

K. Mechanical Systems

1. Introduction

The following Mechanical System Standards provide requirements and guidelines for use by the Consultant in the design and construction of mechanical systems at the University of Chicago.

The Consultant shall work under the guidance of the University mechanical engineer, coordinating all technical requirements, including acceptable materials and manufacturer -model for equipment and system components, with the University mechanical engineer and project team to produce a cohesive design that meets the project scope, budget and schedule. Design shall generally meet the requirements of national, state and Chicago Code and recommendations of all industry standards. All known exceptions shall be brought to the attention immediately and steps taken to resolve outstanding issues to ensure an orderly flow of design. A continuous dialogue shall be maintained so that any issues related to design and drawings can be reviewed and agreed upon. Design review will serve as confirmation of design and not issues to be addressed for the first time. The final design shall meet the approval of the University Mechanical Engineer.

The mechanical system design shall meet the following requirements:

- A. Meet the intended building and programmatic functions.
- B. Easily modified for changes without significant alterations.
- C. Durable to meet its intended life (Reference Vol IV for Life Cycle Costs Analysis)
- D. Able to operate automatically with minimal attention from facilities staff.
- E. Require minimal maintenance.
- F. Energy efficient and able to recover to normal operating conditions quickly from weekend set back.

2. Design reviews

The purpose of the design review is for the Consultant, in working with the Owner's team, to establish the Owner's Project Requirement and complete the Basis of Design document along with necessary documents, drawings, and communications to agree on the final design. Once that has been agreed upon, the Consultant will, via design review submittals and meetings, demonstrate to the Owner that the team is on track to complete the design requirements. At the same time, the progress review documents will also demonstrate that the design phase contains the necessary scope, content, and details as required by the University to be issued for competitive bidding while staying within budget and schedule. The progress review and final documents shall also include necessary information for the operation of the building. Prior to issuing design documents for University review, the architect or prime design consultant shall coordinate all building disciplinary items including architectural, structural, MEP/FP etc., and exterior and site items so that they are ready for review.

A. Required Design Reviews:

The following requirements are for mechanical site utilities (steam, chilled water, compressed air, City water, storm sewer, sanitary sewer, gas), mechanical HVAC,

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plumbing, fire protection, and building automation systems. These items and the level of detail have been identified based on previous experience as representing elements that will lead to a successful project. The University realizes that each project's delivery process will be unique and specific requirements will need to be discussed at the onset and throughout the duration of the project. Prior to issuing the submittals for each phase for owner review, all documents shall be fully coordinated among various disciplines, reviewed and signed off by the lead design firm.

Tasks	1st Review submittal	2nd Review submittal	3rd Review submittal
1 Calculations including heating/cooling loads, Life Cycle Analysis etc.	80%	90%	99%
2 Schematic, flow, riser and network configuration diagrams with flow and line size.	90%	95%	99%
3 Single line floor and roof plans: showing equipment and distribution with flow and capacities.	100%		
4 Double line floor and roof plans: showing equipment, components, controller and distribution with flow, capacities and size.		80%	99%
5 Motor list: showing horsepower for all mechanical and plumbing items.	90%	99%	99%
6 Equipment schedules: for all equipment with headings and known data.	50% (Schedules with heading of all anticipated equipment.)	80%	99%
7 All drawings properly edited: drawing index, symbols and abbreviations, drawing number system, drawing nomenclature, line weight and scale.	50% (Drawing index, symbols, abbreviations included)	90%	99%
8 Typical details, sections and elevations: all items applicable to the project; AHU general arrangement; piping connection to equipment; PRV station; trap piping; metering; equipment room views; piping arrangement at AHUs, reheat coils, fans coils, radiators, hot water heaters, heat exchangers etc; condensate piping gravity drain to flash tank and receiver.	50%	90%	99%
9 Equipment room general arrangement with dimensions: showing all equipment, duct and piping arrangement, demonstrating suitable room size and serviceability.	50%	80%	99%
10 Architectural plans and elevations: showing location and size of air intakes and exhausts; locations of mechanical and plumbing equipment, reliefs and vents; demonstrate means and path for access to all MEP items.	50%	80%	99%
11 Design details of where common thermal bridges can exist.		80%	99%
12 Civil plans showing site utilities: showing tie in point, location entering the building terminating inside the basement; path of travel, depth of bury, spacing relative to other utilities and landscape items.	50%	80%	99%

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13	Campus Utilities Change Authorization form.	90%	95%	99%
14	Campus Excavation Authorization form.	90%	95%	99%
15	Basis of design documentation.	100%		
16	Specifications: table of contents applicable to all items; applicable sections.	70%	80%	99%
17	Spreadsheet of major equipment and components: showing proposed manufacturers; long lead items.	80%	95%	99%

3. General Design Requirements

- A. Mechanical room drawings shall have service area clearly indicated on drawings with note to maintain service area clearance space. Provide stair access to roof mounted equipment.
- B. All equipment shall be installed within building envelope, in equipment rooms.
- C. Mechanical rooms shall have walkways with 6'-0" clear space for service.
- D. Mechanical rooms shall have stair access at minimum.
- E. Means for equipment removal shall be included in building design, provide mechanical hoist as required.
- F. Location of major equipment on roof is considered unacceptable.
- G. Design systems for future flexibility. Systems shall be easily adaptable to space layout changes.
- H. Access to mechanical rooms shall be arranged such that entry does not disturb the occupants or normal functions of the building. Where applicable, service elevators shall be sized for equipment removal from machine rooms.
- I. Mechanical shafts shall be designed to allow service on each floor and shall have provisions for future duct routing.
- J. Prior to start of design, a complete design phase schedule shall be published to incorporate review period and comment resolution period. Each phase shall be complete prior to moving on to the next phase. A set of deliverables including concept presentation, calculations, contents of drawings, and specifications shall be defined and presented to Facilities Services Operation prior to start of design.
- K. The mechanical design shall be approved by the University Mechanical Engineer prior to issue for construction.
- L. Any exceptions to the above items must have prior written approval from Facilities Services Project Manager.

4. Plan and Specification Requirements

- A. Consultants shall coordinate all construction documents with other trades. Ceiling heights, structural interferences, and electrical requirements shall all be reviewed. Coordination of all disciplines shall be done during project design phase and take place within each phase of the project design schedule.
- B. All work shall be specified, specifications shall be formatted in the current CSI's Master Specification format.
- C. Operations and Maintenance Manuals shall be submitted during construction. Manuals shall be formatted in current CSI's Master Specification format. Reviewed O&M Manuals shall be submitted in full prior to FS Operation participation in start-up activities near the end of construction and to be coordinated with Information Resources standards.
- D. Record drawings shall be submitted as CAD files and .pdf file format.

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- E. Completion of project shall include Operation and Maintenance Manuals. Consultant shall detail outline for Contractor's submission and review with University.
- F. Plans and specifications shall include warranty and owner training. Warranty shall include materials and labor during first two years operation from substantial completion date or completion of all punch list items, whichever is later.

5. System Design Requirements

- A. Refer to the Building Performance Guidelines Matrix (Volume 4)
- B. A Basis of Design (BOD) narrative shall be submitted at the beginning of each phase of design. The document shall identify all design assumptions and the design intent for the mechanical systems. Life Cycle Cost Analysis and estimated utility usage shall be included. The BOD will be updated throughout the design phases of the project to reflect any revisions or re-evaluations of the project.
- C. Mechanical systems shall be central air handling units with VAV box for areas with high occupancy and load fluctuation and Dedicated Outdoor Air Systems with radiant, chilled beam etc. for ordinary occupancy with relatively steady load. Finned tube convection hydronic system shall be provided for perimeter heat. Other system types will be considered, with prior approval. Considerations will be based on effectiveness, serviceability, life cycle cost, and energy efficiency.
- D. Building heating and cooling load shall be determined by Block load calculations and Peak Space load calculation.
- E. Outdoor and indoor design shall meet the University of Chicago's Building Performance Guideline conditions. System sizing must consider tolerance of system components as a whole. Heating systems shall be designed with redundancy.
- F. Equipment and spaces shall be selected and designed to meet sound limits for occupancy type as established in Chapter 47 of ASHRAE 2007 Handbook – HVAC Applications or latest equivalent. Design shall meet the mid range of the sound limits defined in ASHRAE.
- G. Provide sound calculations for University Engineer's review.
- H. Design shall meet the City of Chicago sound requirement at City Lot Line and shall be quieter than existing day night time sound level on the ground level.
- I. Buildings may be designed for 100 years. Therefore building system components will need to be replaced during the building life. Equipment must be capable of replacement without significant down time.
- J. Ventilation and Air Change rates shall meet ASHRAE 62.1. Designer shall review ventilation effectiveness even during minimum air flow in variable air volume systems.
- K. Supply airflow diffusers and exhaust grilles shall be located to assure that air movement goes from clean areas to less clean areas, i.e. from corridor to mop closet to prevent odors/contaminants from permeating the building.
- L. Labs shall be negatively pressurized, unless directed otherwise by owner. Classrooms and office space shall be positively pressured.
- M. Supply, return, and exhaust grilles shall be located so air will flow towards the most contaminated area of the space. Short circuiting of airflow shall be minimized between supply and return/exhaust.
- N. Consultant shall complete piping pressure drop and ductwork static pressure calculations.
- O. Provide structural support for piping details for University Engineer to review.
- P. Equipment cut sheets shall be included with DD phase review.
- Q. Perimeter heating shall be incorporated in spaces with large windows.

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- R. Electric heating is generally not allowed.
- S. In new building or addition design, a wind analysis shall be performed to determine the best location of ventilation intake and exhaust air locations.
- T. The campus operates 24 hrs/7days a week. Construction shall have appropriate isolation for all systems.
- U. A Computational Fluid Dynamics (CFD) model is recommended to be performed where airflow patterns are critical. Discussion with Owner shall determine where required. CFD modeling can also be used establish thermal comfort and ventilation effectiveness for non-traditional mechanical systems. Non-traditional system proposal shall be discussed with Owner prior to design.
- V. Equipment cooling with domestic water is prohibited.
- W. Avoid small fan coil units, fan powered boxes and unit heaters where possible to minimize service points. Where used, equipment shall be controlled by the BAS.
- X. Design hydronic systems with two-way valves.

6. Campus Utility Systems Summary

The University generates steam and chilled water from central utility plants and distributes via tunnels and buried piping to various buildings on campus.

A. Steam:

- i. Steam is distributed at 175 psig and 80 psig to University buildings and at 125 psig to the Medical Center. Upon entering each building, pressure is generally stepped down via 175/80 and 80/15 pressure reducing stations. Generally, piping and components used for distribution are rated for 300# class. Valves shall be 300# rating steel body gate valves or triple offset butterfly valves. Flanged bolts shall be ASTM A193 B7 bolts, H2 nuts or SAE grade 8 bolts. This include all piping and components leaving the central utility plant, travelling via the campus distribution piping and entering the building up to and including the first pressure reducing station. Piping and components shall be steel with welded connections or flanged connected to larger sized components. This includes the first isolation valve upon entering the building to the isolation valve downstream of the pressure reducing station and the entire condensate trap assembly. This also includes piping and components from the discharge of the building condensate receiver pump to pipe leaving the building. Provide threaded pipe unions for connection to both sides of steam trap. Include the following requirements:
 - a. Pipe anchor design for the pressure reducing station.
 - b. Piping flexibility analysis for new piping to the pipe anchor at the pressure reducing station.
 - c. Flanged bolt torqueing.
 - d. Safety relief calculation for valve and pipe sizing and support.

Piping downstream of the first pressure reducing station and upstream of the building main condensate return receiver and pump shall be 150# class.

The 300# class campus distribution piping shall be hydro tested to 400 psig. The 300# class piping located inside the building shall be hydro tested to 300 psig. Piping that are 150# class shall be hydro tested to 1.5 times the operating pressure but not less than

150 psig. Test pressure shall be at a steady reading for not less than 4 hours. After that is achieved, pressure shall be reduced to the pressure class and be left overnight and check for maintaining the same reading. During the test, all joints shall be exposed for visual inspection.

All pipes shall be chemically cleaned, flushed, and treated in coordination with the University contracted water treatment provider.

B. Chilled Water:

- i. Chilled water is distributed to campus buildings via underground buried piping. Pipes are generally HDPE PE4710 SDR-11 with DR9 fittings. All joints are butt fusion welded. Piping connection to isolation valves shall be flanged with factory trimmed pipe termination to allow valve disc travel. Isolation valves shall be 250# body rating with 250# bolt pattern, ductile iron body and disc, stainless steel shaft, EPDM seat, and made in USA. Flange bolts and nuts shall be stainless steel and be tightened to specified torque. HDPE piping shall be hydro tested at 200 psig for 4 hours with steady pressure reading and all joints exposed and be left overnight at 150 psig to maintain steady pressure with no leak. Re-torque bolts after 24 hours. Maintain 50 psig pressure during backfilling, following University trenching requirement.
- ii. Upon entering a building, the HDPE pipe shall be transitioned into steel pipe via a building shutoff valve with flanged or lugged connection.
- iii. Building chilled water system shall be 150# class steel pipe. Building 80 feet and taller shall have plate and frame heat exchanger isolating the building static pressure.
- iv. Chilled water bridge with metering, valves, controls, and instrumentation shall be provided near building entrance location inside a mechanical room. Piping and components in direct contact with campus chilled water shall have a higher rating than piping on the building side of the plate frame heat exchanger. On the campus side, piping 4 inch and larger shall be steel with welded connection. Piping 3 inch and smaller shall be Type K copper with brazed joints. Connection to equipment and components shall be flanged or brazed. Coils shall have .035 tube thickness. On the building side, type L copper with silver solder is allowed. Unitary equipment with thickest tube coil despite less than .035 is allowed. Threaded connection is not allowed.

C. Building HVAC Systems:

- i. HVAC systems shall include air distribution, exhaust and hydronic systems for heating and cooling, generally system shall be centralized.

7. Building Mechanical System Requirements

A. Air Handling Systems

- i. General
 - a. Air Intake & Mixing
 - Location of intake and exhaust shall be considered during design, with regard to prevailing wind and contaminant sources to prevent entrainment of

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- contaminants and reentering at intake of adjacent buildings and also cause nuisance to pedestrians on campus ground.
- ii. Unit Startup Services
 - a. Units shall have factory startup services. Installing contractors shall not start or operate equipment until factory personnel provides startup service. Owner shall be notified in advance for observing factory testing.
 - iii. Industry Standards
 - a. AMCA, ARI, NEMA, UL listed, ASHRAE
 - iv. Factory testing
 - a. Leak test casing, including access doors, at 10 inch pressure. Total leakage not to exceed .5% of design air flow.
 - b. Test for deflection at 10 inch pressure not to exceed 1/360 of span at sidewall and roof of air handling unit.
 - c. Testing for performance at design air flow and static pressure and measure motor amperage and fan rpm.
 - d. Operating at design flow and static pressure, measure fan vibration at each of the three directions. Vibration velocity shall not exceed .05 in/sec at each direction.
 - e. Operating at design flow and static pressure, collect sound data for 8 bands at AHU inlet, outlet, and side. Noise level shall not exceed limit set by acoustic consultant.
 - v. Custom Indoor Air Handling Units
 - a. Unit Casings & Base
 - Units shall have minimum 4" insulated double-wall construction for walls, roof, and bottom.
 - Casing shall be "no through wall" type of construction such that with 50F in the air stream and 95Fdb and 50% RH ambient environment, there shall be no condensation in the outside casing and base.
 - Limit AHU size to 40,000 cfm and below such that units can be factory built in one piece or in sections suitable for rigging, installation, and future replacement.
 - Provide sleeved penetration with cap for field installation of instruments. No drilling through casing of AHU is allowed in the field with prior approval.
 - vi. Doors
 - a. Provide access doors in each section for maintenance. Doors shall be a minimum of 24" wide.
 - b. Door shall have 12"x12" view window. View window shall be insulated double pane with safety wire as needed.
 - c. Doors shall have double gasket, with 2 to 3 handles and be installed to open against the pressure.
 - d. Instrument test hole with sleeve and cap shall be provided at each door.
 - vii. Fans
 - a. Units shall be configured in the draw-through type arrangement.
 - b. Fans shall be selected for additional 15% airflow capacity.
 - c. All fans shall be AMCA certified and rated for intended use.

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- d. Fans shall be scheduled on the drawing. Schedule shall include the following: Equipment Tag, total flow, total pressure drop, fluid temperature, outlet velocity, wheel diameter, wheel type and class, arrangement, rotation, brake horsepower, motor horsepower, voltage, power phases, and manufacturer model.
 - e. Fans shall be non-overloading type. Recommend backward incline or air foil type.
 - f. Fans shall be arranged in an array preferably with 2 to 4 fans, direct driven type with the appropriate number of blades and built in acoustic housing to meet low noise requirement.
 - g. Fans shall be provided with base, sheaves and motor directly mounted from the factory.
 - h. Fan critical speed shall be a minimum of 25% greater than the fan design speed. The fan shall be statically and dynamically balanced.
 - i. Fans shall have vibration isolators.
 - j. Provide a VFD to control air volume.
 - k. Fan bearings shall be self-aligning, pillow block or ball bearing, regreasable and shall have an average life (L10) of at least 200,000 hours. All grease fittings shall have lube lines extended for ease of service.
 - l. Fan shall be coated as required for intended use. A minimum of factory primer and baked enamel finish shall be provided.
 - m. Provide rail and lifting lug for removing motor out of air handling unit.
- viii. Motors
- a. Motors shall be premium efficiency and rated for use with variable speed drives.
 - b. All motors shall be NEMA rated for intended use.
 - c. Variable Frequency Driven Motors – Induced Voltage Bearing Current Mitigation Strategies
 - All motors operated on variable frequency drives (VFD) shall have shaft grounding ring on the drive side and preferably insulated bearing on the non-drive side of the motor.
 - d. Motor couplings shall be selected for a service of 1.5 service factor based on motor horsepower.
- ix. Coils
- a. All coils shall be ARI certified and pressure tested.
 - b. All coils shall be of drainable design with counter flow circuiting. (air and water)
 - c. Coil tube shall be copper and have 5/8 inch diameter, wall thickness of 0.035 inch and 0.095 inch thick aluminum fins.
 - d. Preheat coils for 100% outside air shall be designed for -15° F to 55°F. Inlet water temp of 180° and 20° or 30° rise with 30% propylene glycol.
 - e. Preheat coils for recirculated air systems shall be designed for minimum 20°F temperature rise. Glycol shall be limited to equipment rooms. Preheat coil shall be sized for outdoor design temperature when the heat recovery wheel is not in operation and also be able to deliver even air temperature across the face of the coil in the reduced operating range when the heat recovery wheel is in operation.

- f. Chilled water coils shall be designed for 45° F entering water temperature with a 12° to 16° rise in temperature and up to 15 feet water side pressure drop. Glycol shall not be used.
- g. Face velocity of chilled water coils shall not exceed 450 fpm.
- h. The designer shall schedule all coils on the drawings.
- i. Coil assembly shall have provisions to facilitate total or partial removal from coil bank.
- j. Provide stainless steel coil frame for cooling and heat recovery and galvanized steel frame for heating coils.
- k. Each coil section shall have connections and valves for flushing.
- x. Drain Pans
 - a. All drain pans shall have slope in two planes to eliminate stagnant water conditions and promote positive water drainage.
 - b. All drain pans shall be insulated double walled 304 stainless steel construction.
 - c. Drain pans shall extend a minimum of 4 inches upstream and 24 inches downstream of the cooling coil.
 - d. All drain connections shall be on side of unit.
 - e. Where cooling coils are stacked, intermediate drain pans shall be provided. Intermediate drain pans shall have down-comers to the lowest drain pan constructed of type 304 stainless steel.
- xi. Dampers
 - a. All dampers shall be low leakage type with blade seals. Outside air dampers shall be insulated. Intakes shall be designed to prevent the intake of rain and snow. Linkages shall be provided for multiple damper sections.
 - b. Location for actuator installation shall be noted and be installed with base plate for mounting by others. Actuation torque shall be noted in submittals.
- xii. Lights & Outlets
 - a. Provide lights in each section with conduits wired to a common external light switch; light fixture shall be moisture proof tight utilizing energy efficient light.
- xiii. Filters
 - a. All filters shall be modular 24"x24" or 12"x24".
 - b. Prefilters shall be MERV 8 type.
 - c. Final filters shall be MERV 13 or 14 similar to 3M 4 inch high flow and high capacity type.
 - b. Sound limitations: Fans shall be selected with the lowest sound level.
 - c. Humidifiers (if specified)
 - Humidifiers shall be low pressure steam type with insulated manifold. Humidifier shall be selected to produce the required humidification with short absorption distance.
 - Installation of primary humidifier is recommended to be prior to cooling coil. Duct installation and other installation locations shall be installed with straight section with no obstructions within absorption distance. When installed in ductwork, ductwork shall be stainless steel with a minimum of 24 inches upstream of humidifier and 24 inches past absorption distance.
 - Humidifier shall be provided with separate inverted bucket traps for steam manifold and dispersion connections. Traps shall be provided with inlet strainers.

- Humidifier air flow switch and temperature interlock shall be provided.
- d. Heat recovery wheel shall be installed in a rigid frame with regreasable bearing. Drive assembly shall include a durable belt and tensioner properly aligned.
- xiv. Semi-custom Air Handling Units
 - a. General requirement shall be similar to custom air handling units except that casing thickness can be 2 inch; some internal components are made by the same manufacturer. Air leakage shall not exceed 1% of design air flow. Factory testing is not required.
 - b. Use limited to 4,000 cfm or less.

B. Exhaust Fans

- i. General
 - a. Industry Standards
 - AMCA, NEMA, UL listed, NFPA 70, ASHRAE
- ii. Chemical resistance material or coating is required for exhaust fans in corrosive areas, such as laboratory fume hood exhaust.
- iii. Venturi exhaust stack fans shall be used for laboratory and fume hood exhaust.
- iv. Exhaust fans shall be located to avoid exhaust air re-entrainment and recirculation into intake louvers.
- v. Exhaust fans shall be located within penthouse mechanical rooms. Exhaust ductwork from discharge or positive pressure side shall be welded construction to prevent leakage into building.
- vi. Industrial Construction Utility type exhaust fans are preferred for long lasting service.
- vii. Belt driven centrifugal exhaust fans shall have motor coupling selected for a service factor of 1.5. For 7-1/2 HP or smaller, use adjustable pitch sheave selected at midpoint of rpm range. For 10 HP or larger, use fixed pitch sheave. Fan drives 1 HP or large shall have 2 belts; 10 HP or larger shall have 3 belts; 50 HP or larger shall have 5 belts. Bearing shall have L10 life 200,000 hours. Provide ground shaft rings for motors with variable speed drives.
- viii. Wind analysis shall be provided prior to locating exhaust fans to prevent re-entrainment of exhaust air to intake louvers in predominant wind directions.
- ix. Fans shall be dynamically and statically balanced to prevent vibration. Fan shall be factory balanced not to exceed .05 in/sec vibration velocity in each of the three direction. After installation, vibration limits shall be verified.
- x. Provide spring type isolators sized to match the weight of each individual fan.
- xi. Provide flexible connectors on inlet and discharge side of fans.
- xii. Check all units for proper performance, fan and/or motor rotation and adjust as required.

C. Chilled Water Systems

Campus chilled water shall be used for building cooling. Cooling coils shall be sized using 45°F entering chilled water. Building with coils located 85 feet above ground shall have building system isolated with plate frame heat exchanger. Heat exchanger shall be selected for 2° approach temperature. 58°F cooling water shall be utilized for chilled beam, radiant and IT room cooling.

D. Ductwork Systems

- i. General
 - a. SMACNA Duct Construction Standards
 - b. Identification
 - c. Ductwork shall be designed to limit overall airflow energy. Use low velocity and minimal obstructions as possible to keep fan static pressure to a minimum.
 - d. Ductwork systems shall be looped on floors to minimize size of ductwork and facilitate future modifications.
 - e. When ductwork system serves multiple floors, provide balance damper on each floor for building balance.
 - f. Ductwork installed for wet labs or other wet spaces shall be constructed of stainless steel.
 - g. All ductwork shall meet SMACNA leakage class A and have leakage test. Low pressure ductwork or ductwork downstream of VAV boxes can have sealant applied after installation at all joints and corners of joints in lieu of pressure testing.
 - h. Noise and vibration must meet room criteria with performance testing verification.
- ii. Supply Duct
 - a. All supply ductwork shall be externally insulated.
 - b. High Pressure duct from air handling unit to terminal box.
 - Velocity shall not exceed 2,000 fpm.
 - Pressure Drop shall not exceed 0.2 inches per 100 feet.
- iii. Low Pressure
 - a. Velocity shall not exceed 1,500 fpm.
 - b. Pressure Drop shall not exceed 0.08 inches per 100 feet.
- iv. Exhaust Ductwork
 - a. Velocity shall not exceed 1,500 fpm.
 - b. Pressure Drop shall not exceed 0.08 inches per 100 feet.
- v. Outside Air Ductwork
 - a. Velocity shall not exceed 1,000 fpm.
 - b. Pressure Drop shall not exceed 0.08 inches per 100 feet.
 - c. Outside air ductwork shall be insulated.
- vi. Fume Hood Exhaust Ductwork
 - a. Fume hoods must pass AHRAE-110 test.
 - b. Ductwork shall be constructed of corrosive resistance material.
 - c. All joints shall be welded.
 - d. Minimum metal thickness of 18 gauge.
- vii. Dampers
 - a. Volume Dampers
 - b. Fire/Smoke Dampers
- viii. Diffusers
 - a. Supply air diffusers shall not be located where airflow patterns will have an adverse affect on fume hood operation.
- ix. Duct lining
 - a. Internal lining of ductwork is not allowed.
- x. Terminal Boxes

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- a. When VAV system serves laboratories, a monitoring system shall be provided to maintain proper room pressurization.
 - b. Laboratory shall have pressure monitoring controls.
 - c. VAV box casing shall have all internal seams and corners caulked.
 - d. All internal liners must have FSK surface and be continuous around, securely fastened with open edge taped and covered with metal.
 - e. Terminal box shall have blade seals around damper, leakage not to exceed 5 cfm @ 1 inch static pressure.
 - f. Shaft shall be square and bolted to damper; provide mounting plate for actuator to be fastened with bolts and nuts; flow cross type of air flow measuring station; control panel shall have cover that is removable with wing nuts; access door shall be double insulated type, with continuous gasket around the edge
 - g. Terminal boxes shall be installed to allow full service to unit controls and coil removal. Orientation shall be specified.
 - h. All terminal boxes shall have at least 3 feet of straight duct upstream of inlet.
 - xi. Chilled beams or radiant panels: with flexible copper tubing stub out of housing for external soldering between panels and to building system pipe; no mechanical pipe connection is allowed.
 - xii. Fan Powered Boxes
 - a. Use of fan powered boxes is not allowed.
 - xiii. Sound Attenuators shall be used at AHU, fans, and other noise creating equipment as needed to meet project sound requirements.
 - xiv. Fume Hoods shall be designed and tested for 80 FPM face velocity
 - a. Installation shall follow “clean room or laboratory” requirements for air changes.
 - b. Energy savings design shall be incorporated for night set back options.
 - c. Fume hood shall be suitable for 60 to 110 fpm face velocity.
- E. Hydronic Piping Systems
- i. General
 - a. Identification shall be labeled per University Standards. Provide color and markings on for each piping system.
 - b. Minimum pipe size shall be ¾ inches.
 - c. Triple duty valves are not allowed.
 - d. Provide check valves where required. Check valves shall be ball type.
 - e. Building hydronic heating and cooling systems subjected to pressure from campus distribution system pressure:
 - All piping accessories and components in direct contact with the campus distribution system shall be 150 psi rated. Provide shut off valves at the bottom of building risers and piping takeoff on each floor. Such valves shall have the same rating as those used for building isolation.
 - f. Building hydronic heating and cooling systems not subjected to pressure from campus distribution pressure:
 - These systems include those that are isolated from campus distribution via building heat exchangers or stand-alone systems.
 - 3 inch and smaller:

Copper pipe type L (if within stand alone building or isolated from campus chilled water by plate frame heat exchanger) with silver soldered joint; ball valve with Teflon seat. If directly connected to campus chilled water system, pipes shall be steel and welded and flanged to equipment. Use type K copper with brazed joint if connected to smaller equipment and components.

- 4 inch and larger:
Steel pipe with welded connection and flanged to equipment. Use butterfly valves with ductile iron body and disc and EPDM seat if connected to campus system; use cast iron body with bronze EPDM seat if in standalone building.
- ii. Provide at least 3" building drain with ball valve.
- iii. Install shutoff duty valves at each branch connection to supply and return mains, and at supply and return connection to each piece of equipment.
- iv. Install calibrated balancing valves in the return water line of each heating or cooling element and elsewhere as required for system balancing.
- v. Install 3 inch building drain valves and 3/4 inch valve at other building low points for draining.
- vi. Install piping at a uniform grade of 0.2% upward in direction of flow.
- vii. Reduce pipe sizes using eccentric reducer fitting installed with level side up.
- viii. Install branch connections to mains using tee.
- ix. Install strainers upstream of each control valve, pressure-reducing valve, solenoid valve, pump, and elsewhere as indicated. Install ball valve with plug at strainer for blowdown.
- x. Install manual air vents at high points in piping with runout to drain.
- xi. Install automatic air vents with isolation ball valve in mechanical equipment rooms only.
- xii. Install control valves in accessible locations close to connected equipment.
- xiii. Piping layout on floors shall be looped design to allow for future renovations or modifications.
- xiv. Whenever possible design piping for reverse return.
- xv. Install bypass piping with (ball or butterfly) valve around control valve. If multiple, parallel control valves are installed, only one bypass is required.
- xvi. Install ports for pressure and temperature gauges at coil and equipment inlet and outlet connections and elsewhere as indicated.
- xvii. Install bronze or brass valve to separate steel and copper pipes. Do not use di-electric union.
- xviii. Chilled water usage point above 85 feet elevation from the ground shall be provided with a plate and frame heat exchanger with less than 2°F. approach for hydraulic isolation.
- xix. All piping components shall have steel body with 300lb rating and have welded or flanged connections. Use ASTM A193 B7 bolts, 2H nuts or SAE grade 8 bolts.
- xx. Threaded connection is allowed in equipment room. Distribution piping throughout building shall be welded, brazed or silver soldered. No mechanical joints allowed.
- xxi. Provide temperature and pressure wells at chilled water and heating water system components and eg coils.

- xxii. Provide 4 inches dial gauge and temperature gauges with “plus” and ¼ inch brass connection. Use ½ inch takeoff from pipe with root valve/reaction. All span and range must work with operation range.
- xxiii. Provide plate and frame heat exchanger for process cooling with city water as backup only.

F. Valves for chilled water systems

- i. Campus distribution chilled water valves in tunnels and building basements used for isolation and in chilled water bridge on the campus side of the heat exchanger:
 - a. 3 inch and smaller:
 - 600 psig CWP rated, MSS SP-110.
 - Provide ball valves with extended quarter turn handle with steel or bronze body; blowout proof stem, chrome plated brass ball, teflon seats with bronze trim.
 - b. 4 inch and larger:
 - ASME Class 150 flanged, 200 psig CWP rated; MSS SP-67
 - Provide butterfly valves, stainless steel, or ductile iron disc; stainless steel shaft; EPDM seats; flanged or lug connection; use ASME A193 bolts and B7 nuts or grade 8 bolts with washer. For all tightening procedures use ASME B31 piping valves and fitting standards.
- ii. Direct buried chilled water distribution valves shall be ductile iron body and disc, EPDM seats, stainless steel shaft with body rated for 250 psi; 250 psi flanged bolt pattern for 20 inch and larger; 125 flanged bolt pattern for 16 inch and smaller; see separate details for installing valve, actuator, extension, and ground attachment.
- iii. Isolation valves for steam and condensate for campus distribution and return in tunnels, vaults, and building basement up to and including the main PRV station and downstream of main receiver returning to central:
 - a. 3 inch and smaller
 - Provide gate valve with 300 psi rated (800 psi for 2 inch and smaller) steel body with welded connection (flanged connection to be prior approved by the University Mechanical Engineer in a case by case basis).
 - b. 4 inch and larger
 - Provide butterfly valve with 300 psi rated; carbon steel ASTM A216 grade WCB body with triple offset disc construction, 13% chromium hard faced, and welded connection (flanged connection to be prior approved by the University Mechanical Engineer in a case by case basis).
 - 4 inch and larger isolation valves can also be gate valves or triple offset butterfly valves.
- iv. Valve Actuators
 - a. Except for high temperature application such as steam and condensate systems, or systems requiring high torque for closing against operating pressure, all actuation for valves and dampers shall be electric driven with 4-20 maDC control signal.
 - b. Valves used for high temperature application such as steam systems or large size requiring high torque beyond the available rating of electric actuators, pneumatic actuators can be used. These are typically valves that are 8 inches

or larger in size. Compressed air for distribution shall be regulated down to no higher than 60 psi. A current to pressure converter shall be provided so that air pressure is for valve actuation with 4 – 20 maDC control signal and having the capability of adjusting for fast acting, slow acting and also failed in last position. The building design shall include a duplex oil-less air compressor and dryer.

v. Pressure Testing

- a. Piping system shall first be assembled and erected, then pressure tested and finally blownout and cleaned.
- b. Do not install insulation or paint to piping until testing is complete. Otherwise insulation shall be removed for testing at the contractor's expense.
- c. Lines open to atmosphere such as safety relief lines and lines downstream of the last shutoff valve need not be tested. These lines shall be visually inspected to determine that all joints are installed properly.
- d. Pressure vessels and other equipment built and tested to codes and specifications need not be tested.
- e. Preparation for Testing
 - At the time of testing, pipe metal temperature shall not be below 40°F.
 - All pipe joints shall be visually inspected for proper installation.
 - All piping systems shall be checked for adequate vent and drain connections.
- f. Pumps, compressors, heat exchangers, safety valves, flame arrestors, vessels, rupture disks, self-contained regulators, and any other equipment shall not be subjected to the piping test pressure. The equipment shall be bypassed or disconnected, and pipe ends blind flanged or removed and a spool piece inserted in its place.
- g. When it is necessary, for practicality, to include a vessel or other equipment, the test pressure shall not exceed the allowable cold limit of the equipment. Prior approval must be obtained from the University Mechanical Engineer.
- h. Piping connected to other lines (existing lines or lines installed by others) shall be isolated or blanked off for testing.
- i. All restrictions, such as flow nozzles and orifice plates, which interfere with filling, venting or draining shall be removed from the piping.
- j. Instrumentation piping shall be tested together with the piping system up to the block valve nearest to the instrument. All instruments shall be excluded from the test by either disconnecting the piping at the instrument and capping the pipe or closing the blocking valve nearest the instrument.
- k. Automatic control valve shall be in the open position unless provided with a by-pass permitting application of pressure to both sides.
- l. Expansion joints shall be provided with temporary restraints if required for the additional pressure load under test, or they shall be isolated during the pressure test.
- m. Piping systems subject to extended hydrostatic test periods shall be provided with a protected device to relieve excess pressure due to thermal expansion.
- n. One or more calibrated indicating test gauges shall be installed in the piping to coordinate the pressuring operation. The location for test pressure gauges

is at the bottom of the system for liquid service. When test gauges are installed at the top of a system, care shall be taken to ensure that over-pressuring of the piping and piping components does not occur at the bottom of the system due to the additional pressure imposed by the static head of the test media.

- o. Test pressure for campus steam and condensate distribution with 300# class pipe shall be at approximately 400 psi.
- p. Test pressure for campus chilled water distribution using HDPE pipes shall be at 200 psi.
- q. Test pressure for building 80# steam and hydronic systems with 150# class pipe shall be at 220 psi.
- r. Test pressure for building 15# steam system shall be at approximately 125 psi.
- s. Equipment can be tested at 1.0 times the rated pressure. Therefore, after the piping pressure test, the equipment shall be connected and tested at the lower pressure.
- t. Test Procedure
 - Test procedure shall be provided for review prior to testing. Test report with sign off shall be provided after testing.
 - Test fluid shall be clean water. A suitable filter shall be provided at the fill line if sand, rust or other particles are present at the test water.
 - Another suitable fluid may be used if there is possibility of freezing.
 - Compressible fluid such as gas or air shall not be used.
 - Piping system shall be slowly filled with test fluid. All vents and other connections which serve as vent shall be open during filling, so that all air is vented prior to applying pressure.
 - Before test pressure is applied the piping must be allowed to assume approximately the same temperature as the test fluid.
 - Hydrostatic test pressure shall be 225 psig or 1.5 times maximum working pressure, whichever is greater.
 - Hydrostatic test pressure shall be maintained with no noticeable loss in pressure for a sufficient length of time to visually inspect all joints for leaks, but not less than four hours.
 - There shall be no evidence of weeping or leaking.
 - Leaks shall be marked and identified for repair. Major repairs or additions to the piping system shall be retested. Minor repairs may be waived with the permission of the University Project manager. Repairs shall be inspected and observed for leaks.
 - System isolation valves shall also be tested for leaks.
 - Upon completion of the test, systems shall be drained and returned to their pretest condition. All items removed, blocked-off or disassembled shall be reinstalled, reassembled, and made operative as required.
- vi. Flushing of Piping
 - a. General
 - Cooling water includes chilled water and cooling tower water.
 - Heating hot water includes pre-heat and re-heat hot water.

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- Piping system shall first be assembled and erected, then pressure tested and finally flushed and cleaned.
- b. Preparation for Flushing
 - Piping system shall be visually inspected for proper installation and continuity.
 - All welds are to be hammered.
 - Small equipment such as reheat coils that has restricted flow passages or areas where sediment could collect shall either be bypassed or removed and replaced by a spool piece.
 - Large equipment such as pumps, coils, and heat exchangers etc. shall have temporary strainer or basket provided by the piping contractor with galvanized woven wire cloth 0.35 mesh 6x6 installed at the inlet of each equipment.
 - All instrument lines shall be disconnected, flushed separately and then reconnected at the conclusion of the cleaning operation.
 - All low points and dirt legs shall have temporary blow-off valves installed by the piping contractor.
- c. Flushing Procedure
 - All pipes shall be flushed at not less than their design flow rate.
 - Where possible, piping systems should be sectionalized and full system flow rates provided through individual sections.
 - Strainers shall be inspected frequently during the flushing operation and cleaned if necessary.
 - Flushing operations shall continue until all extraneous materials are no longer collected at the baskets and strainers.
- vii. Chemical Cleaning of Piping
 - a. Chemical cleaning shall be sub-contracted by the piping contractor to a chemical cleaning contractor pre-approved by the University.
 - b. Cleaning procedures shall be prepared by the chemical cleaning contractor and submitted to the University Mechanical Engineer for review and approval.
 - c. A pre-approved chemical shall be circulated within the piping system to remove grease, oil, corrosion products, mill scale, and dirt. This cleaning will provide clean surfaces for promotion of uniform protective film by corrosion inhibitors. Final concentrations, temperature, and contact time shall be determined prior to start of cleaning.
 - d. After cleaning, drain the system and immediately begin the filming process to allow rapid forming of a uniform impervious film on the piping surface to stifle corrosion reaction. Fill the system with water. Inject a pre-approved chemical and circulate the solution in the piping system.
 - e. Any additional steps of cleaning and filming required by the project will be performed at this time.
 - f. Upon completion of flushing and cleaning operations, all temporary piping, strainers, and baskets shall be removed from the piping

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system unless otherwise specified. Tanks, sumps, cooling tower basins, and troughs are to be drained and thoroughly cleaned. Equipment and piping shall be returned to their pre-flush condition and permanent strainers must be cleaned.

- viii. Cooling Tower Piping Flushing and Cleaning
 - a. Cooling tower system must not be filled, flushed, and cleaned until chemical and biological treatment system is planned, installed, and operable.
 - b. Prior to filling the system, take pictures of tower basin, distribution deck, and vertical surfaces for project record.
 - ix. Requirements for Radiographic Testing of Pipes
 - a. Chilled water and condenser water piping within the chiller plant shall require radiographic testing. Other piping to be tested shall be defined by the project requirements.
 - b. The piping contractor that performs the pipe welding shall provide the quality of weld to pass such inspection and include all preparation work for testing. The contractor will hire the testing agency to inspect 20% of the welds. Welds to be tested shall be chosen by the University assisted by the consulting engineer. Acceptance criteria for the radiographic test shall be per ASME B 31.1 paragraph 136.4.5. If there are any failed welds identified in the first 20%, another 20% sample will be taken. If another failure is found in the 20% sample, testing of all welds will be required. The piping contractor pays for the testing of welds and all work to repair the welds.
 - x. Pipe Cleaning and Testing Reports
 - a. Pipe cleaning and testing forms shall be provided by the contractor performing the work.
 - b. The forms shall include date, project name and number, starting and ending time of cleaning and testing, related specification, test pressure, applicable system, method used, chemical used, exposure time, residual concentration, signatures and title of technician performing the test, and University representative witnessing the test.
 - c. The forms shall be completed and signed immediately after the test and to be included as part of the commissioning document.
 - d. The pipe cleaning and testing report shall be submitted to the University Project Manager before system startup. This report shall be part of the commissioning document.
 - xi. Water treatment of piping systems shall be current water treatment preferred provider.
- G. Steam Piping Systems
- i. General
 - a. Provide 4 inch dial with loop seal and isolation valve pressure gauges upstream and downstream of PRV station.
 - b. Flanges shall be 300lb rating.
 - c. Threaded connection at steam trap shall be 2,000lb rating forged steel.
 - d. Note on drawings anchoring and expansion locations. Spring Loops are not allowed.
 - e. Provide condensate receiver with duplex pumps or more mounted on concrete pad.

- f. Provide gauges and sight glass at condensate receiver, 4 inch dial.
- g. Provide circuit setter at condensate pump discharge.
- h. Pressure gauge upstream and downstream of condensate pump.
- i. Provide flexible connection at condensate pump discharge.
- j. All trapped condensate shall be routed to a flash tank and gravity drained into the receiver.
- k. High pressure flash tank shall have steam flashed back to lower building steam system.
- l. Lower pressure trap condensate shall be flashed to a flash tank prior to flowing back to the condensate receiver.
- m. Low pressure flash tank and receiver shall be vented directly to the roof for vent.
- n. Provide turbine type condensate meter, with discharge test port/ball valve for calibration. Provide orifice DP or vortex type transmitter to measure flow. Provide meter sizing calculation for review. Meter must be capable to measure design flow as well as low flow in the summer months with accurate and repeatable results.
- o. All piping components shall have steel body with 300lb rating and have welded or flanged connections. Use ASTM A193 B7 bolts, 2H nuts, or SAE grade 8 bolts.
- p. All piping shall be pitched in direction of flow.
- q. Flash tank shall be installed upstream of condensate receiver, vented to atmosphere outside.
- r. Provide PRV for sizes 4" and under. Use PRV for 6" and larger. Self-regulating SRV, drip pan elbow. Provide PRV and SRV sizing and calculations for review. Provide pipe flexibility analysis for review. Show anchor guide design.
- ii. Steam Traps
 - a. Use only bucket traps on high pressure steam. Use F/T traps on low pressure steam.
 - b. High and medium pressure traps shall be connected to flash tank prior to entering condensate receiver.
 - Flash tanks shall be vertical and not less than 18 inch diameter.
- iii. Low Pressure Steam
 - a. Pipe shall be schedule 40 steel pipe.
- iv. Clean Steam, use RO water for humidification, with carbon filtering.
 - a. Humidifier shall be Dry Steam.
- v. Steam Condensate shall be schedule 80 steel pipe.
- vi. Installation
 - a. Steam piping shall be pressure tested and flushed.
 - b. Hydro test shall be 4 hours with steady pressure. Test pressure shall be approximately 1.5 times highest potential operating pressure or pipe pressure, whichever is higher. The highest potential operating pressures is the pressure that would occur in the event of a pressure reducing valve failure. Low pressure steam systems shall be hydro

tested at 120 psig (80 psig operating pressure times 1-1/2). All joints shall be exposed for visual inspection.

- c. High and medium flash steam shall be recovered.
- d. Low pressure condensate and condensate from flash tank shall enter a pipe header with mechanical isolation valve prior to entering main building condensate receiver.

H. Insulation Systems

i. General

- a. All cold or heated ductwork, piping, and equipment shall be insulated for energy efficiency and to reduce condensation sweating.
- b. Insulation material selection to be based on hot or cold application. Thermal limits of the selected material must be specified.
 - Mineral Fiber: 0°F to 1,900°F (Upper Limit)
 - Elastomeric: 0°F to 220°F (Upper Limit)
 - Calcium Silicate: 100°F to 1,200°F (Upper Limit)
- c. Selected insulation material must be formulated/treated to inhibit corrosion-under-insulation (CUI). Applicable standards include:
 - ASTM C665 – Corrosivity to steel
 - ASTM C795 Corrosion
 - ASTM C871 Corrosion
 - ASTM C692 Corrosion
 - ASTM C1617 Corrosion
- d. Selected insulation material must be formulated/treated to inhibit the growth of fungi and similar organisms.
- e. Thermal Resistance and thermal conductivity must be considered for insulating material selection and application – provide R and K-value for each specified product.
- f. Fire performance rating of insulating materials to be based on ASTM E 84, NFPA 255, and UL 723
- g. Compressive strength: Insulating material selection and specification must identify appropriate compressive resistance and be based on application, location, and installation requirements. Applicable standards include:
 - ASTM C165
 - ASTM 1621

ii. Applications

- a. Equipment
 - Equipment such as Storage Tanks, Air Separators, Heat Exchangers, Condensate Pumps, and Chilled water pump bodies shall be insulated.
- b. Piping
 - Piping shall have Mineral-Fiber with vapor barrier insulation, Flexible Elastomeric insulation, or Calcium Silicate insulation. Joints and elbows shall have protective cover jackets.
 - Joints and seams shall be sealed with vapor-retarder mastic.
 - Apply insulation over fittings, valves and specialties, with continuous thermal and vapor retarder integrity.

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- Apply insulation continuously through hangers and around anchor attachments.
 - Install insert materials and apply insulation tightly to join the insert.
 - c. Ductwork
 - Use indoor board insulation in exposed areas such as mechanical rooms.
 - Use blanket insulation in concealed areas including above the ceiling.
 - Use outdoor board insulation in outdoor areas including the roof.
 - Insulation shall not be installed until duct leakage testing has been performed and approved by the University project representative.
 - iii. Installation
 - a. Provide weld pins to support insulation for rectangular ducts. Locate on sides and bottom, 12" on center starting 3" from the butt joints. Apply clip washers to pins on the surface of insulation. Cut off pins to flush with washer.
 - b. Insulation shall not be compressed more than 20%.
 - c. Provide 2" overlapping of vapor barrier jacketing at all longitudinal and butt joints.
 - d. Cover all protrusions with additional insulation thickness.
 - e. All ductwork requiring insulation shall not have ductwork in direct contact with hanger or support. Provide 6" wide 2 pound density urethane foam board inserted between duct and hanger.
 - f. Apply mastic to all joints, corners, end of insulation and pins to form a continuous vapor barrier. Do not use staples or other means to break the vapor barrier.
- I. Pumps
- i. General
 - a. Rate pumps for system static pressure.
 - b. Select pump motors to be non-overloading over the full range of the pump performance curve without utilizing any of the service factor.
 - c. Select pumps for an impeller diameter not greater than 90% of the maximum pump impeller diameter.
 - d. Install liquid filled pressure gage on pump suction and discharge, use single gage with multiple input selector valve.
 - e. Provide non-slam silent check valve and shutoff valve at pump discharge.
 - f. Provide strainer upstream of all pumps.
 - g. All piping must be supported independently of the pumps.
 - h. All pump to motor shaft coupling shall be aligned.
 - ii. In-Line, Close Coupled, Centrifugal Pumps
 - iii. Construction
 - a. Motor pull out without disturbing piping.
 - b. Stainless steel shaft.
 - c. Mechanical seal with bellows and gasket. Verify components are compatible with the fluid pumped.
 - iv. Motors
 - a. Motors shall be premium efficiency type.

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- v. Base-Mounted, Separately Coupled, Centrifugal Pumps
 - a. Select end suction or double suction pumps depending on the size, application, and life cycle costing.
- vi. Typical Applications
 - a. Building chilled water booster pumps.
 - b. Campus chilled water and condenser pumps.
 - c. Building heat water system pumps.
- vii. Construction
 - a. Provide integral mount on volute to support the casing, and attached piping to allow removal and replacement of impeller without disconnecting piping or requiring the realignment of pump and motor shaft.
 - b. Select mechanical seal on all applications except consider packing seal for abrasive fluids.
 - c. Mechanical seal with bellows and gasket. Verify components are compatible with the fluid pumped.
 - d. Provide EPDM coupling sleeve for all pumps.
 - e. Provide vibration monitoring for large pumps. See FS Project Manager for more information.
- viii. Variable Frequency Driven Motors – Induced Voltage Bearing Current Mitigation Strategies
 - a. All motors operated on variable frequency drives (VFD) shall have insulated bearing on the non-drive end and a shaft grounding ring (SGR) on the drive/shaft end of the motor.
 - b. All shaft grounding rings (SGR) shall be provided and installed by the motor manufacturer or contractor and shall be installed in accordance with manufacturer's recommendations.
- J. Installation
 - i. Service Clearance
 - a. Provide space around pumps for pump access and for electrical components and access required by NEC.
 - b. Specify that at least one final alignment be performed in the field.
 - c. Pump Pad shall be level. Pump shall be level. All bolts to be loosened to demonstrate no mechanical force at pump.
 - d. Pump and motor vibrations shall not exceed .05 In/sec velocity in any of the three directions. Verification required after installation.
 - e. Pump shall not operate above 60 HZ in normal operation.
- K. Domestic Water Systems
 - i. Domestic Hot water heater shall be of semi-instantaneous type without storage tank. Hot water recirculation for fixtures with flow rates of 1 gpm or more shall be within 20 feet of the most remote fixture. Recirculation for fixtures with flow rates less than 1 gpm shall be within 2 feet of the most remote fixture.
 - ii. All cold water and hot water piping including recirculation shall be insulated.
 - a. All domestic water pipe shall be copper up to 6 inches. 8 inch and larger shall be cement lined ductile iron.
 - b. Galvanized pipe is not allowed.
 - iii. Fittings:

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- a. Wrought-Copper Fittings: ANSI B16.22, streamlined pattern.
 - b. Galvanized Cast-iron Threaded Fittings: ANSI B16.4, Class 125, standard pattern, for threaded joints. Threads shall conform to ANSI B1.20.1.
 - c. Ductile-iron Gasketed Fittings: AWWA C110, Schedule 150, with cement mortar lining and AWWA C111 rubber gaskets.
 - d. Cast-iron Threaded Flanges: ANSI B16.1, Class 125; raised ground face, bolt holes spot faced.
 - e. Cast Bronze Flanges: ANSI B16.24, Class 150; raised ground face, bolt holes spot faced.
- iv. Pipe Applications:
 - a. Install Type L, drawn copper tubing with wrought copper fittings and solder joints for 4 inch and smaller above ground, within building.
 - b. Install Type K, annealed temper copper tubing for 2 inch and smaller with minimum number of joints, below ground and within slabs.
 - c. Install cement-lined ductile-iron pipe with rubber gasketed joints below ground outside the building.
- L. Drainage and Vent Systems
 - i. Above ground drainage and vent pipe and fittings:
 - a. Hub-and-spigot, cast-iron soil pipe and fittings
 - Pipe and Fittings: ASTM A 74, Extra Heavy weight, cast-iron soil pipe and fittings.
 - Gaskets: ASTM C 564, rubber.
 - Calking Materials: ASTM B 29, pure lead and oakum or hemp fiber.
 - ii. Underground building drain pipe and fittings:
 - a. Hub-and Spigot, cast-iron soil pipe and fittings
 - Service class Extra Heavy weight, cast-iron soil pipe and fittings.
 - Calking Materials: pure lead and oakum or hemp fiber.
 - iii. Installation:
 - a. Horizontal pipe and fittings 5 inches and larger must be suitably braced to prevent horizontal movement, at every branch opening or change of direction by use of braces, blocks, rodding, or other approved method, to prevent movement or joint separation.
 - b. All drain and vent piping shall be tested to 10 feet water column applied to highest point for 4 hours with no leaks.
- M. Plumbing Fixtures
 - i. Follow water consumption guidelines set forth in Volume III. C. Sustainability section regarding use of dual-flush, low flow fixtures where feasible.
 - ii. Automatic Flush valves:
 - a. Sensor operated, battery powered by water flow turbine with back-up manual actuation.
 - iii. Faucets:
 - a. Sensor operated, battery powered by water flow turbine at public installations.