

update

How YORK® centrifugal chillers save up to \$800,000 in energy costs compared to competitive high-efficiency designs

When centrifugal-chiller owners come to Johnson Controls for a factory visit, an interesting conversation often takes place.

We start by asking how they control Entering Condenser Water Temperature (ECWT) for their centrifugal-chillers at off-design conditions. Those who own YORK® chillers say that they let ECWT go as low as 55°F. Those who own competitive chillers often say that the manufacturer's service personnel told them ECWT has to be held at 75°F for proper chiller operation.

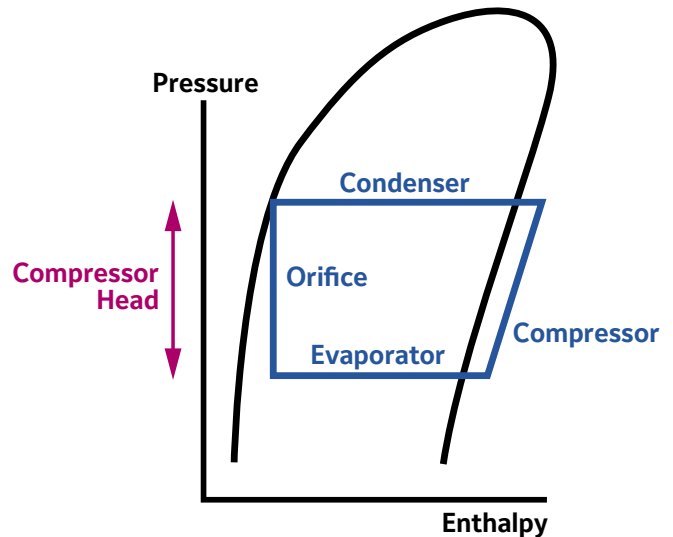
When we tell the latter group that colder ECWT settings could result in energy-cost savings of as much as \$800,000 over the life of the chiller, they then start asking questions, such as: How can you possibly obtain those energy savings? This *HVAC&R Engineering Update* answers that question and explains why YORK centrifugal chillers achieve a level of energy savings that competitive high-efficiency machines have yet to reach.

Compressor head: The key to understanding off-design performance

Differences in off-design performance begin with the chiller compressor. The compressor uses energy to raise the refrigerant from evaporator pressure to condenser pressure. The difference between these two pressures is known as compressor "head." When head is reduced, less energy is consumed.

While there are many conditions that can affect compressor head, the factor with the greatest impact is ECWT. By utilizing colder ECWT to lower the condenser pressure, head can be reduced by over 50%. That means chiller energy consumption will also be dramatically reduced.

How much? Consider this example: a given chiller running with 44°F Leaving Chilled Water Temperature (LCHWT) and 85°F ECWT consumes 232 kW. The same chiller running with 44°F LCHWT and 55°F ECWT requires only 152 kW – a savings of 35%. This serves to illustrate the marvelous energy-saving potential of colder ECWT.



Centrifugal chiller refrigeration cycle.

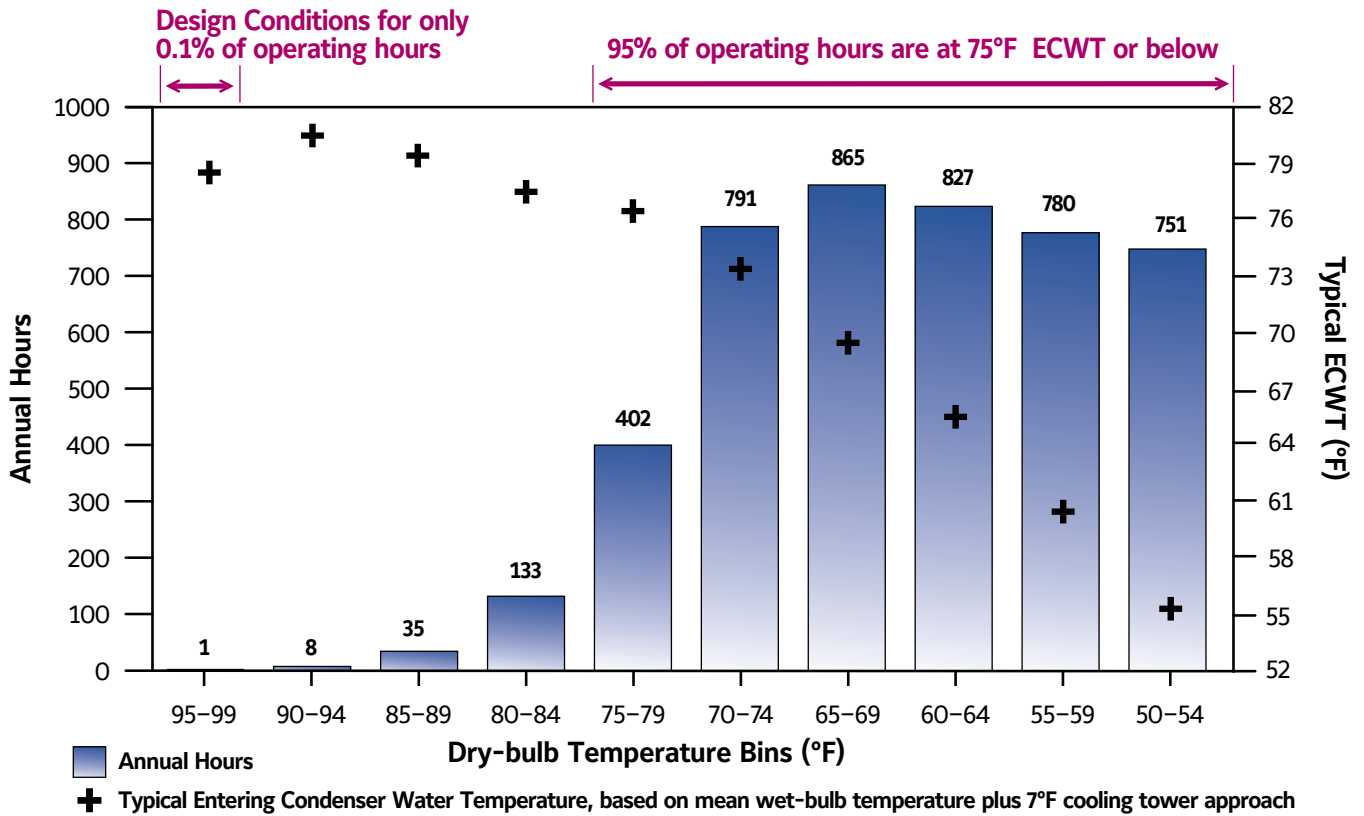


Figure 1: New York City weather data.

Decrease your ECWT, increase your savings

The amount of energy saved by colder ECWT is a function of how often it occurs during chiller-plant operating hours. So, how prevalent is colder ECWT? It turns out there are a surprisingly large number of operating hours when chillers have colder ECWT available. Illustrated above is a portion of the annual weather data for New York City, based on 30-year averages, showing hours spent at various dry-bulb temperatures and the typical ECWT available at those dry-bulb temperatures.

If we assume that a chiller system operates whenever the outside air exceeds 50°F (below that, an airside economizer handles the cooling load and the chillers are shut off), then a chiller system in New York City could potentially run for a total of 4,600 hours.

Of all those hours, note how little time is spent at design conditions. The temperature reaches 95 – 99°F for only 1 hour per year, so the chiller plant runs at design conditions

less than one-tenth of one percent of the total potential operating hours. That time is not spent at the highest wet-bulb temperature, so it too could be considered off-design conditions.

Next, note how much time is spent in the temperature bins between 75 – 79°F and 50 – 54°F: almost 4,400 hours. This is significant because the weather data says that in those temperature bins, the wet-bulb temperature occurring at the same time is 68°F or lower. With a typical cooling tower offering a 7°F approach between wet-bulb temperature and ECWT, that means the ECWT is 68° + 7° = 75°F or colder for 95% of the chiller-plant potential operating hours. Obviously, here is where you can have the greatest impact on chiller energy.

The savings potential is even more dramatic in a city like San Francisco, as illustrated on page 3. A San Francisco chiller plant has the potential to run 7,500 hours, with ECWT 75°F or colder for virtually 100% of the time.

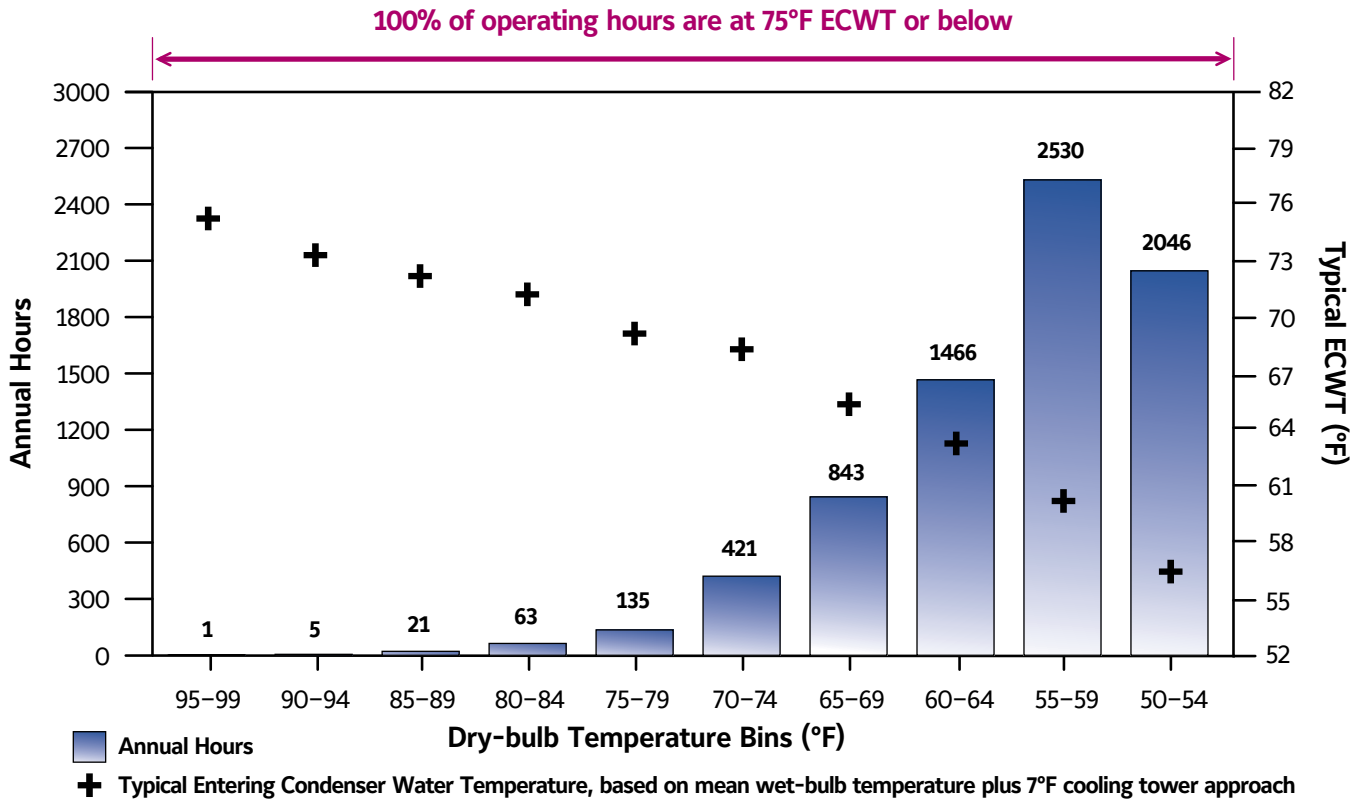


Figure 2: San Francisco weather data.

So if one high-efficiency chiller can use ECWT as cold as 55°F, while another is artificially limited to a minimum ECWT of 75°F, what kind of energy savings are available? Using New York City weather data and utility costs, with a chiller plant consisting of two 450 TR chillers, the average savings are approximately \$6,300 per year. Over a 25-year chiller life, assuming a 5% rate-of-return on investing the savings, the total savings could reach \$300,000. Using San Francisco weather data and utility costs, the savings could reach \$16,500 annually, or \$800,000 over the chiller life!

While the savings in each city will vary with weather data and utility rates, the general principle holds true – colder ECWT can generate major chiller energy savings.

The question is sometimes raised whether colder ECWT will require the cooling-tower fan to run longer, increasing its energy usage. This is true, but trivial. Keep in mind that a 450 HP chiller motor might require only a

25 HP tower-fan motor. With that kind of HP ratio, plus the effect of two-speed motors and multiple fans cycling, the increase in tower energy is small. In fact, cooling tower manufacturers recommend utilizing the lowest ECWT allowed by the chiller manufacturer.

Why some chillers are left out of the cold

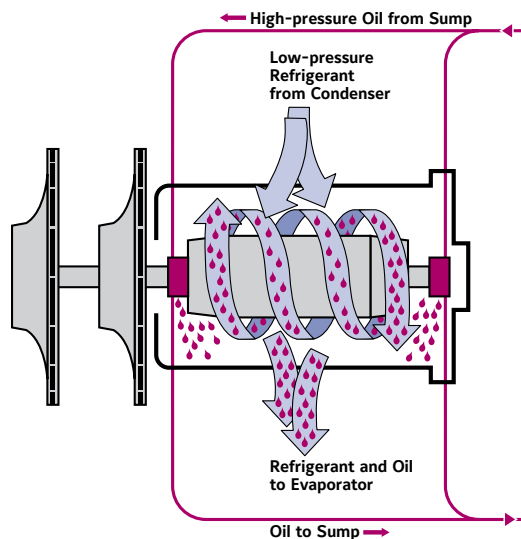
Why can't all chillers offer these kinds of savings? That question has been asked of us by so many owners of competitive chillers that we decided to investigate. One of our primary sources of information was service personnel who work on these chillers.

One of the reasons for an artificially high ECWT limit is the problem of oil loss through a hermetic motor. At both ends of the motor are bearings that are continually supplied with pressurized oil to lubricate the motor shaft. Refrigerant from the condenser flows into the motor housing, cools the motor windings, and then drains to the evaporator. Between the oil and the refrigerant are two bearing shaft seals. These seals rely on

the refrigerant pressure being high enough to prevent the oil from penetrating the seal and leaking into the refrigerant circuit.

The problem occurs when colder ECWT lowers the refrigerant pressure in the condenser and the hermetic-motor housing. The pressure is no longer high enough to keep the seal tight. Oil begins to leak from the bearing into the motor housing, mixing with the refrigerant. The refrigerant/oil mixture then drains to the evaporator, where the oil is trapped (because the chiller has no oil-return system in the evaporator, as YORK chillers do). Eventually, the chiller runs out of oil and shuts down on low oil pressure. Service technicians tell us that the chiller can run out of oil in as short a period of time as 2 hours.

At colder ECWT, oil supplied to bearings leaks into hermetic-motor housing, mixes with refrigerant, and eventually gets trapped in evaporator.



A second problem is refrigerant stack-up in the condenser. Before refrigerant from the condenser can enter the evaporator, it must pass through an expansion device. The most commonly used expansion device on centrifugal chillers is an orifice. In a single-stage chiller, there is one orifice; in a two-stage chiller, two; and in a three-stage chiller, three.

The refrigerant pressure in the condenser must be high enough to force the refrigerant through the orifice(s) and into the evaporator, even when colder ECWT has reduced the condenser pressure. In YORK chillers, with their single orifice, this is not a problem. However, multi-stage chillers can run into problems as ECWT falls. There is no longer sufficient pressure in the condenser to push the refrigerant through the multiple orifices and into the evaporator fast enough. As a result, refrigerant backs up into the condenser, starving the evaporator, and the chiller shuts down on low evaporator pressure.

Occasionally, it is suggested that hermetic-drive, multi-stage chillers could be made to work with colder ECWT if the flow of condenser water could be reduced. This would be a mistake for two reasons. First, reducing the water flow would increase the temperature and pressure in the condenser, defeating the purpose of reducing the compressor head. Second, reduced flow would increase the tube fouling, again increasing the head. The only way to obtain these savings is with full flow of colder ECWT.

Find out how much you can save

In the past, efficiency comparisons for large-tonnage chillers have often been based on energy ratings at design-point conditions. The assumption was that low energy consumption at design-point conditions would automatically result in low energy consumption at all conditions. As we've seen, this assumption can lead to erroneous conclusions because not all high-efficiency chillers retain their efficiency at off-design conditions. And this is critical because chillers spend the vast majority of their operating hours at off-design conditions.

YORK chillers, in addition to having impressive full-load performance, can take advantage of ECWT as cold as 55°F to provide superior efficiency at off-design conditions. Over the life of your chiller, the savings can be dramatic. To find out how much you can save, have your Johnson Controls representative do an analysis for you.