THE UNIVERSITY OF TENNESSEE KNOXVILLE

FACILITIES SERVICES

Mechanical Design Criteria

July 2025

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1. GENERAL MECHANICAL CRITERIA

- Equipment criteria should include:
  - Long-range operation
  - Reliability targeting a 25-30 year service life
  - Off-the-shelf technology, preferably
  - Electric motors that are premium efficiency and VFD rated
- Energy-saving and cost-reduction strategies and technologies should be evaluated via both initial and life-cycle cost analyses.
- Equipment shall be located to:
  - allow for required service areas around equipment
  - allow service personnel to stand on floors or permanent platforms to the greatest extent possible
- Deviations from these criteria shall be discussed on a case-by-case basis with UTK Facilities Services (UTFS).

2. UTILITIES

2.1.SOURCE OF HEATING AND COOLING

- Use campus steam:
  - For space heating via heating water loops, where available
  - Large domestic water heating loads
- For smaller loads, use an electric water heater
- Maximize the use of the cooling plant capacity
- The designer should consult with UTFS to determine future cooling needs for surrounding buildings
- Variable refrigerant flow systems require UTFS approval.

2.2. OUTAGES

- All outages must be coordinated with UTFS in advance
- A written outage plan must be provided to UTFS 14 calendar days ahead of the outage and must include:
  - Start time
  - Expected duration
  - Description of work
- If specialty or custom parts are required, the availability of those items must be confirmed before outage scheduling
- All parts must be on site before the start of the outage

2.3. INTERFACE WITH OFF-CAMPUS UTILITY COMPANIES

- All interactions with off-campus utility companies must be coordinated through UTFS
  - This applies equally to interactions during the design and construction phase of all projects.

2.4. METERING

- All utilities shall be metered at the entry point to buildings
- Consult UTFS on:
    - Any requirements for additional submetering for specific uses
    - the specific make and model of meters to be used, as there may be utility company requirements
- All meters shall be revenue-quality devices
- Irrigation water should be metered separately from domestic water
- Boiler, chiller, and cooling tower make-up and blowdown water shall be metered separately

3. DESIGN AND ENERGY EFFICIENCY

Unless otherwise stated in specific building/space criteria, the following design conditions shall be used. These conditions also apply to the selection of all equipment.

Indoor Design Conditions	Outdoor Design Conditions
Cooling: 72 FDB	Summer: 95 FDB; 80 FWB
Heating: 72 FDB	Winter: 0 FDB
Dehumidification: 50% RH	

- The indoor relative humidity should not exceed 50% RH
    - This may result in dehumidification as the primary driver for distribution or equipment design, or selection.
- Systems shall be capable of maintaining the indoor design conditions across all conditions in all spaces
    - Especially for spaces with highly variable occupancies or equipment loading
- Indoor design conditions for animal facilities require special consideration:
    - Air changes should generally be a minimum of 15 air changes per hour in all operating modes
    - Room conditions shall be maintained throughout the entire air flow range (min to max)
    - Head loads must meet specific animal temperature requirements
- Heat load calculation must use software that utilizes ASHRAE's Heat Balance Method
- Each new building shall be energy modeled from software that utilizes DOE's EnergyPlus simulation
- New buildings shall have an EnergyStar rating of at least 80.

4. PRESSURIZATION REQUIREMENTS

- Buildings shall be positively pressurized relative to the outdoors
- Laboratory spaces shall be negatively pressurized relative to adjacent public spaces

5. AIR DISTRIBUTION

5.1. DESIGN

- Air distribution must be as uniform as possible, with temperature variation not exceeding 2°F across all load conditions
    - Particular attention is required for spaces with highly variable occupancies or equipment loads
- Ducted return air systems are preferred
    - Plenum return systems shall not be permitted
- Mechanical rooms shall not be used as return or outside air plenums.
- In ductwork layout, the following features should be minimized:
    - duct crossings
    - duct paralleling
    - duct backtracking
    - other similar complicating features
- For all occupied spaces, noise levels should not exceed NC 35
- For classrooms and teacher spaces, noise levels should not exceed NC 30
- Sound and vibration control may be required for both equipment and duct systems
- Provide opposed blade dampers
    - This includes airflow control applications for open-close operation
- All dampers shall be capable of closing “bubble-tight”.

5.2. REGISTERS, GRILLES, AND DIFFUSERS

- Locate air outlets to provide a proper throw, drop, and spread at or above:
    - 20 fpm (minimum) and 75 fpm maximum room velocity
- The range of supply air outlet velocities should be 500-750 fpm
- The range of return and exhaust inlet face velocities should be 300-500 fpm.
- Supply air should be introduced through round neck, louvered-face ceiling diffusers
- Dampers, where provided with diffusers, should be radial type
- Ceiling return and exhaust air registers and grilles must be grid core type
- Ducts serving return or exhaust air ceiling registers should be sized to accommodate the full face of the register
    - Do not provide round or flex duct to serve return or exhaust air ceiling registers.

5.3. DUCTWORK

- Fibrous duct shall only be used as insulation on metal duct
- Other than Ductmate® systems, joints in low-pressure supply air ducts located in unconditioned spaces must be sealed using Hardcast® pressure-less tape with RTA-50 adhesive (or a similar product)
- Rectangular branch take-offs should be of a 45-degree tap-in type
- Splitter dampers, extractors, and scoops are unnecessary
- Bellmouth fittings should be used for round duct take-offs
- Duct elbows and factory elbows are to be the full radius type, r/D = 1.5
- Radius elbows with square throats shall not be used

- If mitered 90-degree elbows are necessary, they should include a factory-made turning vane
- Provide manual volume dampers where required, for proper adjustment and balance of airflows
    - Damper must have blades with a minimum of 20-gauge thickness
- Medium and high pressure ducts must be factory-fabricated double-wall round or flat oval
    - with factory insulation and perforated liner
- Take-offs must be the conical type
- Divided flow fittings must be provided where required
- Joints should be sealed with Hardcast® pressure-less tape with RTA-50 adhesive, or a similar product
- Specify ducts to be leak tested per SMACNA's "Air Duct Leakage Test Manual."
- Flexible duct with 1" thick insulation should be used to connect supply air diffusers to main or branch ducts
- Specifications must include applicable duct pressure
- Duct length should be limited to 4 feet
- Ducts must be installed without kinks or sags and supported with 3/4 in. wide metal bands
- The minimum inside radius of any bend should be 1/2 the diameter of the duct.
- Access doors or panels 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
    - Other similar system components.
- Doors should be:
    - within reach of obstructions such as turning vanes and dampers
    - at approximately every 20 feet in long ducts for cleaning and maintenance if no other means of access is available
    - as large as practical
    - able to be opened or removed without the use of tools
- The location of inaccessible doors and other mechanical equipment (including valves, dampers, coils, VAV boxes, fan coil units, and other similar system components) should be coordinated with architectural design
- A minimum 24" x 24" access door should be included in inaccessible ceilings and walls as necessary for access
    - Access doors shall be located within reach of the equipment to be serviced.
- Maintain 2-1/2 duct diameters of straight duct before VAV box inlets
    - Final connection must be aligned properly to avoid restricted air flow to the box
- Shot pins are not allowed for supporting ductwork and sheet metal specialties

5.4. AIR SIDE ECONOMIZERS

- Damper actuators shall be mounted outside of the air stream
- Screens of corrosion-resistant material smaller than ½ in. mesh must protect the outdoor air intakes
- Return and outside air ductwork and dampers must be arranged to create complete mixing of the airstreams before entry of the air handling unit
    - Stationary blenders or baffles must be provided where mixing cannot be achieved
- Inline return air fans, where required, shall be:
    - the mixed flow type
    - belt-driven,
    - with lubrication fittings outside the fan housing.

  Integrating a hinged access door for inspection and cleaning is required for fans
- Fans should be selected for an outlet velocity of 3000 fpm maximum
    - Vane axial fans are not acceptable

5.5. VAV BOXES

- Variable air volume boxes are to be the pressure-independent type
    - Must include pressure taps and air flow curves for air flow and pressure measurements
    - Air leakage (fully closed) must not exceed 2% of the design air volume at 8 in. static inlet pressure
    - Total pressure drop should not exceed 0.5 in. wc
    - Boxes should be normally closed, have access doors, and:
        - a minimum 1 in. thick foil-faced glass fiber liner or double wall construction
- For most applications requiring heating, boxes with hot water coils must be provided
- Boxes with hot water coils should be provided for most applications requiring heating
    - The use of fan-powered boxes should be minimized
    - Fan-powered boxes may be considered for spaces with high heating requirements or where high minimum air flow rates are required
- Heating water coils should have:
    - Tubes: minimum of 0.02 in. thick
    - Fins: 0.006 in. aluminum fins with a maximum of 12 fins/inch
    - Casings are to be insulated with fiberglass duct wrap where condensation may occur
    - Do not include PT plugs and drain valves on piping to VAV boxes, coils
- Boxes installed above inaccessible ceilings should have adequate access
    - The engineer is responsible for coordinating this with the architect
- Boxes and hot water valves are to be furnished with DDC controls
    - Controllers should be fully programmable
    - Monitor and adjust airflow min/max setpoints via DDC
    - Monitor leaving air temperature.

5.6. MECHANICAL VENTILATION AND EXHAUST

- Install corrosion-resistant registers directly over sources of odor and moisture in sanitary facilities (toilets, locker rooms, janitor's closets, etc.)
    - Do not connect other spaces' ventilation to sanitary exhaust systems
- For mechanical and electrical rooms with heat-generating equipment (steam PRV stations, boilers, heat exchangers, chillers, switchgear, etc.) :
    - Supply air on the cool side of the room and exhaust on the hot side
    - Use thermostatically controlled exhaust fans to maintain room conditions as required for proper equipment operation
- Exhaust air shall be ducted directly to the fan
    - Ceiling registers shall be connected independently to the main ductwork to facilitate balancing and reduce noise
- Exhaust fans must be:
    - The centrifugal type
    - Directly driven, preferably
    - Selected for a maximum wheel tip speed of 3500 rpm
    - Corrosion-resistant gravity-type backdraft dampers
        - With blade edge and end seals
    - Fitted with an accessible non-fused disconnect switch in or at the fan base
    - Fitted with hinged housing at one edge for motor/drive access (when available)
- Fans should be AMCA-certified
    - With motor starters with a "soft start" or variable speed drives for motors larger than 5 hp
- Locate fans on building roofs or in mechanical rooms, when possible
    - Avoid installation above ceilings or other concealed/inaccessible spaces
- Use sound-attenuating roof curbs
    - Minimum height of 12 in.
    - Must be approved by UTFS only
- Control exhaust fans via DDC system or by interlocking with the respective air handling unit
- For fan systems with bypass air intakes
    - Design the bypass to minimize rainwater entry into the intake, ductwork or building

5.7. FIRE AND SMOKE DAMPERS

- Fire dampers must be:
    - U.L. labeled dynamic rated
    - Curtain-type dampers.
- Dampers must be:
    - Type "B" for low pressure
    - Type "C" 100% free area for high-pressure duct
- Smoke dampers shall be classified per U.L. Standard 555S.

5.8. AIR FILTRATION

- All systems shall have final filtration of MERV 14 or better.

    - Use MERV 8 pre-filters to prolong the service life of final filters
- Filter boxes/housing must include a hinged access door on each side
- Seal all joints between filter segments and ductwork with gaskets or sealant to prevent air leakage
- For large filter banks:
    - Install 3in. stiffening straps vertically between every second frame
- A Magnehelic® gauge shall be installed across each filter bank.
- At final inspection:
    - All filters must be new and clean in all equipment
    - A complete, new spare set of filters is required for all equipment in addition to those installed
- Filters in use during the construction period will only be accepted with prior UTFS authorization

6. INSULATION

6.1. GENERAL

- Insulation linings, coverings, vapor barriers, etc., and the adhesives must:
    - have a flame spread of no more than 25
    - a smoke-developed rating of not more than 50 as tested (per ASTM Standard E84)
    - be installed per the manufacturer's recommendations
- Insulation must be thick enough to prevent condensation on the exterior surface
- A vapor barrier should be provided on the exterior side
    - which can serve as a finishing cover for the insulation

6.2. DUCTWORK

- Insulate all supply, return, and outside air ductwork and plenums in unconditioned spaces
    - Preferably on the exterior
    - Consult with UTFS if an internal liner is needed for sound control (per NC criteria section 6.1)
- Insulate cold air duct components prone 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
- Ductwork not internally lined or factory insulated must be wrapped with
    - minimum 2 in. thick glass fiber insulation with a vapor barrier
- Ensure all operational components are accessible:
    - Leave manual volume damper handles, airflow station pressure ports, access door handles, duct mounted instrumentation, etc., exposed or accessible above the insulation vapor barrier
    - Provide stand-off brackets and locking quadrants for damper handles to allow adjustment without disturbing the insulation vapor barrier
- Insulate outdoor air ducts and plenums on the exterior with glass fiberboard insulation and seal to make them weatherproof
- Wrap supply and return air ducts with glass fiber insulation

    - Do not insulate exhaust ducts, unless connected to heat recovery or high-temperature exhausts

6.3. PIPING AND EQUIPMENT

- Insulate the following piping systems
    - Domestic hot and cold water
    - Space heating and chilled water
    - Rainwater leaders
    - Refrigerant suction lines
    - Steam and steam condensate
    - Piping traced with heating elements
    - A/C unit drain piping
- Building's BMS must monitor heat tracing elements
- Slip-joint piping is not permitted
- Insulate all valves (except pressure reducing valves), including:
    - Strainers, fittings, flanges, tanks, and hydronic specialties
    - Heat exchangers
    - Condensate receiver tanks and associated piping
    - Emergency generator mufflers and exhaust piping
    - Air release tanks
    - Chilled water pumps
- Do not insulate:
    - Compression tanks
    - Condenser water piping inside the building or in mechanical rooms
- On condensate receiver tanks and piping:
    - Leave all connections and gauges uncovered by insulation
- Use glass fiber sectional pipe insulation for most pipe applications
- At pipe fittings (tees and ells), provide factory-premolded glass fiber fittings equivalent to HAMFAB
    - Finish with class fabric and vapor barrier mastic
- Do not use glass fiber blanket inserts with PVC covers for pipe fitting insulation
- Fittings 8" and larger may be field mitered
- Insulate valves, strainers, flanges, etc, with mitered insulation segments of the same type and thickness as adjoining pipe insulation
- Insulate chilled water pump casings, large valves, and strainers in stem PRV stations
    - Custom-made, field-measure, removable, and reusable covers
- Below-grade piping must be either:
    - Factory pre-insulated type or
    - Insulated with Foamglas® and Pittwrap® jacket.
- Use Foamglas® insulation for piping exposed to weather and located in manholes
- For Foamglas® with Pittwrap® jacket:
    - Pipe must be embedded in sand
    - Cover with approximately 2 feet of sand above the pipe

- Insulation of piping and fittings shall allow for thermal expansion and/or contraction
    - especially where bends or loops are present
- Prefabricated, pre-insulated steam piping must include:
    - Steam service pipe
    - Insulation
    - Air gap
    - Jacket pipe allowing venting and draining of the air gap
- Include a temperature sensing line to detect steam leaks and approximate location
    - Route sensing line into a building, not to a manhole
- Steam piping insulated with Foamglas® with Pittwrap® must be pitched to drain condensate back to the steam vault drip leg
- Refrigerant suction piping and A/C unit drains must be insulated with flexible, elastomeric pipe insulation
    - Where exposed to weather, finish with a vapor barrier jacket
- The following are to be insulated with flexible, sheet-type elastomeric insulation:
    - Air separators
    - Chiller evaporators (including flanges)
- The following are to be insulated with board-type heavy-density glass fiber insulation and finished with a canvas jacket:
    - Heat exchangers
    - Hot water air separators
    - Condensate receiver tanks
        - On condensate receiver tanks and piping, no connections should be covered by gauges should be covered by insulation
- Insulated piping, valves, and fittings within 7 ft. of floors or work surfaces must be:
    - Finished with 0.016" smooth aluminum jacket
    - Secured with sheet metal screws and 1/4'" aluminum ban ds
- A corrugated or textured jacket is not acceptable
- Use factory-formed aluminum elbow covers for fittings and similar components
- Finish insulated piping above grade exposed to weather and in manhole tunnels with aluminum jacketing
- Any heat tracing elements must be:
    - Installed before the installation of insulation
    - Thermostatically controlled with a status light visible outside of the insulation
- At each hanger and support point, protect insulation with a 14 galvanized shield and the shield must:
    - extend to the centerline of the pipe and be centered in the hanger
    - be a minimum length of 12"
- For piping 3" or larger with glass fiber insulation
    - Insert a section of Foamglas® between the pipe and the metal shield to prevent insulation crushing

7. HYDRONIC SYSTEMS

7.1. DESIGN

- Size hydronic piping for pipe friction loss between 1-4 ft/100 ft
    - 2.5 ft/100 ft. represents the mean to which most systems are designed
- Flow velocity limits:
    - Max 8 fps for pipes larger than 2in.
    - Max 4 fps for 2 in. and smaller pipe
    - Min 2 fps for all pipe sizes
- Include a buffer tank if the hydronic system does not meet the minimum volume requirement for the equipment
- Piping runouts greater than 10 ft. in length must have a minimum size of ¾ in.
- Use nominal pipe size to select and designate all piping in the contract documents
- Chilled water systems must be designed for leaving water temperatures of 42-43°F
- Hot water systems must be designed for a leaving water temperature of 180-190°F
- The chilled water coil temperature differential must be:
    - No less than 16F for central station and built-up equipment
    - No less than 12F for terminal equipment
- The hot water coil temperature differential should generally be 30°F
- The system should use variable flow with two-way control valves (instead of three-way)
- Provide variable frequency drives at pumps
- Chillers must be capable of turning down as the flow decreases
- A three-way valve is allowed at the end of a loop to maintain loop flow
- All controls must be BACNET capable
- For multiple chiller systems with variable primary flow:
    - Design the system to maintain the required system flow even when not all chillers are operating
- For buildings served by the campus distribution system:
    - Provide a strap-on flow meter with a minimum of 1% accuracy to meter building flow
    - If a tertiary pump is used, include a control valve in the distribution system return line to regulate return water temperature back to the system
- Process cooling systems must include provisions to use the building's domestic water supply as a redundant cooling source
- The system must automatically switch to the redundant source if:
    - Flow is lost or
    - Loop temperature exceeds the emergency setpoint
- Heating coils that may be exposed to air temperatures below freezing should have run-around pumps in their piping to ensure continuous full water flow through the coils and prevent freezing

7.2. PIPING

- Piping 2 in. and smaller shall be Type L, hard-drawn seamless copper tubing
- Use wrought copper, solder joint type fittings, ANSI B16.2

    - Elbows must be a long radius pattern
    - Solder must be 95-5 type
- Do not use “Tee pullers” in place of tees on copper piping
- ProPress® fittings are allowed if the manufacturer’s installation instructions are followed and with prior approval from UTFS.
- Piping 2-1/2 in. and larger shall be seamless black steel, Schedule 40, ASTM A-53, Gr. B, or A106
- Use welded or flanged fittings per ANSI B16.9
    - Elbows are to be long radius pattern
- Field-fabricated fittings are not permitted
- Use forged steel, gasketed flanges, ANSI B16.5, welded neck type at flanged connections
    - Slip-on type may be used on a straight pipe
    - Flanges must be compatible with valve and equipment connections
- For branch connections one half the main diameter or smaller, use saddle-type, forged steel welding fittings
- Aquatherm® and similar piping products may be used for specific applications with prior UTFS approval
- Welding must comply with ANSI Code for Pressure Piping, Section B31.1
- Use single “V” butt joints with optimum fusion and 100% wall penetration of wall thickness
- Weld piping using shielded arc electrode-electric arc process
- Butt joints must be made with split backing rings
- Avoid direct welded connections to valves, strainers, and equipment whenever possible
- Contractors must provide certification for all pipe welders per ASME, Section IX
- Install valves in each branch circuit of all chilled and heating water
- Provide a drain located at the lowest point of the main riser
- Install dielectric unions where steel piping connects to copper piping systems
    - Prefer steel-to-brass-to-copper transitions when possible
- For horizontal pipe size changes, reducing fittings with eccentricity down (maintain bottom level)
- Make all piping take-offs from the top of mains or headers
- Do not use “bullhead” tee connections on return piping
- Provide adequate support for horizontal piping:
    - Max 7 ft spacing for piping/tubing 1-1/2in. and smaller
    - Max 10ft spacing for piping 2in. and larger
- Additional supports must be provided:
    - Within 18in. of all changes in direction
    - At all vertical pipes
    - Within 18in. of valves 4in. and larger, or other points of concentrated weight
- Use roller-type guided supports where piping is subjected to expansion
- All supports and hangers must be designed specifically for the piping material being supported
- Provide adequate shields between the pipe insulation and supports
- Shot pins are not acceptable for supporting piping or hydronic specialties

- All piping must be identified with snap-on or strap-on labels showing flow direction
    - Labels must be equivalent to those by Seton or Brady
- Band colors:
    - Green: chilled water and condenser water
    - Yellow: hot water piping
- Adhesive labels or painted markings are not acceptable for piping identification
- Specify piping to be thoroughly flushed before it is put into operation.

7.3. VALVES

- Use full port, two- (or three) piece ball valves with soldered end connections and extended stems for hydronic piping 2in. and smaller
- Valves must have a stainless steel ball and stem
- Rated for 600psig WOG
- Should be similar to Apollo 77-200
- Use butterfly valves on piping 2-1/2in. and larger with the following specifications
    - Lug-type body
    - Bronze disc
    - EPT seat
    - Extended neck
- Valves must be rated for “bubble-tight” service, 200 psig working pressure
- Butterfly valves should also be used in condenser water piping
- Valves 6in. and smaller:
    - Provide level handles with infinite throttling and memory stops
- Valves 8in. and larger:
    - Use worm gear operators with and wheel and position indicator
- For gear-operated valves located 10ft or more above the floor or work surface:
    - Provide chain wheel, chain, and guides for operation
- Provide a sufficient number of valves to ensure proper isolation of piping systems:
- In addition to equipment connections, install valves at:
    - All major pipe branches and risers
    - Service entry for each floor in multi-story buildings
    - Entry to every laboratory, kitchen, equipment room, or other spaces with extensive piping connections

7.4. AIR CONTROL AND DRAINS

- Hydronic systems must include air/dirt separation devices to reduce entrained air and sediment in the piping
- Provide manual air vents at:
    - All high points
    - Elevation changes in piping
    - Intervals along piping runs
- Use ball valves with a minimum size of ¼ in. for all air vents
- Use full-bladder type tanks as the preferred method for air confinement in the piping system
- Provide drain valves at low points in the piping system and as needed in mechanical rooms

- Use ¾ in. ball-type valves with capped hose-end connections
- Install drain valves on air-separators and strainers, accessible from the mechanical room floor, and pipe drains to a floor drain
- Hydronic lines must have a minimum pitch of 1 inch per 40 feet
- The pipe should pitch downward toward a drain point and upward toward vent points

7.5. SPECIALTIES

- Install 20 mesh strainers at the suction of each pump and equipment as recommended by the manufacturer, including control valves
- Strainers larger than 1 inch must have a ball-type blow-down valve piped to a floor drain
- Use suction diffusers instead of strainers on end suction pumps
- Remove pump strainers on end suction pumps
- Remove pump strainer screens after confirming that construction debris has been eliminated
- Triple-duty valves are not preferred
- Properly selected control valve Cv values and pump VFD control should eliminate the need for them
- If used, valves must be straight pattern, in-line type
- Do not install balancing valves on the discharge of variable speed pumps
- Install flow balancing valves (circuit setters) at:
    - Each air handling unit coil
    - Coil bypass lines
    - Terminal unit coils
    - Major branch lines and other locations as needed for balancing and monitoring
- Equip all balancing valves with a metering kit
- Specify or show valve sizes on the drawings
- For variable flow systems, use automatic flow balancing valves instead of circuit setters
- Consider installing hydronic system filters (full flow or bypass type) when connecting new piping to existing systems
    - Coordinate and discuss filter requirements with UTFS

7.6. INSTRUMENTATION

- Provide thermometers with wells at the inlet and outlet of each:
    - Chiller evaporator
    - Chiller condenser
    - Heat exchanger
- Install the thermometer on chilled water and hot water supply lines serving each mechanical room
- Thermometers must be readable from the mechanical room or platform
- Thermometers must be adjustable-angle type with a minimum 9in. scale
- The temperature range should be specified on drawings

- Thermometer wells must be:
  - ¾ in. NPT
  - 2-1/2 in. extension neck for insulated piping
- All wells must be fully packed with heat-conducting compound
- Provide a single pressure gauge for each pump
  - Pipe the gauge from both suction and discharge flanges with isolation valves
- Use compound-type gauges for pumps
- All gauges must:
  - Be 4-1/2 in. in size
  - Have 0.5% accuracy over the full scale range
  - Include impulse dampeners and needle or ¼ in. ball valves
- Install pressure-temperature fittings (P-T plugs) at the inlet and outlet of each:
  - AHU heating and cooling coil
  - Chiller evaporator and condenser
  - Heat exchanger
  - Control valve 2in. and larger
- Provide one P-T test kit
- Do not provide P-Ts on small terminal unit coils (including VAV box HW coils, fan coil units, etc.)
- Flow meters shall be a clamp-on type with no liquid contact
- Meters must use transit-time flow measurement with two transducers sized for the pipe diameter
- All transducers supplied must have an accuracy better than 1% of the flow reading
- Calibration and transducer data must be stored in non-volatile memory within the transducer junction box or flow meter
- Flow meters must compensate for temperature changes during system startup and shutdown
- Meters should operate accurately without any low-flow cutoffs or dead spots
- Flow meter electronics shall be housed in a NEMA 2, 3R, or better enclosure
- Flow meters must display:
  - Flow rate
  - Flow velocity
  - Mass flow
  - Total flow
  - Signal strength
  - Signal quality
  - Liquid sonic velocity
  - Reynolds regime (laminar/turbulent/transition)
- Meter must be able to output multiple options:
  - 4-20 mA
  - 0-1V or 0-10V voltage
  - RS-232
  - Binary output pulse
  - Relay alarm for total and meter status
- Meters must have the ability to:
  - status alarm for fault conditions

    - Set the 4-20 mA output for alarm fault conditions (i.e. 2 mA for alarm)
- Provide flow and BTU meters to monitor flow and energy for each building and key areas within
- Monitor the flow and energy use of the following throughout each building:
    - Cooling water
    - Heating water
    - Process water systems
        - Connect the monitoring to the DDC system for the building
- Consult with UTFS regarding the need for additional flow and energy monitoring in specific spaces in buildings
- All controls must be BACNET compatible

7.7. PUMPS

- Pumps for hydronic systems should be:
    - Flexibly coupled
    - Bronze-fitted
    - Centrifugal type with:
        - Cast iron or steel bases with drain pans
- Provide internally flushes mechanical seals rated for 200°F
- Preferred pump types:
    - End inlet with diffusers
    - Split case dual inlet pumps for higher flow rate applications
- Pumps for hydronic systems should be flexibly coupled, bronze-fitted, centrifugal type with cast iron or steel bases with drain pans. Provide internally-flushed mechanical seals rated for 200°F. End inlet with diffusers is the preferred pump. Split case pumps, dual inlet pumps, are preferred for applications with higher flow rates.
- Motor speed should not exceed 1750 rpm
- Consider 1150 rpm pumps for high flow, low head applications
- Acceptable pump manufacturers:
    - Bell & Gossett
    - Armstrong
    - Taco
- Provide variable speed drives (VSDs) for motors larger than 5 hp
- For motors larger than 20 hp, the VSD must also function as a soft starter
- All drives must be BACnet compatible
- Pumps above 20hp must be floor mounted
- Condenser water pumps must have stainless steel shafts
- Select pumps at the most efficient point
- Ensure pumps do not overload at any point on the pump curve
- Flat-curve pumps are preferred over steep-curve pumps for HVAC systems
- Avoid specifying the largest or smallest impeller size
- Do not add unnecessary head to the pump specification
- Locate pumps on the ground or basement level mechanical rooms
- Mount in-line pumps at heights allowing service access

    - Typically, not more than 3 feet above the standing surface to allow access without ladders or lifts
- Review available spacing to ensure proper installation footprint and adequate access for maintenance servicing
- Base-mounted pumps must have the base filled with non-shrinking grout
- Pump couplings must be properly aligned
- Specify each pump to be provided with one spare set of bearings and mechanical seals

8. STEAM SYSTEMS

8.1. DESIGN

- Steam systems should be the two-pipe type
- Campus distribution provides high-pressure steam ~125 psig
- Use low-pressure steam (0-15 psig) for space heating and domestic water heating
- Use medium pressure steam (16-60 psig) for process applications
- Do not use high-pressure steam for heating purposes

8.2. PIPING

- Use seamless black steel ASTM A-106 Grade B for steam and condensate piping
- Schedule 80 for steam piping 2 in. and smaller
- Schedule 40 for steam piping 2-1/2 in. and larger
- Use 2000 lb or 3000 lb forged steel for fittings
    - Cast iron fittings are not acceptable
- Use screwed or welded joints for piping 2 in. and smaller
- Use welded or flanged joints for piping 2-1/2 in. and larger
- Elbows must be long radius type
    - Unless otherwise noted
- Flanges should be:
    - Weld neck or slip-on
    - Raised face
    - With a non-asbestos gasket
        - Gasket shall be either:
            - stainless steel spiral wound strip with graphic filler or
            - compressed inorganic fiber with nitrile binder rated for saturated steam at system design pressure and temperature
- Flange bolting shall be with carbon steel bolts or studs
- Condensate piping shall be the same as steam, except for Schedule 80 stainless steel
- Pipe fittings, welding, supports, identification, and cleaning must comply with Section 6 requirements
- Use spiral wound metallic flange gaskets
- For horizontal pipe size changes, use reducing fittings with eccentricity up, and maintain the bottom level
- Provide adequate compensation for pipe expansion and contraction
- Include anchors, guides, expansion, loops, and joints where required

    - Show all required devices on the drawings
- Select all supports and restraining devices based on system stress analysis
- Ensure all devices can sustain static and dynamic loads per applicable codes
- For rollers, piping saddles must match or exceed the insulation thickness
- For slides, a Teflon slide surface shall be integral to the slide design
- All pipe supports must be secured in position
- Whenever possible, cast anchor and guide supports into base slabs
- Supports providing only vertical support may be secured via stainless anchor bolts, instead of being cast in place
- Do not use insulation as a pipe restraint or support in anchoring systems
- Anchors must be welded to the piping with full welds along contact lines
- The pipe should be pitched slightly from the anchors towards the steam vaults on both sides of the anchor points
- Wear must occur between saddles and rollers or between guides and their contact points
    - With no wear on the piping
- Anchors used for underground piping must be shown on engineered drawings
- Use pipe hangers specifically designed for steam and condensate applications
- Use tube-type “Yarway” expansion joints with single or double ends, flanged or butt welded
- Expansion joints must include packing glands with screw-down plungers for adding packing evenly around the stuffing box as needed
    - Additional packing is added evenly around the expansion joint via the packing cylinders
- Strictly follow the manufacturer’s instructions for installation and maintenance without exception
- Bellows-type expansion joints are prohibited for steam and condensate piping
- Steam and condensate piping must pitch down to drains and up to vent points
- Minimum pitch for steam lines: 1 in. per 40 ft
- Minimum pitch of condensate line: 1 in. per 20 ft
- Use snap-on or strap-on labels for all piping identification, showing flow direction
- Labels should be equal to those manufactured by Seton or Brady
- Use yellow bands for all steam and condensate piping
- Include pressure information on steam pipes
- Adhesive labels or painted markings are not acceptable forms of piping identification
- Flush piping with water to remove loose debris before testing
- Test all steam and condensate piping hydrostatically at 225 psig for a minimum of 4 hours without a pressure drop
- If leaks are found and repaired, repeat the test
- The project manager must witness the test being performed
- After testing, clean piping by steam blowing before connecting to the campus distribution system
- Perform three steam blows with cooldown periods between each, to thermal cycle piping and remove welding slag and debris

- Muffle or quench exhaust ends to keep noise at or below 85 dBA measured 50 ft from the discharge pointer
- Take precautions to prevent debris from settling on cars, buildings, or people nearby
- Remove all inline instruments or devices before flushing, steam blowing, and testing; replace with spool pieces as needed
- Design any temporary piping per ASME B31.1 standards
- Reinstall all instruments and devices after successful testing

8.3. VALVES

- Provide gate valves on steam and condensate lines to isolate risers, branches, equipment, control valves, fixtures, etc.
- For gate valves 6 in. and larger located more than 10 feet above the floor, install chain wheel, chain, and guides
- Gate valves (2in. and smaller):
    - 800 lb. socket weld, OS&Y, solid wedge disc
    - Forged steel body, ASTM A105 with max 0.31% carbon
    - Rate for 365F campus steam temperature
- Globe valves (2in. and smaller)
    - 800 lb. socket weld, OS&Y, loose disc
    - Forged steel body, ASTM A105 with max 0.31% carbon
    - Stellited disc and integral seats
    - Welded bonnet and bolted gland
    - Dimensions per ANSI B16.10
- Check valves (2 in. and smaller)
    - 600 lb. socket-weld, horizontal lift type
    - Cast steel body (ASTM A216 Grade WCB, max 0.30% carbon) or forged steel body (ASTM A105, max 0.31% carbon)
    - Stellited disc with integral seats
    - Bolted cap with contained Flexitallic (or equal) gasket
    - Socket weld end dimensions must comply with ANSI B16.11
- Gate valves (2-1/2 in. and larger):
    - Class 300, OS&Y, flexible wedge disc
    - Cast steel body and bonnet (ASTM A216 WCB)
    - Bonnet gasket: Stainless steel spiral wound
    - Hard-faced seat rings
    - Disc: CA-15 or 13% CR overlay
    - Stem: 410 stainless steel; back seat also 410 SS
    - Packing: graphite
    - Bonnet studs: A193 Gr. B&; nuts: A194 Gr. 2H
    - Face-to-face dimensions: ASME B16/10
    - Weld ends: ASME B16/25; Flanged ends: ASME B16.5
    - Include a steel grease fitting
    - Equivalent to Crane fig. 33 (flanged) or 33-1/2 (butt weld)
- Globe valves (2-1/2 in. and larger):
    - Class 300, OS&Y, bolted bonnet
    - Cast steel body and bonnet (ASTM A216 WCB)

    - Bonnet gasket: stainless steel spiral wound graphite
    - Hard-faced seat rings
    - Disc: 13% chrome overlay
    - Stem, gland, and back seat: 410 SS
    - Packing: graphite
    - Bonnet studs: 193 Gr B7
    - Nuts: A194 Gr. 2H
    - Face-to-face dimensions: ASME B16.10
    - Weld ends: ASME B16.25
    - Flanged ends: ASME B16.5
    - Equivalent to Crane fig. 151 (flanged) or 151-1/2 (butt weld)
- Check valves (2-1/2 in. and larger):
    - Class 300, Bolted Cap
    - Cast steel body and cap (ASTM A216 Grade WCB)
    - Cap gasket: stainless steel spiral wound with graphite
    - Hard-faced seat rings
    - Disc: 13% CR overlay
    - Hinge: WCB
    - Hinge pins: 410 SS
    - Cap screw: A307 Grade B
    - Cap studs: A193 Gr. B
    - Nuts: A194 Gr. 2H
- Gate valves 8 in. and larger in high-pressure piping shall include an integral bypass and valve
- Steam distribution valves shall be provided with weld-end connections

8.4. SPECIALTIES

- Provide Y-pattern strainers rated 250 lb. SWP (or 300 lb. for steam pressures over 100 psig) upstream of all control values, pressure reducing valves, steam traps, etc.
- Steam traps should be the inverted bucket type with 1 in. connections
- Traps must be installed below the steam line to ensure proper condensate drainage
- Orifice sizes in the traps shall be selected to match system design conditions
- Install steam traps with the following components:
    - Isolation valves
    - Unions
    - Check valves
    - Strainer with blowdown valve
- Float and thermostatic traps may be used where steam pressure can range from full supply pressure down to vacuum
- Size traps for twice the maximum equipment condensate load
- Bypass lines around steam traps are not required
- Route all condensate from buildings and steam trap discharge to a vented flash tank
- Route from flash tank to condensate receiver
- Pump condensate from the receiver to the condensate return line
- Use elevated tanks when feasible to allow gravity drainage of condensate
- Provide each tank with a thermometer and an inlet strainer

- Direct injection of condensate from a trap into a pumped condensate return line is not permitted
- Condensate pump/receiver sets shall be duplex type
- Provide each set with:
    - A flow-operated mechanical alternating switch
    - Sight glass
    - Check and gate valves on each pump discharge line
- The condensate pump must be rated for continuous operation of pumping 212°F fluid
- Back pressure in the condensate line must be taken into consideration when sizing the pump set
- Use standard “off the shelf” electric motors for condensate pumps to allow easy replacement from typical suppliers
- Install pressure gauges on:
    - Discharge of each condensate pump
    - Upstream and downstream of each pressure-reducing valve
    - Steam supply to heat exchangers
- Gauges shall be 4-1/2” in size with 0.5% minimum accuracy over the full scale
- Equip each gauge with an iron coil siphon and needle valve
- Install a clamp-on condensate flow meter to monitor steam flow for each building

8.5. PRV STATION

- Use a pressure-reducing valve station to reduce high-pressure steam from the campus distribution system to medium and low pressure for:
    - Process applications
    - Space heating
    - Domestic water heating
- 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
    - Transfer valves (where required)
- Reducing and regulating valves shall be:
    - Normally closed
    - Air-loading, diaphragm-operated
    - 250 lb. SWP, cast iron body with stainless steel trim and “Stellited” renewable seat ring (for less than 100 psig)
    - 300 lb. cast steel regulating valve (for greater than 100 psig)
- Select valves to ensure noise levels do not exceed 90 dBA
- Valves 2” and larger shall have flanged connections
- Locate PRV stations near exterior walls to allow access to ventilation air
- Maintain a minimum 12-inch clearance between piping, flange, etc., and the wall

8.6. CONVERTERS

- In most instances, install a heat exchanger to provide hot water for the building heating system where steam is available
- Heat exchangers should be:
    - Steam-to-water, shell, and U-tube construction
    - ASME labeled for 125 psig working pressure
- Submit a manufacturer's data report certifying compliance with the latest ASME code for pressure vessels
- A National Board Commission-certified inspector must sign report
- Steam supply pressure to control valve: 10-15 psig
- Capacity must account for a fouling factor of 0.001
- Downstream steam pressure should be about 80% of the upstream pressure
- Provide a single F&T trap (if capacity allows), sized for twice the condensing rate
- Locate heat exchangers near exterior walls for access to ventilation air
- Heat Exchanger bundles must be constructed of 316 stainless steel
- Locate heat exchangers/converters with sufficient space for tube bundle removal, inspection, and repair/replacement

8.7. STEAM VAULTS AND TUNNELS

- Steam vaults must allow safe, adequate movement and work clearances for operating/replacing valves, traps, and components
- Typical internal size: 10 ft x 10 ft x 8 ft high, with 12-inch-thick walls
- Use larger vaults as needed to maintain proper working clearances
- Steam vaults must have two openings for egress, ventilation, and component removal/installation
- Openings must be sized to accommodate component removal/installation
- Optimal opening placement: diagonally across the vault, not on the same side
- Sump holes must be a 12" x 12" x 6" (Length x Width x Depth)
- An additional top access opening is permitted for valve operation or service
- Access opening must have a water seal to prevent water ingress when closed
- Vault covers must be:
    - Lightweight
    - Lockable
    - Rated for vehicle loads
    - Designed for steam vault applications
    - Labeled with stainless steel ID tags showing the vault number
- Access openings must include galvanized steel ladders up to 6" below the cover (no cast-in-place steps)
- Apply sprayed or rolled-on membrane for full steam vault waterproofing
- Apply extra coats at joints and penetrations to ensure a watertight seal
- Use approved "link seal" products for watertight piping penetrations
- Vault walls, roof, floor, and reinforcement must be structurally designed by a licensed structural engineer
- Steam tunnels must have at least 8 feet of head clearance and 3 3-foot clear aisle for walking and material transport

- Tunnels to be cast in place with egress openings approximately every 300 feet
- Provide natural ventilation with thermostat-controlled fans as needed
- Fans must include hand/off/auto switch
- Waterproofing to match methods used for steam vaults

9. HEAT TRANSFER EQUIPMENT

9.1.AIR HANDLING UNITS

- Provide field-assembled or factory-fabricated central station air handling units
- All sections must be double-wall with 2 in., 3.0 lb. density fiberglass or foam insulation
- Use perforated interior liner in the fan section (typical applications)
- Include positive-draining, double-wall stainless steel drain pans
- Provide intermediate drain pans where coils are stacked
- The layout must allow access for servicing fans, filters, and coil replacement
- Provide access to both sides of each coil
- If access isn't possible through fan or filter sections, include full-size access sections with hinged doors (minimum 18" wide)
- Where space allows, install hinged access doors on both sides of fan casings, access sections, filter sections, and mixing boxes
- Do not use screws or bolts for coil access
- Install units and field-assembled plenums on a minimum 4 in. high concrete housekeeping pad
- Rails may be acceptable in certain applications
- If the unit fan lacks built-in isolation, install on spring vibration isolators
- Use opposed blade dampers for mixing boxes with a max 1% air leakage of the rated flow
- In the O.A. damper section, include:
    - One minimum O.A. damper
    - One maximum O.A. damper (for economizer operation)
- Also provide a return air damper
- Belt drives must be sized for at least 150% of motor horsepower
- Use a minimum of two belts per drive
- Fan bearings must be grease-lubricated, self-aligning ball or roller type, externally mounted, and rated for 200,000-hour life
- Extend lubrication lines to an easily accessible location
- Provide one spare set of bearings and belts for each fan
- Provide variable speed drives for all motors over 5 hp
- AHU schedule on drawings must include:
    - Total static pressure
    - External static pressure
    - Component static pressures (coils, filters, dampers)
- Indicate whether the filter static pressure is included in or separate from the external static pressure
- Total static pressure should be the sum of external and component static pressures

- The filter static pressure indicated should be the change-out pressure
- Guideline 1: Use ¾ of the range between the initial and final (terminal) pressure drops
- Guideline 2: Do not exceed twice the initial pressure drop
- Install a properly ranged and sized thermometer in the discharge duct of each air handling unit
- Air handling unit submittals shall include fan curves for maximum and minimum operating conditions

9.2. UNITARY SYSTEMS

- Unitary systems and components shall closely comply with the criteria outlined elsewhere in this document
- Provide unitary systems with hot gas reheat for humidity control
- Microchannel condensing and reheat coils are prohibited
- Unitary systems shall be equipped for standalone economizer operation
- Mount systems on roof stands, not roof curbs
- Roof stands shall be 18" to 30" above the finished roof surface
- Unitary systems must be directly connected to the building DDC system

9.3. COILS

- Cooling and heating coils must have:
    - Minimum 0.007 in. aluminum plate fin secondary surface
    - 0.024 in. seamless copper tubing with no more than 11 fins per inch
- Avoid spiral-type configurations
- Limit the physical height of cooling coil sections to 45 inches
- Select AHU chilled water coils with a minimum 16°F temperature rise
- Select hot water coils for a 30°F temperature drop
- Cooling coils should be piped so that chilled water is supplied on the air leaving side and is returned on the air entering side
- Install unions or flanges to allow coil removal without disturbing upstream piping
- CW coil face velocities should generally not exceed 500 fpm
- Show coil pull space on mechanical room floor plans

9.4. CHILLERS

- Location
    - Locate chillers at ground level or in basement mechanical rooms
    - Ensure sufficient clearance for maintenance, repair, and replacement of components, including evaporator and condenser tube bundles
- General Requirements
    - Chillers must modulate down to 40% of rated capacity
    - Provide low-pressure chillers with a high-efficiency OEM purge system, including:
        - Air-cooled condensing unit
        - Purge the condensing tank
        - Pump-out compressor

    - Purge exhaust limit: max 0.05 lb refrigerant per lb of purged air
    - Include low ambient control
    - Provide power factor correction capacitors to maintain a minimum 0.90 PF from 40-100% load
    - Equipped with motor soft or wye delta starters
    - Max chiller noise level: 85 dBa
    - Leaving water temperature: 42°F (except for ice storage applications)
    - Evaporator temperature must not drop below 32°F
    - Evaporator/condenser tubes: 0.028 in. copper, smooth or enhanced
- Acceptable Manufacturers
    - Trane, McQuay, Carrier, or York
- Refrigerants
    - Low GWP refrigerants may be used in equipment
- Centrifugal Chillers
    - Use centrifugal water chillers for projects requiring over 200 tons
    - Only one compressor unit is acceptable (open or hermetic type)
    - Use soft starters or wye delta starters; VFDs are not permitted
    - Water boxes must include davits or hinged doors for easy tube service and cleaning
- Air Cooled Chillers
    - Microchannel condensing coils are not permitted on air-cooled chillers
- Controls
    - Chillers must have microprocessor-based controls compatible with the campus energy management system and support remote control
    - Safety and operating controls must include:
        - Current limiting overload device
        - Evaporator and condenser pressure/temperature gauges
        - Oil pressure gauge
        - Temperature cutouts for:
            - Low chilled water temperature
            - Low refrigerant temperature
            - High motor, compressor discharge, oil, and bearing temperatures
        - Pressure cutouts for:
            - Low oil pressure
            - Low refrigerant pressure
            - High condenser pressure
        - Oil pump switch
        - Guide vane time delay switch
        - Evaporator and condenser water flow switches
        - Pilot lights for safety circuit indicators
- Start Up
    - A factory start-up report must be provided before final acceptance

9.5. COOLING TOWERS

- Cooling towers must be induced draft, crossflow type, with stainless steel construction
- Include PVC fill and stainless steel or PVC louvers; must meet current CTI design standards
- Avoid counter-flow towers
- Fans must be gear-driven or direct drive with a low turndown ratio for variable speed operation
- Belt drives require prior approval from UTFS
- Cooling tower submittals must include CTI performance curves
- All steel components (panels, frame, basins, covers, fan deck, fan cylinder) must be Series 300 stainless steel with Series 300 stainless steel fasteners
- All factory seams in the cold-water basin must be fully welded and leak-warranted for 5 years
- Bolted seam stainless steel basins are not permitted
- The entire cooling tower, including fan motor, drive system, bearings, and structure, must carry a comprehensive 5-year warranty
- Fiberglass or plastic components are not acceptable
- Base design on entering/leaving water temperatures of 95°F and 85°F, respectively, with 80 FWB ambient temperature
- Drift loss must be less than 0.001%
- Coordinate cooling tower location on site with UTFS
- Review tower basin and condenser pump elevation to prevent cavitation
- Ladders to cooling tower platforms and fan decks must extend to the grade/roof deck and meet OSHA standards
- Provide two ladders where access to both sides of the fan deck is needed
- Install handrails and service platforms per OSHA requirements
- Provide adequate heat in the basin and exposed piping to prevent freezing in cold weather
- Use a variable-speed fan to control condenser water temperature
- Maintain setpoint by adjusting fan speed and operating two 3-way diverting valves (one in supply, one in bypass), in series
- Bypass lines must match the full supply pipe size and be located in the mechanical room
- Interlock tower fans with condenser water pumps so that fans operate only when pumps are running
- Vibration limits must comply with the CTI Cooling Tower Manual
- Limits must be maintained throughout the warranty period without requiring maintenance beyond normal scheduled operation
- Any vibration limit switches must be field-adjusted to meet CTI standards
- Provide all required taps and ports for CTI testing
- CTI performance and capacity testing is required for field-erected towers
- UTFS reserves the right to test all towers for capacity, performance, and drift during the warranty period
- The installing contractor is responsible for correcting any deficiencies identified during testing

- Cooling towers must not produce prominent tonal sounds audible in surrounding buildings or areas

10. TESTING AND BALANCING

- HVAC system design must include provisions for balancing air and water systems
- Balancing components include:
    - Dampers
    - Temperature and pressure test connections
    - Flow meters
    - Balancing valves
- Air and water systems balancing must be performed by an independent agency or subcontractor
- The balancing subcontractor must be certified by AABC or NEBB
- Air side testing and adjustment must include:
    - Equipment and motor data
    - Traverse airflow measurements for all main supply, return, outside, relief, and exhaust air ducts (especially at AH units and ducted fans)
    - Static pressure at the inlet and outlet of each AH unit, exhaust/relief/return fan, coil, and filter bank
    - Entering and leaving air temperatures at AH unit coils
    - Fan RPM, motor voltage, and amperage; include fan curves for AH units, return, and exhaust fans in the report
    - Airflow rate and pressure differential for each VAV box
    - Airflow rate at each register and diffuser
- Water side testing and balancing must include:
    - Equipment and motor data
    - Differential pressure and water flow rate at each AH unit, heat exchanger, chiller evaporator, and condenser, and all flow meters (including those serving terminal equipment)
    - Entering and leaving water temperatures at AH unit coils
    - Shut-off head, full flow head, final head, and final flow rate for each pump; include pump curves, motor voltage, and amperage in the report
    - Entering and leaving pressure at each AH unit coil, chiller evaporator, condenser, and heat exchanger
    - Testing and balancing of the domestic hot water recirculating system
- The balancing report must include a drawing or sketch showing:
    - Each terminal unit, register, and diffuser with the spaces they serve
    - Each AH unit, with clearly marked test points

11. CONTROLS

- All mechanical systems must include direct digital controls (DDC) with electronic operators. Pneumatic controls are prohibited
- Approved controls vendors:
    - Trane
    - HSC – Automated Logic
    - Hoffman Building Technologies – DISTECH

- Equipment with proprietary controllers (e.g., chiller plant controllers) must be fully compatible with DDC systems and BACnet IP
- For buildings with existing DDC systems undergoing expansion or partial renovation, coordinate with UTFS to define the appropriate controls scope before design completion
- All control systems must use a fully open protocol with no hidden points
- Coordinate all control system installations with UTFS to ensure full integration with the UTFS front-end system
- This requirement also applies to equipment or systems with independent controllers outside the main DDC system
- Provide a new PC or laptop for DDC system monitoring with each new building controls installation
- A new PC or laptop is not required for renovations or repairs of existing systems
- All DDC software must:
    - Be provided to UTFS at no additional cost
    - Be capable of connecting to all control systems of the same vendor on campus

11.1. GRAPHICS

- Provide software graphics with pictorial representations of controlled equipment and devices, viewable on the PC monitor
- UTFS must have the ability to modify or add graphics
- Each VAV graphic must display the serving AHU in text format on the screen

11.2. CONTROL WIRING

- The control subcontractor is responsible for furnishing and installing 24V control wiring
- The electrical subcontractor is responsible for:
    - Furnishing and installing all 120V and above wiring and conduit
    - Required starter coils, starters, and control panels not included in packaged units
- Coordination with the electrical engineer is required

11.3. GAUGES

- All manual gauges on air or water systems must have a valve cock installed below them
- This allows gauge replacement without shutting down the monitored service

11.4. THERMOSTATS

- Room thermostats must be electronic, compatible with the DDC system, and include communication ports
- Provide setpoint adjustment with Fahrenheit scale; accuracy ±1°F
- Locate thermostats to avoid interference with light switches
- Configure controls to allow separate heating and cooling setpoints (e.g., heat to 68.5°F, cool to 73.5°F) with a dead band between them

- Indicate all thermostats, including night low limits, on HVAC floor plans
- Provide protective guards where thermostats may be vulnerable to damage

11.5. HUMIDITY SENSORS

- Provide humidity sensors in each control zone
- Wall and duct-mounted humidity sensors must have ±2% RH accuracy
- Use thin-film platinum type temperature sensors in combination sensors, if required
- Locate wall humidity sensors to avoid interference with light switches
- Indicate all humidity sensors on HVAC floor plans
- Connect all humidity sensors to the building DDC system

11.6. AIR AND WATER DP SENSORS/TRANSMITTERS

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

11.7. CONTROL VALVES

- Use equal percentage type ball valves for sizes 8 in. and smaller
- Equipped with electronic actuators with spring return
- Automatic flow controls are not permitted
- Use traditional manual circuit setters for flow verification and commissioning
- Provide bypass valves for critical systems and all heating in air handlers

11.8. CONTROL DAMPERS

- Provide opposed blade dampers with a maximum air leakage of 1% of rated flow

11.9. TEMPERATURE CONTROL DRAWINGS AND SEQUENCES

- Provide schematic drawings showing the sequence of operation for each HVAC system, including AHUs, chillers, cooling towers/condensers, boilers, heat exchangers, exhaust fans, etc.
- Schematics and sequences must appear on the HVAC drawings, not in the Project Manual
- Sequences must be clear, concise, and written as simply as possible

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

I. Start the Air Handler
   a) BAS
   b) Occupied Mode HOA Sw.
   c) Min OA damper*
   d) Smoke dampers*

e) 100% OA damper*
f) RA fan (economizer)*

II. Control the Temperature
a) Cooling Coil
b) Economizer*
c) Heating Coil
d) Air Flow*
e) Dehumidification

III. Control the Preheat*
a) F&B dampers*

IV. Control the Air Flow (VAV AHU)*
a) RA fan (economizer)*

V. Safeties
a) Freezestat
b) Smoke Detectors

VI. Unoccupied Mode
a) Temperature Setback
b) De-energize*

VII. Monitor
a) SA temperature
b) SA Fan Status
c) OA temperature and Humidity (global)
d) Filter DP
e) RA temperature and Humidity (economizer)*
f) Preheat Temperature*
g) Duct SP (VAV AHU)
h) SA CFM*
i) RA CFM (economizer)*
j) Minimum OA CFM*
k) Space Temperature and Humidity (dehumidification control)*
l) RA Fan Status (economizer)*

- Hydronic DP transmitters must be initially set to 15 psig, with final adjustments by the TAB agency
- Show all DP and SP sensor/transmitter locations on the plans
- Do not specify SP sensors to be located "2/3 length of SA duct"

12. PLUMBING

12.1. DOMESTIC COLD WATER SYSTEMS

- Domestic cold water service will connect to the existing site main
- Pressure booster pumps will be used if necessary
- Cold water will supply:
  - Toilet rooms
  - Mop receptors
  - General-purpose sinks
  - Wall hydrants
  - Other specific equipment as needed

- A minimum pressure of 25 psig is required for water closet flush valves to function properly
- Pressure-reducing valves (PRVs) will be installed just downstream of the meter
- A full-size bypass loop will be provided around both the PRV and the meter
- Two reduced-pressure backflow preventers (RPBPs) of equal size will be installed in parallel just downstream of the meter bypass loop
- These RPBPs will protect the site system from contamination
- Each RPBP will be:
    - Sized for full flow conditions
    - Installed to allow equalized flow between them
- Each assembly will include:
    - A Y-strainer with a drain plug connected to the blow-off port for flushing
    - An air gap
    - Upward-facing test cocks
- Isolation valves will be installed:
    - Before the Y-strainer
    - After the backflow preventer assembly
- The configuration allows either RPBP to be removed without disrupting service
- System capacity will be determined using fixture unit values
- Appropriate code factors will be applied
- Actual equipment demands will also be considered in the sizing

12.2. DOMESTIC HOT WATER SYSTEMS

- Provide domestic hot water systems with supply and return piping to always maintain hot water at all fixtures
- Distribute hot water at 120°F to:
    - Lavatories
    - Showers
    - Sinks
    - And other required equipment
- Provide local booster heaters for equipment needing higher temperature water
- Produce hot water using steam-fired instantaneous hot water generators (e.g., PVI COBREX or similar)
- Size system capacity based on fixture unit values, applicable code factors, and actual equipment demands
- Provide circuit setters on branch recirculating lines at each floor

12.3. SERVICE PIPING

- Aboveground domestic hot and cold water piping should be:
    - Type L hard-drawn copper with wrought copper fittings or
    - PEX-a piping and fittings
- Water lines installed underground should be:
    - Type K copper with wrought copper fittings or
    - HDPE with appropriate fittings
- Underground piping thickness should be suitable for the expected roadway or vehicle loads

- Soldered joints shall use lead-free 95-5 solder
- Press-type joints are not permitted
- Underground HDPE piping may be considered after UTFS review
- Mechanically formed tee connections are not acceptable for piping tees
- Outside water mains shall be AWW.A bell and spigot cement-lined ductile iron (250lb class) with black asphaltum coating, or HDPE with appropriate fittings
- Underground valves shall comply with A.W.W.A standards for domestic water mains
- Underground piping shall be sized with a thickness suitable for roadway vehicle loading
- All mechanical underground valves shall be “right-handed” with shut-off clockwise and opening counterclockwise
- Install valves for each of the operations with a “T Handle” operator
- Valves shall be exercised periodically during construction to ensure ease of operation
- Service water piping shall be clean and free of gravel and debris upon completion
- Service water piping shall be tested and disinfected per applicable code requirements
- Testing shall be performed by an approved third-party testing lab
- Provide water hammer arresters in domestic water piping as needed to eliminate noise and prevent damage from excessive vibration
- Provide an isolation valve for each water service main, branch main, riser, floor branch in multi-story buildings, branch line serving a group of fixtures, and each equipment connection
- Valves for pipes 2 in and smaller shall be two-or three-piece, full-port ball valves with stainless steel balls and stems
- Valves for pipes 2-1/2 in and larger shall be lug butterfly valves
- Pipe hangers shall be specifically designed for the piping and insulation materials used
- Space hangers to prevent pipes from sagging between supports
- Provide hangers at every change of direction in the piping
- Piping identification shall comply with Section 8 of these design criteria
- Specify snap-on or strap-on labels with flow direction indicators, equal to Seton or Brady products
- Band colors should be:
    - Green for domestic cold water
    - Yellow for domestic hot water and hot water return
    - Red for fire protection
    - Yellow for natural gas
- Adhesive labels and painted markings are not acceptable forms of pipe identification

12.4. SANITARY AND STORM DRAINAGE SYSTEMS

- Provide a separate sanitary drainage, waste, and vent system for all water closets, lavatories, service sinks, and similar fixtures
- Connect sanitary drainage by gravity directly to the site sewer system

- Size system capacity based on fixture unit values, applicable code factors, and actual equipment demands
- Provide a stormwater drainage system for all roof drains, clear waste, and area drains connected to the storm system
- Ensure compliance with the University of Tennessee Illicit Discharge Policy when designing the drain connection to the storm system
- Provide cleanouts for access to horizontal and vertical drain lines to allow inspection and removal of obstructions
- Cleanouts shall be spaced no more than 100 feet apart, measured from the upstream entrance
- Cleanouts are required at any change of direction greater than 45 degrees
- For buildings sewers 8 in. and larger, provide manholes located no more than 200 feet from the junction of the building drain and building sewer
- Provide manholes at each change in direction
- Provide manholes at intervals not exceeding 400 feet apart
- Sanitary and storm drainage system materials shall comply with applicable codes and standards
- Pipe fittings shall be appropriate for the materials used
- Cast iron piping shall be used:
    - For underground locations with less than 4 ft of cover in areas with traffic loading
    - Where pipe coverage exceeds 15 feet before or after installation
    - Where crossing above or below water mains, other drain lines, and steam lines
- Pitch piping to drain at a minimum slope of ¼ in. per foot for piping 3 in. and smaller
- Pitch piping at a minimum slope of 1/8 in. per foot for piping 4in. and larger
- Route discharge from sump pumps separately to exterior structures located to prevent any pressurized waste backflow from re-entering the building

12.5. GREASE INTERCEPTORS

- Grease interceptors shall be sized and installed per the Knoxville Utilities Board Grease Control guidelines

12.6. INSULATION

- Insulate hot, cold, chilled water, and roof drain piping to prevent energy loss and condensation
- Cold and chilled water piping insulation shall include an exterior vapor barrier
- Insulation shall comply with Section 6

12.7. FIXTURES AND SPECIALTIES

- Plumbing fixture material shall be non-absorptive and acid-resistant
- Provide a schedule on the drawings indicating each type of fixture specified, including supply and waste sizes, trim, accessories, manufacturer, model number, etc.

- Schedules in the project manual are not acceptable
- Provide a ¼-turn ball valve at each fixture
- Each fixture, floor drain, or other equipment connected to the drainage system shall have a separate trap installed as close to the fixture as possible, with a cleanout for each trap
- Wall-mounted fixtures shall be supported with floor-mounted fixture carriers
- Water closets shall be wall-hung for new construction
- Floor-mounted water closets may be considered in renovation projects with existing floor-mounted units, only with prior UTFS approval
- Provide water-efficient fixtures
- Install sensor-activated flush valves or lavatory faucets
- Include faucet temperature adjustment where needed
- Urinals shall be 1/8 gal low-flush type with battery-operated flush valves
- Water closets shall have battery-operated flush valves rated at 1.1 gal/flush or less
- Lavatory faucets shall be selected for a maximum water usage of 0.5 gpm at 60 psi
- Bottle fillers must be equipped with lead, cysts, microplastics, chlorine taste, and odor filters
- Fire hydrants shall be a 3-way design with two hose connections and one pumper connection
- Main valve opening shall be 4-1/2 in. unless otherwise required for specific use
- Hydrants shall be rated at 250 psig working pressure and 500 psig static test pressure
- Hydrants shall be open with a left turn

12.8. FIXTURE PREFERENCES

- The following is a list of the UTFS preferred manufacturer and, in some cases, the preferred model number for various plumbing fixtures. These preferences are not strict requirements, but shall be considered when selecting the basis of design and creating the design specifications:
    - Backflow Preventers: Wilkins
    - Fire Hydrants: Mueller Super Centurion 250 3-way
    - Domestic Water Pumps: Grundfos
    - Floor and Roof Drains: Zurn
    - Wall Hydrants: Zurn
    - Sump Pumps: Zoeller
    - Sanitary Sewerage Pumps: Zoeller
    - Instantaneous (Tankless) Water Heaters: PVI COBREX Double Wall
    - Water Closets and Flush Valves: Zurn with 1.1 gpf
    - Urinals: Zurn with 0.125 gpf
    - Mop and Service Sinks: Zurn
    - Kitchen Sinks and Faucets: Symmons, Elkay, and Zurn
    - Sinks: Elkay
    - Lavatories and Faucets: Zurn
        - Manual Faucets For Dormitories: Symmons Verity SLS4912PP-05, push-pop drain.

        - Specify Symmons P-26 grid drain with color to match faucet if grid drain is needed.
    - Safety Showers and Eye Washes: Bradley
    - Thermostatic Mixing Valves: Symmons for point of use, Bradley for emergency fixtures
    - Water Coolers: Elkay with Bottle Fillers
    - Shower Valves and Showers: Symmons
    - ADA Shower Trim (No Spray) and Valve:
        - Shower Trim: Symmons Verity 4991TRM
        - REQUIRED Shower Valve: Symmons Verity 261XBODY
    - ADA Shower Trim With Hand Shower and Valve:
        - Shower Trim: Symmons 4995TRM
        - REQUIRED Shower Valve: Symmons 261XBODY
        - REQUIRED Shower Diverter Valve: Symmons 2DIVBODYSRT
    - Shower Bases: Comfort Designs with 10 year warranty
    - Single Bottle Fillers: Elkay LZS8WSSP-CLYQ
    - Bi-Level Bottle Fillers: Elkay LZSTL8WSSP-CLYQ

13. FIRE PROTECTION

- The building shall be fully sprinklered with automatic wet pipe sprinkler systems as the primary fire suppression type
- Use dry pipe sprinkler systems in spaces subject to freezing
- Wet sprinkler systems on each floor shall take their water supply from a fire protection standpipe system, creating a combined sprinkler/standpipe system
- The water supply shall be provided by connections to the site water system before the domestic water meter
- Provide a fire department connection at the building
- The sprinkler system design shall comply with applicable editions of NFPA Standard 13
- The installing contractor shall provide a sprinkler system layout sized by hydraulic calculations
- Design documents shall comply with the State Board's minimum criteria for fire protection sprinkler design
- Provide a Class I wet standpipe system to supply fire department hose valves and sprinkler systems on each floor
- Design shall be with applicable editions of NFPA Standard 14
- All fire pump couplings shall be metallic
- Elastomeric pump couplings are not allowed
- Flexible sprinkler head fittings similar to Aquaflex may be provided if acceptable to the Tennessee Fire Marshal

14. LABORATORY SYSTEMS

14.1. LABORATORY AIR PRESSURIZATION CONTROL

- Laboratories with fume hoods or for defined pressurization requirements, provide a system to control air pressurization

- This system shall control:
    - Supply air
    - Hood exhausts
    - General exhausts
    - And any other exhaust air flows
- This system shall not include temperature control devices, but shall receive temperature control inputs from the building DDC system

14.2. LABORATORY WATER SYSTEMS

- Laboratory area sinks, cup sinks, and required equipment drainage shall be collected into a separate acid waste system and discharged into a neutralization basin before entering the site sanitary waste system
- Acid waste piping shall be fire-retardant polypropylene with heat-fusion joints
- Provide laboratory-grade purified water where required for general lab uses such as testing, rinse water, and wash water
- Purified water shall be distributed in a continuous loop system
    - Minimize dead leg fixtures
- Piping and fittings shall be beta-polypropylene with socket welded joints
- Valves and supplies shall be of materials that will not contaminate purified water before use
- A third-party vendor contracted by UTFS shall provide the water purification system
- Provide space in a ventilated mechanical room with necessary power and supply, and return piping connections for the equipment skid
- Equipment sizing shall be based on design, demand calculations, and required purity; coordinate carefully during design
- The use of domestic water for process cooling is prohibited except as emergency backup

14.3. LABORATORY COMPRESSED AIR

- Where required, provide laboratory compressed air using duplex multi-stage oil-free scroll air compressors
- Compressor discharge pressure shall meet program requirements, but not be below 115 psi
- Size compressor unit for a one-third on, two-thirds off duty cycle
- Provide automatic drains, vents, relief valves, manual valves, gauges, pressure regulators, filters, belt guard, and control accessories
- Provide a refrigerated air dryer at the wet tank to maintain a system dewpoint of -40°F
- Desiccant dryers should be installed between the compressed air loop and the building supply line.
- The compressed air system shall be equipped with an ASME-rated wet tank at the outlet of the air compressor
- Provide an alternator to automatically start the second compressor if the first fails to maintain receiver pressure
- The alternator shall alternate the starting order of the compressors to balance run time

- Multi-stage scroll compressors shall have a self-contained control system wth the ability to lock out a single stage in case of failure
- The compressor unit shall be mounted on a 4 in. concrete housekeeping pad with vibration isolators

14.4. LABORATORY VACUUM SYSTEMS

- An alternator shall be provided to automatically start the second compressor if the first fails to maintain the receiver pressure
- The alternator shall alternate the starting order of the compressors to balance run time
- Multi-stage scroll compressors shall have a self-contained control system with the ability to lock out the single-stage in case of failure
- Where required, provide laboratory vacuum systems using duplex multi-stage oil-free scroll vacuum pumps
- Vacuum pressure shall be based on programmatic requirements
- Multi-stage scroll machines shall have a self-contained control system with the ability to lock out a single stage in case of failure
- Provide an ASME-rated buffer tank between the building outlet and the vacuum pump
- The vacuum pump shall be mounted on a 4 in. concrete housekeeping pad with vibration isolators

15. CONTRACT DOCUMENTS

- Contract documents shall be easy to interpret without extensive study and must convey the design philosophy of the systems
- Isometric drawings or sketches are not acceptable
- All floor plans should show room numbers and names, and column lines
- Plan drawings shall include a graphic scale and a north arrow, preferably showing both true north and building north
- Mechanical plans shall show all ductwork and duct fittings to scale
- Except for flexible runouts, ductwork shall not be single-line
- Use standard drafting conventions for turns, joints, size changes, drops/rises, and crossings
- Include section views where ductwork conflicts with other ducts, piping, structure, or electrical, especially in corridors
- Mechanical plans shall show size and air quantity for each diffuser (neck and face size), register, and manual balancing damper
- Provide an air distribution schedule
- Indicating size and air quantity range on the schedule does not eliminate the requirement to show this information on the plans
- For VAV boxes, mechanical plans or schedules shall show the minimum air quantity required, considering:
    - Box capability
    - Space outside air requirements
    - Minimum air motion in the space served

- Include sound data
- Identify all hydronic piping and show flow directions
- Show piping on the same plans as ductwork if feasible
- Draw all mechanical rooms at ¼" scale
- Show clearances for coil replacement on all floor plans
- Provide a ¼" longitudinal section view of all AHUs, including piping, walls, ceilings, or top structure, etc. (a section, not an elevation)
- Show duct thermometers in section views
- Mechanical drawings or schedules shall indicate the filter thickness or depth for each filter type in all equipment
- Show the design or change-out static pressure for each filter type
- Indicate the range of the differential pressure gauge across the filters on the project plans; do not show only initial and final pressures
- Simplified piping schematics of all hydronic systems with two or more chillers, boilers, or heat exchangers should be included at the appropriate scale
- Provide a one-line, simplified schematic diagram for the chilled water or hot water system when two or more chillers, boilers, or heat exchangers (including existing equipment) are included in the hydronic system
- The diagram shall show how components relate to each other, including pumps, control valves, air release tank, two-pipe changeover valves (if applicable), and flow meters
- Show flow direction and avoid line crossings
- Do not show gauges, thermometers, isolation valves, strainers, or other minor piping components
- Specifications shall be concise, complete, brief, and accurate
- List two manufacturers and model numbers as sufficient
- Use only the necessary information extracted from the manufacturer's specifications
- Thoroughly edit specification sections for the specific project, including appropriate product and installation descriptions
- Remove inapplicable sections and paragraphs from standard specification sections
- Unedited specifications will not be accepted