# Selecting a Recirculating Chiller & Cooling Capacity Factors

## SELECTING THE PROPER RECIRCULATING CHILLER IS A FUNCTION OF FOUR FACTORS:

- The heat load generated by the device being cooled (Q)
- The maximum acceptable temperature of the fluid exiting the heat source (TOUT)
- Available fluid flow rate
- Ambient operating conditions (V)

Often, an equipment manufacturer will specify the set point temperature and flow rate of the required chiller. In this case, selecting a recirculating chiller is simple. Simply mark the intersection of the desired cooling capacity and set point temperature on the chiller graph. Any chiller with a performance curve above or equal to this point will provide enough capacity. Next, use the pump graph to select a pump for your recirculating chiller which meets the desired flow rate.

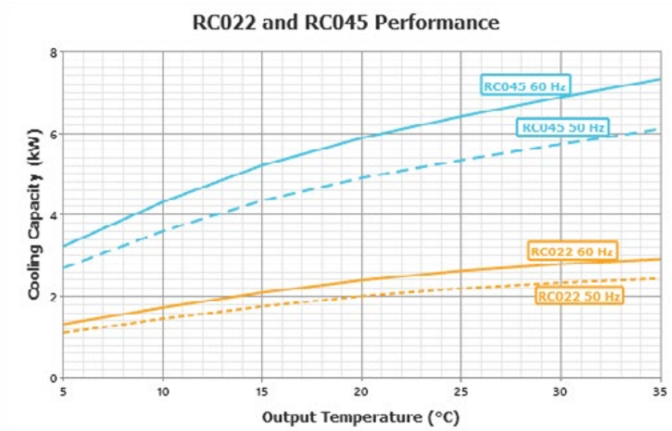


*Figure 1: Recirculating Chiller RC022-RC045 Thermal Performance Curve at 50 and 60 Hz*

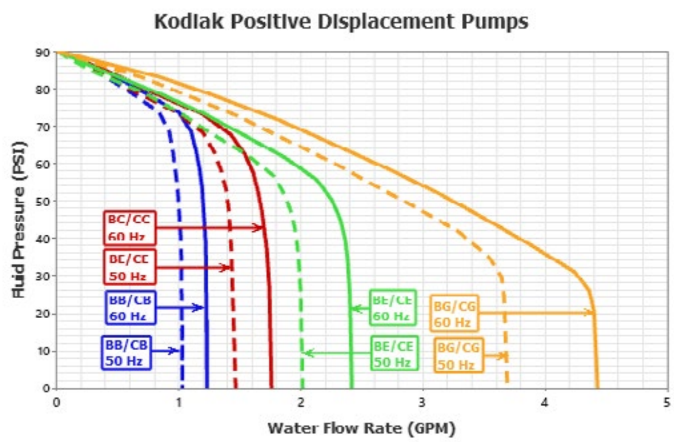


*Figure 2: Recirculating Chiller System Flow Curve*

## EXAMPLE 1

A chiller needs to supply 2 gpm at 20°C to an x-ray tube that generates 2,000 W of heat. The power supply is 60 Hz. Marking this point on the chiller graph we can see that an RC022 would be an appropriate choice. From looking at the pump curves we see that a BE pump would provide the necessary flow rate.

If the Heat Load (Q) is known, but the Flow Rate is unknown, the following equation can be used to determine the required flow rate.

| | |
|---|---|
| $\dot{V}$ Where: | $\dot{V} = Q/(\rho \cdot C_p \cdot (T_{OUT} - T_{IN}))$<br><br>$\dot{V}$ = Fluid flow rate   $\rho$ = Fluid Density<br>Q = Heat load   $C_p$ = Fluid specific heat<br>$T_{OUT}$ = Max. Fluid temp. exiting the heat source<br>$T_{IN}$ = Fluid temp. exiting the chiller |

## EXAMPLE 2

A laser head generates 2,000 Watts (6,824 BTU/Hr) of heat. The fluid temperature must not exceed at 20°C (68°F). With a cooling fluid of water, 60 Hz power, at 20°C ambient, what is the appropriate recirculating chiller?

Using the thermal performance graphs (Figure 1), draw a horizontal line at the required heat load (2000 W). As shown, the RC022 would match this requirement at 13°C (55°F). This is TIN (the temperature exiting the recirculating chiller). Therefore, the calculation then becomes:

$$\dot{V} = 2000\ W/(990\ kg/m^3 \cdot 4180\ J/kg°C\ (20°C - 13°C))$$

$$\dot{V} = 6.9 \times 10^{-5} m^3/s \text{ or } 1.1\ gpm$$

$$\rho_{water} = 990\ kg/m^3,\ Cp = 4180\ J/kg°C$$

Next, determine if the recirculating chiller can meet the required flow rate. As shown on the system pump graph (See Figure 2), the 1.3 gpm positive displacement pump (standard on the RC022) would more than satisfy the flow requirement.

More information about our Recirculating Chiller Options in our Recirculating Chiller Section

## KEY ASPECTS OF ENVIRONMENTAL CONDITIONS AND CHILLER DESIGNS THAT IMPACT TOTAL COOLING CAPACITY

Recirculating chillers are refrigerated liquid cooling systems that are used in numerous industries including medical, military, laser, and analytical instrumentation. Chillers are used to keep a component such as laser head, detector panel, or another temperature-sensitive device at a constant temperature and/or to remove waste heat and prevent overheating of critical components.

When selecting a recirculating chiller, several factors should be considered that could affect cooling capacity. These factors include ambient air temperature or facility water temperature, chiller set temperature, process fluid, chiller maintenance, and more. Chiller manufacturers generally provide cooling capacity ratings based on a 20°C water delivery temperature and a 20°C ambient temperature. However, what happens if the ambient temperature is higher or lower than 20°C? What if the coolant is supplied to the process at 5°C instead of at 20°C? What if a coolant other than water is used? How do all these variations affect the cooling capacity of a chiller?

## RECIRCULATING CHILLERS AND THE REFRIGERATION CYCLE

In order to understand how these factors can impact the cooling capacity of a chiller, it is necessary to understand first how a chiller operates. A compressor-based recirculating chiller works by using the latent heat properties of a refrigerant to remove heat from a process and reject it to ambient air or to facility water. (Figure 3) In order to transfer this process heat to the ambient air or facility water, the refrigeration system must provide a refrigerant temperature below the temperature of the process fluid to be cooled. Later in the process, the system must raise the temperature of the refrigerant to a level above the temperature of the medium that is used for rejecting the heat.

A chiller is a complex system, but the basic components are the compressor, condenser, thermostatic expansion valve(TXV), and evaporator. Starting at the compressor, the refrigerant coming from the evaporator is compressed from a saturated gas to a high-pressure, high-temperature gas. Then hot gas is passed through the condenser, where it is cooled and condensed into a saturated liquid by rejecting the heat to cooler ambient air (air-cooled condenser) or to facility water (water-cooled condenser). The refrigerant then passes through the TXV, across which its pressure and temperature drop considerably. The refrigerant temperature is now lower than that of the process fluid and, as a result, heat is transferred from the process fluid to the refrigerant causing it to evaporate into a low-pressure gas. The cycle is once again repeated as the gas flows back to the compressor.

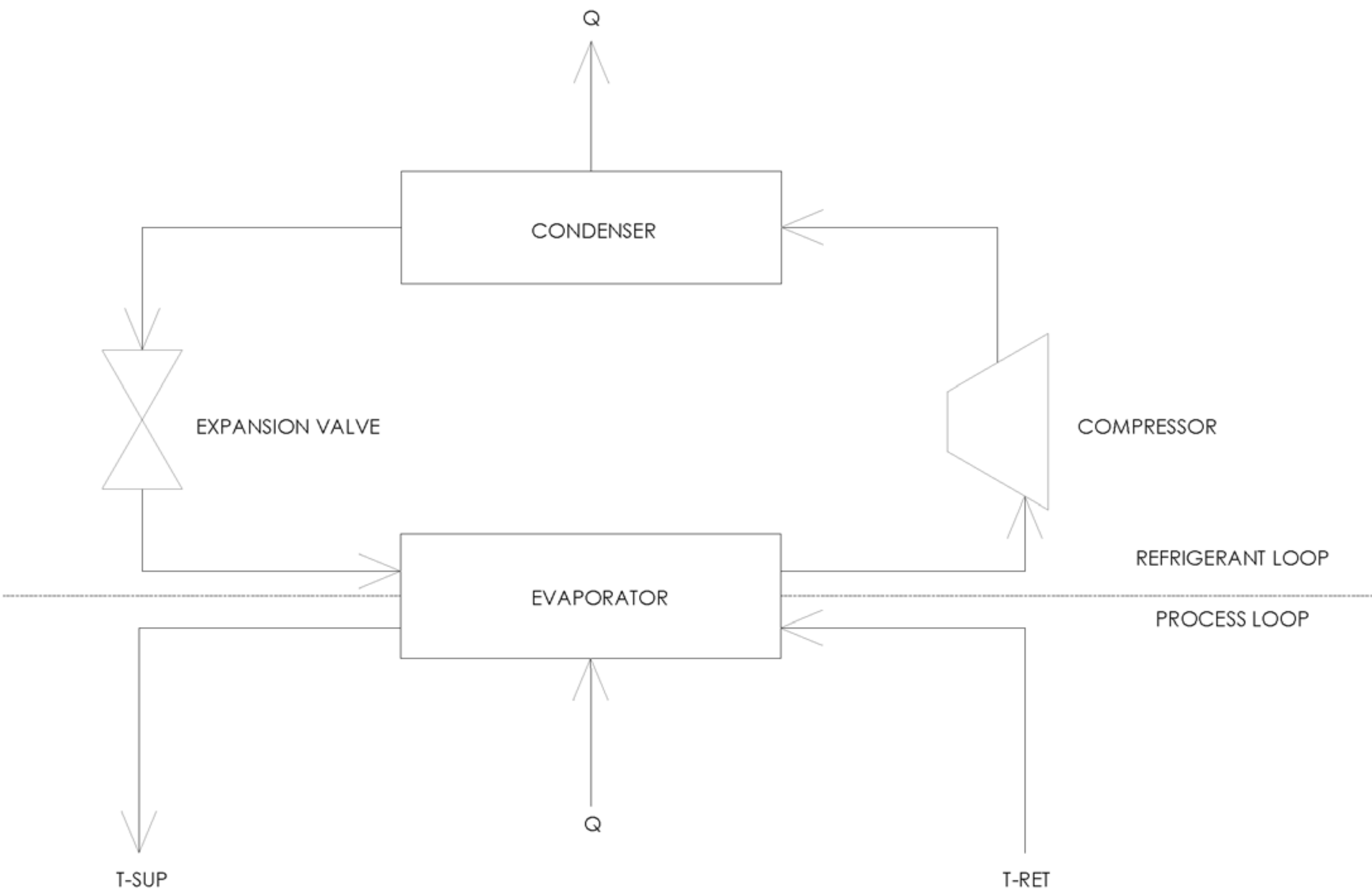


*Figure 3: Chiller's Refrigeration Cycle*

The condenser and evaporator are heat exchangers that transfer heat from one medium to another. In the case of an air-cooled condenser, an aluminum-finned copper tube liquid-to-air heat exchanger is typically used for rejecting heat from the hot refrigerant gas to the ambient air. A water-cooled condenser, on the other hand, uses a liquid-to-liquid heat exchanger to transfer heat from the hot refrigerant gas to the facility's water. In the case of the evaporator, a liquid-to-liquid heat exchanger is typically used to transfer heat from the process fluid to the refrigerant. The performance of a heat exchanger depends on many factors, including the process fluid used, incoming fluid temperatures, flow rates, materials of construction, and design of the heat exchanger. With all other factors being equal, the driving force behind the transfer of heat from one fluid to another is the difference in incoming fluid temperatures.

## AMBIENT AIR AND FACILITY WATER TEMPERATURE AFFECT

Ambient air temperature or facility water temperature play an important role in the cooling capacity of a chiller. In order for the condenser to reject total heat (process heat load plus heat of compression) to ambient air or facility water, the temperature difference between the hot refrigerant gas and ambient air or facility water must be sufficient. For example, Boyd chillers typically operate at condensing temperatures between 32.2°C (90°F) and 43.3°C (110°F) and reject heat to 20°C (68°F) ambient air (see Figure 4) or 24°C (75°F) facility water. Water-cooled condensers can reject the same amount of heat to a higher facility water temperature because water is a much better heat transfer fluid than air and does not require as large of a temperature differential between the two incoming fluids.

As ambient air or facility water temperature increases, the ability of the chiller condenser to transfer process heat from the refrigerant to ambient air or facility water is reduced, causing higher condensing pressures that could result in reduced system performance. Therefore, if the recirculating chiller will be exposed to ambient temperatures above 20°C, sizing calculations should be run to determine the required cooling capacity. Similarly, if ambient temperature decreases, performance will improve due to the larger initial temperature differential. When sizing a chiller, it is essential to know your maximum ambient temperature or facility water temperature so that you can select a chiller with enough cooling capacity to meet your application's needs. Consult with an applications engineer for assistance in sizing a chiller.

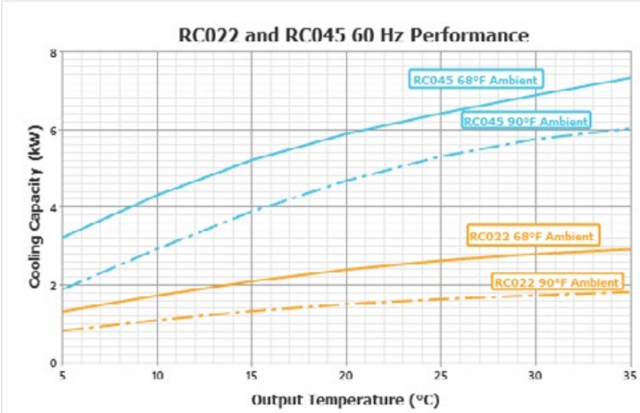


*Figure 4: Recirculating Chiller RC022-RC045 Thermal Performance Curve at 68°F and 90°F*

## SET TEMPERATURE AFFECT

Similar to the condenser, evaporator performance decreases if the difference in incoming temperatures between liquid refrigerant and returning process water temperature is reduced. This occurs if the chiller is set to run at a low temperature, such as 5°C instead of 20°C. Returning process water temperature will be lower if chiller supply temperature is lower and there will be less temperature differential to drive heat transfer. The performance of a chiller decreases as the set temperature decreases. Similarly, the performance of the chiller will improve as the set temperature increases up to maximum temperature within the recommended temperature range. (See Figure 4.).

## PROCESS FLUID AFFECT

The process fluid used in the recirculating chiller also impacts performance. Cooling capacity for chillers is typically based on using water as the process fluid, so using a process fluid other than water could result in less cooling capacity. For example, some recirculating chillers are designed to be compatible with polyalphaolefin (PAO) as the process fluid. PAO is typically used in military applications because of its dielectric properties and/or wide operating temperature range. However, all other factors being equal, the cooling capacity of a PAO chiller will be less than the cooling capacity of a water chiller since PAO has a lower specific heat, lower density, and lower thermal conductivity than water.

## CHILLER OPERATION AND MAINTENANCE AFFECTS

Another factor that affects chiller performance is condenser and evaporator maintenance. Dust accumulation on air-cooled condensers or fouling of tubes or flow passages on water-cooled condensers or evaporators leads to decreased chiller performance. When dust or debris accumulates on the fins and fan blades of air-cooled condensers it restricts airflow, resulting in a loss of chiller cooling capacity. If the chiller will be operated in a dusty or dirty environment, routine maintenance or cleaning should be scheduled and/or the chiller should be oversized. Fouling of water-cooled condensers due to scale formation, corrosion, and/or biological growth from poor water quality could also result. Fouling forms an insulator layer on the internal walls of tubes that impedes heat transfer between the refrigerant and water, resulting in the deterioration of chiller efficiency. By using clean water with corrosion inhibitors, the risk of fouling can be minimized. See our application note "Recirculating Chiller Tune Ups: Operation and Maintenance of Your Coolest Equipment" for more information.

## OTHER FACTORS

In rare cases where an air-cooled recirculating chiller is located at a high altitude location, lower density air will affect cooling capacity. Since mass flow rate is equal to volumetric flow rate times density, if density decreases a higher volumetric flow rate must be supplied by the condenser fan in order to provide the same cooling capacity that you would have at sea level. One option is to oversize the recirculating chiller to ensure cooling capacity needs are met. Humidity is another factor that affects chiller performance when the supply process coolant temperature is below the ambient dew point. In such cases, if the chiller lines, evaporator, and pump are not insulated, condensation may form on these surfaces causing a loss in cooling capacity. Untreated metals' surface can also experience damage from corrosion. Therefore, insulation is strongly recommended. It is also necessary to keep in mind that a 230 VAC 50 Hz chiller has approximately 17% less cooling capacity than a 230 VAC 60 Hz chiller due to the slower frequency with which the pump, compressor, and fan motors rotate (Figure 1). The performance of a chiller depends on ambient air temperature or facility water temperature, chiller set temperature, process fluid, operation and maintenance, and more. It's crucial to consider all of these factors when selecting a chiller as well as when operating one. This will help to ensure uptime of the equipment the chiller is cooling. View our Recirculating Chiller Section to compare options on your own or reach out to our Engineering Team for help determining how much cooling you need for your system.