, pressure gage, thermometer, drain, anode rods and controls as required.

Electric heaters shall be provided with commercial grade heating elements, electric screw-in or bolt-on, immersion type not exceeding 18kw per step. The safety controls shall be automatic and include high-temperature-limit and low water cutoff devices.

Natural gas burners shall be atmospheric or powered-vent for natural-gas fuel. Automatic gas-ignition system and components shall comply with ANSI Z21.2. Include pressure rating, capacity and pressure differential required for water heater and gas supply. Automatic Valves shall be ANSI Z21.21, appliance, electrically operated, on-off automatic valve.

3-1.5.1.1 Stands

Stands shall be water heater manufacturer's factory-fabricated, steel stand for floor mounting and capable of supporting a fully charged water heater. Include dimension that will support bottom of water heater a minimum of 18 inches above floor.

3-1.5.1.2 Drain Pans

Drain Pans (if required by code) shall be corrosion-resistant metal with raised edge. Include dimensions not less than base of water heater and include drain outlet not less than NPS 3/4-inch. Option: Provide floor drain next to water heater in lieu of drain pan.

3-1.5.1.3 Piping Manifold Kits

Piping Manifold Kits shall be water heater manufacturer's factory-fabricated inlet and outlet piping arrangement for multiple-unit installation. Include piping and valves for field assembly that is capable of isolating each water heater and will provide balanced flow through each water heater.

3-1.5.1.4 Finishes

The Interior finish shall be constructed of materials and thicknesses complying with NSF 61 barrier materials for potable-water tank linings and shall extend into and through tank fittings and outlets and the outer steel jacket housing (tank and insulation) shall have an enamel finish.

3-1.5.2 Expansion Tanks

The expansion tank shall be commercial grade, factory-fabricated, ASME steel,
pressure-rated tank constructed with welded joints, 150-PSIG working-pressure rating and a factory-installed butyl-rubber diaphragm. Include air pre-charge to minimum system-operating pressure at tank. Interior finish shall be constructed of materials and thicknesses complying with NSF 61, barrier materials for potable-water tank linings and shall extend into and through tank fittings and outlets.

3-1.5.3 Backflow Preventers

Backflow preventers shall be compliant with ASSE standards for appropriate application as required by local codes and authority having jurisdiction. Coordinate mounting height with local code. 48 inches minimum is recommended. The backflow preventer shall be installed in an accessible location to facilitate testing and servicing.

3-1.5.4 Water Hammer Arrestors

Water hammer arrestors shall be provided at each elevation change of every horizontal branch to fixture batteries, at all quick-closing valves (mechanical make-up, drinking fountains, flush valves, single lever control faucets, temperature regulating valves, dishwashers, etc.) for both hot and cold water.

3-1.5.5 Eye Wash/Shower Stations

Provide Emergency Eyewash/Face Wash/Shower Station per the latest ANSI/OSHA, local codes or authority having jurisdiction. The station shall provide an eyewash/face wash at 2.5 GPM each (two for 5 GPM total) or deluge shower at 20 GPM each shall be tempered immediately at the fixture or group of fixtures (within 25 feet) to deliver "tepid water" 85°F - <100°F at 30 psig, within 10 seconds for a period of 15 minutes and shall account for temperature drop across the valve (generally 45°F or 70°F) at flow.

3-1.5.6 Hose Bibs

Hose bibs shall be bronze body, wheel handle, with renewable composition disc, threaded or solder joint inlet, ASME B1.20.7 garden hose threads on the outlet and integral or field-installed,

3-1.5.7 Wall Hydrants

Wall hydrants shall be ASME A112.21.3M, non-freeze type, key operated, threaded or solder joints, integral or field installed, non-removable, drainable, hose connection vacuum breaker with ASME B1.20.7 garden hose threads on outlet. Spacing for exterior wall hydrants shall be every 200 ft. Provide at least one wall hydrant on every exterior wall.

3-1.5.8 Trap Seal Primer Valves

Trap Seal Primer Valves shall be factory fabricated, enclosed electronic trap primer system with bronze body, ball valve, atmospheric vacuum breaker (ASSE 1001),
electrical brass body solenoid valve, Type-L copper manifold with distribution units (the number of outlets shall be suitable for the application) with compression connection for water distribution. Electrical components shall include single point power connection with manual override switch, 24 hour timer with relay and adjustable delay. All components shall be factory assembled in a 16 gauge steel box recessed or surface mounted. The entire assembly shall be tested and certified to ASSE 1044 and the electrical component are tested and certified to U.L. Standard #73.

3-1.5.9 Thermostatic Water Mixing

Thermostatic Water Mixing Valves shall be manually adjustable with bronze body. Provide check stops and unions on hot and cold water supply inlets, adjustable temperature setting in accordance with ASSE 1017.

3-1.6 Condensate Drainage

Condensate drainage shall be indirectly piped to storm drainage system.

Pumped condensate piping shall be copper type L, and gravity condensate piping shall be Drain-Waste-Vent (DWV) type (PVC or other non-metallic piping is not allowed).

The following is required for new construction in locations containing a raised access floor (RAF):

- Data Center/Machine Room - Provide a drainage system with properly placed floor drains to accommodate leaks, humidifier purges and maintenance oriented drainage. The drainage system shall be equipped with trap primers and shall run into the sanitary system.

3-1.7 Sanitary Drainage and Vent Systems

A complete sanitary drainage system shall be provided for all, but not limited to, plumbing fixtures, sanitary floor drains, kitchen equipment and equipment with sanitary, soil or waste drainage/discharge. Chemically treated mechanical discharge from cooling towers, boilers, chillers, blowdown and other mechanical equipment shall discharge to the sanitary drainage system for treatment and protection of the environment and waterways.

3-1.7.1 Sanitary Piping and Fittings

Underground soil/waste and vent piping shall be hub and spigot, cast iron soil pipe, service- weight class with hub and spigot or cast iron, soil-pipe fittings and compression joints with elastomeric gasket (by pipe manufacturer).

Aboveground soil/waste piping shall be CISPI hub-less (“No-Hub”), cast iron pipe with heavy duty, type 304 stainless steel couplings.
Aboveground vent piping shall be hub-less (“No-Hub”), cast iron pipe, hub-less, cast iron, soil-pipe fittings and heavy duty, type 304 stainless steel couplings or DWV (Drainage, Waste and Vent - Yellow Print).

3-1.7.2 Sanitary Equipment

3-1.7.2.1 Grease Interceptor

Drains and fixtures discharging grease laden waste within 10 feet of the cooking battery, mop and service sinks in kitchen areas, and as required by the state health department and local authorities shall discharge to a grease interceptor prior to connecting into the sanitary sewer. Grease interceptors shall be sized compliant with requirements of the local authority. Where permitted by the local authority, interior grease interceptors shall be compliant with the Plumbing and Drainage Institute (PDI) PDI-G101.

Exterior underground gravity grease interceptors shall be sized per manufacturer guidelines or the latest Uniform Plumbing Code but shall be reviewed by Project Manager/Engineering Department for approval. A central grease interceptor located outside, below-grade with a ladder built into the basin wall in an approved basin shall be provided to the maximum extent practical.

3-1.7.2.2 Sanitary Floor Drains

Provide trap primers for all sanitary drains (floor drains, receptors, open site drains, hub drains, etc.). Verify/Confirm that all existing sanitary drains have been installed with trap primers. Any existing sanitary drains without trap primers shall be upgraded with trap primers.

Single fixture restrooms do not require floor drains. In general, floor drains shall be cast iron body type, 3-inch diameter outlet, with 6-inch diameter nickel-bronze strainers for public toilets, kitchen areas and other public areas.

Receptors, open-site drains, hub drains and similar drains shall have dome bottom sediment strainers (in addition to pedestrian/vehicle grate strainers where required) to reduce splashing, increase free area and prevent debris blockage. Drain body, frame and grate strainers shall be rated for expected wheel loading, and shall include drain adapters, extensions, receivers, deck clamps and similar as required by the building construction. Drain strainer free area shall be equal to or greater than the free area of the calculated outlet pipe size area. Drain strainers in pedestrian areas shall be heel-proof type. Every drain and system opening shall have 1/4-inch maximum strainer openings for rodent-proofing. Drains accepting indirect waste shall have an appropriately-sized funnel that matches the same material as the drain strainer.
Receptor drains outlets shall be two-times (2x) the area of combined inlet pipe areas. Equipment room areas shall require large diameter cast iron strainers and parking garages shall require large diameter tractor grates rated for expected wheel loading. Ramp drainage shall require either trench drains or roadway inlets when exposed to rainfall.

3-1.8 Storm Drainage System

A complete storm (rainwater) drainage system shall be provided for all storm (rainwater) drainage for, but not limited to, foundation, sub-soil, ground water, roofs, plazas, balconies, decks, canopies, area wells, parking structures/garages and similar applications.

3-1.8.1 Storm Drainage Equipment

3-1.8.1.1 Automatic Sump Pumps

Sump pumps shall be located inside the building limits and only be used where gravity drainage cannot be achieved. Only storm (rainwater) and clear water drainage from the lowest floors of the building shall be connected to an automatic sump pump. Storm (rainwater) and clear water drainage systems from upper floors shall flow by gravity to the public storm sewer system.

Provide duplex pumps, submersible, with lead-lag capability. Each discharge pipe shall not be less than 4 inches in diameter. Motors shall be hermetically sealed, capacitor start, with built-in overload protection, electrical characteristics as scheduled.

Basin shall be fiberglass construction of indicated dimensions with inlet connections of size and location indicated. Maintain minimum of 3 feet depth below lowest inlet invert. Provide steel base plate with mounted galvanized guide poles and stationary discharge with support for each pump. Provide removable discharge connection on pump for positive locking and sealing to stationary discharge.

Piping and valves shall be standard weight schedule 80 PVC discharge piping with matching fittings. Vent piping shall be no-hub cast iron. Vent piping shall run directly to the roof. Valves shall be suitable for the material in which they are installed.

Cover shall be circular steel cover with gas tight gasket, hinged access door with wire rope for pump removal, openings for pump discharge pipes, vent connection, power control and alarm wiring.

Control equipment shall be wall-mounted in an UL-listed NEMA-1 rated enclosure. Equipment shall be located clear of pump access and not require disconnecting to remove pumps. Controls shall include (2) two fused motor switches, (2) two automatic starters providing overload & low voltage protection, (4) four enclosed mercury float switches and automatic alternator.

Provide automatic pump controls with level regulators or pressure sensors. Controls
shall start lead pump, start standby pump, and stop pump. Alternator shall automatically transfer the operation from one pump to the other and also start the second pump in the event the first pump does not handle the load.

Specify that all testing shall be performed by a factory-authorized service representative and witnessed by the Project Manager/Engineering Department unless directed otherwise. Testing procedures shall be repeated until the Project Manager/Engineering Department is satisfied with the results. Sump pumps shall be connected to the emergency generator power system.

3-1.8.1.2 Sand/Oil Separator

Drains in vehicle parking structures and fuel-oil unloading stations shall discharge to a sand/oil separator prior to discharge to the storm sewer system as required by current codes, state and/or local authority having jurisdiction.

3-1.8.1.3 Elevator Sump Pumps

An elevator sump pump shall be provided for all elevator pits. Pump and control system shall be capable of pumping water while containing oil. The system shall function automatically and shall provide for an alarm and separate LED lights in the event of (a) the presence of oil in the sump, (b) high liquid in the sump, (c) high amps or a locked rotor condition. All alarm events to be sent to Metasys. Elevator sump pump shall be simplex pump, submersible type and approved to UL 778 standards. Sump pump shall be furnished with thermal and overload protection, oil sensing probe and be capable of operating continuously or intermittently. The motor housing shall be constructed of #304 stainless steel and mechanical seals shall be housed in a separate oil-filled compartment.

The elevator sump pump controller shall be approved to UL 508 standards and housed in a NEMA 4X enclosure with a see-through window for observation of operating functions. The controller shall be equipped with an 8-pin twist lock receptacle, dual solid state Oil-Minder relays with variable sensitivity settings, an over current relay, self- cleaning stainless steel sensor probe, high decibel warning horn with silent switch, dual floats, clearly marked terminal board with remote monitoring contact. The controller unit, junction box, pump, floats and sensor shall be factory assembled as a complete, ready- to-use system and shall be tested and approved as a complete system by a nationally recognized testing laboratory. The system shall allow for the main controller to be located outside of the elevator hoist way to be monitored for all functions without entering the elevator shaft. Alarm shall also remotely annunciate to the Metasys.

Elevator sump pump discharge piping shall be type-K hard copper tube with lead free solder joints.

Specify all testing shall be performed by a factory-authorized service representative
and witnessed by the Project Manager unless directed otherwise. Testing procedures shall be repeated until the Project Manager is satisfied with the results.

3-1.9 Plumbing Fixtures

3-1.9.1 General

Provide all code, user, occupancy, safety and emergency required plumbing fixtures. Plumbing fixtures shall be manufactured by companies that comply with the site-specific maintenance requirements and compliant with current codes and standards. All plumbing fixtures/accessories shall be commercial grade, vitreous china and white in color. The fixtures shall have motion/user sensing devices for fixture operation. Plastic plumbing fixtures are prohibited.

All fixtures above a raised floor shall be supported separately from floor (e.g., from slab or from wall). For locations of high density fixture use, fixtures shall be wall-mounted and provide an access door to the plumbing chase to allow access to all valves, as well as all piping accessories, that require maintenance. For locations of low density fixture use, fixtures shall be floor-mounted.

3-1.9.2 Water Closet

Water closets shall be vitreous china, low consumption, siphon jet, elongated bowl, elongated open front, stainless steel posts with check hinge toilet seat made of heavy duty solid plastic. Provide externally adjustable, sensor operated flush valve with mechanical manual overrides for all work. Flush shall be dual flush with 1.1/1.6 GPM. Sensors shall be hard-wired. Carriers shall have support legs and feet.

A wall hung water closet is the preferred design approach. To the maximum extent practical, do not anchor carriers to CMU walls or drywall partitions.

3-1.9.3 Lavatory

Lavatory shall be vitreous china, front overflow, sensor operated faucet with thermostatic mixing valve for tempered water application, 0.5 GPM aerator, vandal resistant finish, offset drain and grid strainer, chrome stops and flexible supplies. Sensors shall be hard-wired. Provide pre-manufactured molded trap and supply insulation. Provide one ABA manual faucet with gooseneck per group of lavatories.

3-1.9.4 Urinal

Urinal shall be vitreous china, low consumption, wall hung, siphon jet and externally adjustable, sensor operated flush valve with mechanical manual overrides for all work. Flush shall be 0.5 GPM. Sensors shall be hard-wired. Provide appropriate carrier as per manufacturer recommendations.
3-1.9.5 Sinks

Sinks shall be stainless-steel with garbage disposer. All mop sink (Service Sink) shall be a minimum of 24 inches by 24 inches by 10 inches floor set, molded stone, with chrome plated wall-mounted service faucet, vacuum breaker, integral stops, adjustable wall brace, pail hook and hose thread spout, stainless steel wall guards, quick drain connections, 3-inch stainless steel combination dome strainer and lint basket, quick drain connector, hose and mop bracket.

3-1.9.6 Water Coolers and Filling Stations

Integrated bottle filling stations shall be ADA compliant and include water filters with visual LED filter monitor to indicate when replacement is necessary with automatic filter reset. The Basis of Design product shall be Halsey Taylor model# HTHB-HAC8WF, Elkay model# LZS8WSSP or approved equal. The finish shall be platinum vinyl or equivalent. Refrigerated unit shall provide 8 GPH capacity cooled to 50°F at 90°F ambient air temperature. Refrigerant shall be R-134a.

3-1.10 Fuel

3-1.10.1 Natural Gas

Identify the design values of fuel gas supplied for these systems. Below ground piping to be thermoplastic polyethylene (PE) piping (ASTM D2513), with an 18 gauge copper tracer wire. Above ground piping to be Schedule 40 Black Steel (ASTM A53), with threaded connections on piping NPS 2 inches and smaller, and welded connections on piping 2.5 inches and larger.

Do not interrupt utilities serving facilities occupied unless permitted by authorities and then only after arranging to provide temporary utility services. For concealed gas piping within buildings, install piping in airtight conduit constructed of Schedule 40, seamless, black steel pipe with welded joints. Vent conduit to outside and terminate with screened vent cap. Do not locate valves above ceilings. Do not install concealed piping in solid partitions, except where passing through partitions or walls.

Construct drips and sediment traps using tee fitting with bottom outlet plugged or capped. Install fuel gas piping at uniform grade of 0.1 percent slope upward toward risers. Use eccentric reducer fittings to make reductions in pipe sizes. Install fittings with level side down. Connect branch piping from top or side of horizontal piping.

Provide pressure gauge downstream from each line pressure regulator. Install vent piping for gas pressure regulators and gas trains, extend outside building and vent to atmosphere. When connecting to appliances, provide shut-off valves within 72 inches of connection. Provide sediment trap as close to connection as possible.

Use engraved plastic-laminate equipment nameplate or sign on or near each service meter, pressure regulator and specialty valve. Paint exterior service meters, pressure
regulators and specialty valves gray and above grade piping yellow.

3-1.10.2 Fuel-Oil

Provide electrical components, devices and accessories that are listed and labeled as defined in NFPA 70, Article 100, by testing agency acceptable to authorities having jurisdiction, and marked for intended use. Comply with ASME B31.9 for fuel oil piping materials, installation, inspection and testing. All fuel oil storage, design, repair and removal shall meet the requirements of the local jurisdiction. All designs shall attempt, to the maximum extent practical, to minimize disruptions to existing facilities. Coordinate with the Project Manager/Engineering Department regarding designs which require disruptions to existing facilities to ensure temporary measures are included within the design.

3-1.10.2.1 Sulfur Content

Fuel oil used for generators shall have a maximum sulfur content of 0.05% product by weight. Fuel oil used for heating shall have a maximum sulfur content of 0.3% product by weight.

3-1.10.2.2 Piping

All above ground piping 2-inches and smaller shall be copper, type K, brazed, and 2 ½- inches and larger shall be schedule 40 Black steel, welded connections. Flanged connections shall be provided with Flexitallic CGI spiral wound gaskets, or approved equal.

Install concealed piping in airtight conduit constructed of Schedule 40, seamless, black steel pipe with welded joints. Vent conduit to outside and terminate with screened vent cap. Do not locate valves above ceilings. Do not install concealed piping in solid partitions, except where passing through partitions or walls. Prefabricated double wall pipe is preferred over pulled pipe within pipe for oil systems so as to maintain an air gap at containment pipe bottom. Hangers and Supports for pipe hanger and support devices shall follow NFPA 54 and MSS SP-69.

3-1.10.2.3 Minimum Pressure

Unless otherwise indicated, minimum pressure requirement for fuel oil piping is 150 PSIG. Below ground piping shall be double-wall fiberglass reinforced plastic (FRP), with an 18 gauge copper tracer wire (following UL 971).

3-1.10.2.4 Containment Sumps

Piping containment sumps shall be used as collection points for potential piping leaks. Sumps shall be installed at all low points of the underground piping system and any transitions between steel pipe and non-metallic pipe. The containment pipe of the double-wall pipe shall terminate at the walls of the sump, allowing fuel that leaked from the product pipe to drain into the sump. A leak sensor installed in the sump shall
be used to monitor the underground piping system. The containment sumps shall be constructed of fiberglass reinforced plastic or high density polyethylene. Provide access ladders and traffic rated lids for containment sumps.

3-1.10.2.5 Fuel-Oil Transfer Pump

Fuel-oil transfer pumps shall comply with UL 343 and HI 3.1-3.5, two-stage, internal-gear, positive-displacement, rotary type. Include steel base, foot-mounted, cast-iron housing, steel gears, bronze bearings, steel shaft, mechanical seals, and built-in pressure relief bypass. Use V-belt drives with guard or direct close coupled. Strainers shall be duplex, basket type with corrosion-resistant-metal-screen baskets. Controls shall have automatic operation with pump alternator and broken-line, oil shutoff feature.

The primary fuel oil transfer pumps shall be centrifugal, submersible, turbine type. Each primary tank shall have N+1 pump configuration. The pumps shall operate in a lead/lag sequence alternating after each run. The pumps shall be designed so that any pump shall be capable of supplying fuel to all of the day tanks with a 50% safety factor. The pumps shall be installed in an enclosure to provide protection from damage and the elements. The enclosure shall be provided by the fuel tank manufacturer and shall allow for easy access to the pump for inspection and maintenance.

The return fuel oil transfer pumps shall be centrifugal, submersible, turbine type. The return pumps shall be used along with the overflow tanks to return any excess fuel back to the primary tanks in the event of a control failure. Two return pumps shall be dedicated to one overflow tank and shall operate in a lead/lag configuration. The minimum capacity of each return pump shall be equal to that of one supply pump.

3-1.10.2.6 Miscellaneous Provisions

Use engraved plastic-laminate equipment nameplate or sign on or near each service meter, pressure regulator and specialty valve. Paint exterior service meters, pressure regulators and specialty valves gray and above grade piping brown. Call for a field quality report for inspection, testing and purging according to ANSI Z223.1, Part 4 Inspection, Testing and Purging, and for requirements of authorities having jurisdiction.

3-1.10.3 Fuel-Oil Tanks

3-1.10.3.1 Aboveground Storage Tanks

Fuel tanks shall be Aboveground Storage Tanks (AST) constructed of, at a minimum, 3/16-inch thick steel in accordance with the UL standard 142. The tank shall have, at a minimum, 1/4-inch thick Styrofoam insulation and an impervious barrier of 30 mil high density polyethylene membrane. The insulation and impervious barrier shall be protected with a reinforced concrete vault, with tanks listed by UL 2085 and 142.16 standards. The exterior of the concrete vault shall be treated with a two-part water
based epoxy paint to protect tanks from inclement weather. For larger storage volume applications, double-wall steel ASTs (Highland Fireguard, or approved equal) shall be considered.

3-1.10.3.2 Day Tanks

Provide dedicated day tanks for each generator. Day tanks shall be double wall, and shall comply with applicable codes. Day tanks shall be sized to provide 8 hours of fuel supply to the generator at full load. The contractor shall take into account pump suction elevation within the tank for tank sizing.

3-1.10.3.3 Overflow Tanks

Overflow tanks shall be provided to return any excess fuel to the primary tanks caused by a controls failure. The overflow tank shall be the same capacity as one of the day tanks.

3-1.10.3.4 Redundancy

Evaluate redundancy requirements on a project-by-project basis including but not limited to fuel tank quantity, interconnecting piping between tanks, redundant piping paths and remote fill operation.

A redundant fill connection shall be provided for each fuel system to provide N+1 fuel fill reliability. The redundant connection shall be located at each set of fuel system storage tanks, and shall allow for direct unloading of tanker trucks to the storage tanks. Each redundant fill connection shall be protected from weather and contain a method for securing the fill port.

3-1.10.3.4 Accessories

The tank accessories shall include overfill protection, venting, support legs, thermal corrosion protection, vehicle and bullet impact protection and shall comply with UFC section 79-7 (Appendix # A-11-F-1) and galvanized steel access steps where required. Use an ultrasonic sensor for monitoring oil level. Central or local monitoring/alarm shall be as directed by the Project Manager/Engineer. The fuel storage tanks shall be provided with access stairs and platforms arranged so that access is provided to all equipment located in the tank that requires regular maintenance.

3-1.10.3.5 Secondary Containment

Secondary containment area required around tank(s) shall contain a minimum of 100% of total tank volume. In some local jurisdictions, requirements may be required to provide greater than 100% of total tank volume. Coordinate with the local jurisdiction to ensure requirements are in compliance. Provide rainwater z-type drain and mount tank(s) on concrete pad of sufficient elevation (relating to possible height of retained water) to avoid standing water against the tank. All registration or notification of regulatory requirements for any installation, repair or removal of
underground storage tanks, shall be conducted by the Contractor.

3-1.10.4 Fuel Piping Distribution

Fuel piping distribution shall be designed to incorporate a header system with the installation of two or more tanks. The tanks shall have isolation capabilities so that any tanks in the grouping can be filled or pumped into each other in the event that a tank needs to be serviced or taken out of service. In the event where the tanks are a distance from a road, a remote fill station with redundant pumps shall be provided with automatic fill shutoff valves located at the tanks. If there exists a site fuel unloading pumping system and the new tanks are within a reasonable distance, the new tanks shall be piped using existing pumps at the filling station.

3-1.10.5 Urea System

Urea tubing, piping, valves and fittings shall be stainless steel. Piping shall conform to ASTM A 312/A 312M, Type TP304L, seamless only. Piping smaller than 8 inches shall be Schedule 40S. Urea piping shall be welded. Fittings 2-inches and smaller shall be socket welded type and conform to ASME B16.11. Fitting materials shall be stainless steel that conforms to ASTM A 182/A 182M, Type F304L. Connections at valves shall be flanged. Connections at equipment shall be flanged except that connections to the diesel engine may be threaded if the diesel-engine manufacturer’s standard connection is threaded. Connections to equipment shall be made with stainless steel vibration isolation type flexible connectors. Urea pumps shall be stainless steel construction including housing, gears and shaft. Underground piping shall be flexible corrugated stainless-steel Piping Type 316L, with polyurethane jacket.

Circulation of urea shall be required for the whole urea system (tank and distribution piping). Provide heating and insulation of urea system components to keep urea above its salt-out temperature. Urea storage tanks shall be UL 142 single-wall, stainless-steel tanks fabricated and tested in accordance with NFPA and UL labeled. Provide controls and accessories typical of fuel oil tanks. Provide independent fuel control system consisting of tank gauging and monitoring, pump control panels, day tank level control panels, separate pump starters, leak detection and fuel polishing. The fuel control system shall interface with the EMCS and SCADA systems.

3-1.10.6 Valves and Accessories

3-1.10.6.1 General Requirements

Use dielectric fittings for connection to dissimilar metals.

Unions shall be class 150, malleable iron, in accordance with ASME B16.39, with brass-to-iron seat, ground joint, and threaded ends in accordance with ASME B1.20.1.

Steel Welded Fittings shall be wrought steel, in accordance with ASME B16.9 or forged steel, in accordance with ASME B16.11.
3-1.10.6.2 Gas

Provide valves and accessories for gas applications that adhere to the following:

a. Malleable-Iron Threaded Fittings shall be class 150, standard pattern, in accordance with ASME B16.3, with threaded ends in accordance with ASME B1.20.1.

b. Steel Threaded Fittings shall be forged steel, in accordance with ASME B16.11, with threaded ends in accordance with ASME B1.20.1.

c. Steel Flanges and Flanged Fittings shall be in accordance with ASME B16.5.

d. Quick-Disconnect Devices shall be in accordance with ANSI Z21.41, convenience outlets and matching plug connector.

e. Valves NPS 2-inches and smaller shall have threaded ends according to ASME B1.20.1 for pipe threads.

f. Valves NPS 2½-inches and larger shall have flanged ends according to ASME B16.5 for steel flanges.

g. Appliance Connector Valves shall be in accordance with ANSI Z21.15 and be IAS listed.

h. Gas stops described below are NPS 2-inches and smaller and are limited to 2-PSIG, bronze body with AGA stamp, plug type with bronze plug and flat or square head, ball type with chrome-plated brass ball and lever handle, or butterfly valve with stainless-steel disc and fluorocarbon elastomer seal and lever handle, 2-PSIG minimum pressure rating.

i. Gas Valves, NPS 2-inches and smaller shall be in accordance with ASME B16.33 and IAS-listed bronze body and 125-PSIG pressure rating.

j. Plug Valves, NPS 2½-inches and larger shall be in accordance with ASME B16.38 and MSS SP-78 cast-iron, lubricated plug valves, with 125-PSIG pressure rating.

k. General-Duty Valves, NPS 2½-inches and larger shall be in accordance with ASME B16.38, cast-iron body, suitable for fuel gas service, with WOG indicated on valve body, and 125-PSIG pressure rating.

l. Gate Valves shall be MSS SP-70, OS&Y type with solid wedge.

m. Butterfly Valves shall be MSS SP-67, lug type with lever handle.

n. Line Pressure Regulators shall be in accordance with ANSI Z21.80.

3-1.10.6.3 Fuel-Oil
For valves 4-inches and larger, provide gear operators. Provide valves and accessories for fuel oil applications that adhere to the following:

a. Hard Copper Tube shall be water tube, drawn temper, Type K in compliance with ASTM B88.
b. Copper Fittings shall be ASME B16.22, wrought copper, streamlined pattern.
c. Brazing Filler Metals shall be Silver Classification BAg-1 in compliance with AWS A5.8. Filler metal containing phosphorus is prohibited.
d. Bronze Flanges and Flanged Fittings shall be Class 150 in compliance with ASME B16.24.
e. Oil Shutoff Valves shall be metal-body ball valve in compliance with UL 842.
f. Pressure-Reducing Valves shall be UL listed for fuel oil service and include bronze body with 150-PSIG minimum pressure rating.
g. Oil Safety Valves shall be UL listed for fuel oil service and include metal body, broken-line, oil shutoff feature, and 40-PSIG minimum pressure rating.

3-1.11 Water Treatment

The A/E shall prepare and submit design drawings and product data for the proposed Water Treatment System for Owner’s review. The A/E shall coordinate their design with the University’s water treatment contractor.

3-2 CLEANING, FLUSHING, TREATING AND TESTING PIPING SYSTEMS

3-2.1 General Requirements

In all cases, the JHU water treatment contractor shall be consulted during design and specified during construction to recommend the proper course of action and proper chemistry requirements based upon the system metallurgy on hand. The industry standard definition of clean is a surface free of mill scale, slag, grease, oil, dirt, and corrosion products. All new piping systems shall be specified to be chemically pre-treated using an agent in compliance with the JHU water treatment contractor’s standards.

Any new/old system shall be specified to be flushed with clean fresh makeup water until the water coming out of the system is identical in content to the water going into the system. This ensures that any chemical agents used are completely rinsed out of the system and any corrosion products, oils, greases, etc. are removed from the system.
The JHU water treatment contractor shall test the water to ensure that the contaminant levels coming out of the system in the effluent are identical to that of the makeup water source, in accordance with AWWA-C651.

Treat means to chemically pre-treat and passivate the system to ensure that the mill scale, slag, grease, oil, dirt and corrosion products are emulsified and flushed from the system. Treat also means chemically treating to ensure that the system is properly protected against microbiological fouling, mineral scaling and corrosion.

All new piping shall be specified to be cleaned, flushed, treated and hydrostatically tested to ensure clean, flushed, treated and leak-free construction prior to University acceptance.

For University buildings the AHJ shall be the Project Manager. For leased facilities, the AHJ shall be the local plumbing inspector and the requirements shall be adjusted as required to comply with the local jurisdiction.

3-2.2 Domestic Water System Piping

Provide the Contractor with specifications for cleaning, flushing, treating and testing domestic water system piping. The following shall be incorporated into the specifications at a minimum (22 00 00 – PLUMBING, GENERAL PURPOSE):

- Cleaning, flushing and testing procedures shall be witnessed by University personnel. Procedures shall be repeated until the Project Manager is satisfied with the results.
- Purge new piping and parts of the existing water piping that have been altered, extended or repaired
- Prepare and submit reports for testing, purging, and disinfecting activities.
- Clean interior of piping system. Remove dirt and debris as work progresses.
- Flush piping system with clean, potable water until dirty water does not appear at outlets. Flushing water shall be piped to sanitary sewer system. Discharge to storm water system is not authorized.
- Test for leaks and defects in new piping and parts of the existing piping that have been altered, extended or repaired. If testing is performed in segments, submit separate report for each test, complete with a diagram of the portion of piping tested.
- Leave uncovered and unconcealed new, altered, extended or replaced water piping until it has been tested and approved. Expose work that has been covered or concealed before it has been tested and approved.
- Cap and subject piping to static water pressure of 50 PSIG above
operating pressure, without exceeding pressure rating of piping system materials. Testing shall be 4-hour duration.

- Repair leaks and defects with new materials and retest piping or portion thereof until satisfactory results are obtained.
- Prepare reports for tests and required corrective action.
- Use purging and disinfecting procedure prescribed by authorities having jurisdiction or, if the method is not prescribed, follow the procedure described in either AWWA C651 or AWWA C652 or as described below:
  - Fill and isolate system according to either of the following:
    - Fill system or part thereof with water/chlorine solution with at least 50 PPM of chlorine. Isolate with valves and allow to stand for 24 hours
    - Fill system or part thereof with water/chlorine solution with at least 200 PPM of chlorine. Isolate and allow to stand for 3 hours.
    - Procedures to be in accordance with IPC 610.1.

After treatment, flush system with clean, potable water until chlorine is no longer in water coming from system after standing time.

- Submit water samples in sterile bottles to the Project Manager. Repeat procedure if biological examination shows contamination.
- Prepare reports for tests by certified lab and certify that water is fit for consumption.

3-2.3 Sanitary Drainage and Vent System Piping

Provide the Contractor with specifications for cleaning, flushing, treating and testing sanitary (soil and waste) drainage and vent system piping. The following shall be incorporated into the specifications at a minimum:

- Test drainage and vent piping according to procedures of authorities having jurisdiction.
- Clean interior of piping system. Remove dirt and debris as work progresses.
- Protect drains during remainder of construction period to avoid clogging with dirt and debris and to prevent damage from traffic and construction work.
- Place plugs in ends of uncompleted piping at end of day and when work stops.
• Protect plumbing vents exposed to sunlight with 2 coats of water-based latex paint.
• Test for leaks and defects in new piping and parts of existing piping that have been altered, extended or repaired, if testing is performed in segments, submit separate report for each test, complete with diagram of portion of piping tested.
• Leave uncovered and unconcealed new, altered, extended or replaced drainage and vent piping until it has been tested and approved. Expose work that has been covered or concealed before it has been tested and approved.
• Test drainage and vent piping, except outside leaders, on completion of roughing-in
• After plumbing fixtures have been set and traps filled with water, test connections and prove they are gastight and watertight. Coordinate smoke or peppermint test with the Project Manager.
• Repair leaks and defects using new materials and retest piping or portion thereof until satisfactory results are obtained.
• Prepare reports for tests and required corrective action.
• Test force-main piping by leaving uncovered and unconcealed new, altered, extended, or replaced force-main piping until it has been tested and approved. Cap and subject piping to static-water pressure of 50 PSIG above operating pressure, without exceeding pressure rating of piping system materials. Isolate test source and allow to stand for 4 hours. Leaks and loss in test pressure constitute defects that shall be repaired. Repair leaks and defects using new materials and retest piping or portion thereof until satisfactory results are obtained. Prepare reports for tests and required corrective action.

3-2.4 Fuel Piping

Provide the Contractor with specifications for cleaning, flushing, treating and testing fuel piping. The following shall be incorporated into the specifications at a minimum:

• Assembled systems shall be blown clean, shall have equipment served isolated from cleaning process, and have oil filters installed after cleaning. Pressure test assembled system at 1.5 times the expected operating pressure. Inspect and test fuel oil piping according to NFPA 30, Testing Paragraph and NFPA 31, Tests of Piping Paragraph, and according to requirements of authorities having jurisdiction.
• Repair leaks and defects with new materials and retest system until satisfactory results are obtained. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment. Report test results promptly and in writing to the Project Manager.
The intent of the flushing operation is to remove bulk solids and water from the system. All new fuel piping, including the transfer line, receipt system piping, supply and return lines to the storage tanks and day tanks, shall be flushed with fuel. Upon completion of system flushing the Contractor shall remove all temporary strainers and filters and replace with new screens and filter cartridges. All water separators/coalescers shall be drained, inspected, and replaced with new.

Temporary 40 mesh cone type strainers shall be installed upstream of all control valves and on the suction side of all polishing system pumps. Any damaged strainers shall be replaced by the Contractor at no additional cost to the University. Remove any accumulated water from storage tanks' sumps and bottoms. Drain water and return fuel via filtration to storage tank. Repeat process until all water is removed.

Begin flushing of fuel system pipelines at low flow rates using the fuel polishing system pumps. Slowly increase flushing flow rate to full flow capacity for a minimum of 30 minutes. For gravity, suction, or other non-pumped piping segments, minimum flushing volume shall be four times the pipe volume. Flushing shall continue until the fuel being delivered is free of construction debris to the satisfaction of the Project Manager. Samples of fuel shall be taken and tested by the designated University agency and shall be free of gross contamination and visible freewater.

3-2.5 Compressed Air Piping

Provide the Contractor with specifications for cleaning, flushing, treating and testing compressed air piping. The following shall be incorporated into the specifications at a minimum:

- With final equipment connections temporarily disconnected, run compressed air system to flush the system and replace all filters after cleaning.

- Testing shall be in accordance with ASME B31.9 Building Service Piping, Chapter 6, Inspections, Examinations & Testing.

3-3 IDENTIFICATION LABELS

Provide vinyl, adhesive type identification labels indicating flow direction and pipe size every 20-linear-feet for all piping both above ceiling and below raised access floor. All lettering sizes shall be per ANSI A13.1. Label all equipment above the suspended ceiling on the bottom side of the ceiling grid. Refer to Table 2-5 in this FC for additional equipment labeling requirements. Exterior piping shall use laminated labels and shall be fastened onto the piping with restraint ties. Coordinate with the Project Manager to obtain valve numbers to be incorporated into the design drawings.
Piping minimum insulation requirements shall comply with ASHRAE 90.1 and as specified herein. Include within the specifications, the project specific Insulation Application Schedule. Capping and/or patching ductwork includes providing insulation as required.

3-4.1 General

Piping systems shall be insulated with rigid molded, non-combustible glass fiber with a thermal conductivity (K) value of 0.23 or less at 75°F. A white, kraft paper-reinforced, vapor retardant jacket shall be provided with glass fiber yarn and bonded to aluminum foil, secure with self-sealing longitudinal laps and butt strips for piping subjected to potential condensate conditions. Elastomeric piping insulation shall have UV protection/coating where exposed to the outdoors.

Insulation thicknesses based on pipe sizing for various piping systems shall comply with Table 3-1 below. Domestic cold water piping systems referenced below include above-ground trap primer piping to and from the distribution unit.

Table 3-1 Piping System Insulation Thicknesses

<table>
<thead>
<tr>
<th>Piping System</th>
<th>Pipe Size (inches)</th>
<th>Insulation Thickness (inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic Cold Water</td>
<td>All Sizes</td>
<td>1</td>
</tr>
<tr>
<td>Domestic Hot Water</td>
<td>≤ 2</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>2 ½ to 4</td>
<td>1-½</td>
</tr>
<tr>
<td></td>
<td>≥ 6</td>
<td>2</td>
</tr>
<tr>
<td>Domestic Recirculated Water</td>
<td>≤ 2</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>2 ½ to 4</td>
<td>1-½</td>
</tr>
<tr>
<td></td>
<td>≥ 6</td>
<td>2</td>
</tr>
<tr>
<td>Rainwater Conductors</td>
<td>All Sizes</td>
<td>1</td>
</tr>
<tr>
<td>Roof Drain Bodies</td>
<td>All Sizes</td>
<td>1</td>
</tr>
<tr>
<td>Condensate Drain</td>
<td>All Sizes</td>
<td>1</td>
</tr>
</tbody>
</table>

3-4.2 Field-Applied Pipe Jacketing

Provide full color-coded PVC jacket for all exposed piping within the mechanical rooms. Jacket shall be cut and curled for the appropriate pipe size (snap-on). PVC jackets for piping, fittings, valves and specialty devices shall be 20 mils thick and shall meet 25/50 fire/smoke spread ratings. The color-coding shall be as follows:

- Domestic Hot and Cold Water – White.

For piping installed outdoors provide exterior jacketing of 0.016 inches thick, smooth finish aluminum jacket factory cut and rolled for the appropriate pipe size. For elbows, fittings, valves and specialties factory prefabricated fittings shall be
used. No field fabricated fittings will be accepted. For joining sections of jacketing, 3/4-inch wide type 304 stainless steel bands shall be used.

3-4.3 Piping at Hangers/Supports

Specify that the Contractor shall perform any and all re-adjustments of pipe hangers/supports following installation of the field-applied pipe jacketing after the pipe insulator has completed their work. Support locations for insulated pipe shall be protected with the appropriate saddle shield. Provide full circumference shields with clamps and U-bolts. The insulation insert of sufficient density shall be cellular glass and extend two inches beyond the end of the sheet metal saddle. The insert shall be a full section that totally encloses the pipe.

3-5 HANGERS, SUPPORTS AND VIBRATION ISOLATION

3-5.1 Hangers and Supports

Design all plumbing supports and hangers in compliance with the IMC and IPC. Pipe hangers and supports systems for above grade applications, shall comply with Manufacturers Standardization Society for Valve and Fittings Industry (MSS). For existing installations, to the maximum extent practical, provide compatible designs that match existing conditions. Coordinate details with the University to avoid undesirable anchor locations to the extent practical.

Provide a minimum of A36 all-thread rods for hangers and supports with a minimum 0.5-inch diameter. Miscellaneous steel, such as plates, bars, angles, etc., shall be a minimum of A36. Provide floor stands for underfloor piping and infrastructure.

Supporting from the RAF system is prohibited.
APPENDIX A REFERENCES

Note: Most current version code/standard shall be used.

INTERNATIONAL CODE COUNCIL

International Building Code
IEBC, International Existing Building Code
IECC, International Energy Conservation Code
IMC, International Mechanical Code
IPC, International Plumbing Code
IRC, International Residential Code

AIR-CONDITIONING, HEATING AND REFRIGERATION INSTITUTE (AHRI)

AHRI 400 – “Liquid to Liquid Heat Exchangers”

AMERICAN NATIONAL STANDARDS INSTITUTE

ANSI/SPRI RP-14, Wind Design Standard for Vegetative Roofing Systems
ANSI A13.1 – “Standard for the Identification of Pipes”
ANSI/Hydraulic Institute (HI) 1.1-1.5 – “Centrifugal Pumps – Nomenclature, Definitions, Application and Operation”
ANSI/HI 9.6.4-2000 – “Centrifugal and Vertical Pumps for Vibration Measurements and Allowable Values”
ANSI/NAAMM MBG531, Metal Bar Grating Manual
ANSI/NAAMM MBG532, Heavy Duty Metal Bar Grating Manual
ANSI/NAAMM MBG533, Welding Standards for Fabrication of Steel, Stainless Steel and Aluminum Bar Grating
ANSI/NAAMM MBG534, Metal Bar Grating Engineering Design Manual
ANSI Z21.15 – “Manually operated gas valves for appliances, appliance connector valves and hose end valves”
ANSI Z21.2 – “Particular Requirements for Automatic Electrical Burner Control Systems”


ANSI Z21.80 – “Line Pressure Regulators”

ANSI Z223.1 – “Inspection, Testing and Purging”

AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING ENGINEERS

ASHRAE Underfloor Air Distribution (UFAD) Guidelines

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

ASME A112.21.3M – “Hydrants for Utility and Maintenance Use”

ASME B1.20.1 – “Pipe Threads, General Purpose, Inch”

ASME B1.20.7 – “Hose Coupling Screw Threads (Inch)”

ASME B16.11 – “Forged Fittings, Socket-Welding and Threaded”

ASME B16.22 – “Wrought Copper and Copper Alloy Solder Joint Pressure Fittings”

ASME B16.24 – “Cast Copper Alloy Pipe Flanges and Flanged Fittings: Classes 150, 300, 600, 900, 1500 and 2500”

ASME B16.3 – “Cast Iron Pipe Flanges and Flanged Fittings”

ASME B16.33 – “Manually Operated Metallic Gas Valves for Use in Gas Piping Systems up to 175 psi (Sizes NPS 1/2 through NPS 2)”

ASME B16.38 – “Large Metallic Valves for Gas Distribution: Manual Operated, NPS 2 1/2 to NPS 12, 125 psig Maximum”

ASME B16.39 – “Malleable Iron Threaded Pipe Unions: Classes 150, 250, and 300”

ASME B16.5 – “Pipe Flanges and Flanged Fittings: NPS 1/2 through NPS 24 Metric/Inch Standard”

ASME B31.1 Power Piping ASME

B31.3 Process Piping ASME B31.5
Refrigeration Piping

ASME B31.9 – “Building Services Piping”

ASME Section VIII, Division I – “Pressure Vessels”

ASME CSD-1: Control and Safety Devices for Automatically Fired Boilers

AMERICAN WATER WORKS ASSOCIATION

AWWA C651 – “Disinfecting Water Mains”

ASTM INTERNATIONAL

ASTM A53 – “Standard Specification for Pipe, Steel, Black and Hot-Dipped, , Zinc-Coated, Welded and Seamless”

ASTM A182/A182M – “Standard Specification for Forged or Rolled Alloy and Stainless Steel Pipe Flanges, Forged Fittings and Valves and Parts for High Temperature Service”


ASTM A934/A934M, Standard Specification for Epoxy-Coated Prefabricated Steel Reinforcing Bars

ASTM B88 – “Standard Specification for Seamless Copper Water Tube”


ASTM E1745, Standard Specification for Plastic Vapor Retarders Used in Contact with Soil or Granular Fill under Concrete Slabs

ASTM E2396, Standard Test Method for Saturated Water Permeability of Granular Drainage Media for Vegetative (Green) Roofing Systems

ASTM E2397, Standard Practice for Determination of Dead Loads and Live Loads Associated with Vegetative (Green) Roof Systems

ASTM E2398, Standard Test Method for Water Capture and Media Retention of Geocomposite Drain Layers for Vegetative (Green) Roof Systems

ASTM E2399, Standard Test Method for Maximum Media Density for Dead Load Analysis of Vegetative (Green) Roof Systems

ASTM E477 – “Standard Test Method for Laboratory Measurements of Acoustical and
Airflow Performance of Duct Liner Materials and Prefabricated Silencers

FEDERAL REGULATIONS

40 CFR 82 – “Protection of Stratospheric Ozone”

MANUFACTURERS STANDARDIZATION SOCIETY

MSS SP-67 – “Butterfly Valves”
MSS SP-69 – “Pipe Hangers and Supports – Selection and Application”
MSS SP-70 – “Cast Iron Gate Valves, Flanged and threaded Ends” MSS
SP-78 – “Cast Iron Plug Valves”

NATIONAL ASSOCIATION OF CORROSION ENGINEERS (NACE)

NACE RP0169 – “Control of External Corrosion on Underground or Submerged Metallic Piping Systems”

NATIONAL FIRE PROTECTION ASSOCIATION

NFPA 30 – “Flammable and Combustible Liquids Code”
NFPA 31 – “Standard for the Installation of Oil-Burning Equipment”

NSF INTERNATIONAL

NFPA 61 – “Drinking Water System Components – Health Effects”

PLUMBING AND DRAINAGE INSTITUTE


UNDERWRITERS LABORATORIES

UL Standard 73 – “Standard for Motor Operated Appliances”
UL Standard 142 – “Standard for Steel Aboveground Tanks for Flammable and Combustible Liquids”
UL Standard 343 – “Standard for Pumps for Oil-Burning Appliances”
UL Standard 508 – “Industrial Control Equipment”
UL Standard 842 – “Standard for Valves for Flammable Fluids”
UL Standard 2085 – “Standard for Protected Aboveground Storage Tanks for Flammable and Combustible Liquids”
## APPENDIX B GLOSSARY

### ACRONYMS

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>A/E</td>
<td>Architect / Engineer</td>
</tr>
<tr>
<td>DoR</td>
<td>Designer of Record</td>
</tr>
<tr>
<td>FC</td>
<td>Facilities Criteria</td>
</tr>
<tr>
<td>IAQ</td>
<td>Indoor Air Quality</td>
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<tr>
<td>RAF</td>
<td>Raised Access Floor</td>
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APPENDIX C – Change/Variance Form

LETTER HEAD OF REQUESTOR

Date: ______________________________

REQUEST FOR DEVIATION FROM THE JHU
ARCHITECTURAL AND ENGINEERING DESIGN STANDARDS

Project Name: ________________________________
JHU Project No.: ______________________________

In accordance with the Architectural and Engineering Design Standards, October 2019, the undersigned requests approval for modification of:

Section, Discipline, Part, Paragraph, Subparagraph:
_______________________________________________________________________________________________
_______________________________________________________________________________________________

Description of Proposed Changes:
(First, repeat the Standard as stated in the Design Standards, then describe the modification recommended.)

Justification for Proposed Changes:
(State the reason(s) for the modification, including value engineering analysis, particular needs of the user, improved technology, etc.)

The requested deviation from the Design Standards is consistent with good engineering and construction practices, and is consistent with the intent of the Design Standards. It is understood that an approval of this modification does not affect the standard as stated.

Requestor: __________________________________________
(Signature)

Typed or Printed Name: ________________________________

JHU Approvals:
Project Manager: ________________________________
(Sign and date)

JHU Review Architect/Engineer: ________________________________
(Sign and date)

Director of Design and Construction: ________________________________
(Sign and date)

Space Reserved for JHU Comments: