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**

Use ASHRAE Climatic Data for Region X to determine outside design conditions. Davis conditions are in parentheses.

1. 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).
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. For cooling tower selection use the 0.1 percent design wet bulb conditions (74 degrees).

**THERMAL COMFORT**

Comply with ASHRAE Standard 55-2004, 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.

Thermal Comfort - Compliance. ASHRAE Standard 55-2004 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 that are 20 feet inside of and 10 feet to either side of the operable part of the window. The areas of operable window must meet the requirements of ASHRAE 62-2001 paragraph 5.1 Natural Ventilation. And, multi-occupant spaces where transient occupant groups share the space must provide temperature and ventilation controls to meet group needs and preferences.

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 Ventilation Rate Procedure of voluntary consensus standard ASHRAE 62.1-2004, Ventilation for Acceptable Indoor Air Quality ASHRAE Standard 62.1-2004.

For Naturally Ventilated Spaces
1. Design natural ventilation systems for occupied spaces to meet the recommendations set forth in the CIBSE (Chartered Institution of Building Services Engineers) "Good Practice Guide 237" [1998]. Determine that natural ventilation is an effective strategy for the project by following the flow diagram process shown in Figure 1.18 of the CIBSE Applications Manual 10: 1997, "Natural ventilation in non-domestic buildings."

2. And either of the following:
   a. Use diagrams and calculations to show that the design of the natural ventilation systems meets the recommendations set forth in the CIBSE Applications Manual 10: 1997, "Natural ventilation in non-domestic buildings."
   b. Use a macroscopic, multi-zone, analytic model to predict that room-by-room airflows will effectively naturally ventilate at least 90% of occupied spaces.

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 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% 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 Standard 62.1, including maintaining the area-based component of the design ventilation rate.

Space CO2 alarms and demand controlled ventilation setpoints 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 400 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 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 ft2), 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% of the design minimum outdoor air rate.

3. For natural ventilation systems, install a CO2 sensor within each naturally ventilated space.

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 number of laboratory air changes per hour is dependent on the hazards, heat, and/or odors to be controlled. At no time during operation will the laboratory room air changes per hour be less than 6.
   b. The ventilation system for animal rooms shall be capable of providing 15 air changes minimum per hour 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 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. The containment of carcinogenic, radioactive, or infectious animals/agents within mixed-use buildings needs to be evaluated on a case by case basis.
   d. 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 stack height.
   b. Special air cleaning devices may be required for some fume hood applications as required by the local Air Quality Management District.

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 ASHRAE Handbook of Fundamentals, 1997, Chapter 15, or the Environmental Protection Agency (EPA) Guideline for Fluid Modeling of Atmospheric Diffusion, EPA-600/8-81-009 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.

MECHANICAL 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 most recent American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) handbooks.

TELECOMMUNICATIONS ROOMS
The telecommunications room shall be dedicated to the telecommunications function and related support facilities and shall not be shared with mechanical installations other than those dedicated for telecommunications. Ductwork or piping not supporting equipment dedicated to the telecommunications room shall not be installed in, pass through or enter the telecommunications room.
METERS AND GAGES FOR HVAC PIPING 23 05 19

<table>
<thead>
<tr>
<th>Utility or Service</th>
<th>Manufacturer</th>
<th>Model #</th>
<th>Accessories/ Order Options</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chilled Water</td>
<td>Onicon Data Industrial or Equal</td>
<td>System 10 Flow Meter Model F-12xx Series 2300 with 2 Analog output cards</td>
<td>Data Splitter: Phoenix Contact MCR-1CLP-1/-I-00</td>
<td>This is a matched system with Temp &amp; Flow instruments included. System must be specified and order per building design. Model number may change based on building design loads. MCR passive isolator, for the electrical isolation of current signals without auxiliary power, 1-channel. input signal: 0(4). ..20 mA, output signal: 0(4). ..20 mA <a href="http://www.phoenixcontact.com">http://www.phoenixcontact.com</a></td>
</tr>
<tr>
<td>Steam Condensate</td>
<td>Niagara Meter Master or Equal</td>
<td>MTX-413 2&quot; Turbine type with Pulse output and remote display</td>
<td></td>
<td>Model number may change based on building design loads. This instrument needs to be specified and ordered per building design loads.</td>
</tr>
<tr>
<td>Steam</td>
<td>Per CSDG EMS Specifications</td>
<td></td>
<td></td>
<td>Yokogawa Yewflo Vortex style DY with NIST certification</td>
</tr>
</tbody>
</table>

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.

TESTING ADJUSTING AND BALANCING FOR HVAC 23 05 93

Contact University’s Representative for campus standard specification.

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 Royston 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 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

<table>
<thead>
<tr>
<th>COMMISSIONING OF HVAC</th>
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<tbody>
<tr>
<td>TESTING OF HYDRONIC PIPING</td>
</tr>
<tr>
<td>Isolate from the system all existing piping systems and new or existing equipment which may be damaged by test pressure. Test only new piping with water at 150psi. Final connection between new and existing piping shall be tested at normal system operating pressures. No loss in pressure or visible leaks shall show after 4 hours at the pressures indicated.</td>
</tr>
</tbody>
</table>

| TESTING OF GAS PIPING |
| See Testing Requirements for gas systems in Division 22. |

| TESTING OF DUCTWORK |
| All ducts rated for 2 inch pressure class and greater are to have at least 20 percent of the ducts randomly tested for air leakage per SMACNA. Ducts to be tested are to be chosen by University's Representative. |

| TESTING OF SMOKE DETECTORS IN DUCTWORK |
| Conduct differential pressure (DP) test in accordance with the detector manufacturer's requirements. Locate sampling tube upon completion of air balance. Perform DP and smoke test in accordance with manufacturer's requirements. Submit report with the fire alarm pretest. |

| AIR HANDLER UNIT TESTING |
| The cabinet shall be tested at the unit's supply fan design operating static pressures. Cabinet leakage shall not exceed 1 percent of scheduled CFM. Leak testing shall be performed by measuring the airflow pumped into the air handling unit at the design operating static pressure. All unit openings shall be sealed. The air shall then be pumped into the unit until the appropriate operating pressures are achieved. Air flow measurements shall be performed in compliance with AMCA Standard 210. The testing shall be performed at the factory and may be witnessed by the |
University's Representative. A detailed report, including all data and test methods, shall be presented to the University's Representative prior to equipment shipment.

TESTING OF FUME HOOD SYSTEM
The laboratory fume hood system must be 100% field-tested As Installed in full accordance with ASHRAE 110, and must 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. Each hood will be rated as follows:

- Fail: Smoke was visibly observed escaping from the hood
- Poor: Reverse flow of smoke is evident near opening
   - Lazy flow into hood along opening perimeter
   - Slow capture and clearance
   - Observed potential for escape.
- Fair: Some reverse flow in hood not necessarily at opening
   - Limited turbulent vortex flow inside hood
   - Smoke is captured and clears readily
   - No visible escape.
- Good: Good capture and quick clearance
   - Limited vortex flow inside hood
   - No reverse flow regions
   - No visible escape

Each Hood must be rated either Fair or Good in order to pass this test.

TESTING OF REFRIGERANT PIPING
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 500 microns breaking the vacuum each time with nitrogen.

INSTRUMENTATION AND CONTROL FOR HVAC
Start/stop control of all HVAC equipment in new construction shall be by the campus Energy Management System (EMS). Equipment may be electrically interfaced for start/stop control in functional groups by a single control point.*

Provide a complete operational direct digital control system for temperature control of building HVAC, local electric analog and digital controls for all equipment and a communications interface to existing campus EMS as required.

Due to the depth of the Controls and Instrumentation requirements, request the latest information from the University's Representative.

LABORATORY VARIABLE AIR VOLUME (VAV) CONTROLS
GENERAL
Laboratory airflow control system shall be Phoenix, Tek-Air, Siemens or equal, and must meet the following criteria. Refer to Division 11 on Laboratory Equipment for additional related requirements.

Manufacturer must have a minimum of 10 existing successful installations in full operation; three of which must be in California. Each installation must have at least 20 laboratory controllers. The manufacturer must be in the business of providing laboratory variable airflow control systems for a minimum of five years.

Manufacturer’s system must be 100 percent field tested and installed in full accordance with ASHRAE 110. A qualified independent testing company must perform fume hood field tests on each hood to determine face velocity and airflow patterns as described in Paragraphs 2 and 3 (above). Test data must be provided to EH&S for review and approval before installation is accepted. 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.

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.

6. Fed/OSHA, 29 CFR.
10. ACS - American Chemical Society, Chemical Health and Safety Division.
11. NIH - National Institutes of Health.
12. EPA - Environmental Protection Agency.

FUME HOODS
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. Flow visualization tests in accordance with ASHRAE 110, Paragraph 6.1 must also be performed, with no spillage of smoke as described in section 2 above. Negative room pressurization shall be maintained throughout testing.

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.

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 setpoints, 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.

ROOM PRESSURIZATION
The laboratory control system must continuously determine supply airflow, exhaust airflow and with the known minimum air change rate must use the cfm offset method for ensuring design lab pressurization. A room offset value of 10% of the maximum air value to the room is recommended or 100 cfm, whichever is greater.

AIR CHANGE RATE
All labs must be designed to meet or exceed the minimum air change rate of 6 air changes per hour (ACH). At no time will the air change rate fall below 6 ACH. EH&S and Operations & Maintenance may require higher air change rates to mitigate unique hazards in the laboratory. Design Professional to provide calculations indicating design ACH for each lab, noting if fume hood exhaust or equipment heat gains dictate ACH.

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. Laboratory terminal devices shall have linear flow performance characteristics and provide minimum turndown ratios 5 to 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.
2. 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.

3. 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.

4. A loss, increase and/or decrease of airflow shall be transmitted to the fume hood or room controller as appropriate.

5. 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.

6. All terminal devices that require factory calibration shall be calibrated, in accordance with NIST, to the job specific airflows indicated on the Drawings.

7. In order to guarantee safety and compliance, laboratory airflow control systems that do not measure actual airflow must provide independent airflow measuring stations. Independent airflow measuring stations shall be provided at each supply air valve, general exhaust air valve and fume hood exhaust air valve for each laboratory or pressurized space. The signals from these measurement stations shall be directly linked to the central BAS. Airflow measurement stations shall consist of an averaging airflow sensor, which shall provide an average duct velocity pressure to an airflow transmitter. Airflow transmitters shall provide an output of 4-20 mA proportional to velocity pressure. Airflow transmitters shall have an accuracy of at least ±0.5% of the transmitter range.

TURN DOWN RATIO
Minimum turn down ratio of 5:1.

INSTRUMENTATION
Airflow measuring devices and sensors shall be of rugged construction. The air terminal devices shall have transducers manufactured by Rosemount, Bailey, Bristol, or Foxboro. Accuracy shall be no less than plus or minus 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
Compatibility/interface with direct control systems (DDC) and must have the capability of integrating into any DDC systems via 0-10 volt signals or 4-20mA signal. Phoenix requires the Celeris system, which allows for either MODBUS or BACNET integration. A lab controls interface hardware and required translator must be provided.

Tek-Air also requires a separate lab controls host computer and translator. A Lab Control interface hardware and required translator must be 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. Siemens is the only manufacturer that offers direct integration to Building Energy Management System using Native Siemens (FLN) communication protocol. Design documents shall clearly identify the points that are required to interface with Energy Management system and assure system is designed to accommodate the need.

Coordinate for the actual points transferred. Design documents shall clearly identify the points that are required to interface with Energy Management system and assure system is designed to accommodate the need. Points that require changeable setpoints at CHCP:

1. Zone schedule
2. Zone occupied cooling setpoint
3. Zone occupied heating setpoint
4. Zone unoccupied cooling setpoint
5. Zone unoccupied heating setpoint
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 setpoint
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 setpoint by x percent for y minutes (1 alarm per occurrence)

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, 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. Calibration shall be performed in accordance with ASHRAE Standard 111 or latest edition and AMCA 210.

COMMISSIONING
Commissioning of the laboratory airflow control systems is mandatory, and project specific requirements, must be discussed with the University. The Design Professional shall develop commissioning requirements as part of laboratory airflow control specification.

<table>
<thead>
<tr>
<th>FACILITY FUEL-OIL PIPING</th>
<th>23 11 13</th>
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</thead>
<tbody>
<tr>
<td>PIPING</td>
<td></td>
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<tr>
<td>Black steel schedule 40 plain end with black malleable iron fittings.</td>
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</table>

<table>
<thead>
<tr>
<th>FACILITY NATURAL GAS PIPING</th>
<th>23 11 23</th>
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</thead>
<tbody>
<tr>
<td>PIPING</td>
<td></td>
</tr>
<tr>
<td>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. Above ground: Standard weight Schedule 40 black steel pipe with 150 pound malleable iron fittings for piping, 1.5&quot; inch and smaller and welded fittings for piping in vertical shafts, fan rooms and all piping 2 inches and larger.</td>
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</tr>
<tr>
<td>VALVES:</td>
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<tr>
<td>Service: 125 lb. gate valve.</td>
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</tr>
<tr>
<td>Bench Valves: Ball type with tapered sockets with ball and seat compatible with piping materials. Provide valve operating wrenches.</td>
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</tbody>
</table>
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**

**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.
2. Provide CHW piping with mixing bridge between CHW S&R, sized for half max flow with modulating valve and check valve to restrict supply flow into return.
3. Provide BTU meter in CHW return on Campus CHW loop side of bridge.
4. Provide full size by-pass with check valve around CHW pumps for first stage cooling.
5. Provide two CHW pumps each sized for 60% max flow requirement. Pumps to have VFDs (no manual by pass).
6. Provide two HHW pumps each sized for 60% max flow requirement. Pumps to have VFDs (no manual by pass).
7. Size piping for a maximum of 3 feet friction loss per 100 feet at maximum flows.

**PIPING, JOINTS AND FITTINGS**

Underground: 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. 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.

**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**

**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: Black carbon steel schedule 40 welded up to 10 inches by an AWS certified welder in accordance with ANSI B31.9.
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.

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

**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. 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 to be TLV J-series, 300#, cast iron, no by-pass. 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.

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**HVAC AIR DISTRIBUTION**

**SYSTEMS DESIGN**
Indicate on the drawings or specifications that low loss duct fittings are to be installed per SMACNA (see section 2: Design for Energy Efficiency and SMACNA HVAC Systems Duct Design, 1990).

Specify appropriate SMACNA duct air leakage class (see SMACNA HVAC Air Duct Leakage Test Manual and SMACNA Technical Paper on Duct Leakage, dated 12/92). Identify duct pressure classes on the ductwork plans, that is 1/2, 1, 2 etc., inside a triangle (see Sheet Metal & Air Conditioning Contractors' National Association, Inc. (SMACNA) HVAC Duct Construction Standards, Figure 1-1).

**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. 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 not exceed 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 with Titus, HEP or equal 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 unless shown otherwise, and no abrupt changes or offsets of any kind in the duct system shall be permitted.

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 Ventglas, Durodyne or equal, flexible connections on inlet and outlet of each fan or as shown on the Drawings. Seal all seams around fan and coil housings airtight with clear caulking 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.

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

FUME HOODS
Refer to Division 11 on Laboratory Equipment for information on fume hood construction.

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.

### CENTRAL COOLING EQUIPMENT 23 60 00

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

#### ELECTRICAL
All motors larger than 1/2 horsepower shall have 3 phase characteristics.

#### MICROPROCESSOR BASED CONTROLLERS
All refrigeration system controllers shall be fully adjustable, field programmable, electronic direct digital control (DDC) type controllers. The controller shall have the capability to control compressors, condensers and refrigerated cases. The controller must have the ability to provide sensor and transducer control. The controllers shall include a keypad interface and shall not require the use of a computer to program. PLC controllers are not acceptable.

#### CONDENSING UNITS
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.

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 hermetics with inherent 3-leg overload protection.

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. Condensing unit noise shall not exceed 78 decibels tested in accordance with ARI standards. Condensing units shall carry a contractor 5 year warranty.
MECHANICAL REFRIGERATION
All refrigeration pressure relief lines shall be piped to a location outside the building, 20 or more feet from an intake vent, operable window, etc.

A refrigerant receiver will be required on all pump down systems.

All pressure controls will utilize flex hoses and not capillary tubes. Capillary tubes are acceptable on systems less than ½ horsepower.

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.

Liquid and suction filter driers shall be included on all systems.

Low temperature refrigeration systems shall include a suction accumulator and will operate as a pump down system.

A complete wiring and control diagram will be permanently affixed in a waterproof container to the inside of each compressor control panel. An oil failure control will be required on all compressors with an oil pump.

Hot gas bypass valves will be installed with schrader valve access and ball valve isolators.

All refrigeration systems will be provided with a high and low pressure switch.

PIPING
At all times during brazing and soldering a nitrogen purge is required.

ACR copper pipe is required for all refrigerant piping and all copper to copper joints shall be made with 15% silfos and all copper to brass and copper to steel connections will be made with 45% silversolder.

All 90 degree elbows will be long radius. Suction P traps shall be manufactured as one piece and not field assembled.

All vibration eliminators will be installed parallel to the compressor crankshaft.

Suction lines shall be sloped ½ inch per 10 feet toward the compressor and vertical risers shall require a trap ten feet on center.

All outdoor insulation will be painted with insulation paint or covered with an insulation shield.

EVAPORATORS
Units shall have direct expansion cooling coils mounted in aluminum casing and be horizontally supported from the ceiling.

Coil shall have copper tubes hydraulically expanded into aluminum fins. Pitch coils in casing to provide drainage.

Evaporator drain will be provided with a trap outside of the refrigerated areas.

Drains will include a clean out tee and a pipe union and will not be reduced from the manufactured provided line size.

Freezer drains will include a drain line heater and rubber insulation.

Fan motors shall have built-in thermal over-load protection. Systems having electric defrost shall include an evaporator fan thermostat and defrost termination control.

Contractor shall replace refrigerant filter driers after 48 hrs of run time.

**PACKAGED OUTDOOR HVAC EQUIPMENT**

Draw through air handling units are required. Provide a local magnehelic filter gauge. Coordinate with Energy Management System and provide magnehelic indicator/electronic transmitter (Dwyer model 605 or equal) to measure pressure differential across the filter. Air handlers 7.5 HP 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. Systems with heating and cooling coils shall be configured with the heating coil receiving the incoming air before the cooling coil.

**PACKAGED OUTDOOR, HEATING & COOLING MAKE-UP AIR-CONDITIONERS**

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 3/4 horsepower shall be direct drive multi-speed or variable speed motors with permanently lubricated bearings.
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.
7. Low ambient controls: All mechanical cooling which is subject to winter operation such as server rooms, data rooms, and machine rooms shall be equipped with low ambient control option either factory or field installed. Low ambient control shall regulate speed of...
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. Thermostat Controls
   a. Multistage programmable 7 day
   b. Memory retention after loss of power
   c. No batteries required
   d. 2 stage heat and cool
   e. Heat pump compatible
   f. Dual set point with adjustable deadband
   g. Large alphanumeric display backlit
   h. Easy programming
   i. Display either degrees F or C
   j. Locking keypad feature
   k. 5 min short cycle protection
   l. Soft start compatible
   m. Remote sensor compatible

15. Provide 18/8 conductor thermostat cable installed in a dedicated conduit.