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PROCESS COOLING & EQUIPMENT

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Closed-Loop Cooling Systems 101

By HydroThrift Corp.

Dry, evaporative and liquid-to-liquid cooling systems are explained.

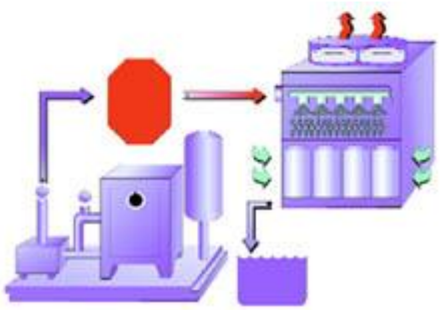

Figure 1. In a cooling tower system, a pump is used to circulate water to the heat-producing equipment or process (heat load), where heat is transferred to the water. The water is then pumped to the cooling tower.

Cooling tower systems have been used by industry for years to provide a means of removing waste heat generated by machinery or manufacturing processes. A simplified cooling tower system consists of a pump to circulate water to the heat-producing equipment or process (heat load), where the heat is transferred to the water. The water is then pumped to the cooling tower where it is cooled (figure 1).

The cooling tower contains a surface, commonly called fill. The warm water entering the cooling tower is distributed uniformly over the fill area and flows vertically downward. Fans force air to flow across the saturated fill either horizontally (crossflow) or vertically (counterflow), causing a small portion of the circulated water to evaporate. The evaporation of some of the water removes the heat from the remaining water. The cooled water is collected in the tower basin or an external tank or reservoir (referred to as a cold well), which is located beneath the tower or inside a building. The cooled water is then pumped back to the heat source and the process repeats itself.

Therefore, a cooling tower system recirculates the cooling water, which comes in direct contact with ambient atmospheric air, or is open to the environment, and uses the process of evaporation to reject heat to the environment.

The negative aspect of a cooling tower is the cooling water is directly open to the environment. Airborne particulate contaminants are washed out of the air by the water flowing over the tower. The water also absorbs oxygen and other gases, including products of air pollution. The evaporation process causes the minerals that were initially dissolved in the water to be left behind as fine, highly abrasive particles. It also causes the mineral concentration of the remaining water to increase. As a result, cooling tower water quickly becomes highly contaminated water that causes fouling, scaling, corrosion and erosion of heat transfer surfaces. These detrimental effects can increase maintenance costs as well as incur unscheduled equipment and process downtime and loss of productivity.

By contrast, a closed-loop cooling system circulates coolant and rejects heat using heat exchangers in such a manner that the coolant does not come into direct contact with the environment at any time. The coolant remains clean, uncomtaminated, and does not cause fouling, scaling, corrosion or erosion of heat transfer surfaces.

There are three principle types of closed-loop cooling systems to consider: air-cooled or dry (no water is consumed), evaporative (heat is rejected using the process of evaporation, water is consumed) and liquid-to-liquid.

Figure 2. A dry type cooling system uses an air-cooled heat exchanger or radiator. It is the industrial equivalent of an automobile engine cooling system. The illustration on the left shows the airflow of this type of cooling system.

Dry Type or Air-Cooled. This system uses an air-cooled heat exchanger or radiator to reject heat to ambient atmospheric air (figure 2). It is the industrial equivalent to an automobile engine cooling system. The coolant, usually a glycol/water mixture, is circulated through the heat load, then to the air-cooled heat exchanger, where heat is rejected to the environment (ambient atmospheric air). The advantage of this system is the total elimination of water consumption and sewer disposal costs. Water-cooled machinery becomes air-cooled.

An air-cooled heat exchanger can only cool the coolant to a temperature above the prevailing ambient dry bulb temperature. A typical design dry bulb temperature is usually the 1 percent summer design condition as found on ASHRAE (American Society of Heating, Refrigeration & Air-Conditioning Engineers) tables. A typical value for much of the continental United States is 95ºF. The cool coolant temperature is determined by the selection of the approach temperature (approach temperature is the cool coolant temperature design dry bulb temperature) of the air-cooled heat exchanger to worst-case summer dry-bulb temperature. A typical and practical approach temperature for an air-cooled heat exchanger is 10ºF (-12ºC) or greater. Therefore, typical cool coolant temperatures for an air-cooled closed loop cooling system for much of the continental United States is 105ºF (41ºC) or higher.

Temperature control of the coolant is accomplished by cycling the air-cooled heat exchanger fans on and off in response to the temperature of the cool coolant leaving the heat exchanger. This prevents over-cooling of the coolant during cold weather operation.

The closed-loop dry cooling system is suitable for cooling reciprocating air compressors, hydraulic equipment, various types of furnaces, quenching and other types of equipment or processes capable of operating at elevated coolant temperatures.

Evaporative Type. This type of system uses a closed-circuit evaporative fluid cooler and the process of evaporation to remove heat from the coolant. An evaporative fluid cooler usually consists of a serpentine steel coil, galvanized on the exterior surface; a water basin; a spray pump with water-distribution piping; and a fan.

The coolant, usually a glycol/water mixture, is circulated by means of a process pump through the heat load, absorbing heat, and then flows to the coil in the evaporative fluid cooler. The fluid cooler spray pump pumps water from the fluid cooler basin and sprays the water uniformly across the exterior surface of the coil. The fan blows air across the wet surface on the outside of the coil. The forced evaporation of some of the water on the coil surface cools the coolant flowing through the coil. The coolant is never in contact with the environment, hence the name, "closed circuit fluid cooler."

Evaporative cooling devices such as cooling towers and fluid coolers work on an approach to wet bulb temperature. Wet bulb is a function of the moisture content, or relative humidity, of ambient air. ASHRAE tables are again used to determine the wet bulb for a given locality, and the 1 percent summer design condition typically is used. Approach temperatures are usually 5 to 7°F (2.78 to 3.89°C) or greater to design wet bulb temperature. For much of the continental United States, a typical design wet bulb temperature is 78°F (26°C) with cool coolant temperatures of 85°F (29°C) possible.

Temperature control of the coolant is accomplished by cycling on and off the fans that force the air to flow over the coil. Fan dampers can also be used on fluid coolers having centrifugal fans. An increasingly popular method of control is to use a variable frequency drive to control fan motor speed and therefore evaporation rate.

The spray water portion of the fluid cooler, like a cooling tower, is open to the environment, so it will become contaminated by airborne debris. Maintenance usually consists of cleaning debris from the basin on an as-needed basis.

A cooling system that uses evaporation as the means of rejecting heat consumes water and requires make-up water to continue to operate. A typical water consumption rate for a cooling tower or closed evaporative fluid cooler is 4 gal/min for each 1 million BTU/hr of heat load, with 2 gal/min being lost directly to evaporation, and 2 gal/min going to drain, (blowdown). The purpose of the water going to drain or blowdown, is to remove some of the impurities that are washed into the water, and to allow makeup water to replace water lost to blowdown to dilute the buildup of mineral concentration caused by the evaporation of the water. A proper blowdown rate is critical to successful operation of an evaporative fluid cooler. An increase in the concentration of minerals in the spray water can cause scale to form on the fluid cooler coil and reduce its ability to reject heat.

Liquid-to-Liquid Type. This type of cooling system utilizes shell-and-tube or plate-and-frame heat exchangers to transfer the heat from one cooling fluid to another (figure 3).

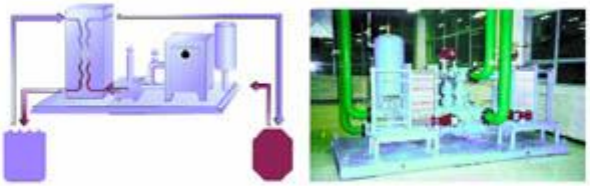

Figure 3. A liquid-to-liquid type of cooling system utilizes shell-and-tube or plate-and-frame heat exchangers to transfer the heat from one cooling medium to another. The illustration on the left shows the liquid flow of this type of cooling system.

The coolant -- usually a glycol/water mixture, but treated water, deionized water or other fluid can be used -- is circulated through the heat load, absorbing waste heat. Then, the mixture travels to the heat exchanger, where the heat is transferred to another cooling fluid such as cooling tower, chilled, well, river, lake or ocean water, or a closed-loop glycol/water system as previously described.

When one of the cooling fluids such as cooling tower water is contaminated, and fouling of the heat exchanger is likely, then a standby heat exchanger is desirable. Should the operating heat exchanger become fouled for any reason, valves permit the fouled heat exchanger to be isolated from the system. This way, the heat exchanger can be cleaned without shutting down the system or the equipment being cooled.

The temperature of the coolant in a liquid-to-liquid closed loop system is determined by the design approach temperature of the heat exchanger and the maximum cool entering temperature of the fluid doing the cooling. The approach temperature for a heat exchanger is the difference between the leaving temperature of the fluid being cooled (hot side) and the entering temperature of the fluid doing the cooling (cold side).

For example, if the cold-side cooling fluid is cooling tower water that is available on a worst case basis at 85°F (29°C), and a plate-and-frame heat exchanger is used with a 5°F (-15°C) design approach temperature, then the coolest possible hot-side coolant temperature is 90°F (32°C).

Temperature control of the coolant can be accomplished by using a control valve to regulate the flow of the cold-side fluid in response to the leaving hot-side coolant temperature. This is desirable only if the cold-side coolant is clean and contaminant-free. If the cold-side fluid is contaminated with solids, then a control valve that will bypass varying amounts of hot side coolant in response to its leaving temperature is used. The fluid that is contaminated with solids should be allowed to flow at a maximum rate to keep the velocity high and minimize the possibility of solids dropping out and fouling the heat exchanger.

A variant of a liquid-to-liquid cooling system is a liquid-to-refrigerant cooling system, which is a chilled water system. Chilled water, or the chilled coolant side of the system, can be open or closed while the refrigerant side of the system is always closed.

The coolant used in a closed system is usually an ethylene glycol/water mixture. Ethylene glycol is considered a hazardous, toxic material. If toxicity is a concern, propylene glycol can be used; however, propylene glycol has poorer heat transfer characteristics than ethylene glycol and is more expensive. The type of glycol used and the concentration of the mixture affect the circulating pump and heat exchanger selection regardless of cooling system type.

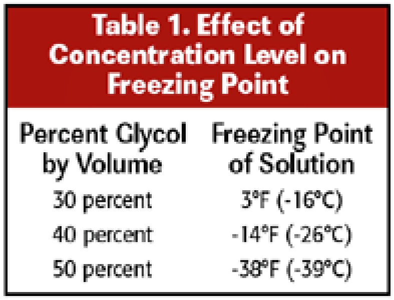

Table 1. Effect of Concentration Level on Freezing Point

Percent Glycol by Volume	Freezing Point of Solution
30 percent	3°F (-16°C)
40 percent	-14°F (-26°C)
50 percent	-38°F (-39°C)

The glycol selected for use, either ethylene or propylene, should be industrial grade and contain an inhibitor package consisting of corrosion inhibitors, a buffer to neutralize acid formation and a foam suppressant. Automobile antifreeze should not be used.

The level of freeze protection required determines the concentration of the glycol. Table 1 displays the concentration level as related to the degree of freeze protection provided by ethylene glycol/water mixtures by volume. The 30 percent water/glycol mixture shown in table 1 is the minimum practical concentration at which the inhibitor package is effective. Glycol/water mixtures of less than 30 percent result in the inhibitor package being so diluted that it is not effective. The percentage of glycol/water mixture by volume is first determined by the level of freeze protection required (determined by worst winter temperatures at the installation site), with 30 percent glycol/water being the minimum allowable mixture. If freezing conditions are not expected to be encountered, then city water with an acceptable corrosion inhibiter is suitable for use.

Closed-loop cooling systems provide clean, nonfouling, nonscaling, noncorrosive coolant for many types of industrial equipment and processes. Equipment and cooling system maintenance costs are reduced, and equipment reliability and productivity are increased. Equipment life is extended. Accurate temperature control of the coolant is provided, further increasing the reliability of critical equipment.

For more information: Call (330) 837-5141 or visit www.hydrothrift.com.