How to determine the amount of heat a recirculating chiller adds to a room

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Thermo Scientific™ ThermoChill I recirculating chiller

Goal

Determining the amount of heat a recirculating chiller releases into a room is essential for establishing the HVAC (heating, ventilation and air conditioning) system load, which is often miscalculated or not considered at all. In addition to the heat released from the application (or process heat), electricity consumed by the chiller is also converted to heat. By using the power consumption method to compute power usage (utilizing the power consumption of the chiller, process heat, and the type of condenser the chiller has for calculations), one can determine the heat output in the room where the chiller is located. This is helpful in determining the optimal location of the chiller or when sizing of a new HVAC system.

Often, not enough consideration is given to selecting the optimal type of chiller condenser, the chiller location, HVAC system capabilities or some combination of these. Such lack in consideration may result in uncomfortably high room temperatures that will also degrade the cooling capacity of the chiller.

The power consumption method calculates the amount of heat released from a chiller and is a primary consideration in the successful selection and installation of a chiller where performance is maintained, worker comfort is assured and additional costs for changes are minimized. This technical note will review the total amount of heat released by a chiller to optimize its selection and placement.

Recirculating chillers are used for many cooling applications. They supply a source of temperature controlled fluid, typically water, which removes heat from a process. This heat is transported back to the chiller where it is transferred to the refrigerant gas. Like most products that use electrical power, chillers also create their own heat from the fan motor, compressor, pump and electronics. Where the heat energy is transferred depends on the type of chiller being used, or more specifically, whether the chiller uses an air-cooled or water-cooled condenser.

For an air-cooled chiller, electrical energy used by the chiller is converted to heat and added to the room where the chiller is located. The heat load from the application (process heat) is also released into the room from the chiller's condenser.

For a water-cooled chiller, the process heat is removed from the condenser by a source of facility water. Heat from the water circulation pump and the compressor is also added to this water. The remaining heat generated by the chiller is released into the room, but is significantly less heat than an air-cooled chiller.

By using the electrical data from the chiller and heat load data from the process, the amount of heat added to the room by a chiller can easily be calculated. To calculate the energy usage, refer to the chiller's serial number tag that should also have the electrical specifications on it or request the information from the manufacturer.

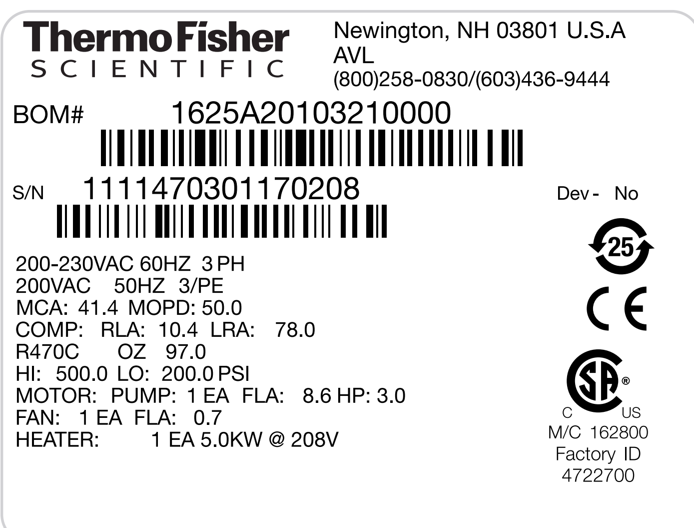


Figure 1: Three Phase serial tag.

The formula for converting electrical specifications to watts is simply:

$$voltage[V] \times square\ root\ phase[\emptyset] \times amps[A] = watt[W]$$

Essentially, this calculation requires knowledge of the voltage range, power phase and total amount of electrical current (Amp draw) on which the chiller operates. Whereas on single phase chillers the voltage range and Amp draw are normally referred to on the system's serial number tag, on three phase chillers the Amp draw may need to be calculated from the serial number tag data (see Fig. 1). On three phase units or where specified, the Amp draw is the sum of the compressor Running Load Amps (COMP RLA), pump motor Full Load Amps (MOTOR PUMP FLA) and fan Full Load Amps (FUN FLA).

NOTE: Because the data above is only going to be used to size a HVAC system, we are going to ignore the "Power Factor"[1] of some components that result in a slightly lower use of electrical energy than the calculations shown here.

* See https://en.wikipedia.org/wiki/Power_factor.

Air-Cooled Chiller Example

Here is the power data of a powerful air-cooled chiller that can cool 10 kW of heat and has a large centrifugal pump:

200-230V 60Hz 3 PH
MCA: 22.3 MOPD: 35.0
COMP: RLA: 10.4 LRA: 78.0
MOTOR: PUMP: 1 EA FLA: 8.6 HP: 3.0
FAN: 1 EA FLA: 0.7

From this data we can calculate the maximum power consumption (watts).*

200-230V 60Hz 3 PH: Indicates it operates on between 200 and 230 Volts, 60Hz and three phase power.

MCA (minimum circuit ampacity): is used by the electrician to size the wiring to the chiller, but is not used for our calculations.

MOPD (maximum over-current protection device): is used by the electrician to size the circuit breaker, but is not used for our calculations.

COMP: RLA: 10.4 Compressor RLA (running load amps): indicates that the compressor uses 10.4 amps.

LRA (locked rotor amps): is what the motor will draw if it is locked or prevented from turning. This is used as an approximation of what the motor will draw briefly as it starts and is not used for our calculations.

MOTOR: PUMP: 1 EA FLA: 8.6 – (FLA = full load amps): indicates that the pump motor uses 8.6 amps.

HP: Indicates that the pump horse power is 3.0 and is not used for our calculations.

FAN: 1 EA FLA: 0.7: Indicates that the one fan uses 0.7 amps.

Now we can total the amp draw:

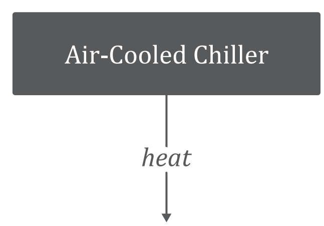
$$10.4_{comp} + 8.6_{pump} + 0.7_{fan} = 19.7\ amp\ total$$

Then we can convert amps to watts using the formula from above:

$$230\,V \times \sqrt{3}\emptyset \times 19.7\,A = 7{,}848\ watts$$

NOTE: It is possible that some components like the fan or the pump motor may be single phase even though they are installed in a three phase unit. So again, our calculated load may be slightly higher than actual, but our calculation will give a reasonable estimate for HVAC system planning purposes.

Because this is an air-cooled chiller, all of the electrical power used is converted to heat and ends up in the room. To complete the room heatload calculation you add the process heat from your application. For this example let's add the full 10,000 watts (10 kW) for a total heatload from the air-cooled chiller to the room of 17,848 watts (17.8 kW).



$$4.1\ kW_{comp} + 3.4\ kW_{pump} + 0.3\ kW_{fan} + 10.0\ kW_{process} = 17.8\ kW_{room}$$

$$17.8\ kW_{room} \times 3.412\ BTU/kW = \ 60{,}734\ BTU_{room}$$

This represents the worse case load to the HVAC system from the chiller under this process load.

* See https://en.wikipedia.org/wiki/Power_factor.

Water-Cooled Chiller Example

Chillers with water-cooled condensers use slightly less energy because they do not require a large fan to move air across the condenser and the calculation for the heat added to the room is more involved.

The same chiller with a water-cooled condenser looks like this:

200-230V 60Hz 3 PH
MCA: 22.0 MOPD: 35.0
COMP: RLA: 10.4 LRA: 78.0
MOTOR: PUMP: 1 EA FLA: 8.6
FAN: 1 EA FLA: 0.4

Where we have 10.4 amp from the compressor, 8.6 amp from the pump motor and 0.4 amp for the fan (water-cooled units still have a small fan to exhaust the heat from the case) for a total amp draw of 19.4 amp.

Then we can convert amps to watts using the formula from above:

$$230\ V \times \sqrt{3}\emptyset \times 19.4\ A = 7{,}728\ watts$$

Adding our process heat of 10 kW we have a total load of 17728 watts or 17.7 kW.

While that is not much different than our air-cooled chiller, the big difference is where the heat ends up.

First, all of the process heat goes into the facility water supply.

Process heat:
10.0 kW to the facility water
0.0 kW to the room

Next, about 94% of the compressor power is converted into heat by raising the refrigerant gas temperature during compression (heat-of-compression) and is also removed by the (facility) water-cooled condenser.

Compressor heat:

$$230\ V \times \sqrt{3}\emptyset \times 11.4\ A = 4.413\ watts\ (4.1\ kW)$$

4.1 kW x 0.94 = 3.9 kW to the facility water
4.1 kW – 3.9 kW = 0.2 kW to the room

Pump heat:

$$230\ V \times \sqrt{3}\emptyset \times 8.6\ A = 3{,}426\ watts\ (3.4\ kW)$$

When you do work on water by pumping it, you also add heat.

The amount of heat varies with pump horse power (HP), type, flow and pressure.

For an approximation of pump heat into the room we take the power usage of the pump (3.4 kW) and subtract the pump HP converted to kW. While the pump HP is not always on the serial number tag, the manufacturer should be able to supply it or it will be on the pump motor itself.

For this example we use a chiller with a very large centrifugal pump that is 3 HP. The horse power to kilowatts conversion is:

$$\mathrm{kW_p} = \mathrm{HP_p} \times \frac{0.746\ \mathrm{kW}}{\mathrm{HP}}$$

kW_p= Total pump power (kilowatts)
HP_p = pump horse power
3HP*0.746 kW/HP = 2.24 kW
3.4 kW – 2.24 kW = 1.16 kW to the room.
The remaining 2.24 kW goes into the facility water.

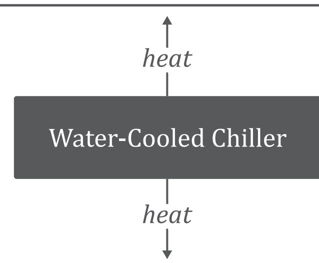
Fan heat:

$$230\ V \times \sqrt{3}\emptyset \times 0.4\ A = 159\ watts\ (0.2\ kW)$$

0.0 kW to the facility water
0.2 kW to the room

the total heat load from the water-cooled chiller to the room is:

$$0.0\ kW_{process} + 0.2\ kW_{comp} + 1.2\ kW_{pump} + 0.2\ kW_{fan} = 1.6\ kW_{room}$$



the total heat load from the water-cooled chiller to the facility water is:

$$10.0\ kW_{process} + 3.9\ kW_{comp} + 2.2\ kW_{pump} + 0.0\ kW_{fan} = 16.1\ kW_{facility\ water}$$

$$1.6\ kW_{room} \times 3.412\ BTU/kW = \ 5{,}459\ BTU_{room}$$

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Conclusion

	Chiller Heat (kW)	Process Heat (kW)	Room Heat (kW)	Room Heat (BTU)	Facility Water Heat (kW)
Air-Cooled Chiller	7.8	10.0	17.8	60,734	N/A
Water-Cooled Chiller	7.7	10.0	1.6	5,459	16.1

An air-cooled chiller will have all of the process heat from the application plus the power used by the compressor, pump and fan added to the room.

A water-cooled chiller on the same application will have zero process heat, 6% of the compressor heat, some of the pump heat and all of the fan heat for a greatly reduced heat load to the room.

Water-cooled chillers significantly reduce the heat that will have to be removed by the HVAC system, but they require a source of facility water that both meets the flow/pressure requirements of the chiller and can dissipate the extra heat being put into it.

Conversely an air-cooled chiller requires a HVAC system that can remove the extra heat, but is a standalone system not requiring other facility resources.

If your facility has or will have either a chilled water system or sufficient HVAC to run either air or water cooled chiller(s) then the amount of energy used to remove the heat from the facility is about the same. However, there are other considerations:

- How many chillers will the facility have?
- Will additional chillers be added in the future?
- Will all of the chillers be in the same room or location?
- Will people be working in the same room as the chillers?
- Even if there is sufficient HVAC system capability in the room or location of the chillers, does it move enough air to keep the chiller operating efficiently and the workers in that area comfortable?
- If more chillers are added in the future, will the HVAC system still be able to keep up with both the required BTU and airflow capacity? If not, how difficult and expensive will it be to add capacity?

Where either more chillers will be added in the future or some multiple number of chillers are going to be installed now, using water-cooled units might be a better choice as it is typically easier to add more water lines than it is to add HVAC ducting.

If just one or a few smaller chillers are added per facility, room or area with little to no requirement for additional chillers in the future, and the HVAC system already has enough cooling capacity and air flow, then an air-cooled chiller is likely to be the logical choice.

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