ENGINEERING WHITE PAPER

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Chiller Heat Balance and 3 GPM/Ton Cooling Tower Flow Rate

For anyone familiar with chiller sizing, 2.4 GPM/ton will give you a 10F delta-T across the evaporator. For cooling tower sizing, the rule of thumb is 3.0 GPM/ton for a 10F delta-T across the tower. You may also be aware that although a cooling ton is 12,000 BTUH, a heat rejection ton is 15,000 BTUH.

It is important to note that in each case, the ratio of these numbers is 1.25 to 1, i.e. 3.0 GPM/ton is 25% more than 2.4 GPM/Ton and 15,000 BTUH is 25% more than 12,000 BTUH.

This relationship is no longer valid.

To understand why, let us consider the heat balance for a water chiller. The refrigeration cycle is shown below in Figure 1. You may recall from thermodynamics that for a closed system, the energy in equals energy out. For a chiller, the energy input is the building load absorbed in the evaporator plus the electrical energy input to the compressor. The energy output is the heat rejected in the condenser.

The horizontal line in the graph to the right represents enthalpy (energy) and as you can see, the length of the line 1-2 (evaporator) plus line 2-3 (compressor) equals the length of the line 3-4 (condenser).

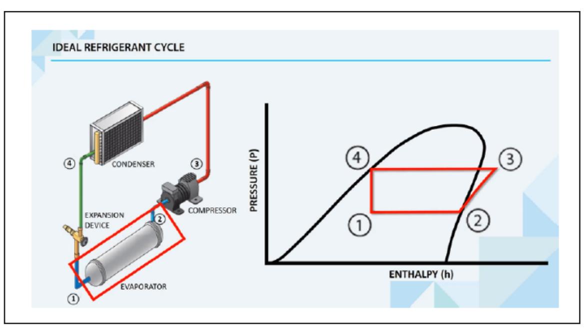

Figure 1 Refrigeration Cycle

In a perfect system, these are identical. In a chiller, there are other minor electrical loads for controls, oil heaters, etc. But the heat balance should be within 5%. AHRI Standard 550/590 used for rating chiller performance establishes 5% as the maximum heat balance variance when conducting an AHRI certified test.

So, the question is; What would be the compressor power input required to make the heat rejection equal to 125% of the building's cooling load? Or put another way; What power input would make 3.0 GPM/ton and 15,000 BTUH valid for a cooling tower with a 10°F delta-T?

The equation for water heat gain is BTUH = 500 x GPM x ΔT. For an evaporator load of 1 ton (12,000 BTUH) and a 10F delta- T, the flow rate is 2.4 GPM/ton. If there is truly a 15,000 BTUH condenser load for the same 10F delta-T, then the power input to the compressor must be (15,000 – 12,000) = 3,000 BTUH. The conversion factor from BTUH to watts is 0.293 watts/BTUH. Therefore, 3,000 BTUH is 879 watts or 0.879 kW. For this one-ton load, our efficiency would need to be 0.879 kW/ton to get a 10°F delta-T with 3.0 GPM/ton in the condenser loop. This may have been typical in the mid-20th century, but it is not valid for current water-cooled chillers.

A more typical full load efficiency of 0.560 kW/ton equates to a power input of 560 watts for our one-ton system. Converting watts to BTUH (560/0.293) = 1,911 BTUH meaning we only need to reject (12,000 + 1,911) = 13,911 BTUH in the condenser. In addition, the flow rate required to accomplish this over a 10°F delta-T would be 2.78 GPM. Therefore, the flow rate required for a 10°F delta-T on a condenser loop is 2.78 GPM/ton.

To study the impact of this on a chiller plant, let us assume you are working with a client who has requested a 500-ton chiller and a tower based on 3.0 GPM/Ton at 90/80°F.

In this case, I recommend always starting with the chiller selection. A 500-ton WME magnetic bearing chiller with 1,500 GPM of 80°F entering condenser water would have a leaving condenser water temperature of 89.2°F. If we force a 10°F delta-T across the condenser (80/90°F), the resulting flow rate would be 1,380 GPM (2.76 GPM/ton). You will want to use these numbers when selecting the cooling tower. If you were to use 1,500 GPM at 90/80°F, the tower would be nearly 10% oversized.

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Upsizing the tower may be desired for a few reasons. Colder water in the tower loop reduces the overall power consumption of the chiller plant in most cases. It is why the Seattle Energy Code requires tower sizing to be based on a maximum of 86°F water back to the tower and not the typical 95/85°F. In addition, some engineers will want a safety factor incorporated in sizing the tower. But now that tower performance is verified by CTI, an independent testing organization, cooling towers and fluid coolers and accurately rated. In addition, the chiller load often has a safety factor and as these factors add up, the cooling equipment is often oversized. I see more problems associated with minimum load stability than not having enough cooling capacity.

If there are any questions or concerns, please feel free to contact the engineering department.

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