Warming Up to Chillers
A Guide to Understanding Chilled Water Systems

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Chilled water systems are the primary means of cooling most commercial and industrial facilities and also can be used to cool equipment or products, such as during the pasteurization of dairy products, juices and other foods/beverages or bulk tank storage of these products prior to packaging.

Yet even though cooling is the common purpose, the design of chilled water systems can vary considerably from facility to facility. Centralized or district chilling systems or a series of chillers can be used to address the specific needs of a company. The following article looks at various chilled water systems and how different components function.

> Nearly half of all energy used in commercial buildings is HVAC-related.
> Source: Energy Information Administration, Annual Energy Outlook 2006

A Closed Loop System
The primary job of any chilled water system is to remove heat from a product, space or system. To do this, chilled water systems transfer heat from water being pumped through a piping network to a refrigerant such as R-134a or ammonia. Four kinds of water chillers are available for commercial and industrial use. The most widely used of these – centrifugal – are found in large industrial and commercial operations. Other types (reciprocating, rotary screw, and absorption chillers) are often found in applications ranging from small to mid-sized operations.

Some process chilled water systems are packaged as open systems. An alternative chilled water system is a closed loop system, which means water is used as the cooling media and does not exit or enter the system once it is in operation. When the chiller components are connected through a piping network to the load (*see diagram, next page*), the chilled water can be pumped throughout the network to manage loads in the primary loop – the loop that circulates water through the chiller – as well as in a secondary loop – which addresses other uses on the system.

The Water Chilling Cycle Step 1: Chillers
The first step in chilling water involves the process of turning the refrigerant from liquid to vapor so that heat can be absorbed from the water. To chill the water, several types of heat exchangers can be used, which can be located at both ends of the closed loop system, or on the primary or secondary chilled water distribution loops. The following is a list of the most commonly used heat exchangers:

- Shell and tube heat exchangers. In this design, the refrigerant can be either in the tubes or in the shell while the chilled water remains on the opposite side. As the water flows through the shell and tube heat exchanger, heat from the water is absorbed by the refrigerant and the refrigerant changes from a liquid to a vapor.

- Plate and frame heat exchangers. These exchangers use metal, corrugated plates to transfer heat between two liquids or refrigerant in a closed loop system. As water flows between the plates, heat from the water is absorbed by the refrigerant in an adjacent plate cavity. The advantage of this system is that the liquids are exposed to a much larger surface area over a smaller physical footprint.

- Falling film heat exchangers. These exchangers, used in open loop systems, employ the plate exchanger concept where refrigerant, like ammonia, is allowed to vaporize between the plates as it absorbs heat from the water, which flows over the outside of the plate. Water enters through a distribution pan, flows over the plate evaporator and into an insulated holding tank before being pumped to the cooling application. With these exchangers, water can be chilled as low as 33°F without freeze-up problems or fear of damage to the chiller system.

- Ice builders. Another open loop system is the ice builder, which is made of steel or copper coils submerged in a tank of water. Refrigerant passes through the pipe coil at 8.5°F and allows ice to build on the coil during off-peak production times, then melt during peak production hours. Ice builders can effectively reduce the demand on a refrigeration system as well as reduce a facility's peak electrical demand. (Additional information on ice builders is available in a previous Hixson white paper.)

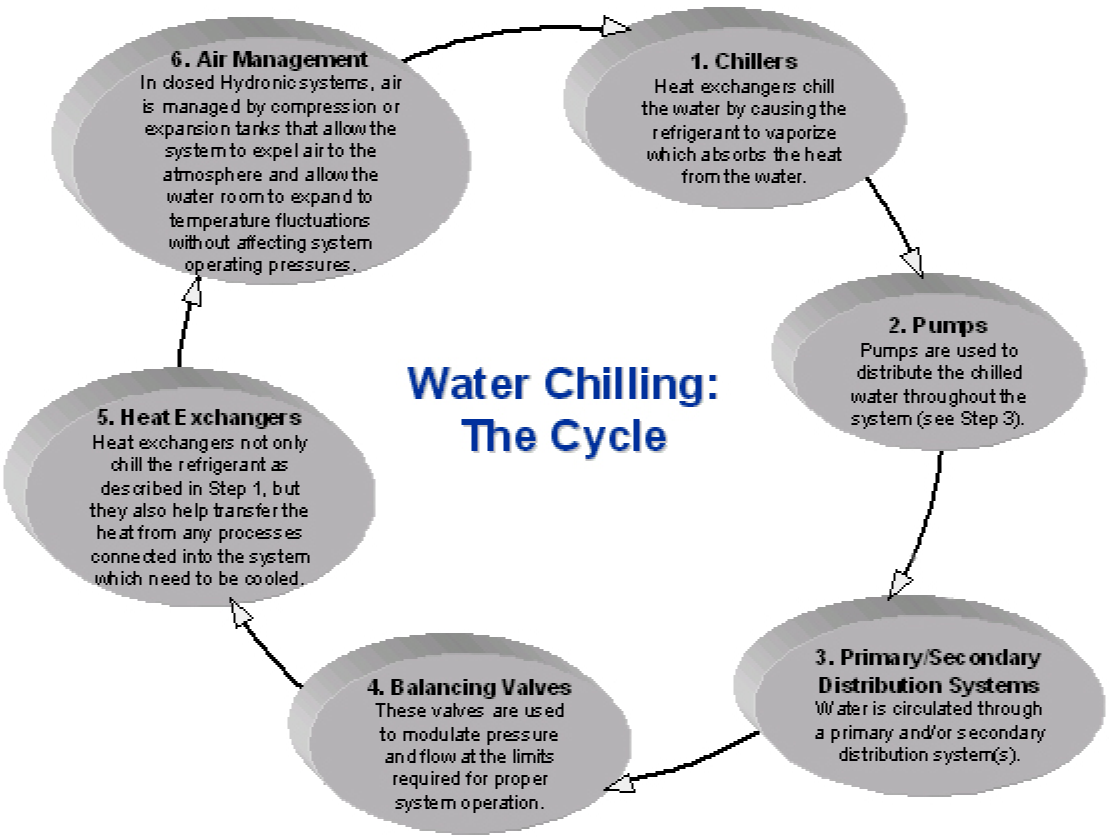

Diagram: How Water is Chilled

The Water Chilling Cycle Step 2: Pumps
Pumps, which distribute chilled water throughout the systems distribution network, can be installed on the primary and secondary water loops, depending on flow, pressure drop or temperature requirements of the system. While there are many different types of pumps available for this operation, some of the more typical ones designed for industrial applications are:

- End suction pumps. These pumps feature a base-mounted, single-stage, end-suction design with a foot-mounted volute to allow removal and service of the entire rotating assembly without disturbing the pump piping.

- <u>In-line</u>. This is a close-coupled, single-stage pump designed for horizontal and vertical in-line mounting and capable of being serviced without distributing piping connections.

- <u>Horizontal split-case pump.</u> Typically used in large, district chilled water systems, horizontally split-case pumps are base-mounted, single-stage pumps that allow internal components to be accessed without removing electrical components or connectivity piping.

The Water Chilling Cycle Step 3: Network Distribution
In a chilled water system, there can be multiple loads – all requiring varying flows, pressures and temperatures – creating the need for primary and secondary loops or networks. In these cases, pumps are used to circulate chilled water through these loops.

There are several advantages to the primary/secondary mode of operation:

- <u>Hydraulic isolation</u>. The load is decoupled from the primary loop which reduces the pressure drop associated with the piping, valves and the coil that supplies the load in each associated zone. This reduces the overall head required on both the primary and secondary pumps, which in turn lowers the pump horsepower required.

- <u>Thermal isolation</u>. Thermal isolation can be achieved by disconnecting the load from the primary loop using a balanced common pipe between the supply and return of the primary loop. The secondary piping ties into common balanced piping between the supply and return connection of the primary. This provides a means to decouple the secondary distribution piping, thus providing a thermal break between the two networks.

- <u>Horsepower reduction</u>. By reducing the overall pressure drop seen by each pump in the system, the head required to achieve the required flow is reduced, which lowers the horsepower required to meet the designed pressure drop and flow rate.

- <u>Operational cost savings</u>. By reducing the horsepower required to supply chilled water to the load, the overall annual operating costs are reduced.

However, there are also disadvantages in that there are additional costs for the installation and maintenance of additional piping, insulation, control piping and pumps.

The Water Chilling Cycle Step 4: Balancing Valves
As chilled water flows through the network, it passes through a series of valves. There are many different types and styles of valves used, but all primarily serve the common purpose of balancing the system. Valve types include:

- <u>Three-way valves</u>. Most associated with constant volume systems, these devices are used to modulate water flow to the load without changing the constant volume of water flow to the system.

- <u>Two-way valves.</u> Most associated with variable speed/variable volume systems, these devices modulate flow to the load by changing the constant volume of water flow to the system.

- <u>Manual balancing valves</u>. These have an adjustable orifice that can be changed by hand to provide a specific pressure drop and flow.

- <u>Flow-limiting valves</u>. These valves vary the flow based on differential pressure to provide a specific flow rate.

The Water Chilling Cycle Step 5: Heat Exchangers
The next phase in the process is transferring the heat from any processes being cooled along the network (e.g., pasteurization) to the chilled water system. The same types of heat exchangers listed in Step 1 are also used in this process.

The Water Chilling Cycle Step 6: Air Management
Air in a closed Hydronic system can be managed by using one of two methods. A compression tanks allows the air and the system water to touch and the air in the system is not required to be bled from the system. An expansion tank physically separates the air and system water using a diaphragm or bladder. When expansion tanks are used in a closed system, air must be completely bled from the closed system.

Because air has to be taken out of the system for it to work effectively, expansion tanks are used to allow the water room to expand and contract during temperature fluctuations in the chilled water systems operation. In particular, tanks are used to improve air management include:

- Compression tanks. In these tanks, air is separated from the system by the air removal device and serves as the expansion point for the system.

- Inline Air Separators. These separators operate by collecting air off the top of the water flow. The air is then directed back to the compression tank and vented to the atmosphere. The sizing of this type of air separator is based on the velocity of the water which is determined by the flow rate.

- Centrifugal Force Air Separators. This type of air separator uses tangential nozzles to create a vortex at the center of the vessel. Since the air is lighter than the water the air is collected in the whirlpool of the vortex and directed back to the compression tank so that it can be vented to the atmosphere.

- Automatic Air Vents. Selected based on the system operating pressure and their venting capacity, these float-type devices are, for the most part, sized based on system maximum working pressure more than the discharge capacity of the valve.

How Do They Do It?
Designers and engineers of chilled water systems use a number of different tools to create an optimal chilled water solution. These include the psychometric chart and air flow calculations; sensible and latent load calculations; existing room data, including constraints on the space as well as the refrigeration system; manufacturer's data, including catalog ratings and selection software data; and analysis of all collected data and computed calculations. For example, the following formula, which expresses the relationship between chilled water temperature and water flow, is one of the most widely used by engineers to answer specific questions regarding the operation of the chilled water system:

1 ton of refrigeration = 1 T_R
1 T_R =144 BTU/lb x 2000 lb/day x 1 day/24 hours
1 T_R =12,000 BTU/hr

Q=cooling load in BTUs
Q=GMPx500x ΔT°F

Where…
- British Thermal Unit (BTU) is the quantity of heat required to raise the temperature of one pound of water by one degree Fahrenheit.
- Gallons Per Minute (GPM) is the flow rate of a fluid.
- Mean Temperature Difference (ΔT) is the change between the inlet temperature and outlet temperature of a unit mass.
- Dry bulb temperature (°F) is the temperature of the room as measured with a standard thermometer.

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- Diaphragm tanks. These tanks, which feature a resilient membrane placed between the system liquid and a pre-charged air head in the tank, allow expansion and contraction to occur without direct contract between the system liquid and the air charge.

- Bladder tanks. In these tanks, the bladder is installed inside the tank (similar to the diaphragm tank) and the air charge is contained within the bladder like a balloon.

Understanding Your Own Complex System

With all of its interconnected, looped systems of pumps, valves, heat exchangers, etc., a qualified engineer can be of invaluable assistance in helping you better understand your chilled water system from the inside out and operate it at peak efficiency.

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