SECTION 23 - HVAC
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23-1 INTRODUCTION

A. The following mechanical guidelines shall be utilized to design and document new construction and renovation projects for the University. All designs are subject to review and approval by the University and appropriate authorities having jurisdiction.

B. In the following text, UCSF Medical Center shall be referred to as the “University” which includes: UCSF Medical Center Facilities, referred to as "Facilities" and UCSF Medical Center Office of Design and Construction, referred to as "D&C".

C. The guidelines describe criteria, performance, and materials requirements for mechanical systems. Design professionals can recommend changes to specific guidelines as appropriate to meet the project program and goals, but shall not incorporate changes without the University’s written approval. Recommended changes that reduce quality, utility, flexibility and energy efficiency criteria described herein shall be submitted with cost/benefit analyses.

D. This document was prepared prior to the opening of the new Mission Bay Hospital, and does not address guidelines for renovations or future development at the UCSF Medical Center at Mission Bay.

23-2 HVAC OVERVIEW

A. University HVAC Infrastructure: The following are brief descriptions of HVAC infrastructure in non-Mission Bay Medical Center Buildings. Descriptions are not necessarily up-to-date. For renovation projects, review archive drawings, survey existing conditions, recommend testing of existing systems where appropriate, and interview Facilities personnel to ascertain current conditions.

1. Moffitt Hospital Mechanical System Overview

   Ventilation Systems: H. C. Moffitt Hospital is mostly served by original central air handling systems (installed in 1952) that serve multiple floors. All original air handling systems, except surgery air handling units S-7 and S-8 on the 5th Floor, lack air conditioning. Most original supply and exhaust fans are fed by normal power, which is no longer code-compliant. Many above-ceiling air handling units have been installed over the years to air condition renovated portions of Moffitt Hospital; most notably the ICU units, 1st Floor Emergency Department, and areas of 3rd Floor Radiology. Any renovation project should carefully evaluate the age, condition, performance, and code compliance of the ventilation system.

   Heating Systems: Moffitt Hospital was originally steam heated via low pressure steam heating convectors in patient rooms, and low pressure steam pre-heat coils at the air handling units. Original steam heating is still in use in many areas. High pressure steam is supplied from the Parnassus Campus Central Utility Plant. A pair of steam-to-heating water heat exchangers in a Penthouse mechanical room provide heating water to renovated areas delivered via 3" risers near the dumbwaiters in the East Wing. These risers are heavily utilized. Heating water system upgrades are anticipated that will increase capacity. Any renovation project that requires heating water should carefully evaluate the current demand and capacity of the heating water system.

   Chilled Water System: The recently upgraded chilled water system consists of one 600 ton capacity electric centrifugal chiller (installed in 2013), and one 285 ton capacity steam-driven lithium bromide absorption chiller (installed in 1988). Three new primary chilled water pumps and two new secondary chilled water pumps were installed in 2013. The system is capable of meeting all current air conditioning loads in Moffitt Hospital. The old steam absorption chiller will be replaced with an electric chiller in the future. The chilled water distribution system has been modified over the years, is convoluted, and includes interties with the Long Hospital chilled water system. Any renovation project that requires chilled water should carefully evaluate the current chilled water demand and distribution capacity at the proposed points of connection.

HVAC Controls: Original pneumatic controls have been repaired and/or replaced and are mostly still in use today. Recent renovations have installed direct digital controls (Andover Continuum), which are monitored at Facilities offices in L210 and at other energy management system workstations. See Sections 23-25 hereinafter for further descriptions.

OSHPD Status: Moffitt Hospital is an OSHPD 1 facility, I-2 Occupancy, seismically rated SPC-2 and NPC-3R.

2. Long Hospital Mechanical System Overview

Ventilation Systems: J. M. Long Hospital is mostly served by original central air handling systems installed in 1978. Systems are documented in original drawings titled "H.C. Moffitt Hospital Modernization - Step 1".

- Five large built-up fan systems (S-9 through S-13) are manifolded in the Basement and serve the Basement through the 5th Floor. These fan systems lack air conditioning and, in many areas, lack individual zone temperature control.
- Floors 6 through 15 in the tower each have a dedicated supply fan located on that floor (the 15th Floor air handling unit is on the 16th Floor roof). Original units lack air conditioning. Air handling units serving the 6th, 7th, 11th, 12th, 13th, and 15th Floor have been replaced and now provide partial or full air conditioning.
- Original air handling units serving 4th Floor surgery (S-1 and S-2) are being replaced with one large rooftop air handling unit (above the 1st Floor Emergency Department) a smaller rooftop air handling unit on the south roof (above O.R. 9), and a smaller rooftop air handling unit above O.R. 4.
- Numerous small air handling units serve other areas of Long Hospital.

Large general exhaust fans in the Penthouse exhaust all areas of Long Hospital. Most original supply and exhaust fans are fed by normal power, which is no longer code compliant. Many above-ceiling air handling units have been installed over the years to air condition renovated portions of Long Hospital, most notably for 3rd Floor Radiology. Floor-mounted air conditioning units have been installed in the Basement Sterile Processing Department. Any renovation project should carefully evaluate the age, condition, performance, and code compliance of the ventilation system.

Heating Systems: Long Hospital patient rooms are mostly heated via heating water convectors with individual room controls. Main fan systems have low pressure steam pre-heat coils. An original medium pressure steam-to-heating water heat exchanger in the Basement generates heating water for baseboard convectors on patient floors and duct reheat coils in other areas of the Hospital. The heating water system is operating near capacity on cold days. Although recent distribution improvements have been made, there is inadequate pipe sizes and differential pressure to deliver heating water to certain areas during periods of peak demand. Any renovation project that requires heating water should carefully evaluate the current demand, and distribution capacity at the proposed points of connection.

Chilled Water Systems: Long Hospital has two original 150 ton capacity steam-driven lithium bromide absorption chillers in the Basement, and two 160 ton capacity air cooled chillers on the roof. The system is stressed to deliver adequate chilled water on warm days, partially because of distribution and pumping issues. The chilled water distribution system is convoluted and includes interties with the Moffitt Hospital chilled water system. The old steam absorption chillers will be replaced with one or more electric chillers in the future. Any renovation project that requires chilled water should carefully evaluate the current chilled water demand and distribution capability at the proposed points of connection.

HVAC Controls: Original pneumatic controls have been repaired and/or replaced and are mostly still in use today. Recent renovations have installed direct digital controls (Andover Continuum), which are monitored at Facilities offices in L210 and at other energy management system workstations. See Sections 23-25 hereinafter for further descriptions.

OSHPD Status: Long Hospital is an OSHPD 1 facility, I-2 Occupancy, seismically rated SPC-4 and NPC-3.

3. Parnassus ACC Building Mechanical System Overview

Ventilation Systems: Original 1969 supply fans SF-1, SF-2, SF-3, and SF-4 in the Penthouse serve the Plaza Level through the 8th Floor of ACC Building. These fan systems deliver 100% outside air and include medium efficiency pre-filters, hot water heating coils, and double-width double-inlet centrifugal supply fans. Each supply fan feeds two of the building's four supply air risers. Existing systems are constant volume. ACC Building is a licensed clinic associated with a Hospital, and mechanical systems are obliged to conform to OSHPD 3 requirements in the California Mechanical Code (CMC). Several aspects of the original fan systems do not meet CMC requirements: they lack high efficiency final filters, lack controls to maintain constant air volume delivery, and lack air conditioning for sensitive areas. Renovation projects often supplement original ventilation with local air conditioning, air filtration, and zone temperature control improvements. Original 1969 exhaust fans EF-1, EF-2, EF-3, and EF-4 are suspended on D and F Levels of the Parking Garage and serve the Plaza Level through the 8th Floor. Exhaust fans discharge into the Parking Garage. Any renovation project should carefully evaluate air conditioning and code compliance strategies with the University.

Heating Systems: Space heating is accomplished via duct heating coils. There are a limited number of original heating coils on each floor, with up to a dozen rooms in each temperature control zone. A new plate and frame medium pressure steam-to-heating water heat exchanger and two new variable speed heating water pumps were installed on D Level in 2011. High pressure steam is supplied from the Parnassus Campus Central Utility Plant. There is sufficient heating water generation capacity to support the installation of reheat coils on multiple floors. However, heating water distribution improvements (riser sizes) have not been made, and it may become difficult to meet increased reheat demands on renovated floors. Any renovation project that requires heating water should carefully evaluate the demands on and capacity of the heating water distribution system.

Chilled Water System: Main fan systems SF-1, SF-2, SF-3 and SF-4 lack air conditioning. There are two air cooled chillers on the Penthouse roof with chilled water risers running down an internal areaway. A small chiller serves the ambulatory surgery center on the Plaza Level. A larger chiller serves supplemental air conditioning loads on the 1st through the 8th Floor, with chilled water stub outs on each floor; this chiller is heavily utilized and may be replaced in the near future. An additional chiller on the Parking Garage roof serves loads on

C Level. Any renovation project that requires chilled water should carefully evaluate current chilled water demand, generation capacity, and condition of the existing chiller being utilized.

HVAC Controls: Original pneumatic controls are mostly still in use today. Recent renovations have installed direct digital controls (Andover Continuum), which are monitored at Facilities offices in L210 and at other energy management system workstations. See Sections 23-25 hereinafter for further descriptions.

4. Mt. Zion Hospital Campus Mechanical System Overview

The Mount Zion Campus consists of very old (1914 Hellman Building) to relatively new (2010 Osher Building) structures. The great variety of mechanical systems preclude description in this overview. Buildings include critical care hospital buildings, the Helen Diller Family Comprehensive Cancer Center, a Cancer Research Building, Women's Health Center, Osher Center for Integrative Medicine, and numerous medical office buildings. For renovation projects, review archive drawings, survey existing conditions, and interview Facilities personnel to ascertain current conditions.

OSHPD Status: OSHPD 1 buildings at Mt. Zion include Buildings A, B, D, and R. Buildings A, B, and D are seismically rated SPC-2 and NPC-2. Building R is seismically rated SPC-4 and NPC-2. The University received an exemption from NPC-3 requirements at Mt. Zion until 1/1/2030.

B. Design Considerations

1. Properly functioning HVAC systems and controls, healthy indoor air quality, code compliant ventilation, and occupant comfort shall be the prime considerations in mechanical designs. In addition, the designer must also satisfy requirements for future expansion, provide ease of maintenance, and minimize life-cycle cost. Because of the longevity of University buildings and the great expense of modifying or replacing existing mechanical systems, the designer shall strive to ensure that the proposed systems are capable of meeting the long term needs of the building in which they are installed. Select systems and components for minimum 40-year service life, unless other appropriate service lives are agreed upon.

2. Appropriate HVAC systems are dependent on building occupancy and program, as well as system demand, available space, efficiency criteria, and capacity to accommodate future load increases. For smaller renovations, modifications to existing HVAC systems will be necessary. It is important that proposed HVAC systems be evaluated during preliminary planning phases. During schematic design, evaluate likely design alternatives. Design control systems to provide optimal operation of the entire system.

   For new construction, the mechanical engineer shall participate in the building study and conceptual design to ensure fully integrated and appropriate designs.

   The mechanical engineer shall consult and coordinate with the Architect, the University, and the University’s Consultants, on the selection of mechanical systems.

3. In addition to compliance with code requirements and specific HVAC requirements herein, review and incorporate appropriate recommendations of organizations that prepare standards and guidelines for hospitals and various functions therein. Some of this information may be in the form of periodical publications. These may include:

- Facilities Guidelines Institute (FGI) Guidelines for Design and Construction of Health Care Facilities
- ASHRAE Standard 170 Ventilation of Health Care Facilities
- ASHRAE HVAC Design Manual for Hospitals and Clinics
- Association for the Advancement of Medical Instrumentation (AAMI) Standard 79 Comprehensive guide to steam sterilization and sterility assurance in health care facilities
- United States Pharmacopeia Convention (USP) Chapter 797 Pharmaceutical Compounding - Sterile Preparations
- CDC & HICPAC Guidelines for Environmental Infection Control in Health-Care Facilities
- Guidelines - Infection prevention and control in health-care facilities in which hematopoietic cell transplant recipients are treated, *Bone Marrow Transplantation* (2009) 44, 495-507
- UCSF Hospital Epidemiology and Infection Control: Guidelines for Care of the Immunocompromised Patient, Policy 4.1

C. Energy Performance Criteria

1. HVAC systems are a significant component of total building energy consumption. HVAC systems shall be designed to meet energy performance targets that are established by the University of California Office of the President (UCOP), the University, and/or other entities. Goal setting may focus on meeting a certain percentage less than California Title 24, achieving LEED certification, or maximizing PG&E Savings by Design rebates. Resources and guidelines that may be applied to University projects include:
   - UC Policy on Sustainable Practices, current version dated August 27, 2013.
   - UCSF Sustainability Action Plan, dated April 21, 2011.
   - USGBC LEED Rating Systems and Alternative Compliance Paths for Healthcare, as appropriate for the project.
   - ASHRAE Advanced Energy Design Guide for Large Hospitals.
   - ASHRAE Advanced Energy Design Guide for Small Hospitals and Healthcare Facilities.
   - PG&E Savings by Design incentive programs, which vary year-to-year.

2. LEED Certification: Certain University projects are required to achieve LEED certification or achieve a minimum certification under the University's program equivalent to the United States Green Building Council's (USGBC) LEED program. Incorporate energy saving design features and assist in achieving the agreed upon certification level for this project. For most projects:
   - Provide energy modeling and system optimization as necessary to qualify for the Minimum Energy Performance Prerequisite and as many Optimize Energy Performance Credits as possible.
   - Include HVAC system commissioning to qualify for Fundamental Commissioning and Verification Prerequisite and the Enhanced Commissioning Credit.
   - Provide electrical and HVAC system monitoring to qualify for the Advanced Energy Metering Credit.
   - Design ventilation and control systems to qualify for the Enhanced Indoor Air Quality Strategies Credit.
   - Provide sufficient occupant controllability and monitoring to qualify for the Thermal Comfort Credit.
   - Design systems to qualify for the Acoustic Performance Credit.

23-3 BASIS OF DESIGN AND SYSTEM DESCRIPTIONS

A. During the initial stage of project design, prepare a mechanical Basis of Design (BOD) document. Submit this document at the earliest possible time, but no later than at the end of Schematic Design. The BOD shall summarize relevant design criteria, evaluate demands on new and existing utilities, and describe proposed new and modified systems. At each subsequent design checkpoint (Design Development, 50% Construction Documents, etc.), inform the University of any significant changes to the approved BOD. For projects where formal Outline Specifications are required, the BOD will serve as the mechanical portion the Outline Specifications. The BOD should address the following topics, as appropriate:

- Design Criteria:
  - Applicable codes and standards.
  - Outdoor design conditions.
  - Indoor design conditions.
  - Minimum ventilation rates for each type of space.
  - Pressure relationships (room-to-room).
  - Air filtration and purification requirements.
  - Air conditioning requirements.
  - Internal cooling load criteria and diversity factors (known loads and assumptions).
  - Noise criteria.
  - Room air distribution strategies.
  - Diversity factors to be used in load calculations.
  - Criteria for sizing major mechanical equipment.
- System Descriptions for each New and Modified Mechanical System:
  - System type, configuration, and control strategy.
  - Equipment and material descriptions.
  - Reserve (future) capacity, redundancy, and other special design features.
- Impacts on Building Infrastructure:
  - New or increased demands on existing building utilities.
  - Tie-in strategies to minimize utility shutdowns.
  - Recommended infrastructure testing or upgrades to support new project.

The BOD shall be augmented with system diagrams and layout sketches commensurate with the current design stage.

B. Mechanical System Diagrams

1. Include a single line, no scale, diagram of each mechanical system, including supply and exhaust air, hot water heating, steam, chilled water and cooling water on the mechanical plans. Show equipment names, sizes, flow rates, dampers, valves, and direction of flow arrows. Show the normal position for each valve, either normally open (NO) or normally closed (NC). Diagrams are not required for minor modifications to existing systems, except that the design engineer shall verify adequate capacity at the points of connection.
   - For all projects, include detail diagrams in the Construction Documents to fully describe valves and specialties at coil and heat exchanger connections, sterilizer connections, humidifier connections, steam trap assemblies, pump assemblies, and other equipment connections.

2. Include riser diagrams of supply and exhaust duct systems that serve multiple floors. Show equipment names, main and branch sizes, approximate airflow rates at each floor, fire smoke dampers (at risers only) and primary volume control devices (dampers, splitters, etc.). Individual room outlets need not be shown. In hospitals, include pre-demolition and post-demolition balancing instructions to maintain required airflows in occupied areas.

3. For heating water, chilled water, and steam systems, include riser/distribution diagrams showing equipment or source locations, main pipe sizes, flow direction arrows, branch flows at each floor, and location of primary circuit balancing valves.

4. For significant renovation projects, update system configuration, sizes and primary flow rates on AutoCAD system diagrams provided by the University. Return updated diagrams in matching format.

23-4 HVAC DESIGN CRITERIA

A. Codes and Standards: Design mechanical systems in accordance with all applicable Codes and Standards. Standards shall be referenced by the design professional to establish minimum product quality and installation criteria.

A statement shall be included in the project Specifications instructing the Contractor that nothing on the Drawings or in the Specifications shall be construed to permit work not conforming to applicable rules and regulations, and to provide without extra charge any additional material and labor required to comply with applicable rules and regulations.

B. OSHPD 1 Requirements

1. For critical care hospital spaces under OSHPD jurisdiction, design HVAC systems for full OSHPD 1 compliance as described in the California Mechanical Code (CMC). Significant design requirements are described in the following sections of the 2013 CMC, although all applicable requirements in the CMC must be followed.

325.1: Temperature and humidity control for sensitive areas or rooms.
326.0: Emergency power requirements.
402.0: This section on ventilation air shall not be used for OSHPD facilities. Fresh air ventilation by means of natural ventilation (windows) shall not replace mechanical ventilation.
403.0: Fresh air ventilation rates shall not be determined in accordance with 403.1 through 403.6 calculation methods.
407.0: Ventilation system for OSHPD 1 shall comply with requirements of 407.1 through 407.5, and Table 4-A. Where specific room types are not listed in Table 4-A, then provide a minimum of 6 air changes per hour of outside air for 100% outside air systems, and a minimum of 6 air changes per hour of total air and 2 air changes per hour of outside air for systems that recirculate air. Airflows in Table 4-A are the minimum required at all times; actual airflow rates required to maintain room temperatures listed below will normally result in higher air change rates. In VAV systems, minimum ventilation rates shall not drop below air change rates in Table 4-A.
407.5: Variable air volume systems shall include VAV boxes in exhaust/return ducts from each zone; exhaust/return VAV boxes shall modulate in conjunction with supply air VAV boxes.

408.0: Air handling system filtration shall comply with requirements of 408.1, 408.2, 408.4, and Table 4-B. Air handling systems shall have pre-filters with minimum 30% efficiency (MERV 8), and final filters downstream of supply fans and cooling coils with minimum 90% efficiency (MERV 14).
409.0: Ductwork shall comply with requirements of 409.1 through 409.4.
410.0: Comply with special requirements for laboratory fume hoods in hospitals.
412.0: Comply with requirements for boiler, mechanical, and electrical rooms.
413.0: Odorous rooms shall be exhausted at a minimum rate of 10 air changes per hour.
414.0 - 417.0: Airborne infection isolation rooms and protective environment rooms shall comply with the requirements of these sections.
602.1 & 407.4.1.4: Ceiling spaces or other concealed spaces shall not be used as ducts or plenums. All supply, return, and exhaust ventilation shall be ducted to ceiling inlets and outlets.
602.3.1: The use of flexible duct is limited to 10 feet at connections to terminal devices, reduced to 6 feet at the University.
605.1: Thermal acoustical lining materials shall not be installed within ducts, terminal boxes, sound traps and other in-duct systems serving areas such as operating rooms, delivery rooms, etc., unless terminal filters with 90% efficiency (MERV 14) are installed downstream of the duct lining.

2. Pressure relationships shall comply with CMC requirements. For rooms not listed in Table 4-A, comply with requirements stipulated elsewhere in CMC. Maintain a negative air balance in:
   - Waiting areas.
   - Rooms that are not cleaned regularly (such as mechanical and electrical rooms).
   - Rooms that have the possibility of generating odors (such as break rooms and locker rooms).
   - Rooms that generate a significant amount of heat and are maintained at higher than normal temperatures.
   - Ceiling spaces.

C. OSHPD 3 Requirements

1. For clinical spaces and ambulatory surgery centers that are not part of OSHPD 1 critical care hospitals, design HVAC systems for full OSHPD 3 compliance as described in the California Mechanical Code (CMC). Significant design requirements are described in the following sections of the 2013 CMC, although all applicable requirements in the CMC must be followed.

325.3: Temperature and humidity control for sensitive areas or rooms (applicable if special procedures are to be performed in the OSHPD 3 facility, such as outpatient surgery).
326.0: Emergency power requirements are applicable for surgical clinics only.
402.0: This section on ventilation air shall not be used for OSHPD 3 facilities. Fresh air ventilation by means of natural ventilation (windows) shall not replace mechanical ventilation.
403.0: Fresh air ventilation rates shall not be determined in accordance with 403.1 through 403.6 calculation methods.
407.0: Ventilation system for OSHPD 3 shall comply with requirements of 407.1 through 407.5, and Table 4-A. Please note requirements for waiting areas in primary care clinics in Table 4-A. Where specific room types are not listed in Table 4-A, then provide a minimum of 6 air changes per hour of outside air for 100% outside air

systems, and a minimum of 6 air changes per hour of total air and 2 air changes per hour of outside air for systems that recirculate air. Airflows in Table 4-A are the minimum required at all times; actual airflow rates required to maintain room temperatures listed below will normally result in higher air change rates. In VAV systems, minimum ventilation rates shall not drop below air change rates in Table 4-A.

407.5: Variable air volume systems shall include VAV boxes in exhaust/return ducts from each zone; exhaust/return VAV boxes shall modulate in conjunction with supply air VAV boxes.

408.0: Air handling system filtration shall comply with requirements of 408.1, 408.2, 408.4, and Table 4-B. Air handling systems serving rooms with direct patient contact or clean supplies in a licensed clinic, including waiting rooms, shall have pre-filters with minimum 30% efficiency (MERV 8), and final filters downstream of supply fans and cooling coils with minimum 90% efficiency (MERV 14).

409.0: Ductwork for OSHPD 3 clinics shall comply with requirements of 409.1 through 409.4.

412.0: Comply with requirements for boiler, mechanical, and electrical rooms.

413.0: Odorous rooms shall be exhausted at a minimum rate of 10 air changes per hour.

414.0 - 417.0: If the clinic is to include airborne infection isolation rooms or protective environment rooms, then they shall comply with the requirements of these sections.

602.1 & 407.4.1.4: Ceiling spaces or other concealed spaces shall not be used as ducts or plenums. All supply, return, and exhaust ventilation shall be ducted to ceiling inlets and outlets.

602.3.1: The use of flexible duct is limited to 10 feet at connections to terminal devices, reduced to 6 feet at the University.

605.1: Thermal acoustical lining materials shall not be installed within ducts, terminal boxes, sound traps and other in-duct systems serving areas such as operating rooms, delivery rooms, etc., unless terminal filters with 90% efficiency (MERV 14) are installed downstream of the duct lining (applies to OSHPD 3 surgical clinics only).

2. Pressure relationships shall comply with CMC requirements. For rooms not listed in Table 4-A, comply with requirements stipulated elsewhere in CMC. Maintain a negative air balance in:
   - Waiting areas.
   - Rooms that are not cleaned regularly (such as mechanical and electrical rooms).
   - Rooms that have the possibility of generating odors (such as break rooms and locker rooms).
   - Rooms that generate a significant amount of heat and are maintained at higher than normal temperatures.
   - Ceiling spaces.

D. Seismic Design Criteria:

1. Work with the project structural engineer to identify project specific seismic criteria in accordance with the CBC and Chapter 13 of ASCE 7-10, including seismic design category, risk category, importance factor, seismic design force parameters, interstory drift, and seismic relative displacement requirements.

2. Show equipment weights in equipment schedules. Where available from the manufacturer, include the height and location of the center of gravity.

3. Detail seismic restraints for rigidly mounted and isolated equipment on the Construction Documents. Suspended equipment mounted with isolators shall be seismically braced using cables. Floor mounted isolated equipment shall use isolators with snubbers, either integral to or separate from the isolators. Floor mounted isolators (spring or neoprene) shall be rated for seismic loading. Non-rotating, fixed equipment shall be anchored directly to the structure.

4. Specify when seismic bracing of suspended utilities is explicitly required by the Building Code. For OSHPD projects, all piping over 1" size, trapezes weighing over 10 pounds per lineal foot, conduits over 3" size, ductwork over 6 square feet, and in-line HVAC equipment exceeding 75 pounds require a designed bracing system with details and structural calculations. Seismic restraints for suspended ductwork, piping, and conduits may be detailed on the drawings or, alternatively, a current OSHPD Preapproval of Manufacturer's Certification (OPM) seismic restraint system can be specified. If an OPM is specified, then project-specific seismic restraint shop drawings showing the locations and details for all restraints must be provided by the Contractor and reviewed during the Construction phase by the MEOR/EEOR and SEOR (this requirement should be included in the specifications or as a general note on the Construction Documents). If an OPM is specified, then require that a copy of the approved OPM to be maintained on the jobsite, and that seismic restraint shop drawings refer to all relevant details in the OPM.

5. When seismic bracing is not explicitly required by the code, the Construction Documents should include a requirement for the Contractor to install sway bracing whenever unbraced swaying utilities could swing and hit something that could cause damage. This can be Contractor-designed and is generally field-verified by pushing sideways on the piping/conduit and seeing how much it moves and whether anything nearby is susceptible to damage in an earthquake.

6. Specify flexible connections between fixed/braced equipment and unbraced distribution systems. Specify flexible connections between isolated equipment and connected distribution systems.

7. Special Seismic Certification: For OSHPD buildings rated SPC-3 or better and all buildings where nonstructural components have an importance factor (I_p) of 1.5, require that non-exempt mechanical or electrical equipment and components have Special Seismic Certification in accordance with 2013 CBC Section 1705A.12 and ASCE/SEI 7-10 Section 13.2.2. Equipment and components requiring Special Seismic Certification and certification procedures are clarified in OSHPD Code Application Notice CAN 2-1708A.5, available at website http://www.oshpd.ca.gov/FDD/Regulations/pinscans.html (this CAN is for the 2007 code but provides clarifications that is not available for the 2013 CBC). Acceptable procedures for Special Seismic Certification include Analysis, Shake Table Testing, and Experience Data, as described in 2013 CBC Section 2-1705A.12. Wherever practical, specify equipment with OSHPD Special Seismic Certification Pre-Approval (with currently effective OSP number).

8. All specified concrete anchors must have a current ESR Report indicating acceptance for use in cracked concrete.

E. Emergency and Standby Power Provisions

The following mechanical equipment in OSHPD 1 facilities shall be on emergency power and shall remain in operation during periods of utility power outage:

- All supply, return, and exhaust fans.
- Heating systems and controls.
- HVAC monitoring and control systems.
- Humidification equipment.
- Fire and smoke dampers.
- Alarms for airborne infection isolation rooms and protective environment rooms.
- Supplemental equipment room air conditioning equipment, with approval by Facilities.

For OSHPD 3 and non-OSHPD facilities, establish and coordinate emergency and standby power requirements for HVAC equipment and systems for code compliance. For equipment and systems not required by code to be on emergency power, consult with the University if certain equipment and systems are required to remain in operation during periods of utility power outage.

For all facilities, connect air conditioning equipment for telecommunication rooms to emergency or standby power sources.

F. Indoor and Outdoor Criteria for Heating and Cooling Load Calculations

Heating and cooling load calculations shall be based on methods outlined in the ASHRAE Load Calculation Applications Manual. Additionally provide energy modeling as necessary to achieve LEED point criteria and/or PG&E Savings by Design incentives, and to perform life cycle cost evaluations of design options. Load calculations shall be done using an approved computer program such as Trane Trace or Carrier HAP. Energy simulations shall be performed using an approved computer program such as EnergyPro, eQuest, or equal DOE-2 based simulation program. Life cycle cost analyses are only required where specifically called for in the project program or design professional's scope of services. At approximately 50% construction documents, submit engineering calculations that are the basis of design for review by the University.

Design parameters and sizing criteria shall be as follows unless otherwise directed in the project program or agreed upon to meet specific project requirements. Comply with CMC Table 325.0 - Heating, Cooling, and Relative Humidity Requirements for Sensitive Areas or Rooms.

TABLE 23-1
PARAMETERS FOR HEATING AND COOLING LOAD CALCULATIONS

OUTDOOR & INDOOR DESIGN CRITERIA	MEDICAL AND ADMINISTRATIVE OFFICES, ETC.	ACUTE CARE PATIENT AREAS AND ROOMS	TABLE 325.0 SENSITIVE AREAS & ROOMS
Summer design dry bulb (DB) & mean coincidental wet bulb (WB)	84° F DB & 65° F WB	84° F DB & 65° F WB	87° F DB & 66° F WB
Use the following ambient temperature selecting air-cooled rooftop equipment	95° F DB	95° F DB	95° F DB
Winter design - Outdoor	38° F DB	35° F DB	35° F DB
Summer design - Indoor (1)	74º F	70º-75° F & RH (2)	Per CMC Table 325.0 (2)
Winter design - Indoor (1)	70º F	70º -75° F & RH (2)	Per CMC Table 325.0 (2)
Minimum outside air changes	2	Per CMC Table 4-A	Per CMC Table 4-A
Minimum total air changes	4	Per CMC Table 4-A	Per CMC Table 4-A
Single Room Cooling Load Calculations			
Internal loads: people	1.0 x room peak	1.0 x room peak	1.0 x room peak
Internal loads: Lighting	1.0 x room peak	1.0 x room peak	1.0 x room peak
Internal loads: Equipment (3)	1.0 x room peak	1.0 x room peak	1.0 x room peak
Envelope load	1.0 x room peak	1.0 x room peak	1.0 x room peak
Safety factor	+10% sensible load	+10% sensible load	+10% sensible load
Main Duct and Central Cooling Coil Sizing for AHUs Serving One Floor			
People load	0.80 x sum of room peaks	0.90 x sum of room peaks	0.90 x sum of room peaks
Lighting load (with lighting controls)	0.80 x sum of room peaks	0.80 x sum of room peaks	0.90 x sum of room peaks
Equipment load	0.80 x sum of room peaks	0.80 x sum of room peaks	0.90 x sum of room peaks
Envelope load	1.0 x sum of room peaks if AHU serving one Façade; 0.8 x sum of room peaks if AHU serving multiple facades	1.0 x sum of room peaks if AHU serving one Façade; 0.8 x sum of room peaks if AHU serving multiple facades	1.0 x sum of room peaks if AHU serving one Façade; 0.8 x sum of room peaks if AHU serving multiple facades
Ventilation load	1.0 x total ventilation load	1.0 x total ventilation load	1.0 x total ventilation load
Supply fan and main duct sizing, constant air volume (CAV) systems	Sum of room CFM	Sum of room CFM	Sum of room CFM
Supply fan and main duct sizing, variable air volume (VAV) systems	0.90 x sum of room CFM	0.90 x sum of room CFM	0.90 x sum of room CFM
Main Duct and Central Cooling Coil Sizing for AHUs Serving Multiple Floors			
Block load diversity - People	0.75 x sum of total room people	0.80 x sum of total room people	0.80 x sum of total room people
Block load diversity - Lights	0.75 x sum of total	0.80 x sum of total	0.80 x sum of total

	room lights	room lights	room lights
Block load diversity - Equipment	0.60 x sum of total room equip.	0.70 x sum of total room equip.	0.70 x sum of total room equip.
Block load diversity - Envelope	1.0 x sum of room peaks if AHU serves one Façade; 0.8 x sum of room peaks if AHU serves multiple Façades	1.0 x sum of room peaks if AHU serves one Façade; 0.8 x sum of room peaks if AHU serves multiple Façades	1.0 x sum of room peaks if AHU serves one Façade; 0.8 x sum of room peaks if AHU serves multiple Façades
Block load diversity - Ventilation	1.0 x total ventilation load	1.0 x total ventilation load	1.0 x total ventilation load
Supply fan and main duct sizing, constant air volume (CAV) systems	Sum of room CFM	Sum of room CFM	Sum of room CFM
Supply fan and main duct sizing, variable air volume (VAV) systems	0.85 x sum of room CFM	0.85 x sum of room CFM	0.85 x sum of room CFM
Supply duct if outside - heat gain & loss (4)	5%	5%	5%
Central Heating Coil Sizing			
Envelope load	1.0 x sum of room peaks	1.0 x sum of room peaks	1.0 x sum of room peaks
Outside air load	1.0 x total ventilation load	1.0 x total ventilation load	1.0 x total ventilation load
Morning warm-up add to heating coils in AHU	25% if not 24/7	0	0

DB = Dry Bulb   WB = Wet Bulb   ACH = Air Changes per Hour

Notes:

(1) Establish temperature control accuracy (± 1° F, ± 2° F, etc.) required for each space. Establish specific indoor temperature criteria for each specialized occupancy. Room temperatures shall be setpoint controllable, with controls to reset room temperature setpoint and/or control range based on a time-of-day schedule and/or occupancy.

(2) Establish upper and lower limits for relative humidity (RH) for each specialized occupancy and whether or not setpoint control and active humidification or dehumidification equipment are necessary. Unless otherwise directed, relative humidity shall be allowed to float within its acceptable range, and shall be controlled (with humidification or dehumidification sequences) when it is out of range.

(3) Calculated load may have diversity factor applied to individual pieces of equipment or as a group, or not at all if it can be documented to the University that the diversity is not applicable.

(4) If main ductwork is substantially located outside or in unconditioned spaces.

G. Airside Diversity

Account for airside diversity in variable air volume (VAV) systems. Apply airside diversity in sizing air handling equipment and associated major cooling equipment. Do not apply diversity to sizing of branch ductwork, zone airflows, and diffusers. Discuss proposed diversity multipliers with the University prior to system selection. System components for which diversity should be considered include:

- Solar Heat Gain: Computer load program should determine maximum block load as well as zone peak loads. Each exposure will reach peak cooling conditions at a different time of the year.

- Equipment Heat Gain: Spaces will not reach design equipment heat gains simultaneously. Equipment heat gain diversity multipliers of 50 percent to 75 percent can be realized with VAV systems.

H. Lighting and Equipment Loads

Air conditioning loads shall be based on specific lighting and equipment in each space, including allowances for identified future equipment. Utilize diversity factors to establish building block loads for equipment sizing. Where specific loads are not available (early in the design), design for the following minimum lighting and equipment loads:

Room Classification	Lighting, Watts/ Sq. Ft. (7)	Equipment, Watts/ Sq. Ft. (6)
Corridors	1.0	0.5
Patient Rooms (1)	1.5	1.5
ICU Patient Rooms	1.5	2.0
Patient Holding Areas (2)	1.5	1.5
Waiting Areas	1.0	1.0
Operating Rooms, Cath Labs	2.5	8.0 (3)
Delivery Rooms	2.0	0.5 (3)
Nurseries	1.5	0.5
Treatment/Exam Rooms	1.5	0.5
Emergency Dept. Trauma Rooms	2.0	5.0
Imaging Procedure Rooms	1.5	10.0 (4)
Pharmacy/Medicine Rooms	1.5	4.0 (5)
Clinical Laboratory Areas	1.5	5.0 (6)
Soiled Workrooms	1.2	4.0
Clean workrooms	1.2	2.0
Offices and Admin Areas	0.9	2.5
Toilet & Housekeeping Rooms	0.6	0.5
Storage and Receiving Rooms	0.8	0.5
IT Rooms	1.0	50.0

Notes:

(1) Including protective environment rooms and airborne infection isolation rooms.
(2) Including PACUs and similar areas.
(3) Estimate realistic equipment loads based on programmed equipment and surveys of similar spaces.
(4) Evaluate loads based on imaging equipment, other room equipment, and appropriate percentages of "on-line" and "stand-by" operating modes. Separately evaluate loads in control and equipment rooms.
(5) Assess pharmacy equipment, hoods, and quantity of Pyxis or other medicine dispensing machines.
(6) Clearly document design loads, usage factors, and assumptions for each room. Equipment loads shall be as realistic as possible, recognizing both initial requirements and allowances for future loads. Do not overstate equipment loads and design systems to accommodate lighter than anticipated loads.
(7) Lighting loads shall be based on the actual lighting design for the building spaces. Utilize diversity factors for automatic lighting controls (e.g., occupancy and daylighting controls) to establish building block loads for HVAC system sizing.

I. Occupant Loads

Air conditioning loads shall be based on actual occupancy estimates for and activities within each room. Utilize diversity factors listed above and agreed upon with the University to establish building block loads for equipment sizing. Where occupancy estimates are not available, design occupancy densities based on California Code of Regulations Title 24:

For Staff:

Sensible	=	345 Btuh/person
Latent	=	435 Btuh/person

For Patients:

Sensible	=	255 Btuh/person
Latent	=	255 Btuh/person

Confirm final patient and staff densities with the Architect and the University.

J. Exterior Loads

For new buildings, assist the Architect and the University in evaluating building orientations, materials, and systems to minimize heat gain and loss in the building.

For renovations, calculate external loads at design outdoor and indoor conditions using actual building envelope data. For older buildings, evaluate infiltration based on actual glazing and room pressurization.

K. Ventilation and Airflow Requirements

1. In OSHPD buildings, outside air delivery to individual rooms shall comply with CMC Table 4-A. For rooms not listed in Table 4-A, provide a minimum of 2 air changes per hour of outside air, unless the room is required to be under negative pressure and has minimal cooling load, in which case air changes shall be dictated by pressurization requirements. Rooms not listed in Table 4-A shall be provided with more than 2 air changes per hour of outside air if necessary to meet cooling loads and comply with requirements in the following paragraph.

2. In non-OSHPD buildings, outside air brought into a building for ventilation and indoor air quality shall conform to the latest edition of ANSI/ASHRAE Standard 62.1, California Mechanical Code, and California Energy Code for Ventilation for Acceptable Indoor Air Quality, whichever is more stringent. The minimum design quantity of outside air shall be that determined according to the standards plus an additional 20 percent. Higher outside air volumes may be considered to achieve LEED Indoor Environmental Quality credits.

3. Building air intakes shall be located so that they do not introduce foul air (i.e., near cooling towers, exhausts, vehicle emissions, garbage dumpsters, generator exhausts, exhaust discharge from other buildings, etc.).

4. In determining heating and ventilating air quantities, consider all factors that may affect air quantity and use the largest resulting quantity:
   - Air changes required by code.
   - Air changes recommended by infection control guidelines or other clinical imperatives.

- Air changes required to heat or cool the space or control humidity.
- Make up air required for non-recirculated spaces, kitchen hoods, or other special exhausts.
- Air changes necessary to achieve LEED Indoor Environmental Quality credits for indoor chemical and pollutant source control.

5. Heating: Criteria for supply airflow shall be based on the reduction of objectionable air currents in the occupied zone per ASHRAE Standard 55. Supply air temperature required to meet the space heating load should not exceed 90° F (up to 100° F allowed under special conditions).

6. Cooling: Airflow required to cool a space that is not mechanically cooled shall be based on a maximum allowable air temperature rise within the occupied zone of not more than 10° F above the coincident outside air temperature. Where operable windows are present and the space does not require high efficiency air filtration or pressurization control (non-OSHPD spaces only), the required airflow may be the combined volumes of mechanically supplied and natural ventilation.

7. Diversity: All heat sources, gains and losses, must be properly accounted for, with due regard to diversity and timing of intermittent loads.

8. Provide mechanical ventilation for enclosed stairwells, trash rooms, elevator machinery rooms, mechanical equipment rooms, and electric equipment rooms as follows:
   - Provide supply and exhaust air to electrical and elevator equipment rooms in quantities sufficient to prevent a temperature rise that would impair proper equipment operation. Where solid state controls are used, establish appropriate room temperature criteria. Filter supply air if it is not from the filtered building system. Evaluate mechanical cooling options for rooms with high heat gains requiring large air volumes.
   - Provide exhaust only for trash rooms, maintaining a negative pressure in the room to confine odors.
   - Provide sufficient supply and exhaust ventilation to mechanical and electrical equipment rooms to prevent temperatures above 90°F. Use a minimum of one cubic foot per minute per square foot for cool rooms and two cubic feet per minute per square foot for hot rooms.

L. Recirculation and Exhaust

1. Most patient care areas at the University are 100% exhausted. For special conditions, such as recirculation in individual patient rooms, procedure rooms, or operating rooms to increase total air changes without increasing outside air demand, discuss air quality and acceptability of air recirculation with the University and the University’s Department of Hospital Epidemiology and Infection Control.

2. For non-patient areas, recirculation of HVAC system air is useful to reduce peak loads and energy requirements. During occupied periods, system dampers/controls must be configured to provide at least the minimum required outside air by utilizing a separate minimum outside air damper section and actuator. Controls for systems with mechanical cooling shall include an economizer sequence.

3. Exhaust all air for the rooms listed below or any other rooms with odorous or hazardous airborne materials that should not be recirculated:

- Waiting areas.
- Toilet rooms.
- Janitors' closets.
- Spaces and storage rooms where dirty, noxious, or hazardous materials are used or stored

4. Consider common general exhaust systems to serve related areas. Design separate exhaust systems for airborne infection isolation rooms, fume hood and biological safety cabinet exhaust, wet exhaust, grease exhaust, or other special exhaust. Review combined exhaust systems with the University.

M. Air Conditioned Spaces

1. Air conditioning for occupant comfort is not mandatory in non-OSHPD buildings. Where conditions indicate potentially high internal or solar heat loads, discuss air conditioning options, or provisions for its future addition, with the University. In general, mechanical cooling shall be provided for the following spaces:
   - All patient care areas and waiting areas
   - Computer facilities
   - Food preparation areas
   - Clean and/or sterile storage areas
   - Spaces with high internal heat gains
   - Clinical pharmacies and laboratories
   - Other spaces where the need is clearly demonstrated.

2. Differentiate areas requiring conditioned air from those requiring only ventilation, and design systems accordingly.

N. Telecommunication rooms (MDF, BDF and IDF rooms) with microprocessor equipment and computer rooms shall be cooled to maintain conditions required by the equipment. Confirm individual room temperature and relative humidity criteria with the Medical Center's information technology services manager. Maintain continuous and dedicated environmental control (24 hours per day, 365 days per year). Note that the equipment can operate at a higher temperature than would be considered for an occupied space. If the telecommunication equipment room is not occupied, then room temperature shall be based on the equipment requirements. Provide supplemental air conditioning where ventilation alone would demand excessive air changes, or where the ventilation system does not run 24/7. Connect supplemental cooling equipment to the equipment branch of the emergency power system if available. Evaluate rack-mounted cooling systems for large computer rooms with high-density server racks.

1. If mechanical cooling is provided, then additionally provide back-up ventilation or a back-up unitary air conditioning unit that will keep the room below its maximum temperature limit in the event the primary air conditioning system fails.

O. Other High Heat Load Environments:

1. Unless equipment requires continuous User interaction, locate high-heat-load equipment in separate rooms or partitioned areas. Control environment to temperature recommended by manufacturer, but not greater than 86°F.

2. Design separate or supplemental chilled water or unitary cooling systems for spaces with high heat load or off-hour cooling requirements. Use of DX fan coil units with outdoor

condensing units should only be considered if alternative cooling methods are not available. The use of DX cooling shall be specifically approved by Facilities. Condensing units have a very short life expectancy on the Parnassus and Mt. Zion campuses.

3. Provide direct exhaust of excess heat whenever practical. Strategically place exhaust air inlets at locations where equipment heat is rejected.

P. Elevator equipment rooms shall be ventilated and/or conditioned to meet the elevator manufacturer's requirements. Where solid state controls are used, establish appropriate room temperature criteria. Transfer air from conditioned spaces may be used to cool elevator equipment rooms, with appropriate fire smoke damper protection.

Q. Electrical rooms shall be ventilated only to maintain room at less than 85°F. Main building transformers should be located outdoors, where possible.

R. Zoning of spaces shall follow good design practice with respect to core versus perimeter spaces, exposure and shall comply with the following:

1. All patient rooms, treatment/exam rooms, nurses' stations, procedure rooms, reading rooms, and all sensitive rooms listed in CMC Table 325 shall have individual room temperature control.

2. Exterior offices or other administrative areas with same exposure may be on the same zone (up to four offices).

3. Corner offices with glazing on west, east, or south exposures shall have a separate zone.

4. Separate zones shall be provided for executive offices, conference rooms, and large meeting rooms, and large team rooms.

5. Normally non-occupied spaces with minimal cooling loads may be part of adjacent zones. Do not locate thermostats in the non-occupied space.

6. In non-OSHPD buildings, high occupancy spaces such as conference rooms shall be controlled using occupancy sensing to ensure that when in unoccupied mode, the ventilation to the space is reduced to near zero or turned completely off if conditioned by a separate system. Provide demand control ventilation and carbon dioxide sensors as stipulated in the California Building Energy Efficiency Standards.

7. Spaces that are not similar in occupancy and loading shall not be zoned together.

S. Install thermostats at readily accessible locations. In patient and procedure rooms, preferred locations shall be where the thermostat will read the average room temperature felt by the patient. In offices and conference/meeting rooms, preferred locations shall be next to doors on the strike side (with door open or closed). Thermostats shall not be installed on outside walls, near supply diffusers or heat sources, or where primary throw from supply diffusers wash over the thermostat. Standard height shall be at 48" to the top. If thermostats are installed over counters then the height shall be at 44" to the top.

T. Off-Hour Operation in Non-Clinical Buildings: During off-hours the environmental systems (lighting, heating, cooling, and ventilation) will be reduced to minimum levels consistent with safety. Room(s) with different operating hours shall be designed to avoid turning on large parts of the building HVAC system to accommodate use (i.e., computer rooms).

U. New Shafts: Provide shafts at least 25% larger than required for ductwork and piping for future use. Provide access panels or doors to allow access to shafts for future installation of piping or ductwork. Wherever new pipe risers are installed, provide branch stubouts with valve and cap for future use on each floor.

V. System Design Parameters:

1. A stand-alone building is a building that is not connected to utilities produced in the campus Central Plant. To facilitate operations and maintenance, space heating and steam boilers shall be located in a mechanical basement or on the first floor. Provide generous service space for the boilers and plan for equipment service and replacement.

2. Boilers: Industrial quality, steel, flexible-tube, water tube boilers having a full-load efficiency of not less than 85 percent and a turndown ratio of at least 1:4 shall be selected. The primary fuel for boilers shall be natural gas. Gas fired boilers shall be provided with low NOx burners for compliance with BAAQMD requirements.

3. Heating Water Systems: For buildings with boilers, design heating water systems at not more than 180°F with large heating coils selected for a minimum of 40°F drop in temperature and small re-heat coils selected for a maximum of 30°F drop.

4. Chilled Water Systems:

a. Chilled water supply differs from campus to campus and within each campus and/or building. OSHPD 1 buildings typically have dedicated chillers. Supply water temperature ranges between 42° to 46° F.

b. Chilled water pumps are generally not required in campus buildings, as adequate differential pressure may be available in the chilled water loop. The design team shall check with Facilities on estimated differential pressure available at the project site. New chilled water pumps shall be controlled using variable speed drive technology. Controller shall use a differential pressure sensor as the primary control to maintain adequate operating pressure.

c. Selection criteria for cooling coils:
- Entering chilled water temperature: 45° F
- Water temperature rise: 16° F
- Maximum water pressure drop: 10 feet w.g.
- Chilled water coil face velocities:

System Type	**Maximum Coil Face Velocity at Design Airflow (FPM)**		
	Annual Operating Hours		
	8am - 5pm M-F	8am - 11pm M-F, or 8am - 5pm everyday	8am - 11pm 7 days a week, or 24/7
Constant Volume	350	325	300
Variable Air Volume @ peak airflow	450	425	375

d. Two-way single seated control valves shall be used for control at main chilled water coils. Smaller coils may use industrial quality characterized ball valves. Provide normally closed control valves. Provide thermometers and pressure test ports on the inlet and outlet of the coil(s) and on the building supply line. Provide globe-style circuit balancing valves at each control valve and on each branch of multi-section coils.

e. Connect to campus chilled water as directed by the University to comply with the campus chilled water master plan.

f. Piping in utility tunnel and trenches shall be welded steel pipe.

g. Chilled water piping shall use ball or flanged butterfly valves for shutoff service as appropriate for the line size.

h. Branch piping to building shall be sized on building block load. Size pipe based on a maximum of 4 feet w.g. pressure loss per 100 feet of pipe using the Darcy-Weisbach equation for the appropriate pipe material.

i. Check if existing pipe taps are available for connection. If not, connection to existing shall be hot tapped, or connection shall be made during a scheduled off-hour CHW shutdown.

j. Air separators and expansion tanks are not required in buildings using central plant chilled water. Stand-alone buildings with chilled water shall have air separator located on the suction side of the pump.

5. Air Distribution Systems:

a. Design low pressure loss duct systems for energy efficiency and low noise.

b. Install above-ceiling supply and exhaust air terminals as close to the ceiling as practical to facilitate adjustment and servicing. The top of air terminals, particularly supply air terminals and heating coils, should be no more than 3 feet above the ceiling.

c. In OSHPD buildings, provide variable air volume or constant air volume terminal units in exhaust ducts from each zone. Exhaust VAV boxes shall modulate in conjunction with supply air VAV boxes to maintain constant airflow differentials in each space.

d. Room Air Distribution: Work closely with the Architect and the University to achieve effective airflow patterns in all spaces. Where displacement ventilation is not used, select high-aspiration ceiling supply diffusers sized and located for effective mixing of room air at maximum and minimum airflow, so that little or no thermal stratification occurs. Air velocity in the occupied zone shall be less than 50 fpm. Follow design guidelines in 2011 ASHRAE Handbook - HVAC Applications - Chapter 57 - Room Air Distribution, and 2012 ASHRAE Handbook - HVAC Systems and Equipment - Chapter 20 - Room Air Distribution Equipment.

W. HVAC Noise Control

1. HVAC systems shall be designed to not exceed background noise levels listed below. For areas not listed below, design to NC levels listed in the 2011 ASHRAE Handbook - HVAC Applications, Chapter 48 - Noise and Vibration Control, Table 1. Where appropriate, the

design team shall retain an acoustical consultant to review design approaches and details to assure that HVAC noise levels in occupied spaces.

Room Classification	Maximum NC
Patient Rooms, LDRs, and LDRPs	30
ICUs, PACUs, and Nurseries	30
Individual Offices and Conference Rooms	30
Waiting Areas	35
Patient Holding Areas, pre-treatment	35
Operating Rooms and Cath Labs *	35
Treatment and Exam Rooms	35
Imaging Procedure Rooms *	35
Radiology Reading Rooms and Charting Rooms	35
Nurses Stations and Similar Open Work Areas	35
Patient Area Corridors	35
Dining Rooms	35
Break Rooms, Locker Rooms, and Similar Spaces	35
Open Administrative Areas	35
Clean and Soiled Workrooms, Supply and Storage Rooms	40
Pharmacies and Laboratories	40
Food Prep Areas	40
Dishwashing Rooms	45

***** Excluding the noise contribution of medical equipment.

Noise levels for design compliance exclude noise from University equipment, personnel located within spaces, or non-HVAC ambient noise from outside the space.

2. Fans in air handling units shall be selected for efficient and quiet operation. Review air handling unit inlet and discharge octave band sound power levels, perform noise calculations, and determine necessary silencer insertion losses (if applicable). If the project has an acoustical consultant, then furnish fan and air handling unit submittals and sound power levels and coordinate appropriate sound attenuation methods. Provide horizontal ducts at the discharge of air handling units so that noise control may be applied in the horizontal ducts before the ducts enter occupied spaces.

3. Exhaust fans should be selected for efficient and quiet operation. Duct elbows should be located at least three (3) diameters upstream of exhaust fan inlets. The design of the ductwork should leave enough duct length so that silencers and/or lined duct may be installed if determined necessary.

4. For existing fans to be reused, require dynamic balance verification and rebalancing to ensure that the fans operate at the minimum possible fan speed, static pressure, and noise levels.

5. Flow-generated noise is as important a consideration as fan noise in designing HVAC systems. If the project has an acoustical consultant, then furnish plans with main ducts and velocities highlighted to allow analysis of flow noise once the HVAC system and layout have been established. Comply with maximum duct velocities elsewhere in these guidelines. Incorporate the following guidelines for flow noise mitigation:

- To reduce pressure drop of duct fittings and therefore to reduce flow generated noise, use low pressure-drop duct fittings. Locate duct fittings away from each other to avoid additional pressure drop caused by "system effects", and rumble noise. Use smooth transitions, with long radii, and straight ducts at the entry into all rooms and air terminal devices. Avoid using ductwork with large aspect ratios, particularly near the fans.
- Whenever possible, large ducts should not run above noise sensitive spaces, such as patient rooms, to avoid duct breakout noise problems. Consider 5/8" sheet rock beneath duct to reduce noise.
- Insulated flexible ducts are effective products for noise control. When using flexible ducts, branch ductwork should be installed as high as possible and drop vertically to diffusers and grilles using long radius elbows. Crimped or angled flexible duct connections at diffusers should not be accepted.
- Duct volume dampers should be installed as far from diffusers and grilles as possible. The use of opposed blade dampers or other restricting devices directly behind the face of diffusers and grilles should be prohibited.

6. Select diffusers and grilles with manufacturer's catalogued NC level 5 points or more lower than the NC requirement of the space served. This is because the manufacturer's NC data are measured in rooms with highly absorptive surfaces and a uniform air velocity distribution throughout the neck of the diffuser. Select diffusers and grilles with even lower NC levels where the design places diffusers or grilles in close proximity to one another. To reduce airflow noise at diffusers and grilles, ducts should be hung as high as possible, and drop vertically to the diffusers through flexible ducts.

7. Plumbing Systems: Support all water piping, both supply and waste water, in both horizontal and vertical runs, through Acousto-Plumb system, or equal, resilient plumbing support isolators. For pipes that cannot use Acousto-Plumb isolators, use a resilient wrapping or clamp system employing an element of wool, felt, neoprene, or other suitable materials, such as felt lined hangers, Tolstrut cushion strip and neoprene isolators, Superstrut Cush-A-Strip, Cush-A-Clamp, or equal.

8. Vibration Isolation:
   - Isolate rotating mechanical equipment from building structure by means of vibration isolators. Provide flexible connections to all rigidly supported ductwork and piping which connect to resiliently supported equipment. Provide looped and flexible electrical conduit connections to allow free motion of isolated equipment.
   - If the project has an acoustical consultant, then specify vibration isolation methods as recommended. If the project does not have an acoustical consultant then specify vibration isolation for large pieces of equipment mounted above ground level according to 2011 ASHRAE Handbook - HVAC Applications, Chapter 48 Noise and Vibration Control, Table 47 Selection Guide for Vibration Isolation.

23-5 GENERAL MECHANICAL REQUIREMENTS

A. Maintenance Access Requirements

1. Design the installation so that access is possible to all valves, dampers, expansion joints, fire dampers, motors, filters, control devices, instrumentation and other products requiring access for servicing, adjustment, repairs, replacement or maintenance. In renovated areas, maintain access to all existing devices.

- Show ceiling access openings on design drawings and require that they be shown on shop drawings.
- Show ceiling access openings as blocked out areas on BIM models so that clash detection will identify obstructions that pass through access spaces.

2. Design the installation so that normal operations such as operating valves, cleaning strainers, servicing or replacing equipment and control devices, draining and venting hydronic systems, replacement of filters, and lubrication of bearings, etc., can be performed safely while standing on a floor or ladder.

3. Group concealed valves, dampers, controls and equipment requiring service access, such as heating coil control valve assemblies, so as to be accessible through a minimum number of ceiling tiles or access doors. Require that ceiling access openings are clear of piping, conduits, wires, bracing, supports, and similar items that might inhibit access.

4. During the design, coordinate the quantity and approximate locations of ceiling access openings and access doors. Require the Contractor to coordinate exact quantities and locations. Do not permit valves, controls, and other devices to be installed in walls or areas that cannot be adequately accessed.

5. Provide lifting eyes or rails in the structure above sump pits or heavy equipment to aid in equipment removal. Size to suit equipment weight.

6. Mechanical room piping shall be arranged to maintain minimum 7’-0” headroom and 3’-0” wide clear passageways. Route piping along walls to floor sinks/drains to avoid potential tripping hazards. Piping in mechanical rooms shall be exposed and all valves and specialties shall be readily accessible.

7. Wherever ductwork and piping run horizontally across roof, indicate minimum clearances above the roof and methods of attachment that facilitate future roofing.

B. Phased Construction and Temporary Use

1. Should construction and occupancy occur in phases, with the University taking occupancy at the end of each phase, include specific provisions so that mechanical systems serving occupied areas are complete and operable at the end of each phase. Where necessary, include provisions for temporary mechanical and piping systems to allow University occupancy. Where systems have not been turned over to the University, which may not occur until Final Acceptance of the project, require that the Contractor provide labor and materials, including temporary utilities and controls, to operate new systems for the University’s use until the entire project is complete.

2. Specify interim testing and balancing to allow partial occupancy of project areas. Where required, HVAC systems shall operate continuously during all phases of construction.

C. Existing Utility Shutdowns and Demolition

1. Determine and discuss utility shutdowns and shutdown options with the University at appropriate times during the design so that appropriate planning can occur and the design can be tailored to minimize the extent of disruptive shutdowns.

2. For shutdowns or demolition that affects occupied areas, require that utility shutdowns only occur during time periods designated by the University. Require that piping, ductwork and/or controls be prefabricated, installed to the extent possible, and ready for final connection to keep shutdown durations to an absolute minimum.

3. Shutdown of rotating equipment such as fans, pumps, compressors, and similar items shall be performed only by University personnel and not by the contractor. Require that the contractor provide written requests for utility shutdowns with sufficient notice for University planning and notification of affected departments.

D. Operating and Maintenance Manuals

1. Coordinate operating and maintenance manual submittals with Division 1 requirements. Require that Contractor submit two hard copies and one electronic copy of preliminary operating and maintenance manuals before work is 50 percent complete. Include a provision that no payment will be made for any mechanical work beyond 70 percent completion until the University's Representative has received preliminary operating and maintenance manuals. Require submittal of the corrected final operating and maintenance manuals not less than 30 days prior to scheduled training sessions. Final submittal shall include two hard copies (unless Division 1 requires more copies) and one electronic copy.

2. Operating and maintenance manuals shall include a complete set of accurate as-built shop drawings, approved submittal data for all serviceable products, instruction sheets, bulletins, and all pertinent information required by the University for proper start-up, maintenance, operation, and adjustment of each and every piece of equipment furnished. Include a copy of the final Test and Balance Report.

    a. Bind product information in adjustable loose-leaf 3-ring D-ring binders, typed and indexed into Sections following the alphanumeric system used in the Specifications, and tabbed for easy reference. Coordinate the quantity of hard copy manuals required; typically two copies are required in addition to electronic versions.

    b. Require that wiring diagrams be specific to the product/system provided, and that all non-applicable diagrams are crossed out in the manuals. Generic wiring diagrams are not acceptable.

    c. Require that product data sheets indicate the specific model provided, and that all models not provided are crossed out in the manuals.

    d. Require inclusion of final commissioning test sheets for individual systems, and indicate final pressure settings on all systems, including refrigerant charges in DX systems.

3. For large projects, the Contractor shall provide separate binders for related Specification Sections and word as follows, with tabs for each equipment item therein. Furnish separate binders for the following work:
    - Binder No. 1: Chillers, cooling towers, boilers, heat exchangers, pumps, variable frequency drives, motors, solids separators, air separators, suction diffusers, and other hydronic specialties.
    - Binder No. 2: HVAC piping, valves, hydronic instruments, chemical treatment, heating coils, seismic bracing, and related supports and insulation.
    - Binder No. 3: Plumbing piping, fixtures and trim, water heaters, fuel oil piping, storage tanks, fuel oil specialties and controls, and fire protection equipment.

- Binder No. 4: Air handling equipment, including coils, filters, variable frequency drives, motors, drives, and sound attenuation devices.
- Binder No. 5: Ductwork and duct accessories, including fire and smoke dampers, constant (or variable) volume terminal units, air inlets and outlets, and automatic dampers.
- Binder No. 6: HVAC controls.
- Binder No. 7: Final Test and Balance Report.
- Information can be combined in binders up to 2-1/2".

4. Required information for each type of equipment shall be included in the following sequence:
    - Equipment Summary Sheets: List all equipment, tag numbers, locations, manufacturer's name and model numbers, installing contractor's name, address and phone number, local service representative's name, address and phone number, and complete schedule of equipment operating data including motor, belt and sheave data.
    - Extended Warranties: Furnish separate signed warranty statements for each extended warranty. Clearly state warranty period, and all inclusions and exclusions. Indicate name, address and phone number for warranty calls.
    - Maintenance Summary Sheets, including:
        - List all required periodic inspections, testing, maintenance and lubrication, and references to page numbers within product literature for more complete instructions.
        - Type, size and replacement number for belts and sheaves. Indicate proper belt tension. Contractor shall furnish any special tools required to measure or obtain required this tension.
        - Bearing type, replacement number and size, recommended lubricant, and lubrication period shall be indicated for equipment with regreasable or oil-lubricated bearings.
        - For refrigerant systems, the quantity and type of refrigerant used, evacuation level achieved prior to filling system with refrigerant, and operating pressures at key points in the system.
    - Detailed Equipment Data Sheets, including:
        - Manufacturer's service manual.
        - Recommended spare parts lists.
        - Flow diagrams.
        - Troubleshooting tables.
        - Fan and pump curves.
        - Wiring diagrams
        - Exploded views.
        - Parts lists.
        - Optional accessories.
        - Assembly and disassembly instructions.
        - Detailed installation, start-up, operating and maintenance instructions.
        - Data for spring isolators and flexible connectors with related equipment.
        - Start-up and test reports for chillers, cooling towers, variable frequency drives, pumps, fans, and similar items.
    - Specify that the Contractor download all current web-based product and O&M information for all products furnished and burn onto DVDs or flash drives. Files shall be organized and indexed for easy retrieval.
    - Specify that the contractor create a comprehensive electronic version of the final approved O&M manual in PDF format. PDF files shall have sidebar

indices/bookmarks for easy routing to specific products within the O&M manual. Organize and index the electronic O&M manual similar to the hard copy versions.

E. Start-Up and Commissioning

1. Mechanical designs shall include provisions for mechanical system checking, start-up, testing, adjusting, balancing, fine-tuning, and troubleshooting as required to provide systems in proper operating condition and with optimum efficiency. Specify responsibility of Contractor to coordinate work and identify and resolve installation and operational problems during the start-up period. Where individual pieces of equipment are to be started up by, or under the supervision of, manufacturer's technicians or authorized representatives, require assistance from the Contractor as necessary to start up, test, and troubleshoot new systems and equipment.

2. Require that the Contractor to provide troubleshooting, fine-tuning, seasonal adjustments, and other corrective actions for one year following the date of Final Acceptance, including maximum 24-hour response to complaints or operational problems. Work performed during this period shall be considered warranty work.

3. At the outset of design, discuss requirements for HVAC system commissioning with the University and the project commissioning agent. Identify systems to be commissioned, commissioning standards to be followed, responsibilities of the various parties, preparation of functional performance test protocols, University training, and documentation for LEED Certification.

F. University Training

1. Familiarization Tours: During the course of construction, before ceilings are closed, specify that Contractor shall provide familiarization tours for University's operating personnel to acquaint them with new mechanical work and equipment locations.

2. During or immediately following system commissioning, specify that Contractor shall fully instruct the University's operating personnel in the operation, adjustment, and maintenance of mechanical equipment and systems as follows:
   - Contractor to provide the services of factory-trained instructors to provide on-site training for complex equipment and packaged systems, such as chillers, boilers, variable frequency drives, computer room air conditioning systems, humidification systems, packaged thermal storage systems, and pure water systems.
   - Contractor to provide instruction on new HVAC controls.
   - Contractor shall provide instruction on all other aspects of system operation and coordinate training sessions by above-noted instructors.
   - Where safe and efficient operation of mechanical systems is predicated on attendance at University training sessions, require that training sessions be professionally videotaped; provide four (4) DVD or flash drive copies of training video, including full written versions and appropriate references to operating and maintenance instructions.
   - Require written acceptance of training by University's Representative.

G. Mechanical Demolition in Occupied Buildings

1. Any demolition that will interrupt existing services to other floors or areas must not be done until after new ductwork, piping and/or controls serving these areas is prefabricated, installed to the extent possible, cleaned, tested, and ready for final connection.

2. Current or original design airflows shall be maintained at all times in occupied areas outside of the demolition area. For Hospital renovation projects, include detailed pre-demolition, post-demolition, intermediate, and final air balancing instructions as appropriate.

3. Trace existing piping to be removed and cap at mains or risers. Remove abandoned domestic water piping to the nearest active branch or main. University's Representative shall be advised of all required shutdowns in advance.

4. Wherever existing piping is cut and shall remain in service, provide threaded or flanged caps for pressure piping, and pressure-tight no-hub caps for no-hub systems. Provide isolation valves at the end of all abandoned pressure piping with specified valve tags.

5. Wherever existing ductwork is cut and shall remain in service, provide minimum 20 gauge cover plates over duct openings, set in a bed of mastic sealant, and secured with No. 10 sheet metal screws maximum 4 inches on center.

H. Cleaning and Closing:

1. Require that the Contractor thoroughly clean all equipment, fans, motors, piping, and all other materials free of all rust, scale, and other dirt before insulation or painting is done.

2. Require that open ends of ductwork and piping be sealed from the time they arrive on the jobsite to the time they are connected in the field.

3. Wherever work is performed above existing ceilings, require that the contractor protect floor and furnishings below from all dust and debris. Wherever the ceiling is opened, require that the Contractor vacuum clean top of ceiling, ducts, and pipes within four feet of the opening.

4. Require that all plumbing fixtures, motors, electronics, and rotating machinery be covered during construction and protected from dirt and water.

5. After installation is complete, require that the Contractor:
   - Thoroughly clean new ductwork and plenums inside and out before ceilings are installed and fans are operated.
   - Restore any damaged or marred surfaces to their original condition.
   - Clean piping systems.
   - Replace throwaway air filters used during construction with new filters before project is turned over to University.
   - Clean all foreign matter from coils, terminal devices, thermostats, diffusers, registers and grilles.
   - Thoroughly clean equipment of stains, paint spots, dirt and dust. Remove temporary labels not used for instruction or operation.

6. Duct Cleaning: Coordinate extent of duct cleaning with the University. In general, any renovation project that includes ductwork over 20 years old shall include duct cleaning. Cleaning shall conform to the National Air Duct Cleaners Association (NADCA) Standard for Assessment, Cleaning, and Restoration of HVAC Systems - 2013, and shall include the removal of visible dirt, debris, and other contaminates. Use an industrial HEPA- filtered

vacuum and rotary brush system appropriate for each surface. Coat existing acoustic insulation with an approved anti-microbial and erosion resistant coating.

I. Pipe and Duct Penetrations

1. Design and detail all utility pipes penetrating exterior walls with sufficient flexibility for normal settlement of building or backfill. Take particular care with cast iron and pressure piping. Coordinate compaction specifications for backfill that supports utility piping entering or leaving the building.

2. For new buildings constructed on piles, assume that soil beneath the ground floor slab will settle considerably and that braced supports for underground piping, anchored to the ground floor slab, will be required. Ensure that pea gravel backfill will flow around piping as the ground settles.

3. Design and detail the manner in which pipes and ducts pass through roofs, interior walls, floors and ceilings. Clearly indicate contractor's responsibility for locating, framing, cutting or drilling holes, and for adequate flashing and sealing.

4. Where cutting of existing concrete walls or floors is necessary, require Contractor to locate and avoid reinforcing steel using pacometer or other detection methods. Where possible, leave 1-1/2" concrete cover over reinforcing steel. Coordinate with the project structural engineer when cutting of reinforcing steel cannot be avoided.

5. Design and detail pipe and duct penetrations so that a minimum opening remains after installation. Specify and detail effective seals for openings to prevent passage of rodents, vermin, fire, smoke and liquid spills.

6. Where pipe or ducts are insulated, provide for continuous insulation through openings.

J. Stray Heat Avoidance

1. Minimize unnecessary heat gains to outside air ventilation systems. Under summer conditions, deliver outside air with a minimum temperature rise above ambient conditions. Avoid the following conditions where practical:
   - Large electric motors located in air plenums.
   - Air intakes on south wall of building.
   - Uninsulated plenums where substantial temperature differences exist.
   - Ducts passing through hot spaces.
   - In dual duct systems, inappropriate proximity or inadequate insulation of hot and cold ducts. This condition can also occur in a supply and exhaust system where ducts are adjacent.

K. Testing

1. Require that Contractor provide all labor, material, equipment, and temporary connections necessary to accomplish tests specified in Division 23 and as required by Code and authorities having jurisdiction. No portion of the work shall be covered until after it has been inspected, tested and approved.

2. Where applicable, testing shall be performed in strict accordance with governing codes and regulations and under the supervision of authorities having jurisdiction.

3. When testing is to be witnessed by the University's Representative, the University's Inspector of Record, or other authority, require that the Contractor provide at least 5 days notice prior to testing date.

4. Require written reports documenting procedures, results, and certification that each test has been satisfactorily completed. Certification shall include identification of portion of system tested, date, time, test criteria, test medium and pressure used, duration of test and name and title of person signing test certification document.

23-6 HVAC SYSTEMS

A. HVAC System Redundancy: HVAC systems for patient care and other special occupancies shall be designed for reliable 24/7 operation. Early in the design, establish redundancy criteria for HVAC equipment and review with the University. As a minimum, redundancy should be provided for the following HVAC system components:
   - Heating Hot Water Boilers or Heat Exchangers: CMC mandates standby equipment for primary heating system equipment. Provide at least two heating water boilers or steam-to-heating water heat exchangers, such that the system can meet peak demand with any one boiler or heat exchanger out of service. Large steam-to-heating water heat exchanger shall have two steam control valves.
   - Heating Hot Water Pumps: Provide at least two main building circulating pumps, such that the system is capable of delivering 100% of the system capacity with one of the pumps out of service. For systems with multiple boilers, provide one primary pump per boiler.
   - Chilled Water Pumps: Provide at least two main building circulating pumps, such that the system is capable of delivering 100% of the system capacity with one of the pumps out of service. For systems with multiple chillers, provide one primary pump per chiller and one standby pump capable of serving any chiller.
   - Tower Water Pumps: For systems with multiple cooling towers, provide one pump for each cooling tower and one standby pump capable of serving any cooling tower.
   - Fanwall Systems: For fanwall arrays with more than four fan cells, select fans and/or motors such that system can deliver required airflow with one fan cell out of service.

   For other critical equipment, such as exhaust fans serving critical care areas, where is impractical to have fully redundant equipment, it may be appropriate to specify a replacement motor, or other critical parts, that will allow rapid replacement. Review redundancy criteria on a case-by-case basis.

   Review individual equipment quantities, system configuration, and overall system capacity (including future capacity) with the University.

B. HVAC Systems for Critical Care Areas

   1. Patient care areas shall be designed with "once through" 100% outdoor air systems. New HVAC systems shall be outfitted with pressure-independent Variable Air Volume (VAV) terminal units and duct mounted hot water heating coils. Constant Air Volume (CAV) air terminals shall be considered if the system does not benefit from VAV option. HVAC systems shall operate continuously. Supply and exhaust VAV and CAV systems shall maintain design pressure differentials within rooms and areas as required by code and clinical program.

C. HVAC Systems for Administration Areas and Non-OSHPD Buildings

1. Air handling systems for administrative, office, conference, and other general use facilities shall employ VAV reheat systems or other energy efficient systems that meet the University's energy performance policy and comply with the California Building Energy Efficiency Standards. Incorporate airside dry-bulb economizers to provide free cooling when ambient conditions permit.

2. Air handling systems for these buildings are best kept simple and zoned consistent with the building use and occupancy schedules. Ideally, large conference rooms or assembly areas with intermittent use should not be connected to units that supply routine office space.

3. Air handling systems in these buildings may have the following features:

    a. Single supply and return fans without redundant components.

    b. Night setback and morning warm-up control modes.

    c. Mixing plenums with minimum and maximum outdoor air damper to accommodate minimum ventilation and economizer operations.

    d. Minimum 30% efficient pre-filters and minimum 85% efficient after filters.

    e. Fully ducted return air system with building pressure control sequences.

4. HVAC systems for central computer rooms shall meet specific temperature, relative humidity, and reliability criteria established by the University's Information Technology Services group. Supplemental cooling may be appropriate for smaller IDF rooms that are normally ventilated by the building air handling system. Review specific requirements for each space with the University.

D. Clean Spaces for Sterile Compounding:

1. Where pharmaceutical or other clean rooms are included in the project program, confirm room classifications, process and equipment loads, and environmental control requirements. Clean rooms require special consideration and design. Drawings and specifications must address all aspects of clean room performance, fabrication, and installation. Clean room classification, testing, monitoring, design, construction, start-up and commissioning shall comply with the ISO 14644 series of standards.

2. Select equipment, air velocities, and plenum and duct sizes for minimum noise within the work area.

3. Provide a method for injecting test media into the fan return plenum, and for sampling test media density upstream of HEPA filters. Discuss provisions with the University. Functional performance testing of clean rooms shall be performed by the University's testing agency.

E. Conversion to Variable Flow:

1. New piping systems shall be variable flow. Control valves shall be two-way. Whenever an existing system is constant flow, consult with the University to determine if system should be converted to a variable flow piping system.

F. Heat Recovery:

1. State-of-the-art energy recovery technologies with project-proven efficiency and pay-back are welcomed at the University. Discuss methodologies and equipment types and manufacturers with the University. Systems must be made of materials suitable for the University's marine environment. Life Cycle Cost Analysis or other approved resource may be required to justify energy recovery.

2. For air-side heat recovery, provide minimum 30% efficient filters upstream of heat recovery device.

23-7 BASIC MECHANICAL MATERIALS AND METHODS

A. Product Selection

1. Specify new products throughout. Select products of the highest available quality that will provide efficient operation and have long life expectancies. Products should require low maintenance and be easily serviceable.

2. Items of a given type should be the product of the same manufacturer. Select products that have been in satisfactory commercial or industrial use in continuously operating systems for at least three years. Exceptions to this requirement should be discussed with the University.

3. Major equipment items should be supported by local service organizations. Service organizations shall be qualified to render satisfactory service on a regular and emergency basis.

B. Attachments to Structure

1. Coordinate where requirements for concrete expansion anchors and other fasteners will be specified, often times in Division 5. Refer to concrete anchor testing requirements, which may be specified or shown on Structural, Mechanical, or Architectural Drawings.

2. Specify stainless steel anchors and fasteners for use outside and in outside air intake plenums, and zinc-plated for other locations.

C. Welding

1. Require that all shop and/or field welding in connection with mechanical work be performed in strict accordance with Title 24, California Code of Regulations (CCR), and pertinent recommendations of the American Welding Society (AWS). Specify minimum welder qualifications.

2. Specify where field and shop welding will be inspected by the University's Testing Agency in accordance with Title 24, CCR. Coordinate inspection requirements with the University's Representative , and include appropriate references to Division 1 requirements.

3. Require appropriate exhaust ventilation wherever welding occurs in occupied buildings.

D. Electrical Requirements

1. Ensure that electrical controllers, disconnects, devices, and wiring specified in Division 23 conform to requirements of Division 26 - Electrical. Coordinate all electrical voltages, motor control requirements, disconnect switches, and related work with electrical design engineers.

2. Verify available power supply voltages prior to specifying mechanical equipment.

E. Motors

1. Unless special characteristics are required, motors shall be NEMA Design B, totally enclosed fan cooled (TEFC), single speed, Insulation Class “F”, 1.15 Service Factor, rated for continuous duty at 40 degrees Centigrade with low slip, low starting current, and normal starting torque. Rotor shall be precision balanced in accordance with NEMA MG 1-1998, “Motors and Generators,” 7.08. Consult with the University when selecting motors for special operating conditions.

2. Motors 1 horsepower and larger shall be premium efficiency in accordance with IEEE Standard 112 Test Method B.

3. Bearings:
   - Motors 10 horsepower and smaller (up to frame size 215T) shall have optional permanently (double) sealed ball bearings.
   - Motors larger than 10 horsepower shall have regreasable, double shielded, single-row deep-groove ball or roller bearings with a grease filling and relief plug for purging during lubrication. Exceptions to this criteria will be considered for outdoor motors on a case-by-case basis, where permanently sealed bearings may provide longer life.
   - Specify bearings with minimum AFBMA L-10 Life of 50,000 hours for belt-driven applications and 150,000 hours for direct-coupled applications.

4. Voltage:
   - Motors smaller than 3/4 horsepower shall be single phase, 60-cycle, for 120 volt or 208 volt service, unless available power dictates a different voltage.
   - Motors 3/4 horsepower and larger shall be three phase, 60 cycle, voltages as appropriate and approved by the University.

5. Motors driven through variable frequency drives (VFDs) shall be rated for "Inverter Duty" with triple-coated 200 degree Centigrade copper magnet wire capable of withstanding 1600V spikes (with a minimum voltage rise time of 0.1 microsecond) experienced with dV/dt IGBT waveforms as defined in NEMA MG 1-1998, Part 31. Motors shall be fully compatible with the approved variable speed drives and rated to operate from 5 percent to 200 percent of rated motor speed.
   - Specify every motor driven through a variable frequency drive to have an Aegis SGR, or equal, shaft grounding ring that utilizes conductive microfibers to redirect shaft current from the shaft to the motor frame, bypassing the motor bearings entirely. Shaft grounding ring shall be maintenance free, with full circumferential contact of motor shaft. SGR shall provide efficient discharge of high-frequency shaft voltages induced by variable frequency drives.
   - Motors 10 horsepower and smaller can be provided with ceramic bearings that meet bearing criteria above in lieu of shaft grounding rings.

6. Coordinate proper protection and control for every motor.

7. Motors shall be selected such that the driven equipment brake horsepower requirement (including any applicable drive losses) is between 70% and 95% of the motor rating. Intent is to not oversize motors.

F. Variable Frequency Drives (VFDs)

1. Specify VFDs for fans and pumps in variable flow or variable volume systems.

2. The University has standardized on ABB drives, to match existing, predominantly ACH550 for HVAC applications. Review VFD style, options, enclosures, and accessories from manufacturer's standard product to meet project specific project requirements with the University.
   - Specify VFDs with E-Clipse across-the-line bypass where the normal operating speed of the motor is within 10% of 60 Hz.
   - Specify VFDs with E-Clipse across-the-line bypass for belt driven fans, and require that fan sheaves be replaced during system balancing so that fan operates at design condition near 60 Hz.
   - Specify primary/secondary VFDs in the same enclosure where redundancy is required and the normal operating speed of the motor is less than 54 Hz or greater than 66 Hz.
   - Where redundancy is not required and motor does not operate near 60 Hz, specify VFD without across-the-line bypass.
   - If more than three VFDs of the same size are specified, then specify one spare VFD of each size provided on the project, or as agreed upon with the University.

3. Warranty: Specify that VFDs and motors driven through VFDs shall be warranted for a period of three years from the date of start-up.

4. Voltage and current distortion generated by VFD and attenuation devices, as installed, shall not exceed the following criteria as referenced by IEEE Standard 519, General Category:
   - Total harmonic distortion (THD) shall not exceed 5% RMS of fundamental input voltage at full load with maximum 3% RMS on any single harmonic at the point of common coupling to the distribution system.
   - Line voltage distortion shall not exceed 5% in amplitude of fundamental input voltage.

5. Specify that VFDs have DC link reactors on the positive and negative rails of the DC bus to reduce the level of harmonics reflected back into the building power system. Link reactors shall not reduce efficiency or cause a voltage loss at the drive input.

6. Specify spare VFDs (electronic drive and control components) for systems supporting critical areas.

7. VFDs in exterior locations shall be enclosed within a NEMA 4X stainless steel control panel or behind a weatherproof door of air handling unit enclosure. Where appropriate, specify sealed enclosures with internal air conditioning.

8. Require the following factory testing:
   - All printed circuit boards shall be burned-in at elevated temperature for at least 15 minutes. Each board shall be 100% tested on equipment calibrated to ISO-9001 standards.
   - Test VFD for a minimum of 15 minutes at full load.

- Monitor for correct phase current, waveform, phase voltages, and motor speed.
- Test current limit by simulating a motor overload.
- Test all other protective features.
- Test for proper grounding using a HYPOT voltage test. For 208 - 240 VAC, use 1500 VAC. For 460 VAC, use 2200 VAC. For 600 VAC, use 2500 VAC. Leakage current during test shall not exceed 100 micro amps. Leakage current during test shall not exceed 100 micro amps.
- Test all adjustable controls and ranges.
- Test bypass operation and all interface controls and signal response.

9. Require the following field testing and start-up by VFD manufacturer's factory authorized field service technician:
   - Inspect for physical damage, proper anchorage, and grounding.
   - Inspect for compliance with drawings and specifications.
   - Compare overload heater rating with motor full-load current rating to verify proper sizing. (Require contractor to remove any power factor correction capacitors connected on load side of heaters.)
   - Check tightness of bolted connections using calibrated torque wrench.
   - Measure insulation resistance of each starter section phase-to-phase and phase-to-ground with the starter contacts closed, the protective device open, and the solid state controller isolated. Test voltage shall be in accordance with Table 10.2 of NETA ATS-1995, "Acceptance Testing Specifications for Electrical Power Distribution Equipment and Systems."
   - Submit written results of field testing and start-up for each unit.
   - Demonstrate proper operation and control in manual, automatic, and bypass modes.

G. Motor Starters

1. Coordinate requirements for motors starters, which shall be specified in Division 26.

2. Specify VFDs for motors 25 HP and larger to allow soft starting, even if the driven equipment is intended to be used at constant speed.

H. Lubrication

1. Specify that installer properly lubricate all bearings before operation of the equipment, and carefully observe equipment operation immediately after start-up.

2. Lubrication points shall be both visible and safely accessible after installation of equipment. Specify extension pipes wherever needed to meet access requirements.

I. Equipment Guards

1. Require equipment guards over belt driven assemblies, drive couplings, pump shafts, exposed fans, and elsewhere as required by Code.

J. Pipe Identification

1. Identify and color-code all piping, including concealed piping. Provide directional arrows to indicate direction of flow. Refer to Tables 23-2 and 23-3 below.

2. Identification shall consist of wrap-around plastic markers, equal to Seton Set-Mark "Snap-Around Markers" Brady, Calpico, or equal, with stainless steel spring fasteners for larger sizes. Coordinate with the University where stenciled pipe identification may be required (piping in trenches, tunnels, etc.).

3. Locations for pipe identification:
   - Adjacent to each valve, including vent and drain valves.
   - At each branch and riser take-off.
   - At each pipe passage through wall, floor, and ceiling construction, on both sides of penetration.
   - On all horizontal runs spaced 25-feet maximum.
   - Labels must be as conspicuous as possible from normal points of reference.

TABLE 23-2
PIPE IDENTIFICATION

DRAWING SYMBOL	LABEL NAME (2)	LABEL COLOR (1)
CA	Compressed Air (3)(4)	Y
CHWS	Chilled Water Supply	GW
CHWR	Chilled Water Return	GW
CWS	Condenser Water Supply	Y
CWR	Condenser Water Return	Y
DCW	Domestic Cold Water	GW
DHW	Domestic Hot Water	Y
DHWR	Domestic Hot Water Return	Y
DI	Deionized Water	GW
DIR	Deionized Water Return	GW
DSP	Dry Standpipe	R
DR	Drain	Y
HHWS	Heating Hot Water Supply	Y
HHWR	Heating Hot Water Return	Y
HPS	High Pressure Steam (over 100 psi) (3)	Y
HPR	High Pressure Condensate Return	Y
ICW	Industrial Cold Water	GW
IHW	Industrial Hot Water	Y
IHWR	Industrial Hot Water Return	Y
LPS	Low Pressure Steam (1-15 psig) (3)	Y
LPR	Low Pressure Condensate Return	Y
MPS	Medium Pressure Steam (20-100 psig) (3)	Y
MPR	Medium Pressure Condensate Return	Y
NG	Natural Gas	Y
PR	Pressure Relief	R
PW	Pure Water (7)	GW
SP	Fire Sprinkler	R
SV	Steam Vent (6)	Y
TCA	Temperature Control Air (3)(5)	Y

DRAWING SYMBOL	LABEL NAME (2)	LABEL COLOR (1)
WSP	Wet Standpipe	R
Medical Gases:		
O2	Oxygen	GW
MA	Medical Air	Y
MV	Medical Vacuum	W
N2O	Nitrous Oxide	B
N2	Nitrogen	BL
CO2	Carbon Dioxide	GR
WAGD	Waste Anesthetic Gas Disposal	V
Laboratory Gases:		
L-A	Laboratory Air (3)	Y
L-VAC	Laboratory Vacuum	GB
L-CO2	Laboratory Carbon Dioxide (3)	Y
L-N2	Laboratory Nitrogen (3)	GW
L-O2	Laboratory Oxygen (3)	Y

TABLE 23-2 NOTES:

(1) Color coding for pipe labels:
- Y Yellow background with Black lettering.
- GW Green background with White lettering.
- GB Green background with Black lettering.
- W White background with Black lettering.
- R Red background with White lettering.
- B Blue background with White lettering.
- W White background with Black lettering.
- BK Black background with White lettering.
- GR Gray background with White or Black lettering.
- V Violet background with White lettering.

(2) Labels shall spell out the full name in capital letters. Order custom labels as necessary. For services not listed, use agreed upon Drawing Symbols, Label Names, and Colors. All labels shall indicate flow direction.

(3) Indicate average operating pressure in psig within parenthesis; e.g. (50).

(4) Applies to compressed air for pneumatically operated automatic doors or shop air.

(5) Labels required for main temperature control air only; typically 20 psig. Signal air with variable pressure is typically 1/4" or smaller, and does not require labeling.

(6) Atmospheric vent.

(7) Depending on water purity, alternate identification might be DW - Distilled Water or Demineralized Water.

TABLE 23-3
PIPE AND INSULATION LETTERING

Pipe and Insulation O.D. (in Inches)	Minimum Letter Height (in Inches)
3/4 to 1-3/8	1/2

1-1/2 to 2-3/8	3/4
2-1/2 to 7-7/8	1-1/4
8 to 10	2-1/2
Over 10	3-1/2

K. Valve Tags

1. Identify all valves with 2" x 4" minimum size laminated plastic tags. Tags shall have a light background with black or blue lettering. Exception: Use a red background and white lettering for fire protection valves.

2. Tags shall state the system served by the valve, valve size, the coil, room number(s) and/or area of the building served by the valve, whether the valve is normally open (N.O.) or normally closed (N.C.), and purpose of the valve.
   - Control valve tags shall state the manufacturer and complete model number of the valve and actuator, water flow rate (gpm) or steam flow rate (lbs./hr.), valve size, equipment served, and valve flow coefficient.
   - Circuit balancing valve tags shall state the valve manufacturer and model number, balanced water flow rate, date installed, and the note, "Use calibrated flow charts furnished for this valve."

3. Attach tags with a light brass chain. Exception: For valves on dry standpipes, sprinkler risers, and wet standpipes that exposed in occupied spaces or stairwells, attach valve tag to wall adjacent to valve.

4. Valve Charts: For new systems, specify that the contractor provide complete schematic flow diagrams of each new piping system, indicating the location and function of each valve, and whether the valve is normally open or closed. Charts shall identify each system and show the actual arrangement, line sizes, equipment, coils, and other essential features of system.
   - Specify that charts be electronically drafted with minimum 1/8-inch lettering and large symbols, readily legible. Charts shall be prepared in AutoCAD.
   - Specify that each chart be mounted in an aluminum frame with a clear, hardened acrylic plastic front. Charts shall be easily removable for making changes. Charts should be mounted on mechanical equipment room walls at locations approved by the University's Representative.

L. Equipment Identification

1. New equipment shall be identified using the Medical Center's standard abbreviations and nomenclature as summarized below. Consult with the University to obtain the next sequential equipment number.

TABLE 23-4
EQUIPMENT NOMENCLATURE

ABBREVIATION	EQUIPMENT TYPE
ACU	Air Conditioning Unit (refrigerant-based cooling
AHU	Air Handling Unit
FCU	Fan Coil Unit (refrigerant-based or water coils)

ABBREVIATION	EQUIPMENT TYPE
CU	Condensing Unit (compressor/condenser side of split system)
HP	Heat Pump
DCW	GW
DHW	Y
DHWR	Y
DI	GW
DIR	GW
DSP	R
DR	Y
HHWS	Y
HHWR	Y
HPS	Y
HPR	Y
ICW	GW
IHW	Y
IHWR	Y
LPS	Y
LPR	Y
MPS	Y
MPR	Y
NG	Y
PR	R
PW	GW
SP	R
SV	Y
TCA	Y
WSP	R
O2	GW
MA	Y
MV	W
N2O	B
N2	BL
CO2	GR
WAGD	V
L-A	Y
L-VAC	GB
L-CO2	Y
L-N2	GW
L-O2	Y

2. Specify engraved plastic labels that are riveted or epoxy-glued to the equipment. Labels on rooftop equipment should be fastened with stainless steel pop rivets or screws. Cardholders in any form are not acceptable. Specify blue labels with white lettering. Primary equipment

identification shall be minimum 3/4" high and underlined, and additional information shall be minimum 1/4" high.

3. Require that equipment labels state the equipment name and number, area of the building served, and primary performance data including air (or water) flow rates, air (or water) pressure drops, entering and leaving air (or water) temperatures, etc., and year installed.

23-8 INSULATION

A. Pipe Insulation

Service	Material	Remarks
Heating Hot Water, Domestic and Industrial Hot Water and Hot Water Return, Low Pressure Steam and Condensate, and Chilled Water Piping	(a) Inside Buildings: Molded glass fiber with All-Purpose white jacket and 0.030" thick Zeston 300 Series, or equal PVC fittings covers (0.020" thick PVC fitting covers acceptable for piping 2" and smaller).	Manville Micro-Lok AP, or equal
	(b) Outside Buildings: Molded glass fiber with minimum 0.020" thick stainless steel jacketing applied over pipe and fitting insulation.	All jacketing lapped to shed water
Domestic and Industrial Cold Water, Process Cooling Water (60° - 90° F), and Condenser Water Piping		No insulation required.
Refrigeration Piping (Suction Lines)	(a) Inside Buildings: As specified for chilled water piping above.	
	(b) Outside Buildings: Closed-cell elastomeric.	Armacell AP Armaflex, or equal. All joints glued with Armstrong 520, or equal and coated with WB Armaflex, or equal finish.
Medium and High Pressure Steam and Condensate Piping	(a) General Inside Buildings (to maximum 300°F): Molded glass fiber with All-Purpose white jacket and 0.030" thick Zeston 300 Series, or equal PVC fittings covers. Seal all gaps.	Manville Micro-Lok AP, or equal
	(b) General Outside Buildings (to maximum 300°F): Molded glass fiber with minimum 0.020" thick stainless steel jacketing applied over pipe and fitting insulation.	Lab all seams to shed water.
	(c) In Mechanical Rooms and Underground (above 300°F): Cellular glass with minimum 0.024" thick aluminum applied over piping and fitting insulation.	Pittsburgh Corning "Foamglas", or equal. Provide "Pittwrap", or equal insulation jacket on underground piping.

Notes for Pipe Insulation Table:

- Insulation, jackets, facings, adhesives, coating, and accessories fire hazard shall be rated in accordance with ASTM E84, UL Standard 723, and meet requirements of NFPA 90A.

- Specify minimum thicknesses in accordance with the California Building Energy Efficiency Standards and ASHRAE 90.1. Increase minimum thicknesses by 0.5-inch for piping on the roof or exposed to un-tempered outside air conditions.
- Specify Johns Manville, Owens-Corning, Certain-Teed, or equal as manufacturers for fiberglass insulation products. Specify Pittsburgh-Corning, Johns Manville, or equal for cellular glass insulation products. Specify Armacell, Rubatex, or equal for closed-cell elastomeric insulation products. Specific models should be listed for at least the first named manufacturer. Other manufacturers and products shall be specified where their use is suitable. Discuss alternate materials or methods with the University.
- Specify application methods for selected insulation materials.
- Specify calcium silicate thermal hanger shields to protect glass fiber and non-rigid pipe insulation from crushing in hangers. Specify welded pipe saddles for hot steel pipes 4-inches and larger supported on rollers.
- In heating water, steam, and domestic water piping, do not insulate unions, strainer blowdown valves, regulators, steam traps, circuit balancing valves, or control valves. Seal exposed edges of insulation with glass cloth and mastic. See requirements for lace-up insulation jacketing covers below.
- Insulate domestic and industrial cold water piping in concealed or warm areas where condensation might occur.
- Specify reinsulated piping systems for chilled water and heating water piping installed underground, Rovanco, Perma-Pipe/Ricwill, Thermacor, or equal. Outer jacket shall be high density polyethylene (HDPE). Carrier pipe shall be specified carbon steel or copper pipe. Carbon steel joints shall be butt-welded. Copper joints shall be silver brazed. Where possible, straight sections shall be supplied in pre-measured lengths with piping exposed at each end for field joint assembly. Insulation shall be nominal 2 pcf density polyurethane foam for straight sections and preformed polyurethane foam for all fittings. To ensure no voids are present, contractor shall inspect all insulation using one of the following three methods: visual check prior to application of the protective jacket; infrared inspection of the entire length; or X-ray inspection of the entire length. Insulation thickness shall be as specified above.

B. Hazard Rating: Insulation, jackets, facings, adhesives, coating, and accessories shall be rated in accordance with ASTM E84, UL Standard 723, meeting requirements of NFPA 90A, and acceptable to the California State Fire Marshal:
   - Flame Spread: Maximum 25.
   - Fuel Contributed and Smoke Developed: Maximum 50.

C. Delivery, Storage and Handling: Require that all insulation material be delivered to project site in original, unbroken factory packaging labeled with product designation and thickness. Shipment of materials from manufacturer to installation location shall be in weather tight transportation. Insulation materials delivered to jobsite shall be stored so as to protect materials from moisture and weather during storage and installation.

D. Jacketing for Exterior Insulation: Specify minimum 0.020" thick Type 304 or 316 stainless steel with integral bonded polykraft moisture barrier and longitudinal Pittsburgh Z-Lock, or equal seam. Secure jacketing with minimum 0.5" wide x 0.020" thick aluminum straps maximum 18" on center. Specify matching jackets for all fittings, flanges, and specialties.

E. Specify pre-fabricated removable insulation covers for high temperature valves, piping specialties and equipment flanges requiring periodic disassembly. Covers shall be shop fabricated assemblies comprised of a woven fiberglass cloth inner liner rated for 1000 degrees Fahrenheit, fiberglass and non-asbestos ceramic fiber blanket insulation, and covered with a waterproof, gray color 17.5 oz/sq yd silicone rubber coated woven fiberglass outer jacketing. Seams shall be sewn with high-temperature lacing. Jacket shall be flexible, reusable, and custom designed for each individual valve or shape to provide close contour fit with no overlapping seams or gaps. Assembly shall be secured with buckle and strap assemblies (with D rings) or fabric-backed heat resistant Velcro tabs. Insulation blanket shall be in two layers, each one- 1-inch thick, with an overall R factor of 5.4. Manufacturers: Plant Insulation Co. “Temp-Mat,” S.R. Corp. Valve Insulation Covers (Suisun, California), Thermal Energy Products Inc., or equal.

F. Duct Insulation

1. For rectangular ductwork in mechanical equipment rooms and in areas where ductwork is exposed to view, specify glass fiber semi-rigid board insulation, three-pound density, FRK jacket, minimum 1-1/2 inch thick, Owens-Corning Type 703, or equal.

2. For round ductwork and rectangular ductwork hidden from view, specify glass fiber duct wrap insulation, minimum one-pound density, FRK jacket, minimum 1-1/2-inches thick, Owens-Corning Type 150, or equal.

3. For insulation on roof, specify glass fiber semi-rigid board insulation, minimum six-pound density, FRK jacket, minimum two inches thick, and sloped to shed water. Cover insulation with foil-backed self-adhering jacket, Polyguard “Alumaguard 60”, or equal. Jacket is a laminated waterproof membrane consisting of a peel-and-stick rubberized bitumen adhesive compound with a cross-laminated high strength polyethylene backing film and aluminum foil surface, 60 mils thick, UV resistant, weatherproof and vapor proof. Install with “cold weather activator” by same manufacturer to improve adhesion.

G. Equipment Insulation

Service	Material	Remarks
Equipment - Hot	Molded hydrous calcium silicate; or	Finish with 6 oz. canvas.
	Molded glass fiber with All-Purpose white jacket; or	Finish with 6 oz. canvas.
	Cellular glass	Finish with 6 oz. canvas.
Equipment - Cold (below 50° F)	Foamed polystyrene; or	Finish with 6 oz. canvas.
	Closed-cell elastomeric	Armstrong AP Armaflex. All joints glued with Armstrong 520 and coated with WB Armaflex finish.

Notes for Equipment Insulation Table:

- Discuss selected insulation materials and methods with the University.
- For hot equipment, specify pre-fabricated removable insulation covers described above for components that require periodic service or access, such as heat exchanger heads or pumps.
- For cold equipment, insulation shall be removable without damage (other than breaking vapor seal) for components that require periodic service or access.
- Where two finish coats are specified on jacketing, they shall be of different colors to verify complete coverage.

- Where 6-ounce canvas is indicated, secure with Fosters, Arabol, or equal lagging adhesive. If the finished surface is not to be painted, then apply a second coat without thinning. Use vapor proof lagging adhesive for cold applications.

H. Fire Resistive Pipe and Duct Insulation

1. In certain building types, certain above-ceiling ducts and pipes may require fire-rated enclosures, such as grease exhaust ducts, fume exhaust ducts, and certain plastic piping. For these applications, specify a UL listed assembly consisting of a lightweight, non-asbestos, ceramic fiber blanket totally encapsulated in foil/scrim having a service temperature rating of 2300 degrees Fahrenheit. Fire resistive duct and pipe wrap shall be used in conjunction with compatible UL through-penetration firestop systems. Include appropriate installation details. Systems include 3M “Fire Barrier Duct Wrap 615+”, 3M "Fire Barrier Plenum Wrap 5A", and Nelson “FSB Flameshield", or equal.

23-9 BASIC PIPING MATERIALS AND METHODS

A. Medium and High Pressure Steam Piping (Over 15 PSI)

1. Design Criteria:
   - Size medium and high-pressure steam piping as recommended in ASHRAE Fundamentals Chapter 22 - Pipe Sizing, Table 15. Do not size piping for pressure drops in excess of 2.0 psi per 100 feet, or velocities in excess of 10,000 feet per minute. Minimum pipe size shall be 3/4-inch.
   - Size all piping with an allowance for 25% future increase in design flow rate. For extension of piping into areas with limited medium and high pressure steam service, consult with the University as to whether piping should be further increased in size to accommodate future growth in demand.

2. Materials:
   - 2 Inches and Smaller Piping: ASTM A106, Grade B, Schedule 80, carbon steel, threaded. Specify Schedule 160 nipples at drip legs.
     - Fittings: ASTM A105 Grade II/ANSI B16.11, 3000 lb. forged steel, threaded.
     - Unions: Forged carbon steel, Class 3000. Refer to Flanges, Unions, and Couplings below.
   - 2-1/2 Inches and Larger Piping: ASTM A53, Grade B, Type E or S, Schedule 80, carbon steel, welded.
     - Fittings: ASTM A234 Grade WPB/ANSI B16.9, standard weight, seamless, carbon steel, welded.
     - Flanges: Class 300. Refer to Flanges, Unions, and Couplings below.

B. Low Pressure Steam Piping (0 to 15 PSI)

1. Design Criteria:
   - Size low-pressure steam piping as recommended in ASHRAE Fundamentals Chapter 22 - Pipe Sizing, Table 15. Do not size piping for velocities in excess of 8,000 feet per minute. Minimum pipe size shall be 3/4-inch.
   - Size all piping with an allowance for 25% future increase in design flow rate. For extension of piping into areas with limited low pressure steam service, consult with the University as to whether piping should be further increased in size to accommodate future demand growth.

2. Materials:
    - 2 Inches and Smaller: ASTM A53, Type F, Schedule 80, carbon steel, threaded.
        - Fittings: ASTM A105 Grade II/ANSI B16.11, 3000 lb. forged steel, threaded.
        - Unions: Forged carbon steel, Class 3000. Refer to Flanges, Unions, and Couplings below.
    - 2-1/2 inches and Larger: ASTM A53, Grade B, Type E or S, Schedule 80, carbon steel, welded.
        - Fittings: ASTM A234 Grade WPB/ANSI B16.9, standard weight, seamless, carbon steel, welded.
        - Flanges: Class 150. Refer to Flanges, Unions, and Couplings below.

C. Condensate Return Piping

1. Design Criteria:
    - Size steam condensate piping as recommended in ASHRAE Fundamentals Chapter 22 - Pipe Sizing, Tables 20 through 23. Size pumped condensate return same as for heating water piping. Minimum pipe size shall be 3/4-inch.
    - Size all piping with an allowance for 20% future increase in design flow rate. For extension of piping into areas with limited steam service, consult with the University as to whether piping should be further increased in size to accommodate future growth in demand
    - Provide carbon steel piping and nipples at steam trap assemblies, as specified for steam service. Provide a heavy brass nipple at the steam trap discharge isolation valve; downstream piping shall be copper as specified below.

2. Materials:
    - 4 Inches and Smaller, Indoors, Downstream of Steam Trap Assemblies: ASTM B88 seamless, Type K, hard drawn copper tubing with silver brazed joints.
        - Fittings: ANSI B16.22 wrought copper, solder joint. For fittings not available in copper, specify ANSI B16.18 cast bronze, solder joint. Mechanically formed tee connections are not acceptable.
        - Joints: Specify brazing alloy containing minimum 15 percent silver with copper and zinc, and maximum 5 percent phosphorous (BCuP-5), Bellman-Melcor “Silvaloy 15,” J.W. Harris “Stay-Silv 15,” or equal.
        - Unions: Class 250, threaded or soldered/brazed ends. Refer to Flanges, Unions, and Couplings below. Provide unions at steam traps, equipment connections, upstream of isolation valves, and where necessary for installation.
        - Flanges: ANSI B16.24, Class 150, cast copper alloy. Refer to Flanges, Unions, and Couplings below. “CTS” companion flanges not permitted.
        - Use threaded joints for valves and piping specialties in copper piping, 2 inches and smaller.

D. Heating Hot Water, Chilled Water, and Cooling Tower Water Piping

1. Design Criteria:
    - Size heating water, chilled water, cooling tower water, and closed circuit heat pump/cooling water piping according to Table 6.5.4.5 in ANSI/ASHRAE/IES Standard 90.1-2010. This table is based on studies that optimize the cost and

efficiency of hydronic systems. This table includes sizing criteria for pipes 2-1/2 inches and larger.

- For pipe sizes 2 inches and smaller, size piping for a maximum pressure loss of 12 feet per 100 feet of straight pipe for "Variable Flow/Variable Speed" systems, and for a maximum pressure loss of 6 feet per 100 feet of straight pipe for all "Other" systems. Pressure loss shall be determined using the Darcy-Weisbach equation for the appropriate pipe material. Minimum pipe size shall be 3/4-inch.
- Size all piping with an allowance for 20% future increase in design flow rate. For extension of piping into areas with limited heating or chilled water service, consult with the University as to whether piping should be further increased in size to accommodate future growth in demand.

2. Materials:
   - 4 Inches and Smaller: ASTM B88 seamless, Type L, hard drawn copper tubing.
     - Fittings: ANSI B16.22 wrought copper, solder joint. For fittings not available in copper, specify ANSI B16.18 cast bronze, solder joint. Mechanically formed tee connections are not acceptable.
     - Joints 2 inches and smaller shall be soldered. Specify lead-free solder, Canada Metal “Silvabrite 100,” J.W. Harris “Bridgit,” or equal 95 percent tin-5 percent antimony (95-5) solder.
     - Joints 2-1/2 inches and larger shall be brazed. Specify brazing alloy containing minimum 15 percent silver with copper and zinc, and maximum 5 percent phosphorous (BCuP-5), Bellman-Melcor “Silvaloy 15”, J.W. Harris “Stay-Silv 15”, or equal.
     - Unions: Class 250, threaded or soldered/brazed ends. Refer to Flanges, Unions, and Couplings below. Do not provide unions for copper piping 1 inches and smaller unless necessary for installation or future servicing.
     - Flanges: ANSI B16.24, Class 150, cast copper alloy. Refer to Flanges, Unions, and Couplings below. “CTS” companion flanges not permitted.
     - Use threaded joints for valves and piping specialties in copper piping, 2 inches and smaller.
   - 6 Inches and Larger: ASTM A53, Grade B, Type E or S, Schedule 40, carbon steel, welded.
     - Fittings: ASTM A234 Grade WPB/ANSI B16.9, standard weight, seamless, carbon steel, welded.
     - Flanges: Class 150. Refer to Flanges, Unions, and Couplings below.
     - Condenser Water and Cooling Tower Water Piping: After fabrication of spool pieces, grind smooth all protrusions, slag, weld beads, edges, corners, etc. Then clean and hot-dip galvanize in accordance with ASTM A123 and Standard Specifications of the Hot-Dip Galvanizers Association, Inc. Provide minimum coating thickness of two ounces of zinc per square foot of pipe wall on each side. Do not weld piping after galvanizing.

E. Miscellaneous Drain and Vent Piping

1. As specified for cooling tower water piping above.

2. Alternate for Sizes 2 Inches and Smaller:
   - Pipe: ASTM A53, Type F, Schedule 40, carbon steel, hot-dip galvanized.
   - Fittings: ASTM A126/ANSI B16.4, Class 125 cast iron, or ASTM A197/ANSI B16.3, Class 150 malleable iron, threaded, hot-dip galvanized.

- Unions: Malleable iron, Class 250, hot-dip galvanized. Refer to Flanges, Unions, and Couplings below.

F. Refrigerant Piping

1. Design Criteria:
   - Size and arrange refrigerant piping to ensure adequate refrigerant flow and uniform return of lubricating oil, and to prevent slugging of liquid refrigerant into compressors, or refrigerant flash in the liquid line. Size refrigerant piping in accordance with recommendations in ASHRAE Refrigeration Handbook Chapter 1 - Halocarbon Refrigeration Systems. For packaged refrigeration systems, such as variable refrigerant flow systems, size piping in accordance with systems manufacturer's instructions; provide accurate lengths, fitting counts, and vertical offsets to system manufacturers for input into sizing programs.
   - Liquid and suction lines for maximum 3.0 psi pressure drop. For systems that unload to less than 37% of maximum capacity, provide dual suction risers with tight U-bends at top and bottom of risers, and size risers for proper oil transport back to the compressors.
   - Where project is to be LEED Certified, utilize acceptable refrigerants as outlined in LEED Energy and Atmosphere category.
   - Specify a replaceable element filter/dryer with 3-valve bypass in each refrigerant circuit, with sightglass. Provide manual liquid and suction line shutoff valves with charging connections at condensing unit and DX coil. Provide purge valve and relief valve in each circuit.
   - Specify appropriate refrigerant piping specialties, including bull’s-eyes, thermal expansion valves, solenoid valves, suction and discharge pressure gauges, isolation valves, and filter/dryers as manufactured by Mueller Brass Co., Milwaukee, Sporlan, Henry, or equal. Where needed, specify flexible connectors by Flexonics, American Brass Co., or equal. Specialties requiring periodic service and replacement, such as filter/dryers, shall be provided with a 3-valve bypass and injection ports on the device side of the isolation valve, so that device can be evacuated and charged prior to reconnecting to system.

2. Materials:
   - ASTM B88 Type K or L hard drawn copper tubing conforming to ASTM B280 ACR (air-conditioning and refrigeration) with silver brazed joints. Piping and fittings shall be factory cleaned, deoxidized, dehydrated, and sealed by the manufacturer prior to shipment. Sizes 1/4-inch and smaller shall be annealed (soft).
     - Fittings: ANSI B16.22 wrought copper, solder joint. All fittings shall be rated for 300 psi working pressure.
     - Joints: Specify brazing alloy containing minimum 15 percent silver with copper and zinc, and maximum 5 percent phosphorous (BCuP-5), Bellman-Melcor “Silvaloy 15,” J.W. Harris “Stay-Silv 15,” or equal. Dry nitrogen shall be continuously purged through the line during brazing.

3. Installation: Specify the following requirements for the installing contractor.
   - Surfaces to be joined must be thoroughly cleaned. When soldering stop valves or solenoid valves, wrap valves with moist fabric to absorb excessive heat. Valves should be partly open to relieve heat buildup.
   - Support refrigerant piping to prevent strain on equipment, and to maintain required slopes without sagging. Support copper tubing on maximum 6 foot centers and at each elbow and branch takeoff. Insulated pipes shall have minimum 3” long, 16

gauge galvanized sheet metal or equivalent rigid insulation sleeves to protect insulation at pipe supports. Insulation shall be continuous through supports and penetrations. Uninsulated pipes shall be isolated from supports by means of felt wrapping or resilient isolators.
- Direct expansion valves shall be located over DX coil drain pans or auxiliary drains pans to capture dripping condensate.
- Refrigerant piping and specialties should never be installed below ground.
- Testing:
  - Refrigerant pipe shall be tested in accordance with the American Standard Safety Code for Mechanical Refrigeration American Standards Association (ASA) B9 1. The high side of the refrigerant system shall be tested with dry nitrogen at 300 PSIG and the low side at 150 PSIG.
  - Tests shall be applied for a minimum of 4 hours or until completion without pressure change other than that caused by expansion and contraction of testing medium.
  - No piping shall be insulated or otherwise covered until satisfactorily pressure tested.
  - Evacuation: Provide triple evacuation of refrigerant piping. Evacuation shall be performed with expansion valves and solenoid valves open. The first evacuation shall be to 1000 microns. Vacuum shall be broken with dry nitrogen and the system brought up to 15 psi. The second evacuation shall be to 500 microns; again vacuum shall be broken with nitrogen and the system brought up to 15 psi. The final evacuation shall be to 250 microns. The project inspector should sign off on each evacuation. System shall be immediately charged with refrigerant after the final evacuation.
  - Refrigerant lines shall be kept absolutely clean and dry prior to operation. A temporary compressor suction filter shall be installed during initial operation. After 2 days running time, the liquid line filter-drier shall be changed and the suction screen removed. Oil filters, if applicable, shall be cleaned.

G. Compressed Air and Pneumatic Control Air Piping

1. Design Criteria:
   - Size pneumatic control air piping using a maximum pressure loss of 5 percent of initial pressure to furthest point of use under maximum demand.

2. Materials:
   - ASTM B88 seamless, Type L, hard drawn copper tubing with soldered joints.
   - Fittings: ANSI B16.22 wrought copper, solder joint.
   - Solder: Canada Metal “Silvabrite 100,” J.W. Harris “Bridgit,” or equal 95 percent tin-5 percent antimony (95-5).

H. Flanges, Unions, and Couplings

1. Flanges:
   - 2-1/2 Inches and Larger: ASTM A105, ANSI B16.5, hot forged steel, welding neck pattern. Do not allow slip-on flanges.
   - Use flat face flanges with full-face gaskets for mating with other flat face flanges. Use raised face flanges with self-centering flat ring gaskets only when connecting to equipment, valves, or specialties with raised face flanges.

- Flange pressure class indicated in respective piping service is minimum required. Mating flange pressure class shall match pressure class of valve or device to which it is connected.

2. Flange Gaskets:
   - General Service: Asbestos free and suitable for pressure, temperature, and fluid of piping system. Specify non-metallic gaskets in accordance with ANSI/ASME B16.21 and ASTM F104. Unless otherwise indicated or recommended by manufacturer, gaskets shall be Garlock IFG 5500, Klinger, or equal, 1/16-inch thick.
   - Steam and Condensate Service: Flexitallic Style CG, Garlock, or equal, with flexible graphite filler, Type 316 stainless steel winding, carbon steel centering ring, 0.175 inch thickness.
   - Apply Never-Seez, or equal, gasket lubricant rated for minimum 1800° F on all gaskets that might require disassembly, such as strainer and heat exchanger heads, equipment connections, valves, etc.

3. Flange Bolting:
   - Bolts, bolt studs, nuts and washers shall have zinc plated finish, except use hot-dip galvanized finish for galvanized piping and outdoors.
   - For Class 150 flanges, specify carbon steel bolts or stud bolts conforming to ASTM A307, Grade B7 with heavy hex heads. Use with ASTM A194, Grade 1, or better, heavy hex series alloy steel nuts.
   - For Class 300 flanges, specify stainless steel bolts or stud bolts conforming to ASTM A193, Grade B8, with nuts conforming to ASTM A194, Grade 8.

4. Threaded Joints:
   - Paste type soft pipe dope for brush application. Products shall be non-toxic, chemically inert, non-hardening rated for minus 50 degrees F to plus 500 degrees F, bearing UL and AGA approvals. Rector T-Plus 2, Rector No. 5, Loctite, or equal.

5. Unions: As noted for individual piping services above and the following:
   - Steel Piping, 2 Inches and Smaller:
     - Steam Systems: ASTM A105 Grade 2, ANSI B16.11 forged carbon steel, Class 3000, ground joint, steel-to-steel seat; Grinnell, Van Leeuwen, or equal.
     - Water Systems: ASTM A197/ANSI B16.39, malleable iron, hot-dipped galvanized where necessary to match piping, ground joint, bronze-to-iron seat, Class 250; Grinnell Figure 554, Stockham Figure 794, or equal.
   - Copper Piping, 2 Inches and Smaller: ANSI B16.18 cast copper alloy, or ANSI B16.15 cast bronze, ground joint, Class 250, with threaded or solder joint ends; Mueller Brass "Streamline" No. WC-407, Nibco 733, or equal.
   - Unions that use O-rings as a sealing element are not acceptable.

6. Dielectric Couplings:
   - For connections of ferrous piping to copper piping or coils, provide Schedule 40 red brass nipples, minimum length six times pipe diameter; 2 inches and smaller with threaded ends; 2-1/2 inches and larger with flanged connections. Commercial dielectric couplings or unions are prohibited.
   - For connections of ferrous piping systems to copper systems at flanged cast iron valves, specialties, or equipment, provide EPCO Model X, Watts Series 3110, or equal, 125 psi solder joint cast brass or bronze insulating flanges with bolt insulators,

dielectric gasket, bolts, and nuts. Van Stone type copper flanges, such as CTS Flanges, are not acceptable.

7. Grooved-End Fittings and Couplings:
    - Fittings: ASTM A106 or A53, Grade B, carbon steel, full-flow steel fittings designed for use with cut grooved-end pipe and couplings, factory fabricated with combined grooved-ends, flanged ends, welding ends, or threaded ends as required. Clamp-on or saddle-type fittings, plain-end couplings, and drilled-in tee connections prohibited.
    - Couplings: ASTM A536 ductile iron body, ASTM D2000 EPDM gasket, and compatible lubricant, designed to engage and lock grooved-end pipe and fittings. Couplings shall be leak-tight and allow angular deflection, expansion, and contraction. Flexible Couplings: Victaulic Style 77, Grinnell, or equal. Zero-Flex Rigid Couplings: Victaulic Style 07, Grinnell, or equal.
        - Specify all chilled water couplings and all couplings outside of buildings with Type 316 stainless steel, Grade B-8M, Class 2 nuts and bolts.
    - Grooved-end flanges, valves and specialties are prohibited.
    - Finish: Epoxy painted, except where another finish is indicated. Hot-dip galvanized wherever galvanized pipe is specified.

8. Threaded Plugs: Cast bronze, male or female as appropriate.

I. Jointing

1. Fittings:
    - Specify standard manufactured fittings. Do not permit field fabricated fittings, mitered ells, welded branch connections, notched trees, stepped bushings, orange peel reducers, drilled-in tee fittings, and clamp-on branch connections. Reducing bushings may only be used for instrument connections.
    - Make branch take-offs with reducing tees or line size tees and reducers. Branch connections on steel piping 2-1/2 inches and larger which are less than half the diameter of the main may be made with forged branch welding outlets, Bonney Weld-O-Lets, Thread-O-Lets, or equal.

2. Pipe Ends: Perform pipe cutting and end preparation to result in clean ends with full inside diameter. Ream pipe ends to remove burrs and tool marks. Clean all pipe ends and inside of piping before joining.

3. Nipples: Except where space is limited, use minimum 3-inch long nipples. Steel nipples shall be Schedule 80, seamless, except where heavier nipples are required. Close nipples (with less than 1 inch of unthreaded pipe) are prohibited. Where connecting a series of valves and specialties in copper piping, use heavy brass nipples.

4. Threaded Joints: Specify the following:
    - Cut threads so that no more than 3 threads remain exposed after joint is made.
    - Ream pipe ends after cutting and clean before erection.
    - Seal joints with approved sealant compound applied to male threads only.
    - Apply Teflon tape to male pipe threads prior to sealant compound. Remove any excess pipe joint compound.
    - When joining plated, polished, or soft metal piping, use friction wrenches exclusively.

5. Brazed and Soldered Joints:

- Brazing and soldering shall be performed in accordance with ANSI/ASME B31.9, Building Services Piping. Preparation, techniques, and procedures shall be in accordance with the Copper Tube Handbook, as published by the Copper Development Association.
- Specifications shall include the following additional requirements
    - For brazed joints, a continuous fillet of brazing alloy, full thickness of the pipe material, shall be visible completely around the joint.
    - Crimping of copper tubing is prohibited.
    - Overheated or deformed joints shall be replaced.
    - Joints shall be wire brushed to bright metal after brazing.

6. Welded Joints:
    - Specify that pipe welding comply with provisions of the latest revision of ASME Code for Pressure Piping, ANSI/ASME B31.9 Building Services Piping, or B31.1 Power Piping, as appropriate, and the ASME Boiler and Pressure Vessel Code. Contractor shall be responsible for quality of welding and shall repair or replace any work not in conformance with specified and referenced codes and standards. To the extent possible, contractor shall perform welding off site. Welding on site shall only occur at times dictated by the University's Representative.
    - Only long radius elbows and full-flow welding fittings for branch connections shall be used. Prohibit cut-in or mitered elbows or welding tees. Branches from welded pipe to screwed pipe shall be made with threaded-welded tee fittings.
    - Examination: Require that the Contractor provide examination services for all pipe welding in accordance with ANSI/ASME B31.1, Table 136.4 or B31.9, as applicable. Personnel performing examinations shall comply with requirements stipulated in 136.1 (A) through (E) or shall be AWS-QC1 certified. Require submittal of periodic reports, signed by the weld examiner, indicating status of project welding quality. Contractor shall be required to arrange for observation of fit-up and welding methods with University's Inspector prior to implementing any welds, including shop welds.

7. Grooved-End Joints:
    - Specify that cutting and installation be performed strictly in conformance with manufacturer's instructions. Specify gasket materials and lubricants compatible with pipe services and temperatures.
    - Grooved-end couplings shall only be allowed for specific services and at specific locations. Discuss allowable services and locations with the University. Unless otherwise approved:
        - Only allow grooved-end fittings and couplings for steel heating water, chilled water, condenser water piping larger than 2 inches.
        - Do not permit more than two mechanical grooved joints in any 20-foot composite run of pipe, except at chiller and heat exchanger connections to facilitate disassembly and servicing.
        - Grooved-end couplings shall only be installed in accessible locations.

8. Unions and Flanges:
    - Unions or flanges are required on both sides of all strainers, pressure regulators, control valves, solenoid valves, steam traps, backflow preventers, water filters, flow meters, and other devices that may need to be removed or replaced, and wherever necessary for the assembly of piping. Provide unions or flanges immediately adjacent to equipment and coil connections and on the equipment or room side and immediately adjacent to isolation and line shutoff valves. Require that unions and flanges be installed to allow removal of equipment without springing pipe.

- Unions: Make sure that ground joint surfaces are free of scratches. Ensure that solder droplets do not contact mating surfaces. Spray mating surfaces with silicone lubricant to enhance seating. Apply manufacturer's recommended torque for each size of union.
- For copper piping 1 inch and smaller, unions shall not be provided except where necessary for installation or future servicing, and where called for in details. Sufficient pipe shall be provided to permit cutting and reassembly at connections to valves and specialties.

J. Valves

1. Valve Applications:
   - Specify gate valves for shutoff service steam and condensate return systems, all sizes and pressures. Exception: Ball valves can be used for shutoff service on low pressure condensate piping 2 inches and smaller.
   - Specify ball valves for shutoff service on water systems, sizes 2-1/2 inches and smaller.
   - Specify circuit balancing valves for throttling and bypass service on water systems, sizes 4 inches and smaller.
   - Specify butterfly valves for shutoff service on water systems, sizes 3 inches and larger.
   - Specify butterfly valves with infinite position memory-stop locking gear operators for throttling and bypass service on water systems, sizes 6 inches and larger.
   - Specify gate valves for shutoff service on other piping systems for sizes 2-1/2 inches and larger.
   - Specify globe valves for (non-balancing) throttling service on other piping systems.
   - Specify silent check valves and throttling style butterfly valves at pump discharge for sizes 2-1/2 inches and larger.
   - Other types of valves may be specified where their use and pressure rating is suitable, except that steam valves shall be as specified. Discuss alternate valve types with the University.

2. Valve Locations:
   - Provide isolating valves across each piece of equipment. Valves shall be arranged so that it is possible to clean strainers and service or remove equipment without draining system or springing piping.
   - Provide valves to isolate separate floors, separate wings, machinery rooms and other natural subdivisions of the building. Provide valves on all branches near connections to risers.
   - Provide valves at services left for future connections (tees, stubs, etc.,), unless they are in a valved zone, or can be isolated by existing valves with minor loss of pipe contents when opened.

3. General Valve Requirements:
   - Gate, globe, check, and ball valves shall be Nibco, Jenkins, Lunkenheimer, Stockham, Milwaukee, Lunkenheimer, or equal, provided they meet construction, quality and pressure ratings indicated below.
   - Pressure Ratings for Valves and Piping Specialties:
     - Valves and piping specialties shall be rated for not less than 150 psi steam working pressure (SWP), unless higher ratings are indicated or required for the service. Specify appropriate pressure ratings for all valves.

- Valves and piping specialties below the 6th Floor of Moffitt and Long Hospitals shall be rated for not less than 250 psi SWP or Class 250.

- Valves in copper piping shall be threaded (with IPS-to-SJ adapters) or flanged. Do not specify solder joint (SJ) valves, except for refrigerant service.
- Ensure that valve is provided with materials suitable for the service and temperature of each system, particularly with respect to discs, plugs, balls, gaskets, seals, linings, and lubricants. For special applications, where indicated materials may unsuitable, discuss with the University before proceeding.
- For outside applications, specify corrosion resistant valve materials. Exposed steel or cast iron shall be hot-dip galvanized or factory finished with epoxy coating system. Contractor shall replace steel washers, nuts, bolts, and fasteners in valve handles and gear housings with stainless steel parts.
- Specify chainwheel operators on valves 4 inches and larger where the operator is 8 feet or more above the floor or operating platform, and on other valves which would otherwise be inaccessible due to height or congestion of work. Chainwheel operators shall be cast iron with adjustable sprocket rim, malleable iron chain guide, and galvanized chain. Extend chain to 3 feet above floor or operating platform. Specify heavy-duty galvanized steel chain hooks secured to wall construction or other suitable structural attachment in order to maintain clear passageways.

4. Gate Valves for Steam and Condensate Service (Steel Piping):
   - 2 Inches and Smaller: Threaded ends, ASTM B105, forged steel body, screwed union bonnet, rising stem, 400 series stainless steel wedge, renewable hardened stainless steel seat, malleable iron handwheel, Class 800, Williams F87T, Walworth, or equal.
   - 2-1/2 Inches and Larger: Flanged ends, steel body, outside screw and yoke (OS&Y), stainless steel or 13 percent chromium hard faced wedge and seat ring, bolted bonnet, Class 300. Stockham Figure 30-OF, Powell Fig. 3003N, or equal.
   - Valves 6 Inches and larger shall be installed with a 1-inch bypass/warm-up valve.

5. Gate Valves for Other Services:
   - 2 Inches and Smaller: Threaded ends, union bonnet, rising stem, bronze body rated for 150 psi SWP and 200 psi WOG, conforming to MSS SP-80; Nibco T134, Jenkins 49U, or equal.
   - 2-1/2 Inches and Larger: Flanged ends, bolted bonnet, OS&Y, iron body, bronze trim, rated for 125 psi SWP and 200 psi WOG, conforming to MSS-SP-70; Nibco F617-0, Jenkins 651A, or equal.

6. Globe Valves Steam and Condensate Service (Steel Piping):
   - 2 Inches and Smaller: Threaded ends, union bonnet, replaceable S42000 stainless steel disc and seat ring, bronze body, malleable iron hand wheel, rated for 150 psi SWP and 300 psi WOG, conforming to MSS SP-80; Nibco T276-AP, Jenkins 592J, or equal.
   - 2-1/2 Inches and Larger: Flanged ends, bolted bonnet, OS&Y, renewable bronze seat and disc, bronze trim, iron body, rated for 125 psi SWP and 200 psi WOG, conforming to MSS SP-85; Nibco F718B, Jenkins 613, or equal.

7. Globe Valves for Other Services:
   - 2 Inches and Smaller: Threaded ends, union bonnet, integral seat, renewable TFE seat disc, bronze body and trim, malleable iron hand wheel, rated for 150 psi SWP and 300 psi WOG, conforming to MSS SP-80; Nibco T235, Jenkins 106-A, or equal.

- 2-1/2 Inches and Larger: Flanged ends, bolted bonnet, OS&Y, renewable bronze seat and disc, bronze trim, iron body, rated for 125 psi SWP and 200 psi WOG, conforming to MSS SP-85; Nibco F718B, Jenkins 613, or equal.

8. Check Valves:
    - 2 Inches and Smaller, General Service: Threaded ends, horizontal swing type, screw-in cap, regrinding type bronze disc for water service, TFE seat disc for steam, renewable seat and disc, bronze body, rated for 150 psi SWP and 300 psi WOG; Nibco T433B/Y, Jenkins 352, or equal.
    - 2 Inches and Smaller, Compressed Air Service: Threaded ends, union bonnet, lift type, stainless steel spring loaded, renewable bronze seat, stainless steel or teflon disc, bronze body, rated for 300 psi air; Stockham B-322T, Jenkins Fig. 54, or equal.
    - 2-1/2 Inches and Larger, General Service: Flanged ends, horizontal swing type, bolted bonnet, renewable bronze seat and disc, iron body, rated for 125 psi SWP and 200 WOG, conforming to MSS SP-71; Nibco F918B, Jenkins 624, or equal.
    - 2 Inches and Larger Silent Check Valves for Use at Heating Water, Chilled Water, and Tower Water Pump Discharge: Flanged ends, iron body, bronze trim, globe style, rated for 200 psi WOG; Mueller Steam Specialty No. 105M-AP, Combination Pump Valve Company, or equal.
    - 3 Inches and Smaller Check Valve for Use at Steam Condensate Pump Discharge: Threaded ends, ball cone type, ASTM B584 bronze body, Type 316 stainless steel spring, RTFE reinforced Teflon ball check, and brass trim; Conbraco 61-100 Series, Mueller Steam Specialties, or equal.

9. Triple Duty Valves: Due to significantly higher pressure drop than separate isolation valves and silent check valves, do not specify or accept triple-duty valves at pumps.

10. Ball Valves:
    - 1 Inch and Smaller: Full port, threaded ends, Type 316 stainless steel ball and stem, reinforced TFE seat rings and packing, blowout-proof stem, two-piece bronze body ASTM B584 Alloy 844, rated for 150 psi SWP and 600 psi WOG, conforming to Federal Specification WW-V-35B, Type II, Class A, Style 3; Nibco T-585-70-66, Jenkins, Apollo, or equal.
    - 1-1/4 Inches to 2-1/2 Inches: As specified for smaller ball valves above, except three-piece body, conforming to Federal Specification WW-V-35B, Type II, Class A, Style 3; Nibco T-595-Y-66, Jenkins, Apollo, or equal.
    - Specify plastic covered steel lever handles for uninsulated valves, extended vertical tee handles for insulated valves, and nonconductive polycarbonate sleeved handles (equal to Nibco "Nib-Seal") for chilled water valves.
    - For strainer blowdown and line drain valves, specify Model T-585-70-66-HC, similar to above, except with 3/4-inch hose connection, cap, and chain.
    - For low pressure steam and condensate service, specify Model T-585-70-66-ST, similar to above, except with minimum 250 psi steam rating.
    - For pure water service using Type 316 stainless steel piping, specify stainless steel ball valves conforming to Federal Specification WW-V-35, Type II, Class C, Style 3. Nibco T-580-S6-R-66, Jenkins, Apollo, or equal.

11. Butterfly Valves:
    - 3 Inches and Larger: Full lug style ASTM A216 WCC carbon steel body, Type 316 or 416 stainless steel stem, continuous stem pinned to disc or two-piece stem in full compliance with MSS-SP-68, with machined rectangular drives and sockets, Type 316 stainless steel disc, PTFE seats suitable for 250° F water, bronze bushings to

isolate the rotating stem from the stem journal, stem extended minimum two inches to clear insulation, rated for bubble-tight end-of-line service at 250 psi and 200° F water. Body and operators shall be epoxy coated. Nibco Model LCS-6822 (Class 150), Kennedy, or equal.

- Do not specify butterfly valves for whole building isolation. Specify gate or globe valves for this service.
- Attach to specified flanges with heavy hex bolts and lock washers. Piping shall be removable on one side while valve is closed. Apply Never-Seez, or equal, lubricant rated for minimum 1800° F on all lug bolts to ease future disassembly.
- Operators:
  - Valves 4 Inches and Smaller within 8 Feet of Floor: Galvanized steel handle with minimum of nine positions to lock valve disc, including positive stops at full open and closed positions.
  - Valves 4 Inches and Smaller for Throttling or Balancing Service: Infinite position galvanized steel handle with position indicator and integral bolted type memory stop.
  - Valves 5 Inches and Larger and 4 Inches Size where Elevated Location Requires Chainwheel Operators: Heavy-duty gear operated handwheel, or chainwheel where required, with position indicator, marked dial plate, and locking memory stop.
  - For outdoor or penthouse applications, metal parts shall be hot-dip galvanized or factory finished with epoxy coating system. Gear housings shall be weatherproof. Replace all fasteners, nuts, bolts, and washers on the face of lever or gear housings with stainless steel fasteners, nuts, bolts, and washers.

12. Gauge Cocks: For water service, use specified ball valve, 3/8-inch size. For steam and condensate service, use specified gate valve, minimum 3/8-inch size.

13. Vent Cocks: Use specified ball valve, 3/8-inch size.

K. Steam System Specialties

1. Strainers:
   - 2 Inches and Smaller: Y-type, ASTM A216 Grade WCB cast or forged steel body, threaded ends, Type 316 stainless steel or monel screen, maximum 20 mesh, rated for 984 psig saturated steam pressure; Mueller Steam Specialty, Armstrong, Spirax/Sarco, or equal.
   - 2-1/2 Inches and Larger: Y-type, ASTM A216 Grade WCB steel with flanged ends, ANSI Class 300, rated for 600 psig saturated steam pressure, stainless steel screen with 1/32-inch perforations; Mueller Steam Specialty No. 762, Spirax/Sarco Fig. 34, Armstrong, or equal.
   - At low pressure steam trap assemblies, install strainers with 1/2 inch blowdown gate valve, 3 inch long heavy brass nipple, and cap. Do not provide blowdown valves on steam or high pressure condensate strainers.
   - Apply Never-Seez, or equal, lubricant rated for minimum 1800° F on blowdown threads, O-rings, and gaskets to ease periodic disassembly.

2. Steam Traps:
   - Size all steam traps, in Specifications or on Drawings, by required capacities and pressure differentials.

- Provide complete steam trap assemblies at all low points of steam piping where condensate could accumulate, at end-of-lines, at bottom of headers and risers, and at all coil and heat exchanger connections. Control valves shall be considered end-of-lines and require drip trap assemblies upstream, except where branch lines are self-draining; i.e., branch piping slopes continuously down from control valve back to steam main. Provide unions at trap connections and arrange to permit inspection and removal of trap body without disassembly of piping. Provide isolation valves, strainers, test tees, and check valves at all trap assemblies.
- Low-Pressure Steam Traps at Heat Exchangers: Armstrong Series J and M, Hoffman, Spirax/Sarco, or equal, float and thermostatic type, ASTM A48 Class 30 cast iron body rated for 175 psi saturated steam, all stainless steel internals including float, water valve, seat, double fulcrum type valve operator, and sealed air vent. Internal parts shall be removable and replaceable without breaking pipe connections.
    - For vacuum return systems, install float and thermostatic traps with Armstrong Model TTF-1, or equal, thermostatic air vent with Type 304L stainless steel body, beryllium-copper bellows, stainless steel internals, rated for 300 psi steam. Install above steam chamber and outlet connection to trap.
- Steam Traps for High and Low-Pressure Drip Trap Assemblies: Confirm style to be specified with the University.
    - For constant pressure systems with a continuous condensate load, specify Steamgard, or equal, no known equal, modified venturi nozzle with no moving parts, all stainless steel construction. Select model and size based on system pressure and estimated condensate flow rate. Traps shall be rated for at least 150 percent of system pressure. Install with 40 mesh strainer upstream of steam trap. Steamgard traps must be carefully applied in accordance with manufacturer's instructions, and is not recommended in some cases. Consult with the University.
    - For locations that do not experience a continuous condensate load or pressure, specify Armstrong Series 800-813, Hoffman, Spirax/Sarco, or equal, inverted bucket trap with internal strainer and check valve. Body rated for 250 psig at 450 degrees Fahrenheit, maximum operating pressure 150 psi, ASTM A48 Class 30 cast iron body, all stainless steel internals. Minimum pipe connection 3/4" inch. Maximum orifice size 1/8-inch, unless a larger orifice is required for the expected condensate load.

3. Steam Pressure Regulating Valves:
    - Armstrong GP 2000, Hoffman, Kaye & MacDonald, or equal, with ductile iron body, ANSI class 250/300 flanges, stainless steel trim, rated for minimum 250 psig at 450°F, with Armstrong K-1 air operated pilot, automatic capacity control from zero flow to full rated capacity. Pressure reducing station shall provide 97 percent accuracy in downstream pressure control.
    - For large sizes, specify noise attenuating devices as necessary to meet requirements of Occupational Safety and Health Act for 8 hours continuous exposure, or as necessary to limit valve noise to 85 dbA at 3 feet from valve. Insulation shall not be considered as a sound attenuating device. Noise reducing orifice plates, if provided, shall be stainless steel, sized by manufacturer to match pressure regulating valve capacity.
    - For main building supply pressure reducing stations, specify two valves in parallel, both sized for 100% of the building load.
    - For two-valve pressure reducing stations, one valve shall be sized to handle approximately 1/3 of station load and the other valve for approximately 2/3 of station load. Operation shall be such that on increase in load, smaller valve shall gradually

open to its full position and upon further increase in load, larger valve shall gradually open with smaller valve full open. On decrease in load, reverse shall occur.

- Install so that valves are readily accessible for inspection and maintenance. Provide unions or flanges on each side of valve and on pilot actuator connection (if used). Provide with isolation valves, bypass globe valves, pressure gauges, safety relief valves, and as recommended by the pressure regulating valve manufacturer.

4. Steam Back Pressure Regulating Valves:
    - Use at flash tanks to limit pressure buildup and other applications as appropriate. Armstrong Model GP-200R with ductile iron body, stainless steel trim, externally piloted to provide automatic capacity control from zero flow to full capacity, rated for minimum 250 psig at 450 degrees F, or equal, no known equal. Valves 2 inches and smaller shall have threaded ends and unions; 2-1/2 inches and larger shall have flanged ends.

5. Steam Safety Relief Valves:
    - Provide on the downstream side of pressure regulating valves and elsewhere as required by Code. Show all relief valve locations and set pressures on the Drawings.
    - Specify minimum capacity of steam pressure relief valve or valves to provide for full discharge of the capacity of the largest regulating valve without allowing the lower pressure to rise more than 6 percent above the highest pressure at which any valve is set.
    - Spence Model 41, Kunkle, Watts Regulator, or equal, ASME Code, Section VIII, with bronze or cast iron body, threaded inlet and outlet connections up to 2-inch size and flanged connections over 2-inches, copper alloy disc, stainless steel spring located in housing, ASME stamp and test lever. Specify with Kunkle Figure 299, Sarco, or equal, cast iron drip pan elbow piped to floor drain.
    - Show discharge piping of steam relief valves extended to open air, preferably through the roof or wall to a safe discharge area. Do not allow discharge into any room or area within the building. At a minimum, steam relief piping shall be full size of the relief valve.

6. Steam Vacuum Breaker:
    - Adjustable from 1/4 to 20 inches Hg vacuum, 3/4-inch IPS threaded brass body, stainless steel spring, brass trim, rated for 150 psig at 240 degrees F; Hoffman No. 62, Armstrong, or equal.
    - Install at steam condensate outlet from steam heating coils, at steam-to-water heat exchangers, and as required for proper condensate drainage at any other steam using apparatus.

7. Vertical Flash Tank:
    - ASME Code constructed and stamped for 150 psig working pressure, black steel shell, flanged inlet and outlet, registered with the National Board of Boiler and Pressure Vessel Inspectors; Armstrong Model AFT-6, Chemline Corporation, or equal. Specify with factory welded steel legs and base plates. Size flash tank for 150 percent of maximum anticipated high pressure condensate flow rate. Protect with relief valve and back pressure regulating valve described above.

8. Condensate Receivers and Return Units:
    - Size condensate receivers for a minimum storage capacity of 10 minutes.

- Size condensate return pumps to empty condensate receiver (from high to low water level switches) within one minute. Size condensate pump head at least 10 PSI higher than the maximum anticipated backpressure at design flow rate.
- Provide redundant pump(s) at condensate return units.
- Provide a compound pressure gauge at each condensate pump, connected to both the inlet and discharge sides of the pump.
- Provide a thermometer on the condensate receiver, with the thermometer well at a level that is always under water.

9. Steam and Condensate Piping:
   - Steam Piping: Pitch mains down at 1" per 40'-0" in direction of flow. Pitch runouts to terminal equipment and control valves at 1/2" per 1'-0" for proper condensate drainage. Use bottom flat eccentric reducers for changes in size. Make branch take-offs from top of mains. Provide a minimum of three elbows in branch piping to terminal equipment to provide flexibility for expansion and contraction. Provide minimum 6-inch long line size drip legs at the base of each riser and at low points where condensate could accumulate. Provide minimum 4-inch long line size dirt pockets below drip legs with 3/4-inch capped blowdown valve at base of dirt pocket. Install strainer baskets in steam lines horizontal so that condensate does not collect.
   - Condensate Return Piping: Slope as indicated to allow gravity return. Connect branches to top of return mains. Use bottom flat eccentric reducers for changes in size. Medium pressure return can be lifted maximum 12 feet to return mains. Low pressure return and any return downstream of temperature regulating valves shall be gravity return with no lifts allowed. Support traps weighing over 25 pounds independently of connection piping.
   - Pumped Condensate Return Piping: Install same as condensate return piping, with lift limited by the condensate pump head and system configuration.

L. Water System Specialties

1. Pressure Ratings for Piping Specialties:.
   - Water system specialties shall have ratings listed below, unless higher ratings are indicated or required for the service. Specify appropriate pressure ratings for all piping specialties.
   - Regardless of pressure ratings listed below, water system specialties below the 6th Floor of Moffitt and Long Hospitals shall be rated not less than Class 250.

2. Strainers:
   - 2 Inch and Smaller, Steel Pipe: Y-type, cast iron or ductile iron body, threaded ends, stainless steel or monel screen, maximum 20 mesh, bronze plug, Class 250 class; Mueller Steam Specialty No. 11FCB, Armstrong Type AISC, Spirax/Sarco Model IT, or equal.
   - 2 Inches and Smaller, Copper Pipe: Y-type, bronze body, thread ed ends, stainless steel or monel screen, maximum 20 mesh, Class 250; Spirax/Sarco Model BT, Mueller Steam Specialty No. 352, Armstrong Type F4SC, or equal.
   - 2-1/2 Inches to 4 Inches, Copper Pipe: Specify Y-Type, ASTM B62 cast bronze, flanged ends, stainless steel or monel screen, maximum 1/16 inch perforations, bolted screen retainer with off-center blowdown connection, metal filled graphite cover gasket, 100 mesh stainless steel liner permanently bonded to screen, Class 300, Mueller Steam Specialty No. 852, Armstrong, Spirax/Sarco, or equal.
   - 2-1/2 Inches and Larger, Steel Pipe: Y-Type, ASTM A126 Class B cast iron body, flanged ends, stainless steel or monel screen, maximum 1/16 inch perforations up to

4-inch size and 1/8-inch perforations for larger sizes, bolted screen retainer with off-center blowdown connection, Class 250; Mueller Steam Specialty No. 752, Armstrong Type A1FL-250, Spirax/Sarco CI-250, or equal.

  - o Specify equivalent basket strainers for larger sizes installed near the floor to improve service access.
  - o Specify permanent magnets in strainers at each pump suction. Magnets shall be removable cast Alnico No. 5 channel magnets and shall create a continuous magnetic field around the entire screen circumference. Magnets shall be secured with stainless steel retaining lugs and threaded rods.
  - o For outdoor applications, specify appropriate weatherproof epoxy coating.
  - o For cooling tower water service, specify with permanent 40 mesh stainless steel liner spot welded to screen, or recommend another continuous cleaning method. Specify a spare screen and liner of each size.
- Strainers are required ahead of pump suctions, control and regulating valves, steam traps, and at other appropriate locations. Show all strainers on the Drawings; do not rely on general notes.
- For hydronic systems and steam condensate, specify that strainers be installed with specified ball valve same size as the blowdown plug, 3-inch long brass nipple, and 3/4-inch hose connection and cap. Installation shall have blowdown connection at low point of strainer basket.
- Specify strainers with temporary 80 mesh stainless steel liners which shall be removed after specified cleaning and flushing. Removed liners shall be turned over to the University's Representative at the end of the project.
- Apply Never-Seez, or equal, lubricant rated for minimum 1800° F on blowdown threads, O-rings, and gaskets to ease periodic disassembly.

3. Automatic Air Vents:
   - Brass or semi-steel body, 150 psig WP at 250 degrees F, copper or stainless steel float, stainless steel valve and seat, non-opening with negative pipeline pressures; Amtrol No. 720, Spirax/Sarco, or equal. Epoxy paint finish for non-brass bodies. Route 1/2-inch bleed line to floor drain.
   - Provide automatic air vents on air separators and at system high points where air will periodically accumulate. Show all automatic air vents on the Drawings; do not rely on general notes.

4. Manual Air Vents:
   - Manual air vent assemblies shall consist of a line size air chamber (maximum 2 inch size), 1/2-inch ball valve, and 3/8 inch or 1/4 inch bleed piping. Require manual air vents at all high points and at all downward elbows where air could accumulate in heating water, chilled water, and cooling tower water piping.
   - Air vent bleed lines shall be routed to facilitate line venting without inhibiting access to valves or equipment. For manual air vents above finished ceilings, bleed lines shall extend at least 6 inches below adjacent piping and terminate at an accessible location not more than 18 inches above ceiling. A secondary bleed valve shall be provided at termination with 4-inch tail piece.
   - Provide manual air vents and drain valves on the equipment side of all coil and equipment isolation valves such that all branch piping at equipment or coil can be drained and filled without having to drain or vent main piping.
   - Provide manual air vents and drain valves between each set of isolation valves in distribution piping such that all piping between isolation valves can be vented and drained with that section of pipe isolated from the rest of the system.

5. Expansion Tanks:
    - Diaphragm type with welded steel tank, ASME code construction and stamped, 125 psi working pressure at 240 degrees Fahrenheit, steel base with welded brackets for anchorage to floor slab; Wessels, Amtrol, Bell and Gossett, or equal. Provide with system connection, air charging valve, and drain plug. Integral heavy-duty butyl rubber diaphragm shall provide permanent sealed-in air cushion and be removable for inspection or replacement. Schedule sizes and charging pressures on the Drawings.

6. Pipe Flexible Connectors:
    - Corrugated metal braided flexible connectors are preferred. Carefully select hose and braid material, end connection type and material, pressure and temperature ratings. Indicate required live length and/or allowable offset dimensions. Select braided flexible connections for lateral deflection only; braided hose is not suitable for axial motion.
    - Provide sufficient elbows and offsets at heating water connections to duct coils to utilize the natural flexibility of copper piping. Alternately, consider the use of braided flexible connectors at zone heating coils where significant differential movement is expected. For OSHPD projects, see 2013 CMC 1201.3.7.
    - Braided Metal Flexible Connectors: Flexonics Series 401M, Hyspan, or equal, corrugated Type 321 stainless steel hose and braid. Minimum working pressure of 280 psig at 70 degrees F. Maximum temperature rating of 1500 degrees F. Select live length to permit minimum 1.0-inch lateral movement. Install to permit lateral motion only.
        - 2 Inches and Smaller: Type 304L stainless steel threaded union ends. Alternately, plain ends and separate unions are acceptable.
        - 2-1/2 Inches and Larger: Type 304L stainless steel flanged ends, 150 lb. ASA forged raised face weld neck flanges.

    - Installation: Include the following requirements in the project Specifications:
        - Installed flexible connectors shall experience zero static deflection when systems are at operating temperature and pressure. Support piping as close as possible to flexible connectors, maximum 24 inches away.

7. Pressure Regulating Valves:
    - 2-1/2 Inches and Smaller: Bronze body, threaded ends; renewable stainless steel seat, temperature-resistant diaphragm, sealed cage construction, 25 to 75 psi adjustment range, 300 psi maximum inlet pressure; Watts 223, Armstrong, or equal. Indicate pressure setting on the Drawings.
    - 3 Inches and Larger: Cast iron body, flanged ends, stainless steel trim, temperature-resistant Hycar rubber diaphragm, sealed cage construction, 30 to 80 psi adjustment range, 200 psi maximum inlet pressure; Watts 2300, Armstrong, or equal. Indicate pressure setting on the Drawings.

8. Chemical Pot Feeders:
    - Minimum 5-gallon capacity, heavy-gauge welded steel fabricated from ASTM A135 pipe with 3-1/2-inch diameter neck opening, O-ring cap assembly and 3/4-inch NPT system and drain connections. Maximum working pressure shall be 200 psi at 212 degrees F. Specify with factory welded support legs so that cap is approximately 36 inches above the floor and drain connection is not less than 15 inches above the floor. Specify with factory-applied primer and chemical resistant epoxy finish inside and outside. Schedule pot feeders on the drawings. Manufacturers: J. L. Wingert Co., Griswold, Clow, or equal.

- For buildings that are connected to central campus utilities, evaluate with the University whether or not a chemical pot feeder is required.

9. Air Separators:
    - Provide centrifugal type air separators in new heating water and chilled water systems. For buildings that are connected to Central Utility Plant systems, evaluate with the University whether or not a building air separator is required. The air separator should be located in the warmest portion of the system. Size centrifugal air separators for a maximum water pressure drop of 1 psi. Schedule air separators on the Drawings.
    - Centrifugal type air separator, constructed in accordance with ASME Code and stamped 125 psig design pressure; Bell & Gossett "Rolairtrol", Armstrong, or equal. Threaded ends for sizes 2 inches and smaller; flanged ends for sizes 2-1/2 inches and larger. Vessel shall have diameter minimum three times nominal inlet/outlet pipe diameter. Specify with internal stainless steel air collector tube. Specify appropriate support attachments, which may be factory-welded hanger brackets or base ring.

10. Solids Separators:
    - Consider the use of centrifugal solids separators for cooling tower systems and when modifying old steel closed-loop distribution systems. Discuss applicability with the University.
    - Separators shall be in-line centrifugal vortex type designed to remove separable solids from liquids. Separators shall remove 98 percent by weight of separable solids 200 mesh (74 microns) and larger. Schedule separator size, flow rate and pressure drop on the Drawings.
    - 2 Inches and Smaller: Minimum 0.135-inch thick stainless steel construction, 150 psig operating pressure, threaded inlet and outlet connections, 3/4-inch purge outlet, factory supplied mounting clamps; Lakos Series IL-S, Metraflex, or equal.
    - 2-1/2 Inches and Larger: Minimum 0.25-inch thick carbon steel construction, certified and stamped ASME Code construction for 125 psig working pressure, Class 150 flanged inlet and outlet, 1-1/2 inch purge outlet, 3/4 inch auxiliary outlet, venturi pressure relief line, base ring for anchorage to concrete base, inspection port, 3/4 inch air vent port, 1/2 inch inlet and outlet gauge ports, 2 inch upper dome inspection port, factory enamel finish; Lakos Series R-TS, Metraflex, or equal.
    - Provide each solids separator with a Lakos Model LR, or equal, motorized ball valve and controller. Valve shall have stainless steel body, ball, and stem, teflon seats, rated for 200 psi operating pressure. Valve actuator shall be in a NEMA 4 enclosure and include a single phase, reversible, permanently lubricated motor with built-in overload protection.
    - Detail a minimum 16-inches x 16-inches x 8" tall covered stainless steel receptor for solids separator blowdown, with an internal removable 20 mesh Type 316 stainless steel screen. Provide with stainless steel support legs to hold receptor minimum 8 inches above the floor. Pipe screened effluent to floor sink.

11. Chilled Water Storage Tanks:
    - Consider a chilled water storage tank for small chilled water systems where compressors are expected to cycle on and off under low load conditions. Size storage tank volume equivalent to normal system flow rate for the period of time that the system minimum-off-timer will prevent compressor operation (normally 3 to 5 minutes).
    - Storage tank shall be carbon steel, constructed in accordance with ASME Code and stamped for 125 psi working pressure. Specify with a flanged inlet as low as possible,

incorporating an internal distribution tree with not less than 24 downward facing holes for low velocity water entry into tank. Specify with flanged outlet on top of tank, inspection opening, 3/4-inch drain and thermometer well tappings, factory welded steel angle support legs, and steel base plates.
- For large systems, consider stratified storage tanks, such as CBI Strata-Therm, or equal thermal energy storage tanks.

12. Water System Relief Valves:
    - Bronze body, threaded ends, brass seat and trim, lever operated, non-adjustable factory set discharge pressure, constructed, rated, and stamped per ASME Code; Kunkle Series 20, Watts Regulator, Consolidated, or equal.
    - Provide relief valves on all equipment requiring pressure relief, including fired and unfired pressure vessels, heating water generators, on the downstream side of pressure regulating valves, and elsewhere as required by Code. Show all relief valve locations on the Drawings.
    - Show discharge piping extended to open safe drain with adequate capacity for anticipated maximum discharge.

M. Thermometers and Pressure Gauges

1. Temperature/Pressure Test Ports:
    - Specify Peterson Equipment Company “Pete's Plug” Model 710, Sisco Plug, or equal, brass body, 1/2 inch NPT threaded end, Nordel valve core rated to 275 degrees F, with color-coded and gasketed cap. For piping with more than 1-inch thick insulation, specify Type XL 3-inch long models so that cap extends beyond pipe insulation.
    - Provide test ports on the inlet and outlet connections to coils, chillers and heat exchangers, and at other locations to facilitate system testing, balancing, troubleshooting, and servicing.
    - Where test ports are installed above ceilings, install horizontal to provide the easiest possible angle for reading gauges. For 3/4 inch and smaller piping, elbow mount test ports to permit full insertion of temperature probe.

2. Pipe Thermometers:
    - Specify Weksler Type AF, Weiss, or equal, adjustable angle bimetal thermometers, 5-inch diameter, all stainless steel construction, dished anti-parallax dial, glass front, externally adjustable for recalibration, accuracy plus or minus 1.0 percent of range, separable socket connection. Approximate ranges:
        - Heating Hot Water System: 30 to 240 degrees F, two-degree increments.
        - Chilled Water System: 10 to 100 degrees F, one-degree increments.
        - Tower Water Systems: 30 to 130 degrees F, one-degree increments.
    - Provide pipe thermometers on the inlet and outlet connections to main building heating and cooling coils, chillers, heat exchangers, cooling towers, near each energy management system temperature sensor, and at other locations requested by the University.
    - Carefully consider how to achieve full immersion of thermometer well in active flow streams. Specify longest practical stem lengths. Elbow mount sensor wells in pipes up to 2-inch size; increase elbow one pipe size at insertion points. Provide tee fitting at elbow with insertion well in blind end of tee.
    - Thermometers shall be located and adjusted for easy reading while standing on the floor or viewing platform.

3. Pressure Gauges:
   - Specify Weksler Type AA4, Weiss, or equal, 4-1/2 inch diameter dial, with black cast aluminum case, threaded black cast aluminum ring, gasketed glass front, Type 316 stainless steel socket, Type 316 stainless steel spring tube, precision stainless steel movement with micrometer needle adjustment, accuracy 0.5 percent of full scale. Specify ranges that most closely encompass system operating parameters.
   - Provide pressure gauges across pumps, pressure regulating assemblies, near each energy management system pressure sensor, and at other locations requested by the University. A single pressure gauge should be provided at pump installations, and be piped to inlet and discharge tappings. A pressure gauge should be provided across (cooling tower water) strainers having permanent fine mesh liners.
   - Provide pressure gauges with specified gauge cocks (ball valves) and filter type stainless steel pressure snubbers specifically selected for liquid, air, or gas service. Pressure gauges for steam and condensate service shall be installed with brass or stainless steel coil syphons.
   - Pressure gauges shall be connected to system piping using minimum 3/8 inch hard drawn copper tubing. Where a single gauge is used to measure pressure at multiple points, provide gauge cocks for each branch within 12 inches of gauge. Contractor shall locate and adjust pressure gauges for easy reading while standing on the floor.

4. Differential Pressure Gauges:
   - Specify Barton Model 227A, Rosemount, or equal, differential pressure indicator, range as appropriate to match associated venturi or differential pressure transmitter. Differential pressure sensing and actuating unit shall consist of a dual 1.625 inch outside diameter liquid-filled rupture-proof Type 316 stainless steel bellows assembly, fully temperature compensating between minus 40 and plus 180 degrees F, internal range springs within each bellows, beryllium copper torque tube, stainless steel torque shaft, and miniature ball bearings for accurate operation without hysterisis or backlash, all contained within a self-venting and draining Type 316 stainless steel housing rated for 500 psi SWP. 1/4-inch NPT top and bottom connections. Indicator shall be rugged, easy-to-read, precision made, with jeweled rotary motion, micrometer screws for zero and range adjustments, internal linearity adjustment, 6-inch diameter die-cast aluminum case, and glass cover sealed with elastomer ring. Minimum certified accuracy of plus or minus 0.5 percent of full scale differential pressure, including linearity, hysterisis, and repeatability.
   - Provide high quality differential pressure gauges where permanent differential pressure type flow meter indication is required, and adjacent to differential pressure transmitters for variable speed pumping systems. Install with bypass and bleed valves so that all air can be purged from gauge tubing.

N. Flow Measurement and Balance Valves

1. Calibrated Balancing Valves:
   - Specify Armstrong CBV, Tour & Andersson, or equal, Y-type globe valve with integral differential pressure taps, memory-stop locking device, and calibrated vernier-type ring scale with at least four complete rotations between full open and closed. Valves shall be rated for a working pressure of 200 psi at 250 degrees F and shall provide tight shutoff. Sizes up to 2 inches shall be bronze with threaded ends. Sizes 2 inches to 4 inches shall have 150 psi cast iron bodies, flanged ends, and brass trim. Circuit balancing valves shall not be used for shutoff service; provide adjacent shutoff valve.

- Select sizes appropriate for scheduled flowrates. For water flows less than 1.5 gpm, specify 1/2-inch "low flow" models rated for water flow rates down to 0.3 gpm. For other water flows, specify balancing valves with fully open pressure drop between 2 and 10 feet w.g. at design flow rate. Show reducers as necessary if circuit balancing valve is smaller than line size. Require that specific sizes and flow ranges be submitted for approval.
- Specify calibrated balancing valves at each heating and cooling coil section, at chillers and heat exchangers, and at other locations to facilitate system testing and balancing. For piping larger than 4 inches, provide butterfly valves with throttling style handles and separate flow meter.
- Specify installation in accordance with manufacturer's recommendations for certified accuracy; with minimum of five diameters of straight pipe up stream and three diameters downstream. Require Contractor to locate and orient to allow easy reading of vernier scale.
- Calibrated balancing valves shall be insulated, except that balancing valves at heating coils not subject to continuous flow (i.e., if the circuit has a 2-way control valve) do not require insulation. Specify removable insulation with Velcro fasteners or metal jacket. Require Contractor to maintain vapor barrier on chilled water applications.
- Automatic Flow Limit Valves: Valves that automatically limit flow rate using spring and orifice devices are not considered reliable for long-term use and shall not be specified.

2. Visible Water Flow Indicators for Medical Equipment Connections:
    - Specify water flow indicators adjacent to calibrated balancing valves for connections to medical and laboratory equipment, where equipment vendors and/or Users might need to adjust water flow to equipment. Require printed labels adjacent to devices indicating design water flow.
    - Specify Dwyer VFCII, or equal, no know equal, constructed of acrylic plastic with metering tube machined into body, stainless steel float, stainless steel spring float stops, 1-inch NPTM taps for inline or back pipe connections, threaded caps for plugging unused connections, accuracy plus or minus 2 percent of full scale, rated for 100 psig at 120°F. Specify appropriate flow range for each application.

3. Water Flow Meters for System Metering and Balancing:
    - The following flow meter is for systems with separate flow metering and balancing devices. Where these functions can be combined without additional pressure loss to the system, then specify calibrated balancing valves as described above. Where continuous water flow and energy (BTU) monitoring is being provided, then specify the BTU monitoring system described in Paragraph 4 below; the flow meter furnished as part of that assembly can be used for system balancing.
    - Specify Fluidic Techniques HRR Flow Tubes, Gerand Venturis, or equal, venturi-type flow meters complete with portable dry-type master meters, pressure taps, quick connect couplings, and stainless steel needle valves. Flow meters shall be fully machined for maximum accuracy, plus or minus 2.0 per cent certified accuracy, with a maximum permanent pressure drop less than 20 percent of the meter differential pressure. Sizes up through 2 inches shall be bronze with threaded ends. Sizes 2-1/2 inches and larger shall be Type 304 stainless steel with flanged ends. Provide engraved laminated plastic tag with brass chain indicating venturi size, system, flow rate, and differential pressure reading at design flow rate. Select flow meters to generate approximately 150-inch water column (w.c.) of pressure differential at design flow rate.

    - Require submittal of large size full range flow charts in the project O&M manual.
    - Require submittal of the algorithm for converting the differential pressure signal to gpm for use by the energy management system.
- Portable Metering Kit: Where multiple flow meters are provided on a project, specify a high quality metering kit consisting of two 6-inch diameter differential pressure gauges (high range and low range), two 10-foot hoses rated for 400 psi at 400 degrees F, quick disconnect valves, manifold with equalizers, bleed and vent valves, and check seals. Low range 0 to 50 inch w.c.; high range 0 to 250 inch w.c. Minimum certified accuracy of plus or minus 0.5 percent of full scale differential pressure, including linearity, hysterisis, and repeatability. Product: Barton Model 227A, Gerand, or equal, with all special features specified.
    - Specify installation of both gauges in an aluminum or rigid plastic carrying case with gauges and piping manifolds permanently mounted.
    - Require submittal of operating instructions and typewritten schedule indicating all flow stations, locations, design flow rates, and design meter readings.

4. Energy (BTU) Monitoring Stations:
    - Specify the following flow and temperature monitoring system where BTU monitoring is required for heating water and chilled water systems.
    - Specify Onicon System-10, Spire Metering Technology T-MAG, or equal, hydronic energy metering system consisting of an electromagnetic flow meter and a matched pair of temperature sensors. No moving parts shall be required. Entire assembly shall be furnished with a NIST traceable certificate of calibration.
    - Temperature sensors shall be factory bath-calibrated together so that the calculated differential temperature used in the energy calculation is accurate within plus or minus 0.15° F, including combined errors from the individual sensors and internal calculations. Sensor calibration shall be NIST traceable and certified.
    - Sizes 3" and Larger: Specify Onicon F-3500 series, Spire Metering Technology, or equal, insertion electromagnetic flow meter. All wetted metal materials shall be Type 316 stainless steel. Each flow meter shall be individually wet-calibrated against a primary volumetric standard that is accurate to within 0.1% and NIST traceable. A certificate of calibration shall be provided with each flow meter. Accuracy shall be within plus or minus 1.0% of reading from 2-20 feet per second water velocity, with overall turndown of 80:1.
    - Sizes 2-1/2" and Smaller: Specify Onicon F-3100 series, Spire Metering Technology, or equal, inline full bore electromagnetic flow meter with Type 316 stainless steel outer body material, stainless steel flow tube, Type 316 stainless steel sensing elements, ebonite liner for chilled water service, PTFE liner for heating water service, rated for 14° to 122° F media. Each flow meter shall be individually wet-calibrated and accurate to within ±0.4% of reading from 3.3 to 33 feet per second (FPS) water velocity, ±0.75% of reading from 1 to 3.3 FPS, and ±0.0075 FPS at flows less than 1 FPS. A certificate of calibration shall be provided with each flow meter. Install in copper piping with minimum 10 diameters of straight pipe upstream, and 5 diameters of straight pipe downstream.
    - Control panel shall be NEMA 4X rated, with LCD display and keypad, and have four (4) 4-20 mA or 0-10 VDC outputs signals for each temperature sensor, flow meter, and BTUH calculated value. Provide pulse output for total energy consumption. Additionally provide serial network communication using BACnet, Lonworks, or Modbus protocol, as needed to communicate with the energy management system.

Each meter shall be factory programmed for its specific application, and be field-programmable using the panel keypad.

- Follow manufacturer's written commissioning instructions. Complete manufacturer's commissioning checklist and submit with project closeout documents.

5. Water Meters for System Consumption Monitoring:
   - Provide each make-up water assembly with a water meter to track total consumption between water treatment intervals.
   - Specify Neptune T10, Hersey, or equal, magnetic driven, positive displacement water meter with flat nutating disc and conforming to AWWA Standard C700, "Standard Specifications for Cold Water Meters". Bronze body, stainless steel bolts and trim, threaded connections, sweep hand totalizer with 6 numeral wheels, hinged cover plate, suitable for the maximum expected flow.
   - Where remote monitoring is required, specify models with electronic pulse transmitter and a wide range of accurate operation. Transmitters shall be serviceable without interrupting meter operation.

6. Refrigerant Head Pressure Control Valves:
   - For water cooled condensers, specify Johnson Controls V46 Series, Honeywell, or equal, two-way direct acting pressure actuated modulating valve, cast brass body, threaded ends.
   - Provide refrigerant pressure actuated control valves on cooling water lines to condensers. Size valves in accordance with valve manufacturer's instructions, based on condensing unit capacity and acceptable refrigerant head pressure rise above opening point (from cold room or refrigeration equipment manufacturer).
   - For critical reliability applications where condenser cooling system has a recirculating water supply with once-through city water for emergency backup, require that the head pressure control valve be adjusted in the field to provide stable operation using either recirculating water or city water as the cooling source. Under such condition, balance maximum recirculating water and city water flow rates using circuit balancing valves on each supply line. Adjust system to operate with the lowest reasonable water flow and highest reasonable temperature rise under both operating conditions.

O. Pipe Supports

1. See Seismic Design Criteria in Paragraph 23-4-D.

2. Specify all pipe support products and methods. Do not leave to the Contractor's discretion. Take particular care with vertical pipe supports to allow for expansion and contraction. Support all risers from floor at their base so that weight is not carried at wall brackets or riser clamps.

3. Support piping on common trapeze hangers where feasible. Coordinate design of pipe supports and structural attachments with the project Structural Engineer.

4. Do not allow valves or equipment to support the weight of piping.

5. Isolate all uninsulated copper and glass pipe by means of a felt-lined hanger or manufactured resilient isolators.

6. Protect all insulated pipe from crushing at supports by means of sheet metal and calcium silicate insulation shields, or pipe saddles secured to pipe.

7. Specifications shall include requirement that concrete inserts and anchors for pipe hangers shall be pull-tested in accordance with California Building Code requirements.

8. Corrosion Protection: All carbon steel products, including all rods, fasteners, and other hardware that are exposed in mechanical and electrical equipment rooms shall be hot-dip galvanized in accordance with ASTM A123 and the Standard Specifications of the Hot-dip Galvanizers Association, Inc. Coating thickness shall be not less than 2.5 ounces of zinc per square foot of surface
   - Welding of galvanized products shall be avoided wherever possible and shall only be allowed where specifically approved by the University. Where field welding is required, clean and grind smooth welds, and paint welded area with two coats of Zinc-Rich Coating or other high zinc content paint complying with MIL-P-21035.
   - Stainless steel is an acceptable alternate to hot-dip galvanizing provided that all associated nuts, bolts, washers, and related hardware are stainless steel.
   - All steel products, including all rods, fasteners, and other hardware that are located outside the building (covered or uncovered) shall be stainless steel.

P. General Installation Requirements for Piping

1. General: Installation procedures to be followed by the Contractor shall be included in the project Specifications.

2. Do not permit contact between uninsulated copper piping and metal surfaces such as conduits, tie wires, and wall studs that may be sources of stray current corrosion. Protect penetrations through metal surfaces using specified isolators.

3. Prohibit bull-head tee connections in either mixing or diverging flow.

4. Steam and condensate piping shall not be installed below grade within building footprints.

5. Specify and detail complete firestopping systems for penetrations through fire-rated walls and floors, in accordance with the UL Fire Resistance Directory, “Through Penetration Fire-Stop Systems.” Firestopping details shall be approved by the California State Fire Marshal or OSHPD.

6. Sloping and Draining:
   - Require that piping be sloped in the direction of flow as follows:

Service	**Inclination**	**Slope**
Steam and Condensate	Down *	1/8-inch per foot
Heating Water, Chilled Water, *and Cooling Tower Water	Up	1 inch per 40 feet
Condensate & Indirect Drains	Down	1/4-inch per foot
*Refrigerant Liquid, Suction, S and Hot Gas	Down	1/8-inch per foot

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eam branch lines to automatic control valves shall be sloped back towards the main. Steam strainers in horizontal piping shall be installed with strainer basket in a horizontal plane to be self-draining.

- Require bottom flat eccentric reducers in steam and condensate piping. Require top flat eccentric reducers in heating water and chilled water piping and at pump connections.
- Connect steam and condensate branch piping to top of mains.
- Where possible, connect heating water and chilled water branch piping to bottom of mains to allow self-venting of branch piping.
- Require 3/4-inch drain valves (ball valves) with 3/4 inch capped hose connections at all low points in piping and at locations where scale or debris could accumulate. Nipples at drain valves and strainer blowdown shall be red brass, minimum 3 inches long.
- Require manual air vents at all high points and at all downward elbows where air could accumulate in heating water, chilled water, and condenser water piping. Survey new installations to verify the provision and proper location of manual air vents prior to insulating piping.
- Design condensate drainage at all locations where condensate could accumulate. Terminate condensate drain lines over floor drain, funnel, or floor sink such that condensate flow does not spill onto floors or create a hazard. Provide suitable traps and vents such that condensate flows freely, without accumulation, especially where drain lines penetrate ducts, air handler casings, plenums, or other pressurized spaces.

Q. Thermal and Seismic Expansion Compensation

1. New piping systems shall be designed for thermal expansion and contraction using expansion loops, offsets, guides, and anchors. Locate guides and anchors to allow expansion and movement without warping or loss of line or grade, or causing damage to equipment or building. Mechanical expansion joints shall be used if expansion loops are not possible.

2. For heating water distribution piping, where main piping is longitudinally braced or anchored:
   - Avoid short direct connections from heating coils to mains.
   - Extend branch run-outs to heating coils away from mains for a total distance not less than five percent (5 percent) of the distance to the nearest main pipe brace or anchor.
   - For OSHPD projects, see 2013 CMC 1201.3.7.

3. Include seismic joints to accommodate the maximum anticipated horizontal and vertical differential movement where piping crosses building seismic joints. Manufactured seismic joints and swing joints can be used. Provide rigid seismic restraints in two directions on each side of seismic joints in piping.

4. Provide shut-off valves on both sides of manufactured seismic and expansion joints.

R. Cleaning and Chemical Treatment

1. General:
   - During construction, require that all openings in piping be closed to prevent entrance of foreign matter. Pipes, fittings, valves, and specialties shall be clean prior to connecting to system.

- Do not allow raw untreated water to be used in HVAC piping systems, even for system testing.
- The following procedures, to be followed by the Contractor, shall be included in the project Specifications.
- Prior to specifying specific chemicals, consult with the University and coordinate with existing chemical treatment currently used at Parnassus, Mt. Zion, and other campuses.
- For short lengths of new piping in existing systems, in lieu of comprehensive cleaning and flushing specified below, allow new piping to be pre-cleaned at the shop and sealed prior to shipment to the jobsite. Require submittal of shop procedures that will ensure the removal of all oil, grease, mill scale, and normal accumulations of dirt and silt generally found in new piping that has been stored for a period of time. Piping should be securely sealed after shop cleaning. Observe new piping material in the field to ensure that is properly sealed.

2. Procedure for Heating Water, Chilled Water and Cooling Tower Water Systems:
   - Isolate new sections of piping from existing. Provide temporary bypasses and/or valves at the end of new runs, so that all new piping can be cleaned and flushed. Provide temporary pot feeder, water meter, gauges, valves, circulating pump, and power connections as necessary to accomplish cleaning and flushing procedures. Circulation shall be not less than 50 percent of design in all circuits.
     - Temporary circulation systems shall be provided with a line size Lakos solids separator, or equal means for removing particles 200 mesh and larger.
     - Should portions of new piping systems be placed into service without specified cleaning, then clean entire system shall be cleaned as specified herein.
   - Open control and regulating valves and preliminarily adjust circuit balancing valves so that every leg of new piping has approximately design flow during cleaning period. Periodically open bypass ports on 3-way valves so that bypass legs are cleaned.
   - Install temporary 80 mesh stainless steel liners at all strainers during start-up and cleaning. Remove and clean liners every 24 hours, or more often if necessary, until entire system runs absolutely clean. Remove temporary liners after system cleaning has been accepted and deliver uncleaned liners to the University's Representative. Clean and reinstall permanent liners at cooling tower water strainers.
   - Remove flow monitoring devices and other instrumentation subject to fouling or damage prior to cleaning procedures. Replace with nipples or spool pieces until cleaning is complete.
   - Cleaning and Treatment Chemicals:
     - Chemical Cleaner for Closed Loop Systems: San Joaquin Chemicals SANASOLV 6103, Garratt-Callahan, or equal, alkaline formulation designed to remove oil, grease, mill scale, and normal accumulations of dirt and silt generally found in process piping after new construction.
     - Chemical Cleaner for Systems Containing New Galvanized Pipe: Garratt-Callahan Formula 221-L, San Joaquin Chemicals, or equal, specifically formulated to clean and passivate zinc surfaces.
     - Corrosion Inhibitor for Closed Loop Systems: San Joaquin Chemicals SANACOR 2301, Garratt-Callahan, or equal, borate-nitrite type inhibitor formulated to protect ferrous and non-ferrous (copper and brass) surfaces from corrosion attack. Inhibitor shall contain no chromium, zinc, or phosphate, and be buffered to provide effective protection at low treatment levels. For existing systems, coordinate with existing chemical inhibitor in

use; typically Garratt-Callahan products at Moffitt/Long Hospitals, and San Joaquin Chemicals at Mt. Zion campus.

- Procedures for Closed Loop Systems:
    - Add chemical cleaner via the bypass feeder at a rate of 5 gallons per 1,000 gallons of system water volume. Dosage will vary depending on approved chemical cleaning product.
    - Circulate cleaning solution for 48 hours. Briefly open blowdown valves at strainers, solids separators, and system low points after 1 hour, 4 hours, and 24 hours (and more often if warranted), so that debris does not accumulate. Add additional chemical cleaner as necessary to maintain concentration.
    - After circulating for 48 hours, drain to waste and make up with fresh water. Drain rate shall not exceed make-up capacity of system. Continue flushing until rinse water alkalinity is within 10 ppm of raw water and is clear and colorless. Document alkalinity tests and measurements.
    - At completion of flushing, close drain valve(s) and add corrosion inhibitor via the bypass feeder until 300 to 500 ppm free and available nitrite is in the system.
    - From the time the chemical cleaner is added to the system to the time the corrosion inhibitor is added to the system, the circulating water pump(s) shall not be turned off.
    - After Addition of Corrosion Inhibitor: Shut off pump(s); remove, clean, and reinstall strainer baskets; remove temporary components; reinstall flow monitoring devices and other instrumentation removed during system cleaning; and prepare system for pressure testing. Corrosion inhibitor concentration shall be continuously maintained.
- Open Cooling Tower Water System:
    - Clean and flush new piping as specified for closed loop system. Use cleaning chemical designed to passivate new galvanized piping.
    - Thoroughly clean out all dirt and debris in the cooling tower basins.
    - Automatic condenser water chemical treatment system shall be selected to control microbial growth and corrosion. Select appropriate system in consultation with the University.
- University or University's designated water treatment company shall supervise final treatment of all systems. Contractor shall provide complete a record of chemicals used, quantities added, and final concentrations.

3. Steam Systems: Same as for water systems except prior to cleaning, remove traps and temporarily replace with spool pieces. Blow-down piping with steam after cleaning and before traps are reinstalled. Isolate new pipe for cleaning and pressure testing before connection to existing systems.

4. Arrange for daily inspections during system cleaning and flushing. University's Representative shall observe condition of strainer linings, system blow-down, and test measurements for alkalinity and treatment chemical concentrations. Open portions of piping systems for inspection by University's Representative, up to three places for each system, at locations as directed. If any foreign matter is found on strainer linings or in system, repeat cleaning and flushing procedures until no foreign matter is found in any system. Submit daily reports, signed by Contractor and Project Inspector, certifying procedures and results of system cleaning, flushing, and treatment.

S. Testing

1. General:
    - The following procedures, to be followed by the Contractor, shall be included in the project Specifications.
    - Clean and purge equipment and piping before each test.
    - Test new piping systems before connecting to existing systems. All parts of system, including coils and heat exchangers, shall be tested.
    - Work may be tested in sections, if necessary. In this case, tests of subsequent sections shall include all connections between previously tested sections and section being tested.
    - Should any piece of equipment or material fail in any test, immediately remove, repair, or replace with new and retest system.
    - Should any system component not be rated for the test pressure, then temporarily replace the component with a spool piece during pressure testing. Reinstall component after testing is complete and test component at normal operating pressure.
    - Perform tests in accordance with applicable Code requirements. Arrange for witnessing by University's Representative and authorities having jurisdiction.
    - Connections to and capping or plugging of existing piping shall be done with special care, since the joint will be tested only under normal working pressure.
    - Test all piping before insulating or concealing.

2. Test Pressures and Durations:
    - Test all water piping systems first with compressed air and then hydrostatically to 150 psig at the lowest point. During the air test, spray all threaded and flanged fittings, tappings, and valves to identify leaks. During the hydrostatic test, retain 150 psig test pressure for a minimum of twenty four (24) hours.
    - Test all steam and condensate with compressed air to 150 psig; retain this pressure for a minimum of twenty four (24) hours. During the test, spray all threaded and flanged fittings, tappings, and valves to identify leaks. Additionally test steam and condensate return piping at operating temperature and pressure after insulation.
    - Test all compressed air piping with compressed air to 150 psig; retain this pressure for a minimum of twenty four (24) hours. During the test, spray all threaded fittings, tappings, and valves to identify leaks. Isolate any controllers or other devices which could be damaged by this pressure.
    - Test all refrigerant piping in accordance with field test pressures specified in CMC Section 1123 and ASHRAE Standard 15. All field piping shall be leak tested with dry nitrogen at a minimum pressure of 600 psi; maintain this pressure for twenty four (24) hours. No leakage is permitted. Perform these tests prior to connecting refrigerant piping to equipment.
    - Test refrigerant relief piping with compressed air to 150 psig. Retain this pressure for a minimum of four (4) hours.
    - Test pressures in pounds per square inch are an initial pressure to be applied to lines being tested, together with test medium. Final pressures at the end of test period shall be no more nor less than that caused by expansion or contraction of the test medium and piping due to temperature changes. Specify permissible pressure drops, based on size of system being tested and medium used for test.
    - Include visual checks of the entire system during application of test pressures for water medium leakage, soap bubble or similar for air and nitrogen medium, and halide torch for refrigerant medium after charging.

3. Check all valves within tested systems for tightness and operate valves at least once from open to closed to open while valve is under test pressure. Replace any valves that leak or do not operate smoothly and properly.

4. Each test shall be documented by a report identifying the project name, system tested, notes that clarify the exact extent of the test, test medium and pressure, date, time started and initial gauge reading, time ended and final gauge reading, statement of results, Contractor's Certification Signature, and the University's Inspector of Record's approval signature.

T. Equipment Cooling Water Systems

1. Except as a short term emergency back-up, do not use once-through industrial water for equipment cooling. Design a circulating water system that rejects heat to an open or closed circuit cooling tower or chilled water system as appropriate.

2. Confirm cooling water temperature, flow, pressure, and water quality requirements with equipment suppliers.

3. Where cooling water with a high degree of purity is required for medical equipment cooling, lasers, or other sensitive equipment, provide a dedicated closed loop cooling water system with a plate-type heat exchanger, manufactured cooling water heat exchanger and pump package, or a separate refrigerated system. Confirm design approach with the University.

U. Centrifugal Pumps

1. General:
    - Discuss pumping equipment, redundancy, and control strategies with the University.
    - Obtain certified pumps curves showing pump performance characteristics with pump and system operating curves plotted. Evaluate NPSH conditions when applicable. For parallel pumping applications, evaluate system performance with single or multiple pumps operating.
    - Selected pumps shall have performance curves that rise continuously from maximum delivery to shutoff. Select pumps with shutoff head not less than ten percent greater than design head. Pumps shall operate at or near peak efficiency, and be capable of operating at 25 percent beyond design flow without exceeding break-off point. Do not select operating points within 5 percent of the maximum published impeller diameter.
    - Select motors that can operate over entire capacity range of pump without exceeding horsepower rating. Where applicable, select motors suitable for parallel operation and operation through specified variable frequency drives. Specify TEFC, premium efficiency motors.
    - Require isolation valves on suction and discharge lines at each pump.
    - Require a single pressure gauge to read suction and discharge pressure at each pump.
    - Require strainers upstream of all pumps. Suction diffusers shall be used as strainers. Consider basket strainers for open condenser water systems.
    - Require check valves downstream of all pumps.
    - Motor starters and VFDs for pumps shall have Hand/Off/Auto switches.
    - If project does not include an acoustic consultant, then provide vibration isolation for new pumps in accordance with Table 47 in the 2011 ASHRAE Handbook - HVAC Applications, Chapter 48 - Noise and Vibration Control.

2. Materials:
    - Select pumps that are non-overloading. Specify that pump impellers be hydraulically and dynamically balanced in accordance with Hydraulic Institute's *American National Standard for Rotodynamic Pumps for Vibration Measurements and*

Allowable Values (ANSI/HI 9.6.4 - 2009). Pumps shall be balanced to less than 0.13 inches per second RMS velocity at operating rpm.

- Where available, specify with replaceable bronze wear rings securely locked in place.
- Specify high strength hardened stainless steel shafts, oversized, with easily replaceable bronze shaft sleeves.
- Require gauge tappings on pump casing to accurately measure pump head.
- For centrifugal pumps, specify inside mounted mechanical shaft seals, end-face rubber bellows type, John Crane Type 1, or equal, with carbon rotating washer, tungsten-carbide stationary seat, Viton elastomers, and water flush across face of seal. Springs and other metal parts shall be Type 316 stainless steel.
- Except for systems with very clean water, specify flush filter with bypass line. Pump discharge shall be piped through a stainless steel cyclone separator, John Crane Abrasives Separator 400 Series, or equal.
- Spare Parts: For each pump, specify a complete gasket and seal replacement kit, including complete mechanical shaft seals, shaft sleeves, and bearings. All parts shall be vacuum-sealed for long storage life and identified with part numbers and pump tag numbers.

3. Pump Installation and Start-up: The following procedures, to be followed by the Contractor, shall be included in the project Drawings and Specifications.
    - Design adequate clearance around pumps for maintenance and repairs.
    - Specify 1/4-inch ball valves on air vent and drain connections on pump casings. Provide a downward turned 1/4-inch copper elbow downstream of the air vent valve and a horizontal 1/4-inch copper stubout downstream of the drain valve.
    - Decrease to pump suction from line size with long radius reducing elbows, top flat eccentric reducers, or reducing suction diffusers.
    - Support piping adjacent to pump such that no weight is carried on pump casings. Require exact alignment of piping connections so that no deflection or stress is transmitted to the pump.
    - Install flexible connections at pump suction and discharge. Specify braided metal flexible connectors as described earlier.
    - Mounting and Alignment for Base-Mounted Pumps:
        - Foundation (or concrete inertia base) shall extend minimum 4 inches beyond baseplate of pump on all four sides. Clean and roughen top of base. Set anchor bolts in concrete base. Use double nuts or wedges to level pump base with 3/4 inch to 1-1/4 inch grout space under baseplate. Align pump and motor shafts by adjusting wedges or double nuts. Form a dam around base and pour non-shrinking grout under base to a level of 1-inch above bottom of base. Fill all voids and allow to set.
        - After installation and prior to start-up, require alignment of pump and motor shafts using a laser alignment system, performed by an experienced alignment technician. Require submittal of written certification that pumps are operating at not more than one-half the manufacturer's recommended tolerance for parallel and angular variance in alignment. Require submittal of all pre-alignment data, target values, tolerances, and final aligned condition.
    - Pre-Operating Checks: Require performance of all system pre-operating checks recommended by pump manufacturer. After specified cleaning and flushing and before system balancing, require removal of start-up liners from system strainers and suction diffusers.
    - Operating Checks:
        - After starting pump, check bearing temperature, mechanical seal temperature, and motor amperage.

- Ensure that pump operates at specified system water temperatures without vapor binding or cavitation, and is non-overloading in parallel or individual operation.
- Measure and record the preliminary flow, head and brake horsepower data and compare with pump curves to show proof of satisfactory performance.

- Replacement Impellers for Constant Speed Heating Water, Chilled Water, and Cooling Tower Water Pumps 10 Horsepower and Larger:
  - At the beginning of system balancing, open all circuit balancing valves and set all control valves for full flow. Make first adjustment to design GPM using main balancing valve at pump discharge. Subsequently, adjust branch circuit balancing valves to obtain design GPM in all branches. Only readjust main balancing valve, if necessary, after consultation with the University's Representative. When balancing is complete, measure and record pump GPM, total pump head, differential pressure across the main balancing valve, and motor brake horsepower under the following conditions.
    - As balanced at design flow rate.
    - With main balancing valve at pump wide open (maximum flow condition).
    - With downstream deadhead (no flow condition).
  - Following initial balancing, require that manufacturer grind a new impeller for each pump to diameter indicated by University's Representative. Pump manufacturer's representative shall visit the site, replace the original impeller, and turn the original over to the University's Representative. With the new impellers in place, the University's Test and Balance Agency shall rebalance system to design water flow at main pump balancing valves. Balancing valve tag shall indicate final balanced valve setting.
    - Following impeller replacement, revise the pump nameplate with the new impeller diameter and new operating conditions.

- Field Vibration Test and Analysis for Pumps 10 Horsepower and Larger:
  - Pump vibration tested by pump manufacturer, in accordance with Hydraulic Institute standards.
  - Make adjustments to pump alignment, foundations, pipe connections, and supports as necessary to limit maximum vibration amplitude, peak-to-peak, to 3.0 mils.
  - Submit field vibration test reports.

23-10 CHEMICAL WATER TREATMENT

A. Chemical treatment systems and programs are in place in most Medical Center buildings. When projects will modify existing water treatment systems, consult with the University and, where appropriate, with the University's designated water treatment company to coordinate with existing chemical treatment programs currently in place at Parnassus, Mt. Zion, and other campuses.

B. Where new chemical treatment systems are required:

1. Provide automatic feedwater conditioning equipment for steam boilers, hot water boiler systems, and steam and hot water heating systems connected to generators and converters. Include water conditioning of make-up and feedwater to steam boilers. Coupon racks are not required at buildings unless directed by the University.

2. Chemical Feed Tanks: Chemical pot feeders shall be provided for new closed loop systems. Provide a minimum of a five-gallon by-pass chemical feed tank. Tank shall be piped on discharge piping to pump, across the pump shut-off valve. This location is to eliminate chemical slugging of pump seals. Chemicals shall be circulated throughout the total system before reaching pump seals.

3. Automatic Feedwater Systems:
    - Feedwater systems shall have totaling water meters on the inlet line.
    - Verify water pressure at the feedwater system. Feed pressure at the inlet shall exceed the manufacturer's recommended minimum pressure by at least 20%.
    - Automatic blowdown and chemical feed systems are to maintain a desired level of dissolved solids concentration in the water with the use of a conductivity controller.
    - Feed water systems shall include a heated tank, and duplex or triplex feed water pumps based on the system requirement.

23-11 BOILERS AND ACCESSORIES

A. Appropriate replacement boilers will depend on current system configuration, demand, required redundancy, and required capacity during construction. Intent is to select highly efficient natural gas fired boilers and appropriate accessories. Boilers for OSHPD 1 facilities shall also fire with standby diesel fuel. Boilers shall be specified to comply with current and anticipated future BAAQMD NOx emission requirements. At the beginning of design, identify all boiler types and sizes that reasonably meet the project program, and evaluate and present comparative efficiencies, turndown ratios, modulating control capabilities, burner options, natural gas and fuel oil train options, reliability, life-expectancy, and cost. Also evaluate and present alternative system configurations, redundancy, installation sequencing. Proceed with design approach selected by the University.

23-12 BREECHINGS, CHIMNEYS, AND STACKS

A. Stack size shall be determined based on criteria in the California Mechanical Code and by the stack manufacturer's computer program.

B. Preferred boiler stack is a UL listed positive pressure double-wall stainless steel vent piping system. Where used, all stack system components shall be from one manufacturer, and be installed strictly in accordance with manufacturer's installation instructions.

C. Specify no-loss stack heads for boilers and water heaters on roofs. No-loss stack heads provide vertical flue discharge without the use of rain caps.

23-13 PACKAGED WATER CHILLERS

A. Appropriate chiller selections will depend on system configuration, energy source, demand, required redundancy, and required capacity during construction. For systems in excess of 200 tons capacity, select highly efficient water cooled centrifugal chillers with variable speed compressors. At the beginning of design, identify appropriate chiller and pump types, sizes, and arrangements. Evaluate and present comparative system configurations, efficiencies, capacity control capabilities, reliability, serviceability, life-expectancy, and cost. Proceed with design approach selected by the University.

B. Refrigerants are presently limited to HCFC-123 and HFC-134a for centrifugal chillers, and future replacements with lower global warming potential. HCFC-22 machines should not to be considered.

23-14 PACKAGED COOLING TOWERS

A. Appropriate cooling towers for water cooled chillers depend on system configuration, chiller sizes, required redundancy, and required operability during construction. At the beginning of design, identify appropriate cooling tower and tower water pump types, sizes, and arrangements. Cooling towers with variable frequency drives for fan motors are required, to permit close control of leaving tower water temperature and to control fan noise during the evening and night. Cooling towers should be all stainless steel, with premium efficiency severe duty TEFC or TEAO fan motors. Evaluate and present comparative system configurations, noise levels, efficiencies, capacity control capabilities, reliability, serviceability, life-expectancy, and cost. Proceed with design approach selected by the University.

23-15 HEAT EXCHANGERS

A. Select plate-and-frame or shell-and-tube heat exchangers as appropriate for the media and temperatures involved. Review selections, approach temperatures, and fouling factors with the University. Where steam is primary heat source, consider a second heat exchanger (in series) to pre-heat the secondary media with steam condensate, prior to returning condensate to the steam plant.

B. Shell-and-Tube Heat Exchangers: Specify with removable tube bundle, carbon steel shell, naval brass full bonnet size tube sheet, minimum 0.030-inch thick 3/4-inch O.D. seamless copper tubes, and brass transverse baffles and tube supports. Units shall be inspected, certified, and stamped for 150 psi working pressure in accordance with ASME Code for unfired pressure vessels.

C. Plate-and-Frame Heat Exchangers: Specify with Type 316 stainless steel plates, SA516 Grade 70 carbon steel frame and pressure plate, minimum 150 lb. ASA rated flanged ports (for pipe connections over 2"), double sealed gasket barrier at the ports, minimum 150 psi working pressure, ASME Code Section VIII "U" stamp.

23-16 AIR HANDLING EQUIPMENT

A. General Requirements for Fans and Air Handling Equipment:

1. Roof-mounted fans and air handling units (AHUs) at Parnassus and Mt. Zion campuses shall be all Type 316 stainless steel construction (Type 316L wherever welding is required), unless otherwise directed by the University. Rooftop equipment at Mission Bay and other buildings out of the fog belt shall be fabricated with minimum A60 galvanized sheet metal with long life marine grade coatings as described in Paragraph E “Fan and Air Handler Coatings” below.

2. Central fans and air handling equipment, including internal components, should be designed for a minimum life expectancy of 40 years.

3. Fans and air handling system components must be fully accessible for service and routine maintenance.

4. Consider sectionalized or built-up construction for AHUs within existing buildings where access is restricted. Where required, specify field-erected units using double wall sheet metal plenum panels and doors as described in Paragraph 23-20-D.

5. Schedule all pertinent physical and performance characteristics of fans and air handling unit components on the Drawings. Review custom AHU layouts indicating all components, access doors, casing openings, and service clearances with the University. Layouts shall include plan and sectional views that identify the overall height and vertical location of duct connections, dampers, louvers, etc.

6. Design ductwork connecting to fans to minimize “system effects” in accordance manufacturer’s recommendations and recommendations in the AMCA Fan Application Manual.

7. Fan systems designed for parallel or manifold operation shall be protected against backward rotation of fan wheels with gasketed, vertical, pressure activated backdraft dampers at the fan inlet with near zero system effect (similar to Huntair fan wall inlet backdraft dampers), or motorized isolation dampers rated for maximum 2% leakage at design total fan static pressure. Gravity backdraft dampers are not acceptable for fan isolation. Motorized isolation dampers, when required, should be positioned a minimum of 1-1/2 duct diameters from the fan inlet or 2 diameters from the fan discharge. Isolated fan shall restart when isolation dampers have just begin to open, with timing adjusted to avoid backward rotation.

8. Require fan and AHU manufacturers to submit certified sound and air ratings based on tests performed in accordance with AMCA Bulletins 210, 211A, and 300. See AMCA Standard 99, Standard Handbook, for definitions of fan terminology. Schedule maximum sound power levels on the Drawings.

9. Fan wheels and belt drives that are readily approachable shall be protected with OSHA-approved wire mesh screens. Select screens with minimum 90 percent free area. Screens shall be stainless steel, welded to sheet metal hems or angle frames that attach to the equipment. Provide removable screens or hinged openings therein where necessary for bearing inspection, lubrication, or tachometer readings.

10. When fan discharges are vertical and open to the weather, specify welded drain connections on the bottom of the fan housing. For fume hood exhaust fans, provide stainless steel plugs at drain connections, coated with Never-Seez, or equal, lubricant.

11. Install VFDs and electronic temperature control panels for rooftop fans in clean, ventilated environments, such as Penthouses.

B. Fans

1. Design Criteria:
   - New air handling units and exhaust fans for certain OSHPD facilities require Special Seismic Certification. Wherever practical, specify equipment with OSHPD Special Seismic Certification Pre-Approval (with currently effective OSP numbers).
   - Centrifugal fans should be specified for most applications. Select size and type of fan based on efficiency and noise considerations. Selected fans and motors shall have

performance characteristics capable of future flow and static pressure increases of at least 10 percent. Select fans for variable air volume systems for peak efficiency at the average operating condition.

- Due to their high noise levels, axial fans should not be specified without prior consultation with the University.
- Fan systems designed for parallel or manifold operation shall be protected against backward rotation of fan wheels with motorized isolation dampers located to minimize system effect.
- For large systems, fan wall technology is acceptable and may provide advantages in terms of space utilization, efficiency, and reliability. Review operational features and controls with the University, including individual fan control, optimization, and integral backdraft dampers. Specify VFD control panel with individual fan output terminals and disconnect switches. Specify appropriately sized thermal overload relays for each motor installed downstream of the drive-bypass contactors.
- Schedule fan operating conditions, including airflow, static pressure, fan RPM, minimum efficiency (or maximum brake horsepower), fan Class, Arrangement and Rotation, wheel type and size, motor data, and maximum sound power levels. Indicate any future operating condition that fans must be capable of meeting. Evaluate estimated performance losses due field conditions, system effect, and belt-drive components.
- Fan ratings shall be approved by AMCA and shall be based upon tests performed in strict accordance with the Test Code adopted jointly by AMCA and ASHRAE. Each fan shall bear, near the manufacturer's nameplate, the seal authorized by AMCA indicating that ratings are certified. Fan sound levels shall be determined in an AMCA-certified lab in accordance with AMCA Standard 300.
- Isolate fans from the building structure using appropriate spring and/or neoprene isolators. See Paragraph 23-4-W-8 - HVAC Noise Control, Vibration Isolation. Provide flexible connections between isolated fans and ductwork. Where fans are located inside air handling equipment, they shall be internally isolated and seismically restrained.
- Where structurally transmitted vibration or duct-borne HVAC noise is a concern, retain an acoustical consultant to evaluate interior noise levels and recommend appropriate isolation and sound attenuation measures.
- Direct drive fans are preferred. Use VFDs for capacity adjustment and control.
- Specify at least two belts for belt driven fans larger than 2 horsepower.
- Specify TEFC motors for all applications, unless agreed upon otherwise with the University. Specify that motors over 1 HP be premium efficiency type.

2. Housed Centrifugal Fans for Rooftop Exhaust, Air Handling Units, and Built Up Systems:
   - Specify with continuously welded scroll and side panels. Specify minimum gauges. Require a heavy gauge welded steel support frame and pedestal, continuously welded to fan housing. Specify inlet and outlet flanges, scroll drains, scroll access panels, and other special features as appropriate for each application.
   - Require full or narrow width aluminum alloy airfoil blades selected for optimum performance, continuously welded to hub and inlet shroud. Specify AMCA Class II construction for fan operating at static pressures in excess of 2.0" wg; specify higher AMCA classes to suit special applications. Schedule or specify fan Arrangement to suit the application. Fan shaft and wheel shall be dynamically balanced to meet AMCA Standard 204-96, Fan Application Category BV-4 with better than Grade G2.5 residual unbalance (flexibly mounted on the test stand with maximum 0.15 inches per second peak velocity amplitude measured in the horizontal, vertical, and axial directions).

- Single thickness backward inclined steel blades can be selected for smaller sizes.
- Single thickness forward curved steel blades can be selected for low static pressure applications (less than 1.5-inch w.g.).
- Bearings: Oversized pillow block ball bearings selected for a minimum AFBMA L10 life of 100,000 hours. For larger fans, specify rollers bearings with same rating.
- For outdoor fans, specify full weather cover over motor and drive, constructed of stainless steel with stainless steel studs and wing nuts.

3. Additional Requirements for Housed Centrifugal Exhaust Fans:
    - Fume hood and isolation room rooftop exhaust fans should have upblast discharge.
    - Single-width, single-inlet housed centrifugal fans are generally preferred for exhaust.
    - Locate fans at the discharge end so that a negative pressure exists in all exhaust ducts within the building.
    - Exhaust discharges shall be at least 25 feet horizontally and minimum of 10 feet vertically above outside air intakes.
    - Inline fans with motors or drives exposed to exhaust air streams should not be used.

4. Unhoused Centrifugal Plug Fans for Air Handling Units and Built-up Systems:
    - Specify minimum AMCA Class II construction, preferably with shaft and bearings out of the inlet air stream. Fan performance curves should have a rising pressure characteristic extending through the operating range and continue to rise well beyond the efficiency peak.
    - Specify with fully welded structural steel base, and welded attachments for spring isolators, seismic restraints, and thrust restraints. Fan inlets shall be attached to non-isolated plenum walls with high tensile strength heavy glass fabric; Duro Dyne Corporation “Durolon,” Ventfabrics “Ventlon,” or equal. For large fans with high static pressure rating, specify thrust restraint spring isolators to resist horizontal thrust and prevent base spring isolators from grounding against the floor or seismic restraints.
    - Specify heavy-gauge die-formed or extruded aluminum airfoil wheel with blades continuously welded to backplate and inlet shroud. Solid stainless steel fan shaft sized to run at a minimum of 20 percent greater than the maximum AMCA class speed. Shaft and wheel shall be statically and dynamically balanced to meet AMCA Standard 204-96, Fan Application Category BV-4 with better than Grade G2.5 residual unbalance (flexibly mounted on the test stand with maximum 0.15 inches per second peak velocity amplitude measured in the horizontal, vertical, and axial directions).
    - Specify heavy duty pillow block roller bearings with horizontally split cast iron housings. Bearings shall be grease lubricated with copper grease and relief lines and pressure type lubricating and relief fittings, Alemite, Keystone, or equal. Bearings shall be rated for minimum AFBMA L-10 life of 100,000 hours at maximum class rating.
    - Non-Stainless Steel and Non-Aluminum Components: Cleaned and painted with one coat of primer prior to assembly and finished with epoxy coating with minimum 3.0 mil dry film thickness.

5. Plug Fans for Fan Walls:
    - Multiple AMCA Class II, Arrangement No. 4 (direct drive) centrifugal plug fans with shafts and motors out of the inlet air stream. Fan performance curves shall have a rising pressure characteristic extending through the operating range and continue to rise well beyond the efficiency peak. Performance rated in accordance with AMCA Standard 210.

- Each fan cube shall include a heavy gauge galvanized steel inlet wall and fully welded structural steel angle iron frame to support a T-frame motor and fan wheel assembly. Fans and motors shall be resiliently anchored to frames using center bonded two-piece neoprene rubber mounts that isolate movement in all directions.
- Fan wheels shall be heavy-gauge die-formed or extruded aluminum airfoil type with blades continuously welded to backplate and inlet shroud. Each motor and wheel assembly shall be statically and dynamically balanced to meet AMCA Standard 204-96, Fan Application Category BV-5, and better than Grade G.55 residual unbalance per ANSI S2.19 (maximum 0.022 inches per second peak velocity amplitude measured in the horizontal, vertical, and axial directions), at design RPM.
- Inlet cone shall be fully streamlined and precision spun, designed for inlet efficiency and stall-free performance.
- Each fan cube shall be provided with coplanar acoustical silencers and inlet straightener grid that reduce bare fan discharge sound power levels by a minimum of 15 db (re 10E-12 watts) in all eight octave bands when compared to the same fans without the silencers. The silencer shall not increase fan total static pressure or increase the length of the airway tunnel length. Acoustical fill shall be non-absorbent and non-shedding melamine foam.
- Each motor and fan wheel assembly shall be wired to a control panel containing a single variable frequency drive sized for the total connected horsepower of all fan motors contained in the array. Control panel shall include both a primary and stand-by variable frequency drive.

6. Curb Mounted Rooftop Exhaust Fans:
   - Low profile, heavy gauge spun aluminum housing with rolled ends. Easily removable top cover shall protect motor and drive assembly. Heavy gauge galvanized steel angle and plate frame shall rigidly support wheel, motor, and drive assembly. Heavy gauge aluminum base with a smooth inlet venturi. Fan manufacturer shall provide matching roof curb.
   - Aluminum wheel, backward inclined, non-overloading shape with tapered inlet shroud. Statically and dynamically balanced to within 0.10-inch/second RMS velocity. Cast iron variable pitch drives. Permanently sealed and lubricated pillow block ball bearings, minimum AFBMA L10 life of 100,000 hours, designed for minimum 600 lbs. radial load and 240 lbs. vertical thrust load. Oil resistant, non-sparking, non-static belts rated for 24,000 hour life at maximum fan speed.

C. Fan Drives

1. Design Criteria:
   - Direct drives fans with a VFD for speed control is the first choice, and shall be provided wherever practical.
   - Where belt-drive fans are necessary, specify V-belt drives rated for not less than 150 percent of motor horsepower.
   - When belt drives are used, initially provide adjustable pitch sheaves with design speed near the mid-point of the adjustable sheaves, and size fan motors to operate at all sheave positions without overload. Adjustable sheaves shall only be used for start-up. Require Contractor to replace with fixed sheaves during final system balancing.
   - Where belt driven fan is operated through a VFD, provide final sheaves that will result in fan operating near 60 Hertz at design conditions.

2. Sheaves and Slide Rails:

- Specify fine-grain, high-strength grey cast iron suitable for specified fan belts, diameter and grooves selected for minimum 2.0 service factor, dynamically balanced to a minimum Grade of 2.5 for smooth operation at all speeds up to 6500 feet per minute tip speed, precision bored to minimize fretting corrosion on the shaft, with keyway and set screws. Specify with epoxy coating suitable for corrosive environment. Products: Woods, Browning, or equal.
- Sheaves shall be aligned to within 1.5 degree of true alignment in all cases.
- Mount motors on heavy-duty welded steel slide rails; Woods "QS," Browning, or equal.

3. Belts:
   - Gates Quad-Power II PowerBand 3VX or 5VX, to match existing, as appropriate for horsepower, or equal, banded V-belts joined together by a permanent, high strength tie band to control belt-to-belt distance and prevent sideways bending. Kevlar or aramid tensile cords, extra tough double fabric cover, flat back construction, with a minimum operating temperature range of -30° C to +60° C. Belts shall be selected for minimum 1.5 times the nameplate motor horsepower. Specify one spare set of matched belts for each new fan.

4. Guards:
   - Belt guards shall be in conformance with Cal OSHA standards. Where it is necessary to adjust belts, lubricate bearings, or take tachometer readings, provide guards with hinged or easily removable sections of sufficient size to perform such work.

D. Air Handling Units and Built-Up Systems

1. Design Criteria:
   - Air handling systems shall be designed for long life, efficient and quiet operation, and ease of maintenance. Commercial-grade packaged air handling units do not generally include construction features and materials that will provide 40 plus years of service. Consider custom packaged air handling equipment with design features specified below. For built-up systems, carefully specify construction features and materials for each component.
   - Size components generally according to the following maximum face velocity and/or static pressure drop criteria; discuss deviations from criteria with the University.

Outside air intake louvers:	350 FPM / 0.10" WG
Exhaust louvers:	500 FPM / 0.25" WG
Heating coils:	600 FPM / 0.15" WG
Cooling coils:	See 23-4.V.4 - Chilled Water System Design Parameters
Medium Efficiency Pre-Filters:	450 FPM / 0.25" WG (clean)
High Efficiency Final Filters:	400 FPM / 0.40" WG (clean)
Sound attenuators:	700 FPM / 0.30" WG
Outside air & exhaust air economizer dampers:	1200 FPM / 0.15" WG
Return air economizer dampers:	2000 FPM / 0.40" WG

2. Materials:
   - Construction features and materials indicated below will vary depending on the air handler manufacturer(s) around which the design is based. Carefully evaluate and

specify appropriate construction features and materials that specified manufacturers can meet.

- Criteria below are for packaged systems. Specify similar component requirements for built-up systems. See plenum construction requirements in Paragraph 23-20-D above.

3. Cabinet Construction:
   - Specify that casings, including dividing panels between components, be constructed with minimum 16-gauge panels, channel-formed and fastened together on maximum eight (8)-inch centers. Exposed sheet metal screw fasteners on the outside of rooftop units are not preferred; if provided, all such fasteners shall be Type 316 stainless steel and gasketed. Specify that roof panels utilize standing seam construction and be sloped a minimum slope of 1/2 inch per foot to shed water. Divert rainwater spilling from the roof away from access doors and electrical components on the outside of the unit.
   - Specify double-wall construction with minimum 20-gauge perforated inner panels. Inner panels between outside air louvers and air filters should be solid and constructed of stainless steel or coated steel as specified for exterior panels. Wall and roof insulation should be minimum 2-inch thick, minimum 3-pound density fiberglass.
   - Specify that all non-stainless steel interior and exterior panels, reinforcements, fasteners, and hardware shall be coated in accordance with “Fan and Air Handler Coating” requirements below. Alternately, interior panels and reinforcements can be unpainted Type 316 stainless steel, in which case all fasteners and hardware shall be stainless steel.
   - Specify all-welded structural channel or hollow tube, with all surfaces cleaned, primed, and finish coated in accordance with “Fan and Air Handler Coating” requirements below.
   - Specify minimum 12-gauge stainless steel floor panels with embossed tread pattern, with seams welded to subfloor channels (drive screws not acceptable) and continuously sealed with polyurethane sealant. Require that underside of the entire unit be insulated.
   - Specify access doors into each section, double wall, with minimum 16-gauge inner and outer panels, and minimum 2-inch thick, 3-pound density insulation. Specify that doors be full height of cabinet up to 75 inches high. Specify double-gasketed access doors, in which each gasket provides an airtight and watertight seal. Specify that full height access doors have a minimum of three easily adjustable heavy duty roller cam latches and heavy-duty stainless steel hinges. Specify stainless steel access door hardware, except that hinges, latches, and paws may be of industrial quality and corrosion-resistant composite material.
     - Specify minimum 12 inch by 12 inch double-pane glass viewing windows in access doors in fan sections, humidifier sections, and other sections with operating equipment, hermetically sealed with desiccant between panes.
     - Specify extruded aluminum and continuously welded access-door frames.
   - Perimeter Curb: Evaluate the applicability of factory fabricated curbs, field fabricated concrete curbs, and field erected steel framework. Review design approach with project structural engineer. Include complete details for the selected approach.
   - Where unit includes temperature control panels, VFDs, and coil valving, specify units with internally ventilated vestibules to contain control panel, VFDs, and all valving and trim in easily serviceable arrangements.
   - For units with walk-in sections, specify vapor-proof and corrosion-resistant marine lights in each accessible section. Specify illumination levels of minimum 15

footcandles in fan sections and minimum 10 footcandles in other sections, including vestibules. Specify 3-way weatherproof light switches and GFI-protected weatherproof power receptacles. 120V conductors shall be minimum No. 12 AWG copper, Type THHN/THWN/MTN, and be run in galvanized conduits. Bring all wiring for lighting and receptacles to a junction box for a single point of external connection to a 120VAC circuit.

- Specify conduit and power wiring:
  - Final connection to fan motors should be with liquid-tight flexible metal conduit, maximum length three (3) feet.
  - Conduit penetrations through unit casing and internal sections should be sealed airtight and watertight. Require that the Contractor provide complete instructions for disassembling and re-assembling power and control wiring for sectionalized units from the unit manufacturer.
  - Specify that power wiring be Building Type (600 Volt Class) with PVC insulation, Type THHN/THWN or Type XHHW manufactured per UL Standards 83 and 1063, manufacturered by Rome, General Cable, Okonite, Southwire, or equal.
  - Internal conduits should be EMT with weatherproof connectors and j-boxes. All conduits, junction boxes, and connectors should be coated as specified for interior components.
  - Exterior conduits should be NEMA RN 1 polyvinyl chloride (PVC) coated galvanized rigid steel conduit with PVC coated weatherproof boxes, and NEMA 4X enclosures for exterior devices.

4. Coils:
   - Coils shall be ARI certified and factory tested at minimum 350 psi air pressure under water prior to shipment.
   - Specify minimum 14 gauge Type 316 stainless steel casings (16 gauge acceptable for coils less than 12 square feet). Coil connections shall be copper or brass. For steel piping systems, specify a minimum of 6 diameters of brass piping at coil connections. For improved serviceability (where possible), select coils with no more than 8 rows and no more than 10 fins per inch.
   - Water Coils: Specify minimum 5/8-inch outside diameter, minimum 0.025-inch-thick seamless copper tubes, with minimum 0.035-inch-thick return bends. Circuiting as required for performance. Arrange multi-row coils for counterflow. Turbulators not permitted. All joints silver brazed.
   - Steam Heating Coils: Specify minimum 5/8-inch outside diameter, minimum 0.035-inch-thick seamless copper tubes, with minimum 0.049-inch-thick return bends. Circuiting as required for performance. All joints silver brazed. Rated for minimum working pressure of 150 psig at 366° F. Steam coil tubes should be pitched to drain toward the condensate header minimum 1/8-inch per foot. Specify tapping for thermostatic air vent at top of coil header.
   - Specify minimum 0.0095-inch-thick copper fins, flat or configured as required for performance, tubes mechanically expanded into fins.
   - Specify heavy seamless copper headers with die-formed collars for brazed tube joints, convex end caps, vent and drain connections, and brazed connections for piping.
   - Complete coil assembly, including casing, should be degreased, cleaned, etch primed, and immersed in Luvata Electrofin E-Coat, Heresite P-413, TechniCoat 10-1, or equal, baked epoxy-phenolic coating. Dissimilar metals, such as exposed copper return bends and tubes in contact with galvanized casing, should be encapsulated with a suitable epoxy polymide to prevent galvanic corrosion. Coating should be

applied in four consecutive immersions, with oven curing between each coat. A phenolic sealer should be applied to finished surfaces to seal micro-porosity. Finished coating shall show no softening, blistering, cracking, crazing, flaking, or loss of adhesion. Sprayed coatings of any kind are not acceptable. Minimum total dry film thickness of 2.0 mils.

- For each cooling coil, specify continuously sloped minimum 16-gauge double-wall Type 316L stainless steel drain pans with continuously welded seams and insulation between pans. Drain pans should extend a minimum of 2 inches upstream and 18 inches downstream of the cooling coil and be sloped in two directions to a minimum 1-1/4 inch MPT stainless steel drain connection, which is welded to the bottom of the pan and extended through the unit base. Drain pans should extend around ends of coils and collect any condensate on return bends and headers. Call for intermediate welded stainless steel drain pans for stacked coils with minimum 1-inch stainless steel or copper downspout to lower drain pan. Require a unit access door downstream of every drain pan. Require access to coil headers and return bends for inspection and repair.
- Construction Considerations:
    - Coil headers should be inside the unit. Call for header vent and drain valves (use specified ball valves) at each coil, at accessible locations and discharging into drain pans.
    - Coil inlet perimeter should be blanked off with minimum 16-gauge Type 316 stainless steel sheet metal to ensure that no air bypasses the coil.
    - Multiple coils should be selected to meet heating or cooling capacity. Individual coils should be a maximum of 10 feet wide and 3 feet high, and capable of replacement without major rigging.
    - Coils should be individually removable. Configure piping to permit coil replacement without affecting other coils or connecting piping. Individual coils should be separately valved so that, if any individual coil fails, it can be isolated, drained, filled, and vented while the remaining coils stay in operation. Show a manual circuit balancing valve for each coil.
    - Individual coils must be fully accessible on both the upstream and downstream sides to permit inspection and cleaning.
    - Configure unit to ensure even and consistent airflow across the entire coil surface.
    - Where heating coils are combined with cooling coils, the heating coil should be first in the air stream. Exception: For single zone systems with dehumidification controls, heating coil may need to be in a downstream position, in which case the cooling coil control valve will be overridden open when outside air temperature approaches freezing, to protect the coil from freezing.

5. Filters and Filter Holding Frames:
    - Specify and schedule air handling unit air filters. See Part 23-24 for air filtration requirements.
    - Filter holding frames shall be factory fabricated as part of the air handling unit with either walk-in upstream access or side access. Walk-in upstream access is preferred.
    - Upstream Access: Specify upstream access for filter banks wider than 4 feet, and wherever practical in smaller units. See Part 23-24 for filter holding frame requirements. Specify that air handling unit floor be adequate to support the weight of maintenance personnel.
    - Side Access: For smaller units with limited access (such as above-ceiling units), specify side access for filter banks with extruded aluminum filter tracks and

replaceable polypropylene pile gaskets. Specify closed-cell neoprene gaskets on access doors to ensure tight edge seal for filters. Specify a maximum leakage of 0.5% at 1" wg differential pressure across the filter bank.

- Filter Gauge: Specify a Magnehelic air filter gauge, 0 to 1 inch WG range, across each filter bank using stainless steel static pressure-sensing tips and copper tubing. Gauge should be mounted approximately 4 feet above the unit base in a sheet metal enclosure with a hinged cover plate so that gauge is not exposed to sunlight. Require an engraved laminated plastic nameplate on or above cover plate indicating filter bank identification, recommended replacement pressure drop, and quantity, size, and efficiency for replacement filter cartridges. Physically mark and note the face of the filter gauge with clean and dirty filter drops.

6. Fans: As described above.

7. Motors and Variable Frequency Drives: As described in Parts 23-7.E and F.

8. Airflow Monitoring Stations:
    - Where supply and/or return airflow monitoring is necessary for control sequences, specify remote duct-mounted airflow monitoring stations in straight sections of ductwork. Where optimal locations for duct-mounted airflow monitoring stations are not available, consider integral fan inlet cone airflow monitors.
    - For economizer systems, provide positive method for measuring and monitoring outside air CFM, particularly minimum outside air CFM.

9. Ultraviolet Germicidal Irradiation (UVGI):
    - In patient care areas, specify UVGI lamps as part of the air handling unit.
    - Specify UV Resources RLM Xtreme, V-Flex by Altru-V (UVDI), or equal, UV-C lamps and mounting assemblies. Lamps should provide 360 degrees UV-C irradiance to surfaces and the air stream.
    - Specify drip-proof Type 304 stainless steel power supply housings.
    - Specify high output lamps, wind chill resistant, T5 diameter, hot cathode, requiring approximately 2.3 Watts per inch of length, producing not less than 0.75 Watts per inch of length of UV-C radiation at 254 nm.
    - Mount lamps between 6" and 12" downstream of the cooling coil discharge. Lamps should extend the full width of the air handling unit, such that coil headers and return bends are irradiated. Horizontally adjacent lamps should overlap so that there are no gaps between adjacent lamps. Horizontal rows should be spaced maximum 14" on center, with the bottom row maximum 10" above the cooling coil drain pan, and the top row maximum 10" down from the unit roof. Offset adjacent lamps in each horizontal row to facilitate lamp replacement. Total UV-C radiation shall not be less than 7.2 Watts per square foot over the entire air tunnel.
    - Specify door-interlocked safety switch to turn off lamps when access door is opened.
    - Specify a UV screened glass window for viewing the lamp assembly.
    - Specify four (4) spare lamps, one (1) spare socket, and one (1) spare power source and housing for each air handling unit.

10. Economizer Section and Automatic Dampers:
    - Show or schedule economizer damper and minimum louver sizes and arrangements. Specify separate two-position minimum outside air and exhaust air dampers sized to permit the design outside air percentage. Damper linkages, bearings, and actuators should be arranged for easy service inside units.

- Outside air and relief air automatic dampers should be stainless steel, parallel blade, arranged to open in the same direction as adjacent louvers. Return air automatic dampers can be aluminum or stainless steel, opposed blade. Minimum requirements for dampers:
  - Frames: For outside air and exhaust air dampers, specify minimum 3 inch x 1 inch x 12 gauge channel frames fabricated from Type 316 stainless steel with stabilizers and internal corner bracing. For return air dampers, specify stainless steel as above or minimum 0.125-inch thick aluminum frames.
  - Blades: For outside air and exhaust air dampers, specify blades fabricated from minimum 14 gauge Type 304 stainless steel, single skin, with V-grooves at center and ends. For return air dampers, specify stainless steel as above or minimum 0.080-inch thick double skin airfoil shape aluminum blades.
  - Seals: Specify EPDM blade edge seals, mechanically attached to blade, field replaceable, and flexible stainless steel compression jamb seals.
  - Leakage: Specify guaranteed maximum leakage of 10 CFM per square foot at 1 inch WG static pressure differential when closed.
  - Axles: Specify minimum 3/4-inch diameter stainless steel for dampers greater than 36-inches wide, and 1/2-inch diameter for shorter blades. Axles should be welded or bolted to blades. Specify outboard support bearings for control shafts.
  - Bearings: Specify stainless steel sleeve type bearings pressed into frame.

11. Air Handling Unit Air Intake and Discharge Openings:
    - Design Criteria:
      - Air intakes for building ventilation systems shall be located away from ground-level pollution sources and building exhausts. Preferred location is elevated on prevailing wind side of building (west side). Keep air intakes away from loading docks, vehicular areas, and trash areas.
      - Coordinate air intake and exhaust locations with the Architect and the University during early design stages.
      - Avoid intake and exhaust openings on exterior walls with required fire ratings.
      - Provide access for upstream and downstream maintenance and cleaning of all louvered or screened openings.
    - Specify AMCA certified intake and exhaust louvers suitable for expected wind direction and velocity:
      - Frames: Minimum 12-gauge Type 316 stainless steel with welded corners.
      - Blades: Minimum 16-gauge Type 316 stainless steel, with intermediate blade support for louver blades longer than 48 inches.
      - Specify drainable outside air dampers with drain gutters in head frame and each blade, and downspouts in jambs.
      - Specify 0.5-inch mesh stainless steel bird screen on the inside of outside air intake louvers. Specify 1" mesh stainless steel bird screen on the inside of relief air louvers.
      - Louvers shall be flush with outer unit casing.

12. Refrigeration Systems (For Units with Integral Compressors and DX Cooling Coils):
    - Wherever practical, specify air handling units with chilled water cooling coils. Where chilled water is not available, specify DX units.

- Specify condensing section and cooling coil with complete operating and safety controls. Condensing equipment and performance shall be rated in accordance with ARI Standard 520, ANSI/ASHRAE 15 Safety Code, NEC, ETL, or UL/CSA.
- Schedule complete electrical and performance characteristics of condensing section and DX cooling coils.
- Specify in detail all required features, including number of circuits, control stages, compressor type, condenser coils and fans, refrigerant piping and insulation, refrigeration piping accessories, hot-gas bypass, electrical system and safety features, and sequence of operation.
- Specify condenser coils with copper tubes and coated copper fins. Coils and fins should be coated with Luvata ElectroFin E-Coat, factory applied, or equal corrosion protection system.
- Specify a 5-year parts-only warranty on compressors and compressor accessories.
- Factory Testing: Specify that fans and cooling system be factory run tested to ensure structural integrity, low vibration, and properly operating refrigeration system controls and accessories.

E. Fan and Air Handler Coatings

1. Fully research and carefully specify available coatings for non-stainless steel components to ensure a minimum 40-year service life. Following is one acceptable specification.

2. Interior and exterior surfaces, including the structural base and hidden surfaces, and excluding the stainless steel floor panels and stainless steel fasteners, shall be washed in a heated phosphoric acid bath clean of all oil and mill scale and coated with a dry powder-baked polyester coating similar to Tiger #7035, Drylac Series 49, or equal. Coatings shall be lead and cadmium free.
   - Coating shall have excellent color and gloss retention; show no blistering or loss of adhesion following a 1500-hour five percent (5%) salt spray resistance test 95 degrees Fahrenheit and 95% relative humidity per ASTM B117; show maximum 1/16" blistering following a 1500-hour 100% relative humidity test at 100 degrees Fahrenheit per ASTM D2247; remain flexible and unfractured to the point of metal rupture following a direct impact adhesion test per ASTM D2794; show no loss of adhesion between coating and substrate following a cross hatch adhesion test per ASTM D3359 (Method B).
   - Each panel, liner, and interior partition component shall be individually coated and baked following shearing, notching, punching, and forming to provide 100% powder coverage over all surfaces and metal edges. The coating process shall be completed prior to assembly of the unit to ensure that all joined surfaces (panel-to-panel joints) are finished coated. Spray or brush applied coatings after assembly are not acceptable.

F. Suspended Air Handling Units

1. Design Criteria:
   - Since most original fan systems at University buildings lack cooling coils, suspended air handling units are often necessary to meet programmatic needs.
   - Design criteria for component sizing should follow criteria for air handling units and built-up systems described above.
   - VFDs and control panels for suspended equipment should be located in mechanical rooms or closets for easy access.

- Ensure complete and easy access to unit pre-filters, final filters, fan sections, coil valve assemblies, and electrical connections.

2. Materials:
   - Materials and construction features described above for air handling units and built-up systems generally apply to suspended air handling units, although lighter gauge panels may be appropriate and certain features are not relevant (such as unit-mounted VFDs, economizer dampers, unit lighting, convenience outlets, louvers, etc.).
   - Standard coatings can be specified for the exterior of suspended units. If the unit handles predominantly outside air, then interior materials and coatings should be as specified for rooftop air handling equipment.
   - Specify suspended equipment with non-fused disconnect switches, to avoid code required clearance issues.

G. Fan Coil Units

1. Design Criteria:
   - Chilled water fan coil units are preferred to cool spaces that dissipate large amounts of heat. Outside air required to ventilate the space should be supplied from the main air handling system.
   - Fan coils units normally do not have the same life expectancy criteria as central air handling units, so commercial grade products can be considered. Commercial grade fan coils are not appropriate for patient care areas, which require high efficiency final filters.
   - Select suspended, wall mounted, or floor mounted fan coil units as appropriate for the application. Specify overflow drains or secondary drain pans for fan coil units installed above sensitive electronic equipment or as required by Code.
   - Carefully select and specify air filtration appropriate for the space served. Specify separate filter boxes where high efficiency filtration is required or appropriate.
   - Ensure easy access to fan coil unit internal components and coil assemblies.

2. Commercial grade fan coil units should be certified under ANSI/AHRI 440 and bear the AHRI seal. Specify finished cabinets if exposed on occupied areas. Specify with permanently lubricated motor bearings.

23-17 REFRIGERANT BASED AIR CONDITIONING SYSTEMS

A. General Requirements

1. The University must approve the use of unitary and refrigerant based equipment prior to design. Air cooled equipment is generally inefficient, has a short life expectancy at University campuses, and often lacks the redundancy and/or controllability required for critical applications. Unitary and refrigerant based equipment and systems should be limited to situations where central heating and cooling utilities are unavailable or inappropriate. Review preliminary equipment and system selections with the University.

2. Where available, specify air cooled condenser coils with stainless steel casings, copper tubes, and coated aluminum or copper fins. Coating should be Luvata ElectroFin E-Coat, factory applied, or equal corrosion protection system.

3. Split systems larger than 20 tons capacity shall include suction and discharge service valves, crankcase heaters, liquid sight glass, filter drier, vibration isolation, lift traps, and solenoids. See Paragraph 23-9-F for additional refrigeration system requirements.

4. Window and through-the-wall air conditioning units should never be used. Obtain written direction from the University wherever such equipment is contemplated.

B. Refrigerant based systems are presently limited to HFC-410A and 407C (for small systems), and future replacements with lower global warming potential. HCFC-22 machines should not to be considered.

C. Variable Refrigerant Volume (VRV) Heat Pumps and Air Conditioning Systems

1. Consider variable refrigerant flow technology (such as Daikin VRV, LG VRF, and Mitsubishi City Multi) for 24/7 cooling applications where main building chillers do not operate at low outside air temperatures. Controllability of VRV systems is superior to single speed split system condensing units with indoor fan coils.

2. For most applications, air-cooled condensers are most appropriate, but have limited life expectancy. Consider water-cooled systems where a reliable source of cooling water is available.

3. Design VRV systems to maximize efficiency and reliability. Review all such applications and system configuration with the University. Carefully specify all aspects of variable refrigerant flow systems, particularly system interface with the building energy management system.

23-18 HUMIDITY CONTROL EQUIPMENT

A. Design humidification systems and controls when Code-mandated minimum relative humidity levels cannot be maintained. Carefully determine the appropriate size of humidifies. Oversized humidifiers are difficult to control, and supplemental humidification is only marginally required in San Francisco. For existing spaces, monitor room relative humidity to establish basis for sizing humidification equipment. Where appropriate, plant steam and/or clean steam generators shall be used; confirm steam quality with the University. Where precise control and/or superior low capacity control is required, consider ultrasonic type humidifiers, with an appropriate demineralized water source. Review humidification equipment types with the University, as well as monitoring and control strategies.

B. Dehumidification, where active control is required, shall be provided by controlling dewpoint temperature at air handling system cooling coils. Where this approach is inappropriate, such as relative humidity control in manufactured cold rooms, specify desiccant type dehumidifiers.

23-19 TERMINAL HEATING AND COOLING COILS AND CONVECTORS

A. Water Coils

1. The design of heating and cooling coils and piping shall consider all aspects of the installation, including performance, air and water side balancing, maintenance, longevity, and replacement. All coils and control valve assemblies shall be readily accessible. For coils

with 2-way control valves, install the strainer, circuit balancing valve, and control valve on the (lower) heating or chilled water supply line, to be more readily accessible.

2. Zone Heating Coils:
   - Specify minimum 0.025-inch thick copper tubes, minimum 0.035-inch thick copper return bends, minimum 0.010-inch thick aluminum fins (maximum 12 fins per inch), seamless copper headers, all joints shall be silver brazed.
     - For 100% outside air systems on the Parnassus Campus with air filtration less than MERV 13, specify coils with minimum 0.008-inch thick copper fins, maximum 8 fins per inch, and minimum 16 gauge stainless steel casings.
   - Casings minimum 16 gauge galvanized steel with 1.5-inch face flanges. Coils 12 inches wide and small can use slip-and-drive duct connections.
   - ARI certified, factory tested at minimum 350 psi air pressure under water prior to shipment.

3. Cooling Coils at Fan Coil Units:
   - As specified for zone heating coils, except with minimum 0.008-inch thick copper fins and stainless steel casing.
   - Specify double-wall insulated stainless steel drain pans extending entirely around the coils and headers, with external drain and overflow connections.

B. Convectors

1. Consider heating water convectors for environments where people are seated near tall glazing. Convectors keep glazing warmer than overhead systems, reducing radiant heat transfer during cold weather, and provide significantly more comfort for occupants working near the windows.

2. Specify that convector enclosures be heavy duty, minimum 18 gauge pre-galvanized steel with a durable baked-on powder-coated finish. Provide individual zone temperature control using modulating control valves. Specify access doors where concealed control valves are part of the convector assembly.

3. Specify hanger brackets that support the weight of people standing on the convector. Brackets and fin tubes shall have and provisions for noiseless operation during expansion and contraction of piping.

23-20 DUCTS

A. Air Distribution Systems

1. Air systems should have ducted supply, return, and exhaust. Return air ceiling plenums are limited to non-OSHPD spaces where ceiling plenums do not contain sprayed-on fire proofing or other friable materials.

2. Where ceiling plenum return is utilized:
   - Extend return ducts into each plenum and provide inlets not more than 20 feet on center.
   - Specify screened inlets and sufficient acoustic duct lining to attenuate duct borne noise from reaching occupied areas.

- Show return duct inlet volume dampers downstream of acoustic duct lining. Detail sound boots on return air grilles in offices and private spaces.
- Require that the ceiling plenum be thoroughly cleaned of all dust and debris prior to closing. Cleaning shall conform to NADCA Standard 1992-01. Require that ceiling cleanliness be accepted by the University's Inspector of Record prior to closing ceiling.
- If any work occurs above the ceiling after cleaning and closing, then require re-cleaning prior to closing.

3. Supply air plenums shall not be used for normal HVAC systems, and shall only be considered for special applications.

4. Do not locate heating coils, terminal units, or air valves over fixed seating, in areas with sloped or stepped floors, or where devices would otherwise difficult to access. In rooms with varying ceiling heights, locate terminal units where the shortest ladder can be used even if additional ductwork is required.

5. Use of round ducts is encouraged, for cost and energy efficiency. As duct sizes increases, flat oval can be considered. Rectangular ducts shall be used wherever round ductwork is not practical. Except in constricted areas, use a maximum aspect ratio of 3:1 for cost and efficiency.

6. Exposed ducts outside the building shall be constructed to shed water. Round duct is preferred. If rectangular duct is used, slope the top minimum 1/2-inch per foot to shed water. Provide extra layer of external sealant to all exposed joints and seams.

B. Duct System Design

1. Carefully design fan inlet and outlet conditions. Avoid plenum discharge for housed centrifugal fans. Provide sufficient clearance downstream of un-housed plenum fans (centrifugal plug fans) prior to filters, coils, sound attenuators, or duct connections.

2. Carefully design duct transitions and elbows, particularly in high velocity ducts, branch take-offs from risers, connections to main ducts, and connections of variable air volume (VAV) or constant air volume (CAV) terminal units to supply ducts.

3. To minimize pressure loss, turbulence, and noise in ventilating systems, size ductwork for constant air volume (CAV) systems using the following maximum friction and air velocities:

- Ductwork Exposed in Occupied Areas: 0.06" w.g./100' when < 5,000 CFM; 1,000 FPM when ≥ 5,000 CFM
- Ductwork Above Occupied Areas: 0.08" w.g./100' when < 8,000 CFM; 1,400 FPM when ≥ 8,000 CFM
- Ductwork in Mechanical Rooms, in Riser Shafts, and on Roof: 0.10" w.g./100' when < 10,000 CFM; 1,600 FPM when ≥ 10,000 CFM
- Ductwork Exposed in Occupied Areas: 0.06" w.g./100' when < 5,000 CFM; 1,000 FPM when ≥ 5,000 CFM
- Return Duct Intakes for Plenum Return: 600 FPM through screened openings

- End Branch to Diffusers and Grilles: Not smaller than diffuser neck size

4. Size ductwork for variable air volume (VAV) systems in which system turndown is at least 40% of design airflow using the following maximum friction and air velocities:

   - Ductwork Exposed in Occupied Areas: 0.08" w.g./100' when < 8,000 CFM; 1,400 FPM when ≥ 8,000 CFM
   - Ductwork Above Occupied Areas: 0.10" w.g./100' when < 10,000 CFM; 1,600 FPM when ≥ 10,000 CFM
   - Ductwork in Mechanical Rooms, in Riser Shafts, and on Roof: 0.12" w.g./100' when < 12,000 CFM; 1,800 FPM when ≥ 12,000 CFM
   - Ductwork Exposed in Occupied Areas: 0.08" w.g./100' when < 8,000 CFM; 1,400 FPM when ≥ 8,000 CFM
   - Return Duct Intakes for Plenum Return: 750 FPM through screened openings
   - End Branch to Diffusers and Grilles: Not smaller than diffuser neck size

5. Static regain duct sizing method may be used for supply ductwork, provided the total system static pressure requirement is no higher than the equal friction criteria listed above.

6. Show sufficient main and branch volume dampers to properly balance air systems.

C. Sheet Metal Ductwork

1. Where not otherwise required to meet specific requirements of the project, ductwork shall conform to “HVAC Duct Construction Standards, Metal and Flexible,” Third Edition, 2005, as published by the Sheet Metal and Air Conditioning Contractors National Association, Inc., hereinafter referred to as the “SMACNA Standards”. All ductwork shall comply with the most stringent requirements of the SMACNA Standards, CMC, NFPA, and the following guidelines.

2. Duct Materials:

   - Specify galvanized steel metal for ductwork and plenums. Galvanized sheet metal shall conform to ASTM A924 (formerly ASTM A525) or ASTM A653 (formerly ASTM A527). Minimum galvanized coating shall be G90, 0.90 ounce per square foot. Specify minimum 24 gauge for rectangular ductwork and minimum 26 gauge for round and flat oval ductwork. Specify G90 “Galvaneal”,“Zincgrip”, or equal where painting of galvanized ductwork is required.
   - Specify aluminum for low-pressure wet applications only. Aluminum ductwork shall conform to ASTM B209, Type 3003H-14, and be capable of double seaming without fracture.
   - Specify stainless steel for wet or corrosive applications. Stainless steel ductwork shall conform to ASTM A240 and A480, cold rolled, annealed, pickled, Finish No. 2B for concealed work and Finish No. 4 for exposed work. Unless otherwise indicated, specify Type 316 for fume hood exhaust, and Type 304 for outdoor ductwork and wet indoor applications. Use Type 316L and 304L wherever welding is required.

- See Paragraph F below for fume hood exhaust duct materials.
- Unless a UL listed positive pressure double wall grease exhaust system is used, specify uncoated black steel for grease exhaust ductwork. Grease exhaust ductwork shall be hot or cold rolled, open-hearth soft steel sheet capable of welding or double seaming without fracture, meeting ASTM A366, A568 or A569, and ANSI B32.3. Grease exhaust ductwork shall be sloped back to hood or drainage points.
- Duct flanges, reinforcement, and hangers should be made from the same material as the duct.
- Fasteners for ductwork shall be stainless steel for stainless steel ductwork, otherwise galvanized or cadmium-plated steel. Sheet metal screws shall be minimum #10 size, and extend not more than 1 inch into ducts.

3. Sealants:

- Products: Specify UL listed duct sealants.
  - Sealing Compound: Ductmate Pro-Seal, United McGill Uni-Grip, 3M No. 900, Hardcast IG-601, or equal, specially formulated for sealing duct joints and seams.
  - Gaskets for Flanged Joints: 3M Weatherban Tape 1202, Ductmate 440, or equal, butyl or polymer based tape, FDA or USDA approved.
  - Hard-Setting Joint Tape: Hardcast FTA-20 and DT tape, United McGill Uni-Cast MTA-20 and MDT Tape, or equal.
  - Duct tapes should not be allowed.
- Application: Seal all ducts in accordance with SMACNA Seal Class “A".
  - Ductwork on the roof and outside air ductwork shall be double sealed. In addition to internal duct sealant, seal all transverse joints, longitudinal seams, branch duct intersections, tap-ins, and fitting gores on the outside with two thick coats of brush-on sealant rated for exposed outdoor application. Allow sealant to cure between coats.

4. Duct Jointing Systems:

- Factory fabricated duct jointing systems are permitted provided joint stiffness ratings have been tested and certified in accordance with SMACNA test procedures by an independent testing laboratory. Ductmate 25/35, Lockformer TDC, Engles TDF, or equal.
- Duct flanges should be the same material as duct, with bolted metal corner pieces.
- Joints should be assembled strictly in accordance with latest printed edition of manufacturer's installation instructions using specified gasket tape, triple lapped at corners. Push-on flanges should be screwed or spot-welded to sheet metal duct at each corner and maximum 8 inches on center across flange.

5. Installation: Specify ductwork requirements that will result in a high quality, low noise, and low pressure loss system.

- Require that ductwork not be in contact with ceiling and light supports, wall framing, and other items which might transmit noise into occupied areas. Installed ductwork shall be free of objectionable vibration and noise.
- After duct installation is mostly complete and before ceilings are installed, require that the University’s Test and Balance Agency perform an inspection to identify locations for duct pitot traverses and instrument readings.

    - Require capped pitot traverse and instrument openings in ducts. Specify Ventlok No. 699, or equal Instrument Test Holes with red painted caps for easy visibility.
    - Require that all pitot traverse and instrument hole locations be shown on as-built drawings.
- Coordinate locations for duct smoke detectors.
- For rooftop ducts, require that top of duct or top of duct insulation slope minimum 1/2 inch per foot to shed water. Specify waterproof and vapor-proof insulation jacketing for supply and return ducts on the roof.
- Firestopping: Include appropriate firestopping details on the Drawings for all conditions encountered on project.
- Exposed Ductwork: Require that exposed ductwork be installed neatly, free of kinks and dents, free from oozing or dripping sealant, clean, dust and oil free, acid washed, and ready for prime and finish painting. Ensure that ductwork is completely sealed so that small leaks do not create dirty or discolored surfaces or make objectionable noise. Duct supports and accessories shall be neatly installed and finished.

6. Duct Fittings:

- Require the use of radius elbows wherever possible. Centerline radius should be not less than 1-1/2 times duct width.
- Where space does not permit full radius elbows or radius offsets, require splitter vanes in accordance with Chart 4-1 and Figure 4-9 of the SMACNA Standards. Number of vanes determined by ratio of inner radius (R) to duct width (W) in plane of radius:
    - One Vane: R/W above 0.3.
    - Two Vanes: R/W between 0.1 and 0.3.
    - Three Vanes: R/W 0.1 and smaller.
- Specify square elbows with turning vanes where radius elbows cannot be accommodated.
    - Avoid nested square elbows wherever possible. Where one square turn occurs within one duct width of another, require that trailing edges be provided on vanes in upstream elbow, extending a minimum of 1-1/2 inches beyond each vane parallel to airflow.
    - Avoid unequal elbows with turning vanes wherever possible.
    - Square turns with or without turning vanes should not be allowed in return or exhaust ducts. Use radius turns, with splitter vanes where necessary.
- Offsets: Require that mitered or angled ducts be limited to a maximum of 15 degrees centerline offset. Specify radius elbows for centerline offsets greater than 15 degrees. Where possible, use maximum 45-degree elbows, unless space is limited.
- Transitions: Require that transitions be uniformly tapered with a maximum included angle of 15 degrees for diverging flow and 60 degrees for converging flow. At fan discharges, limit transitions to 10 degrees included angle.
- Rectangular-to-Round Transformations: Uniformly tapering, minimum length of transformation equal to round duct diameter.
- Specify branch tap-ins to rectangular ducts to be 45 degrees flared type for rectangular branch ducts, and 60 degrees conical or radius bell-mouth type for round branch ducts. Specify tap-ins with minimum 1-inch flange, secured to main ducts at maximum 3-inch intervals.
- Sleeves for Pipes, Conduits and Structural Members: Where interference between ducts and pipes or conduits cannot be avoided, require round or streamlined sheet metal sleeves through which pipes, conduits, hanger rods, structural members, etc.

can pass. Construct sleeves of pressure-tight sheet metal tubing with flanged ends, screwed or riveted to duct wall, and sealed airtight. Furnish transition sections upstream and downstream of sleeves such that net cross sectional area of the duct is never less than the duct size indicated.

7. Duct Pressure Classifications: Determine and specify minimum required duct pressure classification for each portion of each duct system on project. Duct construction shall meet the requirements of CMC Chapter 6 and NFPA. Duct pressure classifications should not be less than the following:

    - Except where noted below, require that rectangular supply, return, and exhaust duct systems be constructed to a SMACNA Pressure Class of 2-inch WG. Cross break or bead all sides.
    - Require that rectangular ducts within five duct widths of fans and air handling unit inlet and discharge connections be constructed to a SMACNA Pressure Class of 6-inch WG.
    - Require that rectangular supply ducts upstream of variable air volume terminal units and grease exhaust ducts be constructed to a SMACNA Pressure Class of 4-inch WG.
    - Increase the pressure classification of any system or portion thereof which could be exposed to peak fan static pressure, positive or negative. This includes any supply, return, or exhaust ductwork, fan casing, or plenum between the fan and any automatically controlled fire damper or main duct automatic damper which, by closing, could expose the duct system to peak or shutoff static pressures. Determine peak fan static pressure from fan curves, at shutoff or peak of fan curve, and construct portions of ductwork and plenums that could be exposed to peak static pressures to the nearest pressure class tabulated in the SMACNA Standards which is above the peak fan static pressure.
        - If approved by the University, alternate protection methods may be employed, such as duct pressure relief panels or duct static pressure sensors directly interlocked with the fan motor start circuit.

8. Rectangular Duct Joints and Reinforcement:

    - Low Pressure Ducts (SMACNA Pressure Classes 2-inch WG and below), choice of:
        - Ducts Up to 60 Inches: Standing seam or pocket lock, SMACNA Types T-15, T-16, T-17, T-18, T-19.
        - All Sizes: Flanged, SMACNA Type T-22, using angles of sufficient rigidity and sheet metal of sufficient thickness to avoid the use of tie rods, up to 2 by 2 by 1/4-inch companion angles.
        - Duct connection systems, Ductmate, TDC (SMACNA Type T-25a), or equal, may be used as an alternate for ducts up to 72”, or to the maximum duct width where the alternate joint meets specified stiffness requirements without tie rods, whichever is less.
    - Medium and High Pressure Ducts (SMACNA Pressure Classes 3-inch WG and above), choice of:
        - Ducts Up to 36 Inches: Standing seam or pocket lock, SMACNA Types T-15, T-16, T-17, T-18, T-19.
        - All Sizes: Flanged, SMACNA Type T-22, as for low-pressure ducts.
        - Proprietary duct connection may be used as specified for low-pressure ducts up to 60 inches maximum width.
    - Welded Steel Grease Exhaust Ductwork: Continuously welded longitudinal and transverse joints, minimum 3/8-inch SMACNA Type T-21a flanges. Maximum 1

inch high reinforcement angles, same material as duct, tack welded to duct maximum 6 inches on center on alternate sides. Reinforcement thickness and spacing as required for duct Pressure Class.

- Require the same joint type on all four sides of duct.
- Require that connections to existing ductwork be equivalent to the specified pressure classification for new ductwork. Existing duct joints, if undamaged, may be reused if they meet specified stiffness requirements and can be made airtight. If new joints are required, require Ductmate 35 or other approved flange on each side.
- Specify intermediate reinforcement, where required, on all four sides of duct, bolted or welded together at each corner. Internal tie rods are not allowed for duct reinforcement, except for ducts 85 inches and over. Tie rods, where necessary, shall be 3/4 inch or 1 inch galvanized steel conduits with bolt assembly consisting of rubber washer and friction anchored threaded insert, Ductmate "Easyrod", or equal. Installation of reinforcement and tie rods shall comply with requirements of the SMACNA Standards.
- Specify flat crimped Pittsburgh Lock longitudinal joints, continuously sealed.
- Specify flat "S" slip-and-drive transverse joints for use at fire dampers, tight fitting shear wall and slab penetrations, and only if necessary.

9. Round Ductwork:

- Require that round ductwork for both positive and negative pressure applications be constructed to a minimum Pressure Class of Negative 4-inch WG, as summarized on Table 3-11 of the SMACNA Standards. Use "Unstiffened" sheet metal gauges. Specify United McGill, SEMCO, or equal, prefabricated, machine wrapped, round duct with a tightly sealed spiral locked seam.
- Specify that fittings be minimum two gauges heavier than equivalent straight duct, with continuously welded or spot-welded and continuously sealed seams.
    - Specify mitered or die-formed elbows with centerline radius no less than 1.5 times the duct diameter.
    - Immediately upstream of air diffuser connections, allow minimum 22-gauge adjustable elbows with continuously sealed gores to align flexible duct with diffuser.
    - Preferred branch connections are 45-degree laterals, conical or straight, saddle taps or all welded fittings. Secure saddle taps or flanged connections to main ducts with sheet metal screws, maximum three inches on center. Where 45-degree laterals cannot be accommodated, use 90-degree tee fittings
    - 90-degree tee fittings shall be conical saddle taps or all welded fittings. Conical tee fittings shall be minimum six inches long, with connection to main duct minimum 33 percent larger than branch duct diameter. Secure tee fittings to main ducts with sheet metal screws, maximum three inches on center.
- Joints: Specify couplings with swaged bead in center, SMACNA Type RT-1, secured with sheet metal screws. Secure couplings with sheet metal screws, not more than 6" on center, minimum three places on each side of sleeve.
    - Where flanged connections are required, specify Van Stone angle rings welded to duct, sizes to match mating flanges. Install in accordance with requirements of SMACNA RT-2 or RT-2A.
- Internally Insulated Round Duct: Specify United McGill "Acousti-K27," SEMCO, or equal, double-wall round duct with 1-inch thick internal insulation, spiral-locked exterior duct, and perforated metal inner liner. Comply with other requirements for round ductwork described above.

10. Flat Oval Ductwork:

    - Specify that flat oval ductwork be constructed with minimum sheet metal thicknesses as summarized on Table 3-15 of the SMACNA Standards. Specify United McGill, SEMCO, or equal, prefabricated, machine wrapped, flat oval duct with a tightly sealed spiral lock seam.
    - Specify that reinforcement for flat sides of oval ducts be the same size and spacing as for rectangular ductwork constructed to a Pressure Class of 6-inch WG as summarized on Table 2-6 of the SMACNA Standards. Duct construction shall be capable of withstanding a pressure of 10-inch WG without structural failure or permanent deformation.
    - Specify that fittings conform to gauges scheduled on Table 3-15 of the SMACNA Standards and conform to the seam, joint, and connection requirements indicated for round ductwork.

D. Acoustical Sheet Metal Plenums

1. Acoustic plenums for built-up systems shall consist of minimum 4-inch deep self-supporting wall, floor, and ceiling panels with internal framing channels and reinforcing structural members. Industrial Acoustics "Quiet-Flow," Vibro-Acoustics, or equal.

2. Sound Absorbing Fill: Incombustible, inert, mildew-resistant, vermin-proof, minimum 1.5 pounds per cubic foot density.

3. Wall and Ceiling Panels:

    - Exterior Face and Intermediate Reinforcement: Solid, galvanized steel, minimum 18-gauge, with minimum 18-gauge channel framing around the perimeter of each individual panel, and minimum 18-gauge vertical reinforcement spaced as required to meet Pressure Classification. Panels shall be spot-welded to perimeter frame and intermediate reinforcement maximum 3-inches on center.
        - Specify stainless steel outside panels where plenum exterior is exposed to unfiltered outside air.
    - Interior Face: Perforated, galvanized steel, minimum 22-gauge, with 3/32-inch diameter holes spaced 3/16 inches on centers. Protect all perforations and fill with visqueen during shipment, storage, and until system startup.
        - Specify stainless steel interior panels where plenum handles unfiltered outside air.
    - Pressure Classification: Plenum panels exposed to supply fan positive static pressure shall be constructed equivalent to SMACNA 10-inch WG Pressure Class. Plenum panels not exposed to supply fan positive static pressure shall be constructed equivalent to SMACNA 6- inch WG Pressure Class. Furnish panel gauges, width, and reinforcement per Table 9-1 of the SMACNA Standards for the indicated pressure class. Provide reinforcement gauges and spacing per Table 9-1. No allowance shall be made for inner perforated panels.
    - Provide framed openings for access doors, fan connections, duct connections, pipe and conduit penetrations, filter banks, and coils. Specify minimum 18-gauge channel shaped framing around all openings.

4. Floor Panels: Bottom panels shall be minimum 18-gauge. Top panels shall be minimum 16-gauge. Minimum 18-gauge stiffeners shall be provided maximum 12 inches on center. Floor panels shall be set on a continuous bed of 1/4-inch-thick high-density felt padding.

5. Door Panels: Solid, minimum 18-gauge, minimum 3-inch thick, with continuous airtight acoustic seal around sill, jambs, and head. Provide with three hinges and three adjustable latches, Ventlok 310, or equal. Provide windows in fan sections only. Windows shall have two layers safety glass, each minimum 1/8-inch thick, sealed airtight, with desiccant in air space.

6. Panels and fill material shall meet the following combustion ratings in accordance with ASTM E84:

   - Flame Spread Classification – 15
   - Smoke Developed – 0
   - Fuel Contributed – 0

E. Internal Acoustic Insulation

1. Design Criteria:

   - Use of internal acoustic insulation should be limited to locations where:
     - Acoustic attenuation is required and duct sound attenuators cannot easily be accommodated.
     - Ductwork is exposed, either on the roof or in a space, and external insulation is undesirable.
   - Wherever internal acoustic insulation is required, specify material and installation standards.

2. Materials:

   - Specify Armacell AP Coilflex, Armaflex SA Duct Liner, Nomaco K-Flex, Rubatex, Aerocel, or equal, one (1)-inch-thick, fiber-free, closed-cell elastomeric sheet insulation, erosion resistant per UL 181, suitable for air velocities to 5,000 fpm. Maximum average thermal conductivity at 75 degrees Fahrenheit of 0.27 per ASTM C177-85 or C518-91. Maximum 6 percent water absorption per ASTM D1056. Maximum water permeability of 0.10 per ASTM E96-90 Procedure B. Mold, fungi, and bacteria resistance per ASTM G21/C1338, ASTM G22, and UL 181. Low VOC, non-corrosive and without objectionable odors per ASTM C665 and ASTM C1304. Ozone resistant and rated for use between -40 and 180 degrees Fahrenheit. Insulation shall meet requirements of NFPA 90A, be UL listed and rated under UL Standard 723.
   - Adhesive: Specify Armaflex 520 BLV, Rubatex, or equal, low VOC air-drying contact adhesive, hexane-free, toluene-free, ASTM E84 Flame Spread/Smoke Developed Index below 25/50, color black or clear.
   - Mechanical Fasteners: Specify 1-1/2-inch diameter self-locking steel washers, length to match insulation thickness; Omark 12-gauge “Insul-Pin,” Duro Dyne, or equal.
   - Insulation Coating for Existing Internal Insulation: Specify VSI “Tough-Coat,” Fosters, or equal, quick drying, low odor white acrylic coating. Coating shall be resistant to microbial contamination and tested in accordance with UL 181, ‘Mold Growth and Humidity Test”; ASTM C1071, ‘Fungi Resistance Test,” ASTM G21, “Determining Resistance of Synthetic Polymeric Materials to Fungi,” and ASTM

G22, “Determining Resistance of Synthetic Polymeric Materials to Bacteria”. UL listed and rated under UL Standard 723.

3. Installation: The following installation requirements shall be included in the project Specifications.

   - Internally insulate ducts in accordance with manufacturer's instructions, SMACNA Installation Standards, and the following. Where internal insulation is provided, omit external insulation. In OSHPD facilities, internal insulation is not permitted downstream of high efficiency final filters.
   - Clean surfaces free of dust, grease, and foreign matter.
   - Attach insulation to duct with 100 percent adhesive coverage plus weld pins with self-locking steel washers attached to sheet metal with pin welder gun at no greater than 12-inches on center longitudinally and 6-inches on center transversely, and within 3 inches of all joints, corners, and edges, including longitudinal seams and corners.
   - Provide minimum 24-gauge U- or Z-shaped sheet metal nosing with minimum 1-1/2-inch overlap over face of insulation on all exposed edges, including edges around transverse duct joints, access panels, coils, dampers, fire damper sleeves, and other duct accessories.
   - Repair any torn insulation with a thick coating of insulation adhesive.
   - Immediately remove from the job site any acoustic lining which has become wet during storage and handling, or in the University's opinion is not in compliance in anything less than like-new condition or otherwise not in compliance.
   - Every section of ductwork with internal acoustic insulation shall be sealed at the shop with heavy polyvinyl sheeting and tape. Sheeting shall not be removed until duct is installed.
   - Prior to installation, require submit of a minimum 12 inches by 12 inches by 18 inches long sample duct section with acoustic lining. Approved sample shall be kept at job site for comparison with installed work. No acoustic insulation shall be installed without duct sections being individually inspected by the University’s Inspector of Record.
   - Existing Acoustic Insulation: Indicate on the Drawings where existing internal insulation requires cleaning and protective coating. Prepare lining for coating per coating manufacturer's instructions. Repair any tears and pre-coat any exposed edge as specified above for new acoustic insulation.

F. Fume Hood Exhaust Ductwork

1. Design Criteria:

   - Coordinate with fume hoods and ducted biological safety cabinets specified in other Divisions.
   - Size fume exhaust ducts same as general exhaust ductwork, as described in the Duct System Design herein.
   - Where practicable, fume exhaust ducts shall be accessible for maintenance.
   - Discuss duct material options, costs and benefits with the University. Three material options are described below.

2. Materials:

- Outside of Buildings: Fiberglass Reinforced Polyester (FRP) Ductwork: For round exterior ductwork carrying corrosive fumes, consider FRP ductwork, constructed as follows:
    - Minimum 1/8-inch wall thickness, constructed from chopped glass fiber between 0.5 inch to 2.0 inches in length, with minimum 30 percent glass content by weight, and minimum 7,000 psi tensile strength. Laminate resin shall include minimum 0.1 percent (by weight) ultraviolet absorber; Tinuven P, Cyasorb UV-9, or equal. Fabricate in maximum lengths possible to minimize the number of transverse joints.
    - Interior duct surface shall be smooth and coated with Dynel, or equal interior chemical surfacing mat with Silane finish and styrene soluble binder in 20-mil maximum thickness. Chemical resistance shall be equal to Hetron 197, developed by Durex Plastic Division of Hooker Chemical Corp.
    - Exterior surface color shall match building exterior, unless otherwise directed. Obtain color by a 20-mil fire retardant, air-dried gel coat. Clean and prepare surfaces and provide appropriate exterior primer prior to finish coats.
    - Provide factory-made slip-fit joints of same material on ends of duct sections, delivered to the site as complete assemblies. Where field jointing is required, butt ends neatly and wrap with resin-impregnated, glass fiber mat wrap, overlapping each end of duct or fitting by 2-inch minimum.
    - Fiberglass material, sealants, wraps and coatings shall be rated in accordance with ASTM E84:
        - Flame Spread: Maximum 25.
        - Smoke Developed: Maximum 50.
    - Joint Draw Bands for Connection to Dissimilar Ductwork: Minimum 22-gauge, 4-inch wide, Type 316 stainless steel with No. 1 or 2B finish, secured with two Type 316 stainless steel 3/16-inch diameter stove bolts and nuts. Install with a complete coating of approved caulking.
- Interior Ductwork: Use Type 316 stainless steel ductwork, constructed as follows:
    - Rectangular: Minimum 18-gauge Type 316 stainless steel with Pittsburg lock or continuously welded longitudinal seams and SMACNA Type T-21 welded flange or Type T-22 stainless steel companion angle flanged transverse joints. Flange angles shall be minimum 1 by 1 by 1/8 inch with welded corners, joined using 5/16-inch diameter stainless steel bolts maximum 4-inch on center. Fittings shall be long radius type with welded longitudinal seams.
    - Round: Minimum 18-gauge Type 316 stainless steel. Longitudinal seams shall be Acme lock with welded joints. Transverse joints shall be welded slip joints or Van Stone flanged duct connections, SMACNA Type RT-2, with 1/2-inch flared duct angles and hypalon gaskets. Connect flanges with stainless steel nuts and bolts at 4 inches on center. Make welded slip joints so that condensing moisture inside the duct flows toward the hood. Fittings shall be minimum 18 gauge Type 316 stainless steel, long radius, with continuously welded seams.
    - Sealants: Caulking material shall be chemical resistant, hypalon-based. Gasket material shall be PTFE, Teflon, or modified chemical resistant closed-cell silicone foam strip. Gasket width shall match flange width, thickness as required to accommodate surface irregularities and seal joint airtight.
- Galvanized Steel Ductwork: For non-corrosive fumes where ductwork is fully accessible, and where specifically approved by the University, use galvanized steel ductwork as specified hereinbefore. Use chemical resistant sealants specified above.

For combined fume hood and general exhaust systems, use fume hood exhaust materials specified above up to point of connection with a larger general exhaust duct. Galvanized steel ductwork may be used for the mixed air stream.

G. Canopy Hoods

1. In general, canopy hoods are not acceptable for exhausting hazardous vapors. Provide factory-built fume hoods for containing hazardous vapors.

2. Canopy hoods are acceptable for capturing non-hazardous heat or steam vapor from process equipment.

3. Kitchen hoods shall be designed in accordance with Code. Kitchen hoods are preferred on walls rather than islands for better efficiency.

H. Industrial Exhaust Systems

1. Design industrial exhaust systems for woodworking machinery, grinders, dust collecting, paint spraying or welding fumes, etc., with adequate provisions for entrainment and safe removal of any dangerous substances. Systems shall be designed in accordance with the recommendations of the Industrial Ventilation Manual published by the American Conference of Governmental Industrial Hygienists (ACGIH).

I. Flexible Ductwork

1. Design Criteria:
   - Where space permits, connect to ceiling diffusers and grilles using round flexible duct.
   - In all cases, specify flexible duct with cataloged attenuation properties.
   - Flexible ducts are not allowed in concealed spaces or above hard ceilings. Ductwork above T-bar and spline tile ceilings is not considered concealed.

2. Materials:
   - Acoustically Rated Flexible Ducts: Exterior fiberglass reinforced metalized vapor barrier jacket with a maximum permeance of 0.05 perms per ASTM E96 Procedure A, 1-1/2-inch thick fiberglass insulation (K=.25 at 75 degrees F), acoustically permeable polyethylene inner fabric liner, overlapped and mechanically locked with a formed galvanized steel helix without the use of chemicals or adhesives. UL 181 labeled as a Class I air duct suitable for a working pressure of 10-inches WG and a velocity of 5,500 FPM. Products: Flexmaster Type 1M, Cody West, Thermaflex, or equal.
     - Acoustical performance shall be tested by an independent ETL-certified laboratory in accordance with the Air Diffusion Council's “Flexible Air Duct Test Code” FD 72-R1, Section 3.0, Sound Properties.

3. Installation: Specify minimum installation requirements as follows:
   - Support all flexible ducts at or near mid-length with 2-1/2-inch wide minimum 20-gauge steel hanger collar bent to 1-inch larger diameter than duct size.
   - Installation shall minimize sharp radius turns or offsets.
   - Maximum length shall be 6 feet, with a maximum of one long radius 90-degree bend.

- Cut to exact lengths required and secure inner fabric liner to duct with cadmium or chromium plated steel compression clamps; provide minimum 2-inch overlap over rigid duct sleeve. After clamping inner liner, pull insulation and outer jacket back into position and seal with two complete wraps of 4-inch wide FRK insulation tape.

23-21 DUCT ACCESSORIES

A. Dampers

1. Design Criteria:
    - Show accessible manual volume dampers at major divisions in all duct systems to permit balancing of air quantities. Each branch duct serving a supply outlet or exhaust/return inlet shall be provided with an individual volume damper, installed as far from the outlet and inlet as practical.
    - Specify locking quadrant-type damper operators. Specify standoff brackets to locate operators at outside surface of insulated ducts.
    - Do not specify supply or exhaust grille face dampers. Face dampers often lead to objectionable noise in occupied areas.

2. Damper Materials:
    - Multi-Blade Dampers: Specify minimum16-gauge galvanized steel blades with 6-inch maximum blade width, 1/2-inch diameter steel continuous shafts in bronze bearings, and minimum 1-1/2 inch by 1-1/2 inch by 1/8 inch steel channel frames welded at corners. Specify opposed blade dampers with other details as shown in Fig. 7-5 of the SMACNA Standards. Require that the shaft end be saw cut 1/16-inch deep parallel with damper blade.
    - Single Blade Dampers: Specify minimum 18-gauge galvanized steel blade for dampers less than 24 inches in length, 16-gauge for dampers longer than 24 inches, 12-inch maximum width blade, with V-crimp at edge and center of blade. Specify minimum 3/8-inch continuous square steel shafts (1/2-inch square shafts for ducts over 24-inches wide) with operators and end bearing as described below. Specify other details as shown in Fig. 7-4 of the SMACNA Standards. Round dampers shall be similar with V-crimp at edge omitted. Require that the shaft end be cut 1/16-inch deep parallel with damper blade.
    - Require that single-leaf dampers have no more than 3 percent gaps for edge and end clearance when tightly closed. Require that operating quadrants be installed in easily accessible locations and orientations.
    - Fume Exhaust Dampers: As described above, except constructed of all Type 316 stainless steel.
    - Splitter Dampers: Specify minimum 18-gauge construction, hemmed all four sides, piano hinge with brass pin, minimum length four times width of shorter split unless space is limited, with Ventlok 600 Series, Duro-Dyne, or equal, operators and hardware.

3. Damper Hardware: Specify Ventlok (model numbers indicated below), Duro-Dyne, or equal.
    - Uninsulated Duct Dampers: Specify No. 641, 1/2-inch self-locking regulator and No. 607, 1/2-inch end bearing. Specify 3/8-inch bearings for use with single blade dampers less than 24-inches wide. Specify stainless steel parts for fume exhaust duct dampers.

- Insulated Rectangular Duct Dampers: Specify No. 644, 1/2-inch self-locking regulator with No. 607, 1/2-inch end bearing. Specify 3/8-inch bearings for use with single blade dampers less than 24-inches wide.
- Insulated Round Duct Dampers: Specify No. 637, 3/8-inch self-locking regulator with hat channel standoff and No. 607, 3/8-inch end bearing attached to duct below hat channel.
- Insulated and Uninsulated Duct Dampers above Inaccessible Ceilings, Option 1: Same rod sizes and end bearings for shaft lengths indicated above. Specify No. 680 miter gear with No. 677 concealed damper regulator. Specify natural zinc regulator cover plate, prime painted to match ceiling color finish; install flush with ceiling.
- Insulated and Uninsulated Duct Dampers above Inaccessible Ceilings, Option 2: Specify Young Regulator 270-301-EZ-B Bowden Cable Controls, utilizing concealed regulator and damper blade control with separate volume damper as described above. Regulator shall be rigidly secured to wall framing or backing plates above the ceiling. If mounting location is inaccessible, then mount regulator on top of sheet rock ceiling and specify with integral 3-inch diameter cover plate. Bowden controls can be problematic if not carefully installed, so limit their use to situations in which the following criteria can be met:
  - Maximum damper size of 2 square feet.
  - Locations of cover plates are subject to review and approval by the Architect and the University.
  - Only one long sweeping bend of the cable (maximum 90 degrees of bending) is permitted. Orient the damper actuator and ceiling regulator to meet this requirement.
  - Cut cable to the length required and use no more cable than necessary. Prevent cable from sagging.
  - Operation of the regulator and ability to keep the damper locked in fully open, closed, and intermediate positions shall be tested by the University's Inspector of Record prior to closing the ceiling.
  - Require that the cover plate and screw heads be separately painted to match the ceiling color.
- U-bolt blade fasteners, if used, shall be No. 615, spaced 12 inches on center maximum.

4. Automatic Dampers:
   - Requirements for air handling system economizer dampers are described in Paragraph 23-17.D.10 above.
   - Automatic dampers for fume hood exhaust fan isolation and outside air applications shall be all Type 316L stainless steel construction. For non-fume hood exhaust applications where airflow is filtered and tempered, automatic dampers shall be aluminum or galvanized steel.
   - For dampers larger than 12 square feet, specify heavy duty dampers as described for air handling system economizer dampers. For dampers 12 square feet and smaller, automatic dampers with lighter construction features can be specified.
   - Specify damper operators that are suitable for the damper size and environmental conditions. Each actuator shall control not more than 16 square feet of damper.

B. Fire and Smoke Dampers

1. Design Criteria:

- Obtain floor plans from the Architect and/or the University that indicate all fire-rated walls and ceilings, including smoke barriers and occupancy separations. Assume that all floor penetrations are two-hour fire-rated separations.
- Show all combination fire smoke dampers on the Drawings wherever required in ducts and transfer openings that penetrate fire resistive construction, as required by CBC, NFPA 90A, and the State Fire Marshal. Do not rely on general statements such as, "Install fire dampers in accordance with applicable Codes."
- Be aware of and account for high static pressure loss through small fire smoke dampers. Where appropriate, increase fire smoke damper size so that pressure drop through the open damper is not more than 0.04-inch WG for main ducts and not more than 0.02-inch WG for branch ducts serving individual rooms or outlets.
- Unless otherwise directed, specify 120 VAC electrically actuated fire smoke dampers, which are powered and controlled through the Building Fire Alarm System. Coordinate with Electrical Work.
- Coordinate method and sequence of actuation of all fire smoke dampers with the Fire Alarm System designer. Assist Fire Alarm System designer in the proper placement of duct smoke detectors. Where appropriate, specify fire smoke dampers with integral duct smoke detectors.
- Fire smoke dampers used in atrium or building smoke control systems shall have override capabilities, so that individual dampers can be overridden open or closed by the smoke evacuation sequences.

2. Materials:
   - Electric Combination Fire and Smoke Dampers: 1-1/2-hour rated under UL Standard 555 and further be qualified under UL Standard 555S as a leakage rated damper for use in smoke control systems; Ruskin FSD60, Air Balance, or equal.
     - Electrically controlled closure heat-actuated release device rated for 165 degrees Fahrenheit.
     - Leakage rating shall be no higher than Class I at 250 degrees F.
     - Specify with integral "open" and "closed" end switches to detect and indicate damper position.
   - Two-position Actuators: Specify Belimo FSNF120-US, to match existing, two-position normally closed 120 VAC electric actuators factory-mounted on sleeve to hold damper open. Maximum 9 watts holding power consumption.
   - Modulating Actuators for Fire Smoke Dampers Used in HVAC Control Sequences: Specify Belimo FSAF24-US, or equal, normally closed 24 VAC modulating electric actuators factory-mounted on sleeve. Specify compatible interface modules to accept 4-20 mA or 2-10 VDC input signals for damper modulation; interface modules shall have adjustable zero and span.
   - Integral Smoke Detectors: Where this actuation method is selected, coordinate with the fire alarm system designer. Note all such installations on the Drawings. Integral duct smoke detectors can be mounted on the outside of the fire smoke damper sleeve, with sampling tubes inside the duct; or can be "zero velocity" type, with the smoke detector(s) inside the duct. Entire assembly shall be UL and CSFM listed. Smoke detector shall directly operate the fire smoke damper and provide remote contacts for monitoring trouble and alarm at the Fire Alarm System. Ensure that full access is provided to damper actuator and integral smoke detector.
   - In OSHPD 1 (hospital) buildings, specify below-ceiling position indicator lights and keyed test switch for each fire smoke damper, equal to Ruskin MCB2. Test switch shall be keyed to match existing test switches in the hospital.

3. Installation: Specify the following installation requirements.

- Fire smoke dampers with access panels shall be installed in accordance with all governing Codes, regulations, and listing requirements. Require Contractor to maintain a copy of the manufacturer's installation instructions at the jobsite for use by the University's Inspector of Record.
- Require Contractor to provide minimum 18" access space on actuator side of fire smoke damper. Where there will be less than 18" side clearance for actuator maintenance, specify Ruskin Model FSD 60V, or equal, with vertical blades and bottom-mounted actuator.
- Require that a stenciled or printed self-adhesive label be attached to all fire damper access panels. Tag shall read "FIRE DAMPER" in one-inch high letters. Tag shall also indicate electrical circuit number feeding the damper actuator, and the damper point address in the Fire Alarm System. Supplemental data shall be minimum 1/4-inch high.

C. Duct Access Panels And Doors

1. Design Criteria:
   - Provide sufficient access panels and doors in ducts and plenum walls where required for cleaning and access to equipment and devices in ducts. Pay particular attention to points in duct systems where debris could accumulate, such as adjacent to louvers, screens, turning vanes, and coils. Show all access panels on the Drawings. Do not rely on contractor to provide access panels where they are required but not shown.
   - Size duct access panels appropriately. Where head and shoulder access is required for cleaning or service, specify minimum 18 inch by 18-inch access panels. Where arm access only is required for cleaning, such as upstream of small heating coils and turning vanes, specify minimum 12 inch by 12-inch access panels.
   - Show access doors in grease hood exhaust ductwork at all low points where grease could accumulate, and at intervals that will permit complete cleaning of the duct system.
   - Require that the following warning sign be stenciled in 1-inch high minimum, red letters on opening side (or both sides on walk-through) of access doors and panels between areas or in ducts where there is a positive or negative differential pressure above 0.5 inch WC:

     WARNING
     DOOR (OPENS) (CLOSES) ABRUPTLY
     UNDER (POSITIVE) (NEGATIVE) PRESSURE

   - Design an airlock vestibule entrance at any plenum where the pressure differential is a hazard to personnel using a single door.

2. Materials:
   - Specify that access doors be fabricated using the same material and finish as the ductwork in which installed. Specify access doors with closed-cell neoprene gasket around all four sides of duct opening.
   - For positive pressure ducts operating at greater than 0.5-inch static pressure, specify high-pressure access panels of lift-out design that are pushed into their gasket by duct pressure. Specify Ruskin ADHP-3, or equal, high-pressure access panels with minimum 16-gauge Z-shaped steel frame, formed 16-gauge double wall insulated door, steel spring latches, continuous perimeter gasket, and maximum leakage allowed of 0.5 CFM at 6-inch WG differential pressure.

- For negative pressure ducts and low positive pressure ducts, specify outward swinging hinged or removable access panels that are held onto their gasket by negative duct pressure. Specify minimum 20 gauge double skin access door, with continuous piano hinge and bronze hinge pin. Specify one cam-latch on access doors less than 12 inches longest dimension, three cam-latches (one per side) on access doors 12 inches and larger, and four cam-latches on access doors 18 inches and larger. For larger access panels or higher pressure applications, specify adjustable latches, Ventlok No. 100, or equal.
- Where hinged access panels are impractical or obstructed, specify removable access panels with two latches for panels less than 12 inches longest dimension, four latches (one per side) for panels 12 inches to 18 inches longest dimension, and eight latches (two per side) for panels larger than 18 inches.

3. Installation: Specify the following installation requirements.
   - Require that ceiling access be provided at all duct access doors.
   - Require that access doors and frames be airtight.
   - Require protection at any exposed sharp edges or screw tips around the perimeter of access panels.
   - At end of project, require that all traces of duct sealant be cleaned from access doors and gaskets, and that gaskets be sprayed with permanent silicone lubricant so that doors are easy to operate.

D. Sound Attenuators

1. Design Criteria:
   - Select appropriate duct sound attenuators to reduce sound pressure levels in duct systems and bring HVAC noise levels in occupied spaces within acceptable limits. Use of sound attenuators is preferred over internal acoustic insulation for reducing fan noise.
   - Schedule sound attenuators, indicating overall dimensions, airflow, maximum static pressure loss, and minimum attenuation in each octave band.

2. Materials:
   - Specify factory Industrial Acoustics, Inc. "Quiet-Duct," Vibro-Acoustics, or equal, fabricated sound attenuators in the largest possible modules.
   - Specify sound attenuators with minimum 22-gauge steel shell, equivalent to SMACNA high pressure duct construction, essentially air tight at 8-inch WG differential pressure. Specify minimum 24-guage perforated steel internal baffles. Specify galvanized steel or stainless steel construction, to match the duct system in which it is installed.
   - Specify minimum 3/4 lb. per cubic foot density glass or mineral fiber fill media packed under nominal 5 percent compression, meeting erosion test criteria described in UL Publication No. 181. Material shall be inert, vermin- and moisture-proof. For sensitive applications, where the airstream cannot be in direct contact with insulation media, specify that fill be encapsulated in cleanable polymer sheeting. Fill material shall be rated in accordance with ASTM E84 (Flame Spread/Smoke Developed Index below 25/50).
   - Acoustic Performance: Require that silencer ratings be determined in a duct-to-reverberant room test facility which provides for airflow in both directions through the test silencer in accordance with ASTM Specification E477. The test setup and procedure shall be such that all effects due to end reflection, directivity, flanking transmission, standing waves, and test chamber sound absorption are eliminated.

Acoustic ratings shall include Dynamic Insertion Loss (DIL) and Self-Noise (SN) Power Levels for forward flow (air and noise in same direction with airflow of at least 2,000 FPM entering face velocity).

- Aerodynamic Performance: Require that airflow performance shall be measured in accordance with ASTM Specification E477 and applicable portions of ASME, AMCA, and ADC test codes.

3. Installation: Specify the following installation requirements.
   - Unless otherwise required, install with baffles vertical. Require sheet metal nosing at entering and leaving seams if multiple modules are used. Join to ductwork with flanged connections.
   - Insulate sound attenuators same as for ductwork.

23-22 AIR TERMINAL UNITS

A. Design Criteria

1. Provide air terminal units, constant air volume (CAV) or variable air volume (VAV) as appropriate, for new air handling systems and existing systems that currently use air terminal units.

2. Select the largest size terminal unit that is rated for design maximum and minimum airflow. Size variable or constant air volume terminal units for maximum 2,000 FPM inlet velocity and maximum 0.25" w.g. static pressure loss (excluding heating coil static pressure drop).

3. In OSHPD facilities areas with variable air volume supply, require variable air volume terminal units in exhaust ducts from each zone. Exhaust VAV boxes shall modulate in conjunction with supply air VAV boxes to maintain constant airflow differentials in each space.

4. Specify and detail noise attenuation downstream of supply air terminal units (and upstream of exhaust air terminal units) as required to meet the NC criteria within the occupied space.

5. To reduce terminal unit noise where they are exposed to high main duct static pressure (such as terminal units close to fans and AHUs), require a manual volume damper upstream of terminal unit to lower the pressure differential.

6. Specify and schedule heating coils for all supply air terminal units including interior offices, unless the terminal unit serves a cooling only space such as elevator equipment, computer server, or telecom data room. Select reheat coils at approximately 30°F water temperature drop with 180°F entering water temperature.

B. Materials and Installation

1. Specify pressure independent terminal units with electronically controlled electric actuators.

2. Require that high velocity inlet ducts to variable or constant air volume terminals be straight in, rigid duct, same size as box or valve inlet, minimum two (2) diameters and maximum ten (10) diameters long, without offsets. For longer runs and for any elbows or offsets, require that inlet ducts be sized in accordance with normal duct sizing criteria described earlier.

3. Require the installation of side or bottom access panels (whichever provides superior access) for inspection, adjustment, and maintenance of reheat coils without disconnecting ducts.

23-23 AIR OUTLETS AND INLETS

A. Ceiling Supply Diffusers: Specify Titus TDC-AA, Price AMD, or equal, high-aspiration louver-face aluminum ceiling supply diffusers, sized and located for effective mixing of room air at maximum and minimum airflow, so that little or no thermal stratification occurs. Design multiple supply diffusers evenly spaced in rooms that are larger than 16 feet in any direction. Properly size, locate, and control airflow pattern in each space. Select 2-way throw pattern for diffusers located in corners or long hallways. Select 3-way throw pattern for ceiling diffusers located along a wall; 4-way diffusers should be used for this application with the throw direction toward the wall blanked off with black painted sheet metal at the diffuser neck; evaluate diffuser performance based on one throw direction being blanked-off. Select special diffusers, such as high-performance adjustable linear diffusers, for special applications. At all diffusers and registers with adjustable blades, require adjustment of blades evenly for optimum air distribution. Follow design guidelines in 2011 ASHRAE Handbook - HVAC Applications - Chapter 57 - Room Air Distribution, and 2012 ASHRAE Handbook - HVAC Systems and Equipment - Chapter 20 - Room Air Distribution Equipment.

B. Sidewall Supply Registers: Specify Titus 272FS, Price 22, or equal, double-deflection aluminum supply registers for sidewall supply applications, unless other register types provide superior performance or aesthetic.

C. Ceiling Exhaust and Return Grilles: Specify Titus 3FL, Price 630, or equal, louver-face aluminum exhaust grilles. Locate away from and not aligned with supply diffusers. Size grilles and duct connections appropriately for the airflow (do not specify 22" x 22" exhaust grilles for all applications in lay-in ceilings).

D. Low Wall Exhaust Grilles: Specify Titus Model 350RL-SS, or equal, stainless steel low wall exhaust grilles in airborne infection isolation rooms, operating rooms, and other rooms requiring low wall exhaust, heavy gauge Type 304 stainless steel, 3/4-inch blade spacing, 35 degrees fixed deflection, reinforced corners, No. 4 polished finish, Border Type 1, countersunk screw holes, and flathead stainless steel screws. Install grilles with blades horizontal and front edges pointing down toward floor.

E. Coordinate diffuser style and border type with ceiling system in each space. Specify Titus Style NT, or equal, diffusers and grilles for narrow tee tegular lay-in ceilings in which the face of the ceiling tile is lower than the grid.

F. Diffuser and Grille Finish:

1. For improved longevity and appearance, specify all diffusers, registers, and grilles with Titus "Enviro-Thane", or equal, baked-on urethane finish.

2. Unless a specific color is requested by the Architect and/or the University, specify standard white finish, Titus Color 26 – White, or equal, for diffusers and grilles.

3. For registers and grilles mounted on exposed unpainted galvanized ductwork, specify Titus Color 01 – Aluminum, or equal. For registers mounted on exposed painted ductwork, specify factory finished registers to match the final ductwork color.

G. Ceiling Fire Dampers and Fire Smoke Dampers: Specify steel versions of diffusers and grilles described above where the ceiling is fire rated.

H. Substitutions: Require samples of all proposed substitute diffuser and register types for the University's review and approval.

I. Ensure that minimum VAV airflow settings at maximum heating do not result in stratification or loss of effective mixing of room air. Full heating airflows shall not require leaving coil air temperatures in excess of 90° F. Where necessary, specify VAV sequences that increase airflow for high heating loads to meet these criteria.

J. In general, select diffusers and grilles with manufacturer's catalogued NC level 5 points or more lower than the NC requirement of the space served. This is because the manufacturer's NC data are measured in rooms with highly absorptive surfaces and a uniform air velocity distribution throughout the neck of the diffuser. Select diffusers and grilles with even lower NC levels where the design places diffusers or grilles in close proximity to one another. To reduce airflow noise at diffusers and grilles, ducts should be hung as high as possible, and drop vertically to the diffusers through flexible ducts.

23-24 AIR FILTERS

A. Design Criteria:

1. For OSHPD facilities, specify filter banks and minimum efficiencies that comply with requirements in CMC Chapter 4. CMC Table 4-B only requires 30% efficiency pre-filters upstream of main heating and cooling coils. However, since the University uses primarily 100% outside air, minimum 60% efficiency (MERV 11) pre-filters should be specified; the preferred type are 12" deep mini-pleat cartridge filters for low pressure drop and longevity. In general, do not specify 2" deep 30% efficiency pleated media filters upstream of 60% (MERV 11) pre-filters; they add pressure drop to the system and do not significantly increase the life of the 60% filters.

2. For 100% outside air systems serving operating rooms, cath labs, ICUs, protective environment rooms, oncology nursing units, and wherever else dictated by the project program, specify 30% efficiency (MERV 8) pleated media filters and 90% efficiency (MERV 14) filters in an upstream position and 99.97% efficiency (MERV 17) final filters downstream of the supply fans and cooling coils.

    - Important Note: For protective environment rooms, orthopedic operating rooms, bone marrow transplant operating rooms, and organ transplant operating rooms, CMC Table 4-B requires that the 90% efficiency (MERV 14) filters be downstream of the supply fan, cooling coils, and humidification equipment. These criteria may be followed, or an Alternative Method of Compliance application may be submitted to have the 90% efficiency filters in an upstream position, for the purpose of keeping primary heating and cooling coils clean.

3. For clinical laboratories, specify minimum 90% efficiency (MERV 14) final filters.

4. For hospital administrative areas, staff support areas, bulk storage, food preparation areas, cafeterias, and laundries, specify 30% efficiency (MERV 8) pleated media filters and 90%

efficiency (MERV 14) filters in an upstream position. Preferred main filter type are 12" deep mini-pleat cartridge filters for low pressure drop and superior longevity.

5. For non-OSHPD medical offices, administrative, and similar environments, specify 30% efficiency (MERV 8) pre-filters and 80% efficiency (MERV 13) main filters, as required to achieve LEED Credit EQ 5 indoor chemical and pollutant source control. Certain sensitive applications may require additional high-efficiency final filters downstream of the supply fan or at individual air terminals. Review air filter types, efficiencies, and locations with the University.

6. Specify replaceable factory-assembled filter cartridges. To the extent possible, schedule 24" x 24" filter modules, for ease of replacement and stocking. For high efficiency filters, 12" deep mini-pleat filters are preferred for low pressure drop and superior longevity. Review alternate filter types with the University.

7. Design the largest possible filter banks, for lower pressure drop and fan noise, and to extend the life of the filter media. Maximum face velocity for 80% and 90% efficiency filters shall be 400 feet per minute. Schedule air filter face velocity, initial pressure drop, and replacement pressure drop.

8. Specify visual inspection of new and modified filter banks by the University's Inspector of Record for torn media and bypass using a flashlight or equivalent. Leakage paths around the perimeter of filter banks shall be sealed, and tears in media shall be repaired or cartridges replaced prior to commencing operation of the system.

9. Filter gauges are required at all filter banks. Specify Dwyer 2000 Series, or equal with appropriate operating ranges. Require laminated plastic signs at all filter gauges indicating filter bank name, filter cartridge efficiency, recommended replacement pressure drop, and quantity, size, and model numbers for replacement filters.

10. Design outside air filter banks to prevent moisture saturation of filters. Provide a minimum 3 foot deep drained plenum between intake louvers and air filters.

11. Filter Framing Systems:
    - Specify stainless steel framing systems at air handling units. Specify stainless steel closure panels around the perimeter of filter holding frames, continuously sealed.
    - Specify that low efficiency filter banks (MERV 8 and lower) be fully gasketed.
    - Specify that medium and high efficiency filter banks be fully gasketed and have a guaranteed maximum leakage of 0.5% of design airflow at 1" wg differential pressure.
    - Specify bolt-in-place HEPA filter frames for 99.97% efficiency (MERV 17) or higher filters that are effectively leaktight.

B. Materials:

1. Upstream Pleated Media Prefilters:
    - 2-inch or 4-inch deep, 30 - 35% average dust spot efficiency per ASHRAE Standard 52.10-1992, UL Class 2.
    - High loft, reinforced, non-woven cotton-synthetic blend, with moisture-resistant reinforced Kraftboard frame.
    - Camfil Farr, American Air Filter, Environmental Filter Inc., Purolator, or equal.

2. Low Pressure Drop High Efficiency Mini-Pleat Filters:
    - 12-inch deep, scheduled efficiency per ASHRAE Standard 52.1-1992, UL Class 2.
    - Moisture-resistant mini-pleated glass fiber filter media packs with polyurethane bead separators spaced at approximately 44 mm intervals.
    - Cartridge framing shall consist of molded plastic headers, galvanized steel channels, and extruded aluminum supports. Cartridge shall be gasketed and flanged suitable for side access or upstream loading filter housing systems, as applicable.
    - Camfil Farr Durafil, American Air Filter, Environmental Filter Inc., Purolator, or equal.

3. HEPA Filters:
    - 12-inch deep, 99.97% efficiency (MERV 17) per ASHRAE Standard 52.1-1992, UL Class 2.
    - Moisture-resistant mini-pleated glass fiber filter media packs with acrylic resin binder and fiberglass thread separators spaced at approximately 44 mm intervals.
    - 6063-T5 anodized aluminum frame, suitable for upstream loading.
    - Specify minimum 16-gauge welded stainless steel holding frames with 1" sealing flange. Filter cartridges should be secured with four stainless steel spring-loaded or swing arm clamping assemblies to maintain constant pressure against sealing surfaces.
    - Camfil Farr Durafil, American Air Filter, Environmental Filter Inc., Purolator, or equal.
    - Specify side access bag-in/bag-out housings for HEPA filters for airborne infection isolation room exhaust.

4. Built-Up Filter Banks: Design and detail large field erected filter banks using face mounting Type 316L stainless steel filter holding frames, commonly referred to as Type 8 frames with four (4) stainless steel holding clips per module, specific to the filter cartridge being used. Do not specify or accept Type 9 frames with slip-on retainer clips. Individual frames shall be minimum three (3) inches deep, 16 gauge with welded corner reinforcement and continuous 1/4-inch x 3/4-inch closed cell neoprene gaskets carefully cut and continuously glued so that no leakage occurs around specified filter cartridges. For filter banks more than two modules high, include continuous four (4) inch deep 12 gauge stainless steel flat plate vertical stiffeners between every other column of filters. Attach frames and stiffeners with stainless steel fasteners maximum 8" on center, and provide stainless steel closure panels and structural reinforcement around the bank perimeter.

5. Side Access Filter Banks: Specify side access filter banks for packaged air handling units and fan coil units, fully gasketed with guaranteed maximum leakage of 0.5% at 1" wg differential pressure.

6. Specialty Filters: Specify specialty filters and filter housing systems to meet special project program requirements. Review all specialty filter selections with the University.

23-25 HVAC CONTROLS

A. New HVAC controls shall be fully integrated into the existing the University's Energy Management and Control System (EMCS). At Parnassus Campus, all new controllers shall be Schneider Electric Andover Continuum using BACnet communication protocol to match existing. At Mt. Zion Campus, all new controllers shall be Johnson Controls, using BACnet communication protocol to match existing. New controllers and sequences shall be seamlessly interfaced with existing building control software, sequence, and graphics. Provide full system graphics and User interface for new HVAC controls via web browsers and University EMCS workstations. New HVAC controls shall be connected to emergency power with UPS.

B. Specify that Contractor must support HVAC controls work, and provide support and manpower as requested during system start-up and commissioning. Require that the Contractor provide and install all sensor wells, control valves, and other field devices that are required for HVAC controls work.

C. Control Loops and Sequences:

1. Require that control loops maintain stable temperature setpoints within plus or minus 1.0° F, duct static pressure setpoints within plus or minus 0.05" w.g., and air volume setpoints and differentials within plus or minus 0.5 percent, not counting sensor accuracy. Control loops shall maintain room differential airflow setpoints.

2. Require that control loop parameters, schedules, setpoint ranges, alarm setpoints, and messages be readily adjustable at EMCS workstations or using a portable laptop computer. With a few simple commands, it shall be possible to override any temperature reset schedule and operate systems at fixed setpoints. All setpoint values, reset parameters and other control loop parameters shall be assignable variables and easily adjustable.

3. BACnet interface with mechanical equipment is encouraged wherever available. Nevertheless, require that all input and output points used in active control sequences be hardwired. Monitoring and troubleshooting information can be shared via BACnet. Coordinate with the University what shared information will displayed on system graphics.

D. Require that all software and programming be provided for the University’s use, and that all software licenses be up to date at project turn-over.

E. Construction Documents shall include schematic control diagrams, identification of all required monitoring and control point, and complete sequences of operation for all HVAC systems, including all alarms and failure modes.

For the new air handling systems, include detailed sequences for the following:

- system start/stop, including all conditions under which the fans will stop and automatic restart after power loss
- supply fan speed control
- fire alarm shutdown and fireman's override, integrated with building fire alarm system
- supply air temperature control
- relative humidity control, including supply air high relative humidity monitoring downstream of the humidifier
- humidification and dehumidification enable and disable and modulating controls
- zone temperature control, including supply air temperature reset to minimize cooling and reheat
- zone-to-zone differential pressurization control, where monitored
- exhaust fan speed control
- all necessary interlocks

For new variable frequency drives, include detailed sequences and at least the following monitoring and control points:

- start/stop

- auto/bypass run status
- speed reference signal
- summary alarm
- output current
- fire alarm and fireman's override status

For IT Room fan coil units, include detailed sequences for the following:

- fan start/stop
- room air temperature control

F. Failure Modes: Anticipate possible failure scenarios for system components, and review how systems will react with the University. In general, upon loss of power or communication at controllers, fans and pumps should continue to operate. Upon loss of power or communication at a terminal controller, heating and cooling coils and terminal unit control dampers should fail in their current positions.

G. Monitoring and Alarms: Require that all significant monitored temperatures, pressures, and airflows be programmed with appropriate out-of-range alarms. Monitor the run status of HVAC equipment using current sensing relays or other positive methods. Fully integrate status monitoring and alarms into the existing EMCS. Require that the Contractor provide status and alarm messages as agreed to with the University. Consult with the University as to how alarms should be prioritized and annunciated.

H. HVAC System Graphics: Specify real time dynamic graphics at EMCS workstations and web-based user interfaces. New and modified graphics should display complete system flow diagrams and all control devices. Meet with the University's Representative to review and agree upon information to be displayed on system graphics. Graphics shall show at least the following information, where appropriate:

- individual supply and exhaust fan run status
- total and individual zone supply air and exhaust air CFM
- fire alarm and fireman's override status
- supply and exhaust fan VFD speed output, expressed as a percent of rated motor RPM
- supply and exhaust fan VFD off/drive/bypass status
- supply duct and exhaust duct static pressures, setpoint and actual
- room-to-room differential pressures, where monitored
- outside air temperature
- supply air temperatures, setpoint and actual
- heating coil and cooling coil control valve positions, expressed as a percentage of full open
- zone air temperatures and temperature setpoints
- room relative humidity and relative humidity criteria, wherever monitored
- operating data from air terminal unit and exhaust air valve controllers
- fan coil unit run status
- air filter differential pressure, including main air handler and fan coil unit filter banks
- fire smoke damper open/close status, via end switches, where needed in sequences
- fan coil unit run status
- icons to allow quick modification of setpoints and other parameters, and to move to and from other system graphics
- single line diagram of communication wiring and system architecture

Require a cascade of graphic screens that allow University personnel to move from whole floor information down to detailed information for individual zones. Overview screens should show main duct CFMs and static pressures, average room temperatures and setpoints, and overall floor pressurization. Require thermographic whole floor plans that show rooms within 0.5° F of setpoint in green, rooms more than 0.5° F off of setpoint in amber color, rooms more than 1.0° F off of setpoint in red, and unoccupied rooms in grey (or other agreed upon temperature offsets and colors). Floor plan graphics should show actual room names and numbers. It should be possible to click on any zone and transfer to a screen with detailed zone information.

Require that system graphics show which reheat coil each main duct cooling coil is associated with. Require that supply and exhaust information for a zone be displayed on the same screen with all operating parameters.

I. Historic Trend Logs: Meet with the University to review and agree upon trended points, intervals, and durations.

J. Electrical Energy Monitoring: Meet with the University to review and agree upon monitored information, graphics, and reports.

K. BTUH Monitoring of Heating Water and Chilled Water: Meet with the University to review and agree upon monitored information, graphics, and reports.

L. HVAC System Test Runs: Require 72-hour trend logs of associated point groups to demonstrate that all control loops are operating on setpoint, without unnecessary hunting or cycling. Trended points should be displayed on the same chart using separate, easily identifiable colors and appropriate vertical scales to demonstrate point modulation.

M. HVAC System Commissioning: Require creation and execution of step-by-step testing procedures to validate the functionality and accuracy of all new and existing control sequences that affect the project floors. Procedures should include resetting of setpoints and parameters, manipulation of sensor inputs, initiation of failure modes, and creation of other operating conditions necessary to demonstrate system response to increasing and decreasing variables and alarm conditions.

N. HVAC Control Devices

1. Room Temperature Sensors: Specify thermistor based linear precision sensors, factory calibrated at 70°F, high accuracy element with a rated accuracy of plus or minus 0.18°F from 32° to 150°F, and temperature stability better than 0.036°F per year, in durable ventilated plastic enclosures.

2. Main Duct Temperature Sensors: Specify platinum element linear resistance temperature (RTD) sensors, 1000 ohm resistance at 0°C, temperature coefficient of resistivity 0.00385 ohm/ohm/°C, 3-wire circuit, minimum accuracy plus or minus 0.2 percent of range (Class A), confirming to DIN-IEC 751, approximate operating range -22° to 113°F, allowable relative humidity 0 to 99 percent RH. Kele Model T91U with T90U transmitter, Minco YY807, or equal.
   - Specify Type 304 stainless steel probes or wells. Require closed-cell neoprene gaskets at duct penetration. Require that sensors be located to detect average duct temperature. Specify 25-foot averaging elements where stratified conditions necessitate an averaged reading for accuracy.

- Enclosures: Specify NEMA 1 indoor enclosures where enclosure is not subject to outside air conditions. Specify gasketed NEMA 4X BAPI polycarbonate or stainless steel enclosures where enclosure is subject to outside air conditions.

3. Zone Supply Air Duct Temperature Sensors: Specify thermistor based linear precision sensors, factory calibrated at 70°F, high accuracy element with a rated accuracy of plus or minus 0.18°F from 32° to 150°F, and temperature stability better than 0.036°F per year.

4. Water Temperature Sensors: Specify platinum element linear resistance temperature sensors (RTD), 1000 ohm resistance at 0°C, temperature coefficient of resistivity 0.00385 ohm/ohm/°C, 3-wire circuit, minimum accuracy plus or minus 0.2 percent of range (Class A), confirming to DIN-IEC 751, approximate operating range 30° to 240°F, allowable relative humidity 0 to 99 percent RH (at enclosure).

5. Room Thermostats: Specify electronic thermostats that match those currently in use in the building, with programmable keypad and LCD display of room temperature, and adjustable temperature setpoint.
   - For room thermostats without adjustable setpoint, specify above thermostat with local reset function restricted. Temperature setpoint reset shall occur locally with a password or remotely through the University’s EMCS.
   - Conduct a meeting near the end of project in which each zone is evaluated with the University as to which thermostats should be locally adjustable and which should have restricted access, and what allowable temperature adjustment range should be programmed for each zone.

6. Combined Relative Humidity and Temperature Transmitters for Operating Rooms and Other Sensitive Areas: Specify Vaisala HMT 331, or equal, thin-film capacitive solid-state sensors, range 0% to 100% relative humidity (RH), accuracy (including non-repeatability, hysterisis, and calibration uncertainty) plus or minus 2.0% over entire range and plus or minus 1.0% from 20% to 80% RH, 4 to 20 ma or 2 to 10 VDC output, stability better than 0.5% RH deviation per year, maximum temperature effect of 0.05% RH per degree Fahrenheit, maximum one (1) watt consumption, maximum 15-second response time, -40 degrees Fahrenheit to 130 degrees Fahrenheit operating temperature. Platinum element temperature sensor with output signal accuracy of plus or minus 0.5°F, 4 to 20 ma or 2 to 10 VDC output. Up to 750 feet of #18 AWG twisted shielded pair signal carriers allowable. Transmitter electronics protected in a gasketed, cast aluminum NEMA 4 housing with sensors at the end of a rigid probe with stainless steel sintered filter. Provide with LCD display of temperature and relative humidity.

7. Room Relative Humidity Sensors: Specify Vaisala HMW60/70U, or equal, wall mounted relative humidity sensor/transmitter with filtered sensor, plus or minus 2 percent accuracy from 0 to 90 percent RH, plus or minus 1 percent RH stability per year, ABS plastic housing. Accuracy shall be NIST traceable.

8. Duct Relative Humidity Sensors: Specify Vaisala HMD60/70U, or equal, relative humidity duct sensor/transmitter with stainless steel filtered sensor, plus or minus 2 percent accuracy from 0 to 90 percent RH, plus or minus 3 percent accuracy from 90 to 100 percent RH, plus or minus 1 percent RH stability per year, NEMA 4 cast aluminum housing. Accuracy shall be NIST traceable.

9. Modulating Electric Control Valves for Zone Heating Coils: Specify Belimo, TAC, or equal, non-spring return characterized ball valve. Required features include nickel plated brass body

with Type 316 stainless steel ball and stem, PTFE seals, EPDM O-rings, threaded ends, and rated for minimum 360 psi working pressure at 212°F. Specify valve with a characterized glass-filled Noryl or Tefzel inlet disc to provide an equal percentage flow characteristic.

- Actuators: Specify Belimo LRX24-SR-T Series, TAC, or equal, non-spring return actuators, with 2 to 10 VDC proportional control, 24 VAC input power, maximum 1.5 watts running power consumption, internal electronic overload protection, minimum 45 in.-lb. torque, adjustable run time between 35 and 150 seconds built-in terminal block, position indicator handle, manual override pushbutton, UL listed.

10. Modulating Electric Control Valves for Air Handling Unit Chilled Water Cooling Coils: Specify Belimo G3 and G7(S) Series, TAC, or equal, ANSI Class 250, 3-way mixing-style globe valve. Specify valves 2" and smaller to have bronze bodies, threaded ends, stainless steel trim, spring loaded TFE packing, equal percentage flow characteristic, threaded ends, and rated for minimum 250°F water service. Specify valves 2-1/2" and larger to have cast iron bodies with flanged ends, stainless steel trim, TFE V-ring packing, equal percentage flow characteristic, threaded ends, and rated for minimum 350°F water service.
    - Actuators: Specify Belimo NV Series, TAC, or equal, non-spring return actuators, normally closed, with 2 to 10 VDC proportional control, 24 VAC input power, maximum 3 watts running power consumption, internal electronic overload protection, able to develop 225 pounds of force on valve stem, 150 seconds run time, built-in terminal block, valve stem position indicator, NEMA 2/IP54 housing, UL listed.

11. Modulating Electric Control Valves for Air Handling Unit Steam Heating Coils: Specify Belimo G2 Series, TAC, or equal, ANSI Class 250, 2-way globe valve with bronze body, stainless steel trim, Teflon disc, linear flow characteristic, threaded ends, and rated for minimum 60 psi steam working pressure.
    - Actuators: Specify Belimo NV Series, TAC, or equal, non-spring return actuators, normally closed, with 2 to 10 VDC proportional control, 24 VAC input power, maximum 3 watts running power consumption, internal electronic overload protection, able to develop 225 pounds of force on valve stem, 150 seconds run time, built-in terminal block, valve stem position indicator, NEMA 2/IP54 housing, UL listed.

12. Water Differential Pressure Sensor/Transmitters for Pump Speed Control: Specify Rosemount Model 2051, Fischer & Porter, or equal, pressure sensor and integral 4-20 mA VDC transmitter, rated for minimum 220°F operating temperature, 2000 psi pressure. Select appropriate differential pressure range for each application. Sensor shall be capacitance type, with stainless steel or Hastelloy diaphragm. NEMA 4 enclosure. Accuracy plus or minus 0.25% of calibrated span, including effects of linearity, hysteresis, repeatability dead band. Drift plus or minus 0.25% of upper limit for 6 months. Temperature effect less than 1.5% per 100°F.

13. Airflow Monitoring Stations: Specify Ebtron Gold Series GTx116-PC, or equal, thermal anemometer type airflow monitor with instrument grade hermetically sealed glass encapsulated self-heated thermistor velocity sensor.
    - Specify appropriate types: For in-duct mounting, specify anodized Type 606l aluminum alloy sensor tube and Type 304 stainless steel mounting brackets. For rooftop exhaust duct airflow monitoring, specify internal mounting brackets and watertight conduit connection to outside of ductwork. Where fan inlet airflow monitoring is required (last choice), specify Ebtron Fan Inlet sensor, or equal, Face

Mount style, with sensor tubes rigidly mounted to the face of the fan inlet cone, and sensors offset into the high velocity portion of the inlet cone.

- Require that transmitters be panel mounted at accessible locations. Specify NEMA 4X waterproof enclosure for outdoor applications.

14. Isolation Room Differential Pressure Monitor and Alarm: Specify TSI Model 8630-PM-AG Room Pressure Monitor and 800243 Pressure Sensor, to match existing, "through-the-wall type" using temperature-compensated thermal anemometer sensor technology. Accuracy of plus or minus 0.00001-inch w.g., resolution maximum 5 percent of reading. Wall mounted monitor should include a screen and keypad, menu-driven programming, and a 0-to-10 VDC or 4-to-20 mA output signal proportional to room differential pressure to be monitored by the Medical Center's EMCS.
    - Include a 120VAC/24VAC input power transformer mounted in the ceiling above the room pressure monitor and remote alarm panel.
    - Specify with secondary door alarm delay.
    - Specify visual and audible remote alarm panel mounted in Nurses Station.

15. Damper Operators, Electric: Specify Belimo Model AM24-SR, Siemens, or equal, non-spring return direct coupled actuator, minimum 160 in.-lb. torque, 2 to 10 VDC proportional control signal, 24 VAC power supply, UL listed. Specify actuators with full stroke overload protection, electronic dead band, compensation for damper seal wear, constant running time, built-in mechanical stops, and push button manual override. Require that damper operators be mounted outside the air stream. Indicate normally open or normally closed positions of the damper.
    - On control dampers less than 3 square feet in area, specify actuators with minimum 35 in-lb. torque capacity.

16. Electronic VAV Box Actuator: Specify Belimo Series NMV-D2, or equal, combination differential pressure (airflow) sensor/transmitter with Type NM electric damper actuator, mechanical position indicator with pointer, pushbutton to disengage gearing, 24 VDC input, 3 watts maximum power consumption, 2 to 10 VDC operating signal.

17. Control Cabinets: Specify UL listed, 16 gauge galvanized steel control cabinet with hinged door, key lock, and electrostatically applied powder coat finish.
    - Specify NEMA 1 panels in conditioned indoor spaces.
    - Specify NEMA 4X stainless steel panels in exposed locations.
    - Specify above-ceiling control cabinets with transformers with high and low ventilation slots.
    - Specify control panels in acute care hospitals with OSHPD Special Seismic Certification Preapproval.

23-26 ENERGY AND CONTROL SYSTEM PERFORMANCE MONITORING

A. Specify requirement for continuous monitoring of building and system energy consumption for new or significantly modified systems. Monitoring shall be trended at the University’s EMCS. Identify specific systems and points to be monitored and review with the University.

1. Infrastructure Power Metering:

   Provide separate trended power measurement (not just energy totalization) for:
    - total supply to each building
    - each major infrastructure system component (each chiller, cooling tower, etc.)

- each major lighting circuit (including all hard wired lighting), delineating by type of control (i.e. daylighting) where possible, including total lighting
- each major plug load circuit (including total plug load)
- each major supply, return, or exhaust fan system (allowing total for fans)
- each major HVAC pump (allowing total for pumps)
- each major miscellaneous system (e.g. heat recovery)
- each business unit subject to recharge

Provide accuracy, precision, and trend logging sufficient to:

- continuously monitor for degradation in equipment performance
- identify unintended operation of equipment (unscheduled operation, inappropriate cycling, etc.)
- identify unintended lighting use
- identify unintended patterns of HVAC use
- diagnose dysfunction in VAV system operation
- identify unusual patterns of equipment (plug load) use
- verify intended operation of daylighting and other control systems

2. Natural Gas Metering:

Provide separate measurement for:

- supply to each building
- each major plant component (each hot water boiler, each steam boiler)
- each business unit subject to recharge

Provide accuracy, precision, and trend logging sufficient to:

- identify unintended consumption or operation of equipment

3. Water Metering:

Provide separate flow measurement for:

- total building consumption
- cooling tower consumption
- supply to irrigation systems
- each business unit subject to recharge
- storage tank levels

Provide accuracy, precision, and trend logging sufficient to:

- identify substantial leaks
- identify unintended consumption

4. Chilled Water System Performance:

For each chilled water system above 100 tons capacity, provide measurement of:

- total system power consumption and thermal output
- chilled water and condenser water supply and return temperatures
- chilled water and condenser water flows
- evaporator and condenser differential pressures
- chilled water and condenser water pump speed and differential pressure
- each business unit subject to recharge

Provide accuracy, precision, and trend logging sufficient to:

- verify rated system capacity (tons) and efficiency (COP or kW per ton) over a range of operating conditions (commissioning)
- continuously monitor for degradation in capacity and efficiency over time (operations)
- diagnose reasons for performance degradation or dysfunction, identify maintenance needs (maintenance)
- assess operating capacity under extreme conditions to determine plant ability to handle new loads and otherwise facilitate planning (feedback to design)
- allow determination of load diversity

5. Cooling Tower Performance:

Provide measurement sufficient to determine for system over 100 tons capacity (the same sensor may be used for multiple cells if appropriate, and provided that sufficient redundancy exists to diagnose sensor problems):

- supply, basin, approach, return water temperatures
- water flow
- air supply dry bulb temperature
- air supply wet bulb temperature

Provide accuracy, precision, and trend logging sufficient to:

- verify rated capacity and efficiency
- continuously monitor for and diagnose degradation in capacity and efficiency over time
- identify unintended performance (cycling)

6. Heating Hot Water System:

Provide separate continuous measurement of load for:

- each boiler or major heat exchanger
- total plant output
- each building supply
- each business unit subject to recharge

For each load, provide:

- water flow
- supply and return temperature

Provide the following other points:

- pump power (each)
- pump speed and differential pressure (each)

Provide accuracy, precision, and trend logging sufficient to:

- verify rated output and monitor for degradation in performance
- assess building loads and effect on plant operation
- allow determination of load diversity

7. Steam Systems:

Provide separate continuous measurement of load for:

- each boiler
- total plant output
- each building supply

For each load, provide measurement of:

- steam flow
- pressure

Provide accuracy, precision, and trend logging sufficient to:

- verify rated output and monitor for degradation in performance
- assess building loads and effect on plant operation
- allow determination of load diversity

8. Air Systems:

For each air system, provide measurement of :

- supply and return air temperatures
- return air humidity (or wet bulb temp or other method)
- economizer mixed air temperature
- fan power (see above)
- fan supply and return pressure
- floor static pressure
- outdoor ambient air dry bulb
- outdoor ambient air wet bulb or relative humidity

Provide accuracy, precision, and trend logging sufficient to:

- verify and continuously monitor system capacity and efficiency over time
- diagnose excessive reheat/supply air temperature problems
- diagnose VAV system dysfunction
- diagnose economizer system dysfunction
- verify intended pressurization of isolation rooms and other spaces

9. Domestic Hot Water:

As appropriate and approved, specify requirements for monitoring:

- heat exchanger water flow
- plant loop side supply and return temperature
- DHW supply temperature

23-27 TESTING, ADJUSTING AND BALANCING

A. Air and water system testing and balancing should be performed by an independent Test and Balance Agency retained by the general contractor as a first tier subcontractor, or such work may be performed under separate contract to the University. Confirm approach for each project with the University. If the Test and Balance Agency is separately retained by the University, then specify that the contractor provide all tests, inspections, and preparations necessary to facilitate balancing activities of the Test and Balance Agency. The final test and balance report shall be submitted and approved prior to project substantial completion.

B. Specify that system balancing be performed by an independent firm primarily engaged in and specializing in the field of air and water system balancing. Test and Balance Agency shall be a certified member of the Associated Air Balance Council (AABC) with at least ten (10) years of experience in testing and balancing similar systems. Mechanical contractors shall not be permitted to balance their own work.

C. Testing and balancing shall be performed in complete accordance with the latest versions of:

1. AABC "National Standards for Total System Balance"

2. AABC "Test and Balance Procedures"

3. ASHRAE Standard 111 - Measurement, Testing, Adjusting, and Balancing of Building HVAC Systems

D. Specify that the Test and Balance Agency submit a Performance Guarantee stipulating that all systems have been balanced to optimum performance capabilities within the limits of the design and installation. The Guarantee should stipulate that the Contractor will rebalance any system that fails to maintain optimum performance during the warranty period.

E. Preliminary Investigations: Include detailed instructions on the Drawings describing all preliminary measurements to be recorded before work begins. Require submittal of preliminary measurements before construction begins (electronic submittal is normally adequate).

F. Intermediate Air Balancing Activities: In hospitals and other occupancies where systems serve occupied patient care areas, require immediate air balancing whenever demolition, capping of existing ducts, or connection of new ductwork to existing systems causes airflows to change outside of the project area. Require adjustment of fan speed, main duct dampers, and branch dampers so that existing airflows and pressure relationships are maintained in all areas outside of the project area. Require submittal of intermediate test and balance reports within 24 hours after any duct modifications that affect airflows in other areas. Require complete fan and motor data where total fan airflow is affected. Handwritten documentation on approved forms is normally acceptable for intermediate test and balance reports.

G. Pre-balance Preparation by Contractor: Specify documentation to be furnished to the Test and Balance Agency and complete start-up and checking of all modified systems prior to the start of final air balancing at the end of each phase of work. Require that the Test and Balance Agency be furnished with the latest as-built set of documents with all changes incorporated.

H. Phased Completion of Work: When the project will be completed in phases, require complete testing and balancing services for each phase of the work, including final test and balance reports, so that the spaces may be occupied according to the project schedule.

I. Tolerances: Specify that air inlets and outlets of 200 CFM or less be balanced to within plus 10 percent to minus 0 percent of design, and that air inlets and outlets with higher airflows be balanced to within plus 5 percent to minus 0 percent of design. Specify that temperature readings be accurate to within 0.5° F. Specify that water flow readings be accurate to within plus or minus 5 percent. Specify that pressure readings be accurate to within 0.5 psi for water systems, and 0.01 inch w.g. for air systems.

J. Require that instruments be calibrated within six months of work being performed and checked for accuracy prior to starting the balancing procedure.

K. Deficient Airflows: Require that the Test and Balance Agency make special note wherever abnormal installed conditions (such as crimped flexible ducts, tight offsets, improperly placed or unusual tap-ins or fittings, etc.) do not permit a proper air balance without increasing main duct static pressure or fan speed. Require that such conditions be repaired and rebalanced following repairs.

L. Excessive Noise: Require that the Test and Balance Agency investigate, measure, and report conditions where excessive noise is generated at air inlets and outlets.

M. Validation of Duct Smoke Detector Installations: Require that the Test and Balance Agency measure and report the following at duct smoke detector locations at maximum and minimum design airflows:
- Differential pressure measurements across duct smoke detector sampling tubes.
- Velocity profiles with air velocity measurements at six (6)-inch intervals at sampling tube locations.
- Objective assessment of air turbulence at sampling tube locations.
- Any other measurements requested by the University's Representative or Authority Having Jurisdiction to ensure that duct smoke detectors are installed in accordance with their listing requirements.

N. Special Instructions: Specify special testing and balancing instructions as required for the project, such as duct leakage testing, sound level testing, vibration testing, establishing variable air volume setpoints, establishing static pressure reset setpoints, minimum outside and relief air settings, testing economizer sequences, fume hood certification, testing smoke removal sequences, establishing clean room pressure cascades, etc.

O. Equipment Performance and Capacity Checks: Require complete equipment performance documentation and test measurements in accordance with AABC "National Standards for Total System Balance" and AABC "Test and Balance Procedures" to demonstrate that new and modified equipment is operating in accordance with scheduled performance criteria and manufacturer's published ratings.

P. Sensitive Room Certification: Where certain rooms require specialized testing and certification (such as isolation rooms, etc.), specify complete performance criteria and requirements for start-up, calibration, testing, adjusting, balancing, and certification.

Q. HVAC Controls Cooperation: Require that the Test and Balance Agency work with the HVAC controls installer to establish and validate control sequences. Where sequences require establishment of minimum and maximum air flows, multiple setpoints, reset schedules, or other variable conditions, require that the Test and Balance Agency furnish all testing and balancing necessary to establish required setpoints and fully balance systems under all possible operating conditions. Require that measurements be made under all operating conditions to validate proper system operation under all specified modes of operation.