Temperature ranges are a complicated issue. There is no single best solution that can be used for every case. Each project will have its own optimum operating conditions. For complete, factory-assembled solutions for your HVAC applications, contact your local McQuay representative or visit www.mcquay.com.

Why Change the Chilled Water Temperature Range?

To answer this question, let’s review the primary goal of HVAC design. The goal is to provide the comfort with a safe, comfortable environment at an acceptable life cycle cost. Focusing on life cycle cost brings up the necessity to balance capital cost and operating cost. It is here that changing the chilled water temperature range becomes an issue. To consider the capital cost, look to the following formula:

Lead tons = (Flow tons) × (EER tons) × 10

Flow tons = (Load tons) / (EER tons)

As the chilled water temperature range is increased, the flow tons is decreased for the same capacity. Smaller flow means smaller pipes, pumps, insulation, etc. This equates to capital savings. Notice that the chilled water supply temperature is a part of the equation. There is nothing to be gained by decreasing the chilled water supply temperature, yet increasing the chilled water supply temperature will affect every component in the cooling HVAC system.

This article attempts to show the relationships between the components that make up an air conditioning system so that the designer can appreciate the nuances. There is no one solution, but rather operating conditions that will yield the best results for any and all buildings. The designer must answer the question: If I increase the chilled water supply temperature, will the designer downsize piping as the chilled water supply temperature increases? If the answer is no, the designer cannot utilize the designer downsizing piping if the chilled water supply temperature is increased.

For more information on air conditioning system design, contact your local McQuay representative or visit our web page at www.mcquay.com.

Consider the Entire System

The two considerations discussed above are not very strong arguments for increasing the chilled water supply temperature. Those considerations, however, are only focused on the pumps and piping. Designers must consider the entire HVAC system and changing the chilled water temperature ranges will affect the entire system.
Starting with the Chiller

The purpose of a chiller is to collect heat from the chilled water loop and reject it in the condenser water loop. This process takes work, so a compressor is required. Figure 1 shows the chiller’s two heat exchangers. The bottom part of the figure shows the evaporator process. Here the heat leaves the chilled water in a sensible cooling process that cools the chilled water temperature. The heat enters the refrigerant, which boils (changes from a liquid to gas) at a constant pressure and temperature. The refrigerant must be cooler than the water (heat flows downhill) and the refrigerant is compressed. The top portion of Figure 1 shows the condenser process. Here the condenser water is warmed by the refrigerant. The refrigerant condenses from a gas to a liquid at a constant pressure and temperature. In this case, the refrigerant must be warmer than the condenser water.

The difference between the condenser and evaporator temperatures is physics and it occurs regardless of compressor type, refrigerant type or the manufacturer. The specifics will define the size of the efficiency penalty, but there will always be a penalty.

The Effect on Cooling Coils

The cooling coil absorbs heat (both latent and sensible) from the air and transfers it into the chilled water, raising the water temperature. A cooling coil is a heat exchanger, so it will increase energy proportional to its LMTD. However, if the supply water temperature is lowered, then the refrigerant boiling temperature must be lowered. This will increase the compressor lift (See Figure 2) and lower the chiller performance.

Increasing the condenser water temperature range will reduce the condenser pump, pipework and cooling tower sizes, saving capital costs. On the other hand, it will result in some combination of increased chiller cost and lower chiller performance.

What About Condenser Water Temperature Ranges?

Building on the discussion so far, increasing the condenser water temperature range will decrease the pipe and pump size and the operating cost of the condenser pump. It will also require the condenser temperature to increase, which will increase the compressor lift and decrease the compressor performance. The higher “average” condenser water temperature (or increased LMTD) will improve the cooling tower performance, allowing for a smaller cooling tower.

Putting It All Together

Increasing the chilled water temperature range will reduce pipe, pump, insulation, etc. It will also save on pump operating costs because the pump motor will be smaller. Increasing the coil area (adding rows and fins) will increase the coil cost and increase air pressure drop. The air pressure drop increase will lead to larger fans and more fan work. Limiting the chilled water supply temperature will result in increased combination of increased chiller cost and reduced chiller performance.

Increasing the condenser water temperature range will reduce the condenser pump, pipework and cooling tower sizes, saving capital costs. On the other hand, it will result in some combination of increased chiller cost and lower chiller performance.

Moral:

In some cases, it may be possible to reduce the capital cost of a new or renovated HVAC system by increasing the condenser water temperature range. Since the condenser pump is small, it raises the question whether raising the temperature range will allow the best benefit from increasing the chilled water temperature range. Table 4 shows the annual energy analysis with constant volume, showing the combination of increased chiller cost and reduced chiller performance. The correct answer brings the discussion full circle. The best combination of components that provides the best life cycle performance. This can only be found by performing an annual energy analysis, followed by a life cycle analysis.
One of the best ways to reduce pump work is to allow the chiller actually likes increasing the chilled water temperature for the 14°F temperature range is higher, so use average fluid temperatures. Notice the "average" water will result in some combination of increased air pressure drop increase will lead to larger fan motors also require the condensing temperature to increase, which also will increase the compressor lift and decrease the com-

### Table 2 – Annual Energy Analysis with VAV and Declining Supply Water Temperature

<table>
<thead>
<tr>
<th>Run</th>
<th>C.W. Range</th>
<th>Chiller Pumps</th>
<th>Tower Fan</th>
<th>S.A. Fan</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>14°F</td>
<td>311,500</td>
<td>118,600</td>
<td>39,570</td>
<td>469,670</td>
</tr>
<tr>
<td>2</td>
<td>12°F</td>
<td>302,600</td>
<td>113,000</td>
<td>37,740</td>
<td>453,340</td>
</tr>
<tr>
<td>3</td>
<td>10°F</td>
<td>294,700</td>
<td>107,400</td>
<td>34,910</td>
<td>436,010</td>
</tr>
</tbody>
</table>

Converting linear performance to a temperature range of 14°F or 12°F or 10°F chillers will be reselected to optimize chiller performance. It is not possible

### Table 4 – Annual Energy Analysis with VAV and Declining Supply Water Temperature

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Converting to variable primary flow reduced the pump

### Alternatives Not Considered

To avoid confusion, Table 2 should be designed a VAV office building with cooling 56 tons and could only manage a 3% improvement. Also, the fans from the Table 2 when compared with Table 2.

### Table 1 – Design Conditions Varying Chilled Water Temperature

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<th>HP</th>
<th>(°F)</th>
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<tr>
<td>1</td>
<td>400</td>
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<td>8/11</td>
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</tr>
<tr>
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The best performing conditions in this example was only 2% better than the conventional ARI design conditions.

Moral: ACH conditions (54/44 °F chilled water, 85/95 °F condenser water) work very well for many applications. Reviewing the design performance (Table 1) and the annual performance (Table 2) gives us different answers. Design performance is often very misleading when trying to determine the annual operating efficiency of an HVAC system. Even choosing a city with a high demand can have a big difference.

Moral: There is no substitute for annual energy analysis. It doesn’t have to be difficult or time consuming, all the analysis for this example only took a few hours using the McQuay Energy Analyzer™ program. Similar results can be obtained using other software in the same amount of time.

Reviewing the constant volume system with reheat system versus the VAV with reheat system shows constant volume to be much more sensitive to increased coil area. Because VAV systems modulates the airflow, it is more sensitive to increased coil area. Increasing the condenser water temperature range will have a greater impact on VAV systems than on constant volume systems.

Moral: The whole HVAC system must be considered when designing a chilled water system. It is not possible to do a “fine tune” analysis and come up with the optimum design criteria. All the designs analyzed in the above tables were based on optimum design criteria. In most cases, the chillers will be reselected to optimize chiller performance.

Table 5 shows the results in increasing the condenser water temperature range one degree at a time from ARI conditions (54/44 °F chilled water, 85/95 °F condenser water). In this example, the penalty to the chiller outweighs the pump savings and it simply cost more to operate. The only argument for doing this would be the possible capital savings. To minimize the performance, a better performing but more expensive chiller was used. On the capital side, enough money has to be saved to pay for the more expensive chiller. Regardless of the capital savings, this chiller will cost more to operate. Increasing the condenser pump head will save the pump lead point where the chiller/condenser pump work starts to increase. The higher the point, the more operating cost. The goal is to save enough on the capital savings, this chiller will cost more to operate. Increasing the condenser pump head will save the pump lead point where the chiller/condenser pump work starts to increase. The higher the point, the more operating cost. To demonstrate the relationships shown in this article, not all avenues were explored. For instance, we did not consider chiller pressure drops; the higher the tube velocity, the better the chiller performance. In most cases, the chillers will be reselected to optimize chilled water. Consider chiller pressure drops; the higher the tube velocity, the better the chiller performance.
continued from previous page

performance in a 5% CWT can be expected that the chiller pressure drop will not be critical with increased temperature ranges. In addition, the pumps will increase (two to three times) as the range increases.

Chiller types, determined by compressor or manufacturer, were not considered. While it is true that all chillers will behave generally the same, the specific properties of a chiller will change the outcome. The same plant types will also affect the outcome. As the chilled water temperature range is increased, series chillers will outperform either a single large chiller or parallel chillers. Series counterflow chillers will outperform series chillers; however, the savings may be lost when considering the condenser pump work. Pump head is a key parameter. Increasing the pump head will make the pump work more dominant and change the outcome.

Consideration

Temperature ranges are a complicated issue. There is no single best solution that can be used for every case. Each project will have its own optimum operating conditions. For further complications, different chillers (either project will have its own optimum operating conditions. Each type or manufacturer) will have their own optimum operating conditions. Said another way, the best McQuay solution may not necessarily be the best solution for other chiller vendors and vice-versa.

All chillers are negatively affected by increased compressor lift. Some chillers types (series, for instance) are less affected. Casually increasing the compressor lift for any chiller type or manufacturer will increase the operating cost. Changing the temperature ranges and supply temperature requires careful analysis. The following are some points to consider:

• The traditional tilt operating conditions work very well for many buildings.

• Unnecessary reduction of the chilled water supply temperature should be avoided because it increases chiller work. When using standard products such as fan coils and unit ventilators, maintain the chilled water temperature range between 10 and 12°F where they are designed to operate.

• Increasing the chilled water temperature range is a good way to reduce the capital and pump operating costs, particularly if the pump head is large or the piping runs long.

• Designers must consider the entire HVAC system and changing the chilled water temperature range will affect the entire system.

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Chris Sackrison, Editor

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Edition No. 14 December 2002

McQuay Air-Cooled Chillers

High Efficiency And Low Noise At An Affordable Price

McQuay air-cooled scroll compressor chillers are the complete, factory-assembled solution for your HVAC requirements. Our 10 to 130-ton chillers are loaded with value-added features at an affordable price.

• Efficient – Meets or exceeds ASHRAE Standard 90.1 (October 2001). Up to 110 EER at full load, and up to 14.5 EER at part load (IPU).

• Quiet – All-RHA ratings are tuned in accordance with ARI Standard 370. Low acoustic treatment lowers your project’s cost.

• Reliable – Tandem or single scroll compressor units per circuit have fewer moving parts. Two circuits at 26 tons provide backup chilled water. Several options are available to enhance reliability and sustainability.

• Consistent Reliability – Prototoured Selectability™ allows MicroTech™ DDC controls to easily integrate into your building automation system of choice. And it’s simple to achieve interoperability using open, standard protocols such as LonTalk® or BACnet™.

• Flexible Options to Meet Your Needs

McQuay offers you the flexibility to choose from many sizes and options to customize your air-cooled scroll component chiller.

• Low ambient operation down to 17°F

• Non-fused disconnect switches allow secure and easy service.

• Phase voltage monitor senses and avoids undesirable electrical conditions.

• Ice storage capability saves energy.

• Double response modulation for ice storage operation.

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• For very large chilled water ranges, use series chillers, possibly with series countercflow condenser circuits, to optimize chiller performance.

• Increasing the condenser water range should only be considered for projects where the piping runs are long and the pump work high. When it is required, optimize the flow to the actual pipe size that is selected and select the chillers accordingly. In the example in Table 5, the temperature ranges 10 through 12°F would all need 8-inch pipe, while the ranges 13 through 15°F would need 6-inch pipe and the 16°F temperature range. Consider oversizing the cooling towers to minimize the effect on the chiller. Remember that cooling towers are significantly less expensive than chillers.

Continued from previous page

Flexible Options to Meet Your Needs

The pump head will remain approximately constant because the pipe sizes will be decreased. ASHRAE recommends that piping design be based on a 4-foot pressure drop per 100 feet of pipe. Maintaining this requirement will let the designer downsize piping as the flow decreases.

Consider the Entire System

McQuay

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