Edition No. 7 April 2001

ENGINEERING

SYSTEM SOLUTIONS

In this issue, we highlight the benefits of air-cooled chillers and provide design tips to help achieve a proper operating chiller plant and a satisfied customer. Our second article introduces you to McQuay's line of air cooled chillers – the first in the industry to include solid state motor starters that reduce mechanical stress and promote compressor longevity.

More detailed information on chiller applications can be found in ***Chiller Plant Design*** *– an application guide published by McQuay. Other application guides available from McQuay include* ***Centrifugal Chiller Fundamentals*** *and the* ***School HVAC Design Manual****. For a printed copy or more information, contact your local McQuay Representative or call (800) 432-1342.*

You can find this and other issues of Engineering Systems Solutions on our website at www.mcquay.com. Also, check out our "What's New" page for information and literature on McQuay products.

McQuay provides semi-custom system solutions for commercial HVAC applications. This newsletter is written specifically for the HVAC engineering community. We welcome your comments, feedback, and article suggestions.

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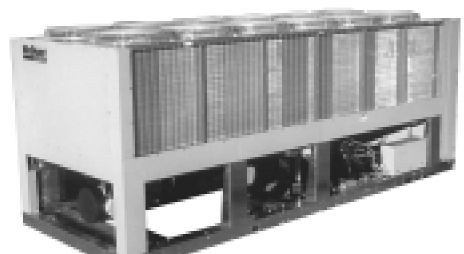
Air-Cooled Chillers
Benefits And Design Tips

Air-cooled chillers have many advantages over water-cooled equipment. While it is true that water-cooled equipment can offer better performance, by the time the condenser pumps and water cooling tower fans are included, the performance difference is not as big as you might think. In fact, at part load conditions, there might not be any difference at all.



The biggest advantage of using air-cooled chillers is that they do not require cooling towers or condenser water pumps. While this has traditionally made air-cooled chillers very popular with small to medium projects, it is becoming more common to see large plants (2,000 tons and larger) that use air-cooled chillers.

Another advantage of air-cooled chillers is they do not require a mechanical room for the chiller. This frees up considerable space for occupant use.

Like all products, air-cooled chillers have special needs when applying them in a design. The following are several of the key items that should be addressed to achieve a proper operating chiller plant and a satisfied customer.

Air Circulation

Air-cooled chillers generate a lot of heat. Consider a 400-ton air-cooled screw chiller. That is equivalent to 4,800,000 Btu/hr. The heat of rejection from the compressors adds another 1,400,000 Btu/hr for a total of 6.2 Million Btu/hr of heat that must be rejected to atmosphere. Air-cooled products use a sensible heat transfer process so the refrigerant condensing temperature must be higher than the ambient temperature. The performance of a chiller can be given at many different ambient temperatures, but the industry norm is to use 95°F.

Locating an air-cooled chiller so that enough air circulation is available is critical to its operating performance. To illustrate this point, let's assume the condensing temperature of the refrigerant is 120°F, the leaving approach is 3°F and the condensing pressure is 260 psig. Using the equation $Q_{sensible}$=1.085*cfm*ΔT and solving for cfm shows this chiller needs 260,000 cfm of ambient air to cool the chiller! Without enough circulation, flow restriction and recirculation can become big concerns.

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Flow Restriction

A 400-ton chiller has twenty-four, 28-inch condenser fans, each with a 2-hp motor. If the chiller location restricts flow, then there will not be enough air to cool the chiller. The result is the condensing temperature rises. If the flow is restricted 10%, then the new condensing pressure becomes 270 psig. The compressors now have to work harder to provide the refrigeration effect.

Recirculation

Recirculation is a more serious issue. Units surrounded by walls higher than the top of the unit can have recirculation problems. Problems also occur when multiple units are too close together. If 20% of the air is recirculated, the condensing pressure climbs to almost 280 psig.

When the building design forces the chiller to be located in a not-so-ideal location, don't assume there is enough design margin to provide reliable operation. Operating conditions can quickly exceed design conditions by a very large margin if the air is restricted a little and there is some recirculation. Add to this the fact that most chillers are located on roofs where the air temperature can be several degrees warmer than ambient, and the chiller can quickly become challenged.

Tips To Resolve Air Circulation Issues

Some air circulation issues can be alleviated by the design of the chiller. Using "U" shape condenser coils allows better airflow across the coils in tight spaces. The chiller controller can also be programmed to "recognize" an airflow problem and reduce the chiller output to protect it. By reducing output, the chiller can avoid going off line. A word of caution here. Beware of manufacturers that allow what seems to be very close unit spacing. They may forget to mention that at high ambient temperatures the unit will unload and reduce capacity to keep the discharge pressure within acceptable limits. You may not want your chillers to unload on the hottest days of the year! The controller can also be programmed to preferentially load refrigeration circuits within a chiller with better airflow patterns to avoid going off line unnecessarily.

McQuay Catalogs such as PM ALS-4 provide detailed information on how much area is required around an air-cooled chiller, multiple chiller installations, locating a chiller in pits, and more. There are also correction factors for re-rating the chiller in adverse conditions. By using these guidelines, reliable, predictable performance is possible. For applications that are not covered in the catalogs, consult your local McQuay representative.

In situations with high ambient temperatures or specific design issues, compressors with solid state starters should be considered. The higher the ambient, the larger the pressure differential the compressor must provide. Solid state starters allow the compressors to accelerate relatively slowly, avoiding jarring of the mechanical components and significantly lowering the inrush current. An added benefit of solid state starters is at the end of a cycle the compressors are slowed to a stop rather than abruptly turned off. Without solid state starters, the pressure differential in high lift applications can cause the compressor to be severely jarred or even rotate backward when stopped.

Close Coupled Concerns

Consider that chilled water is flowing through the piping at about 6 fps. If a roof mounted air-cooled chiller is mounted just above a single, large air-handling unit, then the chilled water can make a round trip in as little as 10 seconds! This can create control stability problems. The concern is that the chiller controller will "hunt" on the control valve for the cooling coil in the air-handling unit. Step unloading chillers, such as reciprocating or scroll types, are even more susceptible to problems. For example, if a 100-ton air-cooled chiller with four, 25-ton compressors is close coupled to a load of 63 tons, the imposed load is between the capacity of 2 and 3 compressors. If the controller uses 3 compressors, the water will become too cold within seconds. With two compressors, the supply water temperature will rise.

Tips To Resolve Close Coupled Issues

In terms of enhancement to the chiller, modern micropressor controllers are a must. They should include PID (proportional, integral, differential) control and preferably fuzzy logic. Another key issue is the use of solid state starters, which reduce both the inrush current and the strain of multiple starts.

Try to avoid close coupled systems in design. Consider increasing the volume of chilled water to 7 times the design flow rate (i.e. 7*960 gpm = 6720 gal.). Process applications or variable flow applications are more sensitive, so even more care should be taken. Process loads can start and stop abruptly, often adding or removing 25% or more load to the chiller. Variable flow systems have two degrees of freedom, temperature range and chilled water flow. It becomes more difficult for the controller to assess the true load on the chiller when both the temperature range and flow rate are varying.

Cold Climates

Colder climates add another dimension to applying air-cooled chillers. Since the chilled water is outside the building envelope, water freezing can be a problem in colder climates. Another issue is refrigerant head pressure control. Looking at the earlier example of a 400-ton chiller with a condensing temperature of 120°F, the approach between the refrigerant and the summer ambient air is 25°F. The design of the chiller is such that there is enough air flow and coil surface area to allow reliable, stable operation when it is 95°F outside. In winter, the ambient temperature can drop to well below 0°F. Now the condenser is too efficient! It has 4 times the airflow it requires.

Tips To Help Resolve Cold Climate Issues

In applications where the ambient temperature will drop below freezing, the following approaches are recommended:

- Select a chiller that has a heat traced and insulated evaporator.
- Provide continuous circulation through the evaporator.
- Include enough antifreeze to provide protection against freezing.
- Insulate and heat trace any exposed piping.
- Drain and flush chiller with antifreeze.

Draining the system in the winter works if the chiller is not required (i.e. systems with airside economizers). Some care should be taken to protect the system in case winter weather sets in before it is shut down. Consider the following:

- Select a chiller that has a heat traced and insulated evaporator
- Provide continuous circulation through the evaporator if the ambient temperature approaches freezing.

If the chillers are needed in winter, adding glycol is a good recommendation. However, glycol lowers the heat transfer properties of water and increases fluid pressure drops. As a result, chiller, pump and coil performance is adversely affected.

Another solution is to use a remote indoor evaporator, which eliminates the need for antifreeze.

To control head pressure, reduce airflow by cycling off fans or using fan speed control. Refer to McQuay's Air-Cooled Chiller catalogs for the ambient conditions that can be met using fan cycling or fan speed control. Be aware that the ambient temperatures listed in the tables assume that there is sufficient chiller load. If there is little chiller load, the chiller will not perform as well as the table data indicates.

Wind can be another issue. If the chiller is exposed to wind (even with the fans off) there may be too much heat transfer. Use wind baffles or locate the chiller behind a screen to reduce wind issues.

Sound

Since the chiller is located outdoors, sound can become an issue. Referring to the 400-ton example above with twenty-four, 28-inch condenser fans and 4 large screw compressors, sound is inevitable. If a centrifugal chiller with a cooling tower is substituted for an air-cooled chiller in this example, the cooling tower would have 50 hp of fans as compared to the 48 hp in the air-cooled chiller. Either way, the sound created by the equipment will have to addressed.

The key sound paths are from the chiller to the property line and from the chiller, through the roof and into the occupied space. Property line sound calculations are straightforward. The sound level drops off as the inverse square of the distance. Sound issues in the space often arise from vibration transmitted to the structure.

Tips To Mitigate Sound Issues

Current chiller offerings have considerable range in sound levels. The best advice for dealing with sound issues is to select for a chiller that is quieter in the first place.

Maximizing the distance to the property line and adding screens around the chiller can further reduce property sound issues. Using a proper structural base with vibration isolation is the best solution for avoiding the transfer of vibration into the building.

Applications in residential areas, such as health care facilities and schools, require special care. What might be acceptable during the day can seem extremely loud at night. Staging off fans at night when the ambient air is cooler and the load is less can help resolve this issue.

Variable Flow Through The Chiller

Large water-cooled plants often (as a matter of course) have primary/secondary designs with variable flow in the secondary loop. One and two chiller air-cooled plant designs can also benefit from variable flow advantages. It can be accomplished with one variable flow primary loop, one set of pumps and variable flow through the chiller.

Tips To Apply Variable Flow

Figure 1 shows a typical piping layout. A bypass line is required when the flow requirement drops below the minimum flow rate required by the chiller. The bypass line should be located away from the chillers so that the return water temperature does not change quickly. A second alternative is to use a few three way valves in lieu of a bypass line. While this simplifies the piping, the three way valves will "consume" flow all the time and reduce the potential pump savings.

The limits on flow range are the maximum and minimum flow rates allowable by the chiller. These can be found in McQuay product catalogs. If the flow rate is too low, laminar flow can occur. A good rule of thumb is the flow rate through a chiller usually can be reduced to 60% based on a 10-degree design temperature range without a problem.

To reduce flow during part load operation, the control valves at the coils must be two-way type. If no bypass is used, then some coils should have three way valves to maintain minimum chiller flow. They must be properly sized to ensure the design ΔT in the chilled water loop is maintained as the load varies.

The best control strategies include chilled water flow meters. With two chillers in parallel, the required flow rate must be known to determine if one or two chillers are required. When one chiller can handle the load and the building flow rate is within the design range of a single chiller, the other chiller can be shut down and isolated to further improve savings. The flow meter can be used to initiate the bypass. The flow rate where the bypass line must be opened is the largest "minimum flow rate" of any chiller in the system.

Different chillers can accommodate different rates of change in flow. The chiller controller must be able to deal with both varying load and varying flow. In addition, different chiller types will have different abilities to deal with variable flow. Most chiller catalogs include recommended change of flow rates and are typically in the range of 5 to 10% change in flow per minute.

Service Access

Like any piece of equipment, air-cooled chillers must be serviced. Space critical issues include minimum clearance in front of the electrical panel (this is a code issue) and access to the evaporator for cleaning and re-tubing. Access around an air-cooled chiller usually isn't a problem if proper air circulation space has been accommodated.

McQuay Air-Cooled Chiller Product Catalogs include recommended service clearances for both the electrical panel and the evaporators. Some manufacturers recommend service clearances for evaporators, assuming that the evaporator will be disconnected from the refrigeration circuit and pulled sideways. This creates a situation where the refrigerant must be removed from the chiller, as well as the refrigerant lines, if any of the tubes need to be replaced. While any chiller can be serviced this way, it is not recommended and should be avoided if at all possible.

Conclusion

Air-cooled chillers offer an excellent alternative to water-cooled chillers and avoid the complication and maintenance issues of cooling towers. While the performance can be diminished from some water-cooled chillers, it is still very good. In addition, there is no power penalty for cooling tower fans or condenser water pumps. Air-cooled chillers are excellent choices for variable flow systems with two chillers in parallel.

Problems stemming from installation usually revolve around airflow concerns. Restriction and recirculation are key concerns that must be addressed during the design phase in order to have a reliable chiller plant.

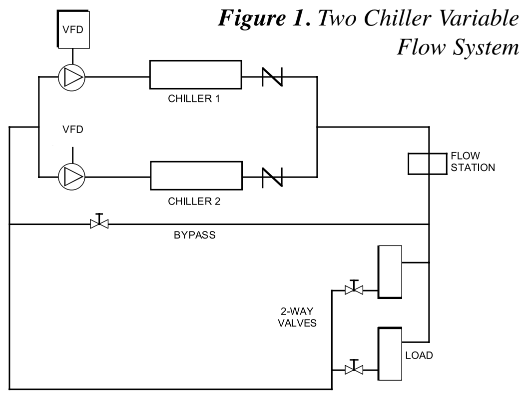

Figure 1. *Two Chiller Variable Flow System*

For More Information

The installation issues raised in this newsletter are covered in much greater detail in the various McQuay product catalogs and application guides. For a copy or more information on chiller applications, contact your local McQuay Representative, call (800) 432-1342.

Application Guides

AG 31-003 – Chiller Plant Design

AG 31-002 – Centrifugal Chiller Fundamentals

AG 31-004 – School HVAC Design Manual

Product Manuals

PM-ALS-4 – Air-Cooled Rotary Screw Chillers

PM-AGZ-3 – Air-Cooled Scroll Compressor Chillers

PM-ALR – Air-Cooled Reciprocating Compressor Chillers

PM-WSCWDC-1 – Centrifugal Compressor Water-Cooled Chillers

McQuay's New Air-Cooled Screw Chiller Offering Cannot Be Beat

At Mcquay, we continue to expand and improve our line of Air-Cooled Screw Compressor Chillers. When it comes to reliability, cost savings and quiet operation, McQuay's chiller cannot be beat.

Reliability First

McQuay's new Air-Cooled Screw Compressor Chillers are the first chiller in the industry to be equipped with solid state motor starters, making them the most reliable chiller in the industry. Solid state starters gradually accelerate and decelerate the compressor motors, reducing mechanical stress and improving reliability. Across-the-line and reduced voltage starters are gone forever. Long compressor life is here to stay. Solid state starters also include surge capacitor, current unbalance, phase failure, over-current protection and self-diagnostics, just to make your life a little easier.

Also, the unique single screw compressor design pioneered by McQuay defines reliability. Single screw compressors have very few moving parts, liquid cooled motors, and balanced loads on all bearings. Along with full factory run testing of all units, these features improve reliability and significantly reduce concerns for the maintenance department.

Lower Energy Bills

With McQuay Air-Cooled Screw Compressor Chillers, efficiency is a key feature. It's designed-in to reduce operating costs for years to come. Full load energy efficiency ratios (EER's) as high as 10.0 and part load efficiencies as high as 13.0 translate into lower energy bill for owners.

Quiet Chillers Make Happy Clients

McQuay Air-Cooled Screw Compressor Chillers are quieter than those of all other manufactures. In fact, they generate half the sound energy of the nearest competitive manufacturer. Let us show you the numbers. Your clients will hear the difference and they will save money by not spending as much to overcome noise problems.

Call your McQuay representative today. Find out how the latest Air-Cooled Screw Compressor Chillers can help you and your clients. While you're at it, don't forget to ask about coupling McQuay Air-Cooled Chillers with McQuay Vision™ customized air handlers or AAF®-HermanNelson® unit ventilators. The combinations are unbeatable for performance, energy efficiency, IAQ and low noise.

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