Making a case for
CLOSED-LOOP EVAPORATIVE COOLING

Plant engineers place considerable emphasis on waste heat recovery and the economic benefits derived when heat pumps and pipes, regenerative units, and heat economizers pay off in energy savings.

Waste heat from ventilation, processes, and combustion equipment exhaust can be effectively used for space and makeup air heating, water and process heating, combustion-air and boiler-feedwater preheating, and other heating and cooling applications.

There is one catch, however. Recoverable heat must be available when needed — and only in the amount needed — if the recovery systems are to pay off. Attempts to store excess waste heat temporarily results in increased system complexity and costs. Usually, there remains a considerable amount of waste heat that must be rejected.

When evaluating heat rejection systems, the plant engineer confronts another economic and conservation decision: How best to help save, in a practical and energy-efficient manner, our dwindling water supply without polluting any segment of the environment.

The solution appears to be through the application of closed-loop evaporative coolers (often referred to as industrial fluid coolers) for air conditioning and industrial process cooling.

A closed-loop evaporative cooler (Figure 1) combines the function of an open cooling tower and a heat exchanger by replacing the wet-deck surface of the cooling tower with a coil-type heat exchanger. The primary cooling mode is evaporative.

The closed-loop evaporative cooler provides several benefits:
- Relatively trouble-free performance throughout the system because the cooling loop is closed and contaminant-free.
- Lower operating and maintenance costs, as much as 20% lower, when compared to tower-heat exchanger combinations.
- Lower loop water temperatures because it uses direct, evaporative heat transfer. For example, at a 78°F wet bulb air temperature, an 83°F loop temperature is economically obtainable.
- Fewer pumps and less associated piping because all of the cooling is accomplished by evaporation in a single piece of equipment.

Closed-loop evaporative coolers also minimize thermal pollution problems and offer an excellent return on investment. It is not unusual to recover the complete installed cost within one year, and returns within two to three years are common.

Heat rejection alternatives

Industrial heat rejection technology has changed dramatically over the past 50 years. Early "once-through" cooling
Evaporative chilling: An energy saver during cool weather

In systems that require chilled water year-round, cooling towers and industrial fluid coolers may be used to cool and recycle the system's condenser water. The same equipment used for evaporative chilling can save refrigeration costs in the cool fall, winter, and spring.

The tower or fluid cooler may produce water cold enough to eliminate the need for running the chiller. In a system that uses evaporatively chilled water, equipment that consumes about 0.2 kW per ton is substituted for a refrigeration machine, which normally consumes 0.7 to 0.8 kW per ton—a 70% to 75% energy savings.

Evaporative chilling can be easily designed into new chilled water systems, or retrofitted to existing systems. A load estimate will predict the number of hours of operation and determine annual energy savings.

For constant-load systems, the winter load is accurately known. For air conditioning systems, the winter load is nearly always less than the summer load. It represents fairly constant internal heat gains.

Because dehumidification is not required in cool weather, chilled water temperatures can be higher, extending the number of hours during which evaporative chilling may be used. Typical winter chilled water temperatures are 50°F supply and 55°F return. The minimum practical leaving-water temperature is 42°F for cooling towers and 45°F for industrial fluid coolers.

Diagrams 1, 2, and 3, show a closed chilled water circuit in summer and winter. In system 4, the chilled water circuit is open to the atmosphere in winter.

1. Closed-loop evaporative cooler

During the summer, the water from the cooler is circulated in a closed loop through the condenser of the chiller. This helps to eliminate fouling or plugging of the condenser tubes year-round. During the winter, the cold water from the cooler is circulated in a closed loop directly through the chilled water circuit.

2. Cooling tower and heat exchanger

During the summer, the system operates as a conventional cooling tower/chiller system. During the winter, the chiller is bypassed and the cold condenser water cools the chilled water through a heat exchanger.

Chiller vapor cycles

During the summer, the system operates as a conventional cooling tower/chiller system. During the winter, the compressor is stopped and a refrigerant valve between the condenser and evaporator is opened. Refrigerant migrates to the condenser, where it's condensed and drains back to the evaporator for another cycle. The chiller operates like a heat pipe, transferring heat through an evaporation-condensation cycle without compression.

Filtration systems

During the summer, the system operates conventionally, with the addition of strainers or water filters in the condenser-water line. During the winter, the cold water from the cooling tower is circulated directly through the chilled water circuit.

Chilled water circuits, designed as closed pressurized systems, are not normally designed to permit access for cleaning and could be rendered unusable if fouling or plugging should occur. The filtration system minimizes any fouling or plugging by removing solid and biological contaminants which could be introduced into the system through the cooling tower.

Dissolved contaminants, which may precipitate on temperature change and in the presence of oxygen, cannot be removed by filtration systems. This must be considered in the design of these systems, as well as the pressure drop and loss of backwash water associated with filtration systems.
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configurations, that relied on the availability of an inexhaustible supply of water, evolved into very sophisticated closed-loop evaporative systems. The systems, when customized with the addition of state-of-the-art corrosion protection systems, two-speed pumping systems, and extended-surface coils, become energy saving, low maintenance, highly efficient systems.

Here is a brief recap of yesterday’s technology.

- **“Once-Through” Cooling (Figure 2):** The “once-through” system previously was used for nearly all process fluid cooling. Increased water and sewage costs, and restrictions on thermal pollution, make this system uneconomical and obsolete.

The simplest of all heat rejection systems uses city, well, or surface water directly in a heat exchanger, and discharges that water into a sewer, to the ground, or back to the surface water source. Because only sensible cooling is involved in the exchanger, the heat removed is solely dependent upon the flow rate and temperature rise of the cooling water. For an assumed 20°C temperature rise of the cooling water, each pound of water will remove 20 Btu.

- **Open Cooling Tower (Figure 3):** One of the early advancements from the “once-through” system, intended to conserve water, substituted an open cooling tower to permit recirculation of cooling water. In a cooling tower, the heated water from the heat source is brought into contact with the air, and only a small portion of the water is evaporated into the airstream. Each pound of water evaporated removes approximately 1,000 Btu, as compared to 20 Btu per pound of water in the “once-through” system with the previously assumed 20°F temperature rise.

This result is a theoretical savings of 98% of the water consumed by the “once-through” systems. In actual practice, however, the savings are approximately 95% because a small amount of water must be “bled off” from the system to control the concentration of dissolved solids in the recirculated water.

While open cooling towers conserve water, they also allow the process water to directly contact the airstream and become contaminated with impurities, which can cause corrosion or scaling of heat exchange surfaces.

- **Open Cooling Tower And Heat Exchanger (Figure 3A):** The temperature of the water leaving the open cooling tower
is determined by the ambient wetbulb temperature. In most areas, design wetbulb temperatures are such that the temperature of the water leaving the cooling tower is higher than well or surface-water temperatures. The higher cooling water temperature and the additional step of heat exchange introduced by the heat exchanger, often limits the cooling applications for the system.

Compared to a closed-loop evaporative cooler, there are additional pieces of equipment to install and pipe. Energy costs may also be higher because the open cooling tower requires a larger pump for the open-water loop.

• Dry-Air Cooler (Figure 4): A dry-air cooler rejects heat from a process fluid by sensible heating of the ambient air that flows through it. Because it doesn't use the evaporative cooling principle, the amount of cooling in the dry-air cooler is a function of the ambient drybulb temperature (measured with a typical thermometer).

Design drybulb temperatures are normally 15° to 25°F higher than design wetbulb temperatures, which often severely limits the cooling application for the system. Where higher process fluid temperatures can be tolerated, the compromise often results in a decrease in process efficiency.

The low specific heat of air results in a large air volume flow rate (approximately four times that of evaporative cooling equipment), with corresponding higher fan horsepower and larger plan area. The net result is a savings of water, but at the expense of increased power consumption in the heat rejection process and higher process fluid temperatures.

• Closed-Loop Evaporative Coolers: As previously stated, the closed-loop evaporative cooler, or industrial fluid cooler, is essentially a cooling tower in which a heat exchanger (cooling coil) has been substituted for the wet-deck fill.

The counterflow technique is the most effective heat rejection method.
Typical selection guidelines for industrial fluid coolers

The following basic procedure, with significant modifications, is used by nearly all manufacturers for selecting counterflow industrial fluid coolers with water as the process fluid.

1. **Determine Range**: Range equals entering-fluid temperature minus leaving-fluid temperature.
2. **Determine Approach**: Approach equals leaving-fluid temperature minus design wetbulb temperature.
3. **Select Performance Factor**: Nomographs, available from suppliers, provide performance factors based on the relationship between wetbulb temperature, approach, and range.
4. **Select unit**: A selection chart provides specific unit criteria determined by the relationship between the performance factor and flow. At a given performance factor, a unit should be selected that has a flow that equals or exceeds the design flow.
5. **Obtain Pressure Drop**: Tables are available that provide the pressure drop for industrial fluid coolers at various water-flow rates.

The following is an example of the selection process.

**Required**: Cool 600 gpm of water from 100°F to 90°F at 78°F wetbulb temperature.

1. **Range** = 100°F - 90°F = 10°F
2. **Approach** = 90°F - 78°F = 12°F
3. **Performance factor** = 6.0 (obtained from nomograph, Figure 5).
4. At a performance factor of 6.0, the unit selected with equal to or greater than 600 gpm is an F1443-P (obtained from selection chart, Figure 6).
5. Pressure drop for 600 gpm through F1443-P is 6.1 psi (interpolated from Table 1).

Baltimore Aircoil provides the subject nomographs for Series V industrial fluid coolers in Brochure S4080/1-0. A copy is available upon request.

Additional benefits include the following.

- **Low system operating costs**: An industrial fluid cooler heat rejection system can economically achieve process fluid return temperatures within 5°F of design wetbulb temperature. This is normally 10°F lower than with cooling tower/heat exchanger systems and 30°F lower than dry-air cooler systems, for a significant increase in process efficiency.
- **Smaller space requirements**: An industrial fluid cooler saves valuable space by combining the heat exchanger and cooling tower in one piece of equipment. It eliminates the need for large water pumps and the piping associated with the cooling tower/heat exchanger system.
- **Smaller capital investment**: The industrial fluid cooler combines the cooling tower and heat exchanger surface, from one supplier. This reduces the cost of handling and installing separate components of the cooling tower/heat exchanger system from separate contractors and provides single-source responsibility for thermal performance.
- **Because industrial fluid coolers use the efficiency of evaporative cooling, they require far less heat transfer surface, fewer fans, and fewer fan motors than a comparable dry-air cooler.**
- **The initial capital investment for the industrial fluid cooler will be substantially less than that required to install a dry-air cooler of comparable capacity.**

Mark D. Buehlman is building trades and light industrial market manager for Baltimore Aircoil Company, Baltimore, MD.