DESIGN GUIDELINE 235000

HOT WATER HEATING SYSTEMS

Scope

Hot water heating systems, including low pressure steam-to-water shell and tube heat exchangers and hot water heating boilers.

Related Sections

U-M Design Guideline Sections:
DG 2.1 - Owner's Project Requirements (OPR) and Basis of Design (BOD)
DG 4.6 - Utilities for University Buildings
DG 230010-H Supplemental HVAC Design
DG X.X Water Chemical Treatment (FUTURE)

U-M Master Specification Sections:
235239 Fire Tube Boilers (Hot Water) (FUTURE)
235716 Steam-to-Water Heat Exchangers

U-M Standard Details:
15189001 - Closed System Shot Feeder Detail
1518903 - Closed System Make-Up Detail
15515011 - Coalescing Separator and Floor Mounted Expansion Tank Detail
MD 235716 001 - Critical Steam to Water Heat Exchanger P & ID
MD 235716 002 - Non-Critical Steam to Water Heat Exchanger P & ID
MD 235716 003 - Steam to Water Heat Exchanger Piping Detail
MD 23XXXX 001 – HWH Boiler P & ID (FUTURE)

Requirements Common to Steam Heat Exchanger and Boiler Systems

The central (heat exchanger (HX) or boiler) heating system type and configuration shall take into account the attributes of the building's distribution network, terminal units, and terminal unit controls. Examples include whether terminal units utilize 2 or 3 way valves and assuring that terminal unit water temperature requirements permit the hot water supply temperature to be reset low enough and frequently enough to produce a significant number of hours when boilers can operate in condensing mode.

Quantity and Sizing

Typically the central heating equipment (HX or boilers) should consist of a minimum of two identical capacity units, each sized for somewhere between 50% and 100% (see rationale below) of the *Peak Diversified Load* (PDL). PDL is defined as the maximum load expected on a diversified heating plant on a design heating day. The engineer of record is responsible for determining PDL.

For existing systems, PDL shall be derived by consulting measured loads from the BAS system data historian. If unavailable, use computerized building energy simulation modeling.

For new systems PDL shall be established using a computerized building energy simulation model (Trane Trace, Carrier E20-II HAP, etc.) that complies with the requirements for simulation programs in ASHRAE 90.1 Appendix G.

To avoid oversizing central heating equipment the model shall account for diversity factors at each terminal load (e.g. terminal reheat, which typically has a high diversity) and shall credit heat recovery systems. When determining the heat recovery system credit, if there is a significant chance of heat recovery failure, assume the largest heat recovery system is not operational.

- <u>Example</u>: The building has two air handlers with heat recovery wheels. One unit can recover 2000 MBTU on a design day, the other can recover 1000 MBTU on a design day. The PDL should be reduced by 1000 MBTU.

- <u>Example</u>: A glycol run-around heat recovery system with redundant pumps and serving multiple coils: Such a system may be deemed to have very low probability of any failure, allowing full credit to be assumed for heat recovery.

Finally, in consultation with the U-M Design Manager, determine the need for future capacity and add it to the PDL. Normally assume no additional capacity. In cases where there is a significant potential for incremental increases in loads due to future renovations, a modest allowance of +/-10% future growth may be included. In some cases allowing space for future *additional* or *larger replacement* central heating unit(s) may be appropriate. Indicate in the Basis of Design document the PDL and any accommodation provided for future capacity needs.

After PDL is determined, consider the implications of losing one unit. If the loss of up to 50% of the PDL in an emergency is manageable through load shedding or shifting to other heating sources, units may be sized for as little as 50% of PDL, though careful analysis may imply sizing at 60-70% of PDL to be more appropriate. Examples of these ***non-critical HWH applications***:

- Buildings where ventilation air can be temporarily reduced.

- Buildings were outside air can be reduced in an emergency by temporarily limiting use of *non-critical* exhaust systems.

- Buildings or portions of buildings where space temperature can be compromised below normal set-points in an emergency.

When sizing heat sources and considering the above load reduction strategies, it shall not be assumed that ventilation air can be reduced by more than 50% or that space temperature can fall below 65°F.

Non-critical HWH applications typically would include offices, classrooms, outpatient facilities, buildings with return air systems, child care facilities, and housing.

A system is considered to be a ***critical HWH application*** if loss of any heating capacity below the PDL is intolerable for the application due to stringent criteria and operational constraints. In this case capacity should be 100% of PDL for each of two units (or three units at 50% capacity, etc.).

Critical HWH applications typically would include in-patient care facilities, animal vivariums, ambulatory outpatient surgical facilities, and 100% outdoor air wet lab buildings.

In rare cases, a small off-peak unit may be required, but only if the turndown of the primary system is incapable of meeting required summer loads without excessive temperature swings. Determine minimum load and verify that the heating units are capable of stable control at this load. Consider all components such as boiler size, pump size, steam control valve size, low flow time delay to control sensors, etc.

Calculations, criteria and assumptions regarding rationale for HX (or boiler) sizing must be clearly defined in the Owner Project Requirements and Basis of Design. Clarify added design capacity for future PDL, if any, as well.

Also refer to U-M Design Guideline 230010-H Supplemental HVAC Design for in-patient and ambulatory facilities.

Emergency Power

Normally pumps and heat sources (boilers) for both critical and non-critical applications should be on emergency standby power. If this requirement pushes the standby power source into the next size increment, consider if it makes sense for one or more heating components to remain on normal power, in particular for non-critical applications. Include all components necessary for the heating unit such as control panels, steam condensate pump units, etc. For critical applications, include domestic water booster pumps if needed for make-up water; for non-critical applications, include booster pumps if it does not impact generator size.

Pump Selection

Pump quantity and flow capacity should generally be selected in a manner similar to heat generating units (considering implications of lost flow). E.G. if two HX at 60% capacity each are provided, two pumps at 60% capacity would be provided. If three HX at 50% capacity each are provided, three pumps at 50% capacity each would be provided.

Piping Considerations

The piping arrangement of the pumps relative to the heat sources should normally be as expressed on the following U-M standard details:

MD 235716 001 - Critical Steam to Water Heat Exchanger P & ID
MD 235716 002 - Non-Critical Steam to Water Heat Exchanger P & ID
MD 235716 003 - Steam to Water Heat Exchanger Piping Detail
MD 235716 XXX – Boiler P & ID (future)

In particular for boiler plants, pipe for reverse return, equal pressure drop flow paths across each heat generating unit.

Maintainability

Design the placement of piping, ductwork and equipment so that full access is provided for maintenance, including primary heat exchanger replacement, without the removal of permanent piping or ductwork. Ensure equipment top access recommendations are met.

Provide adequate maintenance aisles and room door widths or removable panels to allow replacement of the largest heat generating unit or component. For units located in penthouses or other high locations, provide means for future replacement with a crane if other routes are not available. Dash-out/indicate equipment clearances and access pathways on the drawings.

Air Removal and Miscellaneous Accessories

A coalescing combination air/dirt separator shall be installed at the location in the system with the warmest temperature and lowest pressure. When practical considerations preclude both, select the location with the warmest temperature. Refer to U-M Standard Detail 15515011– Coalescing Separator and Floor Mounted Expansion Tank for requirements.

HWH systems shall include a shot feeder and corrosion coupon rack, as well as automatic city water make-up . Refer to U-M Standard Detail 15189001 Closed System Shot Feeder and 1518903 Closed System Make-Up for requirements. For hospital projects a shot feeder may not be required, consult with the U-M Design Manager.

Heat Transfer Fluid and Water Treatment

Water (chemically treated for corrosion resistance) is always the preferred heat transfer medium in HWH systems. Glycol should only be considered when freeze protection cannot be practically provided in any other way. For example, U-M normally prefers pumped heating coils on 100% outside air units, not glycol.

Use the U-M master specification and standard details for water treatment. Refer to U-M Design Guideline X.X Water Chemical Treatment (FUTURE) for further information. Coordinate water treatment with the heat generating unit manufacturer and revise the specification and details, if required, after consultation with the U-M Design Manager.

Design Criteria - Operating Temperatures and Pressures

New HWH systems shall be designed with a maximum HWHS temperature of 140°F, to allow efficient addition of other sustainable equipment such as condensing boilers, ground source or heat recovery heat pumps or solar thermal heat in the future. HWHS/R delta T should be a minimum of 20°F, but preferably as high as 40°F to minimize pumping energy.

For HWH systems serving existing facilities, the goal is to achieve the criteria stated for new systems, above, if possible. Since most older systems were installed with a HWHS of 180°F, or even as high as 200°F, conversion to lower temperature HWH requires careful analysis and may require modifications or additions to terminal equipment and/or building envelop to allow the system to be operated successfully at lower temperatures and/or flows.

HWH systems shall be designed for fill and operating pressures that allow filling without additional booster pumps, provide effective venting and that minimize the use of equipment or piping rated for more than 150 psig. The documents shall include a piping schematic of the hot water heating system. Include expansion tank cold fill pressure (make-up water) and operating pressure on the drawings. Taking into consideration the heating pump pressure boost above the expansion tank operating pressure, verify relief valves and other equipment are selected to meet the operating pressure. Include relief valve pressures settings on the drawings.

Control Strategies and Considerations

Use the following U-M standard details for as the starting basis for general control strategies and configuration:

MD 235716 001 - Critical Steam to Water Heat Exchanger P & ID
MD 235716 002 - Non-Critical Steam to Water Heat Exchanger P & ID
MD 235716 XXX – Boiler P & ID (future)

As the U-M standard details referenced above indicate, for heat exchangers automated isolation valves are typically not required on inactive heat generating units. In most cases, the system can function with water flowing through the inactive units.

The controls strategies outlined below shall be described in detail in the control drawing sequence of operation.

Always include a supply water temperature reset schedule (based on outside air temperature) in the sequence of operation. While an aggressive reset schedule may result in excessive pumping energy, an appropriately selected reset schedule can reduce standby losses from piping and equipment, reduce cooling load during summer conditions, and improve controllability. A proper reset schedule must be provided for condensing boilers to assure condensing mode occurs over the maximum number of operating hours. See the boiler design section below for more information.

For critical systems, consider the need for monitoring system pressure (at the point of expansion tank connection) through BAS/DDC.

For variable flow systems, the HWHS/R differential pressure set point shall be reset based upon worst case valve position, i.e. reset downward until one valve is nearly open.

Based on discussions with manufacturers listed in the referenced U-M master specifications, shell and tube heat exchangers and high efficiency high mass condensing boilers can be modulated down to very low/laminar flow. Pumps however shall be operated at no lower than the pump/motor manufacturer's minimum flow rate. Obtain this flow rate from the pump mfr. and include in the sequence of operation. To assure the minimum flow rate is always attainable, provide a minimum flow by-pass either near the pump or in the longest piping run of the system, as appropriate for the building. Unless it is critical that the system provide rapid building warm-up, the preferred bypass location is near the pump.

Additional Heat Exchanger Design and Installation Requirements

Actual Steam Pressure at the HX

The steam pressure available for use in heat exchangers varies depending on the steam plant serving the facility and the location of the heat exchanger on the steam distribution network. See U-M DG 4.6 Utilities for University Buildings for the minimum steam pressure guaranteed at the building entrance. For buildings supplied with CPP steam, the minimum pressure guaranteed is 6 psig. For CPP supplied steam, the pressure at most building entrances is higher, but typically not higher than 12 psig. Assess the location of the building entrance relative to the steam plant and select steam control valves to provide stable control over the entire minimum and maximum steam pressure range that will actually occur at the control valve inlet. Account for expected distribution losses from the building entrance to the control valve inlet. Normally at least two steam control valves are required for stable turndown capacity control and three or more may be required for high turndown systems. Provided the C_v for each control valve on the control drawings.

Built-Up Versus Packaged HX Systems

U-M generally does not prefer factory assembled heat exchanger packages. Where used, the specification must require that all components comply with related specification sections (which in turn must comply with U-M Design Guidelines), e.g. valves supplied as part of the HX package. Packages must be specified to meet code clearances and require that all components are serviceable without excessive disassembly or total system shut-down.

HX Installation Requirements

Ensure condensate from heat exchangers includes an adequate drip leg to minimize back-up of condensate into the HX. Although at least 15" drip leg is required, the drip leg should be as high as possible for the installation location. Use swing check valves, not spring loaded check valves, at steam traps due to high pressure drop and tendency to cause water hammer in steam condensate piping.

Additional Boiler Design and Installation Requirements

Forced draft, direct vent, high mass fire-tube condensing boilers with minimum 316 grade stainless steel heat exchangers shall normally be specified. Utilize U-M Master Specification 235239 Fire Tube Boilers (Hot Water) (FUTURE) as the basis for the specification for HWH Boilers as it reflects the desired boiler package features, performance requirements and remote monitoring interface capabilities. Extensive editor's notes are included in the specification to assist the A/E. Be sure to turn on hidden text and read those notes.

Provide zero side clearance boilers whenever possible.

Optimizing Condensing Boiler Efficiency

Design the boiler plant for maximum turndown, incorporating Outdoor Air Temperature (OAT) Reset and reduced distribution flow to drive HWHR temperatures down, and increase supply/return delta T, as often and as low as possible, to maximize the number of hours and extent that boiler condensing operation is achieved, while minimizing boiler on/off cycling.

Select heating terminal units/heat emitters that allow relatively low HWHS/R temperatures and high water-side delta T, evaluating any increased cost for emitters against improved boiler efficiency/lower boiler operating cost.

Analyze and provide a project specific OAT reset schedule. The highest HWH supply temperature set point of the reset schedule shall reflect the water temperature required to heat the building a -10ºF OAT. The lowest set point of the reset schedule shall reflect the water temperature required at the warmest OAT requiring heating. The lowest set point shall also be limited by non-envelope influenced heat emitters such as reheat coils on VAV boxes serving internal spaces. In some cases increasing the coil size of such emitters may be justified to provide lower boiler operating cost.

Boiler Piping Considerations

In general, design systems with variable volume primary heating hot water distribution, based on two-way valve controls on heating coils and other terminal units. Avoid dedicated boiler circulation pumps or creating a primary boiler loop, as the preferred fire-tube boiler manufacturers require little or no minimum flow, and have very low (50ºF) minimum heating hot water return (boiler inlet) water temperature requirements. Do not provide designs utilizing low mass water tube boilers with flow switches and the need for boiler pumps; which increase construction and operating costs, unless special circumstances require them.

Boiler Controls

U-M Master Specification 235239 Fire Tube Boilers (Hot Water) contains the University's control requirements for boilers and boiler staging. The specification includes all instruments, shipped-loose devices (including the common HWH supply water temperature transmitter and the outdoor air temperature transmitter), and boiler/boiler plant controller programming required to operate the plant as described below.

Controls shall be provided by the boiler manufacturer to stage the boilers in the combination that continuously produces the best plant efficiency while meeting building load. Generally, operating more boilers at reduced flow and lower part load per unit provides best efficiency. Assure the plant arrangement permits the best plant efficiency to be realized.

Boiler control and boiler staging shall operate independently and stand-alone from the Owner's BAS/DDC system. Therefore the boiler specification includes the common HWH supply water temperature and outdoor air temperature transmitters. The A/E must indicate the mounting location of these devices on the design documents. Control by the Owner's BAS/DDC system shall be limited to control and monitoring of the distribution system (pumps, etc.) and monitoring a common boiler plant alarm generated by the boiler controller. See U-M Standard Detail MD 23XXXX – HWH Boiler P & ID (FUTURE) for additional information.

End DG.