UT Mechanical Design Criteria

APPENDIX CONTENTS

A4.1 GENERAL HVAC CRITERIA

Specific requirements for heating, ventilating, and air conditioning are given in many of the statements set forth in the individual space requirements for the facility. These requirements must be met.

The building HVAC system must provide suitable environmental conditions for the comfort of the users. System flexibility is essential. Occupancy of the building will vary extensively.

System selection must be based on functional performance, flexibility, reliability, life cycle cost, maintenance and service, and energy consumption. None of these items singularly should be the sole criterion for selection of the system.

Equipment should be selected for long range operation and reliability. Systems employing packaged or unitary equipment are generally not desirable. Typically, HVAC equipment in University facilities should be selected for a 25-30 year life span. Equipment should be practical, off-the-shelf technology and generally readily available from at least two manufacturers.

Maximum efficiency in energy is required. Equipment efficiency, proper insulation, and system control and operation are important parameters. Systems that employ heating and cooling simultaneously in order to achieve comfort conditions within a space generally will not be permitted. The requirements for each space within the building should be addressed and the composite of those requirements taken into account in the design.

Comply with **ASHRAE Standard 90.1-2010** and with State of Tennessee High Performance Building Requirements (HPBr) 2015 v1.01Manual.

Environmental factors have a significant impact on building users. The mechanical system must provide the proper environment for effective concentration and efficiency. Space temperature requirements are important and must be met.

Most importantly, the design should follow the engineering philosophy expressed by Albert Einstein, "Everything should be made as simple as possible, but not simpler."

A4.2 SOURCE OF HEATING/COOLING

A. UT Knoxville: Space and domestic water heating are to be provided from the campus steam distribution system. Centrifugal or air cooled screw or scroll chillers should be provided for cooling. The designer should consult Facilities Planning to determine if future cooling plant capacity may by required to service surrounding buildings.

B. UT Chattanooga: Space and domestic water heating and building chilled water are to be provided from the campus HTHW and chilled water distribution systems. Capacity of existing distribution pumps at the Central Plant must be verified.

C. UT Martin and UTHSC: Space and domestic water heating and building chilled water are to be provided from the campus steam and chilled water distribution systems.

D. UT Space Institute: Provide HVAC equipment appropriate for the application.

A4.3 DESIGN CONDITIONS

A. Inside Design Conditions:

1. Cooling: 75°FDB; 50% R.H.
2. Heating: 72°FDB.

B. Outside Design Conditions:

1. Summer: 95°FDB; 78°FWB. Cooling towers should be specified and selected for ambient conditions of 80°FWB. Roof mounted air cooled equipment shall be selected for 100°FDB.
2. Winter: 0°FDB.

A4.4 VENTILATION REQUIREMENTS

Provide a minimum quantity of ventilation air consistent with physiological needs, exhaust make-up, and infiltration neutralization.

Comply with **ASHRAE Standard 62.1-2013**.

Ventilation air is to be introduced through the air handling units by activation of the minimum outside air damper when the supply fan is started.

A4.5 AIR DISTRIBUTION

A. Design:

1. Air distribution must be uniform as possible; temperature variation in the space should not exceed 2°F.
2. There is a definite preference for ducted return air systems; plenum return systems are to be avoided.

3. Mechanical rooms are not to be used as return or outside air plenums.
4. Noise levels generally should not exceed NC 35. Sound and vibration control may be required for both equipment and duct systems.
5. Wall louvers shall be fixed blade type with insect or bird screen as appropriate. Avoid using adjustable blade louvers.
6. There is a definite preference for motor operated dampers at exhaust/relief air louvers or fans. Avoid using gravity dampers at these locations.

B. Registers, Grilles, and Diffusers

1. Locate air outlets to provide a proper throw, drop, and spread at or above 20 fpm minimum and 75 fpm maximum room velocity. In general, range of supply air outlet velocities should be 500-750 fpm, and return and exhaust inlet face velocities should be 300-500 fpm.
2. Grilles, registers, and diffusers should be selected for compatibility with room ceilings, walls, and finishes. Supply air should generally be introduced through round neck, louvered-face ceiling diffusers. Dampers, where provided with diffusers, should be radial type. Slot diffusers, bar grilles, flow bars and light troffer diffusers may be appropriate for some applications.
3. Do not use perforated ceiling diffusers or return or exhaust registers. Avoid supply air diffusers with metal filler panels.
4. The mechanical plans must show size and air quantity for each diffuser (neck and face size), register, and manual balancing damper on the plan. An air distribution schedule must be provided. Do not indicate size and air quantity range on the schedule.
5. Ceiling return and exhaust air registers and grilles are to be grid core type, the same color as the ceiling. Return air registers should be located near the exterior wall of the space served. Provide minimum ½" thick acoustical duct liner in return air ducts when run-outs to return air registers and grilles are shorter than five feet. Ducts serving RA or exhaust air ceiling registers should be sized to accommodate the full face of the register, in most cases at least 24". Do not provide round or flex duct to serve RA or exhaust air ceiling registers.

C. Ductwork

1. Low pressure ductwork must be constructed and erected in accordance with SMACNA "HVAC Duct Construction Standards". Do not provide fibrous duct. Supply and return air ducts should generally be wrapped with glass fiber insulation. With the exception of exhaust to heat recovery devices, do not insulate exhaust ducts.

   Joints in low pressure supply air ducts located in nonconditioned spaces, other than "Ductmate" systems, are to be sealed using Hardcast pressure-less tape with RTA-50 adhesive, or an equivalent product.

   Rectangular branch take-offs should be the 45° tap-in type. Splitter dampers, extractors, and scoops are generally counterproductive. Provide bellmouth fittings for round duct take-offs.

   Duct elbows are to be the full radius type, r/D = 1.5. Radius ells with square throats are not acceptable. Where mitered 90° elbows are necessary, provide with factory-made turning vanes, constructed in accordance with SMACNA HVAC Duct Construction Standards, Fig. 2-3.

   Provide manual volume dampers with minimum 20 gauge thickness blades in ducts where required for proper adjustment and balancing of air flows.
2. Medium and high pressure ducts are generally to be factory-fabricated double-wall round or flat oval with factory insulation and perforated liner. Double wall fittings should be fully

welded. Take-offs are to be the conical type. Adapters are to be provided where double-wall duct transitions to a single wall duct. Factory elbows are to be full radius, 1.5r/D type. Provide divided flow fittings where required. Joints should be sealed with Hardcast tape and adhesive, or a similar product. Specify ducts to be leak tested in accordance with United Sheet Metal's "System Pressure Testing for Leaks" procedure.

3. Flexible duct with 1" thick insulation should generally be provided to connect supply air diffusers to main or branch ducts. Include applicable duct pressure in the specifications. Limit duct length to 4 feet. Ducts must be installed without kinks or sags and supported with ¾-in. wide metal bands. The minimum inside radius of any bend should be one-half the diameter of the duct. Do not use flexible duct for return or exhaust air register connections.

4. Access doors must be provided in ducts for access and inspection of filters, heating coils, sound attenuators, control dampers, fire and smoke dampers, humidifiers, air flow stations, etc. In addition, provide doors within reach of obstructions such as turning vanes and dampers and at approximately every 20 feet in long ducts for cleaning and maintenance if no other means of access is available. Doors should be as large as practical and be able to be opened or removed without the use of tools.

   Coordinate location of the access panels for service access to mechanical equipment including valves, dampers, coils, VAV boxes, fan coil units, etc. in concealed spaces with architect. Provide a minimum 24"×24" access panel in inaccessible ceilings and walls where needed for access to this equipment.

5. Mechanical plans must show all duct fittings. **Ducts, etc. must be drawn to scale**. With the exception of flexible runouts, do not single-line ductwork. Use standard drafting conventions for turns, joints, changes in size, drops or rises, crossings above and below one another, etc.

6. Size ducts serving ceiling return or exhaust air registers for full face opening of register. Do not serve with round or flex duct.

7. Branch ducts serving VAV boxes should be maintained at 2-1/2 diameters straight duct at the entrance to the box, and final connection aligned properly so as not to restrict air flow to the box.

8. Shot pins are not acceptable fastening devices for supporting ductwork and sheet metal specialties.

9. A thermometer of the proper range and size must be provided in the discharge duct of each air handling unit.

D. Air Side Economizers

1. All central air systems greater than 5000 cfm supply air shall be designed to introduce up to 100% outside air for cooling whenever this use will result in lower usage of energy. Design shall include motorized minimum and maximum outside air dampers, return air dampers, exhaust or relief air dampers and, where warranted for optimum economizer operation, a single relief or return air fan.

2. Where feasible, outside air shall be drawn in through wall louvers with relief air discharged above the roof or above intake louvers. Outside air intakes shall be protected by screens of corrosion-resistant material not larger than ½-in. mesh.

3. Return and outside air ductwork and dampers shall be arranged to achieve complete mixing of the two airstreams prior to entry into the air handling unit. Where complete mixing cannot be achieved, stationary blenders or baffles are to be provided.

4. Inline return air fans, where required, shall be the mixed flow type, belt driven, with lubrication fittings outside the fan housing. Provide fans with integral hinged access door for inspection and cleaning. Fans should be selected for an outlet velocity of not greater than

3000 fpm. Vane axial fans are not acceptable.

E. VAV Boxes

1. Variable air volume boxes are to be the pressure-independent type provided with pressure taps and air flow curves for making air flow and pressure measurements. Air leakage through fully closed boxes must not exceed 2% of design air volume at 8-in. static inlet pressure. Total pressure drop should not exceed 0.5 in. wc. Boxes should be normally closed. Provide boxes with access doors. Provide with minimum 1-in. thick foil faced glass fiber liner or double wall construction.

2. Boxes with HW coils should be provided for most heating applications. They are less expensive, quieter, more efficient, and require less maintenance than fan-powered boxes. Fan-powered boxes may be considered for spaces with high heating requirements and where high minimum air flow rates are required.

3. HW coils should have minimum 0.016-in. thick tubes with 0.0045-in. aluminum fins. Fin spacing should not exceed 12 fins/in. Coil casings are to be insulated with fiberglass duct wrap where condensation may occur. PT plugs and drain valves should not be provided on piping serving VAV boxes with HW coils.

4. Mechanical plans (schedules) should show minimum air quantity desired, taking into consideration box capability, space outside air requirements, and minimum air motion in the space served. Include sound data (typically select for NC 25 to NC 30).

5. Provide adequate access to boxes installed above inaccessible ceilings. The engineer is responsible for coordinating this with the architect.

   Boxes, including HW valves, are to be furnished with DDC controls. Controllers should be fully programmable. Air flow should be monitored and minimum and maximum set points adjusted from the DDC system. In addition, monitor box leaving air temperature.

6. Provide ID for all VAV boxes.

F. Mechanical Ventilation

1. Sanitary facilities (toilets, locker rooms, janitor's closets, etc.) shall be exhausted at a minimum rate of 2-½ cfm/sq.ft. Locate corrosion-resistant registers directly over sources of odor and moisture. Other spaces requiring ventilation should not be connected to sanitary exhaust systems. Athletic locker rooms shall be mechanically ventilated at a minimum rate of 10 air changes/hour.

2. Mechanical and electrical rooms containing heat-generating equipment (steam or HTHW PRV stations, boilers, heat exchangers, chillers, switchgear, etc.) shall be mechanically ventilated at a rate not less than 30 air changes/hour. Air should be introduced on the cool side of the room and exhausted on the hot side. Exhaust fans are to be thermostatically controlled.

   Rooms housing refrigerant chillers must comply with the requirements of **ASHRAE Standard 15-2010**.

3. Exhaust air shall be ducted directly to the fan. Ceiling registers shall be connected independently by branches to the main ductwork to facilitate balancing and attenuate noise.

4. Exhaust fans shall generally be the centrifugal type, preferably belt driven, and selected for a wheel tip speed not to exceed 3500 rpm. Fans shall be isolation mounted and have corrosion-resistant gravity type backdraft dampers with blade edge and end seals. An accessible non-fused disconnect switch shall be installed in or adjacent to each fan base. Where available, the fan housing shall be hinged at one edge for access to motor and drive. Provide belt tensioners where available.

Fans shall be AMCA certified. Provide motor starters with “soft start” for motors larger than 10 hp.

Wherever possible, fans are to be installed on building roofs or in mechanical rooms. Avoid installation above ceilings or other concealed or inaccessible locations.

Roof curbs should be of the sound attenuating type with a minimum height of 14-in.

Exhaust fans should generally be controlled by the EMS system or by interlocking with the respective air handling unit.

G. Fire and Smoke Dampers

1. Fire dampers shall be U.L. labeled dynamic rated, curtain type dampers. Dampers shall be type “B” for low pressure and type “C” 100% free area for high pressure duct.
2. Smoke dampers shall be classified in accordance with U.L. Standard UL555.
3. Install dampers in accordance with NFPA 90A and SMACNA standards.

H. Air Filtration

1. Central air systems greater than 2500 cfm shall be provided with cartridge media filters having an initial efficiency of not less than 85% (Merv 13), in accordance with **ASHRAE Standard 52.2**. Pre-filters in the 30% efficiency (Merv 8) range shall be provided to extend the life of the higher efficiency filters.
2. Filter boxes or housings are to be provided with a hinged access door on each side. All joints between filter segments and the enclosing ductwork shall be gasketed or sealed to provide a positive seal against air leakage. In large filter banks, provide 3-in. stiffening straps between filter frames vertically every second frame.
3. A Magnehelic® or Photohelic gauge shall be installed across each filter bank. Indicate the range of the gauge on the project plans.
4. The mechanical drawings (schedules) should indicate the filter thickness or depth of each filter type. The design or change-out static pressure must also be indicated for each type filter. Do not simply show the initial and final pressure.
5. Filters must be new and clean at the time of final inspection. A complete, new spare set of filters is to be provided, in addition to the ones inspected.

A4.6 INSULATION

A. General

Insulation linings, coverings, vapor barriers, etc. and the adhesives used for applying them shall have a flame spread classification of not more than 25 and a smoke-developed rating of not more than 50 as tested in accordance with ASTM Standard E84. Insulation materials must be installed in accordance with manufacturer’s recommendations.

A vapor barrier should generally be provided on the exterior side of the insulation, which can serve as a finishing cover for the insulation.

B. Ductwork

1. All supply, return, and outside air ductwork and plenums in unconditioned spaces must be insulated, preferably on the exterior. Consult with Facilities Planning where liner may be required for sound control. Cold air duct components subject to condensation, including plenums, transitions, VAV box HW coils, fan casings, air flow stations, fire dampers,

apparatus connections, and the top surfaces of ceiling diffusers must be insulated.

2. Ductwork other than internally lined or factory insulated is to be wrapped with minimum 2-in. thick glass fiber insulation with vapor barrier.
3. Specify ductwork manual volume damper handles, airflow station pressure ports, access door handles, duct mounted instrumentation, etc. to be left exposed or accessible above the insulation vapor barrier. Damper handles in externally wrapped ductwork are to be provided with stand-off brackets and locking quadrants to ensure the handle can be adjusted without disturbing the insulation vapor barrier.
4. Outside air ducts and plenums located within the equipment rooms should generally be insulated on the exterior with 2-in thick glass fiber board insulation. Furnish and install corner beads on outside of vapor jacket and cover with strip of glass cloth cemented in place.
5. Duct liner, where provided, shall comply with the Erosion Test Method described in ASTM C1071 and ASTM G22 when tested at a rated velocity of 6,000 FPM.
6. Ductwork exposed to weather shall be insulated with duct board (thickness shall meet the IECC requirements). All ductwork insulation shall be weatherproofed by using Alumaguard or equivalent insulation covering.

C. <u>Piping and Equipment</u>

1. Comply with **ASHRAE 90.1**.
2. <u>All</u> domestic hot and cold water piping, space heating and chilled water piping, rainwater leaders, refrigerant suction lines, steam and steam condensate piping, water piping traced with heating elements, and A/C unit drain piping must be insulated.
3. <u>All</u> valves, strainers, fittings, flanges, hydronic specialties, tanks, etc., including heat exchangers, condensate receiver tanks and associated piping, emergency generator mufflers and exhaust piping, and air release tanks shall be insulated. Chilled water pumps shall be insulated. Compression tanks and condenser water piping inside the building or in mechanical rooms should not be insulated. HW pumps should not be insulated.
4. Glass fiber sectional pipe insulation is to be used for most pipe insulation applications. Glass fiber factory premolded fittings matching basic insulation equivalent to that manufactured by Hamfab should be provided at all pipe fittings (tees and ells) and finished with glass fabric and vapor barrier mastic. **Glass fiber blanket inserts with PVC covers are not acceptable for pipe fitting insulation.** Fittings 8" and larger may be field mitered. Valves, strainers, flanges, etc. shall be covered with mitered insulation segments of the same type and thickness as adjoining pipe insulation.
5. Chilled water pump casings and large valves and strainers in steam PRV stations are to be insulated with custom made, field measured removable and reusable covers similar to those manufactured by Berry Soft Pack Fabricators.
6. Piping below grade, shall be generally factory, pre-insulated type, or be insulated with Foamglas® with Pittwrap® jacket. Discuss further with Facilities Planning. Piping exposed to weather and in manholes should be insulated with Foamglas® with Pittwrap® jacket and covered with aluminum jacket. Premolded fittings shall be provided at tees and ells.
7. Refrigerant suction piping and A/C unit drains should generally be insulated with flexible, elastomeric pipe insulation. Where exposed to weather, finish with vapor barrier jacket and covered with aluminum jacket when subjected to UV rays and lights.
8. Air separators and chiller evaporators, including flanges, are to be insulated with flexible, sheet-type elastomeric insulation.

9. Heat exchangers, hot water air separators, condensate receiver tanks, etc. shall be insulated with board-type heavy density glass fiber insulation and finished with canvas jacket.

10. Free cooling heat exchanger piping from/to cooling tower and run-around coils piping between two coils shall be insulated similar to chilled water piping system.

11. Insulated piping, valves, and fittings within 7-ft. of floors or work surfaces shall be finished with 0.016" smooth aluminum jacket, secured with sheet metal screws and ¼-in. aluminum bands. Corrugated or textured jacket is not acceptable. Fittings, etc. are to be covered with factory-formed aluminum elbow covers.

    Insulated piping above grade exposed to weather and in manholes and tunnels shall also be finished with aluminum jacketing.

12. Protect insulation at each hanger and support point with a 14 gauge galvanized shield which extends up to the centerline of the pipe and is centered inside the pipe hanger. Minimum shield length should be 12". Where glass fiber insulation is used on piping 3" and larger, provide a section of Foamglas® insulation between pipe and metal shield to prevent crushing of insulation. The Foamglas® insert at each support point shall extend minimum 2-in past each end of the protector shield.

A4.7 HYDRONIC SYSTEMS

A. Design

1. Size hydronic piping for a general range of pipe friction loss between 1 and 4 ft./100 ft. A value of 2.5 ft./100 ft. represents the mean to which most systems are designed. Flow velocities should not exceed 12 fps (4 fps for 2-in. and smaller pipe) nor generally be less than 2 fps.

2. Piping runouts greater than 10 ft. in length should be a minimum size of ¾-in.

3. Nominal pipe size or, in essence, pipe I.D. shall be used to select and designate piping in the contract documents.

4. Mechanical plans must show all pipe fittings. **All Pipes, except for those smaller than 6 inches, must be drawn double-line and to scale. All pipes, no exceptions, on enlarged plans and views must be drawn double-line.** Use standard drafting conventions for fittings, turns, changes in size, drops or rises, crossings above and below one another, etc.

5. Hydronic systems must be designed for optimum energy conservation and system flexibility. Chilled water systems should be designed for chiller leaving water temperatures of 42-43°F; hot water systems for 180-190°F.

6. Chilled water coil temperature differential should be no less than 16°F for central station and built-up equipment, and no less than 12°F for terminal equipment. Hot water coil temperature differential should generally be 30°F.

7. Generally, the systems should be variable flow with two-way control valves provided instead of three-way. Variable frequency drives are to be provided at the pumps.

    Where the building is served by the campus distribution system, provide an electromagnetic flow meter with minimum 1% accuracy to meter the building flow. If a tertiary pump is needed, a control valve, equal to B&G's ZoneSav®, should be provided in the distribution system return line to control building return water temperature to the distribution system.

8. For HTHW systems, provide a vortex shedding type flow meter to monitor HTHW flow to the

building.

B. Piping

1. Piping 2-in. and smaller shall be Type L, hard drawn seamless copper tubing with wrought copper, solder joint type fittings, ANSI B16.22. Elbows are to be long radius pattern. Solder shall be 95-5 type. “Tee pullers” shall not be used in place of tees on copper piping. Pro-press type fittings may be considered.
2. Piping 2½-in. and larger shall be seamless black steel, Schedule 40, ASTM A-53, Gr. B, or A106 with welded or flanged fittings, ANSI B16.9. ERW piping may be considered. Elbows are to be long radius pattern. Field-fabricated fittings are not acceptable. Forged steel, gasketed flanges, ANSI B16.5, of the welded neck type are to be used at flanged connections. Slip-on type may be used on straight pipe. Flanges must be compatible with valve and equipment connections. Where a branch connection from a main or header is one half the main diameter or smaller, saddle-type, forged steel welding fittings may be used.
3. Welding shall conform to ANSI Code for Pressure Piping, Section B31.1. All welds shall be of the single “V” butt joint type with optimum fusion and 100% weld penetration of wall thickness. Piping should be welded by the shielded arc type electrode-electric arc process. Butt joints should be made with split backing rings. In most cases, direct welded connections shall not be made to valves, strainers, equipment, etc. The contractor should be required to obtain certification of all pipe welders on the project, in accordance with Section IX of the ASME code.
4. Union or flanged connections should be provided at valves, equipment, etc. Provide dielectric unions at the junction of steel pipe and equipment with copper piping systems. Or, preferably, provide steel to brass to copper connections. Where size changes on horizontal lines, use reducing fittings having eccentricity down, top level. All piping take-offs should be made from the top of mains or headers. Do not “bullhead” tee connections on return piping.
5. Specify adequate support for horizontal piping at intervals of not more than 7 feet for piping and tubing 1½-in. and smaller and not more than 10 feet for piping 2-in. and larger. In addition, supports should be provided within 18" of all changes of direction, at all vertical pipes, and within 18" of valves 4-in. and larger or at other points of concentrated weight. Roller type guided supports should be provided where piping is subject to expansion.

   Provide adequate shields between pipe insulation and supports.

   Shot pins are not acceptable fastening devices for supporting piping and hydronic specialties.
6. Specify identification for all piping to be snap-on or strap-on labels with flow directions, equal to that manufactured by Seton or Brady. Band color for chilled water and condenser water piping shall be green. Color for hot water piping shall be yellow.
7. Specify piping to be thoroughly flushed before it is put into operation.

C. Valves

1. Ball valves of full port, two-(or three) piece body construction with soldered end connections and extended stems shall be used on hydronic piping 2-in. and smaller. Valves should have stainless steel balls and stem and be rated for 600 psig WOG, similar to Apollo 77-200.
2. Butterfly valves with lug-type body stainless steel disc, reinforced PTFE seat, and extended neck shall be provided on piping 2½-in. and larger. Valves should be rated for “bubble-tight” service at 200 psig WP.

   Valves 6-in. and smaller should be provided with lever handles with infinite throttling and memory stops. Valves 8-in. and larger should have worm gear operator with hand wheel and indicator. Where gear operator is 8 feet above floor or work surface provide chain wheel, chain and guides.

Butterfly valves should also be used in condenser water piping.

3. Provide sufficient number of valves for proper isolation of the piping systems. In addition to equipment connections, valves must be provided at all major pipe branches and risers and at each level.
4. In general, valve tags should not be provided.

D. Air Control and Drains

1. Hydronic systems must be provided with air separation devices to minimize the amount of entrained air in the piping circuits. Manual air vents are to be provided at high points, wherever there is a change in elevation of the piping and at intervals of long runs of piping. Ball valves of ¼-in. minimum size should be used for air vents.
2. Full-bladder type expansion tanks are preferred for air confinement in the piping system.
3. Drain valves are to be provided at low points in the piping system and where needed in mechanical rooms. Valves should be 3/4-in. ball type with capped, hose-end connections. Provide a drain valve, accessible from the mechanical room floor, on air separators and strainers and pipe to a floor drain.
4. The minimum pitch of hydronic lines shall be 1-in. in 40-ft. Piping shall pitch down to drain points and up to vent points.

E. Specialties

1. Strainers with 20 mesh screens should be provided at the suction of each pump and at other equipment recommended by the manufacturer, including control valves. Strainers larger than 1-in. shall be provided with a ball type blow-down valve with hose-end connection. Suction diffusers should be used in place of strainers on end suction pumps. The screens in pump strainers should be removed once it has been ascertained construction dirt has been eliminated.

   On condenser water pumps, it is usually desirable to provide a strainer on the pump discharge, ensuring the pump is always filled with water. Usually the strainer on the cooling tower is all that is necessary to protect condenser pumps.
2. Triple-duty valves should generally be provided on the discharge of pumps piped in parallel. Valves should generally be straight pattern, in-the-line type. For variable speed pumps, provide an isolation valve and check valve.
3. Flow balancing valves, or circuit setters, shall be provided at each air handling unit coil, coil bypass line (when applicable), terminal unit coil and at other locations in the piping where required for balancing and monitoring, including major branch lines. Provide with a metering kit, similar to B&G's RO-4. Size of valves should be specified or shown on the drawings. For variable flow systems, provide automatic flow balancing valves equivalent to B & G Circuit Sentry instead of circuit setters.

   Balancing valves are not needed on the discharge of variable speed pumps.
4. Hydronic system filters of either the full flow or bypass type should be considered where piping is to be connected to existing systems. Discuss with Facilities Planning.

F. Instrumentation

1. Thermometers with wells shall be provided at the inlet and outlet of each chiller evaporator, condenser, and heat exchanger. Thermometers should also be provided on chilled water and hot water supply lines serving each mechanical room. Thermometers must be readable from the mechanical room floor or platform.

   Thermometers shall be of the adjustable angle type with minimum 9-in. scales. Range shall be specified on the drawings. Thermometer wells shall be ¾-in. N.P.T. with 2½-in. extension neck for insulated piping. All wells must be thoroughly packed with a heat conducting compound.

2. A single pressure gauge shall be provided for each pump, piped from the suction and discharge flanges with isolation valves. Pump gauges are to be compound type. All gauges are to be 4½-in. size and have an accuracy of ½ % over scale range. All gauges are to be provided with impulse dampeners and 1/4" ball valves.

3. Pressure-temperature fittings (P-T plugs) shall be provided at the inlet and outlet of each AHU heating and cooling coil, chiller evaporator and condenser, heat exchanger, and 2-in. and larger control valve. Provide one P-T test kit. P-T's should not be provided on small terminal unit coils, including VAV box HW coils, fan coil units, etc.

4. Provide flow meters and temperature sensors to monitor flow and energy to the building.

G. Pumps

1. Pumps for hydronic systems should be flexibly coupled, bronze-fitted, centrifugal type with cast iron or steel bases with drain pans. Provide with internally-flushed mechanical seals rated for 200°F. Split case pumps are preferred for applications with higher flow rates.

2. Generally, motor speed should not exceed 1750 rpm. Motor efficiency shall comply with **ASHRAE Standard 90.1**. Consider 1150 rpm pumps for high flow, low head applications.

3. Provide motor soft starters for motors larger than 10 hp.

4. Condenser water pumps shall have stainless steel shafts.

5. Select pumps at best efficiency point. Overloading should not occur at any point on the pump curve. Flat-curve pumps are generally preferred over steep-curve pumps for HVAC applications. Select so that neither the largest nor the smallest impeller is provided. Resist the temptation to specify unnecessary head.

   Locate pumps on ground or basement level mechanical rooms. Carefully review the space available for installation. Consider the installation footprint as well as the access space required to service the pump properly.

6. Installation Requirements: Comply with 2008 ASHRAE Handbook, HVAC Systems and Equipment, p. 43.13. Base mounted pumps must have the base filled with a non-shrinking grout. Pump couplings must be properly aligned.

7. Specify each pump to be provided with one spare set of bearings and mechanical seals.

8. Provide ID for all pumps.

H. Schematic Diagram

Provide a one-line, simplified schematic (not isometric) diagram of the chilled water or hot water system where two or more chillers or boilers or heat exchangers, including existing equipment, are included in the hydronic system. Indicate how the various components relate to one another, and show pumps, control valves, air release tank, two-pipe changeover valves – if applicable, and flow meters. Show flow direction. Avoid line crossings. Do not show gauges, thermometers, isolation valves, strainers, etc.

The diagram must be easy to interpret without a great deal of study and instantly convey a clear picture of the design philosophy of the system. Do not provide isometric drawings or sketches.

When necessary, an isometric piping diagram will be provided to clearly show the tie-in points of a new piping system to the existing piping system.

A4.8 STEAM SYSTEMS

A. Design

1. Steam systems should be the two-pipe type.
2. High pressure (>60 psig) steam is typically the medium available from the campus distribution system for serving the building. Low pressure (0-15 psig) steam should be used for space and domestic water heating applications; medium pressure (16-60 psig) for process applications. Do not use high pressure steam for heating.

B. Piping

1. Steam piping shall be seamless black steel, Schedule 40, ASTM A-53 Gr. B, or A-106. Fittings shall be 150-lb. cast iron for low pressure piping and 250-lb. or 300-lb. cast steel for medium and high pressure piping. Piping 2-in. and smaller shall have screwed joints. Piping 2½-in. and larger shall have welded joints. For UT Knoxville campus, welded end valves, strainers, expansion joints, etc. shall be used in medium and high pressure piping.
2. Condensate piping shall be the same as steam, except Schedule 80.
3. Pipe fittings, welding, supports, identification, and cleaning shall comply with the requirements described in HYDRONIC SYSTEMS. Flange gaskets must be spiral wound, metallic type. Where size changes occur on horizontal lines, use reducing fittings with eccentricity up, bottom level.
4. Provide adequate compensation for expansion and contraction. Generally, roller type guided supports are needed where steam and condensate piping are subject to expansion. Anchors, guides, expansion loops and joints, etc. where required must be shown on the drawings.
5. Steam and condensate piping shall pitch down to drains and up to vent points. The minimum pitch of steam lines shall be 1-in. in 40 feet; condensate lines shall be 1-in. in 20 feet.
6. Specify identification for all piping to be snap-on or strap-on labels with flow directions, equal to that manufactured by Seton or Brady. Band color for all steam and condensate piping shall be yellow. Include pressure on steam pipes.

C. Valves

1. Gate valves shall be provided on steam and condensate lines to isolate risers and branches from mains and to isolate each piece of equipment, control valve, fixture, etc. Gate valves 6-in. and larger installed more than 10 feet above the floor shall be provided with chain wheel, chain, and guides.
2. Valves in low pressure steam piping 2-in. and smaller shall be 125-lb. SWP ASTM B-62 bronze reversible type with solid wedge disc, tapered seat, rising stem, and screwed ends. Valves in 2½-in. and larger piping shall be 125-lb. SWP ASTM A-126 iron body, bronze mounted with outside screw and yoke and flanged ends.
3. Valves in medium and high pressure steam piping up to 100 psig shall be 250-lb. SWP. Provide 300-lb. cast steel valves, strainers, etc. on high pressure piping greater than 100

psig. Gate valves 6-in. and larger in high pressure piping shall have integral bypass and valve.

4. For UT, Knoxville steam distribution system, provide valves in distribution system piping with weld-end connections.

D. Specialties

1. Strainers of 250-lb. SWP, (300-lb. if more than 100 psig steam) Y-pattern shall be provided upstream of all control valves, pressure reducing valves, steam traps, etc. Provide globe blowdown valves piped to the floor on strainers larger than 2-in.
2. Steam traps in low pressure piping should generally be closed float and thermostatic type. Traps in medium and high pressure piping should be inverted bucket type.
3. Provide F&T traps on any equipment with modulated steam supply. Size traps to handle two times the maximum equipment rating. Bypass lines are generally not required around steam traps.
4. Provide pressure gauges on the discharge of each condensate pump, upstream and downstream of each pressure reducing valve, and on steam supply to heat exchangers. Gauges shall be 4½-in. size and have a minimum accuracy of ½% over scale range. Provide each gauge with an iron coil siphon and ball valve.
5. Provide a vortex shedding type flow meter to monitor steam flow for each building. A clamp-on condensate meter may be considered for some applications. Review with Facilities Planning.

E. PRV Station

High pressure steam from the campus distribution system shall be reduced to medium and low pressure for process and space and domestic water heating applications through a pressure-reducing valve station.

1. Reducing stations shall be single or two-valve, single stage type, complete with pressure reducing valves, pressure controller, air loading valves, relief valves, isolation valves, pressure gauges, and, where required, transfer valves.
2. Reducing and regulating valves shall be normally closed, air loading, diaphragm-operated type, 250-lb. SWP with cast iron body and stainless steel trim having "Stellited" renewable seat ring for entering pressures less than 100 psig. For pressures greater than 100 psig, provide 300-lb. cast steel regulating valve. Valves shall be selected so that a noise level of 90 dba will not be exceeded. Reducing and regulating valves 2-in. size and larger shall have flanged connections.
3. Locate PRV stations near exterior walls for access to ventilation air. Piping, flanges, etc. should be at least 12 inches from wall.

F. Convertors

In most instances, where steam is available, a heat exchanger shall be provided to provide hot water for the building heating medium.

1. Heat exchangers shall be steam-to-water type of shell and U-tube construction, ASME labeled for 125-psig working pressure. A manufacturer's data report for unfired pressure vessels is to be submitted to the University certifying that construction conforms to the latest ASME code for pressure vessels. The form must be signed by a qualified inspector who holds a National Board Commission.

2. Steam supply pressure to the exchanger control valve should be 10-15 psig and capacity based on a fouling factor of 0.001. Steam pressure downstream of the control valve should be about 20% of that upstream of the valve. A single (where capacity permits) F&T trap selected for a capacity of 2X the condensing rate should be provided.
3. Heat exchanger-pump-piping "packages" should not be provided.
4. Locate heat exchangers near exterior walls for access to ventilation air.

G. Condensate Units

Units should generally have duplex, 3500 rpm pumps. Elevated tanks are preferred if condensate can be gravity-drained. Provide with tank thermometer, inlet strainer, gauge glass, etc.

A4.9 HEAT TRANSFER EQUIPMENT

A. Air Handling Units

1. Provide field-assembled or factory-fabricated, central station air handling units for mechanical systems. All unit sections should be of double-wall construction with 2-in., 3.0-lb density fiberglass or foam insulation. For most applications, provide a perforated interior liner for the fan section. Provide units with positive draining, double wall stainless steel drain pans. Where coils are stacked, provide intermediate pans. Lay out units to permit servicing and repair of fans and filters and replacement of coils. Provide a separate piping detail for units with multiple or stacked coils.
2. Provide access to each side of each coil. Where access cannot be attained through fan or filter sections, provide full sized access sections with hinged doors, preferably not less than 24" wide. Where space permits, provide hinged access doors on both sides of fan casings, access sections, filter sections, and mixing box sections. Screws or bolts are not acceptable for access to coils, etc.
3. Install units and field-assembled plenums on a minimum 6-in base rail and a 4-in. high concrete housekeeping pad or higher as needed for trap depth of the unit required for proper drainage. If not provided with the unit fan, install on spring vibration isolators.
4. Specify "low leakage" (air leakage not greater than one percent of the rated flow) dampers for mixing boxes. In addition to the return air damper, provide one minimum and one maximum (for economizer operation) O.A. damper in the O.A. damper section. For proper mixing of O.A. and R.A specify parallel blades to be used with blades facing each other to create turbulence and mixing.
5. Belt drives are to be sized for a minimum of 150% motor h.p. For AHU's with capacities greater than 5hp, specify a minimum of two belts for the drives.
6. Fan bearings shall be grease lubricated, self-aligning ball or roller type mounted externally and designed for 200,000-hour life. Bearing lubrication lines are to be extended to an easily accessible location. Provide one spare set of bearings and belts for each fan.
7. Motor efficiency shall comply with **ASHRAE 90.1**. Provide motor soft starters for motors greater than 10 hp.
8. Include in the AHU schedule on the drawings total, external, and component (coils, filters, dampers, etc.) static pressure. Indicate whether or not the static pressure for the filters is included in or independent of external static. Total static pressure should be the sum of external and component static pressures.

Filter static pressure indicated should be the change-out pressure. A guideline for this is ¾ of the distance between the published initial and final or terminal pressure drop. Another is no more than twice the initial pressure drop.

9. Provide a thermometer in the discharge air duct of each air handler.
10. Air handling unit submittals shall include fan curves for maximum and minimum operating conditions.
11. Provide ID for all AHU's, fan coil units, etc.

B. Coils

1. Cooling and heating coils shall have minimum 0.0075-in aluminum plate fin secondary surface and 5/8" O.D. x 0.025-in. thick seamless copper tubing primary surface with not more than 11 fins per inch. Avoid spiral-type fin configurations.
2. The physical height of coils should be limited to 45-in.
3. Select AHU chilled water coils for a minimum 16°F temperature rise and hot water coils for a minimum 30°F temperature drop.
4. Cooling coils should be piped so that chilled water is supplied on the air leaving side and is returned on the air entering side. Arrange unions or flanges so that coils can be removed without removing any additional piping upstream of the unions.
5. In general, CW coil face velocities should not exceed 500 fpm.
6. For 100 per cent outside air preheat applications, steam coils with face and bypass dampers are preferred.
7. Indicate coil pull space on mechanical room floor plans.

C. Chillers

1. Centrifugal water chillers shall generally be provided on projects requiring more than 200 tons. Compressors may be single or multi-stage, open or hermetic. Motor may be oil lubricated or magnetic bearing. Refrigerant should be either R-134a or R-1233zd. Machines shall be specified to deliver water at a temperature of 42°F with an evaporator temperature not below 32°F.
2. Chillers should have microprocessor-based controls compatible with the campus energy management system. Capacity control should be electronic, capable of modulation from 100% to 10% of rated capacity.
3. Evaporator and condenser tubes shall be 0.028-in. thick copper, smooth or enhanced.
4. Provide centrifugal chiller water boxes with davits or hinged doors to optimize service and cleaning of tubes.
5. Where required, provide R-1233zd ch illers with a high-efficiency purge system, consisting of air cooled condensing unit, purge condensing tank, and pump-out compressor. The purge exhaust shall not exceed 0.05 lb. refrigerant per lb. of purged air.
6. Safety and operating controls shall include the following: current limiting overload device; evaporator and condenser pressure/temperature gauges; oil pressure gauge; temperature cutouts for low chilled water and refrigerant temperatures and high motor, compressor discharge, oil, and bearing temperatures; pressure cutouts for low oil and refrigerant pressures and high condenser pressure; oil pump switch; guide vane time delay switch; evaporator and condenser water flow switches; and pilot lights for safety circuit items.

7. Provide power factor correction capacitor to maintain minimum PF of .95 at loads between 40 -100%.
8. Provide motor soft starters for motors greater than 10 hp.
9. Provide noise suppression lagging, Kinetics KC-10-100, or equal, on machines where noise level exceeds 85 dBA (generally R-134a machines).
10. Locate chillers in ground level or basement mechanical rooms with sufficient clearance to perform maintenance, repair, and replacement of components, including evaporator and condenser tube bundles. Incorporate refrigerant alarms and ventilation in accordance with **ASHRAE Standard 15**.
11. Specify a factory start-up report to be provided before final acceptance.
12. Generally, provide packaged, air cooled screw or scroll chillers for loads less than 200 tons. Low ambient and hot gas by-pass controls should be provided for most applications.

D. Cooling Towers

1. Type: Generally, induced draft, cross-flow, stainless steel construction with PVC fill and corrugated polyester louvers with ½" air inlet screens, complying with CTI design standards. Fans are to be gear driven or direct drive.
2. Performance: Base on entering and leaving water temperatures of 95°F and 85°F, respectively, with 80°FWB ambient temperature.
3. Location: Coordinate with Facilities Planning. The elevation of the tower basin and condenser water pump must be thoroughly reviewed to assure pump operation free of cavitation. Ladders serving cooling tower platforms and fan decks must extend to grade or roof deck and comply with OSHA standards. Provide two ladders where needed for access to both sides of the fan deck.
4. Winterizing: Provide sufficient heat in the basin and at the exposed piping to avoid draining during cold weather.
5. Control: Provide a variable speed fan for condenser water temperature control. Maintain set point by varying the speed of the fan and positioning a 3-way diverting valve. (Bypassing to the tower basin is preferable). Interlock tower fans and condenser water pumps so that fans will only operate when pumps are operating.
6. CTI test: Generally, provide for field erected towers.

E. Boilers

For UTHSC, comply with Section 1004, Boilers, from the 2010 International Mechanical Code. Pay particular attention to the requirement for "kill" switches, Section 1006.

A4.10 TESTING AND BALANCING

The HVAC system design must incorporate means for balancing the air and water systems. Such means include dampers, temperature and pressure test connections, flow meters, and balancing valves.

An agency or subcontractor independent of the contractor is required to balance the air and water systems. This subcontractor should be AABC or NEBB certified.

In general opposite season testing and balancing shall be performed to confirm the systems operation. The "Heating Season" shall be defined as October 16 through April 15 and "Cooling Season" shall be defined as April 16 through October 15.

Air side testing and respective adjustment should include the following:

1. Equipment and motor data.
2. Traverse air flow measurement of all main supply air, return air, outside air, relief air, and exhaust air ducts, especially those at AH units and ducted exhaust and return air fans.
3. Static pressure at entering and leaving points of each AH unit, exhaust, relief, or return fan, coil, filter bank, etc.
4. Entering and leaving air temperatures at AH unit coils.
5. Fan rpm and motor volts and amps. Fan curves for AH units and return and exhaust fans must be included in the report.
6. Air flow rate and pressure differential for each VAV box.
7. Air flow rate at each register and diffuser.

Water side testing and respective balancing should include the following:

1. Equipment and motor data.
2. Differential pressure and water flow rate at each AH unit, heat exchanger, chiller evaporator and condenser, and at each flow meter, including flow meters serving terminal equipment (VAV boxes, etc.)
3. Entering and leaving water temperatures at AH unit coils.
4. Shut off head, full flow head, final head and final flow rate at each pump. Pump curves must be included in the report, as well as motor voltage and amperage.
5. Entering and leaving pressure at each AH unit coil, chiller evaporator and condenser, and heat exchanger.
6. When requested, the Testing and Balancing Firm shall conduct to confirm any test results of the report at the presence of the Owner or his authorized representative.

Include testing and balancing of domestic HW recirculating system.

The balancing report must include a drawing or sketch identifying each terminal unit and register and diffuser with respect to the spaces served. Each AH unit should also be identified, with test points indicated.

A4.11 TEMPERATURE CONTROLS

Provide direct digital temperature controls (DDC) with electronic operators for the mechanical systems. The control system must be fully compatible with and tie in to the existing Energy Management System serving the campus. System should be open protocol, based upon either Lonworks or BACNET.

A. Graphics

   Software graphics with pictorial representations of equipment and devices being controlled and actually displayed on the PC monitor must be provided.

B. Control Wiring

   In general, 24v control wiring should be furnished and installed by the control subcontractor. The electrical subcontractor should be responsible for furnishing and installing all 120v and above wiring and associated conduit, required starter coils, etc., as well as starters and control panels not within a packaged unit. This must be carefully coordinated with the electrical engineer.

C. Air Compressors

1. Where required, duplex control air compressors shall be high pressure, low dew point design with single ASME receiver of 30-gallon minimum capacity. Size compressor unit to operate on one-third on, two-thirds off time cycle. Provide automatic drains, vents, relief valves, manual valves, gauges, pressure regulators, filters, belt guard, control accessories, etc.
2. An alternator shall be provided to automatically start the second compressor if the first fails to maintain receiver pressure. It shall also alternate the order of starting the compressors to balance run time.
3. The compressor unit shall be mounted on a 4-in. concrete housekeeping pad with vibration isolators.

D. Pneumatic Tubing

Where used, seamless copper tubing shall be provided for all pneumatic lines. Tubing shall be Type M with either solder or compression connections. Polyethylene tubing may be used only inside equipment enclosures and at thermostat and operator connections (12-in. maximum length).

E. Thermostats

1. Room thermostats shall be the electronic type compatible with the direct digital control system. Provide with communication ports. Thermostats must be provided with setpoint adjustment capability with a temperature scale indication in °F graduations. Sensors without adjustment capability or °F graduations are not acceptable. Accuracy shall be ±1°F. Carefully coordinate locations of wall thermostats so as not to interfere with light switches.
2. All thermostats, including night low limits, etc., shall be indicated on the HVAC floor plans. Mounting height should generally be 5'-0" above the floor. Provide with appropriate guards where subject to damage.

F. Humidistats

Wall and duct mounted humidity sensors shall have ±2% RH accuracy. Combination sensors, where required, shall have thin-film platinum type temperature sensors.

G. Air and Water DP Sensors/Transmitters

Provide DP sensor/transmitters with 3-valve manifold assembly that will allow field test measurements to be taken without interrupting the BAS reading.

H. Control Valves

1. Valves 2-in. and smaller: Equal percentage type, ball type. Provide electronic actuators. Ball valves shall comply with the requirements described in HYDRONIC SYSTEMS.
2. Valves 2-1/2-in. and larger: Equal percentage type, globe type with stainless steel trim. Provide electronic, spring return actuators.
3. Control valves for steam application shall be globe type regardless of the size.

I. Control Dampers

1. Provide Class 1 low leakage dampers with compression type stainless steel grade 304 to close gap between frame and blades.

J. Temperature Control Drawings and Sequences

1. Provide a schematic drawing with applicable sequence of operation for each HVAC system, including AHU's, chillers, cooling tower/condensers, boilers, heat exchangers, exhaust fans,

etc. Schematics and sequences must be shown on the HVAC drawings. Do not include in the Project Manual. Sequences must be clear and concise, written as simply as possible.

2. Sequences for AHU's should typically start with turning the unit on in the occupied mode, then describing the cooling control (with economizer if applicable), describing the heating control (if not sequenced with the cooling), describing air flow control if VAV, including RA fan control, if applicable, describing operation in the unoccupied mode, describing the safeties, and end with a brief description of desired points, etc. to be monitored. Apply the following Temperature Control Sequence for Operation of AHU's. Follow items marked with an asterisk (*) when applicable.

    1. Start the Air Handler
        - BAS
        - Occupied Mode
        - HOA Sw.
        - Min OA damper*
        - Smoke dampers*
        - 100% OA damper*
        - RA fan (economizer)*
    2. Control the Temperature
        - Cooling Coil
        - Economizer*
        - Heating Coil*
        - Air Flow*
        - Dehumidification*
    3. Control the Preheat*
        - F&B dampers*
    4. Control the Air Flow (VAV AHU)*
        - RA fan (economizer)*
    5. Safeties
        - Freezestat
        - Smoke Detectors
    6. Unoccupied Mode
        - Temperature Setback
        - De-energize*
    7. Monitor
        - SA temperature
        - SA Fan Status
        - OA temperature and Humidity (global)
        - Filter DP
        - RA temperature and Humidity (economizer)*
        - Preheat Temperature*
        - Duct SP (VAV AHU)
        - SA CFM*
        - RA CFM (economizer)*
        - Minimum OA CFM*
        - Space Temperature and Humidity (dehumidification control)*
        - RA Fan Status (economizer)*

3. Specify hydronic DP transmitters to be initially set up at 15 psig, then adjusted by TAB agency.
4. Show location of DP and SP sensor/transmitters on plans. Do not specify SP sensors to be located “2/3 length of SA duct”.

A4.12 PLUMBING

Plumbing systems shall be designed in accordance with the requirements of applicable state and local codes.

Design shall incorporate provisions for the handicapped.

A. Domestic Cold Water Systems

Domestic cold water service will be provided from a connection to the existing site main. Provide pressure booster pumps if required. Domestic cold water will serve toilet rooms, mop receptors, general purpose sinks, wall hydrants, and other specific equipment as required. A minimum pressure of 25 psig should be maintained to operate water closet flush valves.

The incoming domestic water service shall be provided with two backflow preventers of equal size piped in parallel to protect the site system from contamination.

System capacity shall be based on fixture unit values with appropriate code factors and actual equipment demands.

B. Domestic Hot Water Systems

Domestic hot water systems shall be provided with complete supply and return piping to maintain hot water at each appropriate fixture at all times. Hot water shall be distributed in the domestic hot water system at 120°F with service to lavatories, showers, general purpose sinks, service sinks, and other specific equipment as required. For requirements for higher temperature water, local booster water heaters should be provided with the equipment.

Generally, hot water should be produced by steam-fired (HTHW for UTC) instantaneous hot water generators, similar to that manufactured by Graham. System capacity shall be based on fixture unit values with appropriate code factors and actual equipment demands.

Provide circuit setters on branch recirculating lines at each floor.

C. Service Piping

Domestic hot and cold water piping shall be Type L hard drawn copper with wrought copper fittings. Water lines installed underground shall be Type K copper with wrought copper fittings. Joints shall be made with lead-free 95-5 solder. Press-type joints may be considered.

Mechanically formed tee connections are not acceptable for piping tees.

Outside water mains shall be A.W.W.A. bell and spigot cement lined ductile iron (250 lb. class), provided with a coat of black asphaltum.

Service water piping shall be tested and disinfected in accordance with applicable code requirements.

Provide an isolation valve for each water service main, branch main, riser, and branch line serving a group of fixtures. Valves shall be two-(or three) piece, full port ball type with SS balls and stem for pipes 2-in and smaller and lug butterfly valves for pipes 2½-in and larger.

Piping identification shall comply with the HYDRONIC SYSTEMS section in these criteria. Specify identification for all piping to be snap-on or strap-on labels with flow directions, equal to that manufactured by Seton or Brady. Band color for domestic cold water shall be green; for domestic hot water and hot water return: yellow. Provide red color for fire protection, blue for compressed air and yellow for natural gas.

D. Sanitary and Storm Drainage Systems

A separate sanitary drainage, waste, and vent system shall be provided for all water closets, lavatories, service sinks, etc. Sanitary drainage shall be connected by gravity directly into the site sewer system. Capacity shall be based on fixture unit values with appropriate code factors and actual equipment demands.

A storm water drainage system shall be provided for all roof, clear waste, and area drains and connected into the site storm system.

Provide required cleanouts for access to horizontal and vertical drain lines to facilitate inspection and provide a means of removing obstructions.

Pipe inside the building above grade shall be service weight coal-tar coated cast iron hubless type with DWV fittings and stainless steel multi-band couplings and neoprene gasket (CISPI 301) joints. Dry vent piping 2-in. and smaller may be Schedule 40 galvanized steel pipe with cast iron threaded drainage fittings.

Pipe inside the building below grade shall be service weight cast iron with bell and spigot ends with joints made with positive double-seal elastomeric compression-type gaskets. Galvanized pipe should not be installed below grade.

Pipe below grade outside the building should be solid wall Schedule 40 PVC with cement joints and DWV fittings.

Piping should be pitched to drain at a minimum slope of ¼-in. per foot for piping 3-in. and smaller, and 1/8-in. per foot for piping 4-in. and larger.

E. Insulation

Hot, cold, and chilled water and roof drain piping must be insulated to prevent energy loss and condensation. Insulation of cold and chilled water piping shall include an exterior vapor barrier. Insulation shall comply with the INSULATION section of these criteria.

F. Fixtures and Specialties

Plumbing fixture material should be of non-absorptive, acid resistant type. Provide a schedule on the drawings – not in the project manual – to indicate each type of fixture specified, including supply and waste sizes, trim, accessories, manufacturer and model number, etc.

A ¼-turn ball valve shall be provided at each fixture. Each fixture, floor drain, or other equipment connected to the drainage system shall have separate traps installed as close to the fixture as possible. Provide a cleanout for each trap. Wall mounted fixtures shall be supported with floor mounted fixture carrier.

Water-efficient fixtures are required. Battery-operated, sensor-activated flush valves and lavatory faucets should be provided. Provide faucet temperature adjustment where needed. Urinals should be 1/8 gal, low-flush type with battery operated flush valves. Water closets must be provided with battery operated 1.6 gal/flush or less valves.

Lavatory faucets for most applications must be selected for a maximum water usage of 0.5 gpm (60psi).

G. Process Systems

Laboratory area sinks, cup sinks, and required equipment drainage will be collected into a separate acid waste system in the building and discharged into a neutralization basin before being discharged into the site sanitary waste system. Acid waste piping shall generally be fire-retardant polypropylene with heat-fusion joints.

Laboratory grade purified (DI) water shall be provided where required for general laboratory uses such as laboratory testing, rinse water, and wash water. Piping and fittings shall be beta-polypropylene with socket welded joints. Valves and supplies must also be of materials that will not contaminate the purified water before the point of being used.

A4.13 FIRE PROTECTION

Typically, the building shall be fully sprinklered with automatic wet pipe sprinkler systems being the primary type of fire suppression. Dry pipe sprinkler systems must be utilized in spaces subject to freezing. The wet sprinkler systems on each floor should take their water supply from a fire protection standpipe system, creating a sprinkler/standpipe system.

The water supply shall be provided by connections to the site water system. A fire department connection shall be provided at the building.

The sprinkler system design shall comply with applicable editions of and NFPA Standard 13. Typically, the installing contractor is required to provide a sprinkler system layout sized by hydraulic calculations. Design documents, however, must comply with the State Board's minimum criteria for fire protection sprinkler design.

Generally, a Class I wet standpipe system shall be provided to supply fire department hose valves and the sprinkler systems on each floor. Design shall comply with applicable editions of NFPA Standard 14.

Flexible sprinkler head fittings similar to Aquaflex may be provided if acceptable to the Tennessee Fire Marshal.

A4.14 General Commissioning Requirements

A. Definition of Commissioning

Commissioning as used in this Design Guidelines, is the systematic process of review, documentation, inspection and performance testing implemented starting with design and extending through construction and occupancy of the facility, utilized to assure that the facility and systems meet the Owner's Project Requirements (OPR). The Owner's Representative along with the Designer's Representative jointly will act as the Commissioning Authority "CxA" for the University. CxA will conduct of the commissioning scope of work for the Basic Commissioning work. For Enhanced Commissioning work, when required, the Owner will hire the third-party Commissioning Agent/Firm to conduct the commissioning scope of work.

B. Objectives of Commissioning

The objective of commissioning of the University of Tennessee facilities is to insure proper, reliable and safe operation of HVAC, plumbing, piping, electrical power and communications systems upon occupancy of each facility.
Commissioning may also be utilized to assure the proper selection, installation and operation of other building systems, such as architectural systems, at the discretion of the University.

C. General Requirements

For most projects, CxA will provide the scope of commissioning services defined herein. These sections are intended to illustrate the scope of commissioning for which the Owner/Designer/Contractor will be responsible to cooperate and facilitate within the Project

Documents. On some smaller projects, the University may determine that commissioning services shall be included within the Contractor's scope of work. In these cases, the project specifications shall require the Contractor to appoint or hire the Commissioning Authority and include in their bid. On all projects unless otherwise approved, the contract documents shall include specifications which require the contractor to cooperate, provide labor, assistance, materials, supplies and information, and otherwise facilitate the work of CxA. Where an Enhanced or Advanced commissioning is used, the independent Commissioning Authority will normally develop the "Commissioning Specifications" sections for inclusion in the Project Documents by the Designer of record. Otherwise, the Designer with input from the Owner will be responsible for developing the appropriate commissioning specifications sections.

D. Systems to be commissioned

On most typical projects the following systems are to be commissioned, as applicable:

1. Central Chiller/Cooling Plant including Cooling Towers, Pumps & VSD
2. Central Boiler/Heating Plant, Pumps & VSD
3. Heating, ventilating, air conditioning and refrigeration (HVAC&R) systems
4. HVAC Controls including IBMS graphic display points and data trending capability
5. Laboratory Airflow Control Valves
6. Fume Hoods and Controls
7. Laboratory Pressurization Controls
8. Heat Recovery Systems
9. Fume Exhaust Fans including their respective bypass damper and heat recovery system operation
10. Exhaust and Supply Fans
11. Steam and Converters
12. Domestic Hot Water Systems
13. Domestic Booster Pumps
14. RO/DI Water Systems
15. Laboratory Gas Systems
16. Branch Circuit Panel Boards
17. Emergency Power Equipment, including generator/transfer switch and switchgear
18. Voltage Drop & Power Circuit
19. Grounding of Panels
20. UPS and Backup Electrical Power Systems
21. Lighting Control System
22. Lighting Level Measurements
23. Smoke Evacuation Systems
24. Renewable Energy Systems
25. Fire Pumps
26. Fire Alarm System
27. Building Envelope/Enclosure
28. Other Special Systems

E. Commissioning Team Members

On most University projects, the Commissioning Team shall consist of the following members:

1. Owners Representative (UTFP)
2. Campus Representative (UTFS)

3. Designer of Record (AOR or EOR)
4. General Contractor Representative
5. Mechanical Contractor Representative
6. Electrical Contractor Representative
7. Test & Balance Firm Representative
8. Controls Contractor Representative
9. Equipment Supplier Representative
10. Commissioning Authority or Agent Representative where Enhanced/Advanced Commissioning is required

F. Commissioning Scope of Work

Most projects shall include the following minimum scope of commissioning work in the Specifications, to obligate the Contractor and the Contractor's subcontractors to participate and cooperate with the CxA:

1. Provide Submittals and other documents for Review
2. Completion of Installation Verification Checklists
3. Cooperate with Pre-Functional Testing of Systems
4. Participate in Scheduled Commissioning Meetings
5. Respond to Commissioning Issues and Field Reports
6. Provide Other Commissioning-Related Information (CRI's), as Requested
7. Assist in conducting Functional Systems Performance Testing
8. Submit O&M Manual documentation for review in a timely manner
9. Assisting and conducting Owner Training

G. Contractor Responsibility

The Contract Documents shall require the Contractor and subcontractors to cooperate, provide labor, materials, supplies and information where required to facilitate the specified scope of commissioning work. The Contractor shall provide all specified assistance in a timely manner, at no extra cost to the Owner, and shall incorporate all commissioning activities and milestones into the overall Project Construction Schedule. Satisfactory completion and acceptance of all commissioning tests and reports shall be a condition for granting Final Completion of the project. Ideally, all functional performance testing shall be completed in order to grant Substantial Completion of the project.

H. Project Closeout

Project closeout requirements shall include the review and recommendation of approval by the CxA of O&M Manuals and Warranty Information. Project closeout requirements shall include the completion of all testing and submission of all commissioning-related reports, certifications and manuals.

I. Owner Training

Contract documents shall require the Contractor to provide assistance, materials and services required to conduct training of Owner's personnel in the operation and maintenance of all major equipment and controls, and to cooperate with the CxA in developing the training agenda and methods.

J. Related Commissioning Specifications Sections

1. Division 21, Fire Suppression
2. Division 22, Plumbing
3. Division 23, Heating, Ventilating and Air Conditioning
4. Division 25, Integrated Building Management System
5. Division 26, Electrical

A4.15 DOCUMENTS

1. Show room numbers and names on all floor plans. Show column lines.
2. Show north arrow, graphic scale and key plan on all plans sheet.
3. Avoid “Key” notes.
4. On plan drawings graphically illustrate scale and include a north arrow with the preferable method representing both true north and building north.
5. Show all ductwork to scale. Provide section views where ductwork appears to conflict with other ducts, piping, structure, electrical, etc., especially in corridors.
6. Ductwork Layout: Avoid duct crossings, duct paralleling, duct backtracking, etc.
7. Identify all piping and show flow directions on all hydronic piping. Generally, piping should be shown on the same plans as the ductwork if feasible.
8. Provide 1/4" scale plan of all mechanical rooms. Show space for coil pull on floor plans. Provide 1/4" longitudinal section view of all AHU’s including piping, walls, ceilings or top structure, etc. A section is required (not an elevation). Typically, show duct thermometers in section views.
9. Provide control schematics and sequence of operation for all systems and equipment, including chillers, boilers, heat exchangers, AHU’s, tertiary systems, etc.
10. Provide simplified piping schematics of all hydronic systems with two or more chillers, boilers, or heat exchangers. Isometric drawings should not be provided unless it is necessary to show connection points of existing to new piping clearly. Non-scaled drawings showing piping and equipment in equipment rooms should not be provided.
11. Generally, select two manufacturers and model numbers for all major equipment items. Include in drawing schedules or specifications.
12. Provide concise, complete, brief - and correct - specifications. Omit from specifications paragraphs such as “Work Included”, “Related Work”, “Scope of Work”, etc. Do not include submittal requirements for each section. Do not include a plethora of manufacturers. Two manufacturers and model numbers are generally sufficient. Only the necessary information should be extracted and used from specifications produced by manufacturers.

    Thoroughly edit specification sections for the specific project. Include appropriate product and installation descriptions. Remove inapplicable sections and paragraphs from typical standard spec sections, etc. Unedited specifications will not be accepted.

END OF APPENDIX