FACT SHEET

# COOLING SYSTEM **OPTIMIZATION**

This fact sheet examines different optimization strategies for cooling systems that can help building owners and operators achieve operational and energy efficiencies. Its purpose is to provide a better understanding of cooling systems, and assist in identifying existing building recommissioning and design upgrade opportunities that allow for quick and low-cost implementation.

## What Is a Cooling System?

Cooling systems in larger facilities are typically made up of chillers and cooling towers[1]. The water that circulates through the building is known as the chilled water loop, and the water that carries heat to the outdoors is known as the condenser water loop.

Chillers have four main components: an evaporator, a compressor, a condenser, and an expansion valve. The evaporator transfers heat from chilled water return to the refrigerant. The refrigerant collects thermal energy in the evaporator and is sent to the condenser via the compressor. The compressor then increases the pressure of the refrigerant to allow the next stage of heat transfer. The condenser collects the heat from the refrigerant and sends it to the cooling towers via the condenser water. The cooled refrigerant travels through an expansion valve and is then transferred back to the evaporator to complete the refrigerant cycle.

Cooling towers are heat exchangers that transfer heat from the condenser water to outdoor air. To achieve this, cooling towers use fans to move air across the flow of water and pumps to circulate the fluid being cooled. Heat is removed from the cooling tower water through evaporation. The two most common types of cooling tower arrangements are open-loop and closed-loop towers. Open-loop cooling towers spray the condenser water directly through the outdoor air, whereas closed-loop cooling towers circulate condenser water in a heat exchanger. Closed-loop cooling towers can be either wet or dry. Wet closed-loop cooling towers spray water across the heat exchanger for greater heat transfer through evaporation in dry weather.

The efficiency of cooling systems can be improved by minimizing the difference between the warm condenser water and cool chilled water temperatures. This temperature difference is known as temperature “lift.” This fact sheet includes examples of how to minimize lift.

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[1] Other cooling systems might include heat pumps, rooftop units, and air-cooled packaged units with direct expansion coils. This factsheet focuses on central cooling plants.

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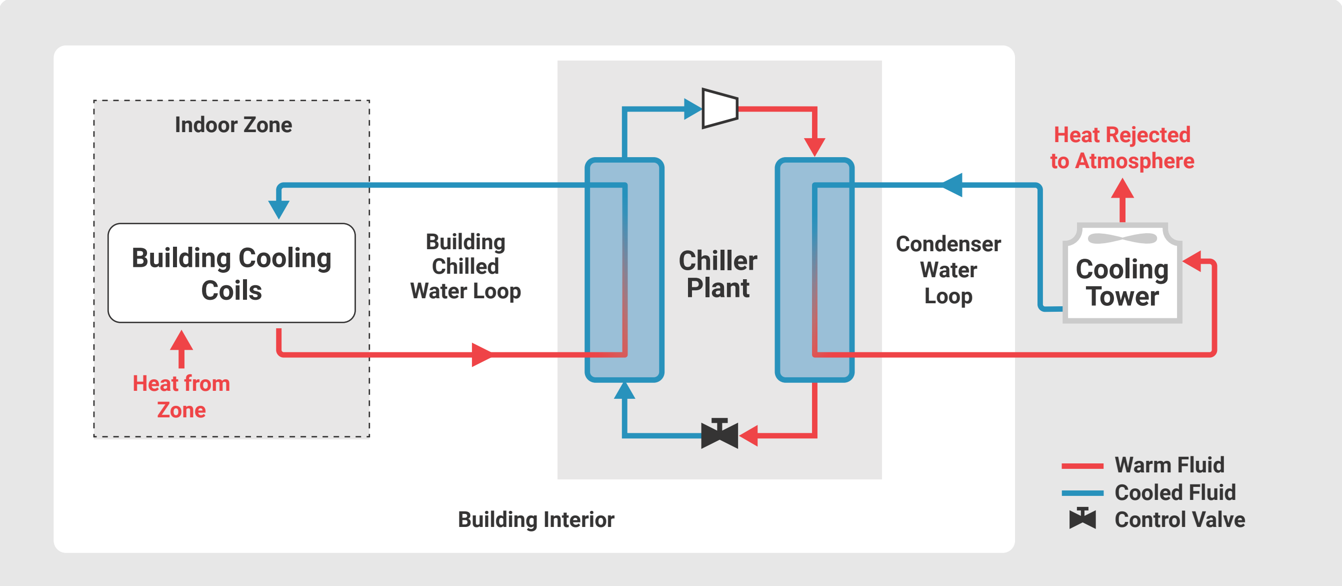

Figure 1: Typical Cooling System

## Chilled Water Temperature Reset

Commonly, the chilled-water supply temperature setpoint is fixed rather than being adjusted based on the building's actual cooling demands. The lower the chilled-water supply temperature, the greater the lift and, thus, the greater the energy used by the compressor. Increasing the chilled-water temperature as much as possible while still maintaining indoor temperature conditions will reduce lift and, consequently, the chiller electricity use.

Control sequences can be implemented to automatically provide the warmest chilled water possible that still satisfies the cooling requirements in the building. Applying an outdoor air reset schedule to the chilled water setpoint is a simple solution. A more advanced way to optimize the reset is to use a trim-and-respond routine that looks at space temperature variance in all zones and continually adjusts the chilled water temperature to ensure all zones are satisfied. Caution should be taken to ensure minimum lift, and temperature requirements set by the manufacturer are adhered to as part of any reset optimization.

## Condenser Water Temperature Reset

For water-cooled chillers (i.e. those with cooling towers), lowering the condenser water temperature will reduce lift, thus also reducing the electricity used by the compressor. The trade-off is that the fans inside the cooling towers must work harder to cool down the condenser water. Typically, the energy saved from reduced compressor use is greater than the energy used to run the fans, resulting in net energy savings. For open-loop cooling towers, where outdoor air is in contact with the condenser water, the temperature reset should be based on wet bulb temperature.

Caution should be taken to ensure minimum/maximum entering/leaving water temperature requirements set by the manufacturer are adhered to as part of any condenser-water reset optimization.

## Chiller Evaporator Isolation

In some cases, a cooling plant may include multiple chillers. When two or more chillers are part of a cooling plant, pumping chilled water through one or more disabled or standby chillers is a waste of energy.

If each chiller has a dedicated circulation pump, the disabled/standby chillers' pumps can often be turned off. Otherwise, isolation valves can be installed on each chiller to isolate the inactive chiller. Provided the circulation pumps are equipped with variable speed drives, they can modulate speed to achieve the design flow and temperature conditions required by the operating chiller(s) only.

## Water-Side Economizer

In most Canadian climates, low outdoor air temperatures are common for a good portion of the year. Mechanical cooling done by the chiller can be decreased or entirely removed in certain situations when the outdoor temperature is cold enough. Cooling systems can use a plate and frame heat exchanger to transfer heat directly from the chilled-water loop to the cooling towers, bypassing the chiller. This is known as a water-side economizer, the working principle which can be seen in Figure 2 below.

The water-side economizer will usually not provide water that is as cold as that from the chiller. However, during shoulder and winter seasons when 'free' cooling is available through a water side economizer, such cold chilled water temperatures are typically not required. Ideally, this measure is implemented alongside chiller evaporator isolation (to avoid circulating water through disabled chillers) and both chilled-water and condenser-water resets (to determine when cooling with the water-side economizer is possible).

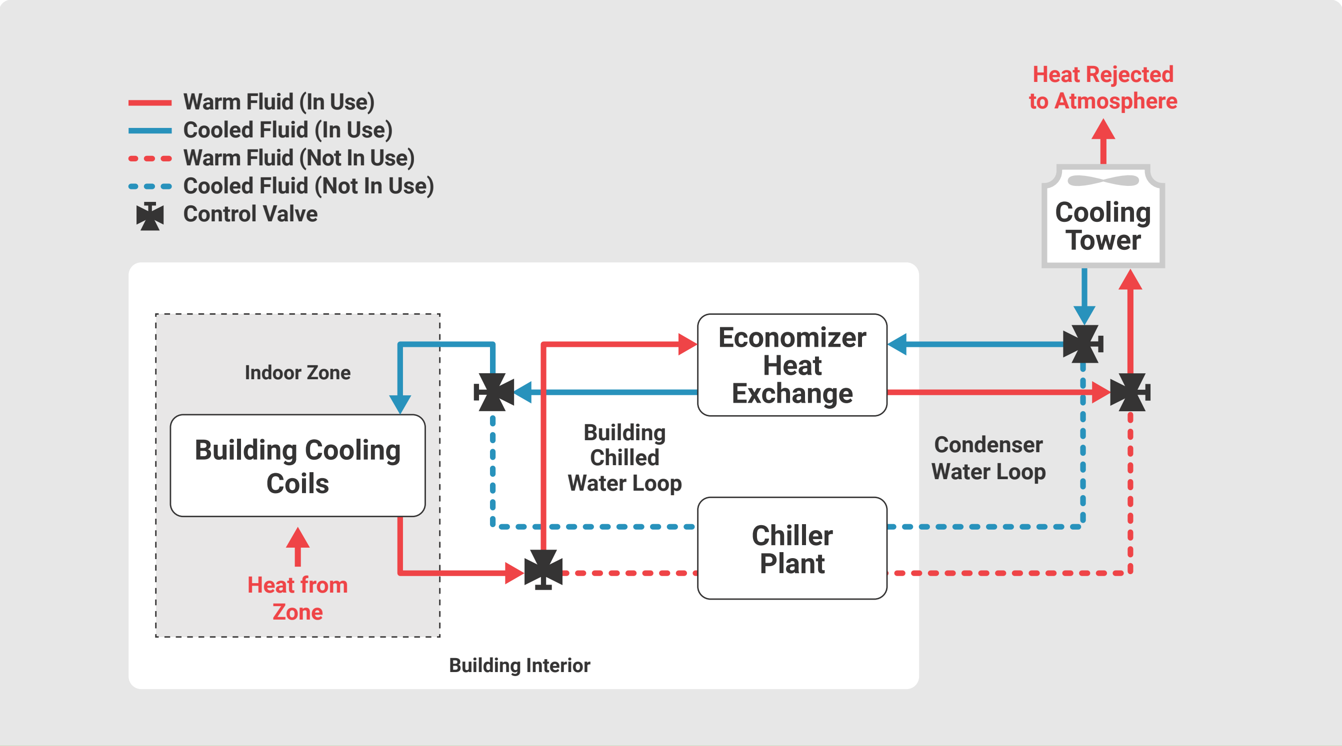

Figure 2: Water-Side Economizer

## Variable Chilled Water Flow

Chilled water pumps often operate at constant flow, either in duty or standby mode, alternating which pump is running. However, cooling coils do not require their designed water flow in mild weather. Varying the chilled water flow rate based on cooling demand will reduce pumping electricity use. Variable speed drives (VSDs) can be installed on chilled water pumps to minimize pump speed while still ensuring all cooling loads are satisfied.

Before implementing this measure, it is necessary to determine if the pumps are suitable for variable flow and if the pump motors are suitable for VSDs. For primary chilled water pumps (those which circulate water through the chillers), the minimum chilled water flow rate needs to be determined from the manufacturer and maintained when the chiller operates. Minimum flows don't apply when the chiller is disabled (e.g. when cooling is provided by a waterside economizer).

## Revise Cooling Tower Staging

When there are multiple cooling towers, they may be set up in a lead/lag configuration, with one of the towers providing most of the cooling necessary for the condenser water. To satisfy the cooling load, the fan for the lead cooling tower might be operated constantly at full/constant speed prior to enabling the fan from the lag cooling tower.

Where cooling tower fans are equipped with VSDs, electricity can be saved by operating all the cooling tower cells at low, modulating fan speeds. The greater heat transfer area will provide the same cooling at lower airflow. Additionally, fans use far less energy at low speeds.

## Maintenance Considerations

Further cost and energy savings for cooling systems can be achieved through properly maintained equipment. Constant cycling and use of cooling equipment results in build-up, clogged filters, and overall wear and tear. Furthermore, dust, dirt, and leaves from the area around the cooling tower can add restrictions and reduce performance. The following list includes maintenance opportunities that can help improve system performance and reliability:

- Annual cleaning of heat exchanger surfaces (fins on coils for air-cooled systems and condenser bundles for water-cooled systems).
- Adding filters to condenser water for systems with open cooling towers.
- Adding side stream filters on chilled water to maintain clean water.
- Ongoing water treatment to minimize pipe and coil fouling, corrosion, and organic growth.
- Creation of a weekly operations log to record conditions and establish when conditions are out of the "normal" range.
- Monthly or bi-monthly cleaning of filters and strainers in piping systems.
- Installing and cleaning air filters upstream of cooling coils to prevent coil fouling and maximize airflow and heat transfer.

The ideal frequency of cooling equipment maintenance can be found in equipment manuals and will vary depending on use.

# CASE STUDY:
# Vancouver Office Building

A 50,000 m$^2$ office building in downtown Vancouver uses a chiller plant with two chillers in series. Chiller 1 is used as the main chiller, and chiller 2 is used as a lag chiller. The chilled water loop runs through both chillers, and unnecessary pumping energy is wasted in the evaporator coils of the lag chiller. In this building, the chilled water pumps run during all occupied hours. Excessive energy is used since the pumps operate at a constant speed, while the cooling load varies according to weather conditions and occupancy.

Installing a three-way valve to allow for isolation of the lag chiller, and variable flow controls for the chilled water loop pumps, decreased the energy consumption of these systems, as shown in Figure 3. Calculated electricity usage savings amount to 15% for the chillers and 53% for the pumps, totalling 130,000 kWh/year or $12,000 annually.

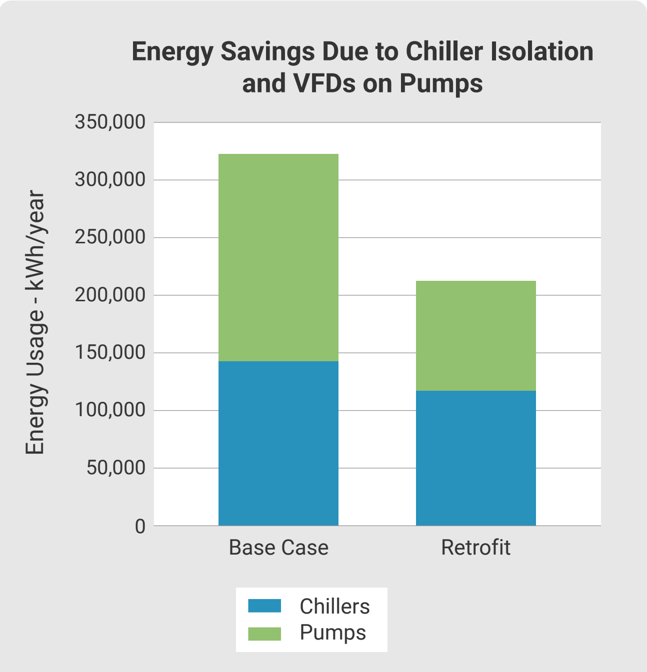

Figure 3: Energy Savings Due to Chiller Isolation and VFDs on Pumps

## Key Takeaways

- Analyzing all components of a cooling system is necessary for optimization given that changes to single components may affect the operation of other components.
- Lift should be minimized by increasing chilled water temperature and lowering condenser water temperature (within manufacturer specifications).
- In mild weather or for cooling needs during the winter, cooling can often be provided with a water-side economizer without operating the chillers.
- Chilled water temperature and flow should be matched to the actual cooling needs of the building.
- Equipment that modulates flow, such as pumps, fans, and valves, can decrease energy usage for cooling systems.
- Maintenance is important to keep chilled water systems operating efficiently.

Cat.: M154-171/2024E-PDF | ISBN: 978-0-660-71072-3