Commercial Hydronic Systems

Hydronic heating and cooling systems use piping systems to carry heated and cooled fluids for comfort and process purposes. Hydronic systems generally include all water systems except those used for domestic potable water. Hydronic systems offer the benefits of occupying less space than ducted systems and the ability to carry large volumes of conditioned water over great distances.

Problems with hydronic systems can be identified and resolved if a technician has an understanding of water terminology and concepts.

Water exists as a solid, a liquid, or as a gas, with each state dependent on the temperature and/or pressure that water is subjected to.

Water loses weight as it is heated. Between the temperature at which water freezes and boils, the weight change per cubic foot of water is just over 2.5 pounds.

Formulas are available to calculate the pressure of water in pounds per square foot and pounds per square inch. At sea level, a cubic foot of water weighs 62.4 pounds.

Pressure drop is defined as the difference in pressure between two points, and is affected by water flow rates.

The change in pressure drop resulting from a change in flow in gallons per minute (gpm) can be calculated with the following formula: (final gpm ÷ initial gpm)2 × initial pressure drop = final pressure drop.

Hydronic system pumps must be capable of handling the effects of pressure drop in piping and other components to deliver the desired quantity of conditioned water to where it is needed.

Head pressure is another measure of pressure expressed in feet of water or feet of head. Formulas are available to convert between pressure in pounds per square inch and feet of head.

Static pressure is created solely by the weight of the water in the system. Static pressure will be highest at the lowest point in the system, and lowest (0 psi) at the highest point.

Commercial hot-water system components are similar to those found in residential applications.

Commercial hot-water boilers are commonly fueled by oil, natural gas, or propane. Dual-fuel boilers and those using electricity are also encountered in commercial applications.

The construction of hot-water and steam boilers is similar; however the two types have different operating and safety controls.

Low-temperature boilers are the most common type. Low-pressure hot-water boilers are designed for a 30 psi maximum working pressure and a maximum operating temperature of 250°F.

Medium- and high-pressure boilers are built to operate at pressures above 160 psig and temperatures well above 250°F.

Copper finned-tube boilers are more lightweight and compact than traditional cast-iron boilers and offer advantages in efficiency because they store less heated water and heat the water faster.

Cast-iron boilers are formed by assembling individual cast-iron boiler sections together. Boiler capacity can be changed by increasing or decreasing the number of sections used.

Two types of steel boilers are the firetube boiler and the watertube boiler. In the firetube boiler, the flue gases are contained inside the tubes, with the heated water on the outside.

In the watertube boiler, the heated water is contained inside the tubes, with the flue gases on the outside.

The Scotch Marine boiler is a firetube boiler used to produce steam or hot water for use in heating and industrial applications

Steel vertical tubeless boilers are used to produce hot water or steam. A top-mounted, fuel-fired burner sends a spinning flame down the length of the boiler.

Electric boilers use immersion resistance heating elements to heat the water. An electric/electronic controller cycles heating elements on and off in response to load demand.

Commercial electric boilers can range in capacity up to 200 boiler horsepower (Bohp). One boiler horsepower equals 9.803 kilowatts.

A float-operated, low-water cutoff control is used to protect boilers from damage that could occur if they were to operate with too low or no water in the boiler.

Copper-finned tube boilers have no significant volume of water on board and require water flowing through the boiler while combustion is present. They are equipped with a water flow switch that shuts off the burner if there is inadequate water flow.

Expansion tanks are used in commercial hydronic systems to accommodate the expansion of water as it is heated. Bladder-type and diaphragm-types are commonly used.

Air in the piping system can affect proper water circulation and cause noise. An air separator slows down the velocity of the water, allowing air bubbles to rise out of the water stream.

Air management in hydronic systems can be accomplished using an air control system or an air elimination system.

Pumps are used to move fluids in commercial hydronic systems. Centrifugal pumps are generally used in applications that do not require extreme pressure differentials and are the most commonly used type.

The impeller in a centrifugal pump spins to create centrifugal force within a casing, increasing pressure and causing the fluid to be discharged at high speed.

A packing gland contains an adjustable follower that exerts force on the packing to control fluid leakage around the pump shaft.

Centrifugal pump impellers are selected based on the application and operating characteristics desired.

Cavitation is condition that occurs when the pressure at the inlet of the impeller falls below the vapor pressure of water. This forms bubbles that travel through the impeller where they implode and cause impeller damage.

Snapping and crackling at the pump inlet, along with vibration, reduced water flow, and a drop in pressure are symptoms of cavitation.

A double-suction centrifugal pump draws fluid in through openings on both sides of the pump. They are used to pump large volumes of fluid.

Multi-stage centrifugal pumps contain two or more stages and can be either single- or double-suction pumps. Each stage has an impeller.

Commercial Hydronic Systems

Static pressure is created solely by the weight of the water in a hydronic system. Since 1 foot of water creates a pressure of 0.0433 psi, static pressure in a system is equal to 0.0433 psi for each foot of height above the system gauge. The measured static pressure will differ from the lowest point of the system to the highest. At the highest point in the system, the static pressure will be 0 psi.

The construction and operation of hot-water and steam boilers are similar, with two exceptions. The operating and safety controls used with hot-water boilers are different than those used with steam boilers. Also, hot-water boilers are entirely filled with water, while steam boilers are not. Low-temperature boilers are the most widely used type of boiler. Low-pressure hot-water boilers can be built to have working pressures of up to 160 psi. Normally, they are designed for a 30 psi maximum working pressure, but are frequently operated below that pressure level, with 12 to 15 psig being common. Low-pressure hot-water boilers are limited to a maximum operating temperature of 250°F. Above this temperature, even water under low pressure will begin to boil and begin to change to steam, creating a dangerous condition. Medium- and high-pressure hot-water boilers are built to operate at pressures above 160 psig and temperatures well above 250°F. In extremely large systems, such high pressures and temperatures allow the water to be circulated great distances (from a central heating plant to other buildings, for example) without losing all heating capacity before arriving at the intended destination. Such systems can also be extremely dangerous.

Steel boilers are fabricated into one assembly of a given size and rating. The heat exchanger surface is usually formed by vertical, horizontal, or slanted tubes. Two types of steel boilers are the firetube boiler and the watertube boiler. In the firetube boiler, the flue gases are contained inside the tubes, with the heated water on the outside. In the watertube boiler, the heated water is contained inside the tubes, with the flue gases on the outside. Smaller capacity steel boilers are usually vertical firetube units. Medium- and large-capacity steel boilers normally use horizontal or slant-mounted tubes. They can be either firetube or watertube boilers. Steel boilers range in size from small residential units of 150,000 Btuh to large systems of 23,500 MBh and above.

In smaller boilers, the heater elements are often mounted horizontally. Capacities of resistance-type electric boilers can range from those required for small residences and light commercial use up to a maximum capacity of about two megawatts, or 200 boiler horsepower (Bohp). (One Bohp equals 9.803 kilowatts.) Boiler operation is controlled by an electric/electronic controller. This controller activates and deactivates the individual heater elements in response to load demands. It also allows for incremental loading of the electric service to reduce line fluctuations and power surges during startup.

Copper-finned tube style units transfer heat effectively with no significant volume of water contained on board. Because of this, they are subject to damage very quickly if the water flow is stopped while combustion continues. For this reason, copper-finned tube units should be equipped with water flow switches. These simple units have a paddle attached, which is placed into the water piping. They are adjusted so that a flow volume that is insufficient for safe boiler operation will not push the paddle forward, allowing the integral switch to remain open. The switch is usually wired directly in series with the combustion controls to shut the unit down when water flow is too low or non-existent.

Pumps are classified as either positive-displacement or centrifugal. Positive-displacement pumps are generally used to pump liquids that have very high viscosities; that is, the liquids are thick and flow slowly. Positive-displacement pumps are generally high-pressure pumps. Centrifugal pumps are used to pump liquids that have low viscosities, such as water or thin fluids. Centrifugal pumps are generally used in applications that do not require extreme pressure differentials, and are by far the most common types used in commercial hydronic systems. To accommodate a variety of design situations and installations, they are available in a number of different configurations.

Multistage centrifugal pumps contain two or more stages and can be either single- or double-suction pumps. Fluid is discharged from one stage to the next through passages in the pump casing. Each stage has an impeller, which is used to increase the velocity of the fluid being pumped until the desired pressure is reached.

In larger systems, a multi-purpose valve is commonly installed in the discharge side of the circulating pump. This single valve functions as a shutoff valve, a check valve, and a balancing valve. It has a calibrated stem used to return the valve to the set position after the valve is used as a shutoff valve. When in the set position, it acts as a balancing valve. The valve is tapped for the installation of two readout valves that enable it to be used as a flow meter. When balancing a system, the pressure drop across the valve can be measured using a differential pressure gauge connected to these readout valves. The measured pressure drop can then be used with a conversion chart to find the corresponding total flow rate of the water passing through the valve.

The three-way valve is often used as a mixing (blending) or diverting valve. As a mixing valve, it has two inputs and one output. It mixes the two water streams into one, based on the position of the valve's plug in relation to its upper and lower valve seats. It is commonly used to mix or blend hot water and chilled water inputs so that the single water stream leaving the valve has a controlled temperature.

The refrigerant vapor from the chiller evaporator is drawn into the chiller compressor. There, the low-temperature, low-pressure refrigerant vapor is converted into a high-temperature, high-pressure vapor so that it can be condensed into a liquid in the condenser. The system shown in the example has an air-cooled condenser.

Tube-in-tube evaporators are sometimes used in smaller units. The expansion device controls refrigerant flow from the condenser to the evaporator to maintain enough suction superheat to prevent liquid refrigerant from flooding the compressor. HCFC-22 refrigerant is used in most installed reciprocating water chillers, but models using non-chlorine refrigerants are being phased in. Reciprocating and scroll liquid chillers have cooling capacity sizes ranging from about 5 tons to 225 tons. Capacity control is normally accomplished using a combination of cylinder unloading, on-off cycling of the compressor(s), or compressor speed control.

Purge units are another type of device used on centrifugal chillers that operate with low-pressure refrigerants, such as HCFC-123. Use of these refrigerants causes below-atmospheric pressures to exist in the system. Because of this, noncondensibles such as air and water tend to leak into and accumulate in the system. A purge unit must be used to remove the noncondensible gases and water vapor from the system. Today's purge units are generally small refrigeration units mounted on the chiller assembly. They draw in refrigerant vapors from the chiller, then chill the vapor below the point of condensation for the refrigerant itself. Any vapor that remains is considered a noncondensible gas other than refrigerant and is released to the atmosphere. Any moisture is captured by filter-driers. The condensed liquid refrigerant is then returned to the chiller. Older purge systems used with CFC refrigerants were quite inefficient and tended to release a significant amount of refrigerant along with the air. Because the refrigerants were relatively inexpensive, this issue presented little concern and the chiller was simply recharged periodically. To comply with new EPA guidelines, purge units have been redesigned to operate much more effectively.

A forced-draft tower is one in which the fans push the air so that it flows up and over the wet decking surfaces. In an induced-draft tower, the fans pull the air rather than push it, so that it flows up and over the decking. Because they use fans, forced-draft and induced-draft towers tend to be small in comparison to natural-draft cooling towers.

Fan coil units are terminals that can be used for chilled-water cooling only, or for both cooling and heating. A fan coil unit includes a fan, finned-tube heating/chilled water coils, air filters, and sometimes an outside air connection with a manual damper. Control is provided using a multi-speed blower or control valves. The blower fan causes the room air to recirculate continuously from the conditioned space through the coil that contains the chilled water. This causes the heat in the room air to be transferred to the chilled water flowing through the coil. The air filter prevents clogging of the coil with dirt or lint carried by the recirculated air. Ventilation boxes with manual dampers can be connected to a fan coil unit. Fan coil units range in size from 100 to 2,000 cfm.

Although the installation of two-pipe systems is a less expensive approach than four-pipe systems, it is important to note that the changeover from one mode to the other can be quite problematic. Hot water introduced to a chiller may cause over-pressurization and opening of the refrigerant pressure relief device. In addition, the chiller compressor may attempt to operate in an overloaded condition. Cold water introduced to some boilers may cause cracking of cast-iron sections or steel welds. Chillers and boilers can sustain serious damage from the introduction of water outside of their normal temperature range. For that reason, there are often periods of time where the changeover cannot be made, especially during the change of seasons. For example, a commercial building may require heating in the morning and cooling by mid-day, as a result of solar gain, indoor heat sources, and the occupants themselves. If the heating water temperature in the loop remains above a safe temperature for introduction to the chiller, then the changeover must be postponed until the water in the piping cools naturally. Systems are rarely equipped with any alternate means of dissipating this heat, and discomfort often occurs while the changeover process awaits a natural temperature change.