Adiabatic systems are most effective in hot, dry environments. They use up to 80 percent less water than traditional evaporative units.

Advantages of Closed-Loop Equipment for Process Cooling

Growing sensitivity to water conservation and the ever-increasing cost to maintain mechanical systems are driving interest in closed-loop evaporative cooling technology.

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It's a common question during the early design phase of large mechanical systems: "Is open-loop or closed-loop cooling equipment better suited for this project?"

When it comes to modern heat-rejection technology, both open-loop and closed-loop cooling equipment provide a distinct set of advantages for the engineer, installer and facility owner. Ultimately, the specific cooling needs of the application, the physical parameters of the installation site, budgetary considerations and environmental goals of the project help determine the type of system that is best-suited and specified.

With very real concerns about the higher water consumption of open-loop systems, closed-loop cooling technology is gaining broader appeal every year.

When properly designed for an industrial process cooling load, both system types can offer energy efficiency, reliability and longevity.

Determining which system is best-suited to a certain application is a task left for the specifying engineer and others who are intimately familiar with the needs of the property. Whether open- or closed-loop heat-rejection equipment is specified, be certain to select equipment that is certified by the Cooling Technology Institute (CTI).

Open-loop equipment

The most prevalent type of large-scale heat-rejection equipment in use today is the open-loop cooling tower. These systems are known for their expansive range in available capacities and configurations, reasonable first cost, and energy efficiency. There are, however, several trade-offs when compared to closed-circuit alternatives. Among the largest compromises with open-loop technology are water consumption and the level of maintenance and water treatment required.

With open-loop equipment, process fluid enters the top of the cooling tower and flows over the fill, or heat transfer media. Within the cooling tower, the process water is open to outdoor air and any contaminants present in the atmosphere. Falling from the fill, water collects in a basin before returning to the facility's cooling loop.

Due to airborne pollutants, incoming contaminants from the make-up water supply and the presence of absorbed oxygen, proper maintenance of all equipment in the loop is critical. This also heightens the importance of water or fluid filtration and treatment. If the process water in the basin of the open tower is not properly treated, filtered and maintained properly, the energy efficiency of the system will be reduced over time due to scaled and fouled heat exchangers and chiller tubes.

Open-loop cooling tower with heat exchanger

An open-loop cooling tower is the best option for heat rejection in many applications. Facilities that are not facing the need to minimize water consumption may benefit from this type of system, as would a property needing to maximize the amount of heat-rejection capacity in a limited mechanical footprint. For the fluid's process heating and cooling loops, however, a closed-cooling circuit is recommended.

In these situations, isolating the cooling tower from the process loop through the use of a heat exchanger may provide an optimal solution. In this way, the benefits of a cooling tower can be provided without requiring the maintenance that an open-loop cooling requires. Isolating the system from the cooling tower through the use of a heat exchanger also eliminates concern for where the heat-rejection equipment is installed with respect to the cooling loop.

Plate-and-frame heat exchangers are used most frequently for this type of design. When a heat exchanger is installed, the cooling tower must be sized properly to accommodate the temperature difference between the cooling tower water entering the heat exchanger and the process water that exists within the heat exchanger.

Isolating the cooling tower with a heat exchanger will substantially reduce the need to maintain downstream components. This also means that the heat exchanger will require routine maintenance. To ensure that both the thermal performance and the pressure drop across the heat exchanger meet design requirements, heat exchangers should be certified per AHRI Standard 400, or a local equivalent such as Eurovent.

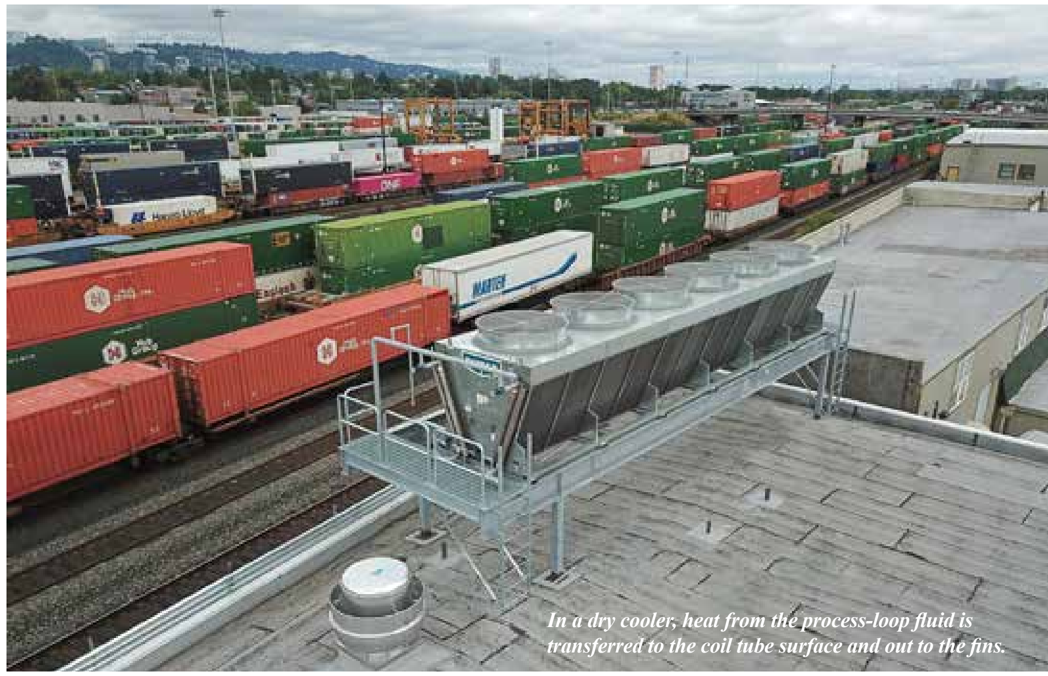
The most prevalent type of large-scale heat-rejection equipment in use today is the open-loop cooling tower. Wide available capacities and configurations, reasonable first cost and energy efficiency are features of open-loop cooling towers.

Closed-loop technology

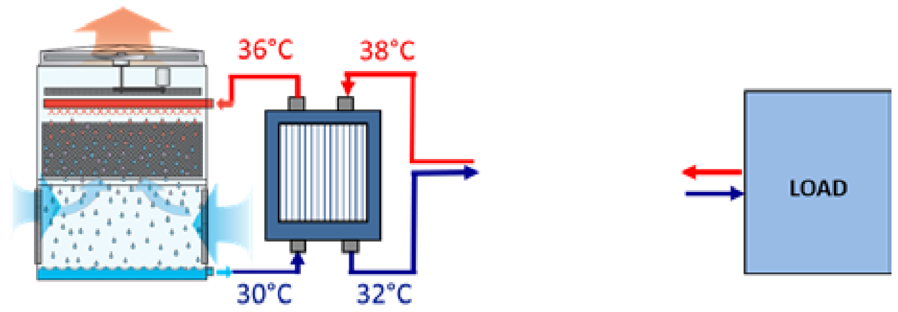
Most cooling tower manufacturers offer a range of closed-circuit coolers – or as they are called, fluid coolers – to provide a heat-rejection alternative for engineers or end users who want (or need) to reduce water consumption and equipment maintenance. Some cooling applications require a closed-loop system for peak efficiency long-term operation. These types of systems generally include the use of small heat exchangers in terminal units or other connected equipment, making maintenance complicated, if possible at all. For example, buildings with water-source heat pump loops – widely used for healthcare facilities as well as office, hotel, high-rise residential buildings – are among one of the largest markets for fluid coolers. Using an open-cooling loop could pose the significant risk of fouling hundreds of heat exchangers in a condominium or similar facility.

Closed-circuit systems are also prevalent among high efficiency chiller applications, data centers, battery plants, grow room facilities and multiple types of industrial process loops.

Water loss through evaporation is either reduced or eliminated, depending on the type of closed loop cooling equipment selected.
The same is true for water treatment chemicals and systems: Closed-loop technology can help to reduce or even eliminate the need for chemical treatment of system fluids.



In a dry cooler, heat from the process-loop fluid is transferred to the coil tube surface and out to the fins.



Isolating a cooling tower from the process loop through the use of a heat exchanger allows a cooling tower to be used without requiring the maintenance that an open cooling loop requires. Plate and frame heat exchangers are most frequently used for this type of design.

While open-loop cooling towers reject heat in a smaller footprint than closed-loop fluid coolers (due to the process fluid being cooled via direct latent heat transfer), closed-loop systems benefit from sustained thermal performance of the entire system. Higher whole-system efficiency over time is achieved because heat transfer surfaces experience less fouling. Closed-loop systems also typically require less pumping horsepower than open-loop systems of similar capacity.

With a closed-loop system, installation savings can be achieved due to the reduced pumping horsepower required, the elimination of an intermediate plate-and-frame heat exchanger and the elimination of valves and additional pipework. This is in addition to the lifetime operational savings due to reduced water treatment and chemicals, reduced water consumption and reduced maintenance.

Comparing just an open tower to a closed-circuit cooler in terms of price, however, does not tell the whole story. The up-front installation costs and operational costs of an open-loop system should be considered. Because the clean system fluid provided by a closed-loop design reduces maintenance and wear to all connected components, equipment lifecycle is lengthened. Reducing maintenance also results in less downtime, which is particularly important for critical process cooling and data center applications.

Compared to open-loop cooling towers, fluid coolers provide more flexibility in terms of where heat-rejection equipment is installed. Closed-loop systems also do not require hydraulic balancing or equalization. Because of this, fluid coolers can be installed at or below the level of the connected system piping. Conversely, installing a cooling tower below grade or below the pump could result in the tower flooding when the unit shuts down.

Closed-loop equipment also provides an advantage for cooling systems operating in subfreezing outdoor temperatures. All open-loop cooling towers must be equipped with basin heaters, a drain-back design or a recirculation system for idle periods in freezing conditions. By contrast, only some types of closed-loop equipment require freeze protection.

Closed-circuit coolers can also provide dry sensible heat rejection when outside ambient conditions are favorable. This dry capacity is an added benefit that can reduce the overall water consumption on a project. If the application conditions allow it, fluid coolers can be sized for full design or partial load based on a dry bulb switchover temperature. This means that the recirculating spray pump can be de-energized when the heat load can be fully satisfied by just the fluid cooler fans. While this operational mode greatly reduces water consumption, energy is also saved because the recirculating pump is off.

The four primary types of closed-loop heat-rejection equipment are:

- ➢ Evaporative closed-circuit coolers
- ➢ Eco/Hybrid closed-circuit coolers
- ➢ Adiabatic coolers
- ➢ Dry coolers

The cooling load of the system, available equipment space, sensitivity to water consumption, maintenance requirements, and project budget should determine which option is best for the specific application.

Evaporative closed-circuit coolers

Evaporative closed-circuit coolers eliminate the need for a heat exchanger between the process loop and the heat-rejection equipment. Unlike a cooling tower, where process water is used as the energy transfer medium and is open to the atmosphere, the coil inside a closed-circuit cooler isolates the process fluid.

In a closed-circuit cooler, process fluid is circulated through coils within the unit. A water-distribution system cascades water over the tubes of the coil, extracting heat from the process loop via evaporation. Air is drawn or forced across the coils, agitating the falling water and increasing the heat transfer. A small amount of this water evaporates due to latent heat transfer through the tube and fin walls of the coil, removing heat from the system. The cooled process fluid returns to the process or facility via the bottom coil connection. Cascaded water drains to a basin and is recirculated back over the coil.

The four primary types of closed-loop heat-rejection equipment are evaporative closed-circuit coolers, hybrid closed-circuit coolers, adiabatic coolers and dry coolers. The cooling load of the system, available equipment space, sensitivity to water consumption, maintenance requirements, and project budget should determine which option is best.

These coolers provide energy-efficient operation in a reduced footprint compared to dry coolers due to evaporation being used as the primary method of cooling. Because blowdown of the basin water is reduced on closed-loop systems, water conservation also is improved when compared to open-loop systems. Because evaporative coolers can oftentimes run dry when ambient conditions are favorable during reduced load conditions, water consumption is eliminated entirely during these periods of operation.

Hybrid coolers

Hybrid coolers combine dry and evaporative cooling to maximize energy efficiency while simultaneously reducing water consumption. These units provide heat rejection in dry mode until the load exceeds dry rejection capacity. At this switch-over point, the unit enters evaporative mode to increase cooling capacity. Operating in wet mode only when needed can reduce annual water consumption, sever expense and eliminate plume (while in dry mode).

Hybrid cooling solutions include a dry cooler with wet trim and an evaporative cooler that runs both wet and dry. Dry coolers with wet trim are suitable where saving water is the top priority. In these systems, the dry cooling coil is placed in series with the evaporative cooling coil. It plays an integral role as part of the cooling system rather than simply having an on/off role.

Alternatively, wet coolers with dry trim are capable of running in wet and dry mode simultaneously by having separate spray sections above the coils. The coils can utilize either evaporative or dry cooling - rather than both at once - which also helps to minimize water consumption. Depending on capacity needs, such units are capable of running in dry mode, partially in wet mode or completely in wet mode.

Compared to wholly evaporative cooling units, both systems reduce water consumption. Space savings is also a benefit of hybrid coolers when compared to adiabatic and dry cooling equipment.

Hybrid coolers are frequently used in critical chilled-water applications where minimizing both water and energy are important. They also are found in data centers and battery plants.

Also called fluid coolers, closed-circuit coolers provide a heat-rejection solution for engineers or end users who want to reduce water consumption and equipment maintenance.

Dry coolers

Dry coolers are best specified where water conservation and reduced maintenance are the key considerations. Because dry coolers do not utilize any water or evaporative cooling, dry coolers eliminate water treatment, plume and Legionella concerns. Dry coolers will use more energy and require a larger footprint than evaporative or hybrid fluid coolers of the same capacity.

In a dry cooler, heat from the process-loop fluid dissipates via heat transfer to the coil-tube surface and out to the fins – not through evaporation. Ambient air is drawn over the coil surface by a fan located at the top of the unit. Heat from the process fluid transfers to the air via sensible cooling and discharges to the atmosphere.

Adiabatic coolers

Adiabatic coolers function in a similar fashion to dry cooling systems but with the addition of pre-cooling pads. Water runs over porous media while air is drawn through the pads, lowering the dry bulb temperature of the incoming air. The influence of reduced dry-bulb temperatures at the coil provides greater heat rejection. As a result, adiabatic systems are most effective in hot, dry environments.

Adiabatic coolers use up to 80% less water than traditional evaporative units. Adiabatic units also deliver the required cooling capacity in a smaller footprint and/or lower fan motor horsepower than a completely dry cooler.

Similar to hybrid units, some manufacturers offer coolers that can operate in dry mode, adiabatic mode or partial-adiabatic mode, in which only a portion of the adiabatic spray pumps are energized. The thermal performance of these units is also fully rated. It is critical that specifying engineers understand that fully rated dry coolers and fully tested pad efficiencies will impact the sizing of units. Inadequately sized equipment will result in greatly increased water usage and energy consumption compared to a fully rated unit.

In conclusion, when determining the type of heat-rejection equipment that should be used on a given project, the specific needs of the facility should dictate whether a closed- or open-loop design is most suitable. Given the growing sensitivity to water conservation, and the ever-increasing cost to maintain mechanical systems, closed-loop technology is seeing wider implementation.