15710

Hydronic and Steam Heat Exchangers

This document provides design standards only, and is not intended for use, in whole or in part, as a specification. Do not copy this information verbatim in specifications or in notes on drawings. Refer questions and comments regarding the content and use of this document to the Yale University Project Manager.

A. Summary

This section contains design criteria for shell and tube heat exchangers and for plate and frame heat exchangers.

B. System Design and Performance Requirements

1. Shell and tube heat exchangers are typically used for heating. Plate and frame heat exchangers are used for cooling applications.

2. The engineer must ensure that no cross-contamination occurs and that the materials are suitable for service.

3. Design heat exchanger piping so that the heat exchanger can be backwashed. Include a floor drain of sufficient size to accommodate the backwash.

4. Provide redundancy for both heating and cooling heat exchanger installations.

5. Provide separate heat exchangers for reheat and for perimeter heating systems.

6. Provide safety pressure relief valves on both sides of the unit between the heat exchanger and shut off valves to guard against thermal expansion when the unit is not in service and to protect against over-pressurization. Provide relief valves on heated fluid connections. Install relief valves full size of valve connection to floor drain.
Yale University Design Standards

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7. Maintain manufacturer-recommended clearances for service and maintenance.
8. Provide piping connections to facilitate heat exchanger service and maintenance.
10. Provide a vacuum breaker at the heat exchanger steam inlet connection.
11. Provide a hose-end valve to drain the shell.

C. Product Standards

1. ASME Compliance
   Fabricate and label heat exchangers in compliance with the ASME Boiler and Pressure Vessel Code, Section VIII: Pressure Vessels, Division 1.

2. Registration
   Fabricate and label shell and tube heat exchangers in compliance with Tubular Exchanger Manufacturers Association standards.

D. Manufacturers

Subject to compliance with the design requirements, provide products by one of the following manufacturers:

1. Shell and Tube Heat Exchangers—Heating and Steam-to-Hot Water Applications
   - ITT Industries
   - Bell and Gossett
   - Armstrong Pumps, Inc.
   - Bryan Steam Corp.

2. Gasketed Plate and Frame Heat Exchangers—Chilled Water Applications
   - Alfa Laval
   - Tranter PHE, Inc.
   - ITT Industries
   - API Heat Transfer Inc.
E. Special Requirements

1. All heat exchangers must have a pressure rating of at least 125 psig for both the shell and tube bundle, even if the operating pressures are less. For high-pressure applications (above 15 psig), the shell and head must be rated for the maximum steam temperature available at the building location.

2. Equip the shell with an ASME-approved pressure/temperature relief device, piped appropriately.

3. Pipe and test heat exchangers using high pressure steam in accordance with the ASME Power Piping Code. Hydrostatic tests are required of all high-pressure components, inclusive of tests across closed valves (leakage tests). Both high- and low-pressure exchangers must be ASME-rated.

F. Installation Guidelines

1. Install glycol heat exchangers only in mechanical rooms.

2. Pipe heat exchangers to enable easy venting.

3. Provide service access with sufficient clearance for draining.

4. Provide sufficient pull space for shell and tube heat exchangers.

5. For plate and frame heat exchangers, provide sufficient space for adding and removing plates.

5. Coordinate plate and frame heat exchanger bolt extensions with nearby piping and equipment.

6. Heat exchanger backwashing must be accomplished without dismantling the unit and by just adding a hose.
G. Quality Control

If this portion of the project includes commissioning, verify that insertions in the project specifications have been made that refer to the commissioning procedures in the commissioning specification section. Verify that the systems and equipment identified in this section of the standards, and listed in the project specifications, do not conflict with commissioning procedures for testing and training.

End of Section
15725
Air Handling Units

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Change History

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A. Summary

This section contains design criteria for air handling units.

B. System Design and Performance Requirements

1. Provide each plenum with a trapped condensate drain piped to an open waste. The trap seal must be deep enough to withstand system pressures, but at least 6” from bottom of drain to bottom of the lowest part of the trap for constant volume systems; 8” for VAV systems—positive or negative at the trap inlet—and maintain trap seal. Allow at least 1" to drain.

2. All built-up systems and all air handling units installed without cooling coils must be constructed with all necessary perforated plates to provide systems resistance equal to the cooling coil.
3. When final filtration is provided in an air handling unit downstream from the cooling coils, make provisions to avoid wetting the filters. Carefully evaluate blow-through units in this application.

4. Air handling unit supply and exhaust air fans serving laboratories are redundant.

5. Air handling units shall have easy access rail type fan assemblies. Service+/or replacement of fan must be easy to accomplish; proper clearances must be observed.

C. Designer Submittals

1. Submit calculations for air handler airflow, pressure sizing and trap depth.

2. The manufacturer's representative must check air handling units of 5 hp and over for proper installation, alignment, belt tension, and operation. File a written report with the engineer, and provide a copy to Yale University. The report must state that at the time of the report the fan is running properly and is acceptable to the manufacturer in every respect.

3. Provide sound-level data by octave band from 25 Hz to 8000 Hz for both supply and return connections at 5 feet distance from the AHU.

D. Manufacturers

Manufacturers offering products that may be incorporated in the work are subject to compliance with the design requirements, in its entirety.

E. Materials

1. Housing Construction for Factory-Built Modular Units

   a. Structural Criteria

      Units must conform to the structural provisions of the BOCA code (with Connecticut addendum), including but not limited to, snow load, seismic forces, and lateral wind loads.
b. **Base**  
   The base must consist of steel beams or channels for direct bearing support of the steel floor and major components in the casing. The base must be painted with rust-inhibiting primer and rust-inhibiting exterior enamel. The base must have steel lifting lugs (1/2" minimum) welded to the corners of each rigging module.

c. **Floor**

   (1) The floor must be of 3/16" thick steel plate welded to the base. Pans must be braced and welded at sufficient intervals to support internal equipment components and live loads without sagging or pulsating. The floor must be painted with rust-inhibiting primer and rust-inhibiting exterior enamel. Floor drains must be 2" Type L copper piping, extended to the bottom closure of the base unit. Insulate all piping within the base frame.

   (2) The underside of the floor must be continuously insulated with two layers of 1-1/2" thick (minimum) rigid fiberglass insulation board, with a density of three pounds per cubic foot.

d. **Coil Drain Pan**

   (1) The main drain pan must extend beneath the entire cooling coil, including the coil pipe header and return bends in the airway. The main drain must extend a minimum of 18" downstream of the coils.

   (2) The main drain pan must be 16-gauge stainless steel, continuously welded to form a watertight basin. The sides must be at least 4" high, with threaded 2" half-couplings welded to one side for drainage.

   (3) Provide intermediate drain pans beneath each stacked cooling coil, extending a minimum of 12" downstream of the coil. These intermediate drain pans must have 2" sides and 1-1/4" stainless steel or copper vertical leader pipes to the bottom pan. Provide dielectric fittings between different materials.
(4) Avoid the use of condensate pumps; the preferred method is gravity drainage. For gravity drainage and efficient removal of condensate, air handling units must be installed with sufficient elevation to allow for required condensate trap and piping run out clearances to drain at least 6” for constant volume systems and 8” for variable volume systems.

e. **Humidifier Drain Pan**

Provide a 16-gauge stainless steel drain pan beneath the humidifier section, with 2” sides and fully welded seams. Provide 2” drain piping from the sloped pan to the unit floor drain.

f. **Walls, Partitions, and Roof Structure**

(1) Designate panel skin thickness, stiffener, frame spacing and thickness, and core density to eliminate panel pulsation and to limit the maximum deflection at design pressures to 1/200 of any span.

(2) Panels must be double-walled, with an inner 20-gauge (minimum) liner and a 16-gauge (minimum) exterior sheet. The inner wall at the fan section must be perforated galvanized steel or aluminum. Panels downstream of the cooling coil and/or the final filter must have fibrous glass completely encapsulated in a high-strength plastic film meeting NFPA 90A requirements to preclude any fiber entraining in the airstream. Exterior surfaces must be suitable for weather exposure (including rust-inhibiting primer and exterior enamel).

(3) The minimum panel thickness must be 4” filled with a full thickness of three pounds per cubic foot fiberglass insulation board. Panel sandwich construction must incorporate a thermal break at all structural members. Panels, including insulation, must meet NFPA-90A fire hazard rating requirements. Noise transmission must be limited so that the noise level does not exceed 65 dB at any location within 10 feet of the unit.

(4) Access doors must be double-walled, with construction and performance as specified for panels. Doors must close tight against the gasket and must be air-tight.
(a) Provide one 12”x12” window (double-glazed acrylic, tempered- or wire-glass) in each door. Provide air-tight runner seals and desiccant in the air space.

(b) Doors must be a nominal 70” high and 24” wide. Doors must have three tapered latches to force the door against the gasket, and must have a full-height stainless steel piano hinge on the upstream side.

(c) Doors on the suction side of the fan must swing outward, and doors on the discharge side of the fan must swing inward. Latches must operate from both sides of the door.

(d) Access doors are required for both faces of heating and cooling coils and at fan sections, automatic dampers, louvers, humidifiers, and filters. Show access sections on the drawings.

(5) Provide removable, gasketed access panels for removal of the fan and motor. Panels must be bolted in place. Provide supports for field mounting of piping, control panels, and miscellaneous lightweight components.

(6) Panels must be factory-sealed and air-tight at the corners and seams, without visible caulking on the casing exterior. Modules assembled in the field with caulking and gasketing must be air-tight, without visible exterior caulking.

(7) Provide sufficient room for removal of the fan and fan shaft from the air handler.

g. Roof

The roof must have a one percent minimum pitch after deflection under snow load, without external standing seams. Cover the assembled roof with a continuous rubber membrane roofing system, with a 20-year warranty. Provide underlayment as required by the roof membrane manufacturer. The roof membrane must be installed by an installer approved by the membrane manufacturer. Roof construction must provide a bearing capacity for suspension of field-installed mechanical piping. Roof construction must be 4” thick, with insulation as specified for wall panels.
2. **Field-Erected Units**
   a. Construct field-erected units on a concrete curb. The mechanical contractor must coordinate the dimensions of the air handling unit with the curb. The contractor must also coordinate the locations of all penetrations, including electrical penetrations and floor drains, with the requirements of the built-up unit. The mechanical contractor must prepare concrete curb drawings and give them to the general contractor for coordination and erection. The concrete curb must be at least 6” high.
   b. Provide vapor-tight, marine-type incandescent lighting fixtures in each air handling unit compartment (and outside the unit on each side, if it is an exterior unit).
   c. Provide galvanized, rigid-steel conduit from the fan motor through the casing wall. Use liquid-tight, flexible-steel conduit for the connection to the fan motor. Rigid conduit must be fixed to the casing and must not interfere with operation or access.
   d. Provide two empty, rigid-steel conduit sleeves at each compartment for ATC wiring and air tubing. Conduit sleeve locations of the must be coordinated by the testing, adjusting, and balancing contractor.
   e. Provide two weather-tight duplex receptacles on the exterior of the unit in appropriate locations. Circuit separately from the lights.
   f. Provide a local disconnect switch for the fan motor, directly outside the fan enclosure.

3. **Packaged Air Handling or Blower Coil Units**
   a. Air handling units must be factory-assembled, tested, and shipped in one piece. Provide the manufacturer's certified drawings before the building steel fabrication drawings are prepared.
   b. Air handling units must consist of:
      - A single wall cabinet, except the wet section
      - A chilled water coil
      - A hot water coil
      - A filter section
Supply fan sections

c. The frame and unit base must be 12-gauge, galvanized steel. The exterior panels must be 18-gauge, galvanized steel. Provide gasketed, hinged access doors to each section.

(1) Provide 1" thick, 1-1/2 lb density insulation that has the following characteristics when tested in accordance with ASTME-84:
   - Maximum K-factor of 0.27
   - Maximum flame spread of 25
   - Maximum smoke developed of 50

(2) Provide lifting brackets on each unit base to accept cable or chain hooks.

d. Provide removable hydronic coils fabricated from 1/2" or 5/8" OD seamless copper tubing with copper heads, mechanically bonded to rippled and corrugated aluminum fins.

(1) Provide vent and drain connections.

(2) Leak test at 250 psig: air pressure under water, guarantee for 150 psig working pressure.

e. Provide a double-walled stainless steel drain pan for the cooling coil that is connected to a threaded drain connection extended through unit base.

f. Provide galvanized steel filter racks, with specified filters accessible from both sides of the unit.

g. Panel filters must be 1” standard efficiency throwaway filters, mounted in galvanized steel filter frames. Provide one complete spare set of filters for each unit.

h. Supply fans must be backward curve centrifugal-type fans.

i. Supply fans must be statically and dynamically balanced for quiet operation.

j. Fan wheels must be fabricated from aluminum, with the fan blades continuously welded to the back plate and end rim.

k. Units must have solid steel fan shafts mounted in heavy-duty 200,000-hour ball bearings that can be lubricated.
1. The entire fan assembly must be completely isolated from the unit bulkhead with neoprene gasketing and mounted on double deflection, spring isolators (minimum 1". deflection).

m. Supply fan motors must be heavy-duty, high-efficiency type motors, with variable-pitch sheaves and adjustable bases for proper alignment and belt tension adjustment. Motors must also be 1800 rpm, open drip-proof type motors with ball bearings that can be lubricated.

n. Wire and test air handling units at the factory before shipment. Wiring must meet NEC and UL standards. Provide 115V control circuit transformers, 115V receptacles, system service switches, and control circuit fuses.

(1) Supply fan motors must have contactors and external overload protection.

(2) The main control panel must be weatherproof with a dead-front cover over the main power circuit controls.

o. Automatic temperature controls and the sequence of operation must be as shown on the control drawings.

p. Provide sufficient room so that the fan and fan shaft can be removed from the air handler.

F. Quality Control Testing—Custom Air Handling Unit Factory Tests

1. Pressure test each coil to be installed in the unit per the latest edition of ARI Standard 410. Bulk sampling test results are not acceptable. Test pressures must be 150 psig for steam preheat coils, 150 psig for water heating coils, and 200 psig for water cooling coils. Tests must be conducted by an independent testing agency. The test results must be reviewed and approved by the engineer before installing the coils.

2. Conduct a vibration test on the fans. Operate the fans at the design RPM. In the case of an air handling unit with multiple fans, conduct the test with each fan operating individually, and with all other possible operating combinations. The fan, motor, drive, and base assembly vibration must be brought to within two mils double amplitude. The test must be witnessed by an independent testing agency and video-taped. The test results and video tape must be reviewed and approved by the engineer before the unit is shipped.
3. Air pressure test the air handling unit at 150 percent of normal operating pressure, per the latest edition of the SMACNA HVAC Air Duct Leakage Test Manual. Conducted both positive and negatively tests. All duct connections must be capped, and the individual modules (if so constructed) must be sealed temporarily.

4. Leakage must not exceed one percent of the total design CFM when operating at 150 percent of the design pressure. A Yale University representative must witness the test. (The contract documents must include a provision for the contractor to include airfare and accommodations for one Yale University representative in the bid price.)

5. Conduct a fan performance test of the assembled air handling unit. The test must include the operation of the fans at three representative output levels. Simulate external duct resistance to demonstrate fan performance. The airflow measurements must be conducted by an independent testing agency and witnessed by a Yale University representative (at the same time as the pressure test for the air handling unit).

6. Conduct a noise level test at 100 percent of the normal operating pressure and 100 percent of the normal system air flow. The noise level cannot exceed 65dB at any location within 10 feet of the unit.

7. Energize all electrical devices before shipment to ensure operational integrity. Tests must be witnessed by an independent testing agency. The results must be reviewed and approved by the engineer before the air handling unit is shipped.

8. The Yale University representative must have at least one week’s time to review the shop drawing of the unit, including sound data, before witnessing any of the above tests.

G. Installation Guidelines

1. General
   a. Install air handling units so that the coil or fan shaft can be replaced.
   b. Provide access to all components for servicing and maintenance.
   c. When mixing return and outdoor air, mixing should supply the cooler (outdoor) air at the top of the mixing box plenum and provide as much distance as possible before the heating or cooling coil.
2. Outdoor Air Intakes
   a. Do not place fresh air louvers near a loading dock or near diesel generator exhaust.
   b. Do not locate intakes near collected organic debris, such as wet leaves, animal nests, trash, wet soil, and grass clippings, or in low areas where dust and moisture collect.
   c. Design outdoor air intakes to exclude rain and snow intake (see Section 15855: Diffusers, Registers, Grilles, and Louvers). Intake louvers must have screens.
   d. Verify that intakes do not provide ledges that will collect bird droppings.
   e. Locate intakes per code to ensure adequate separation and dilution given the contaminant source concentration and nature, the direction of prevailing winds, and building geometry.
   f. Install intakes at least six feet above grade and three feet above the roof.

3. Accessories or Special Features
   a. Units shall be provided with ultraviolet light (UV) systems for mold control. A vapor proof housing shall be provided for the UV lights.

H. Quality Control

1. Field Tests
   a. Air pressure test the air handling unit at 150 percent of normal operating pressure, per the latest edition of the SMACNA HVAC Air Duct Leakage Test Manual. Conduct both positive and negative tests. All duct connections must be capped, and the individual modules (if so constructed) must be sealed temporarily.
   b. Leakage must not exceed one percent of the total design CFM when operating at 150 percent of the design pressure. An independent testing agency must witness the test.
   c. Conduct a fan performance test of the assembled air handling unit. The test must include the operation of the fans at three representative output levels. Simulate external duct resistance to demonstrate fan performance. The airflow measurements must be conducted by an independent testing agency.
2. Commissioning

If this portion of the project includes commissioning, verify that insertions in the project specifications have been made that refer to the commissioning procedures in the commissioning specification section. Verify that the systems and equipment identified in this section of the standards, and listed in the project specifications, do not conflict with commissioning procedures for testing and training.

End of Section
15732
Rooftop Air Conditioners

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A. Summary

This section contains design criteria for rooftop package and custom air conditioners.

B. System Design and Performance Requirements

1. Sound levels at building entrances and exits must meet City of New Haven acoustical requirements.
2. Glycol/hot water is the preferred method for preheat coils. Provide recirculation pumps for each preheat system.
3. Coordinate seismic installations with the structural designer, and verify that code requirements are met.
4. For units equipped with cooling coils, size air handling cabinets for a maximum coil face velocity of 475 fpm.
5. When blow-through units are specified, ensure that there is an appropriate means of distributing air across the entire coil face. The use of plenum fans in blow-through applications is preferred because they promote even air distribution and velocity across the coil face.

6. Plenum fans are preferred in draw-through applications where discharge duct configurations (associated with centrifugal fans) cause system effect losses and noise.

7. To minimize noise from a rooftop units:
   a. Follow ASHRAE and SMACNA recommendations for duct transition geometry near the fan.
   b. Use round ductwork over sensitive spaces.
   c. Locate units as close to the main supporting columns as possible.
   d. Cut out only enough decking for ducts. Do not cut out decking under the entire roof curb.
   e. Do not oversize units.
   f. When an elbow must be placed within 1.5 duct diameters of a high-velocity fan discharge, it should be placed along a radius elbow that does not have turning vanes.
   g. After test and balance has determined the proper fan speed using an adjustable sheave, replace the adjustable sheave with a fixed one of the proper pitch.
   h. Ensure that there is adequate structural support for the equipment and that wall and floor assemblies have sufficient mass to attenuate low-frequency noise around the equipment.

C. Submittals

1. Designer Submittals
   Custom unit designs must be reviewed and approved by Yale University Engineering.
2. Construction Documents

The contractor must certify that rooftop air conditioners, accessories, and components will withstand seismic forces.

D. Product Standards

Products must conform to the following standards:

1. Units must be ARI-certified and listed.

2. Electrical components, devices, and accessories must be listed, labeled, and marked for intended use—as defined in NFPA 70, Article 100—by a testing agency acceptable to authorities having jurisdiction.

3. The refrigeration system must be fabricated and labeled in compliance with ASHRAE 15: Safety Code for Mechanical Refrigeration.

4. The energy-efficiency ratio must be equal to or greater than prescribed by ASHRAE 90.1: Energy Efficient Design of New Buildings Except Low-Rise Residential Buildings.

5. The coefficient of performance must be equal to or greater than prescribed by ASHRAE 90.1: Energy Efficient Design of New Buildings Except Low-Rise Residential Buildings.

E. Manufacturers

Manufacturers offering products that may be incorporated in the work are subject to compliance with the design requirements, in its entirety.
F. Materials
   1. Exterior doors on all custom units must be stainless steel.
   2. Do not use exposed fiberglass ductwork in air handlers.

G. Accessories or Special Features
   1. Whenever possible, provide motor lift rails on units with motors larger than 10 hp.
   2. Spaces for controls must be kept dry and the temperature maintained between 60 and 95°F. Provide a walk-in heated space for controls.
   3. Equip small package units with self-diagnostics.
   4. Factory-installed controls must be compatible with the Yale University building automation system.
   5. Direct-drive actuators and damper blades must be driven by gears instead of linkages. These designs improve the mechanical reliability of the economizer/outdoor air section by reducing the number of moving parts.
   6. Units shall be provided with ultraviolet light (UV) systems for mold control. A vapor proof housing shall be provided for these UV lights.

H. Extra Materials
   Provide two sets of filters and fan belts.

I. Special Requirements
   1. Install gutters above exterior doors that drain away from the doors.
   2. Provide all units with a laptop plug-in port for unit analysis.
   3. Design variable-frequency drive (VFD) enclosures with an appropriate ventilation fan.
   4. Maintain the minimum clearance between VFD cabinets recommended by the manufacturer.
   5. Outside air dampers must be airfoil-type with edge seals to provide a tight-closing, low-leakage damper.
   6. All water coils must have copper tubes and return bends with a minimum thickness of .035." Headers must be non-ferrous. Fin spacing should not exceed 12 fpi.
7. Use only manual reset freezestats; automatic freezestats are not acceptable.

8. All closed-loop heating/cooling systems to rooftop air handlers must have adequate air venting. Vents must be automatic, with a ball valve between the vent and the piping, and equipped to handle system pressure.

9. Unit roofs must be sloped.

10. Drain pans must be at least 18-gauge stainless steel, insulated, and pitched to drain. Drain pans must extend in the direction of airflow far enough to catch condensate at the maximum recommended coil air velocity.

11. Units must have single-point power connections.

12. Each section of the unit that provides service access must be equipped with watertight, wire-guarded marine lights. At least one ground-fault-interruption receptacle must be located at each access side of the unit.

13. Unit curbs must be 12” high and factory-built to ensure the correct fit.

14. At a minimum, provide access doors at fan and cooling coils.

15. Fans, motors, and drives must be internally spring-isolated on a structural steel base, complete with flex connections and lateral restraints.

16. The roof and floor must be of double-wall construction. Panels must be unitized to prevent disturbing the insulation if the panels are removed.

17. Perforated inner walls are acceptable for use in all sections, except in the outside air intake, cooling coil, and humidifier sections.

18. The doors on positively-pressurized sections must swing inward. The doors on negatively-pressurized sections must swing outward.

19. Coils sections must be separated by a minimum space of 18”. Each coil section must be equipped with a full-size access door.

20. Controls must be located in a heated space. Provide sufficient space to work with the door to the air handling unit closed.
J. **Installation Guidelines**

1. Do not block maintenance or coil-pull access doors with equipment or piping installations.

2. Exposed heating or cooling piping and valves on the roof is prohibited. Locate all valves and piping within the building or within the air handling unit.

3. Verify that unit installations are level.

4. All roof penetrations must be sealed and waterproofed.

K. **Quality Control**

If this portion of the project includes commissioning, verify that insertions in the project specifications have been made that refer to the commissioning procedures in the commissioning specification section. Verify that the systems and equipment identified in this section of the standards, and listed in the project specifications, do not conflict with commissioning procedures for testing and training.

*End of Section*
A. Summary

This section contains design criteria for computer room vertical and horizontal air conditioning systems.

B. System Design and Performance Requirements

1. Provide for additional equipment and running online so that if any part of the process cooling system fails, the remaining equipment will continue to properly cool the room.

2. Provide local alarm and an alarm to the building automation system:
   - Temporary loss of power
   - On failure or need for servicing of the equipment
   - Loss of airflow
   - Dirty filters
   - Any overload condition
   - Excessive room temperature

3. Determine whether the use of outdoor air is cost-effective. The cost of humidification might outweigh savings in compressor energy.
4. Specify cooling systems that discharge air at a relative humidity that meets computer manufacturer relative humidity requirements, without relying on underfloor mixing.

5. Coordinate with room designer and to provide methodology to make room vapor-tight.

C. Submittals

Submit the following design and certification documentation.

1. Designer Submittals
   - Estimated cooling load
   - Life cycle cost of humidification
   - Report on the methods used to make the room vapor-tight
   - Life-cycle cost of the cooling system, including cost to make room vapor-tight

2. Product Certificates Signed by the Manufacturer

Specify that computer room air conditioning units be inspected by the manufacturer's authorized representative who shall submit a written report to the engineer with copy to Yale University stating that the computer room units have been properly installed, are operating correctly, and the installation is acceptable to the manufacturer in every respect.

D. Manufacturers—Vertical Units

Subject to compliance with the design requirements, manufacturers offering products that may be incorporated in the work include, but are not limited to, the following:

- Liebert
- Stultz
E. Installation Guidelines

1. When ventilation air is brought into the computer room, provide a positive ventilation system to take in outside air and discharge into the intake of the process cooling system.

2. Ensure that all cracks are sealed, including cracks in any sub-floor, to preclude dust from entering the data processing equipment. Ensure that the room is a vapor-tight envelope.

3. Verify that there is sufficient space in underfloor distribution to allow for the velocity pressure of the air handler discharged air to develop into static pressure. Not doing so can lead to hot spots where the pressure is insufficient to enter the data processing equipment.

4. Avoid running condenser water feed lines in underfloor cavity.

5. Provide accessible shutoff valves.

F. Quality Control

If this portion of the project includes commissioning, verify that insertions in the project specifications have been made that refer to the commissioning procedures in the commissioning specification section. Verify that the systems and equipment identified in this section of the standards, and listed in the project specifications, do not conflict with commissioning procedures for testing and training.
15738

Split-System Air Conditioners

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A. Summary

This section contains design criteria for split-system air conditioners.

B. System Design and Performance Requirements

Provide complete a DX system for central station air conditioning. The system must consist of matching air-cooled condensing units, compressors, piping, controls, wiring, and other accessories, as well as the appurtenances necessary to provide a fully-automatic system. In addition, this section shall include variable refrigerant flow zoning systems.

C. Materials

1. Condenser coils must be aluminum plate fins, mechanically bonded to seamless copper tubes, circuited for subcooling.
2. Provide openings for power and refrigerant connections.
3. Provide a service access panel.
4. Provide copper tubes, circuited for sub-cooling. Provide propeller fans arranged for vertical discharge. Condenser fan motors must have inherent protection, and must be permanently-lubricated and resiliently-mounted. Fans must have safety guards. Provide controls for cycling fans.
5. Compressors must be serviceable, hermetic compressors, with external spring isolators and an automatically reversible oil pump.
   a. Compressors must unload in steps, in response to suction pressure, for partial load operation. Separate compressors from condenser fans and coils.
   b. Multiple compressor units must have stop-start fans and coils. Compressor motors must have a part-winding start.

6. Provide refrigerant piping between air-cooled condensing units and air conditioning units. Refrigerant piping must be equipped with the necessary auxiliary equipment, such as strainers, sight glasses, oil traps, scale traps, changing valves and other devices, to make the system complete and operable under fully-automatic control.

7. Refrigeration piping must be ACR copper tubing made up with wrought copper fittings, using silver solder and installed with a nitrogen charge while soldering. Use the piping size recommended by the manufacturer of the air conditioning unit and matching air-cooled unit. Casings must be galvanized steel finished with baked enamel

8. Provide complete working refrigeration piping diagram(s) for each refrigeration system approved by the manufacturer, including line size. Pre-approve all refrigeration equipment. Components of the refrigeration system shall be identified on the diagram by piece of equipment, equipment manufacturer and model number.

D. Manufacturers
   - Trane
   - York
   - Rheem
   - Dankin
   - Mitsubishi
   - Sanyo
E. Variable Refrigerant Flow Zoning Systems

The system varies power consumption by adjusting the compressor speed to optimize energy usage. This system will allow some indoor units to operate in the cooling mode and other units to operate in a heating mode. The indoor evaporator units must have electronic expansion valves.

F. Quality Control

If this portion of the project includes commissioning, verify that insertions in the project specifications have been made that refer to the commissioning procedures in the commissioning specification section. Verify that the systems and equipment identified in this section of the standards, and listed in the project specifications, do not conflict with commissioning procedures for testing and training.
15752
Humidification Systems

This document provides design standards only, and is not intended for use, in whole or in part, as a specification. Do not copy this information verbatim in specifications or in notes on drawings. Refer questions and comments regarding the content and use of this document to the Yale University Project Manager.

A. Summary
This section contains design criteria for humidification systems.

B. System Design and Performance Requirements
1. Install humidifiers only in areas justified by research requirements. Humidity control must be approved by the Yale University Facilities group.
2. Central plant steam used for heating must not be used for humidification. Steam used for humidification must be generated by a dedicated steam boiler.
3. Provide automatic shut-off valves in steam supply piping for situations when the humidifiers are not in operation.
4. Central humidifiers must be multiple-manifold, steam-jacketed humidifiers, with duct-mounted sensors or controllers and high-limit control.
5. If humidification is undertaken, coordinate with design architect to ensure that the building has an excellent vapor barrier throughout to prevent moisture flow into the building materials.

C. Submittals
Submit humidifier load calculations for worst-case winter and economizer operations.
D. Manufacturers

Subject to compliance with the design requirements, manufacturers offering products that may be incorporated in the work include, but are not limited to, the following:

1. Steam Humidifiers
   - Dristeem Ultrasorb
   - Walton

2. Ultrasonic Humidifiers
   - Stultz
   - Walton

3. Steam-to-Steam Reboilers
   - Dristeem SST Stainless Steel

4. Automizer Type
   - Cool-Fog

5. Electronic
   - Nortec
E. Installation Guidelines

1. Allow sufficient downstream dispersion from humidifiers in the air handling units and ductwork to ensure complete evaporation before impingement on downstream equipment, filters, or fittings.

2. Where necessary, provide a downstream moisture eliminator to provide additional protection against the wetting of air handler components.

3. Review humidifier load for economize operation; it will be maximum. Do not use economize mode of operation without doing a life cycle cost analysis.

4. In areas where DI water is not used, there must be filtering (TBD).

5. If R.O. or DI water used, please use 316 S.S.

F. Quality Control

If this portion of the project includes commissioning, verify that insertions in the project specifications have been made that refer to the commissioning procedures in the commissioning specification section. Verify that the systems and equipment identified in this section of the standards, and listed in the project specifications, do not conflict with commissioning procedures for testing and training.
15755
Dehumidification Systems

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A. Summary

This section contains design criteria for heat wheels, heat pipes, and desiccant-type dehumidification systems.

B. Submittals

Submit the following design and certification documentation.

1. Designer Submittals

Provide a description of how the system will respond during latent-peak and part-load conditions. Provide shop drawings and control sequences.

2. Product Certificates Signed by the Manufacturer

Specify that dehumidifiers be inspected by the manufacturer’s authorized representative, who shall submit a written report to the engineer with a copy to Yale University stating that the dehumidifiers have been properly installed, that they are operating correctly, and that the installation is acceptable to the manufacturer in every respect.
C. Manufacturers

Subject to compliance with the design requirements, manufacturers offering products that may be incorporated in the work include, but are not limited to, the following:

1. Desiccant Dehumidifiers
   - Cargocaire
   - Engelhardlice
   - Low Humidity Sytems

2. Refrigerant-Type Dehumidifiers
   - Desertaire
   - Domestic
   - Dunham-Bush

D. Quality Control

If this portion of the project includes commissioning, verify that insertions in the project specifications have been made that refer to the commissioning procedures in the commissioning specification section. Verify that the systems and equipment identified in this section of the standards, and listed in the project specifications, do not conflict with commissioning procedures for testing and training.
15761
Air Coils

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A. Summary
This section contains design criteria for HVAC system hydronic, electric, and steam coils.

B. System Design and Performance Requirements
1. Initiate a discussion with the Yale University Facilities group about the need for split coils, center supply, and similar types of equipment, to provide good air distribution.
2. Use non-freeze, steam preheat coils wherever steam is available in sufficient quantities. Use hot water-glycol preheat coils where steam is not available.
3. Provide electric coils equipped with perforated plates to equalize airflow across the face.
4. Provide completely drainable chilled water coils. Coils must be ARI certified, and the scheduled performance must be guaranteed by the manufacturer. At design conditions, the coils must provide a minimum water temperature rise of 15°F.
5. The cooling coil face velocity must not exceed 450 fpm for constant-volume systems and 550 fpm for variable-volume systems. Base the cooling coil face area on a maximum face velocity. Provide an intermediate drain trough for each section of coil banks more than one coil high. Extend the trough a minimum of 6" downstream of the coil face, and pipe it individually piped to the unit pan. Each coil section drain must have a deep seal trap and extend to an open sight drain.
6. The cooling section of a built-up unit must have a trapped drain at the bottom. Deep seal traps might necessitate raising the entire unit above the floor or disposing of drainage on the floor below.

7. Preheat coils must be face or bypass steam coils (integral or conventional) or water coils for hot glycol–water systems. Preheat coils downstream of heat recovery wheels or coils may be standard steam distributing coils.

8. Provide hot glycol–water systems for preheat coils, unless face and bypass steam coils (integral or conventional) are used. Hot glycol–water is preferred over steam for heating coils and reheat systems. To maintain flow rates at a relatively high level, reset the hot water temperature inversely with outdoor temperature.

9. Where heat recovery equipment is used in conjunction with a preheat coil, size the preheat coil for the total load in case the heat recovery equipment becomes inoperable.

10. The preheat and heating coil maximum face velocity must be 600 fpm for standard coils and 600 fpm for integral-face and bypass coils to hold the pressure drop to about 0.25” WC.

11. Offset the piping to coils, and arrange shut-off valves and flanges or unions to permit the removal of the coil from the side of the unit.

12. Heating coils immediately upstream of the cooling coils must be designed for face velocities close to that of the cooling coils.

C. Submittals

Provide a list of heating and cooling coil selections.

D. Manufacturers—Steam Coils

Subject to compliance with the design requirements, manufacturers offering products that may be incorporated in the work include, but are not limited to, the following:

- Aerovent
- Armstrong Type C or T coils for below freezing temperatures
- Centifeed
- Wing-bypass steam coils
E. Materials

1. General
   Limit the coil depth to six rows and no greater than 14 fins/in. Use multiple coils if a single coil will not suffice. Allow access space for cleaning on the entrance and exit sides of the coils.

2. Glycol–Water Coils
   a. Coils must have copper tubes with helically-wound aluminum fins.
   b. Casing must be hot-dipped galvanized steel.
   c. Headers must have stainless steel barrels with vents; drains; and serpentine, continuous tube design suitable for 200 psig working pressure.
   d. Coils must be housed in a factory-fabricated frame, independent of the unit casing.
   e. Coil frames must be 11-gauge, hot-dipped, galvanized steel.
   f. Coil frames must support coil sections independently to enable the coil to be removed through the unit casing normal to direction of airflow, without disturbing other coil sections.
   g. Coil casings must have a removable panel on each side.
   h. Cooling coils shall have stainless steel frames.
   i. All connections to coils shall have isolation valves.
Fan Coil Units

This section contains design criteria for hot water, chilled water, and steam fan coil units.

B. System Design and Performance Requirements

1. New buildings should not allow for fan coil units. Fan coil units should only be used if ductwork cannot be installed in an existing building, or if local loads are beyond the capacity of the building air conditioning system.

2. If fan coil units are used, systems must be four-pipe, with floor-mounted units at the exterior wall when serving as perimeter heat. Two-pipe fan coil units may be ceiling-mounted or concealed above the ceiling for cooling only.

C. Submittals

Submit heating or cooling load calculations for fan-coils and the reason why they are needed.

D. Manufacturers

Subject to compliance with the design requirements, manufacturers offering products that may be incorporated in the work include, but are not limited to, the following:

- Carrier
- York
- Trane
E. Materials

1. Fan coil units must include the following components:
   - A galvanized steel cabinet with a baked enamel finish liner, covered with UL 25/50 Mylar or foil.
   - Service panels on the bottom of ceiling-mounted equipment that must be hinged or provided with safety chains to prevent them from falling when opened.
   - Centrifugal, forward-curved, galvanized steel fans, statically and dynamically balanced, with permanently-lubricated or ball bearing shaft bearings.
   - A water coil with aluminum fins mechanically bonded to staggered 1/2” O.D. copper tubes. Leak test the coil at an air pressure of 350 psig.

2. Provide manual valves to isolate each fan coil and drains.
   - Isolation and valves for cooling coils or heating coils shall be located over condenser drain pan.

3. Drain pans shall be cross-braced.

F. Installation Guidelines

Provide for filter, motor, and valve maintenance access.

G. Quality Control

If this portion of the project includes commissioning, verify that insertions in the project specifications have been made that refer to the commissioning procedures in the commissioning specification section. Verify that the systems and equipment identified in this section of the standards, and listed in the project specifications, do not conflict with commissioning procedures for testing and training.
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Radiation

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A. Summary
   This section contains design criteria for hot water, steam radiation systems and chilled water systems. Included are ceiling mounted radiation and valance systems.

B. System Design and Performance Requirements
   Install radiation where wall loss is greater than 200 btuh/lineal ft. Any VAV system shall have perimeter radiation; minimum pressure requirement is 85 psi.

C. Submittals
   Furnish shop drawings that state the pressure range of the radiators.

D. Manufacturers
   Subject to compliance with the design requirements, manufacturers offering products that may be incorporated in the work include, but are not limited to, the following:
   • Runtal
   • Sterling
   • Vulcan
   • Panel Radiator
   • Edwards
E. Materials
1. Enclosures must be galvanized steel with 18-gauge front panels.
2. Enclosure brackets and element hangers must be no farther apart than 4 ft.
3. Support the heating element with sliding saddles, and provide positive positioning of the element in the enclosure. Fins must not impinge on brackets or enclosure joints during expansion or contraction.
4. Provide a tamper-proof, modulating output control damper.
5. Provide hinged access doors with tamper-proof operators.
6. Provide expansion compensators every 20 ft on straight runs.

F. Installation Guidelines
Where feasible, simplify housekeeping procedures for steam and hot water radiation by avoiding the use of floor-set or recessed-in-floor radiation, and mount wall-hung radiation at least 4" off the floor.

G. Quality Control
If this portion of the project includes commissioning, verify that insertions in the project specifications have been made that refer to the commissioning procedures in the commissioning specification section. Verify that the systems and equipment identified in this section of the standards, and listed in the project specifications, do not conflict with commissioning procedures for testing and training.

End of Section
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A. Summary

This section contains design criteria for electric, heating hot water cabinet and unit heaters.

B. System Design and Performance Requirements

1. Cabinet unit heaters should be used in and near outdoor entrances, at the base of stairwells, and in other locations that require heat but do not have the wall space for fin tube radiation.

2. Unit heaters should be used in non-public spaces that require additional heat and have water available. Non-public spaces include mechanical and storage rooms. Electric unit heaters should be used in electric rooms.

3. Electric cabinet heaters should be used only if the cost to run steam or hot water is prohibitive.

4. The mechanical system engineer will determine hot water cabinet heater piping installation guidelines.

5. Ducted hot water units in electric equipment and elevator equipment rooms.
C. Manufacturers

Subject to compliance with the design requirements, manufacturers offering products that may be incorporated in the work include, but are not limited to, the following:

- Carrier
- York
- Trane
- Manufacturer Approved by Yale Facilities

D. Materials

1. Electric Cabinet Heaters
   a. Cabinet heaters must be factory-assembled for field installation. Cabinets must be sheet metal with corrosion-resistant finishes.

   b. Heating coils must be single terminal end, long-life electric fin tube coils, with brazed helical-coiled fins.

   c. Provide cabinet heaters with automatic reset thermal overload protectors.

2. Hot Water and Steam Cabinet Heaters
   a. Cabinet heaters must be factory-assembled for field installation.

   b. Coils must have seamless copper serpentine tubes and aluminum or copper fins bonded to the tubes. Coils must be tested at 200 psig air pressure without leaks.

   c. If filters are required, they must be disposable.

   d. Provide a factory-mounted disconnect switch.

   e. Each unit must be valved separately and have union connections to facilitate easy removal. This includes isolation valves.
3. **Hot Water and Steam Unit Heaters**
   
a. Unit heaters must be factory-assembled for field installation.

b. Coils must have seamless copper serpentine tubes and aluminum or soldered copper fins bonded to the tubes. Coils must be tested at 200 psig air pressure without leaks.

c. Hangers and supports must incorporate vibration and isolators. The motor and fan must be separated from the heater by resilient vibration isolators. Provide OSHA-approved fan guards on the heaters.

d. Each unit must be isolated and valved separately and have union connections to facilitate easy removal.

e. Each unit must be provided with an electrical disconnect switch (no toggle switches permitted).

E. **Quality Control**

If this portion of the project includes commissioning, verify that insertions in the project specifications have been made that refer to the commissioning procedures in the commissioning specification section. Verify that the systems and equipment identified in this section of the standards, and listed in the project specifications, do not conflict with commissioning procedures for testing and training.

End of Section