DIVISION 23 – HEATING, VENTILATING AND AIR CONDITIONING (HVAC)

Includes the following sections:

See Part II for additional information regarding Indoor Pollutant Reduction and Control, Energy Efficiency, etc.

DESIGN REQUIREMENTS

DESIGN DOCUMENTS REQUIRED:

SYSTEMS STUDIES, SINGLE LINE DIAGRAMS, AND CALCULATIONS

The following tasks shall be performed by the design engineer and submitted for review by University Representatives:

1. Studies (HVAC air, water, and BMS controls): Where new HVAC loads or demands are being added to existing systems, the entire system shall be studied and evaluated. This includes field confirmation of University provided "as-built" documentation prior to starting any study's analysis. The entire system performance shall be studied for controls sequence of operations, demand/response performance, static duct/pipe sizes, relative flow velocities and pressure losses, noise generation, and systemic increases in fan and pump motor brake horsepower relative to existing equipment limitations. Furthermore, designer shall confer with University Representatives

to solicit any known limitations or problems associated with each existing HVAC system under consideration of being modified or expected to accommodate added loads or demands. Many older HVAC system's equipment, valves, etc. may be in poor shape, near end of useful lifespan, unsuitable for reliable continued use or being stressed further with additional loads or demands, and may already be on a deferred maintenance list for replacement. All of these issues should be discovered and documented during the design phase to ensure the new revised HVAC systems are properly designed and adequately budgeted for.

2. Coordination with Physical Plant HVAC Shop: The service technicians have a lot of direct experience maintaining existing HVAC systems on Campus and they have a lot of design and equipment specification preferences that change fairly regularly based on challenges encountered post construction on past projects, thus they should be engaged early in the design process to take advantage of any lessons learned and to identify equipment they specifically want and don't want to have to maintain. We try to accommodate their needs as best as possible as long as the specifications are not proprietary and all equipment can be competitively bidden with "or equal" products.

3. System Single Line Diagrams Required:

   a) Where new loads are being added to existing systems, the entire system shall be depicted in a single line diagram. This shall include all existing and new proposed equipment (fans, pumps, etc.), equipment's available output performance versus aggregate existing and new additional loads or demands (Btu/hr), dynamic and/or static flow control balancing devices such as constant or variable volume air dampers and hydronic flow control valves, all duct/pipe sizes, air CFM and water GPM flow capacities, and performance data (internal duct/pipe velocities, air/water pressure losses, etc.), fan CFM at total existing versus new water column in inches, pump GPM at total head pressure in feet existing versus new, etc. All variable speed control instrumentation locations shall be indicated on the critical path with room number matching floor plans. It is highly desirable to have HVAC system sizing spreadsheet calculations and/or equipment tables on the same sheet as the single line diagrams during the design development review stage. The University wants to capture the basis of design graphically and numerically for reference when evaluating these systems in the future.

   b) Water Side Heating and Cooling Piping Systems: The single line diagrams shall be in the form of riser diagrams for multi-story buildings and include all items listed in part a), as well as all branch isolation valves, circuit setters, gauges, drains, vents, thermometers, pressure gauges, safety reliefs, bulb wells for BMS controls and instrumentation, etc. This diagram is intended to be a fully developed Process and Instrumentation Diagram (P&ID) to ensure all trades (HVAC/Elec/Plumbing/BMS) are fully coordinated and there are no gaps in the construction documents. Ultimately this diagram will be used in the commissioning process, and once successfully completed, become a legacy document for accurate evaluation of any future modifications or alterations to the system.

   c) Air Side HVAC Systems: The single line diagram shall be in the form of riser diagrams for multi-story buildings and include all items listed in part a) as well as all branch fixed dampers, variable air volume terminal devices, fume hoods, air controls instrumentation, central system's discrete instrumentation inclusive of variable frequency fan motor control points, smoke detector control points integration to fire alarm, over pressure safety, supply air temperature and/or humidity sensors over each heating and cooling coil, filter pressure drop analog limits before alarm, etc. This diagram is intended to be a fully developed Process and Instrumentation Diagram (P&ID) to ensure all trades (HVAC/Elec/Plumbing/BMS) are fully coordinated and there are no gaps in the construction documents. Ultimately this diagram will be used in the commissioning process, and once successfully completed, become a legacy document for accurate evaluation of any future modifications or alterations to the system.

4. Zone Maps: provide a scaled zone map for each floor including depiction of central HVAC equipment locations and locations of terminal devices serving each zone. This map shall also disclose the location of HVAC airside and waterside

5. Mechanical Rooms: Refer to 23 90 00 for BIM Modeling Requirements.

6. Load Calculations Required:

   a) HVAC load calculations for each individual sub zone and block load for central systems.

   b) Fan sizing: Air side system total flow versus critical path duct pressure losses in inches water column.

   c) Pump sizing: Water side system total flow versus critical path head loss in feet.

   d) Air and Water Balance Schedule on a room basis with subtotal zone basis for sizing of terminal devices. Schedule shall include room name, number, area in square feet, supply/return/exhaust air flows in CFM, room air changes per hour based on total supply and outdoor air ventilation percentage volumetric flow rates, terminal devices minimum/maximum cooling and heating air setpoints per current T-24 programing requirements, disclose the zone requirement for a CO_2 sensor, terminal device's hydronic coil performance data including entering/leaving water/air temperatures, pressure drops, airside terminal device K value, and hot water and cooling water control valve size, 2 or 3 way configuration, and Cv ratings.

7. Load Calculations Native File Format: designer shall submit all calculations in Microsoft Excel spreadsheet format. Use of proprietary applications that the University does not currently own to calculate project load calculations is prohibited.

8. Legacy of Single Line Diagrams and Calculations: It is the University's intent for the Single Line Diagrams and Calculations to be the building's perpetual living model documents that will be continuously modified and or updated for future building remodels, alterations, etc. For this reason, single line diagrams and calculations shall be updated and submitted by the Engineer of Record at the end of the project to reflect as-build conditions. In addition, as-built CAD and spreadsheet calculations shall be submitted in both native AutoCAD .DWG file format, Excel spreadsheet, and Acrobat PDF file formats. Before generating any single line diagrams or calculations, the Design Engineer should confer with Archives to determine if there are already AutoCAD single line diagrams and Excel spreadsheet files available to modify. The newer buildings on campus should have them, but the older ones won't. If Archives does not have them, they will need to be generated from scratch. It is the Design Engineer's responsibility to

ensure they have included the appropriate time and fees in their proposal to generate and deliver these single line diagrams and calculations.

DESIGN CRITERIA AND CONDITIONS:
The following design criteria shall be followed regardless of system type or size. Any deviations from these criteria shall be discussed and accepted by the University's Representative during the preliminary design phase of the project and prior to any construction.

1. UCOP sustainability requirements:
   a. Air Conditioning (Cooling): air conditioning for human comfort at UCSC is generally prohibited. Exceptions are made on a case-by-case basis for:
      - areas that have high internal sensible heat gains that will be deleterious to operations (computer rooms, ADF, IDF, BDF rooms),
      - highly sensitive material storage (libraries with hydroscopicly sensitive books),
      - highly sensitive indoor air temperature and humidity requirements that if not maintained will be deleterious to research results (Labs),
      - highly sensitive medicine storage (pharmaceutical dispensary),
      - highly sensitive human health treatment facilities (student health facility),
      - or any other highly sensitive application not yet considered herein.
      - The Design Engineer will need to justify the use of mechanical air conditioning (beyond economizer air for first stage cooling) by submitting written justifications and load calculations demonstrating the necessity of mechanical air conditioning. The Design Engineer will have to prove that all other architectural design considerations have been incorporated into the design to mitigate and minimize the cooling season's sensible heat gains (i.e.: building orientation, exterior surface glazing shading and reflectance, higher wall insulation, thermal massing to flatten the load profile, high ceilings to allow stratified heat to be captured and rejected, etc.) before consideration of air conditioning can be made by the University's Representative.
   b. Heating: heating by hydrocarbon fuel sources is generally prohibited. For new buildings and modifications to existing buildings, this means providing electric power-based heating systems such as heat pumps or electric resistance heating. Exceptions may be made on a case-by-case basis for: replacement of existing failed, failing, or at end of useful life hydronic space heating natural draft boilers and furnaces (with new higher efficiency condensing type technology and controls) where it can be adequately shown through life cycle cost analysis that new electric power based systems are not feasible. However, as time moves forward this will be a harder and harder justification to achieve.
2. Outdoor Design Temperature Conditions: Use the most recent American Society of Heating, Refrigeration & Air Conditioning Engineers (ASHRAE) Climatic Data for Region X to determine outside design conditions. Santa Cruz conditions are in parentheses.
   a. For 100 percent outside air systems use the 0.1 percent summer conditions column (94 degrees dry bulb/68 degrees moisture content wet bulb (mcwb)) and the 0.2 percent winter conditions (32 degrees).
   b. For 100 percent outside air systems conditioning environmental spaces occupied by animals or insects, special consideration shall be given to design criteria. Sizing of equipment to maintain temperature (and humidity if required) can be critical, depending on the intended

usage of the conditioned space. Equipment in some applications shall be sized to accommodate extreme conditions. For 100 percent outside air stand-alone equipment serving these areas, apply 100 degrees dry bulb for summer and 25 degrees winter outside air temperatures. Review the assumptions, including outside air temperatures, with the University's Representative prior to developing the Basis of Design and equipment selection. There may also be a requirement for this type of HVAC system to be on standby power.

   c. For recirculating air systems use the 0.5 percent summer conditions column (88 degrees dry bulb/66 degrees mcwb) summer conditions and the 0.6 percent winter conditions (35 degrees). Recent UCOP Sustainability Study looked at designing new buildings with consideration of global climate change and made recommendations to add 3 degrees to current ASHRAE dry bulb summer conditions recognizing the need to address current prolonged and recurrent heat waves. This equates to 88 + 3 = 91 degrees dry bulb outdoor conditions.

3. Interior Design Temperature Conditions: use 74 degrees for cooling and 70 degrees for heating. Note for HVAC systems serving animal livestock such as Vivariums or environmental chambers, more stringent animal care codes may override these criteria.
4. Telecommunications Spaces (ADF, IDF, BDF rooms): Temperature range between 68 and 74 degrees F cooling; no heating; Relative Humidity range between 35 percent and 55 percent. See further detail below.
5. For cooling tower selection use the 0.1 percent design wet bulb conditions (69 degrees). Comply with current California Title 24 Cooling Tower Requirements.
6. Internal heat loads:
   a. Lighting: Per Title 24, Part 6. Refer to Part 2 for additional requirements.
   b. Equipment: Per manufacturer's data or latest edition of ASHRAE Fundamentals, Ch. 18.
7. People: Per latest edition of ASHRAE Fundamentals, Ch. 18.
8. The building pressure shall be slightly positive to ambient, but allow exterior doors to close automatically.
9. HVAC system noise: Design Classrooms, Libraries, Study Halls and general office spaces within NC 30 Standards. For large Lecture Halls, Auditoriums, Concert Halls, Recording Studios etc., (where more stringent controls are desirable) consult with the University's Representative to set standards suitable for the intended uses. Design all other areas within the NC standards recommended in the latest edition of ASHRAE Applications Handbook.
10. Air distribution design: (Deviations from these criteria shall be exercised as necessary for proper air balance and acoustic control. Discuss any deviations with the University's Representative.)
    a. Provide adjustable modular core diffusers or double deflection grilles to allow adjustment. Ceiling return and exhaust grilles shall be egg crate type. Diffusers, grilles and registers shall be selected and laid out so that air velocities at the occupied levels do not exceed 50 fpm.
    b. Low pressure ductwork shall be sized at no more than 0.08 inch/100 foot of duct, and not exceeding 1500 fpm.
    c. Medium pressure ductwork shall be sized at no more than 0.2 inch/100 foot of duct, and not exceeding 2500 fpm.
11. Hydronic Distribution:
    a. Pumps shall be selected for stable and efficient operation throughout the entire operating range not only the peak design operating point.

b. Size piping for a maximum friction loss of 3 feet per 100 feet of pipe and a maximum flow velocity of 7.5 fps inside buildings and 10 fps outside buildings at maximum flows.

12. Outdoor refrigeration equipment, air handlers, and HVAC units require a hose bib and 115 volt electrical receptacle be installed within 25 feet to allow cleaning, service and maintenance.
13. For maintenance and access requirements, refer to Part II, Design Requirements, 'Access'.

THERMAL COMFORT

Comply with latest edition of ASHRAE Standard 55, Thermal Comfort Conditions for Human Occupancy and provide a permanent monitoring system and process for corrective action to ensure building performance to the desired comfort criteria.

The latest edition of ASHRAE Standard 55 Paragraph 7 Evaluation of the Thermal Environment provides guidance on measurement of building performance parameters and two methods for validating performance: (a) Survey Occupants and (b) Analyze Environment Variables. The permanent monitoring system required here may apply either approach; survey or technical system, where the process or system is integrated into the standard operating processes of the building.

VENTILATION

Ventilation Rates

For Mechanically Ventilated Spaces, increase breathing zone outdoor air ventilation rates to all occupied spaces by at least 30 percent above the minimum rates required by the latest edition of Procedure of voluntary consensus standard ASHRAE 62.1.

VENTILATION MONITORING

Install permanent monitoring and alarm systems that provide feedback on ventilation system performance to ensure that ventilation systems maintain design minimum ventilation requirements in a form that affords operational adjustments:

1. For mechanical ventilation systems that predominantly serve densely occupied spaces (those with a design occupant density greater than or equal to 25 people per 1000 square feet), install a CO2 sensor within each densely occupied space.
2. For all other mechanical ventilation systems, provide an outdoor airflow measurement device capable of measuring the minimum outdoor airflow rate at all expected system operating conditions within 15 percent of the design minimum outdoor air rate. The University has encountered maintenance difficulties with typical air measurement devices. Consult and review proposed airflow measurement device with University's Representative before specifying for a project.

REQUIREMENTS FOR CO2 SENSORS

To ensure that sensors can reliably indicate that ventilation systems are operating as designed:

1. CO2 sensors shall be located within the breathing zone of the room as defined in the latest edition of ASHRAE Standard 62.1.
2. CO2 sensors shall be certified by the manufacturer to have an accuracy of no less than 75 ppm, factory calibrated or calibrated at start-up, and certified by the manufacturer to require calibration no more frequently than once every 5 years.

3. Required CO2 sensors and outdoor airflow monitors shall be configured to generate an alarm if the indicated outdoor airflow rate drops more than 15 percent below the minimum outdoor air rate required by Standard 62.1 in one of the following ways:
    a. A building automation system alarm visible to the system operator/engineer.
    b. An alarm that is clearly visible to or audible by occupants.

CO2 sensors may also be used for demand controlled ventilation provided the control strategy complies with the latest edition of Standard 62.1, including maintaining the area-based component of the design ventilation rate.

Space CO2 alarms and demand controlled ventilation set points shall be based on the differential corresponding to the ventilation rates prescribed in Standard 62.1 plus the outdoor air CO2 concentration, which shall be determined by one of the following:

1. Outdoor CO2 concentration shall be assumed to be 420 ppm without any direct measurement; or
2. Outdoor CO2 concentration shall be dynamically measured using a CO2 sensor located near the position of the outdoor air intake.

VENTILATION CRITERIA FOR RESEARCH LABORATORIES

Hazardous materials that are used or stored in Chemical, Biological, or Radiological Research and Teaching Laboratories require special ventilation.

1. Room Ventilation
    a. The laboratory ventilation rate is dependent on the hazards, heat, and/or odors to be controlled. At no time during occupied periods will the ventilation rate be less than 1 cfm/sf. The system shall be designed to reduce the ventilation rate during unoccupied periods by utilizing approved sensing technologies. Obtain the University's approval of the reduced ventilation for the type of use and hazards.
    b. Ventilation system for animal rooms:
        i. Individually ventilated cages: Comply with the Association for Assessment and Accreditation of Laboratory Animal Care International (AAALAC) guide.
            1. Rooms where individually ventilated cages are located shall provide a minimum of 1 cfm/sf.
        ii. Open-top cages/rooms: Provide a minimum of 2.5 cfm/sf.
    c. No re-circulation of laboratory or animal room exhaust air to the building air supply.
    d. Both supply air and exhaust air shall be ducted. No open-air plenums.
    e. Animal rooms within mixed-use buildings shall be on a separate, dedicated HVAC system.
2. Room Pressurization and Containment
    a. Laboratories and storage areas shall be maintained negative relative to non-laboratory or storage areas (hallways, offices, conference rooms, etc.); a room offset value of 10 percent of the maximum air value to the room is recommended.
    b. Animal facilities containing noninfectious animals/agents and that are located within mixed-use buildings, shall maintain room air pressure differentials so that room pressure is negative to all adjacent areas.
    c. Positively pressurized laboratories may be necessary under defined circumstances, such as cell culture.

   d. Special containment (ventilated storage cabinets, special local exhaust, etc.) may be required for extremely noxious operations (muffle furnaces, etc.), extremely odiferous materials (mercaptans, sulfur compounds, etc.), carcinogenic, radioactive, or infectious animals/agents.
   e. Toxic gases (arsine, phosphine, etc.) require ventilated cabinets with alarms.
3. Exhaust
   a. The fume hood exhaust discharge location shall be a minimum of 10 feet above the finished roof.
   b. Special air cleaning devices may be required for some fume hood applications as required by the local jurisdiction. Consult the University's Representative for any special requirements.
   c. Fume hood ducts may be ganged onto exhaust plenum w/ multiple fans, with the exception of hot-acid, radioactive, etc.
   d. Plume height determination: For variable volume fume exhaust systems, the exhaust discharge shall be maintained at 3000 fpm to prevent re-entrainment within the building's boundary layer where outdoor air intakes exist (see Wind Tunnel Studies).
4. Wind Tunnel Studies
   a. A wind tunnel evaluation is required for all new construction projects which produces emissions of a hazardous, noxious, odoriferous, or otherwise nuisance character and that may pose a health and safety risk. Common emission sources can include laboratory exhaust, cooling towers, generators, incinerators, kitchen exhaust and vent stacks.
   b. A wind tunnel evaluation may be required for remodeling projects if new exhausts are being added that may impact sensitive receptors or when the total volume of exhaust is being substantially increased or when the project may be affected by nearby existing buildings. Sensitive receptors can include air intakes, courtyards, operable windows or sensitive animal populations that are either part of the facility being remodeled or that exist nearby.
   c. Required Dilution: The required dilution is based on the chemical makeup of the exhaust and the type of receptors that are affected. The minimum required target dilution factor is 1/1,000, as measured from the top of the exhaust fan to the receptor in question. For highly toxic emissions where a 1/1,000-dilution factor is inadequate, the appropriate dilution level should be calculated for the specific application.
   d. Chemical parameters to be evaluated include, but are not limited to: worst case spill releases and modeling with chemicals possessing highest toxicities, greatest volatility and lowest threshold limit values (TLV).
   e. Wind Tunnel Study Parameters: The wind tunnel study chosen shall use best available technology and current industry testing standards. The latest edition ASHRAE Handbook of Fundamentals, or the Environmental Protection Agency (EPA) Guideline for Fluid Modeling of Atmospheric Diffusion, should be consulted. At minimum, the wind tunnel study shall take into account probable evaporation times based on ventilation rates, exhaust stack height & diameter, exit velocity, exhaust location, wind speed & direction, building features and any nearby features that could influence emission dispersion.

TELECOMMUNICATIONS ROOMS

Ductwork or piping not supporting equipment dedicated to the telecommunications room shall not be installed in, pass through, or enter the telecommunications room. Mechanical refrigeration equipment shall not be installed directly above telecom equipment. Consideration of service clearance, access, and the potential of water damage from dripping or leaking equipment or piping shall be given.

All equipment rooms shall be environmentally controlled 24 hours a day seven days a week. If the building system cannot ensure continuous operation, a stand-alone unit shall be provided for the telecommunications space. If a standby power source is available in the building, consideration should be given to connecting the HVAC system serving the telecommunications equipment room to the standby supply.

1. Recommend 6,000 BTU's (1/2 ton) per equipment rack installed in the telecom room.
2. HVAC shall be included in the design of the room to maintain a temperature between 68 and 74 degrees Fahrenheit.
3. A positive pressure differential with respect to surrounding areas should be provided.
4. The humidity shall be maintained between 30 and 55 percent.
5. The filters in the HVAC system should have an ASHRAE dust spot rating of 85 percent or better.
6. If chilled water is used for cooling, provide dedicated piping from main to avoid running the building main pumps during off-peak conditions.

OTHER DESIGN RELATED SUGGESTIONS
The following is a list of Building Committee Suggestions compiled by Physical Plant HVAC/BMS Shops based on many years of lessons learned on past projects on campus and is provided herein in order to help the designer not repeat these lessons. Please note most of these suggestions are mandatory and are somewhat redundant to the above design guidelines, but there may still be some pearls of design wisdom to mine. Also, this list will also grow over time.

Roof Access
·The preferred method to access roof top equipment is to provide an elevator that goes to the roof.
· Stairs are generally okay assuming no heavy lifting is required.
· Equipment ramps are acceptable
· Ships ladders are not acceptable

Equipment Access
Equipment must be safely accessible for service and maintenance. No crawling under or over ductwork to access service panels or doors.
· Reaching from ladders to service equipment is not acceptable.
· HVAC rooftop or attic equipment layout should be designed so fall protection is not required
· HVAC at minimum must be serviceable with clearance above beside and below to safely service and maintain equipment
· Avoid equipment or inspection installations that require lifts to gain access.
· Damper actuators for FSD & VAV's must be safely serviceable from a ladder with clearance above beside and below for service and maintenance without reaching.
· Provide rigging on all motors 40 hp or greater
· Mechanical equipment should never be located in Rest Rooms ceiling spaces without remote access from adjacent spaces.
· Safe access to roof and gutters
· Comply with Cal OSHA testing and installation methods for fall protection.

Building energy management systems
· Adhere to Tridium resource management limitation guidelines
· Follow campus ITS security guidelines
· No Beta testing of software or equipment & SOO strategies

· Use Tridium BMS systems on Niagara network
· Fully utilize LON Modbus or BackNet devices on HVAC systems
· ITS infrastructure activated with emphasis on BMS data port connections for commissioning of systems.
· ITS switches and BMS equipment should be on standby power

HVAC/BMS sequences of operation
· Always provide third party commissioning agent
· Use demand controlled ventilation strategies by measuring Co2 levels.
· Use motion occupancy detectors to reset VAV supply airflow & zone set points for DCV
· Use motion & Co2 detectors in lecture halls and classrooms to reduce operating hours for DCV
· Alarm filter bank Differential Pressure to front end
· Design building HVAC / BMS to meet LEED certification level
· Use supply air static set-point reset.
· Use chilled / heating water D.P set point reset.
· Provide start up commissioning and change of season retro commissioning
· Consider Skyspark or other persistent commissioning software
· Provide alarm if VAV can't meet supply air flow set-point
· Utilize VAV DAT sensor and alarm SAT to zone
· Utilize building optimum start stop
· Utilize building Night purge
· Utilize OSA free cooling

Design Concepts
· Slope all exposed ductwork to keep water from pooling
· Solar loading can be a problem on exposed glass windows
· Use glazing techniques
· Re-heat all interior zones with local temperature control
· Air intake should be drawn from north down low. (Cool)
· Avoid air in-takes on roof (Hot)
· Avoid air in-takes near loading docks and roads
· Do not install grease interceptor vents in or around building air intakes
· Do not install grease interceptor vents in parapet areas on roofs
· Consider inversion when designing air intakes pay close attention to vents and exhaust
· No comfort cooling
· Slope all mechanical room floors to drain
· No mechanical cooling for elevator machine rooms
· No rigid cell cartridge type air filters. Use V-Bank with 30-30 pre-filter
· No radiant floor heat of any type
· Use direct drive fans
· No in-let vanes or cones use VFDs
· Negotiate extended warranties and service contracts on complex building equipment
· Condensing gas equipment must have proper condensate neutralizer and adequate slope.

COMMON MOTOR REQUIREMENTS 23 05 13

All motors 1 HP and over that are used at least 1,000 hours per year shall be premium efficiency. No shaded pole motors on fractional horsepower motors 1/20 HP and larger.

1. Consider ECM motor for fractional horsepower where applicable.

SHAFT GROUNDING

2. Shaft grounding is required on all variable-frequency drive (VFD) assemblies with operating motors 5 horsepower and above. Provide shaft grounding systems manufactured by Aegis, SGS, or equal. Provide factory installed shaft grounding devices, either by motor or equipment manufacturer

3. For field installed devices, consult the University's Representative for approval. If field installed devices are provided, they shall be installed by a certified representative of the equipment, motor, or shaft grounding device manufacturer.

4. Shaft grounding device manufacturer's specific installation literature, specifications, and recommendations shall be followed.

5. Shaft grounding systems shall be installed so that they are accessible for maintenance and inspection.

6. Field installed shaft grounding systems shall be tested for proper conductive path to ground and shall pass manufacturer's published test procedure. Motor shall be grounded to the common earth ground with drive.

7. If motor is subject to contaminants, debris or moisture, special shaft ground systems and/or seals shall be required. Follow manufacturer's applicable recommendations.

8. For motors operating at 100 horsepower or more: Follow shaft ground manufacturer's recommendations. Often it is required by the manufacturer that two shaft grounding devices be installed.

9. Motor bearings shall be guaranteed from electrical bearing fluting damage during the motor warranty period. Motor or bearing(s) shall be replaced at no additional cost to the University.

VIBRATION AND SEISMIC CONTROLS FOR HVAC PIPING AND EQUIPMENT 23 05 48

Isolate all ventilating equipment connections including conduit, piping drains, etc., so that equipment will operate under continuous demand without objectionable vibration.

Support all fans on anti-vibration bases or hangers. Individual fans shall have integral fan and motor bases, spring type, unless otherwise noted.

Selection of the bases or supporting units shall be in accordance with the vibration eliminator manufacturer's recommendations. Minimum static deflection shall be 11/2 inches or as marked on the Drawings.

HVAC PIPING INSULATION 23 07 19

Refrigerant Piping Insulation:

1. Consideration shall be given to the type of refrigeration system to determine type of refrigerant pipe insulation. Industry standard practices shall apply.

2. Industrial piping and long refrigerant lines: Use rigid molded fiberglass pipe insulation of appropriate wall thickness with white kraft paper reinforced with self-sealing longitudinal laps and butt strips. PVC jacket indoors, Aluminum dimple jacket outdoors. No PVC jacketing outdoors.

3. Standard refrigeration systems, walk in boxes, remote condensing units, split systems: Use Armaflex closed cell insulation or equal. Minimum 1/2 inch wall thickness for medium and high temperature applications and minimum 3/4 inch wall thickness for low temperature applications.

4. Small split systems: Pre insulated "line sets" may be utilized.

5. All field or factory installed outdoor closed cell type insulation exposed to the weather shall be painted two coats with white UV protection paint.

COMMISSIONING OF HVAC 23 08 00

Refer to Campus Design Guide, Part IV Standard Specifications, Section 23 08 00 for Commissioning of HVAC.

INSTRUMENTATION AND CONTROL FOR HVAC 23 09 00

Refer to Campus Design Guide, Part IV, Standard Specifications section for requirement. Due to the depth of the Controls and Instrumentation drawings, request the latest information from the University's Representative. Due to the recent industry best practices of integration of both lighting controls (mainly occupancy sensors) with HVAC controls, this specifications section is now replaced by Division 25. Any discrepancies between Division 230900 and Division 250000, the latter shall govern.

Lessons learned:

1. All HVAC controls equipment including manufacturer's packaged unitary controllers, shall comply with the requirements of Division 25. We have had problems in the past where manufacturer's sales representatives provide canned specifications to the Design Engineer that includes the manufacturer's OEM controls. The OEM controls did not meet the requirements in Division 25 that stipulates all programmed logic shall be accessible and modifiable by Physical Plant BMS Shop without having to own proprietary software to make modifications.
2. All discrete control points shall be hard wired and communicate directly with controllers or at a BMS panel's terminal block. We do not want control signals being transmitted through the data network. Reason: if the data network goes down, the HVAC equipment can't receive necessary input to continue to function per the sequence of operations.

INSTRUMENTATION AND CONTROL FOR LAB HVAC 23 09 10

GENERAL

Laboratory airflow control system shall be Siemens, Phoenix, Tek-Air, or equal, and shall meet the following criteria. Refer to Division 11 on Laboratory Equipment for additional related requirements. All laboratory airflow control systems shall be fully open protocol and seamlessly integrate into the NiagraAX Framework (or "NiagraAx"), a Java-based framework developed by Tridium. To date, commissioning experience with past laboratory projects has shown that Phoenix has successfully met the open protocol and full seamless integration into the NiagraAx. That does not necessarily mean the other listed manufacturer's cannot meet this requirement.

Manufacturer shall have a minimum of 20 existing successful installations in full operation; five of which must be in California. Each installation shall have at least 20 laboratory controllers. The manufacturer must be in the business of providing laboratory variable airflow control systems for a minimum of ten years.

Contractor shall have a minimum five similar laboratory airflow control system installations that have been completed in the United States, and have been in successful operation for at least one year. These installations shall employ components and materials similar to the components and materials submitted under these Contract Documents, shall be manifold exhaust/supply systems with multiple connections to fume hoods and laboratory supply and return grills from a manifold. Contractor shall have been in the business of installing laboratory airflow control systems for a minimum of five years. The Contractor shall provide a list describing the required number of installations and include the names, addresses, and the telephone numbers of the consulting engineer and the Owner's Representative for each one.

CODES AND STANDARDS

The laboratory ventilation system shall meet requirements of all regulatory agencies including, but not limited to, the following reference documents. In the event of conflicting requirements, the general rule is to apply the more stringent requirement.

1. American National Standard for Laboratory Ventilation (ANSI/AIHA Z9.5).
2. ANSI/ASHRAE 110, latest adopted edition.
3. ASHRAE, HVAC Applications Handbook, latest edition.
4. National Fire Protection Association, Standard NFPA 45 & NFPA 30, latest adopted edition.
5. US Dept. of Health & Human Services, Public Health Service, National Institutes of Health, NIH Publication No. 86-23.
6. Cal/OSHA, Title 8.
7. ASHRAE Standard 111, latest adopted edition and AMCA Standard 210 "Instrument Calibration."

FUME HOODS

Commissioning of Fume Hood System: The laboratory fume hood system shall be 100 percent field-tested as installed in full accordance with ASHRAE 110, and shall meet 4.0AI0.05 containment of tracer gas. In accordance with Cal/OSHA 5154.1, an average face velocity of at least 100 fpm shall be provided, with no point lower than 70 fpm. Higher than average face velocity may be required for special applications, consult the University's Representative for those conditions. After installation, a qualified independent testing agency shall perform fume hood field tests on each hood. Test data shall be submitted to University's Representative for review by EH&S before installation is accepted. In addition, a separate face velocity test shall be coordinated with the University's Representative and performed by the Facilities Department.

Fume Hood Face Velocity: The control system shall maintain a face velocity between 100 fpm and 120 fpm with 110 fpm being the nominal average value when measured in accordance with Cal/OSHA 5154.1. Room air currents at the fume hood face shall not exceed 20 percent of the average face velocity to ensure fume hood containment. Zone Presence Sensors (equipment designed to reduce face velocity when workers are not present) are not permitted. The minimum range over which the face velocity shall be controlled will be 10 percent to 100 percent of the design opening of the sash.

Face Velocity Controller: The airflow at the fume hood shall vary in a linear manner between two adjustable minimum and maximum flow set-points to maintain a constant face velocity throughout this range. When fume hood sash is totally closed, provide a minimum volume of 150 hood air changes per hour in conformance with ANSI Z9.5 and NFPA 45.

Fume Hood Monitor: Fume hood monitor shall include an emergency maximum exhaust button as required NFPA 45.

Response Time: VAV fume hood controller systems shall meet criteria to ensure the health and safety of the fume hood users. Using ASHRAE 110, latest edition, Paragraph 6.4 VAV Response Test, the face velocity shall be maintained between 80 and 120 fpm for the duration of the test. At no time during the sash movement and face velocity stabilization will the face velocity drop below 80 fpm or rise above 120 fpm. The face velocity shall stabilize at the values measured in the following paragraph within 10 seconds of the start of sash movement. The design opening for the fume hood will comply with the Campus Standard, Division 11. Flow visualization tests in accordance with ASHRAE 110, Paragraph 6.1 shall also be performed, with no spillage of smoke. Negative room pressurization shall be maintained throughout testing.

Fume Hood Exhaust Airflow Control: The fume hood control shall establish an exhaust rate that will provide the desired average face velocity per design. The sash position or face velocity shall be continuously sensed to enable the control system to maintain the desired average face velocity.

1. Through the wall sensing using a hot wire anemometer located in the wall of the fume hood is unacceptable for controlling airflow in fume hoods. Refer to Division 11 on Laboratory Equipment.
2. Control panel locations shall be located on the drawings. Maintenance accessibility is critical.

ROOM TEMPERATURE CONTROL

The control system shall include a control strategy to avoid excessive temperature swings when the room is subject to large, sudden changes in the ventilation airflow. The system shall be designed with separate heating and cooling set points, adjustable by a field technician. Zone temperature sensors shall be provided with a 2 hour temporary occupancy override capability. Occupancy hours, temperature set points, override hours of operation shall be adjustable at the Central Heating/Cooling Plant.

RELIABILITY & ACCURACY

System control methodology shall be based on full supply/exhaust volumetric airflow tracking capability. The system shall have a tight tracking control with supply valves tracking hood exhaust and general exhaust valves.

1. Air velocity instruments – Maximum allowable error in airflow measurements shall be less than 5 percent of flow over the operating range of the air valve.
2. Closed loop control - the closed loop control arrangement is required for laboratory VAV systems. In order to guarantee safety and compliance, laboratory airflow control systems that do not measure actual airflow shall provide independent airflow measuring stations for each air terminal device.
3. Through-the-wall pressure sensing between the laboratory and the corridor is not acceptable.

AIR TERMINAL DEVICES

1. Momentary or extended losses of power shall not change or affect any of the control system's set points, calibration settings, or emergency status. After power returns, the system shall continue operation, exactly as before, without need for any manual intervention. Air terminal devices shall fail in the open (fail safe) position.
2. Room shall be isolated to prevent positive pressure into the space.
3. During emergency conditions, exhaust fan shall allow for egress but shall continue to exhaust to capture fume hood gases.
4. Supply fan speed shall be set during commissioning.
5. Design air outlets and air terminal devices to ensure room noise and acoustic requirement does not exceed those specified in Division 11.
6. Laboratory terminal devices shall have linear flow performance characteristics and provide minimum turndown ratio of 10:1 for fume hood exhaust terminals and adequate turndown for room supply and general exhaust terminals. A Venturi air valve, a bladder type air valve, or a blade damper type air control device is acceptable when coupled with the proper control system. Adequate turndown shall ensure that the airflows specified can be maintained. All air terminal devices shall be pressure independent over the specified differential static pressure operating range. Minimum airflow control accuracy shall be ±5 percent of actual reading over the entire rated airflow range of each device. Overall room control performance shall be substantiated by a third party test report. Minimum to maximum terminal airflow (or vice versa) shall be attained in less than 1 second.
7. All supply air terminal devices shall be constructed of minimum 20 gauge galvanized steel. Damper shafts, where required, shall be solid 316 stainless steel with Teflon or Teflon infused aluminum bearings. Supply terminal air leakage shall not exceed 2 percent of design airflow at 4 inches w.g. positive static pressure. Terminal boxes shall be provided with a bottom access door for damper blade access sufficient to visually inspect and manually break free a bound damper blade.
8. All exhaust air terminal devices shall be constructed of 316L stainless steel or 16 gauge aluminum. Damper shafts, where required, shall be solid 316 stainless steel with Teflon bearings. Aluminum fume hood exhaust terminal devices shall have a baked-on corrosion resistant coating.
9. A loss, increase and/or decrease of airflow shall be transmitted to the fume hood or room controller as appropriate.
10. Discharge and radiated sound power level data for all terminals shall be available and provided at the University's Representative or Design Professional's request. The data shall be in accordance with the test procedure in ARI 880-89 Standard for Air Terminals and all data shall be obtained in a qualified, accredited and ARI approved testing laboratory.
11. All terminal devices that require factory calibration shall be calibrated, in accordance with NIST, to the job specific airflows indicated on the Drawings.

INSTRUMENTATION

Airflow measuring devices and sensors shall be of rugged construction. Electronic sensors exposed to exhaust airflow shall meet the UL913 Standard for Intrinsically Safe Apparatus and Associated Apparatus for Use in Class I, II, III, Division I, Hazardous Locations. Transducer accuracy shall be no less than ±0.15 percent of span over the appropriate full scale airflow range of the air terminal device. Materials shall be 316L stainless steel for all exhaust applications, and 304 stainless steel for supply air applications.

AIRFLOW SENSORS
Multi-point averaging type; 304 stainless steel for all supply air applications. Sensors shall be mounted on support bars as required to achieve an equal area traverse. Support bars over one foot in length shall be supported on both ends. Support bars shall be 304 stainless steel for supply air applications, and 316L stainless steel for exhaust applications.

CONTROL AIR
Provide dedicated minimum 30 psig clean, dry pneumatic supply air to all airflow control devices as required.

INTER-CONNECTIVITY WITH CAMPUS BMS
The laboratory airflow control system shall provide 0-10 volt or 4-20mA signal to signal components and controllers of a different DDC manufacturer. Full laboratory control system integration with the campus DDC system shall be done using BACNET protocol across the campus Ethernet. Conversion of system information to a BACNET protocol shall be the responsibility of the lab system provided.

If host computer is used, the PC shall be a rack mounted industrial grade type P.C. installed in a clean ventilated and accessible location. P.C. cabinet shall be lockable and in a location where temperatures do not exceed 100°F.

Coordinate for the actual points transferred. Design documents shall clearly identify the points that are required to interface with the Energy Management system and ensure the system is designed to accommodate the need. Points that require changeable set points at campus EMS include:

1. Zone schedule.
2. Zone occupied cooling set point.
3. Zone occupied heating set point.
4. Zone unoccupied cooling set point.
5. Zone unoccupied heating set point.
6. Reheat valve position (to exercise valves remotely).

Monitoring only:

1. Supply airflow.
2. General exhaust airflow.
3. Fume hood exhaust airflow.
4. Offset airflow set point.
5. Zone temperature.
6. Zone status (occupied, unoccupied, warm-up, heat, cool, deadband, override).
7. Reheat valve position.
8. Supply air terminal device position.
9. General exhaust air terminal device position.
10. Fume hood air terminal device position.

11. Reheat coil leaving air temperature.

The EMS would then calculate and show on graphic screen the following:

1. Air changes per hour.
2. Offset air flow, actual.
3. Alarm if ACH drops below 6 for x minutes (1 alarm per occurrence).
4. Alarm if offset air flow deviates from set point by x percent for y minutes (1 alarm per occurrence).
5. Energy trending and energy consumption reporting.

INSTALLATION

The manufacturer shall review the system for proper installation and shall warranty the system for parts and labor for five years after the system has been proved and accepted as complete by the University's Representative. The manufacturer shall include two visits to the site after the University's acceptance to confirm the system is operating as commissioned. The first visit shall be at the end of year one and the second visit shall be at the end of year two.

Calibration of fume hood controls, pressure transmitters, and air sensors shall be performed. A written report of each visit shall be provided to the University's Representative, detailing what was done to each component. The design consultant shall include specific report requirements in specifications, and shall discuss the project specific requirements with the University's Representative. Calibration shall be performed in accordance with ASHRAE Standard 111 or latest edition and AMCA 210.

FACILITY FUEL-OIL PIPING 23 11 13

PIPING

Fuel-oil is prohibited on Campus. Use of fuel-oil will need to be reviewed and approved by University Representative prior to design. Its use will most likely be limited to fuel-oil piping, where generators are provided with an integral fuel-oil tank. If it is determined fuel-oil piping is required, it shall be black steel schedule 40 plain end with black malleable iron fittings.

FACILITY NATURAL GAS PIPING 23 11 23

Refer to Division 22 for additional requirements.

PIPING

Underground: Medium density polyethylene piping (MDPE) with butt fusion fittings, or, standard weight Schedule 40 black steel pipe with class 150 welded fittings and all piping shall be protected with polyethylene coating or tape wrap as described above. Note that MDPE is preferred over black steel. Refer to Campus Design Guide, Part III, Construction Divisions, Division 33 for additional requirements.

Above ground: Standard weight Schedule 40 black steel pipe with 150 pound malleable iron fittings for piping, 2.5 inch and smaller. Provide welded fittings for all piping 3" and larger and piping in vertical shafts, and mechanical and utility rooms.

VALVES:

1. Service: 125 lb. gate valve.
2. Bench Valves: Ball type with tapered sockets with ball and seat compatible with piping materials. Provide valve operating wrenches.
3. Gas Shut-off Valves: Earthquake-sensitive gas shut-off valve certified by the Division of the State Architect as conforming to Title 24, CCR. Used only on building services, not on generator services. Refer to Division 33 gas meter assembly details.

FLEXIBLE CONNECTIONS: 3/4 inch or larger by 12 inches long stainless steel hose and braid. AGA certified for service CFH and length.

HYDRONIC PIPING AND PUMPS 23 21 00

SYSTEM DESIGN

1) Where chilled water enters the building, layout piping so that the chilled water supply is to the right of the chilled water return as one faces the building.
2) Provide CHW piping with mixing bridge between CHW S&R, sized for full flow with modulating valve to restrict supply flow into return.
3) Provide BTU meter on the CHW supply on the Campus side of the loop. Refer to Division 33 for BTU metering requirements.
4) Provide full size by-pass with a check valve around CHW pumps for first stage cooling.
5) Provide two CHW pumps each sized for 50 percent max flow requirement. Pumps to have VFDs.
6) Provide two HHW pumps each sized for 50 percent max flow requirement. Pumps to have VFDs.
7) Shaft grounding is required on VFD driven pump motors. Refer to Section 23 05 13 Common Motor Requirements.
8) For hydronic systems where variable water volume (VWV) is used, provide the following:
    a) Install modulating valves with minimum 100:1 turndown ratio and tight shut-off rated to close against a differential pressure of 1-1/2 times pump head.
    b) Locate differential pressure sensor at hydraulically most remote coil (or critical path that defines the system curve).
    c) If hydraulically most remote coil is variable, provide multiple differential pressure sensors and use a low signal selector to send proper signal to variable frequency drive.
    d) Limit total bypass gpm through 3-way valves to 1.5 gpm per pump horsepower by installing balance valve in the bypass of all 3-way valves.
9) In the coil schedule, identify the control valve Cv value.
10) Identify control valve Cv.
11) Provide reverse return piping or pipe looping where applicable.

PIPING, JOINTS AND FITTINGS

1. Below grade/Under Schedule 40 steel, welded fittings. Type L copper tubing 4 inches or smaller and type K copper tubing 5 inches and larger are also acceptable. All below grade copper tubing shall be brazed with silver solder 1000 degrees F.

2. Above ground: Black steel welded, flanged or with grooved fittings. Type L copper tubing 4 inches or smaller and type K copper tubing 5 inches and larger are also acceptable. Copper tubing joints 1-1/4 inch and larger shall be brazed with silver solder 1000 degrees F.
3. Grooved or flanged fittings and joints should not be used on 2-pipe changeover systems.
4. Flexible connections shall not be used on heated water systems.

VALVES

Threaded or flanged, two piece, bronze body, full port, ball valves, with stainless steel ball and stem, for isolation/shut off valves. Isolation valves shall be provided for all heating and cooling pumps, control valves, strainers, and coils that are separate from the valves used for water balance.

Balance valves shall not be substituted for isolation valves. Design criteria for isolation valves shall be based on best practices for optimal location to facilitate maintenance without compromising building operations and shall include the following minimums: one per each floor, one per each main branch, one at each terminal unit, and one on any branch serving more than five terminal units. Piping kits are not acceptable.

STEAM AND CONDENSATE PIPING AND PUMPS 23 22 00

SYSTEM DESIGN

Shall be in accordance with California Code of Regulations:

a. Title 8, General Industry Safety Orders and Construction Safety Orders.
b. Tile 24, Part 4, Appendix B, Chapter 21, Steam and Hot Water Boilers.

Built-up steam systems will be limited to low pressure steam at 15 psig for kitchen cooking appliances (steam kettles, soup kettles, and steamers) and high pressure steam at 80 psig laboratory equipment sterilization (rack washers, large autoclaves, etc.). Steam systems are not to be used for building heating systems.

Size steam pipe for flows between 8,000 and 10,000 FPM. If steam is run through the building, Engineer to calculate requirements for expansion loop and design support.

PIPING, JOINTS AND FITTINGS

Underground/Pre-Insulated: Black carbon steel schedule 40 welded up to 10 inches by an AWS certified welder in accordance with ANSI B31.9. Refer to Campus Design Guide, Part III, Construction Divisions, Division 33 for additional requirements. Joints shall be brazed in powder insulating fill material, Gilsulate 500 XR, or equal. Since the steam systems are limited to kitchen and lab applications, underground steam piping should be avoided at all costs.

Above ground: Black carbon steel schedule 40 welded up to 10 inches by an AWS certified welder in accordance with ANSI B31.9. Schedule 80 for 2 inches and smaller for pressures above 50 psi. All high pressure steam (above 50 psi) shall have fittings rated for a minimum of 300 psi.

Steam Condensate Piping: Type K copper brazed. Brazing filler shall be 5 percent silver inside the building and 15 percent silver when part of the exterior building distribution system. For below grade piping, refer to Campus Design Guide, Part III, Construction Divisions, Division 33 for additional requirements.

VALVES

All high pressure steam (above 50 psi) shall have valves rated for a minimum of 300 psi.

PRESSURE REDUCING VALVES AND REGULATORS

Steam pressures shall be limited to 80 psi for labs, and 15 psi for kitchens.

Kitchens: provide each appliance with a manually adjustable high performance direct acting valve for moderate flow applications where accuracy of +/- 10 % is acceptable and provides for tight shutoff for dead-end service on steam. Product: Armstrong GD-30 or equal.

INSULATION

In Mechanical rooms and outside, insulate with calcium silicate, (fiberglass only on low pressure steam, designed for steam use). Cover with an aluminum jacket in exposed areas and if located 8 -feet or lower. Provide PVC jacket in other locations. No jacket required on steam pipe where there is no chance of getting wet. Insulate steam condensate same as steam pipe.

ACCESSORIES

Kitchen Appliances: Provide each appliance with an inverted bucket steam trap rated for 250 psig maximum operating pressure and 406F maximum temperature. Each trap shall be proceeded with a strainer. Where a battery of appliances are supplied steam from a common header, provide a steam trap on the end of the main to maintain high quality steam in the supply at all times. Product: Hoffman Specialty Bear Trap Series B1, or equal. Water Conservation: Where possible, provide a condensate receiver tank and pump for the condensate from all of the appliances and pipe back to steam boiler's make-up water. Where this is not possible, for each appliance provide manufacturer's condensate cooling kit to meet UPC 810.1 140F temperature limitations for condensate to the nearest floor sink. Note condensate cooling kits require a cold water connection and 120V power. The water needs to be manually throttled to minimize water consumption during condensate discharge and measured with a thermometer to meet the 140F temperature limit.

Laboratories: High pressure steam trap shall be TLV Model J3S-X-10, stainless steel body with free floating ball and thermostatic air vent, or equal (no known equal); no by-pass. Thermostatic steam traps shall conform to Federal Specifications WW-T-696, type I, Style B.

BUILDING CONDENSATE RETURN PUMPS

1. General Requirements:
    a. Provide a condensate return pump package for each building's steam distribution network.
    b. Provide a concrete housekeeping pad for the condensate return pump package.
    c. Provide floor sink next to housekeeping pad for condensation overflow.
2. Performance Requirements:
    a. Provide a complete condensate return package as follows:
        1) Duplex pumps; each pump sized for 100% of building peak load and 3-phase motors
        2) Pumps rated for 200 deg. F condensate temperature

3) Condensing seals rated for 250 deg. F
4) Flash tank separate from the condensate receiver tank, when required by system design. All tanks (pressure vessels) shall be A.S.M.E. rated and stamped for steam system operating pressure.
5) Cast iron receiver tank
6) Pump suction isolation valve
7) Sight glass
8) Temperature gauge
9) Electric pump alternator
10) Float level switches
11) Control Panel, located remotely from the condensate receiver on a wall in the mechanical space within direct line of sight of the pumps
12) High temperature alarm
13) High level alarm
14) Alarms shall have local visual and audible annunciation and remote annunciation to building EMS

3. Products:
    a. Spirax Sarco, Armstrong, or equal.

SUPPORT

Pipe supports shall be on rollers and anchored at changes of direction. Install calcium silicate at supports.

REFRIGERANT PIPING 23 23 00

1. At all times during brazing and soldering a nitrogen purge is required.
2. ACR type L nitrogenized refrigeration grade copper pipe is required for all refrigerant piping. All copper to copper joints shall be made with 15 percent silfos and all copper to brass connections will be made with 45 percent silver solder.
3. All 90 degree elbows will be long radius. Suction P traps and inverted P traps shall be manufactured as one piece and not field assembled.
4. All vibration eliminators shall be installed parallel to the compressor crankshaft.
5. Suction lines shall be sloped 1/2 inch per 10 feet toward the compressor. Low and medium temperature risers shall be trapped 10 feet on center. Trap high temperature vertical risers per manufacturer’s installation literature.
6. All outdoor pipe insulation shall be painted with UV rated insulation paint or covered with a UV rated or aluminum insulation jacket.
7. All piping shall be labeled where entering or exiting equipment and in between, such as on a pipe rack or in a crawl space. Common refrigeration terminologies apply such as "Discharge Gas," "Suction Gas," "Hot Gas," "Liquid Line," etc. Industry standard "arrow" labels showing direction of flow shall accompany each pipe identification label.
8. All refrigerant pipe clamps shall be specifically designed for refrigeration piping and provide vibration and wear protection. Pipe clamping method shall be compatible with insulation type.

TESTING OF REFRIGERANT PIPING

1. Refrigerant piping and systems shall be pressure tested for a minimum of 24 hours. Test pressure shall be 10 percent less than the maximum pressure rating of the weakest component of the system.
2. Each system upon completion of the pressure test shall be evacuated to a minimum of 500 microns. The system shall hold 500 microns for 20 minutes without deviation of more than 10 percent.

HVAC AIR DISTRIBUTION 23 30 00

SYSTEMS DESIGN

1. Indicate on the drawings or specifications that low pressure loss duct fittings shall be installed per Sheet Metal and Air Conditioning Contractors National Association (SMACNA) (see Section 2: Design for Energy Efficiency and SMACNA HVAC Systems Duct Design).
2. Specify appropriate SMACNA duct air leakage class (see SMACNA HVAC Air Duct Leakage Test Manual and SMACNA Technical Paper on Duct Leakage. Identify duct pressure classes on the ductwork plans, such as 1/2, 1, 2 etc., inside a triangle. Refer to SMACNA HVAC Duct Construction Standards, Figure 1-1. Require duct leakage testing for all ducts rated at two (2) inches of water and greater.
3. Design central air handling fan inlets and outlets per SMACNA Section VII (based on AMCA Publication 201 – Fans and Systems) to minimize system affect losses. Ensure design provides sufficient straight duct inlet and outlet lengths to achieve 100% effective duct length.
4. All fans shall be selected to operate to the right of the manufacturer’s system curve (stable regime) separating unstable to stable fan operating conditions. Careful attention to variable volume fan systems operating at lowest speed to ensure the fan is not controlled to operate in the manufacturer’s unstable fan curve regime.
5. All return air shall be ducted. Exception: where existing buildings are being remodeled or altered and have a return air plenum system already in use.

FANS, MOTORS, AND DRIVES:

1. Fans shall be licensed to bear the AMCA ratings seal. Fans shall be tested for air and sound performance in accordance with the appropriate AMCA standard in an AMCA accredited laboratory.
2. The design horsepower rating of each drive shall be at least 1.5 times the nameplate rating of the motor. Proper allowances for sheave diameters, speed ration, arcs of contact and belt length shall be followed in meeting the design horsepower of the drive.
3. All variable speed drives shall be selected to allow an increase or decrease of minimum of 10 percent of design fan speed.
4. Motor shaft grounding: See Division 23 05 13 Common Motor Requirements.
5. Motors over 15 HP: Adjustable sheaves shall be removed and replaced with fixed diameter sheaves prior to final air balancing.

SHAFTS AND BEARINGS:

1. Fan shaft shall be ground and polished solid steel with an anti-corrosive coating.

2. Bearing shall be selected for a minimum L-10 life in excess of 100,000 hours at maximum cataloged operating speed. Bearings shall be locked to the shaft concentrically without marring or burring the shaft.
3. All shaft bearings shall have extended lube lines with zerk fittings. Extended lube lines shall be UV resistant where exposed to the sun.

SHEAVES:

1. Sheaves shall be cast or fabricated, bored to size or bushed with fully split tapered bushings to fit properly on the shafts.

DUCTWORK

Use low pressure drop duct design. Use a round duct wherever space permits. Only use flex duct to connect ducts to terminal diffusers, registers and grilles. Maximum length shall be seven (7) feet. The throat radius of all bends shall be 1-1/2 times the width of the duct wherever possible and in no case shall the throat radius be less than one width of the branch duct. Provide square elbows double thickness turning vanes where space does not permit the above radius and where square elbows are shown. The slopes of transitions shall be approximately one to five, and no abrupt changes or offsets of any kind in the duct system shall be permitted. Limit pressure drop to 0.07 inches H_2O per 100 feet. Insulation shall exceed latest CCR-Title 24, Part 6.

Provide drive slip or equivalent flat seams for ducts exposed in the conditioned space or where necessary due to space limitations. On ducts over 48 inches wide, provide standard reinforcing on the inside of the duct. Run-outs to grilles, registers or diffusers on exposed ductwork shall be the same size as the outer perimeter of the flange on the grille, register or diffuser. Provide flexible connections on the inlet and outlet of each fan. Seal all seams around fan and coil housings airtight with appropriate sealing compound.

DAMPERS

Motor-operated, opposed blade type shall be galvanized iron with nylon bearings, interlocking edges to prevent leakage. Dampers shall have replaceable blade seals and stops for minimum air leakage. Blades shall be 16-gauge minimum, 10 inches maximum width with welded channel iron frame. Frame shall be sealed airtight to ductwork. Dampers with both dimensions less than 18 inches may have strap iron frames. Dampers exposed to the weather shall be weatherproof and made of corrosion proof materials.

SMOKE DETECTORS IN DUCTWORK

For additional information, refer to the University's Standard Specification Section 28 31 00, Fire Detection and Alarm.

Layout ductwork and locate duct smoke detectors to ensure clearance is available upstream and downstream of detectors pursuant to detector manufacturer's requirements. Duct detectors shall be compatible with the building's Fire Alarm System and shall be approved by the Fire Marshal of record. Duct detectors shall be accessible for testing and maintenance.

VAV AND CV BOXES

The maximum air pressure drop (PD) of a bare box shall be 0.07 inches. For 1 row coil add 0.10 inches max. PD and for 2 row coil add 0.15 inches to 0.20 inches PD. For VAV systems, unless calculations indicate otherwise, set minimum air flow for cooling and for heating to 40 percent of the maximum air flow value, or per latest Title 24 requirements.

GRILLES, REGISTERS AND LOUVERS

Provide all outlets with gaskets to minimize the streaking of the walls or ceilings due to leakage. All grilles and registers shall be equipment with opposed blade dampers. All side wall registers shall have adjustable vanes.

FUME HOODS 23 38 16

Refer to Campus Design Guide, Part III Construction Divisions, Division 11 on Laboratory Equipment for information on fume hood construction. Refer to Section 23 09 10 for Laboratory Airflow Control Requirements.

LABORATORY HOOD EXHAUST FANS

1. Fan type shall be carefully engineered and selected to meet or exceed its intended usage.
2. Fan assemblies shall be constructed with corrosion resistant materials engineered for the intended application.
3. Fan shall be licensed and bear the AMCA ratings seal. Fans shall be tested for air and sound performance in accordance with the appropriate AMCA standard in an AMCA accredited laboratory.
4. Each fan shall be vibration tested as an assembly before shipping in accordance with AMCA 204-05.
5. Unit shall bear an engraved nameplate. Nameplate shall indicate design CFM, static pressure, and maximum fan RPM.
6. Unit fasteners exposed to corrosive airstream shall be of stainless steel construction.
7. Provide fan curves for each fan at the specified operation point, with flow, static pressure, and horsepower clearly plotted.

FANS, MOTORS, AND DRIVES:

1. Motors shall be premium efficiency, standard NEMA frame, 1800 or 3600 RPM, TEFC with a 1.15 service factor.
2. Motor shaft grounding: See Division 23 05 13 Common Motor Requirements.
3. Motor maintenance shall be accomplished without fan impeller removal or requiring maintenance personnel to access the contaminated exhaust components. Belt drive configuration (if equipped) shall be AMCA arrangement 1, 9, or 10. High plume arrangement 9 fans shall feature a bifurcated housing with the motor, belt drive (if equipped), and bearings located outside of the contaminated airstream. Direct drive arrangement 4, or direct drive arrangements requiring access and handling of hazardous and contaminated fan components for motor replacement are not acceptable.
4. Drive belts and sheaves shall be sized for 200 percent of the fan operating brake horsepower, and shall be readily and easily accessible for service. Drive shall consist of a minimum of two belts under all circumstances.
5. Fan shaft bearings shall be Air Handling Quality, ball or roller pillow block type and be sized for an L-10 life of no less than 200,000 hours for high plume fans and critical applications, and L-10 100,000 hours for all others. Bearings shall be fixed to the fan shaft using concentric mounting locking collars, which reduce vibration, increase service life, and improve serviceability. Bearings that use set screws shall not be acceptable.

6. All shaft bearings shall have extended lube lines with zerk fittings. Extended lube lines shall be UV resistant.

HVAC AIR CLEANING DEVICES 23 40 00

Refer to 23 31 00 for HVAC Ducts and Casings.

A. General Requirements:
   1. All filtration systems shall meet current minimum LEED Requirements.
   2. Filters shall have a minimum MERV rating for specific applications per the MERV Rating Chart listed herein.
   3. Filter media and construction shall be selected suitable for service duty and application.
   4. Systems New:
   5. Systems Existing:
   6. Systems Air Movement Magnitudes:

B. Performance Criteria:
   1. Minimum aggregate filter area shall be sized for a maximum of 250 ft/min gross face velocity for maximum air flow the filters will experience in either constant volume or variable volume systems.
   2. Maximum filter pressure drop limitations: clean = 0.25” w.c.; fully dirty and alarmed for replacement = 0.50” w.c. (BMS adjustable analog setpoint).
   3. Provide a minimum of MERV rating of 13 when only pleat filters are specified. Discuss replacing the 30/30 MERV 8 pre-filter with a MERV 13 when using V-Bank MERV 14 in larger higher volume applications.

C. Installation Requirements:
   1. Filters shall be individually gasketed to minimize blowby.
   2. Filters shall be individually clipped in place with stainless steel clips.

PARTICULATE AIR FILTRATION (TO BE DEVELOPED FURTHER)
   1. 23 41 13 Panel Filters: .
   2. 23 41 16 Renewable Media Filters: .
   3. 23 41 19 Washable Air Filters.
   4. 23 41 23 Extended Surface Filters.
   5. 23 41 33 High Efficiency Particulate (HEPA) Filtration: .
   6. 23 41 43 Ultra-Low Penetration (ULPA) Filtration: .
   7. 23 41 46 Super Ultra-Low Penetration (SULPA) Filtration: .
   8. Provide fan curves for each fan at the specified operation point, with flow, static pressure, and horsepower clearly plotted.

MERV RATING CHART

Standard 52.5 Minimum Efficiency Reporting Value	Dust Spot Efficiency	Arrestance	Typical Controlle	Typical Applicati	Typical Air

			d Contaminant	ons and Limitations	Filter/Cleaner Type
20	n/a	n/a	< 0.30 pm particle size	Cleanrooms	≥99.999% eff. On .10-.20 pm Particles
19	n/a	n/a	Virus (unattached)	Radioactive Materials	Particles
18	n/a	n/a	Carbon Dust	Pharmaceutical Man.	Particulates
17	n/a	n/a	All Combustion smoke	Carcinogenic Materials	>99.97% eff. On .30 pm Particles
16	n/a	n/a	.30-1.0 pm Particle Size	General Surgery	**Bag Filter**- Non supported microfine fiberglass or synthetic media, 12-36 in. deep, 6-12 pockets
15	>95%	n/a	All Bacteria	Hospital Inpatient Care	
14	90-95%	>98%	Most Tobacco Smoke	Smoking Lunges	**Box Filter**- Rigid Style Cartridge Filters 6 to 12" deep may use lofted or paper media.
13	89-90%	>98%	Proplet Nuceli (Sneeze)	Superior Commercial Buildings	
12	70-75%	>95%	1.0-3.0 pm Particle Size Legionella	Superior Residential	**Bag Filter**- Non supported microfine fiberglass or synthetic media, 12-36 in. deep, 6-12 pockets
11	60-65%	>95%	Humidifier Dust Lead Dust	Better Commercial Buildings	
10	50-55%	>95%	Milled Flour Auto Emissions	Hospital Laboratories	**Box Filter**- Rigid Style Cartridge Filters 6 to 12" deep may use lofted or paper media.
9	40-45%	>90%	Welding Fumes		
8	30-35%	>90%	3.0-10.0 pm Particle Size Mold Spores	Commercial Buildings	**Pleated Filters**- Disposable, extended surface area, thick with cotton-polyester blend media, cardboard frame
7	25-30%	>90%	Hair Spray Fabric Protector	Better Residential	**Cartridge Filters**- Graded density viscous coated cube or pocket filters, synthetic media
6	<20%	85-90%	Dusting Aids Cement Dust	Industrial Workplace	**Throwaway**- Disposable synthetic panel filter.
5	<20%	80-85%	Pudding Mix	Paint Booth Inlet	
4	<20%	75-80%	>10.0 pm Particle Size Pollen	Minimal Filtration	**Throwaway**- Disposable fiberglass or synthetic panel filter.
3	<20%	70-75%	Dust Mites Sanding Dust	Residential	**Washable**- Aluminum Mesh
2	<20%	65-70%	Spray Paint Dust Textile Fibers	Window A/C Units	**Electrostatic**- Self charging woven panel filter.
1	<20%	<65%	Carpet Fibers		

HEATING HOT WATER BOILERS 23 52 00

A. General Requirements:
   1. Heating hot water boilers shall be certified as compliant with Rule 1146.2 of the current Monterey Bay Air Quality Management District (MBAQMD).
   2. Boilers shall meet local county air quality management district standards for emissions.
   3. Heating hot water boilers shall be installed with BACnet interface to the Campus energy management system with external set point reset.
   4. Flow meters: Boiler systems shall have a fuel flow meter that provides a local indication of flow rate and a non-resettable, totalizing measure of gaseous fuel flow measured in cubic feet. The meter(s) shall have a network interface for the building's energy management system.

B. Performance Criteria:
   1. Heating hot water boilers shall have a maximum input of 3,000,000 BTU/H.
   2. Heating hot water boilers over 500,000 BTU/H input shall meet a minimum thermal efficiency of 92% as rated by the Institute of Boiler and Radiator Manufacturers (IBR), Air-Conditioning, Heating, and Refrigeration Institute (AHRI), or comparable certification authority.
   3. Heating hot water boilers shall have a minimum turndown ratio of 3.5:1.
   4. Manufacturer:
      a. Shall have a minimum of twenty existing successful installations of the same model; five of which must be in California.
      b. The heating hot water boiler manufacturer shall review the boiler for proper installation and shall warranty the boiler for parts and labor for five years after the boiler has been accepted as complete by the University's Representative.
      c. The manufacturer shall include two site visits to the site after the University's acceptance to confirm the boiler is operating as commissioned.
         1) The first visit shall be 12 months after the start of the warranty period.
         2) The second visit shall be 23 months after the start of the warranty period.

C. Installation Requirements:
   1. The contractor shall have a minimum of five heating hot water boiler installations in California.
   2. Boiler feed water shall be treated to prevent scaling from hard water. Initial fill shall be with softened water.

FUEL-FIRED HEATERS 23 55 00

Electronic ignition. Heaters over 100,000 btu shall be hard piped to their external shut off valve.
Fan and blower motors shall be wired to allow cooling of the heat exchanger upon cycling on temperature.

MECHANICAL REFRIGERATION 23 60 00

IDENTIFICATION
   1. Refrigerant and compressor oil type shall be clearly marked using nameplates on each unit.
   2. The initial refrigerant charge shall be clearly listed using nameplates on each condensing unit.

3. A permanent nameplate shall be installed on both indoor and outdoor equipment stating the room number the equipment is serving (or located within) and identify each piece of equipment clearly.

ELECTRICAL

1. All Semi Hermetic compressor motors less than 1 horsepower shall have single phase characteristics.
2. All motors over 1.5 horsepower shall have three phase characteristics.
3. Three phase equipment should incorporate a phase monitor.
4. Each refrigeration system shall be served by its own dedicated circuit breaker and disconnect means.

REFRIGERATION TEMPERATURE CONTROL

Refer to Campus Standards & Design Guide, Part IV, Standard Specifications Section 13 21 00 for Controlled Environmental Rooms Requirements.

Systems that can tolerate more than + or -2 degrees F deviation from set-point shall incorporate simplified control systems utilizing industry standard practices for control of refrigeration equipment.

Standard "off the shelf" readily available temperature, operating and limit controls shall be utilized whenever possible. Avoid electro-mechanical remote bulb controls. In their place, use electronic remote sensing controls such as Ranco, Honeywell, Johnson, or equal.

MICROPROCESSOR BASED CONTROLLERS (when necessary to achieve the design temperature requirements)

1. Microprocessor based refrigeration system controllers shall be fully adjustable, field programmable, electronic digital type controllers.
2. The controller shall be designed specifically for the control of compressors, condensers and refrigeration equipment.
3. The controller shall have the ability to provide sensor and transducer control.
4. The controllers shall include a keypad interface with easy to read display, and shall not require the use of a computer to program.
5. PLC controllers are not acceptable unless they are a component of a pre-packaged factory manufactured and engineered refrigeration system.

LOCAL/REMOTE ALARM INTERFACE (when required)

1. Consideration shall be given to local and remote alarming.
2. A separate temperature alarm with Hi/Lo capability is required.
3. Control shall be capable of remote and local alarming.
4. Form C dry contacts N/O and N/C required.
5. Alarm sensor should be placed next to the operating control sensor.
6. Control shall feature user selectable time delay feature.
7. Control adjustment shall be lockable to prevent tampering.
8. Control shall feature an adjustable offset of displayed temperature for calibration purposes.

CONDENSING UNITS

1. The refrigeration system shall be the standard product of a single manufacturer and shall be cataloged as systems, complete with system capacities. All components including controls and accessories shall be furnished by the system manufacturer and shall include a fully piped air-cooled condensing unit (as described below), evaporator (as described below), thermostatic expansion valve, liquid line drier, room thermostat, liquid line solenoid valve, suction line filter, etc.
2. Condensing units shall include motor-compressor, condenser, receiver, electrical control panel and all defrost components completely assembled on a steel rack, piped, wired, run-in and tested by the manufacturer. The motor compressors shall be semi hermetic with inherent 3-leg overload protection.
3. Air-cooled condensing units not located outside the building shall be located in a controlled temperature room. All systems with outdoor condensers or condensing units shall be provided with low ambient controls including a crankcase heater and a condenser fan control.
4. Condensing unit noise shall not exceed 78 decibels tested in accordance with ARI standards. Condensing units shall carry a 5 year compressor warranty.
5. All refrigeration pressure relief lines shall be piped to a location outside the building 20 or more feet from an intake opening, operable window, etc.
6. A refrigerant receiver is required on all pump down systems.
7. All refrigeration systems shall be provided with a high and low pressure switch.
8. Thermal expansion valve systems are required on systems larger than ½ horsepower. All thermal expansion valve systems will include a liquid moisture indicator. Expansion valve bulbs will be secured with brass straps and be insulated.
9. Liquid filter driers shall be included on all systems. Removable suction filter driers shall be utilized when needed to clean up large systems during initial break in period. Suction filter driers or cores shall be removed after a minimum 48 hours of run time.
10. Low temperature refrigeration systems shall include a suction accumulator and will operate as a pump down system.
11. A complete wiring and control diagram will be permanently affixed in a waterproof container to the inside of each compressor control panel.
12. Equipment charged in the field shall have a permanent label affixed to the condensing unit stating the refrigerant type, oil type, and operating refrigerant charge in pounds.
13. An oil failure control will be required on all semi-hermetic compressors with an oil pump.
14. Hot gas bypass valves will be installed with Schrader valve access and isolation ball valves.
15. All low temperature refrigeration systems shall have electric defrost.
16. All freezer condensate drain lines shall be insulated and shall include electrical heat tracing from a separate circuit.

EVAPORATORS

1. Units shall have direct expansion cooling coils mounted in aluminum casing and be horizontally supported from the ceiling.
2. Coil shall have copper tubes hydraulically expanded into aluminum fins. Pitch coils in casing to provide drainage.

3. Evaporator drain will be provided with a trap outside of the refrigerated areas.
4. Drains will include a clean out tee and a pipe union and will not be reduced from the manufactured provided line size.
5. Freezer drains will include a drain line heater and rubber insulation
6. Fan motors shall have built-in thermal overload protection.
7. Systems having electric defrost shall include an evaporator fan thermostat and defrost termination control.

PACKAGED WATER CHILLERS 23 64 00

Packaged Water Chillers: Compressor(s) shall carry a 5 year manufacturer's warranty. Manufacturer's service clearances shall be met, refer to Part II Design Requirements for additional access requirements.

CUSTOM PACKAGED OUTDOOR HVAC EQUIPMENT 23 75 00

Draw through air handling units are required. Air handlers 10,000 cfm and larger including coil ends that are exposed to outside air conditions to have insulated casings to a minimum of R-8, or latest Title 24 requirements. If exposed to return air conditions R-4 is acceptable or latest Title 24 requirements. Provide a variable frequency drive (VFD) for VAV systems and motors over 10 HP.

Systems with heating and cooling coils shall be configured with the heating coil receiving the incoming air before the cooling coil. For chilled water systems connected to the central plant, provide a minimum chilled water delta T of 20 degrees for all AHUs. Note the central chilled water plant chilled water supply is not constant and varies from 45F to 65F.

For heating hot water system, provide a system delta T of 40 degrees or higher.

Maximum desired face velocity for constant and variable flow AHU coils is 450 FPM with the following maximum coil wet air pressure drop (inch water gage). _

ir Face Velocity (PM)	CHW & DX Coil Pressure Drop (inch water gage)	Runaround Coil Pressure Drop (inch water gage)	Heating Hot Water Coil Pressure Drop (inch water gage)
50	0.55	0.50	0.16

For air handlers 5,000 cfm and larger, provide 4-inch Merv 8 pre-filters.

For air handlers 10,000 cfm and larger, provide low pressure drop, UL-approved air filters similar to the following:

Pre Filters: Merv 8A high capacity pleated panel with high strength beverage board Frames. Camfil Farr 30/30 or equal. Filters shall be 24 inches by24 inches by 4 inches when possible.

Final Filters: Merv 13 minimum, high efficiency, high capacity, 4V-bank rigid filter.
Camfil Farr, Durafil ES, or equal.

Filters shall be standard sizes and readily available. Special sizes or special order filters are not acceptable. Filters shall be 24 inches by 24 inches by 12 inches on large equipment.

Filter Housings shall be constructed to prevent air bypass. Filters and/or housings and access doors shall be gasketed. Filter housings shall be constructed of 316L stainless steel channels and assembled with stainless steel hardware including the filter clips.

Filter Efficiency	Desired Maximum Face Velocity (fpm)	Maximum Initial Pressure Drop (in. w.g.)
Merv 8 (40-50 percent)	400	0.17
Merv 11 (60-70 percent)	400	0.17
Merv 13 (80-90 percent)	400	0.19
Merv 15 (90-95 percent)	375	0.23
99.97 percent HEPA	250	0.65
99.99 percent HEPA	200	0.45

Provide a local magnehelic filter gauge for each filter bank. Magnehelic gauges installed outdoors shall have a UV, weather protective cover with a hinged opening to allow easy access and viewing of the gauge. Combination magnehelic filter gauge/transmitters are not acceptable. University's Representative shall coordinate with the Energy Management System to provide an independent transmitter to measure pressure differential across the filter. Transmitter shall have an analog output.

DECENTRALIZED UNITARY HVAC EQUIPMENT 23 81 00

1. A control transformer shall be factory supplied, and be an integral part of the equipment.
2. Gas fired heating equipment (when part of a package unit) shall not be selected in lieu of heat pump units irrespective of available gas service.
3. Refrigeration circuits shall be factory leak tested, dehydrated and be fully charged with refrigerant.
4. Evaporator fans of less than 1/2 horsepower shall be direct drive multi-speed or variable speed motors with permanently lubricated bearings. Belt driven fans should be avoided when possible.
5. Condenser fans shall be direct drive propeller type with permanently lubricated bearings.
6. Filter Grilles shall be used in split systems with 2 or less return air grilles when air handlers are located above finished ceiling. Filter access through a finished ceiling should be avoided.
7. Low ambient controls: All mechanical cooling which is subject to winter operation such as server rooms, telecom rooms, and machine rooms shall be equipped with low ambient control option either factory or field installed. Low ambient control shall regulate speed of ball bearing type condenser fan motor in response to saturated condensing temperature or discharge pressure.
8. Equipment location.
   a. All outdoor compressors require an oil sump heater.
   b. A hose bib and a 120 volt dedicated circuit are required within 25 feet of outdoor equipment.
9. Under 15 H.P. – scroll compressors are preferred over reciprocating type compressors. Over 15 H.P. – Semi-Hermetic reciprocating or screw type compressors are preferred. Semi-Hermetic

compressors shall be equipped with suction and discharge service valves and feature an oil sight glass.

10. 100 percent outdoor air: Units over 5 tons shall have two stages of mechanical cooling. Gas fired heating in this application shall have a modulating burner.
11. All refrigeration circuits shall be equipped with high and low pressure safety pressure switches.
12. On units with belt drive evaporator fans, an air proving differential pressure switch shall be provided and wired to disable the mechanical cooling upon loss of air flow.
13. All compressors shall be mounted on vibration isolators.
14. Wall Mounted Thermostats.
    Refer to Standard Energy Management section.
    Required Control Features:
    a. Multistage programmable 7 day.
    b. Memory retention after loss of power.
    c. No batteries required.
    d. 2 stage heat and cool.
    e. Automatic changeover.
    f. Heat pump compatible.
    g. Dual set point with adjustable dead-band.
    h. Large alphanumeric display backlit.
    i. Easy programming.
    j. Display either degrees F or C.
    k. Locking keypad.
    l. 5 minute short cycle protection.
    m. Soft start compatible.
    n. Remote sensor compatible.
15. Provide 18/8 conductor thermostat cable installed in a dedicated conduit.
16. Low Rise Residential Baseboard Convectors: Hydronic baseboard convector temperature control shall be provided by thermostatic radiator valves with remote operators. Product: Danfoss RA, or equal.

COMPUTER SERVER ROOM AIR CONDITIONERS 23 81 23

1. Dedicated Unitary special purpose computer server room air conditioners shall be used.
2. Avoid belt driven fans and blowers on systems 5 tons or less.
3. Equipment shall incorporate dry contacts for remote alarm monitoring.
4. Server room application may require humidification, dehumidification and reheat capability. Where required, ultrasonic or infrared type humidifier preferred. Canister type steam generators should be avoided if using Campus industrial cold water as the make-up source.

SPLIT SYSTEM AIR CONDITIONERS 23 81 26

1. Variable Refrigerant Flow (VRF) Split Systems:
    a. Manufacturers: Mitsubishi, Fujitsu, Daikin, or equal.
    b. Installers: Shall be certified by the manufacturer.

c. Warranty: Manufacturer 5-year warranty for equipment and parts.
d. Thermostats: Shall feature auto-changeover and separate heating/cooling setpoints.
e. Final field refrigerant charge shall be clearly identified on each outdoor unit.
f. Shall be provided with manufacturer's controls gateway for integration of control points to the Campus BMS system.

CONVECTION HEATING AND COOLING UNITS 23 82 00

1. Heaters over 100,000 BTUH shall be hard piped to their external shut off valve.
2. Fan and blower motors shall be wired to allow cooling of the heat exchanger upon cycling on temperature.
3. A drip leg shall be installed on gas supply piping at each appliance.
4. Gas fired unit heaters installed indoors shall have forced draft combustion.
5. Gas fired equipment installed in a dirty, dusty or otherwise contaminated location shall feature separated combustion.
6. Gas fired equipment installed in a negative pressure environment shall feature separated combustion.
7. Gas fired equipment heating 100 percent outside air or heating air at an inlet air temperature below 40 degrees F shall feature stainless steel burners and heat exchangers.
8. Boilers, steam generators and process heaters that trigger permitting shall have a non-resettable, totalizing gaseous fuel flow meter that measures the quantity (in cubic feet) of fuel combusted by the unit(s). Comply with California Health and Safety Code, Division 26 for local air quality permitting requirements.

BUILDING MECHANICAL ROOMS 23 90 00

The Main Mechanical Room for new buildings should be separated into two rooms. One room, a "hot" room would contain all heat generating equipment such as heat exchangers, etc. The second "cool" room shall contain the pumps, VFDs and other heat sensitive electronics.

The "hot" room should be located to allow natural ventilation through wall louvers. It should be conditioned with a hydronic fan coil that uses 100 percent outside air for the first stage of cooling. The "hot" room set point shall be 90 degrees F with a local override to 78 degrees F. If an occupied space is to be located above this room insulation shall be applied to the overhead deck to not allow the temperature of this room to affect the space above.

The "cool" pump room shall be conditioned via a separate fan coil to maintain 78 degrees F for the electronic equipment.

If a mechanical room contains equipment containing refrigerant, careful consideration shall be given to refrigerant leak monitoring, leak alarm systems, and emergency exhausting mandatory requirements per code, EPA and Cal/ EPA requirements.

The final size and layout of the mechanical rooms is dependent on the final accepted mechanical system and required equipment. All mechanical rooms should be sized adequately to allow, not just code compliant clearances, but manufacturers required service clearances for maintenance staff. Review and coordinate the size, design and layout of the mechanical rooms with the University's Representative.

BIM Model Coordination: All new mechanical rooms shall be designed with a BIM model prior to the genesis of construction bid documents. The BIM model shall include all Division's (11, 21, 22, 23, 25, 26) equipment to be located in the mechanical room as well as showing code minimum and manufacturer's minimum access requirements to equipment dotted in. Division 23 Design Engineer will be responsible to coordinate with all the other Divisions and lead the design team to ensure all equipment can not only fit in the mechanical room, but can be adequately maintained and all required clearances are not violated. Design Engineer shall provide at minimum of two meetings with UC Engineering Staff and Physical Plant Shops to demonstrate a fly through of the mechanical room to ensure all vested parties accept the design before it goes out to bid.

The following standard specification is intended to be edited according to the specifics of the project. Brackets [ ] and areas shaded in gray [e.g. format] indicate requirements that are optional depending upon the type of system being provided or per instructions associated with the [ ] and project requirements. Consult with University's Representative and campus stakeholders.

DOCUMENT UTILIZES TRACK CHANGES TO RECORD YOUR CHANGES AS YOU EDIT.
DO NOT CHANGE THE FOOTER OF THE DOCUMENT

SECTION 23 05 53

HVAC PIPING AND EQUIPMENT IDENTIFICATION

PART 1 - GENERAL

1.1 SUMMARY

A. Section includes:

1. Equipment identification
2. Valve, automatic control valves, dampers (including smoke and combination fire/smoke dampers) and automatic control dampers identification
3. Piping and ductwork identification
4. Signage

1.2 RELATED SECTIONS

A. Section 09 XX XX, Painting

B. Section 23 XX XX

C. Section 33 05 26, Utility Line Signs, Markers, and Flags

1.3 REFERENCE STANDARDS

A. ANSI/ASME A13.1 – Scheme for the Identification of Piping Systems.

1.4 SUBMITTALS

A. Product Data: For each type of product indicated.

B. Samples: Submit samples of each color, lettering style, and other graphic representation required for each identification material or system.

C. Schedules:

1. Valve identification chart: Tabulate valve number, piping system, system abbreviation (as shown on tag), location of valve (room or space), and variations for identification (if any). Mark valves which are intended for emergency shut-off and similar special uses, by special “flags”, in margin of schedule. In addition to mounted copies, furnish extra copies for Maintenance Manuals as specified in Division 1.
2. [Note: if applicable.] Automatic control valve identification chart (obtain from the Building Management System contractor for inclusion with this submittal).
3. Damper identification chart (including smoke and combination fire/smoke dampers).
4. [Note: if applicable.] Automatic control damper identification chart (obtain from the Building Management System contractor for inclusion with this submittal).
5. Lists of pipe and equipment to be labeled.
6. Submit access door numbering scheme and schedule, including access door type, location, size and service.
7. Include list of wording, symbols, letter size, letter style, and color coding for each system.

1.5 QUALITY ASSURANCE

A. Coordinate color coding with the University's Representative for preferred color schemes and service abbreviations and valve and equipment numbering schemes prior to submittal review.

B. Coordinate installation of identifying devices with completion of covering of surfaces where devices are to be applied.

C. Coordinate installation of identifying devices with location of access panels and doors.

D. Install identifying devices, pipe identification and flow arrows before installing acoustical ceilings and similar concealment.

E. Coordinate painting schemes of piping, if required, with University's Representative prior to submittal review.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. Manufacturer:

1. Brady/Seton
2. Stranco
3. Rowmark
4. Or equal

2.2 MANUFACTURER'S IDENTIFICATION

A. Manufacturer's nameplate, name, or trademark shall be permanently affixed to all equipment and material furnished under this Specification. The nameplates of the Subcontractor or Distributor are not acceptable.

2.3 EQUIPMENT IDENTIFICATION

A. Properly identify each piece of equipment with name plates mounted on or near each operations device, including:

1. Main control and operating valves, safety devices, and hazardous units
2. Pumps, compressors, and similar motor-driven units
3. Expansion tanks, air separators, water treatment equipment, and similar equipment.
4. Air handling equipment, fans, coils, fan coil units, unit heaters, filters, sound attenuators, and VAV terminal units
5. Chillers and large refrigeration units
6. Provide identification of each VAV terminal unit and each room temperature sensor, using the same address nomenclature as established by the controls contractor.

B. Identify control panels and major control components outside panels with nameplates.

C. Identify equipment that is out of view behind access doors in unfinished rooms on the face of the access door.

D. Label content:

1. Include equipment's Drawing designation or unique equipment number. Use the same address nomenclature established in the energy management system.
2. Area served
3. Year installed
4. Make and model
5. Equipment size (in CFM, HP, RPM, etc.)
6. If on emergency power, indicate source of power

2.4 NAMEPLATES

A. Provide plastic labels for mechanical engraving with predrilled holes for attachment hardware.

1. Material: rigid plastic laminated impact acrylic, 2 layer, exterior grade, UV stable
2. Thickness: 3/16 inch minimum
3. Maximum label size: Length and width vary for required label content, but no less than 2 inches wide by 1 inch high.
4. Background color:
   a. Normal power: Black, matte finish
   b. Emergency power: Red, matte finish
5. Lettering: White, machine engraved, Futura font, 3/8 inch high, all caps
6. Maximum temperature: Able to withstand up to 160 deg. F.
7. Fasteners: Self-tapping stainless steel screws, except contact type permanent adhesive where screws cannot or should not penetrate substrate.
   a. Mounting screw type to be #8- 18 x 1 /2 drilling or tapping style, 1/4 inch hex washer head, stainless steel, or similar, appropriate for material in which sign is affixed to. A bead of silicone sealer shall be applied on back of sign and at screw locations prior to affixing sign to equipment.
   b. For signs larger than 3 inches by 3 inches, use a minimum of 4 mounting screws.

2.5 VALVE TAGS

A. Attached to the stem of each control valve and line shutoff valve installed under Division 22, with No. 16 brass chain, color-coded plastic laminate tag. Engrave laminate tags with 1-inch designated numbers in accordance with typed schedule showing valve size, locations, service, similar to the following form:

   RW: 3-inches
   Shutoff, Toilets
   3rd Floor
   Column F-8

   1. Engrave identification tags “normally open” (green) or “normally closed” (red).
   2. Do not identify valves where the use is obvious, such as equipment isolation valves.
   3. Tag all valves except fixture stops.
   4. Label HVAC valves “HVAC” plus valve identification number.
   5. Number tags to conform to directory listing number, location, and use.

B. Access panel markers: Provide manufacturer’s standard 1/16 inch thick engraved plastic laminate access panel markers, with abbreviations and numbers corresponding to concealed valve. Include 1/8 inch center hole to allow attachment.

2.6 PAINTED IDENTIFICATION MATERIALS

A. Stencils: Standard fiberboard stencils, prepared for required applications with the letter sizes generally complying with recommendations of ANSI A13.1 for piping and similar applications, but not less than 3/4 inch high letters for access door signs and similar operational instructions.

B. Stencil Paint: Standard exterior type stenciling enamel; black, except as otherwise indicated; either brushing grade or pressurized spray-can form and grade.

C. Identification Paint: Standard identification enamel of colors indicated or, if not otherwise indicated for piping systems, comply with ANSI A13.1 for colors.

2.7 PIPE IDENTIFICATION

A. General requirements for Manufactured Pipe Labels: Preprinted, color-coded, with lettering indicating service, and showing flow direction.

B. Self-Adhesive Pipe Labels: Printed plastic with contact-type, permanent-adhesive backing.

C. Small pipes: For external diameters less than 6 inches (including isolation if any), provide full-band pipe markers, extending 360 degrees around pipe at each location, fastened by one of the following methods:

   1. Snap-on application of pre-tensioned semi-rigid plastic pipe marker.

2. Adhesive lap joint in pipe marker overlap.
3. Laminated or bonded application of pipe marker to pipe (or insulation).
4. Taped to pipe (or insulation) with color-coded plastic adhesive tape, not less than 3/4 inch wide; full circle at both ends of pipe marker, tape lapped 1-1/2 inches.

D. Large pipes: For external diameters of 6 inches and larger (including isolation if any), provide either full-band or strip-type pipe markers, but not narrower than 3 times letter height (and of required length), fastened by one of the following methods:

1. Laminated or bonded application of pipe marker to pipe (or insulation).
2. Taped to pipe (or insulation) with color-coded plastic adhesive tape, not less than 1-1/2 inch wide; full circle at both ends of pipe marker, tape lapped 3 inches.
3. Strapped to pipe application of semi-rigid type, with manufacturer's standard stainless steel bands.

E. Pipe Label Contents: Include identification of piping service using piping system nomenclature as specified, scheduled or shown, and abbreviate only as necessary for each application. Include pipe size and an arrow indicating flow direction.

1. Flow-Direction Arrows: Integral with piping system service lettering to accommodate both directions or as separate unit on each pipe label to indicate flow direction.
2. Lettering Size: At least 1-1/2 inches high.

F. Locate pipe markers as follows:

1. Within one foot of each valve, fitting, thermometer or gauge.
2. At each branch or riser take off.
3. At each passage through walls, floors and ceiling construction.
4. At each pipe passage to underground.
5. On all horizontal pipe runs every 20 ft, at least twice in each room and each story traversed by piping system.
6. Identify piping contents, flow direction, supply and return.
7. Where capped piing is provided for future connections, provide legible and durable tags indicating symbol identification.
8. At wall and ceiling access panels.
9. Practicable variations or changes in locations and spacing may be made with specific approval of the University's Representative to meet specific conditions.

2.8 UNDERGROUND TYPE PLASTIC WARNING TAPE LINE MARKER

A. Refer to Section 33 05 26

PART 3 - EXECUTION

3.1 PREPARATION

A. Clean piping and equipment surfaces of substances that could impair bond of identification devices, including dirt, oil, grease, release agents, and incompatible primers, paints, and encapsulants.

B. Coordination: Where identification is to be applied to surfaces which require insulation, painting or other covering or finish, including valve tags in finished mechanical spaces, install identification after completion of covering and painting. Install identification prior to installation of acoustical ceilings and similar removable concealment.

3.2 DUCTWORK INSTALLATION

A. Access doors: Provide duct markers or stenciled signs on each access door in ductwork and housings, indicating purpose of access (to what equipment) and other maintenance and operating instructions, and appropriate safety and procedural information.

B. Concealed doors: Where access doors are concealed above acoustical ceilings or similar concealment, plasticized tags may be installed for identification in lieu of specified signs.

C. Access doors for fire/smoke dampers: Permanently identify on the exterior by a label with letters not less than 1/2 inch in height reading “FIRE/SMOKE DAMPER”.

3.3 PIPE SYSTEM IDENTIFICATION

A. General: Provide for all systems unless indicated otherwise.

B. Locate pipe labels where piping is exposed or above accessible ceilings in finished spaces; machine rooms; accessible maintenance spaces such as shafts, tunnels, and plenums; and exterior exposed locations as follows:

1. At access doors, manholes, and similar access points that permit view of concealed piping.
2. Near major equipment items and other points of origination and termination.
3. 50 feet intervals.

C. Types: Install pipe markers of one of the following types on each system, and include arrows to show normal direction of flow:

1. Stenciled markers, including color-coded background band or rectangle, and contrasting lettering of black or white. Extend color band or rectangle 2 inches beyond ends of lettering.
2. Stenciled markers, with lettering color complying with ANSI A13.1.
3. Plastic pipe markers, with application system as indicated under "Materials" in this Section. Install on pipe insulation segment where required for hot non-insulated pipes.
4. Stenciled markers, black or white for best contrast, wherever continuous color-coded painting of piping is provided.

D. Locate pipe markers and color bands as follows wherever piping is exposed to view in occupied spaces, machine rooms, accessible maintenance spaces (shafts, tunnels, plenums) and exterior non-concealed locations.

1. Near each valve and control device. Within one foot of each valve, fitting, thermometer or gauge.
2. At each branch or riser take off, excluding short take-offs for fixtures and terminal units; mark each pipe at the branch, where there could be a question of flow pattern.
3. At each passage through walls, floors and ceiling construction, or enter non-accessible enclosures.
4. At each pipe passage to underground.
5. At access doors, manholes and similar access points which permit view of concealed piping. At wall and ceiling access panels. Practicable variations or changes in locations and spacing may be made with specific approval of the University’s Representative to meet specific conditions.
6. Near major equipment items and other points of origination and termination.
7. Spaced intermediately at maximum spacing of 50 feet (15m) along each piping run, except reduce spacing to 25 feet (8 m) in congested areas of piping and equipment.
8. On all horizontal pipe runs every 20 ft, at least twice in each room and each story traversed by piping system.
9. On piping above removable acoustical ceilings, except omit intermediately spaced markers.
10. Where capped piping is provided for future connections, provide legible and durable tags indicating symbol identification.
11. Identify piping contents, flow direction, supply and return.

E. During back-filling/top soiling of exterior underground piping systems, install continuous underground-type plastic line marker, locate directly over the buried line at 12-inches above pipe. Use metallic lined plastic line markers for non-metallic type piping.

3.4 VALVE IDENTIFICATION

A. General: Provide valve tag on every valve cock and control device in each piping system; exclude check valves, and similar rough-in connections of end-use fixtures and units. List each tagged valve in the valve schedule for each piping system.

B. Valves Concealed in Suspended Ceilings: Provide 1/4 inch high plastic tape marker identifying the valve number on the nearest ceiling grid member.

3.5 MECHANICAL EQUIPMENT IDENTIFICATION

A. General: Install engraved plastic laminate sign or plastic equipment marker on or near each major item of mechanical equipment and each operational device, as specified herein if not otherwise specified for each item or device.

1. Signs shall be placed on the equipment in a logical location, easily visible to maintenance personnel, e.g. near control panels, disconnect switches, nameplates, on or near equipment main access doors and panels, etc. Sign and drilling locations shall be approved by the University’s Representative.

B. Optional sign types: Where lettering larger than 1 inch height is needed for proper identification, because of distance from normal location of required identification, stenciled signs may be provided in lieu of engraved plastic, verify with the University's Representative.

C. Lettering size: Minimum 1/4 inch high lettering for name of unit where viewing distances less than 24 inches, 1/2 inch high for distances up to 6 feet, and proportionately larger lettering for greater distances. Provide secondary lettering of 2/3 to 3/4 of the size of the principal lettering.

D. Plasticized tags: Where equipment to be identified is concealed above acoustical ceilings or similar concealment, use plasticized tags installed within concealed space to eliminate text in exposed sign (outside concealment). In rooms other than the security area, mechanical rooms, storage, etc., use thumbtacks for exposed signs with color coded for each type of equipment. Verify with the University's Representative.

3.6 ADJUSTING AND CLEANING

A. Adjusting: Relocate any mechanical identification device which has become visually blocked by Work of this Division or other Divisions.

B. Cleaning: Clean face of identification devices.

3.7 EXTRA STOCK

A. Furnish minimum of 5% extra stock of each mechanical identification material required, including additional numbered valve tags (not less than 3) for each piping system, additional piping system identification markers, and additional plastic laminate engraving blanks of assorted sizes.

1. Where stenciled markers are provided, clean and retain stencils after completion of stenciling and include used stencils in extra stock, along with required stock of stenciling paints and applicators.

END OF SECTION 23 05 53

The following standard specification is intended to be edited according to the specifics of the project. Brackets [ ] and areas shaded in gray [e.g. format] indicate requirements that are optional depending upon the type of system being provided or per instructions associated with the [ ] and project requirements. Consult with University's Representative and campus stakeholders.

DOCUMENT UTILIZES TRACK CHANGES TO RECORD YOUR CHANGES AS YOU EDIT.
DO NOT CHANGE THE FOOTER OF THE DOCUMENT

SECTION 23 08 00
COMMISSIONING OF HVAC

1.1 DESCRIPTION

A. Commission all systems and equipment listed in the table below per the requirements of Section 01 91 00 Commissioning. The Installation/Start-up Verification (ISV) and Functional Performance Test (FPT) forms listed are required [and will be provided by the University]. Refer to the project website for standard commissioning forms.

[Edit the table and the checklists as required by the project.]

Equipment/System	ISV Form	FPT Form
Testing, Adjusting, and Balancing for HVAC	ISV-23 05 93	FPT-23 05 93
Instrumentation and Control for HVAC (Building EMS)	ISV-23 09 00-1	FPT-23 09 00
Instrumentation and Control for HVAC (Laboratory Air Flow Control Systems)	ISV-23 09 10-2	FPT-23 09 10
Control Air Compressor for HVAC	ISV-23 09 43	
Chilled Water Systems	N/A	FPT-23 21 00-1
Heating Water Systems	N/A	FPT-23 21 00-2
Hydronic Piping (Chilled Water and Heating Hot Water)	ISV- 23 21 13	N/A
Hydronic Pumps CHW	ISV-23 21 23	w/ FPT-23 21 00-1
Hydronic Pumps HHW	ISV-23 21 23	w/ FPT-23 21 00-2
Steam and Condensate Heating Piping	ISV-23 22 13	N/A
Metal Ducts	ISV-23 31 13	N/A
HVAC Fans	ISV-23 34 00	w/ FPT-23 73 00
Air Terminal Units - Commercial	ISV-23 36 23	w/ FPT-23 73 00
Air Terminal Units - Laboratory	ISV-23 36 33	w/ FPT-23 73 00
Heat Exchangers for HVAC CHW	ISV-23 57 00-1	w/ FPT-23 21 00-1
Heat Exchangers for HVAC HHW	ISV-23 57 00-2	w/ FPT-23 21 00-2
Cooling Towers	ISV-23 65 00	w/ FPT-23 65 00
Air Handling Systems	N/A	FPT-23 73 00
Packaged, Outdoor, Central-Station Air-Handling Units	ISV 23 74 13	FPT-23 74 13
Custom-Packaged, Outdoor, Central Station Air-Handling Units	23 75 13	FPT-23 75 13
Evaporative Air-Cooling Equipment	23 76 00	FPT-23 76 00

Split-System Air-Conditioners	ISV-23 81 26	N/A
Fan Coil Units	ISV-23 82 19	FPT-23 82 19
Induction Units	ISV-23 82 26	w/ FPT-23 73 00

1.2 RELATED WORK AND DOCUMENTS

A. Section 01 79 00 Demonstration and Training

B. Section 01 91 00 Commissioning

C. Division 23 Heating, Ventilating, and Air Conditioning

1.3 COMMISSIONING DEFINITIONS AND ABBREVIATIONS

A. Refer to Section 01 91 00 Commissioning.

1.4 REFERENCE STANDARDS

A. Sheet Metal and Air Conditioning Contractors National Association (SMACNA) Guidelines

B. American Society for Testing and Materials (ASTM)

C. Associated Air Balance Counsel (AABC) Guidelines for Balancing Procedures and Documentation

1.5 SUBMITTALS

A. Submit commissioning documents for all equipment and systems listed in table above per the requirements of Section 01 91 00 Commissioning.

PART 2 - PRODUCTS

2.1 INSTRUMENTATION

A. Refer to Section 01 91 00 Commissioning.

PART 3 - EXECUTION

3.1 INSTALLATION/START-UP VERIFICATION

A. Perform all checks and tests included in the ISV checklists and complete the checklists as specified in Section 01 91 00 Commissioning.

3.2 FUNCTIONAL PERFORMANCE TESTS

A. Perform all checks and tests included in the FPT checklists and complete the checklists as specified in Section 01 91 00 Commissioning.

3.3 TRAINING OF UNIVERSITY PERSONNEL

A. Provide training of University’s personnel for the number of hours specified in the table below and as specified in Section 01 79 00 Demonstration and Training.

[Edit the table as required by the project. University Representative to coordinate with PPDO - Engineering Services and Physical Plant Services]

Equipment/System	Section Number	Orientation Hours	Training Hours	DVD Recording
Instrumentation and Control for HVAC (Building EMS)	23 09 00	TBD	TBD	N/A
Instrumentation and Control for HVAC (Laboratory Air Flow Control Systems)	23 09 10	TBD	TBD	N/A
Chilled Water Systems	23 21 00	2	4	N/A
Heating Water Systems	23 21 00	2	4	N/A
Condenser Water Systems	23 21 00	2	4	N/A
Steam and Condensate Systems	23 22 13	1	2	N/A
Air Handling Systems	23 73 00	4	8	N/A

END OF SECTION 23 08 00