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

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

DESIGN CRITERIA

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

1. Use the most recent American Society of Heating, Refrigeration & Air Conditioning Engineers (ASHRAE) Climatic Data for Region X to determine outside design conditions. Davis conditions are in parentheses.
   a. For 100% outside air systems use the 0.1 percent summer conditions (103 degrees dry bulb/72 degrees mcwb) and the 0.2 percent winter conditions (30 degrees).
   b. For 100% outside air systems conditioning environmental spaces occupied by animals or insects, special consideration must 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 must be sized to accommodate extreme conditions. For 100% outside air stand alone equipment serving these areas, apply 110 degrees dry bulb for summer and 25 degrees winter outside air temperatures. Review the assumptions, including outside air temperatures, with University Representative prior to developing basis of design and equipment selection.
2. For recirculating air systems use the 0.5 percent (99 degrees dry bulb/70 degrees mcwb) summer conditions and the 0.6 percent winter conditions (34 degrees).
3. For interior temperature conditions, use 75 degrees for cooling and 70 degrees for heating. More stringent animal care codes may override these criteria.
4. Telecommunications Spaces (IDF, BDF rooms): Temperature range between 68 and 72 degrees F cooling; no heating; Relative Humidity range between 35% and 55%. See further detail below.
5. For cooling tower selection use the 0.1 percent design wet bulb conditions (74 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 ASHRAE 2009 Fundamentals, Ch. 18.
7. People: Per ASHRAE 2009 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"/100' of duct, and not exceeding 1500 fpm.
    c. Medium pressure ductwork shall be sized at no more than 0.2"/100' 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.

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

User Controllability of Ventilation

Provide individual temperature and ventilation controls for at least 50% of the occupants. Operable windows can be used in lieu of individual controls for occupants of areas provided they meet the requirements of ASHRAE 62.1 and California Building Codes Titles 24, Part 6. The use of operable windows shall be reviewed and approved by the University.

Ventilation Rates

For Mechanically Ventilated Spaces, increase breathing zone outdoor air ventilation rates to all occupied spaces by at least 30% 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 CO_2 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% 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. CO_2 sensors shall be located within the breathing zone of the room as defined in the latest edition of ASHRAE Standard 62.1.
2. CO_2 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 CO_2 sensors and outdoor airflow monitors shall be configured to generate an alarm if the indicated outdoor airflow rate drops more than 15% 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.

CO_2 sensors may also be used for demand controlled ventilation provided the control strategy complies with latest edition of Standard 62.1, including maintaining the area-based component of the design ventilation rate.

Space CO_2 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 CO_2 concentration, which shall be determined by one of the following:

1. Outdoor CO_2 concentration shall be assumed to be 400 ppm without any direct measurement; or
2. Outdoor CO_2 concentration shall be dynamically measured using a CO_2 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 operation will the ventilation rate be less than 1 cfm/sf (which is equivalent to 6 air changes per hour in a room with a 10' high ceiling). Design Professional to provide calculations indicating design ventilation rate for each lab, noting if fume hood exhaust or equipment heat gains dictate.
    b. The ventilation system for animal rooms (where animals stay overnight) shall be capable of providing 2.5 cfm/sf with 100 percent exhaust to the outside. The air distribution device shall be designed to create a "no draft" environment.
    c. No re-circulation of laboratory or animal room exhaust air to the building air supply.
    d. Both supply air and exhaust air must be ducted. No open-air plenums.
    e. Animal rooms within mixed-use buildings are to be on a separate, dedicated HVAC system.
2. Room Air Pressure Differential
    a. Laboratories and storage areas must 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, should maintain room air pressure differentials so that room pressure is negative to all adjacent areas.
    c. Under defined circumstances such as cell culture and specialized animal areas, positively pressurized laboratories may be necessary.
    d. The containment of carcinogenic, radioactive, or infectious animals/agents within mixed-use buildings needs to be evaluated on a case by case basis.
    e. Special containment (ventilated storage cabinets, special local exhaust, etc.) may be required for extremely noxious operations (muffle furnaces, etc.) or extremely odiferous materials (mercaptans, sulfur compounds, etc.). Toxic gases (arsine, phosphine, etc.) require ventilated cabinets with alarms.
3. Exhaust
    a. Minimum hood exhaust stack height of 10 feet is required for new construction. The results of the wind tunnel evaluation may necessitate a higher or lower stack height.
    b. Special air cleaning devices may be required for some fume hood applications as required by the local Air Quality Management District.
    c. Gang hoods onto exhaust plenum w/ multiple fans.
    d. Size ducts per Industrial Ventilation, 21st edition.
4. Wind Tunnel Studies
    a. A wind tunnel evaluation is required for all new construction. Any new construction project that produces emissions of a hazardous, noxious, odoriferous, or otherwise nuisance character and that poses a health and safety risk, is to be evaluated using best available technology for wind tunnel studies. 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. Target dilution factors are 1/1,000 at minimum, 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 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 must be given.

All equipment rooms must 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.

- Recommend 6,000 BTU's (1/2 ton) per equipment rack installed in the telecom room.
- HVAC shall be included in the design of the room to maintain a temperature between 68 and 72 degrees Fahrenheit.
- A positive pressure differential with respect to surrounding areas should be provided.
- The humidity must be maintained between 30 and 55 percent.

- The filters in the HVAC system should have an ASHRAE dust spot rating of 85 percent or better.
- If chilled water is used for cooling, provide dedicated piping from main to avoid running the building main pumps during off-peak conditions.

COMMON MOTOR REQUIREMENTS 23 05 13

All motors 1 HP and over that are used at least 1,000 hours per year are to 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

Refer to Campus Standards & Design Guide, Part IV, Standard Specifications Section 26 29 23 for requirements.

METERS AND GAGES FOR HVAC PIPING 23 05 19

Refer to the Campus Standard Design Guide, Section 33 05 33 for metering requirements.

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 1-1/2 inches or as marked on the Drawings.

HVAC PIPING INSULATION 23 07 19

Wrap black steel pipe buried in the ground and to 6 inches above grade, including piping in conduit, with one of the following:

1. Polyethylene Coating
   a. Field Joints and Fittings: Protecto Wrap #1170 tape as manufactured by Pipe Line Service Corporation, or Primer #200 tape by Roystron Products, or equal.

2. Tape Wrap
   a. Wrap: Pressure-sensitive polyvinyl chloride tape, "Trantex #V-10 or V-20, "Scotchwrap #50", Slipknot 100, or equal, with continuous identification. Tape shall be a minimum of 20 mils thick for fittings and irregular surfaces, two wraps, 50 percent overlap, 40 mils total thickness. Tape shall be laminated with a suitable

adhesive; widths as recommended by the manufacturer for the pipe size. Wrap 50 feet-0 inches or longer sections of piping with an approved wrapping machine.

b. Field Joints and Fittings: Polyvinyl chloride tape wrap as above. Provide at least two thicknesses of tape over the joint and extend a minimum of 4 inches over adjacent pipe covering. Build up with primer to match adjacent covering thickness. Width of tape of fittings shall not exceed 3 inches. Tape shall adhere tightly to all surfaces of the fittings without air pockets.

Testing: Test completed piping with Tinker and Rasor Co. test machine, or equal.

COMMISSIONING OF HVAC 23 08 00

Refer to Campus Standards & 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 Standards & 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.

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.

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 must 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% 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 measured at any point. The maximum average face velocity shall be 120 fpm. After installation, a qualified independent testing agency must perform fume hood field tests on each hood. Test data must be submitted to University's Representative for review by EH&S before installation is accepted.

Fume Hood Face Velocity: The VAV control system must maintain a face velocity between 100 fpm and 120 fpm with 100 fpm being the nominal average value when measured in accordance with Cal/OSHA 5154.1. Room air currents at the fume hood must not exceed 20% 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 is to be controlled will be 10% to 100% 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. A minimum volume shall be set to ensure airflow through the fume hood even with the sash totally closed.

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

Response Time: VAV fume hood controller systems must 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 must 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 must establish an exhaust rate that will provide the desired average face velocity per design. The sash position or face velocity must be continuously sensed to enable the control system to maintain the desired average face velocity.

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. 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 must be located on the drawings. Maintenance accessibility is critical.

VENTILATION RATE

Refer to Design Criteria, "Ventilation Criteria for Research Laboratories" at the beginning of this Division.

ROOM PRESSURIZATION

Refer to Design Criteria, "Ventilation Criteria for Research Laboratories" at the beginning of this Division.

ROOM TEMPERATURE CONTROL

The control system must include a control strategy to avoid excessive temperature swings when the room is subject to large, sudden changes in the ventilation airflow. The system must be designed with separate heating and cooling set points, adjustable by a field technician, typically 70 degrees F Heating and 75 degrees F Cooling during occupied hours and 65 degrees F Heating and 80 degrees F Cooling during unoccupied hours. Zone temperature sensors must be provided with a 2 hour temporary occupancy override capability. Occupancy hours, temperature set points, override hours of operation must be adjustable at the Central Heating/Cooling Plant.

RELIABILITY & ACCURACY

System control methodology must be based on full supply/exhaust volumetric airflow tracking capability. The system must 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 must 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 must 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. Design air outlets and air terminal devices to ensure room noise and acoustic requirement does not exceed those specified in Division 11.
2. Laboratory terminal devices shall have linear flow performance characteristics and provide minimum turndown ratio of 5:1 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% 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.
3. 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% of design airflow at 4 inches w.g. positive static pressure.
4. 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.
5. A loss, increase and/or decrease of airflow shall be transmitted to the fume hood or room controller as appropriate.
6. 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.
7. 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 must 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 EMS

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 system integration with the campus DDC system must 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 must 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 Energy Management system and ensure 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 must 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

Black steel schedule 40 plain end with black malleable iron fittings.

FACILITY NATURAL GAS PIPING 23 11 23

PIPING

Underground: 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. Refer to Campus Standards & 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, 1.5 inch and smaller. Provide welded fittings for all piping larger than 1.5 inches 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.

FLEXIBLE CONNECTIONS: 3/4 inch by 12 inches long stainless steel hose and braid.

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.
4. Provide full size by-pass with check valve around CHW pumps for first stage cooling.
5. Provide two CHW pumps each sized for 50% max flow requirement. Pumps to have VFDs.
6. Provide two HHW pumps each sized for 50% max flow requirement. Pumps to have VFDs.
7. All motors for use with VFDs shall have shaft-grounding devices to protect bearings against damage caused by shaft potentials. In systems designed for wet or severe environmental applications, the brush contact area shall be sealed to keep contaminants from entering the Shaft Grounding System.
8. For hydronic systems where variable water volume (VWV) is used, provide the following:
   a. Install modulating valves with minimum 100:1 turn down 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.
   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 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

Underground/Under Schedule 40 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. All below grade copper tubing shall be brazed with silver solder 1000 degrees F.
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" and larger shall be brazed with silver solder 1000 degrees F.

Grooved or flanged fittings and joints should not be used on 2-pipe change over 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 control valves, strainers, and coils that are separate from the valves used for water balance. Balance valves are never to be substituted for isolation valves.

STEAM AND CONDENSATE PIPING AND PUMPS 23 22 00

SYSTEM DESIGN

Size steam pipe for flows between 8,000 and 10,000 FPM. If steam is run through building, Engineer to calculate requirements for expansion loop and design support. Size PRVs for 1/3, 2/3 flow.

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 Standards & Design Guide, Part III, Construction Divisions, Division 33 for additional requirements.

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. For below grade piping, refer to Campus Standards & 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 pressure shall be reduced from the high pressure campus distribution system in two stages, the first being a reduction to 80 psi, and the second to 15 psi. Each stage shall have two pneumatically operated pressure regulating valves piped in parallel. The pneumatic air pressure for each PRV shall itself be set by an adjustable pneumatic pressure regulator. Pneumatic piping shall be in hard-drawn copper, and have check valves upstream of the regulators to prevent steam from entering the pneumatic system in the case of a ruptured diaphragm at any of the reducing valves. Manufactured by Leslie Model GPS or equal (no known 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

High pressure steam trap shall be TLV Model J3S-X-10, stainless steel body with free floating ball and thermostatic air vent; no by-pass, to match existing Campus distribution steam system. PRV to be Leslie model GPS, air actuated.

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 copper pipe is required for all refrigerant piping. All copper to copper joints shall be made with 15% silfoss and all copper to brass connections will be made with 45% 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 will be installed parallel to the compressor crankshaft.
5. Suction lines shall be sloped 1/2 inch per 10 feet toward the compressor and vertical risers shall require a trap ten feet on center.
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.

TESTING OF REFRIGERANT PIPING

1. Pressure test to 175 lbs for 12 hours. Each unit upon completion of the pressure test will receive a triple evacuation twice to 1500 microns and finally to at least 500 microns, breaking the vacuum each time with nitrogen.

HVAC AIR DISTRIBUTION 23 30 00

SYSTEMS DESIGN

1. Indicate on the drawings or specifications that low pressure loss duct fittings are to 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. All return air shall be ducted.

FANS

Bearings shall be self-aligning, enclosed and accessible for lubrication.

Drive Design:

1. 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.
2. All variable speed drives shall be selected to allow an increase or decrease of minimum of 10 percent of design fan speed.

3. All motors for use with VFDs shall have shaft-grounding devices to protect bearings against damage caused by shaft potentials. In systems designed for wet or severe environmental applications, the brush contact area shall be sealed to keep contaminants from entering the Shaft Grounding System.
4. Motors of 15 H.P. and less shall have adjustable pitch sheaves.

Sheaves:

1. Sheaves shall be cast or fabricated, bored to size or bushed with fully split tapered bushings to fit properly on the shafts.
2. All sheaves shall be secured with keys and set-screws.

DUCTWORK

Use low pressure drop duct design. Use 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 H2O 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 inside of 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 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

Layout ductwork and locate duct smoke detectors to ensure clearance is available upstream and downstream of detectors pursuant to detector manufacturer's requirements.

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.

GRILLES, REGISTERS AND LOUVERS
Provide all outlets with gaskets to minimize the streaking of the walls or ceilings due to leakage.

FUME HOODS 23 38 16

Refer to Campus Standards & 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
Laboratory hood exhaust fans shall have acid resistant coating on all parts exposed to the air stream.

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 have the capability to control compressors, condensers and refrigerated cases.
3. The controller must 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 must be given to local and remote alarming.
2. A separate temperature alarm with Hi/Lo capability is required.
3. Control must 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 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 contractor 5 year 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 will be required on all pump down systems.
7. All refrigeration systems will be provided with a high and low pressure switch. All pressure controls will utilize flex hoses and not capillary tubes. Field installed mechanical pressure switches (other than fixed direct coupled type) shall be connected to the refrigeration system via flexible hoses specifically designed for this purpose. No copper capillary tubes permitted. Capillary tubes are acceptable only on systems less than ½ horsepower.
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 and suction filter driers shall be included on all systems.
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 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 designed to operate below 0 degrees C **must** have electric defrost.
16. Hot gas defrost may be utilized on systems designed to operate above 0 degrees C.

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 over-load protection.
7. Systems having electric defrost shall include an evaporator fan thermostat and defrost termination control.
8. Contractor shall replace refrigerant filter driers after 48 hrs of run time.

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. If exposed to return air conditions R-4 is acceptable. 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.

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 with the following maximum coil wet air pressure drop (H_2O).

Air Face Velocity	CHW & DX Coil Pressure Drop	Runaround Coil Pressure Drop	Heating Hot Water Coil Pressure Drop
450	0.55	0.50	0.16

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

Filter Efficiency	Desired Maximum Face Velocity (fpm)	Maximum Initial Pressure Drop (in. w.g.)
35 percent	400	0.17
65 percent	400	0.17
85 percent	400	0.19
95 percent	375	0.23
99.97 percent HEPA	250	0.65
99.99 percent HEPA	200	0.65

Provide a local magnehelic filter gauge. Coordinate with Energy Management System and provide a magnehelic indicator/electronic transmitter (Dwyer model 605 or equal) to measure pressure differential across the filter.

Indirect evaporative cooling systems shall be provided for all 100 percent outside air systems and shall be evaluated for systems using high outside air flow rates.

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 be selected in lieu of heat pump units whenever gas service is available.
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% 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.

COMPUTER SERVER ROOM AIR CONDITIONERS 23 81 23

1. Dedicated Unitary special purpose computer server room air conditioners shall be used. If chilled water is used as the cooling source, a backup cooling system shall be provided to provide cooling during temporary outages.
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, de-humidification and re-heat 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.

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% outside air or heating air at an inlet air temperature below 40 degrees F shall feature stainless steel burners and heat exchangers.

BUILDING MECHANICAL ROOMS 23 90 00

The Main Mechanical Room for the project 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 effect the space above.

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

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 convenient service access for maintenance staff. Review and coordinate the size, design and layout of the mechanical rooms with University’s Representative.