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FORMAT

1. Technical specifications content and numbering system shall be based on the most current CSI Master Format.

BASIS OF DESIGN

1. APSU design standards shall not replace fully developed, project and market specific technical specifications, with 3 manufacturers unless indicated otherwise, e.g., Stanley CorMax. Associate shall utilize the standards as a minimum standard to guide the design.
2. Design guidelines supplement building, fire, and other health, safety and welfare codes, and represent practices APSU has adopted regarding the built environment. Where conflicts arise between codes and guidelines, codes take precedent.
3. Coordinate deviation from guidelines with the University Design and Construction (UDC) Department.

RELATED SECTION

1. 22—PLUMBING
2. 26—ELECTRICAL

DESIGN CRITERIA

1. Outdoor air design criteria shall be based on weather data tabulated in the latest edition of the ASHRAE Handbook of Fundamentals. Winter (heating) design conditions shall be based on the 99.6% column dry bulb temperature. Summer (cooling) design conditions for sensible heat load calculations shall be based on the 0.4% dry bulb temperature with its mean coincident wet bulb temperature. Design conditions for the summer (cooling) ventilation load and all dehumidification load calculations shall be based on the 0.4% dew point with its mean coincident dry bulb temperature. Design conditions for evaporation load calculations shall be based on the 0.4% wet bulb with its mean coincident dry bulb temperature.
2. Indoor design temperatures and relative humidity requirements are stated in the Table below. *(NOTE: indoor design criteria and occupied/non-occupied set points and setbacks schedules shall be verified and approved by the owner during design. Also, consideration and elimination of potential high humidity issues that may arise from summer night setback schedules shall be thoroughly analyzed during the design phase.)*

Room	Summer				Winter			
	Occupied		Unoccupied (1)		Occupied		Unoccupied (1)	
	db	%RH	db	%RH	db	%RH	db	%RH
Classrooms / Lecture Halls	75°F	50%	82°F	50%	72°F	---	60°F	---
Data/Comm Rooms	75°F	45%	75°F	45%	72°F	30%	72°F	30%

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Corridors	75°F	50%	82°F	50%	72°F	---	60°F	---
Dining	75°F	50%	82°F	50%	72°F	---	60°F	---
Dormitory Rooms	75°F	50%	82°F	50%	72°F	---	60°F	---
Electrical Switchgear	95°F	---	95°F	---	55°F	---	55°F	---
Electrical Closets	78°F	50%	78°F	50%	55°F	---	55°F	---
Elevator Machine Room	78°F	50%	78°F	50%	55°F	---	55°F	---
Emergency Generator	104°F	---	104°F	---	65°F	---	65°F	---
Athletic Seating & Playing Areas	75°F	50%	82°F	50%	72°F	---	60°F	---
Kitchen	75°F	50%	82°F	50%	72°F	---	60°F	---
Laboratory	75°F	50%	75°F	50%	72°F	30%	72°F	30%
Lobbies	75°F	50%	82°F	50%	72°F	---	60°F	---
Locker Rooms	78°F	50%	82°F	50%	70°F	---	60°F	---
Mechanical Rooms	95°F	---	95°F	---	55°F	---	55°F	---
Offices	75°F	50%	82°F	50%	72°F	---	60°F	---
Toilet Rooms	75°F	50%	82°F	50%	72°F	---	60°F	---
Stairwells	---	---	---	---	65°F	---	65°F	---
Transformer Vaults	104°F	---	104°F	---	---	---	---	---

- a. The following normal building occupied schedule shall be utilized in Academic and Auxiliary Buildings when school is in session:
 - Mon-Fri: 7:00am to 10:00pm
 - Saturday: 8:00am to 6:00pm
- b. The remainder of the time, temperature shall be set back as indicated above.
- c. The HVAC system design and control shall minimize the use of heat when outside air temperature is above 60°F.
- d. The BAS shall be connected to the lighting occupancy sensor auxiliary contacts to allow the HVAC to go to the unoccupied mode when a space is unoccupied for longer than 15 minutes (adjustable). The space temperature, minimum supply air and minimum ventilation air set points shall all be setback to the unoccupied mode.
- e. Utilize 2°F dead band for night heating/cooling modes and utilize staggered morning warm-up / cool-down unoccupied operating modes. Ensure outside air dampers are closed during all unoccupied operating modes.
- f. Dry bulb and relative humidity are to be maintained 6 inches to 6 feet above the floor.
- g. Emergency generator rooms must not exceed temperature with generator running. 7 Must comply with EIA/TIA Standard 569.

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- h. Minimum temperature in the building must be 55°F even when unoccupied for long periods of time (greater than 2 days).
 - i. Cooling system for data/communication and elevator machine rooms shall be dedicated independent system.
 - j. Areas of a building that are anticipated to have occupancy schedules different than the majority of the building shall be served by dedicated independent systems or zoned separately to minimize the operation of the central building HVAC system after normal building occupied hours.
 - k. Minimum winter relative humidity requirements may be omitted upon approval of University.
 - l. Interior thermostatic control zones must not exceed 1,500 sq.ft per zone for open office areas or a maximum of three offices per zone for closed office areas.
 - m. Perimeter thermostatic control zones shall not exceed 300 sq.ft. and shall be no more than 15 ft from an outdoor wall along a common exposure. Corner offices shall be a dedicated zone.
 - n. Thermostatic zoning shall be developed using good engineering practice. Dissimilar spaces shall not be grouped on the same thermostat. Each classroom shall be an independent zone.
 - o. If a building program shows that an office building shall have an open plan layout or if the program does not state a preference, it may be assumed that up to 50 percent of the floor plan shall be occupied by closed offices at some point in the future.
 - p. The HVAC system and controls shall be designed to utilize the full capabilities of the Building Automation System (BAS) to optimize the HVAC system and minimize energy usage. System shall be designed to isolate wings or building sections to allow unused areas to be “turned off” when the spaces are unused.
 - q. The use of energy recovery devices and control sequences are encouraged to reduce utility consumption.
3. Acoustical Design Criteria: The design of the HVAC system must be coordinated to meet the acoustical noise criteria (NC) or room criteria (RC) established for the project and space use.
- a. Duct noise control must be achieved by controlling air velocity, by the use of sound attenuators, by the use of double-wall ductwork with insulation in between, equipment selection, or duct lining. Noise control shall not be controlled by oversizing terminal units.

HVAC LOADS AND ENERGY CALCULATIONS

- 1. The HVAC loads calculations shall be performed with a computer-based program using the latest ASHRAE Handbook of Fundamentals Heat Balance Method (HB), Radiant time Series (RTS) Method, or Transfer Function Method (TFM), developed for the hourly analysis of heating and cooling loads in commercial buildings.
- 2. The program shall be capable of calculating each zone’s peak heating and cooling load as well as the whole-building “block” loads. The program shall, at a minimum, calculate: solar gains

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through fenestration, internal gains from occupants including latent heat for cooling purposes, internal gains from lighting and equipment, outside air loads (sensible and latent) from ventilation and infiltration, and heat gains or losses through fenestration, walls, floors and roofs. The heating load calculations must be done without credit for occupants and internal gains. Losses due to duct leakage shall be accounted for in the load calculation.

3. The HVAC loads calculations report shall include all input and output used in the heating and cooling calculation program, and shall include zone peak heating and cooling loads results, and whole building “block” loads, air-handling unit coil selections, and psychometric process charts.
4. A building energy analysis shall be performed to demonstrate that the building design meets or exceeds the energy performance goals established for the project. Refer to the Energy Conservation Standard for performance goals requirements.
5. The building energy analysis shall be performed using the ASHRAE Standard 90.1 Energy Cost Budget methodology, and must demonstrate compliance with the latest editions of ASHRAE Standard 90.1, 10 CFR 434, and 10 CFR 435. The analysis shall be included in each design submission as described in Energy Conservation Standard.
6. The analysis shall evaluate the energy performance of the building design including the proposed building envelope, HVAC systems and components, the lighting systems, and domestic hot water systems, as well as the proposed control strategies for these building systems.

GENERAL PROVISIONS

1. Provide access panels for valves, filters, dampers, equipment, etc., installed above inaccessible ceilings such as plaster or concealed spline.
2. Provide Mechanical Identification labels to all control panels, disconnects, motor control centers as well as equipment they serve.
3. All pipes, valves and equipment in mechanical rooms, shafts, ceilings and other spaces accessible to maintenance personnel must be identified with color-coded bands and permanent tags indicating the system type and direction of flow for piping systems or type and number for equipment, per ASHRAE Handbook.
4. Provide full metering of all services to each building. Systems to be metered include incoming electric, steam condensate, chilled water, heating water, domestic water and natural gas. Connect to campus BAS.
5. Where buildings have food service, separate sub meters are required for food service. This is in addition to the overall building metering.
6. Utility meters.
 - a. Electric meters are specified in Division 26-ELECTRICAL.
 - b. Steam meters.
 - Venturi, temperature compensated mass flow type
 - Stainless steel 316 construction.

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- Minimum Turndown 38:1
 - Meter shall provide a scalable pulse output to the campus E-Mon utility metering system.
- c. Steam condensate meters shall be high temperature hot water turbine type and shall provide a pulse output to the campus E-Mon electrical utility metering system. Meter shall be installed on the discharge side of the condensate pump.
- d. Chilled water meters.
- Dual turbine, insertion type, suitable for hot tap installations.
 - Stainless steel 316 construction.
 - Minimum Turndown 50:1
 - BMS
- e. Domestic water meters.
- Dual turbine, insertion type, suitable for hot tap installations.
 - Stainless steel 316 construction.
 - Minimum Turndown 50:1
 - BMS
- f. Natural gas meters.
- Constant temperature differential, temperature compensated, insertion type.
 - Stainless steel 316 construction.
 - Minimum Turndown 80:1
 - BMS
7. Housekeeping Pads
- a. All floor mounted equipment shall be set on 4" housekeeping reinforced concrete pads.
 - b. Concrete pad shall extend 1'-0" beyond the base of the equipment.
8. Duct Hangers and Supports
- a. In accordance with SMACNA Standards, material shall be galvanized, using concrete inserts or anchors attached to the concrete. Structural steel and bar joist construction, use welded studs of C-clamps with retaining clip attached to the steel.
9. Rooftop Equipment
- a. Rooftop heating and/or conditioning units should be avoided wherever possible. If used, they shall not be located directly over normally occupied spaces such as offices or classrooms.
 - b. Duct connections to rooftop units shall be provided with flexible connectors
 - c. Return air to unit shall include sound attenuation such as:
 - d. Duct silencer,
 - e. Internally lined ducts by approval only
 - f. A tee so that air enters the return air section of the unit from two different directions.
 - g. If rooftop units are required, 407c and 410a refrigerants shall be utilized.
 - h. All exterior devices supporting exhaust stacks such as guidewire, turnbuckles and hooks shall be constructed of stainless steel.

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10. All cooling equipment (cooling towers, chillers) shall be provided with vibration isolating bases.

23 05 16—EXPANSION FITTINGS

1. Minimum expansion safety factor: 50%
2. Steam and steam condensate.
 - a. Steel Piping 3 inch and under: Stainless steel bellows type with anti-torque device, limit stops, and internal guide.
 - b. Steel piping over 3 inch: External ring controlled type with hydraulically formed stainless steel bellows.
 - c. Steel Piping 2 inch and Over: Spool type expansion, flexible compensator with tapped steel flanges, Teflon or neoprene and nylon body suitable for minimum 150 psi working pressure and 250 degrees Use joints suitable for minimum 125 psi WSP and 400 degrees F, and 200 psi WOG and 250 degrees F.
 - d. Steel Piping 2 inch and Under: Low pressure compensators with two-ply bronze bellows suitable for minimum 125 psi pressure and 250 degrees F and maximum 1/2 inch expansion.
 - e. Steel Piping 2 inches and Over: Copper type with packed sliding sleeve suitable for minimum 125 psi working pressure and 250 degrees F.
3. Hot Water Heating Piping – Flexible-Hose Expansion Joints: Manufactured assembly with two flexible-metal-hose legs joined by long-radius, 180-degree return bend or center section of flexible hose; with inlet and outlet elbow fittings, corrugated-metal inner hoses, and braided outer sheaths.

23 05 19—METERS AND GAUGES

1. Meters and Gauges. Each piece of mechanical equipment shall be provided with the instrumentation or test ports to verify critical parameters, such as capacity, pressures, temperatures, and flow rates. Following are the general instrumentation requirements:
 - a. Thermometers and pressure gauges are required on the suction and discharge of all pumps, chillers, boilers, heat exchangers, cooling coils, heating coils, and cooling towers.
 - b. To avoid pressure gauge tolerance errors, a single pressure gauge may be installed, valved to sense both supply and return conditions. For coils with less than 0.63 L/s (10 gpm) flow, provisions for use of portable instruments to check temperatures and pressures shall be made.
 - c. Duct static pressure gauges shall be provided for the central air-handling unit air supply fan discharge, branch take-offs of vertical supply risers and at all duct locations at which static pressure readings are being monitored to control the operation of a VAV system.
 - d. Differential static pressure gauges shall be placed across filters in air-handling units and to measure building pressure relative to the outdoors.

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- e. A temperature gauge is required at the outdoor air intake to each air-handling unit.
- 1. Thermometers
 - a. 9" scale, cast aluminum or molded glass reinforced polyester case, 3½" brass separable socket (¾" NPT).
 - b. Thermometers shall be 9" scale adjustable angle industrial type with ¾" NPT brass thermowell. All thermometers are to be spirit filled with blue or green reading tube to differentiate the thermometers from red reading mercury type that are not to be used.
 - c. For piping with insulation of more than 2 1/2" provide thermometers with 6" stem and extension neck ¾" NPT 6" brass well.
- 2. Pressure Gauges
 - a. Pressure gauges shall be 4 1/2" dial, cast aluminum metal case with bronze tube and brass socket, 1/4" NPT bottom connection, glass lens, rotary movement with accuracy of ANSI grade "A" as specified in ANSI B40.1. Ranges are to be selected so that the normal working pressure falls as close to the 12:00 o'clock position on the dial as possible.
 - b. Accuracy of ½ percent of the scale range.
 - c. Gauges on pump inlets are to be compound type.
 - d. Gauges on steam service or any liquid which has a temperature in excess of 150 F are to be supplied with steel pigtail syphon.
 - e. Gauges on pump service are to be supplied with brass snubber.
 - f. All gauges are to be installed with 1/4" NPT brass needle valve for shut off.
- 3. Pressure/Temperature Test Plug
 - a. ¼ inch NPT fitting, with cap, 1/8" outside diameter.
 - b. All brass construction for copper pipes and stainless for ferrous pipes.
 - c. Rated for 400 psig, service from 45°F to 275°F.

23 05 48—VIBRATION ISOLATION

- 1. Isolation efficiency shall be ninety percent (90%) or more.
- 2. Incorporate the basic design techniques as described in ASHRAE Applications Handbook, Sound and Vibration Control.
- 3. All rotating equipment in the building must be isolated.
- 4. All piping and ductwork must be isolated as it penetrates shafts and chases to prevent propagation of vibration to the building structure. All openings for ducts and piping must be sealed.
- 5. Isolation hangers must be used for all piping in mechanical rooms and adjacent spaces up to 50 ft. distance from vibrating equipment.

230593—TESTING, ADJUSTING AND BALANCING

- 1. Provide balancing of each heating and cooling air handling system and zone balancing throughout system including flow meters, balance valve, and shut-off valve.

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2. Associate shall place the following note conspicuously on the mechanical drawing and technical specification:

“Testing shall be completed by an independent testing and balancing agency, fully certified by the National Environmental Balancing Bureau, Associated Air Balance Council (AABC), or an independent firm whose principals are registered professional engineers. Firm selection is subject to approval by University. Testing and balancing shall be performed in complete accordance with the AABC "Standards and Instrumentation's Form No. 81226, Volume I".”

3. After building airflow balancing is completed, remove any adjustable pulleys and install fixed pulleys on all air handling motors.

23 07 00—INSULATION

1. All insulation materials shall comply with the fire and smoke hazard ratings (25 for flame spread; 50 for smoke developed) as indicated by ASTM-E84, NFPA 255 and UL 723. Accessories such as adhesives, mastics, cements and tapes shall have the same or better fire and smoke hazard ratings.
2. Ductwork
 - a. Externally insulated with one and one half inch (1½”) thick, 3.0 pound minimum density semi-rigid fiberglass insulation, (k) at 75°F mean temperature, 0.31 BTU/hr square foot F°/inch, foil-reinforced Kraft vapor barrier facing.
 - Outside air intake ducts in mechanical equipment rooms.
 - Supply ducts in mechanical equipment rooms.
 - Return ducts in mechanical equipment rooms.
 - Exhaust and relief ducts in Mechanical Equipment Rooms from back draft or motorized damper to louver.
 - Combustion air ducts.
 - b. Externally insulated with one and one-half inch (1½”) thick flexible duct wrap insulation, (k) at 75°F mean temperature 0.31 BTU/hr square foot F°/inch, foil-reinforced Kraft vapor barrier facing.
 - Outside air intake ducts concealed above ceilings and in shafts.
 - Supply ducts concealed above ceilings and in shafts.
 - Return ducts concealed above ceilings and in shafts.
 - Exhaust and relief ducts above ceilings and in shafts from backdraft or motorized damper to louver.
 - Runout ducts to registers, grilles and diffusers.
 - c. Firestop Blanket, or Firemaster duct wrap, two (2) one and one-half inch (½”) layers which when applied per manufacturer’s instructions. Provide a 2-hour fire rating with zero clearance to combustibles.
 - Kitchen hood exhaust ductwork including entire vertical riser.

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- Boiler flues.
 - d. Six pound (6#) density, two inches (2") thick, rigid foil face vapor seal finish. Cover insulation with a .016 thick aluminum jacket with a three-inch (3") overlap at all transverse and longitudinal joints. Jackets shall be positioned to shed water. Secure in place with $\frac{3}{4}$ " x .020" stainless steel banding on eighteen inch (18") centers minimum.
 - Exposed ductwork above roof
3. Pipe & Equipment Insulation
- a. Piping Insulation – Above Ground, Mineral Fiber or Cellular Glass. All service jacket with self-sealing lap adhesive. Thermal conductivity (k) shall not exceed 0.24 BTUH square foot F°/inch.
 - b. Pipe fittings shall be covered with insulating cement or preformed insulating fitting cover.
 - c. The following equipment and accessories shall be insulated:
 - Hot Water Accessories (Heating and/or Domestic)
 - Valves, flanges, strainers, specialties and fittings shall be insulated.
 - Air separators.
 - Chilled water pump bodies (with a removable wrap)
 - Heating/hot water pumps
 - Convertor and heat exchangers shall be insulated.
 - Cold Water Equipment (Cooling and/or Domestic)
 - Cover steam condensate receivers with 2" rigid insulation.
 - Insulate first eight feet of vent piping from the floor for Personnel protection.
 - d. Pipe fittings shall be covered with insulating cement or preformed insulating fitting cover.
 - e. All exposed piping insulation shall be covered with a jacket.
 - Aluminum: 0.02-inch thick, smooth no vapor barrier for all steam and steam condensate piping systems.
 - PVC jacket: for all other piping systems
 - f. Flexible elastomeric insulation is not acceptable except for insulating refrigeration piping and equipment.
 - g. Pipe insulation thickness shall be per ASHRAE 90.1.

23 09 00—INSTRUMENTATION & CONTROL FOR HVAC

1. General Requirements
- a. Temperature control system shall be an extension of the existing campus Schneider Electric Building System Group, I/A Intelligent Automation (BAS). Provide only Schneider Electric Building System Group, I/A Intelligent Automation control systems as provided and installed by a Factory authorized representative/installer.
 - b. The BAS shall be configured to provide all control, sequences of operation, and systems monitoring as required by these specifications and by the drawings. Provide all required devices, sensors, hardware, software, wiring, controllers, etc. including any required and

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not specifically addressed in this specification but required for system functionality. It shall be the responsibility of the BAS Contractor (BASC) to provide a complete and functioning system.

- c. All building automation wiring shall be provided for a complete and operable system. All wiring shall be installed in accordance with NEC and all local Codes. Run control wiring parallel and perpendicular to building lines; avoid diagonal runs. Division 26 (formerly division 16) will provide 120 V power source to junction boxes as indicated on the electrical drawings. BASC shall furnish and install all additional 120 power to system as required.
- d. BASC shall provide 24 volt step down control transformers and wiring for control devices as required.
- e. The BAS user interface shall be user friendly, readily understood and shall make maximum use of colors, graphics, icons, embedded images, animation, text based information and data visualization techniques to enhance and simplify the use and understanding of the BAS by authorized users.
- f. Provide BAS reports and displays making maximized use of simple English language descriptions and readily understood acronyms, abbreviations and the like to assist user understanding and interpretation. All text naming conventions shall be consistent in their use and application throughout the BAS.
- g. All control panels, routers, valves actuators and wiring shall be labeled. Control wire labels shall identify:
 - Associated Equipment (eg. Boiler)
 - Associated Equipment Tag (eg. B-1)
 - Associated Control Device (eg. Filter differential pressure transmitter)
 - Type of Control Point

23 21 13—HYDRONIC PIPING

1. Notes:
 - a. No water, steam, condensate, or air piping shall be installed in exterior walls without insulation. No water lines shall be installed above habitable spaces. These conditions should be avoided wherever possible.
 - b. Heating water or chilled water piping below ground may be installed in hard temper copper at the Contractor's option. Keep joints to a minimum. Joints shall be brazed.
 - c. Gasket material shall be 150# or 300# type, one-sixteenth inch (1/16") thick. For 300#, Flexitallic gaskets may be used.
 - d. Provide dielectric unions or dielectric flanges at connections between dissimilar metals.
 - e. All plugs for all services shall be brass.
 - f. Slip-on flanges will be acceptable at Contractor's option, where weld neck flanges are specified. Internal and external weld will be required.
 - g. Hex head bolts and nuts shall be used for flanged connections.

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- h. On piping 12 inches and above, standard wall pipe is acceptable in lieu of Schedule 40 pipe.
 - i. Buried or under floor services shall be avoided wherever possible. When not avoidable, these services shall be coordinated with other trades and dimensionally located and noted no other service shall be installed over such services.
 - j. Minimum pipe size shall; be $\frac{3}{4}$ -inch.
2. Direct Buried Chiller Water Piping. Direct buried chilled water piping shall be High Density Polyethylene (HDPE).
- a. All HDPE pipe and fittings shall conform to AWWA C906, except as modified herein. The pipe and fittings shall be rated for a working pressure of 160 psig and have a dimension ratio (DR) of not less than 11 for pipe ranging from 4 inches diameter to 30 inches diameter. HDPE is not to be installed in close proximity to buried steam piping.
 - b. HDPE pipe shall be manufactured from extra high molecular weight polyethylene pipe materials meeting the requirements of ASTM D3350-96. The pipe shall meet the requirements of cell classification PE34544C, standard PE code designation PE3408 as defined by ASTM D3350-96 and D3350. The manufacturer shall certify that the material meeting this specification has exceeded 5,000 hours without failure when tested under ASTM F 1248, and has a hydrostatic design basis for 1,600 psi at 73 degrees F and 800 psi at 140 degrees F when tested under ASTM D 2837. The design pressure of the pipe shall be defined in accordance with ASTM D 3035 and F 714. The pipe shall have a controlled outside diameter.
 - c. Fittings shall be manufactured using the same pressure rating as the pipe. Fittings shall be manufactured to standardized dimensions and shall be compatible with Illinois American Water standard fittings, valves, tees, service saddles, curb stops, and meter stops. Heat fusion fittings shall be manufactured from the same material as the extruded pipe, shall be rated for pressure service at least equal to that of the pipe, and shall have outlets manufactured to the same DR as the pipe. Molded fittings shall be manufactured to ASTM D 3261 and socket fittings to ASTM D 2683. Connections to the existing chilled water system other than HDPE pipe shall be restrained mechanical joint fittings, with stiffeners or inserts if recommended by the manufacturer.
 - d. HDPE fittings shall be factory molded or shop fabricated fittings. Shop fabricated fittings shall be made in strict accordance with the pipe manufacturer's printed recommendations and shall be fully butt fusion joints.
 - e. The pipe shall be designed for a minimum working pressure of 150 psig and for a test pressure of 200 psig.
 - f. Building Entrances: At building entrances, the wall penetration shall be a smooth, core-drilled hole. The pipe shall be Thickness Class 53, flanged on the interior side and having a male end with weld-bead on the exterior side. Allow 18 inches of pipe on both interior and exterior to provide adequate clearance for installation of connecting piping. Use Link-

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Seal or equivalent to seal both the interior side and exterior side of the core-drilled hole. The exterior side Link-Seal shall have stainless steel hardware. The interior side Link-Seal shall be installed so that the bolts are accessible from the interior space.

- g. No Insulation Required Underground: Do not insulate either supply or return piping (underground) except in cases where piping is shallow enough to be exposed to freezing conditions (typically when less than 36 inches deep at Top of Pipe).
 - h. Polyethylene Bag Not Required: A polyethylene bag for corrosion protection is not required by UIUC.
 - i. Air Vents: Install air vents at all local high points in the system.
 - j. Valves: All valves in an underground distribution system, as well as the first valve inside each building, shall be capable of withstanding the required test pressure for the piping, typically 200 psig for underground chilled water piping.
3. Hot water and chilled water systems shall utilize a two-pipe main distribution system arranged in a reverse return configuration. Loop piping for terminal or branch circuits shall be equipped with automatic flow control valves. Each terminal unit or coil shall be provided with isolation valves on both the supply and return, and a flow-indicating balance valve on the return line.
4. All valves shall be of one manufacturer for each type of valve.
5. Valves shall be installed on supply and return piping at all equipment for isolation and/or removal. Ball or butterfly valves depending on size shall be used. Isolation valves, shutoff valves, by-pass circuits, flanges and unions shall be provided for piping at equipment to facilitate equipment repair and replacement. Valves shall also be provided for zones from vertical risers and all major pipe branches, such as at each floor level, building wing or mechanical room.
6. Provide drain valves at air handling unit coils for draining, locate between isolation valve and coil. Provide further drain valves in heating and cooling system as required for draining.
- a. All vertical check valves shall be the silent type.
 - b. Extend relief valve discharge line to outside and routed to discharge away from public areas.
 - c. Valves shall be installed on supply and return piping where applicable at all equipment for isolation and/or removal. Only ball or butterfly depending on size shall be used.
 - d. Isolation valves shall also be installed to isolate floors, wings and risers.
 - e. No piping under $\frac{3}{4}$ " diameter shall be specified.
7. Hydronic Specialties
- a. Pump Suction Diffuser. On each end suction pump, angle type body with inlet vanes, orifice, cylinder and disposable fine mesh start-up and standard strainer. Pressure drop shall not exceed three (3) psi, adjustable support foot.
 - b. Air Vent. Automatic air vent in steel piping, ball float trap, copper piping, automatic vent, gate valve on vent inlet connection and drain line on outlet.

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- c. Expansion Tank. ASME compression tank of the pressure diaphragm type, air charging valve and drain valve.
- d. Air Separator. Centrifugal style air separator, line size without strainer.
- e. Strainer. Screwed, soldered, or flanged body corresponding to the valve schedule constructed and rated for operating pressure.
 - Clean all strainers prior to the Balancing Contractor beginning his work. Cleaning strainers shall entail removing the basket and cleaning, not merely blowing down through valves.
 - “Y” type strainer in mechanical equipment room shall be provided with plugged gate valve the same size as the strainer plug. Valve shall not be installed until after the strainer has been cleaned after one hundred and twenty (120) days.
 - All control valves shall have strainers installed on the upstream side and be trapped and dripped on the upstream side on steam systems for proper operation. Provide blow-down valve, nipple and cap. Run to floor drain where practicable.
- f. Flexible Coupling. Provide a flexible coupling at the following locations:
 - All base-mounted pumps, suction and discharge connections.
 - Chilled water connection on chiller.
 - Condenser water connection on chiller and cooling tower.
 - Water connections to diesel generator
- g. Integral duct and rubber flanges. Pipeline size and for working pressure of 125 psig on closed system. Construction shall be of the arch-type with a coating to prevent ozone attack. Control unit shall be provided with all couplings to prevent excessive movement.
- h. Stainless steel flexible connector with carbon steel flanges heli-arc welded on each end. Fabricated with multi-ply #304 Stainless Steel bellows element and provided with tie rods.
- i. Flow Control Valve. Factory calibrated, direct acting, automatic pressure compensating type, +5% accuracy, corrosion resistant cartridge, self-cleaning. Unions/flanges shall be provided adjacent to valves for servicing. Provided with a metal tag, chain and stamped for system identification.
- j. Circuit Setter
 - Calibrated balance valve, integral EPT check valve, integral pointer, bronze for copper pipe lines, cast iron for steel pipe.
 - Valves shall not be used as tight shutoff valves.
 - Piping one inch and smaller, combination units will be acceptable.
- k. Automatic Glycol Feeder and Pump. Package translucent polyethylene solution container, lid, dual pumping assembly, piping, necessary electrical wiring, 120 volt, low level cut off, alarm indicating excessive pressure or low solution level. Assembly shall be connected to the Building DDC control system to indicate pump operation and low level alarm.
- l. The heat transfer fluid shall be an inhibited glycol based industrial heat transfer fluid specifically formulated for use in HVAC systems. The fluid must contain corrosion inhibitors and buffers and an anti-foam agent, necessary for long fluid and system life.

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Water solution pre-mixed 30% glycol and 70% deionized water, suitable for operating temperatures from -40°F to 250°F.

- Field mixed fluid, automotive antifreeze, uninhibited glycol or field inhibited glycol is not acceptable.
 - System shall be cleaned and flushed prior to adding premixed glycol solution. System must be free of all dirt, weld slag, oil, filings, etc.
 - After the system is filled and properly air purged the solution shall be circulated for at least twelve hours before fluid sample is taken.
- m. Representative samples shall be submitted to the heat transfer fluid manufacturer for the following analysis:
- Water quality
 - Concentration of corrosion inhibitors
 - Pressure of anti-foam agent and buffers
 - Glycol concentration
 - Absence of contaminants
 - Manufacturer's report to be submitted to the Engineer.

23 21 23—HYDRONIC PUMPS

1. General

- a. Guaranteed for minimum 125 psi working pressure, 225°F water temperature on heating water systems and 180°F on cooling and condenser water systems. Minimum working pressure and temperatures can increase based on application.
- b. Selection shall be made near the mid-range of the pump curve. Select the operating point at or near the highest efficiency and to the left side of the maximum efficiency point but not more than 5% from the maximum efficiency curve.
- c. On open system, required net positive suction head does not exceed the net positive head available.
- d. In selecting the pump motors for parallel operation, motor overloading will not occur in the case where only one pump is operating.
- e. Do not use service factor of motor.
- f. All pumps 5 HP and over shall be controlled by a variable speed drive. Small pumps may be controlled by a variable speed drive depending on the application.
- g. Base mounted centrifugal pump and suction diffuser shall be mounted on a 4-inch housekeeping pad or inertia base.
- h. Cooling tower condenser water system - provide internal flush seal with flush line filter.
- i. Glycol pump shall have the capacity corrected for handling glycol solution.
- j. Close coupled or extended shaft motor pumps shall be avoided.
- k. For existing conditions, pumps shall be installed by the nearest floor drain if possible. For new construction, coordinate floor drain locations with pump locations.

2. In-Line Pump

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- a. In-line pumps shall be used for 0-100 gpm applications.
 - b. In-line pumps or fans shall be supported independently from attached pipe or duct with vibration isolation hangers and flexible connectors.
 - c. Bronze fitted construction brass or bronze impeller, cast iron volute and steel pump shaft, mechanical seals.
 - d. Bearings in the pump and motor shall be bronze sleeve or ball bearing.
 - e. Single pump operation, the pump shall not overload the motor if the specified flow rate (gpm) is doubled. Parallel pump operation, the pump shall not overload the motor on any point throughout the head capacity curve.
 - f. Provide sheet metal pans under in-line pumps to collect oil drippage.
3. End Suction Pump
- a. End suction pumps shall be used for 100-500 gpm applications.
 - b. Cast iron casing, flanged suction and discharge connections, non-metallic flexible coupler, regreaseable ball bearing lubrication system on both the pump and motor.
 - c. Vertical split case design, bronze fitted construction with steel shaft, bronze or stainless steel shaft sleeves, bronze impeller, with impeller locked and keyed to shaft, and replaceable bronze casing wearing ring.
 - d. Pump shall not overload its motor on any point throughout the head capacity curve.
 - e. Provide flexible connectors on all base mounted pumps. Provide ball or butterfly valve on suction side and check valve, balance valve and gate valve on discharge side with check valve so located to be serviceable without draining system. Base mounted pumps installed above any occupied floor shall be mounted on concrete inertia bases.
4. Split Casing Pump (not preferred)
- a. Split case pumps shall be used for 500 gpm and greater applications.
 - b. Cast iron casing, flanged suction and discharge connections, motor pump connection of a non-metallic flexible coupler, regreaseable ball bearing lubrication system on both the pump and motor.
 - c. Horizontal split case design, bronze fitted with steel shaft bronze shaft sleeves, bronze impeller, casing wearing ring, and with impeller fixed in a positive position on the shaft.
 - d. Pump shall not overload its motor on any point throughout the head capacity curve.
 - e. Provide flexible connectors on all base mounted pumps. Provide ball or butterfly valve on suction side and check valve, balance valve and gate valve on discharge side with check valve so located to be serviceable without draining system. Base mounted pumps installed above any occupied floor shall be mounted on concrete inertia bases.
5. **SEE FOLLOWING PAGE FOR HYDRONIC PIPING SCHEDULE.**

HYDRONIC PIPING

SERVICE	PIPE SIZE	MINIMUM WORKING PRESSURE & TEMPERATURE	MATERIALS	JOINT	FITTINGS	UNIONS / FLANGES / COUPLINGS	GASKETS	MANUAL ISOLATION VALVES	EXPANSION		
Indoor, Aboveground Chilled Water and Condenser Water	4 inch and smaller	150 psig 200F	Copper ASTM AB88 Type L	Solder ASTM B 32, lead-free alloys. with water-flushable flux per ASTM B 813	Wrought-Copper Fittings: ASME B16.22	Wrought-Copper Unions: ASME B16.22.	----	Ball, Full port, two piece, bronze body, 300 CWP, stainless steel stem, PTFE or TFE seats, stainless steel vented ball. MSS SP-110. Soldered-joint ends.	Bronze hoses and single-braid bronze sheaths with 450 psig at 70 deg F and 340 psig at 450 deg F ratings. Copper-alloy fittings with solder-joint end connections.		
			Schedule 40 Carbon Steel ASTM A53 Grade B CW	Screwed	ANSI/ASTM B16.3, malleable iron Class 250	ANSI/ASTM B16.3, malleable iron Class 250	----	Ball, Full port, two piece, bronze body, 300 CWP, stainless steel stem, PTFE or TFE seats, stainless steel vented ball. MSS SP-110. Threaded ends.	Stainless-steel hoses and single-braid, stainless-steel sheaths with 450 psig at 70 deg F and 325 psig at 600 deg F ratings. Carbon-steel fittings with threaded end connections.		
	4 inch and larger	150 psig 200F	Schedule 40 Carbon Steel ASTM A53 Grade B ERW	Grooved	ASTM A 536, Grade 65-45-12 ductile iron with grooves or shoulders constructed to accept grooved-end couplings; with nuts, bolts, locking pin, locking toggle, or lugs to secure grooved pipe and fittings.	Ductile-iron housing and synthetic rubber gasket of central cavity pressure-responsive design; with nuts, bolts, locking pin, locking toggle, or lugs to secure grooved pipe and fittings.	Grade E EPDM	Butterfly, bi-directional ductile iron, Class 150316 SS stem and disc, polymer coated body. Bubble tight Shut-off. Conforms to MSS-SP67 and MSS-SP25. Lever operated for 4-inch and smaller. Wafer, lug or grooved for 2-1/2 to 4-inch. Gear Operated and double flanged for 6-inch and larger.	Stainless-steel hoses and single-braid, stainless-steel sheaths with 450 psig at 70 deg F and 325 psig at 600 deg F ratings. Carbon-steel fittings with threaded end connections.		
					Butt Welded ANSI/AWS D1.1	ASTM A234, forged steel Class 300				Class 300 steam forged steel slip-on flanges or weld – neck flanges for carbon steel	Spiral wind style, 316L metal winding strip, with flexible graphite filler and CS centering ring gaskets.
					Butt Welded ANSI/AWS D1.1	ASTM A234, forged steel Class 300				Class 300 steam forged steel slip-on flanges or weld – neck flanges for carbon steel	Spiral wind style, 316L metal winding strip, with flexible graphite filler and CS centering ring gaskets.
	Indoor, Aboveground Hot Water & Ethylene Glycol Heat Recovery Piping	4 inch and smaller	150 psig 200F	Copper ASTM AB88 Type L	Solder ASTM B 32, lead-free alloys. with water-flushable flux per ASTM B 813	Wrought-Copper Fittings: ASME B16.22	Wrought-Copper Unions: ASME B16.22.	----	Ball, Reduced port, two piece, bronze body, 300 CWP, stainless steel stem, PTFE or TFE seats, stainless steel vented ball. MSS SP-110. Soldered-joint ends.	Bronze hoses and single-braid bronze sheaths with 450 psig at 70 deg F and 340 psig at 450 deg F ratings. Copper-alloy fittings with solder-joint end connections.	
4 inch and larger		150 psig 200F	Schedule 40 Carbon Steel ASTM A53 Grade B ERW	Butt Welded ANSI/AWS D1.1	ASTM A234, forged steel Class 150	Class 150 steam forged steel slip-on flanges or weld – neck flanges for carbon steel	Spiral wind style, 316L metal winding strip, with flexible graphite filler and CS centering ring gaskets.	Butterfly, bi-directional ductile iron, Class 150, 316 SS stem and disc, polymer coated body. Bubble tight Shut-off. Conforms to MSS-SP67 and MSS-SP25. Lever operated for 4-inch and smaller. Wafer, lug or grooved for 2-1/2 to 4-inch. Gear Operated and double flanged for 6-inch and larger.	Stainless-steel hoses and single-braid, stainless-steel sheaths with 450 psig at 70 deg F and 325 psig at 600 deg F ratings. Carbon-steel fittings with threaded end connections.		
Indoor, Aboveground Make Up Water	4-inch and smaller	150 psig 200F	Copper ASTM AB88 Type L	Solder ASTM B 32, lead-free alloys. with water-flushable flux per ASTM B 813	Wrought-Copper Fittings: ASME B16.22	Wrought-Copper Unions: ASME B16.22.	----	Ball, Reduced port, two piece, bronze body, 300 CWP, stainless steel stem, PTFE or TFE seats, stainless steel vented ball. MSS SP-110. Soldered-joint ends.	----		
Indoor, Aboveground	4-inch and smaller	----	Copper ASTM AB88 Type M	Solder ASTM B 32, lead-free alloys. with water-flushable	Wrought-Copper Fittings: ASME B16.22	Wrought-Copper Unions: ASME B16.22.	----	----	----		

DIVISION 23 00 00—MECHANICAL

23 22 13—STEAM AND CONDENSATE HEATING PIPING

1. Notes:
 - a. Gasket material shall be 150# or 300# type, one-sixteenth inch (1/16") thick. For 300#, Flexitallic gaskets may be used.
 - b. All plugs for all services shall be brass.
 - c. Slip-on flanges will be acceptable at Contractor's option, where weld neck flanges are specified. Internal and external weld will be required.
 - d. Hex head bolts and nuts shall be used for flanged connections except on steam piping 126 psig to 250 psig where studs conforming to ASTM A-193 Grade B-7 with nuts conforming to ASTM A-194 Class 2H are required.
 - e. On piping 12 inches and above, standard wall pipe is acceptable in lieu of Schedule 40 pipe.
 - f. Steam mains and gravity condensate return mains shall pitch down one inch in fifty feet in the direction of steam flow. Steam line branches shall be taken off the top of the main at a 90o or 45o angle.
 - g. No water, steam, condensate, or air piping shall be installed in exterior walls without insulation. No water lines shall be installed above habitable spaces. These conditions should be avoided wherever possible.
2. Swing Check Valves
 - a. A. Swing Check Valves 2" and smaller shall be Class 125, 200 PSI WOG, Cast Bronze body and cap conforming to ASTM-B62. Valves shall be swing type design, threaded or solder ends.
 - b. Swing Check Valves 2-1/2" and larger shall be Class 125, 200 PSI WOG, Cast Iron Body, Bronze trim and bolted cap conforming to ASTM-A126, Class B. Flanged ends, swing type disc.
3. Steam Pressure Reducing Valve
 - a. Pilot-operated reducing valve
 - b. Cast iron construction
 - c. Rated for at least 250 psi service
 - d. Self-contained using inlet steam to operate the pilot
 - e. Diaphragms within the unit shall be constructed of phosphor-bronze or stainless steel
 - f. Pilot valve – cast iron body
 - g. Stainless steel diaphragms and inner valve spring and bronze bellows
4. Strainer
 - a. Screwed or flanges bodies corresponding to the Valve Schedule.
 - b. Constructed and rated for operating pressure as indicated, or higher.

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- c. Clean any strainer prior to the Balance contractor beginning his work and at the end of thirty and one hundred twenty days. Removing the basket and cleaning same.

Usage	Size	Model	Size
Steam System	Varies	Small	1/50"
		Large	3/64"

- d. Provided before any control valve and steam trap.
- e. Line size and not valve or trap inlet size.
5. Steam Trap
- a. Working parts constructed of non-corrosive material that can be removed and replaced if necessary without disturbing connecting piping.
 - b. Sized with continuous discharge capacity in the range of 2 to 3 times the maximum condensate load.
 - c. Inverted Bucket:
 - Medium to high pressure condensate 36-125 psig
 - Minimum 3/4"
 - Construction shall be steel, with stainless steel internal parts, rated for a 300-PSI operating pressure.
 - Provide access to internal parts without disturbing piping; with top test plug and bottom drain plugs, stainless steel bucket, stainless steel seats and plungers, and stainless steel lever mechanism with knife edge operating surfaces.
6. Float & Thermostatic Traps
- a. Low to medium pressure condensate 0-70 psig
 - b. ASTM A126, cast iron or semi-steel body and bolted cover for 250 psig WSP; provide access to internal parts without disturbing piping; with bottom drain plug, stainless steel air vent, stainless steel float, stainless steel lever and valve assembly.
7. Radiator traps are acceptable under radiation cover or inside unit ventilator enclosure.
8. Steam Condensate Pumps. The pump shall be pressure-powered type (Ductile Iron) or (Steel) pump operated by steam, which does not require any electrical energy and is sized to meet the actual maximum capacity of the system being drained. Body construction of ductile iron A395 or steel as required, with lift type check (Bronze) or Stainless Steel Disc Check valves for pumping liquids of specific gravity of 0.65 and above. The pump shall contain a float operated snap-acting mechanism with no external seals or packing and stainless steel trim, and hardened stainless steel mechanism bearing components. Pump to be provided with inlet and outlet check valves attached at factory for ease of field installation.
9. HIGH PRESSURE STEAM (HPS – GREATER THAN 35 PSIG)
- a. A steam main is defined as a steam line that serves a total building gross floor area

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greater than 150,000 gsf and is longer than 100 feet or back feeds another steam line that serves 150,000 gsf and is longer than 100 feet. All other steam lines shall be classified as steam branch lines.

- b. All steam mains shall be installed inside of a mechanical equipment room.
- c. All steam branch lines longer than 100 feet shall be a minimum of 8-inch and shall be valved and capped at the end of the branch for future extension.
- d. Isolation Valves shall be installed in the main loops at a minimum of every 300 feet and at every junction with another steam main to allow for isolation of a section of a failed steam main while back feeding the rest of the system.
- e. Criteria:
 - Normal Operating Pressure: 100 psig
 - Normal Operating Temperature: 338°F
 - Maximum Steam Velocity: 100 fps
 - Minimum Thermal Expansion Safety Factor: 1.50
- f. Insulation: per ASHRAE 90.1
- g. Jacketing: Aluminum 0.02-inch thick, smooth no vapor barrier
- h. Steam main drip traps shall be sized with a 2 times safety factor at full differential pressure and shall be provided every 200 feet or less.

10. PUMPED CONDENSATE (CPCR & PCR)

- a. Criteria:
 - Normal Operating Pressure: 25 psig
 - Normal Operating Temperature: 307°F
 - Maximum Velocity: 6 fps
 - Minimum Thermal Expansion Safety Factor: 1.50
- b. Refer to Pipe, Valve and Fitting Schedule.
- c. Insulation: per ASHRAE 90.1
- d. Jacketing: Aluminum 0.02-inch thick, smooth no vapor barrier
- e. Identification: PCR / CPCR / GCR every 50 feet.
- f. Refer to Steam Powered Condensate Pumps

11. HIGH PRESSURE STEAM CONDENSATE PIPING

- a. Criteria:
 - Normal Operating Pressure: 100 psig
 - Normal Operating Temperature: 338°F
- b. Refer to Pipe, Valve and Fitting Schedule.
- c. Insulation: per ASHRAE 90.1
- d. Jacketing: Aluminum 0.02-inch thick, smooth no vapor barrier
- e. Identification: HPC every 50 feet.

12. SEE NEXT PAGE FOR STEAM AND CONDENSATE HEATING PIPING SCHEDULE

STEAM AND CONDENSATE HEATING PIPING

SERVICE	PIPE SIZE	MINIMUM WORKING PRESSURE & TEMPERATURE	MATERIALS	JOINT	FITTINGS	UNIONS / FLANGES / COUPLINGS	GASKETS	MANUAL ISOLATION VALVES	EXPANSION
High Pressure Steam (35 to 125 psig)	2-1/2 inch and smaller	150 psig 400F	Schedule 80 Carbon Steel ASTM A53 Grade B Seamless	Butt Welded ANSI/AWS D1.1	ANSI/ASTM B16.3, malleable iron Class 250	ANSI/ASTM B16.3, malleable iron Class 250	----	Globe or Ball Valves, Class 300, Bronze, Stainless Steel Disc	Double Metal Bellows Externally Pressurized, 300 psig, Weld End with Anchor Base, Guide Rings, Drain Port & Plug.
	3 inch and larger	150 psig 400F	Schedule 80 Carbon Steel ASTM A53 Grade B Seamless	Butt Welded ANSI/AWS D1.1	ASTM A234, forged steel Class 300	Class 300 steam forged steel slip-on flanges or weld – neck flanges for carbon steel	Teflon style, 316L metal winding strip, with flexible graphite filler and CS centering ring gaskets.	Butterfly, Class 300 Carbon Steel Body, Gear Operator, 316 SS/ENP Disc with graduated RFTE seat, 316 SS Stem, Double Flanged.	Double Metal Bellows Externally Pressurized, 300 psig, Weld End with Anchor Base, Guide Rings, Drain Port & Plug.
Low Pressure Steam (0-35 psig)	2 inch and smaller	150 psig 400F	Schedule 80 Carbon Steel ASTM A53 Grade B ERW	Screwed	ANSI/ASTM B16.3, malleable iron Class 250	ANSI/ASTM B16.3, malleable iron Class 250	----	Globe or Ball Valves, Class 300, Bronze, Stainless Steel Disc	Stainless-steel hoses and double-braid, stainless-steel sheaths with 275 psig at 70 deg F and 200 psig at 600 deg F ratings. Carbon-steel fittings with threaded end connections.
	2 1/2 inch and larger	150 psig 400F	Schedule 80 Carbon Steel ASTM A53 Grade B ERW	Butt Welded ANSI/AWS D1.1	ASTM A234, forged steel Class 150	Class 150 steam forged steel slip-on flanges or weld – neck flanges for carbon steel	Teflon style, 316L metal winding strip, with flexible graphite filler and CS centering ring gaskets.	Butterfly, Class 300 Carbon Steel Body, Gear Operator, 316 SS/ENP Disc with graduated RFTE seat, 316 SS Stem, Double Flanged.	Stainless-steel hoses and double-braid, stainless-steel sheaths with 275 psig at 70 deg F and 200 psig at 600 deg F ratings. Carbon-steel fittings with flanged connections.
Pumped Steam Condensate (0 to 125 psig)	2 inch and smaller	150 psig 400F	Schedule 40 Stainless 316L, ASTM A312 Seamless	TIG Socket or Butt Welded	ASTM A351, Type 316L Stainless Steel	Class 150 stainless steel type 316L slip-on flanges or weld – neck flanges	Spiral wind style, 316L metal winding strip, with flexible graphite filler and stainless steel 316L centering ring gaskets.	Gate, stainless steel body, Class 800, ASME 16.34, body and bonnet of stainless steel, solid wedge disc, flanged ends	Double Metal Bellows Externally Pressurized, 300 psig, Weld End with Anchor Base, Guide Rings, Drain Port & Plug.
	2 1/2 inch and larger	150 psig 400F	Schedule 40 Stainless 316L, ASTM A312 Seamless	TIG Butt Welded	ASTM A351, Type 316L Stainless Steel	Class 150 stainless steel type 316L slip-on flanges or weld – neck flanges	Spiral wind style, 316L metal winding strip, with flexible graphite filler and stainless steel 316L centering ring gaskets.	Butterfly, Class 300 stainless steel body, gear operator, 316 SS/ENP disc with graduated RFTE seat, 316 SS stem, double flanged.	Double Metal Bellows Externally Pressurized, 300 psig, Weld End with Anchor Base, Guide Rings, Drain Port & Plug.
High Pressure Steam Condensate (35 to 125 psi)	2 inch and smaller	150 psig 400F	Schedule 80 Carbon Steel ASTM A-53 Grade B ERW	Screwed	ANSI/ASTM B16.3, malleable iron Class 250	ANSI/ASTM B16.3, malleable iron Class 250	----	Gate, Forged steel Class 800, ASME 16.34, body and bonnet of forged steel, solid wedge disc, flanged ends	Double Metal Bellows Externally Pressurized, 300 psig, Weld End with Anchor Base, Guide Rings, Drain Port & Plug.
	2 1/2 inch and larger	150 psig 400F	Schedule 80 Carbon Steel ASTM A53 Grade B ERW	Butt Welded ANSI/AWS D1.1	ASTM A234, forged steel Class 300	Class 300 steam forged steel slip-on flanges or weld – neck flanges for carbon steel	Teflon style, 316L metal winding strip, with flexible graphite filler and Stainless Steel 316L centering ring gaskets.	Gate, Forged steel Class 300, ASME 16.34, body and bonnet of forged steel, solid wedge disc, flanged	Double Metal Bellows Externally Pressurized, 300 psig, Weld End with Anchor Base, Guide Rings, Drain Port & Plug.
Gravity & Low Pressure Steam Condensate (less than 35 psig)	2 inch and smaller	150 psig 400F	Schedule 80 Carbon Steel ASTM A53 Grade B ERW	Screwed	ANSI/ASTM B16.3, malleable iron Class 250	ANSI/ASTM B16.3, malleable iron Class 250	----	Gate, Forged steel Class 800, ASME 16.34, body and bonnet of forged steel, solid wedge disc, flanged ends	Stainless-steel hoses and double-braid, stainless-steel sheaths with 275 psig at 70 deg F and 200 psig at 600 deg F ratings. Carbon-steel fittings with threaded end connections.
	2 1/2 inch and larger	150 psig 400F	Schedule 80 Carbon Steel ASTM A53 Grade B ERW	Butt Welded ANSI/AWS D1.1	ASTM A234, forged steel Class 150	Class 150 steam forged steel slip-on flanges or weld – neck flanges for carbon steel	Teflon style, 316L metal winding strip, with flexible graphite filler and Stainless Steel 316L centering ring gaskets.	Gate, Forged steel Class 300, ASME 16.34, body and bonnet of forged steel, solid wedge disc, flanged	Stainless-steel hoses and double-braid, stainless-steel sheaths with 275 psig at 70 deg F and 200 psig at 600 deg F ratings. Carbon-steel fittings with flanged connections.

DIVISION 23 00 00—MECHANICAL

23 25 00—HVAC WATER TREATMENT

1. For closed loop heating and chilled water system provide pot type bypass feeders.
2. For tower water system provide pump injection system to proportionally control chemical treatment and dissolved solids. System to include pump and piping system, corrosion coupon rack, control panel with pulse controllers, water meter, injection assembly, solenoid and manual control valves for bleed off. Use non-toxic chemicals approved by local and EPA requirements. The water treatment shall operate automatically with the chemical feed and blow down systems.

23 31 10—DUCTWORK

1. Ductwork shall be designed in accordance with ASHRAE: Handbook of Fundamentals, Duct Design Chapter, and constructed in accordance with the ASHRAE: HVAC Systems and Equipment Handbook, Duct Construction Chapter, and the SMACNA Design Manuals.
2. Energy consumption, security and sound attenuation shall be major considerations in the routing, sizing and material selection for the air distribution ductwork.
3. Supply and return air ducts shall be designed and constructed to allow no more than 3 percent leakage of total airflow in systems up to 3 inches WG. In systems from 3.1 inches WG through 10.0 inches WG ducts shall be designed and constructed to limit leakage to 0.5 percent of the total air flow.
4. Supply and return ductwork shall be sized using the equal friction method. Duct systems designed using the equal friction method place enough static pressure capacity in the supply and return fans to compensate for improper field installation and changes made to the system layout in the future.
5. In buildings with large areas of open plan space, the main duct shall be increased for revisions in future. Air flow diversity shall also be a sizing criterion. Full diversity can be taken at the air-handling unit and decreased the farther the ductwork is from the source until no air flow diversity is taken into account for the final portion of the system.
6. Ductwork shall be fabricated from galvanized steel, black iron, aluminum, or stainless steel depending upon applications and code requirements.
 - a. All roof mounted ductwork shall be all welded construction – aluminum or stainless and internally insulated in supply ductwork.
 - b. Outdoor intake ductwork shall be provided with a drain connection so designed and installed to permit water to run to drain. Pipe drain to nearest floor drain. Intake louvers shall be sized adequately to provide air not in excess of 400 FPM.
 - c. Laboratory Ductwork shall be Type 304 Stainless Steel with No. 4 mill finish.
 - d. Kitchen Exhaust Ductwork
 - Concealed – 16 gauge black iron
 - Exposed – No. 304 Stainless Steel with No. 4 mill finish.
 - All joints welded liquid tight.

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7. Insulated flexible duct shall be restricted to connections between the supply air diffusers and low-pressure supply air ductwork and connections between the air terminal units and the medium or high pressure supply air ductwork.
 - a. Flexible duct shall not be used on exposed ductwork in occupied areas.
 - b. Maximum length of flexible ductwork shall not exceed 5 ft. for air diffuser connections.
 - c. Maximum length of flexible ductwork shall not exceed 3 ft. for terminal unit inlet connections. Flexible connections to terminal unit inlets are not mandatory but allowed to accommodate minor offsets. Flexible ductwork shall not be directly connected to terminal units. The inlet duct collar of terminal units must have a section of straight duct connected a minimum of 3 times the diameter of the inlet.
 - d. Use rigid elbows for changes in directions greater than 45 degrees.
 - e. Do not penetrate firewalls and interstitial decks with flexible ducts.
8. Ductwork Accessories
 - a. Dampers
 - Individual damper blades shall not be over 48" long and axle centers are not to exceed 9". Maximum panel size shall be 48" wide by 72" high.
 - Damper, including frames, linkages, etc., in a special material duct shall be fabricated of the same materials as the duct unless otherwise noted.
 - Each panel 48" x 72" or less shall be provided with its own individual damper control motor.
 - b. Louver
 - Extruded from 0.081" thick extruded aluminum sections, equipped with one-half inch (1/2") bird screen in extruded aluminum frames. Drainable blade design.
 - Intakes. Maximum 500 FPM face velocity with less than 0.15" of water pressure drop. Minimum of forty-five percent (45%) free area, AMCA certified.
 - Exhausts. Maximum 1,000 FPM face velocity with less than 0.25" of water pressure drop. Minimum of forty-five percent (45%) free area, AMCA certified.
 - Install minimum 36" above grade.
 - c. Ductwork Access Door
 - Adjacent to each fire damper, smoke damper, automatic damper, both sides of coils, both sides of in-line fans, filter bank, and as necessary, double walled with 1" - 1-1/2 lb. insulation and cam latches, minimum size shall be 12" x 16". Duct is wider than thirty six inches (36"), two access doors shall be provided.
 - Access door in ductwork with pressure above 2" W.G. shall be access-vacuum relief unit.
 - Access door shall be labeled "FIRE DAMPER", "SMOKE DAMPER", or "COMBINATION SMOKE/FIRE DAMPER".
9. Backdraft Dampers
 - a. All backdraft dampers in curbs shall be all aluminum construction.
10. Smoke Dampers

DIVISION 23 00 00—MECHANICAL

- a. Tested and rated per UL 5555.
 - b. Minimum Class II leakage classification.
 - c. Electric/Electronic operation (pneumatic not acceptable).
11. Fire Dampers
- a. Tested and rated per UL-555.
 - b. Designed for dynamic operation.

23 34 23—HVAC POWER VENTILATOR

1. General
 - a. Fan shall be AMCA rated.
 - b. Belt driven unit, ½ horsepower and over, shall have at least double groove sheaves and dual belts. Drive to have a service factor of at least 125% of motor horsepower.
 - c. Disconnect switch supplied shall be horsepower rated per the National Electrical Code.
 - d. Vane axial fans shall not be used.
 - e. Provide a weatherproof disconnect switch on all roof exhaust fans to lock out unit for repair and/or service.
 - f. All toilet or shower room fans shall be completely non-corrosive in design. Avoid use of direct drive fans only belt drive on shower room exhaust. Ductwork and dampers shall be stainless steel.
 - g. Exhaust fans shall be located directly over pipe spaces wherever possible. When installed otherwise main duct shall have at least three turns or elbows before entering shaft.
 - h. All exhaust fans serving grease laden exhaust shall incorporate an integral grease trap with the fan construction. A secondary protection shall also be installed to protect the surrounding roof in case of a spill or overflow.

23 36 00—AIR TERMINAL UNITS

1. Direct digital control damper operators.
2. Pressure independent.
3. Fan powered terminals shall have the fan parallel to the primary airflow.
4. Maximum NC rating with 1" static pressure at inlet shall be 30 if 450 CFM or less, 35 if 451 to 800 CFM, and 45 if over 800 CFM, for both discharge and radiated noise with 10 dB deduct for room absorption and no allowance for a ceiling. Discharge noise shall be with free discharge and no duct connected to the terminal unit.
5. BAC-net IP protocol communication interface for tie-in to campus BAS.
6. Hydronic reheat coils (where applicable) shall be copper tube with mechanically bonded aluminum fins spaced no closer than 10 fins per inch (FPI) and include a manual air vent and drain valve.

23 50 00 – PRIMARY HEATING

DIVISION 23 00 00—MECHANICAL

1. All new buildings constructed between Drain St. to 8th St. and College St. and Marion St. shall be heated via the campus steam.
2. Heat Exchangers
 - a. Constructed in accordance with the ASME Code for 125 psig minimum working pressure and shall be so stamped.
 - b. Shell and tube type, “U” bend removable tube bundle, with water in the tubes and steam in the shell.
 - c. Provide unrestricted tube removal area on heat exchangers, etc. for removal and/or service.
 - d. Provide 1/3-2/3 steam capacity control to heat exchanger.
 - e. Maximum steam pressure to heat exchangers shall be 35 psi.
3. The use of electric resistance and/or electric boilers as the primary heating source for the building is prohibited. Design and layout of hydronic heating systems shall follow the principles outlined in the latest edition of the ASHRAE Systems and Equipment Handbook.
4. Boilers. Where connecting to the campus steam distribution is not feasible provide the following:
 - a. Provide two (2) natural gas-fired heating hot water boilers each sized for 100% of the peak heating load.
 - b. The boilers shall be high efficiency condensing type. Fire-tube condensing boilers shall be utilized (pulse type and copper fin are not acceptable). Heat exchanger shall be constructed of lower carbon stainless steel.
 - c. The system shall be designed and controlled to take advantage of low return water temperature for continuous operation within the boiler’s condensing region.
 - d. The heating hot water distribution system will be a variable-primary flow configuration with all coils utilizing two-way modulating control valves.
 - e. Two variable speed, in-line or base-mounted, primary hot water pumps will be piped to a common header and isolation valves shall be installed at each boiler to allow any pump to serve any boiler. One (1) pump to serve as full standby.
 - f. The heating hot water system shall utilize 100% water (no glycol).
5. Summer Heating Source: buildings shall be equipped with summer boilers or heat recovery chillers
6. Where finned tube radiation is used, the cover shall be minimum 16 gauge cold rolled steel, sloped top, constructed to permit installation without visible screws and supports at a maximum of four foot centers. Runtel or Panel Radiator type heating units may be used where applicable.
7. Cabinet unit heaters shall be installed at all entries serving major traffic areas. Counter flow units preferred.
8. Propeller unit heaters shall be used for Mechanical Rooms and Storage spaces.

23 60 00—PRIMARY COOLING

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1. The primary cooling system includes chillers, chilled water and condenser water pumps, cooling towers, piping and piping specialties.
2. The chilled water systems shall have a temperature differential between 10°F and 12°F for HVAC systems that primarily use fan coil units and 12°F and 16°F for HVAC systems that primarily use air handling units.
3. The chilled water system shall have a design supply water temperature between 40°F and 45°F.
4. Consideration shall be given to connecting to an existing or creating a new central chilled water cooling precinct in order to maximize energy efficiency and minimize maintenance cost.
5. Mechanical equipment rooms must be designed in accordance with the requirements of ASHRAE Standard 15: Safety Code for Mechanical Refrigeration. Chiller leak detection and remote alarming shall be connected to the BAS.
6. The baseline systems used for life cycle cost analysis shall be as follows:
 - a. Air cooled chillers for buildings with peak block cooling load less than 300 tons.
 - b. Water cooled centrifugal chillers shall be used for buildings with peak block cooling load greater than 300 tons. Air cooled chillers can be of centrifugal type. Due to the pricing points of equipment cost and installation the following is suggested for the life-cycle cost analysis baseline: For peak block cooling loads less than 200 tons, the chiller(s) shall be air cooled with digital scroll compressor(s). From 200 tons to 300 tons, the chillers shall be air cooled screw machines. From 300 to 450 tons, the chillers shall be water cooled centrifugal machines and approved by APSU. Above 450 tons, the chillers shall be water cooled centrifugal machines.]
 - c. Chillers shall be specified in accordance with the latest Air-conditioning and Refrigeration Institute (ARI) ratings procedures and latest edition of the ASHRAE Standard 90.1. Minimum chiller efficiency shall comply with ASHRAE 90.1.
 - d. Integrated part load chiller efficiency shall comply with ASHRAE 90.1.
7. Part load efficiency must be specified in accordance with ARI Standard 550/590.
8. A minimum of two equally sized chillers at 67 percent of the peak capacity (each) shall be provided. All units shall have adequate valving to provide isolation of the off-line unit without interruption of service.
9. In retrofits where limited space exists for two chillers, a single chiller with two compressors and two independent circuits may be considered.
10. Chillers shall be piped to a common chilled water header with provisions to sequence chillers on-line to match the load requirements. All required auxiliaries for the chiller systems shall be provided with expansion tanks, heat exchangers, water treatment and air separators, as required.
11. If multiple chillers are used, automatic shutoff valves shall be provided for each chiller.
12. Chiller condenser piping shall be equipped with recirculation/bypass control valves to maintain incoming condenser water temperature within chiller manufacturer's minimum.

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13. Refrigeration machines must be equipped with isolation valves, fittings and service apertures as appropriate for refrigerant recovery during servicing and repair, as required by Section 608 of the Clean Air Act, Title VI. Chillers must also be easily accessible for internal inspections and cleaning.

23 62 13—AIR COOLED REFRIGERANT CONDENSERS

1. Selected for operating in 95°F ambient conditions
2. Evaporator – seamless copper tubes, roller-expanded into tube sheets. Refrigerant side working pressure of 225 psig, water side working pressure of 150 psig.
3. Condenser coils shall have configured aluminum fins mechanically bonded to seamless copper tubing, leak tested with air under water at 425 psig air pressure.
4. Decorative grilles shall provide protection from exterior damage for coil surface.
5. Starter shall be a Delta-Wye starter.
6. Scroll or screw compressor – screw machine provided with capacity control slide valve, rolling element bearings, differential refrigerant pressure oil pump and oil heater.
7. One (1) year warranty, extended four (4) year warranty for the refrigeration compressors, for compressor replacement only.
8. Capable of operation to 40°F ambient, provided with a flow switch and suction and discharge gauges.
9. Only non-HCFC refrigerants such as R-134a, R407c or R410a shall be specified.
10. BAC-net IP protocol communication interface for tie-in to campus BAS.
11. Manufacturer shall provide start-up supervision.
12. Manufacturer shall provide one (1) year service and maintenance, with a 5-year warranty option.

23 64 16—CENTRIFUGAL WATER CHILLER & 236426—ROTARY-SCREW WATER CHILLER

1. Selection shall be based upon a scale factor of 0.00010 in the evaporator and 0.00025 in the condenser.
2. Evaporator and condenser shall have marine water boxes with drains.
3. Auxiliary water piping for the oil cooler and purge system will be provided by the Mechanical Contractor.
4. Include a device for setting maximum current flow to any point between forty percent and one hundred percent of full load amperes.
5. Factory mounted and wired control panel, which shall include safety controls, operating controls, and an operator interface.
6. Units shall use a non-HCFC such as R134A as the refrigerant.
7. Units shall utilize variable speed compressors.
8. Interconnecting wiring between controls and power wiring from control panel to oil pump shall be included.
9. Unit shall also be provided with factory installed anti-sweat insulation on all surfaces.

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10. Provide vibration isolation pads for the unit.
11. Provide unrestricted tube removal area on chillers, for removal and/or service.
12. BAC-net IP protocol communication interface for tie-in to campus BAS.
13. Complete factory assembled unit shall include all necessary refrigerant piping, valves and fittings to interconnect compressor, condenser, evaporator and all necessary gauge piping.
14. Manufacturer shall provide start-up supervision.
15. Manufacturer shall provide one (1) year service and maintenance.
16. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace components of water chillers which fail in materials or workmanship: 5 year full parts and labor on compressor, compressor motor, bearing and variable speed drive. Warranty commences upon completion of manufacturer's documented start-up procedures.

23 65 00—COOLING TOWERS

1. All water-cooled condensers must be connected to a recirculating heat-rejecting loop. The heat rejection loop system shall be designed for a 10°F temperature differential and a minimum of 7°F wet bulb approach between the outdoor air temperature and the temperature of the water leaving the heat rejection equipment. Heat tracing shall be provided for piping exposed to weather and for piping down to 0.9 m (3 ft) below grade.
2. Induced draft cooling tower with remote condenser water storage shall be baseline design.
3. The cooling tower shall be supplied with no less than the following features:
 - a. Cold water basin to be welded and constructed of 304 Stainless Steel or 301L Stainless Steel.
 - b. Hot water basins to be constructed of 304 Stainless Steel or 301L Stainless Steel.
 - c. Structure and fan deck to be constructed of 304 Stainless Steel or 301L Stainless Steel.
 - d. Framing and casing panels deck to be constructed of 304 Stainless Steel or 301L Stainless Steel.
 - e. Louvers to be constructed of fiberglass reinforced polyester.
 - f. Close coupled banded belt drives or gearbox.
 - g. Each cell to be equipped with a single fan and inverter duty motor controlled by a variable frequency drive.
 - h. Single inlet piping connection (one connection per cell) with integral stainless steel strainer.
 - i. Single outlet connection (one connection per cell) with stainless steel suction strainer with anti-cavitation device.
 - j. Conductance actuated electric water level controls with solenoid valve controls required for operation of solenoid valve plus low level alarm circuit.
 - k. Vibration cutout switch (one per cell, mounted).
4. Handrail, ladders and platforms. Provide the following field installed accessories:

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- a. Internal plenum walkway for ease of access to motors, drives and vibration switches. Provide internal ladder with elevated service platform (required when each cooling tower cell is two-piece, top and bottom).
 - b. Provide air intake screens to prevent birds and large debris from entering towers.
 - c. Provide ships ladder to allow access to top of fan deck.
 - d. Handrails: Aluminum complying with 29 CFR 1910.23. Provide handrail around perimeter of fan deck.
 - e. Ladders and Safety Cages: Aluminum complying with 29 CFR 1910.27. Provide internal ladders to fan decks.
 - f. Vibration Isolation Rails: Zinc coated, epoxy painted spring type with stainless steel nuts and bolts.
 - g. Platforms: Aluminum with a bar grating floor.
5. Control panel (shipped loose) in stainless steel weatherproof enclosure consisting of no less than a non-fused flange mounted disconnect switch, starters and fusing for all fan motors, contactors and fusing for basin heaters (if applicable), terminal strip for all field control wiring, control transformer fused both primary and secondary, electronic thermostat with sensor and bulb well, Hand-Off-Auto switches with pilot lights for all operating devices, and all necessary relays required for automatic operation.
 6. Provide the following to allow for proper maintenance of the cooling tower:
 - a. Hose bibb.
 - b. GFCI
 - c. Lighting
 7. All drains and overflows must be hard piped to a roof drain. Drain and overflows shall be copper or galvanized piping.
 8. For multiple cooling tower cell installations, all of the cells shall be connected by a piped equalization connection. Equalizing weir gates shall not be permitted.
 9. Provide louvered screen wall and epoxy painted platform and supports.
 10. Water fill and drain lines shall be heat traced.

23 73 13—MODULAR INDOOR CENTRAL-STATION AIR HANDLING UNITS

1. All Air Handlers shall be indoor type located in Mechanical Equipment Rooms. Air handlers shall be variable volume and shall incorporate chilled water coils, hot water coils, filters, double wall cabinet construction and a mixing box. Return air carbon dioxide monitoring will be provided on all air handling systems to ensure adequate ventilation air is provided. Areas with occasional high density occupancy such as large lecture halls and dining areas shall utilize CO2 monitoring to reset the minimum ventilation quantity.
2. All ventilation air intakes shall be located at the 2nd floor level or higher and shall be located away from loading docks.

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3. The VAV supply fan shall be designed for the largest block load, not the sum of the individual peaks. The air-handling unit and associated VAV terminals or fan-powered terminals shall have self-contained microprocessor
4. Air handling systems utilizing 15% or greater outside air shall have integral face and by-pass dampers to avoid freeze-up. Heating coils shall have two position control valves in conjunction with the above.
5. Utilize mixing box air shelves, air blenders and/or blow-thru cooling coils to minimize outside air stratification and nuisance freezestat trips. Air blenders shall be capable of providing a minimum mixing effectiveness of 80% when mixing 50% of minus 5°F cold air with 50% of 70°F warm air.
6. Diffusers / Evases: Diffusers or an evase shall be provided on all air handling units with coils in the blow-thru position to distribute the fan discharge air evenly across the upstream coil.
7. Double wall steel insulated casing, removable panels in fan and coil sections.
8. Drain pans shall be made of stainless steel, insulated and adequately sloped and trapped to assure drainage. Drains in draw-through configurations shall have traps with a depth and height differential between inlet and outlet equal to the design static pressure plus 12 inch minimum.
9. Supply and Return Fans.
 - a. Centrifugal double-width double-inlet forward curved and airfoil fans are preferable for variable volume air handlers.
 - b. All fans shall bear the AMCA seal and performance shall be based on tests made in accordance with AMCA Standard 210.
 - c. Fans shall be selected on the basis of required horsepower as well as sound power level ratings at full load and at part load conditions.
 - d. Fan motors shall be sized so they do not run at overload anywhere on their operating curve. Fan operating characteristics must be checked for the entire range of flow conditions, particularly for forward curved fans.
 - e. Fan drives shall be selected for a 1.5 service factor and fan shafts shall be selected to operate below the first critical speed. Thrust arrestors shall be designed for horizontal discharge fans operating at high static pressure.
 - f. Bearing shall be self-aligning, grease lubricated, ball type with extended lubrication fittings.
 - g. All units shall be controlled by a variable speed drive and shall utilize premium efficient inverter duty motors.
10. Coils.
 - a. Individual finned tube coils shall generally be between six and eight rows with at least 2.1 mm between fins (12 fins per inch) to ensure that the coils can be effectively and efficiently cleaned.
 - b. Water heating and cooling coils constructed of copper tubes with mechanically bonded aluminum fins.

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- c. Provide unrestricted coil removal area on air handling units for removal and/or service.
- d. All heating and cooling coils shall be completely drainable without the use of any supplemental equipment.
- e. Maximum velocity through cooling coils and filters is 500 fpm and through heating coils is 650 fpm.

11. Filters.

- a. Air Handling Units
 - Pre-filters shall have a minimum efficiency of 30-35% (MERV 7) per ASHRAE Standard 52.
 - After-filters shall have a minimum efficiency of 89-90% (MERV-13) per ASHRAE Standard 52.
- a. Ventilation Air Handling Units (100% / Dedicated Outdoor Air)
 - Pre-filters shall have a minimum efficiency of 30-35% (MERV-7) per ASHRAE Standard 52.
 - After-filters shall have a minimum efficiency of 60-65% (MERV-11) per ASHRAE Standard 52.
- b. When applicable, and upon consultation with the University, utilize Viledon brand type pocket filters.
- c. All filters shall be pleated throw away type.
- d. Provide dirty filter gauge, magnehelic type, on each unit or system where filters are installed
- e. All air filters shall be readily accessible.
- f. Mechanical Contractor shall replace all filters and clean all strainers at completion of his contract and before final inspection. He shall further provide one spare set of new filters for each air handling device and turn over to University at final inspection.

12. Mixing Section.

- a. Outside air and return air dampers shall be low-leakage construction.
- b. The outside air and return air inlets to the air handler shall be configured to maximize minimize the potential for stratification of outside air.
- c. Air handler systems shall incorporate economizer sequences.

13. Energy Recovery.

- a. Air handling units shall incorporate a heat recovery system to be in compliance with ASHRAE Standard 90.1 and elsewhere found cost-effective based on life-cycle cost analysis.
- b. Energy recovery for air handling units serving typical university occupant spaces (i.e. offices, classrooms, etc.) shall be desiccant (enthalpy) heat wheels.
- c. Energy recovery devices shall be evaluated for air handling units serving laboratories. Devices include run-around coils, heat pipes, and fixed-plate (air-to-air) systems.

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- d. Heat recovery equipment must operate at a minimum of 70% efficiency at winter and summer outdoor design conditions.
 - e. Heat recovery equipment (wheels, coils, etc.) shall be protected by a minimum of 50-55% (MERV-10) filtration.
 - f. Air handling units incorporating energy recover must meet ASHRAE 62.1 requirements. Requirements include but are not limited to those of air classification and recirculation.
 - g. Desiccant (enthalpy) wheels must incorporate a purge device and variable-speed drives for controlling the enthalpy wheel.
 - h. Do not include any load credit due to savings in cooling and heating energies while sizing and selecting the cooling, heating, and airside equipment.
14. Access Doors. Access doors shall be provided at air-handling units downstream of each coil, upstream of each filter section and adjacent to each drain pan and fan section. Access doors shall be of sufficient size to allow personnel to enter the unit to inspect and service all portions of the equipment components.

23 80 00—VARIABLE SPEED MOTOR CONTROLLER

- 1. Description: NEMA ICS 2, IGBT, PWM, VFC; listed and labeled as a complete unit and arranged to provide variable speed of an NEMA MG 1, Design B, 3-phase induction motor by adjusting output voltage and frequency.
 - a. Provide unit suitable for operation of premium-efficiency motor as defined by NEMA MG 1.
- 2. Design and Rating: Match load type such as fans, blowers, and pumps; and type of connection used between motor and load such as direct or through a power-transmission connection.
- 3. Output Rating: 3-phase; 6 to 60 Hz, with voltage proportional to frequency throughout voltage range.
- 4. Any motor ≥ 5 hp shall be a VFD.
- 5. Unit Operating Requirements:
 - a. Input ac voltage tolerance of 380 to 500 V, plus or minus 10 percent.
 - b. Input frequency tolerance of 50/60 Hz, plus or minus 6 percent.
 - c. Minimum Efficiency: 96 percent at 60 Hz, full load.
 - d. Minimum Displacement Primary-Side Power Factor: 96 percent.
 - e. Overload Capability: 1.1 times the base load current for 60 seconds; 2.0 times the base load current for 3 seconds.
 - f. Starting Torque: 100 percent of rated torque or as indicated.
 - g. Speed Regulation: Plus or minus 1 percent.
- 6. Isolated control interface to allow controller to follow control signal over an 11:1 speed range.
 - a. Electrical Signal: 4 to 20 mA at 24 V.
- 7. Internal Adjustability Capabilities:
 - a. Minimum Speed: 5 to 25 percent of maximum rpm.
 - b. Maximum Speed: 80 to 100 percent of maximum rpm.

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- c. Acceleration: 2 to a minimum of 22 seconds.
- d. Deceleration: 2 to a minimum of 22 seconds.
- e. Current Limit: 50 to a minimum of 110 percent of maximum rating.
- f. Self-Protection and Reliability Features:
 - Input transient protection by means of surge suppressors.
 - Under- and overvoltage trips; inverter overtemperature, overload, and overcurrent trips.
 - Motor Overload Relay: Adjustable and capable of NEMA ICS 2, Class 10 performance.
 - Notch filter to prevent operation of the controller-motor-load combination at a natural frequency of the combination.
 - Instantaneous line-to-line and line-to-ground overcurrent trips.
 - Loss-of-phase protection.
 - Reverse-phase protection.
 - Short-circuit protection.
 - Motor overtemperature fault.
8. Automatic Reset/Restart: Attempts three restarts after controller fault or on return of power after an interruption and before shutting down for manual reset or fault correction. Bidirectional autospeed search shall be capable of starting into rotating loads spinning in either direction and returning motor to set speed in proper direction, without damage to controller, motor, or load.
9. Torque Boost: Automatically varies starting and continuous torque to at least 1.5 times the minimum torque to ensure high-starting torque and increased torque at slow speeds.
10. Motor Temperature Compensation at Slow Speeds: Adjustable current fall-back based on output frequency for temperature protection of self-cooled, fan-ventilated motors at slow speeds.
11. Input Line Conditioning: The VFC shall have a DC link reactor to minimize power line harmonics. VFCs without a DC link reactor shall provide a 3% impedance line reactor.
12. Status Lights: Door-mounted LED indicators shall indicate the following conditions:
 - a. Power on.
 - b. Run.
 - c. Overvoltage.
 - d. Line fault.
 - e. Overcurrent.
 - f. External fault.
13. Panel-Mounted Operator Station: Start-stop and auto-manual selector switches with manual speed control potentiometer and elapsed time meter.
14. Indicating Devices: Meters or digital readout devices and selector switch, mounted flush in controller door and connected to indicate the following controller parameters:
 - a. Output frequency (Hz).

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- b. Motor speed (rpm).
 - c. Motor status (running, stop, fault).
 - d. Motor current (amperes).
 - e. Motor torque (percent).
 - f. Fault or alarming status (code).
 - g. PID feedback signal (percent).
 - h. DC-link voltage (VDC).
 - i. Set-point frequency (Hz).
 - j. Motor output voltage (V).
15. Control Signal Interface:
- a. Electric Input Signal Interface: A minimum of 2 analog inputs (0 to 10 V or 0/4-20 mA) and 6 programmable digital inputs.
 - b. Remote Signal Inputs: Capability to accept any of the following speed-setting input signals from the BMS or other control systems:
 - 0 to 10-V dc.
 - 0-20 or 4-20 mA.
 - Potentiometer using up/down digital inputs.
 - Fixed frequencies using digital inputs.
 - RS485.
 - Keypad display for local hand operation.
 - c. Output Signal Interface: A minimum of 1 analog output signal (0/4-20 mA), which can be programmed to any of the following:
 - Output frequency (Hz).
 - Output current (load).
 - DC-link voltage (VDC).
 - Motor torque (percent).
 - Motor speed (rpm).
 - Set-point frequency (Hz).
 - d. Remote Indication Interface: A minimum of 2 dry circuit relay outputs (120-V ac, 1 A) for remote indication of the following:
 - Motor running.
 - Set-point speed reached.
 - Fault and warning indication (overtemperature or overcurrent).
 - PID high- or low-speed limits reached.
 - e. Communications: Factory-installed hardware and software to enable BAC-net IP protocol interface with building management system.
 - f. Serial communication capability shall include, but not be limited to, run-stop control; speed set adjustment, proportional/integral/derivative PID control (Set Point)

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adjustments, current limit, and accel/decel time adjustments. The drive shall have the capability of allowing the DDC to monitor feedback such as process variable feedback, output speed/frequency, current (in amps), % torque, power (kW), kilowatt hours (resettable), operating hours (resettable), relay outputs, digital inputs and diagnostic warning and fault information. Additionally, remote (LAN) VFC fault reset shall be possible. A minimum of 15 field parameters shall be capable of being monitored.

- g. The VFC shall allow the DDC to control the drive's digital and analog outputs via the serial interface. The serial communications interface shall allow for DO (relay) control and AO (analog) control without being tied to a VFC function. In addition, all drive digital and analog inputs shall be capable of being monitored by the DDC system.
16. Integral Disconnecting Means: NEMA KS 1, nonfusible switch with lockable handle.
17. Isolating Switch: Non-load-break switch arranged to isolate VFC and permit safe troubleshooting and testing, both energized and de-energized, while motor is operating in bypass mode.
18. Remote Indicating Circuit Terminals: Mode selection, controller status, and controller fault.
19. NEMA 250, Type 1 enclosure.
20. Accessories:
 - a. Devices shall be factory installed in controller enclosure, unless otherwise indicated.
 - b. Microprocessor based Bypass Controller - Automatic transfer to line power via contactors. A keypad to control the bypass controller is to be mounted on the enclosure door. The bypass keypad shall include a one line diagram and status LEDs to indicate the mode of operation, drive and bypass status and ready & enable conditions. When in the "Normal" mode, the bypass contactor is open and the drive output contactor is closed. In the "Test" position, the drive output contactor is open, in the "Bypass" position, the drive output contactor is open, and the bypass contactor is closed via Start/stop command. Start/stop via customer supplied maintained contact shall be 24V or 115V compatible and shall function in both the "Normal" and "Bypass" mode. The voltage tolerance of the bypass power supply shall be +30/-35% to eliminate the problem of contactor coil burnout. The design shall include single-phase protection in both the VFC and bypass modes.
 - c. Push-Button Stations, Pilot Lights, and Selector Switches: NEMA ICS 2, heavy-duty type.
 - d. Stop and Lockout Push-Button Station: Momentary-break, push-button station with a factory-applied hasp arranged so padlock can be used to lock push button in depressed position with control circuit open.
 - e. Control Relays: Auxiliary and adjustable time-delay relays.
 - f. Standard Displays:
 - Output frequency (Hz).
 - Set-point frequency (Hz).
 - Motor current (amperes).
 - DC-link voltage (VDC).
 - Motor torque (percent).

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- Motor speed (rpm).
 - Motor output voltage (V).
- g. Historical Logging Information and Displays:
- Real-time clock with current time and date.
 - Running log of total power versus time.
 - Total run time.
 - Fault log, maintaining last four faults with time and date stamp for each.
21. Factory Finishes. Metal cabinets must be painted with Manufacturer's standard paint applied to factory-assembled and tested VFCs before shipping.

23 81 23—COMPUTER ROOM AIR-CONDITIONERS

1. Computer Room Air-Conditioners (CRAC) units shall be designed to allow 24-hour operations.
2. Full redundancy shall be incorporated into the CRAC unit design by either providing separate systems or by providing a dual-source system (i.e. DX and Chilled Water) and including multiple fans.
3. CRAC units shall be placed on emergency power.
4. The controls shall be DDC, be capable of operating as stand-alone and shall send all alarm signals to the building management system.

23 81 26—VALANCE HEATING UNITS

1. Radiant ceiling panels shall be made of extruded aluminum panels with copper tubing mechanically fastened to the aluminum extrusion.
2. Insulation shall be placed on the top (plenum) side of the radiant panel installation.
3. Multiple panels may be piped in series with similar thermal loads.

23 82 19—FAN COIL UNITS

1. Fan coil units must be certified under the AHRI Standard Certification Program and must carry the AHRI seal.
2. Fan coil system design shall be based on a 4-pipe configuration, capable of providing on-demand heating or cooling. Fan coil units serving cooling-only rooms (i.e. elevator machine rooms, communications rooms, etc.) shall be 2-pipe units.
3. Fan coil units can be used in vertical, floor-mounted or in horizontal, ceiling-suspended (recessed or concealed) configuration with supply and return duct as required.
4. Select fan coil units to deliver the required capacity at mid-speed. With ceiling-suspended fan coil units, provide acoustic lining in the return air duct (if required) and an acoustic enclosure to dampen the radiated noise.
5. Units shall have DDC controls.

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6. Chilled water and heating water valves shall be two-way modulating control valves wherever variable-speed water flow devices are to be used in the system.
7. Filters shall be the manufacturer's premium filters and no less than a MERV-7 rating.
8. For above ceiling concealed installations provide a secondary condensate pan and condensate overflow switch.

23 82 45—CHILLED BEAMS

1. Chilled beams may be 2-pipe (cooling only) or 4-pipe (cooling/heating) depending on the application and space load.
2. Chilled water and heating water valves shall be two-way modulating control valves and variable-speed pumping is to be used in the system.
3. Active and/or passive chilled beams are acceptable depending on the type of space load and should be selected for the space application.
4. The beam chilled water shall be sized and controlled to a minimum of 2°F above the maximum space dew point. A condensation prevention strategy such as beam chilled water reset, moisture sensor, or temperature/humidity sensors shall be implemented.
5. Chilled beams lengths, nozzle sizing, beam chilled water temperature, primary supply air flow (active beams), primary supply air temperature (active beams), primary supply air relative humidity (active beams), and beam chilled water flow shall all be selected using an iterative selection (beam sizing) process to provide optimal (and balanced) performance in all areas including space conditioning, noise generation, and energy efficiency.

23 4 000—Variable Refrigerant Flow Systems

1. Variable refrigerant flow (VRF) systems may be either a 2-pipe or 3-pipe system.
2. In some instances, the application may require simultaneous heating and cooling and the VRF system shall be selected to accommodate this requirement.
3. Refrigerant compressors shall be inverter / variable capacity style using R410a type refrigerant.

End of Section