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Keeping Chillers Efficient

by Don Clark

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Sensor and Gauge Accuracy Affect Chiller Efficiency

Historically, plant engineers have kept chiller operating logs to measure chiller performai and determine causes of problems. The data collected include readings taken from the chiller during scheduled inspections such as evaporator and condenser temperatures, pressures, flows, running load amps, volts, etc. This schedule varies from every two hou to once a shift, depending on the type of operation and more importantly, personnel constraints. In most facilities, logs were a vital tool in scheduling downtime, preventative maintenance, and inspections based on chiller run hours. Today, it is common for facilitie to maintain logs, but they rarely get reviewed until there is a problem.

Garbage In

The old adage of “garbage in equals garbage out” holds especially true when determining chiller performance. All temperature and pressure sensors/gauges lose their calibration and drift over time. The period of time and amount of drift vary from one sensor to another. Sensors that haven't been calibrated in the last year and are over three years o are almost certainly inaccurate Evaporator and condenser water flows can fluctuate durir seasonal changes, when circulating pumps begin to wear out or there are plant changes from original design. Therefore, if flows aren't measured and adjusted as needed, they a probably far from design.

The potential for human error increases the difficulty of obtaining accurate readings. Workers can very easily flip flop readings, use outlet voltage instead of inlet voltage, transpose values, or use approximations when using mercury thermometers or dial gaug that are not properly sized for the operating pressures. Digital gauges that measure to tl 1/10 reduce human error and provide accurate readings.

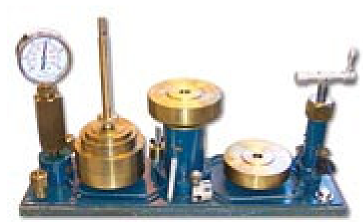
In most facilities today, personnel can be a major problem. Cutting back on preventive maintenance and taking logs has become a target for saving labor. It's hard to argue wit an operating engineer who complains, “I don't have time to take logs on a regular basis, much less evaluate the data.” Compound this with inaccurate data, which renders the readings and logs almost worthless and makes any clear-cut analysis virtually impossible

Determining Chiller Efficiency

A common method for determining chiller efficiency has been to calculate the actual kilowatt per ton (kW/ton) and then the difference between actual and design full-load kW/ton. This method can only be accurate if the chiller is operating at full-load condition when compared to design full load, which occurs on average less than 2% of the time. Kilowatts can be calculated by multiplying the square root of 3 (1.732) by the actual running load amps and the actual volts, dividing that product by 1000 and then multiplyi by the power factor (PF). To calculate tonnage, the evaporator delta temperature (DT), which is the difference between the evaporator water temperature in and the evaporator water temperature out, should be multiplied by the evaporator water flow gallons per minute (GPM) and divided by 24.

Efficiency Technologies, Inc. has taken these calculations to the next level and developec an Internet-based efficiency and trending tool for chillers, boilers, and plate exchangers called EffHVAC. EffHVAC accurately measures chiller performance at all part loads and ar operating condition with a proprietary calculated part load value (CPLV). Comprehensive reports (figure 1) include advanced diagnostics and fault detection that identify the caus of inefficiency (including bad data) and provides detailed corrective action instructions.

Determining Accuracy



There are some obvious ways to tell if sensors are out of calibration. If the DTs vary fron design operating conditions, then it could be an indication that one or both of the temperature sensors are inaccurate or water flow may be off design. If the evaporator leaving refrigerant temperature is greater than the evaporator chilled water out temperature, or the condenser leaving refrigerant temperature is less than the condense water out temperature, it indicates a problem in either the water temperature sensor or the refrigerant pressure sensor. If leaving refrigerant temperatures are not recorded, the pressures can be converted to temperature from a standard refrigerant/temperature cha which can be downloaded at www.EffTec. com.

Garbage Out

Inaccurate data can have a dramatic effect on energy consumption. Every 1°F decrease chilled water temperature caused by an inaccurate high reading creates a 2-4% increase energy use to maintain that unnecessarily low temperature. Not knowing the real temperatures can cost a fortune in wasted energy, not to mention wear and tear on the chiller components, by running out of intended parameters. The four main contributors o bad data are temperature sensors, pressure sensors, water flow, and human error.

Take an example of a chiller with design specifications of design tonnage = 600, full load amps = 500, volts = 460, PF =0.9, design DT = 10°F, gallons per minute (GPM) = 1440 and design kW/ton = 0.598. If this chiller's evaporator water in temperature sensor is reading low by 1°F and the evaporator water out temperature sensor is reading high by F, this gives a combined total of 2°F off or an 8°F DT at full load. When the kW/ton is calculated, it equals 0.747. Dividing 0.598 by 0.747 gives 80% efficiency. Just 2°F drift can make it appear that the chiller is 20% inefficient. This can alter scheduling of maintenance, produce inaccurate cost analysis and skew the plant load profile by 20%, making decisions concerning chiller sizing very difficult. At 80% efficiency, a 600-ton chiller running at 50% load, 24 hours/365 days, at $0.06/kWh would indicate a ~$24,91 loss. This emphasizes why sensors and gauges must be accurately calibrated to 0.1°F.

Temperature Calibration

Temperature gauge calibration is very easy. The gauges to be calibrated must be clean and dirt free. If a commercial temperature bath to perform a 3 or 5 point calibration is unavailable, ~ 2 liters of frozen deionized (DI) water crushed or shaved into very small c pieces and filling an insulated container, such as a Dewer flask or thermos (that will maintain a temperature) can substitute. The container should be filled and refilled with chilled DI water until the ice settles in the bottom of the container, minimizing air pocket in the ice. The calibration dial should be adjusted to read 32.0°F (figure 3), once the readings stabilize after the submerging the entire length of the temperature probe into tl ice bath until the readings stabilize (figure 3).

Temperature sensors for a chiller panel or building automation system (BAS) may not be able to be calibrated. Typically, an offset can be entered into the BAS/chiller software to compensate for calibration. To do this, a calibrated sensor must be used to get an accura temperature reading and the difference between the calibrated sensor and the BAS sens entered as the offset. Entering an offset is not as accurate as using a calibrated sensor a replacing the sensor with one that can be calibrated is recommended.

When refrigerant pressure sensors/gauges calibration drifts, the ability to diagnose problems suffers. Inaccurate pressures can give the indications of fouling or scaling, higl or low refrigerant levels, refrigerant stacking, and non-condensable gasses. Misdiagnosis of these conditions can not only cost in wasted energy, but also potentially damage the chiller.

There are several ways to calibrate pressure sensors/gauges including hand pump calibrators, dead weight testers (figure 4), portable field calibrators, and laboratory calibration services. These devices and services range in price from hundreds to several thousand dollars. If a pressure calibration device is unavailable or cost prohibitive, the sensor/ gauge should be replaced. A typical factory-calibrated gauge can cost under $30 A high quality, coil-type gauge that will hold calibration for a long period of time costs slightly more.

Water Flow

Facility personnel often assume that water flow to the chiller is constant and always at design. Unfortunately, this may not be the case because chillers are dynamic, ever-changing models, which must adapt to the environment around them. They expand and contract from their original design and are subject to wear, tear, and age.

The impact of off-design flow can be illustrated by taking the same chiller design specifications as in the temperature example with a design kW/ton = 0.598, but with a pump that is oversized 20%, making the actual GPM 1728, which would drop the DT to 8.33 at full load. Following the standard kW/ton equation i1 (using design GPM of 1440 i flow is not actually measured), the calculated kW/ton would be 0.717, giving an apparen efficiency of 80% based on inaccurate data.

Four methods for determining flow are an inline flow meter, external flow meter, delta pressure (DP), and DT. Flow meters can be a high quality turbine type, magmeter (inline or ultrasonic (external), and gives the most accurate GPM flow readings. GPM can be determined by DP using a manometer or annubar. DT cannot actually measure GPM, but can determine potentially high or low flows. If an accurate DT at full load is greater than design, it can indicate low GPM. Conversely, if the DT at full load is less than design, it ca indicate high GPM. If inline or ultrasonic flow meters are not available, a handheld manometer can be purchased for a few hundred dollars and are a very effective way to use DP to correct flow.

An even more affordable, but less accurate way to measure DP is to make a DP gauge (Figure 10). A T-pipe attached to a pressure gauge can be modified by connecting a ball valve to each end of the T, and then connect couplings for the pressure lines to the ball valves. The pressure lines to the device should be connected to the chiller's pressure inle and outlet. Readings are obtained by opening the ball valves in turn, taking pressure readings, and then closing the ball valves. The difference between the inlet and outlet pressures is the DP.

Self Defense

Some service companies acquire business by performing basic chiller efficiency calculations. These calculations typically show problems and are followed by the promise improvement or correction if contracted. The ability to know your operations and accurately measure your performance is a valuable asset. Use this asset to prevent bein manipulated by the promise of unrealistic savings that may have been produced by inaccurate data. Having calibrated temperatures, pressures and flows and knowing the true performance of your chiller plant is an excellent way to keep everyone honest.

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