Chilled Water HVAC Systems

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Types of water based systems:
There are three types of HVAC systems that utilize water as a heat transfer medium. The first system, which is used for cooling in dry climates, is called the "Swamp Cooler." This system employs a fan that blows outdoor air or return air over a revolving drum. The drum is covered with a sponge-like material and the lower portion of the drum is immersed in water. As the air passes over the drum, the air temperature is lowered, and the relative humidity of the air is increased as water on the drum evaporates. This evaporation process will remove 760 BTU per pound of water evaporated. However, as mentioned earlier, the process only works in dry climates where the air has a moisture content that is low enough to allow it to accept the additional moisture from the evaporation process.

The second water-based system uses a constant source of water at a temperature of 80°F or less to condense the refrigerant vapor in a standard mechanical refrigeration circuit. This water is called condenser water. This type of unit is known as a packaged water-cooled air conditioner. Condenser water is normally provided by a mall or a large building for use by its tenants. The building then maintains a cooling tower that is used to cool the condenser water and pumps that are used to circulate the water. This type of system is used where there is limited access to outdoor areas such as roofs for placement of outdoor equipment. We will deal with water-cooled systems in detail in a future article.

The third type of water based air conditioning system is called a chilled water system. Chilled water systems utilize a constant source of water at a temperature of approximately 45°F. This water can be provided by a central building chilled water plant, an off-site utility that sells chilled water, or by the tenant's own packaged chiller. Most retail stores with less than 40,000 square feet of floor space do not have their own chillers and depend on Landlord furnished chilled water.

Chilled water system description and operation:
For our purposes, let's assume that the Landlord is providing an uninterruptable source of 45°F chilled water to the building. This water is distributed throughout the building via a piping network. The large horizontal pipes are called mains, the small piping leading to each tenant space are called branches, and the vertical runs are called risers. The chilled water piping is heavily insulated and the insulation is covered with a vapor barrier, which is impervious to moisture. These pipes are carrying a low temperature liquid, and if they were left uninsulated, moisture from the air would condense on the outside of the pipes and drip onto anything below the piping. In addition, heat would be transferred to the piping from the air resulting in wasted energy and a rise in the chilled water temperature.

One or more air handlers serve each tenant. An air handler is a sheet metal box that contains a fan and a cooling coil. The cooling coil is made of copper tubing bent into a serpentine shape with aluminum fins bonded to the copper tubing to increase the heat transfer area. The air handler also contains air filters that remove impurities from the air that is being drawn over the coil by the fan. The fan is also called a blower. A motor drives the blower via a drive belt that has a V section. The air handler may also be furnished with a heating coil that adds heat to the air when heat is required.

Most chilled water air handlers contain a section called a mixing box. The mixing box is a sheet metal section with two openings in it. There is a duct connected to each opening and a damper located within each opening. One duct is used to bring return air from the conditioned space back to the air handler. The second duct is connected to the outdoors and is used to introduce outdoor air for ventilation purposes.

Operation of a system like this is simple. The fan runs continuously, drawing a mix of outdoor air and return air through the air filters. The air is then heated or cooled as it passes over hot coils or cold coils. Chilled water flow to the cooling coil is controlled by a motorized valve. If the space temperature is at or below the setpoint of the thermostat, the motorized valve closes. If the thermostat is not satisfied, the motorized valve opens causing chilled water to flow through the coil.

If the air handler is equipped with a hot water heating coil and a chilled water-cooling coil the system is known as a four-pipe system. In some buildings, the same coil is used for both heating and cooling. During the cooling season, chilled water is circulated through the piping system that serves the air handlers and during the heating season, hot water is circulated through the system. This is known as a two-pipe system. Sometimes heat is provided by an electric resistance coil, a steam heating coil, or a gas fired duct furnace instead of being provided by hot water.

Most chilled water air handlers are installed with outdoor air ducts that can deliver the full volume of air the unit is designed to circulate. This oversized outdoor air duct, the mixing box, and the addition of certain controls, forms the components required for an economizer cycle. When outdoor air temperatures are below a threshold value of approximately 55°F, outdoor air may be used for cooling in lieu of using chilled water. This is an energy saving device in four pipe systems and a necessity in two pipe systems. In buildings with two-pipe systems, the building may be circulating hot water in an attempt to provide heat, while some spaces with high internal loads require cooling. Under these circumstances, outdoor air is the only medium available to provide cooling.

Chilled water system issues:

Insufficient flow:

The most common problem we find with chilled water systems is insufficient water flow to individual air handlers. In a mall, for example, the piping to each tenant's air handler forms a parallel path between the supply and return mains. Water will follow the path of least resistance; therefore, the more resistance to flow (friction) in each path, the less water will flow through that path. The total resistance to flow in any path is a function of the length of run, the diameter of the piping, the resistance of the coil, and the resistance of the valves and fittings. Distance from the pump also plays a role, as does the piping layout. Balancing valves are installed on each branch to add resistance to flow in order to guarantee that each branch receives the volume of water it was designed to handle.

When the system is installed a test and balance contractor sets each valve to balance the flow to each air handler according to the engineer's design. Over time, people change the settings on the balance valves to increase the flow to their individual units in an attempt to increase cooling capacity. Sometimes, individual tenants will add a booster pump to their branch piping in an effort to increase the flow to their air handler. Unfortunately, increasing flow to one air handler decreases the flow to other air handlers served by the same piping system. Your system may be operating perfectly today; another tenant makes some changes and you have insufficient capacity tomorrow.

Another cause of reduced water flow is dirty strainers. Wire mesh strainers are installed at each air handler, upstream of the control valve and the coil. The purpose of the strainer is to protect the valve and the coil from rust and mud that collects in the piping system. Over years, the strainers remove the solids from the chilled water system. As the openings in the wire mesh are covered the strainer begins to offer more resistance to water flow. This reduces the flow, which reduces the ability of the air handler to transfer heat. Strainers should be "blown down" or cleaned at least once each year. If they tend to get clogged, they may need to be cleaned more often.

Dirty coils:

The next most prevalent problem is dirty chilled water coils. Air handlers have a usable life span of up to 30 years. Over time, chilled water coils become obstructed with airborne dirt that renders them inefficient. Unlike mechanical refrigeration units, which freeze-up and leak when the indoor coils get plugged, chilled water coils just become less and less efficient until they reach a point where they cannot deliver enough capacity to cool the space.

Condensate leaks:
Like most air conditioning systems, chilled water systems drop the temperature of the air below the dew point in order to remove moisture from the air. The moisture condenses on the cold coil surfaces and drips down the fins till it collects in a drain pan that sits under the chilled water coil. This condensate is supposed to drain by gravity from the pan into an indirect waste connection. If the pan outlet or the drain line becomes clogged with debris, the condensate overflows the drain pan. All air handlers should be installed with a secondary drain pan to catch any leaks. This secondary pan should be furnished with a water detector that shuts down the unit, or with its own separate drainage piping.

Sometimes air handlers develop condensate leaks due to a process known as carry-over. Carry-over occurs when the droplets of moisture that condense on the coil are blown off of the coil into the air stream rather than dripping down the finned surfaces. If the velocity of the air through the coil is too high (usually over 500 feet per minute) the water droplets can become airborne. A partially restricted coil surface or an attempt to increase the airflow above the manufacturer's rated airflow can cause high air velocity.

Condensate leaks can also occur if the insulation on the chilled water piping gets damaged. The temperature of the piping is well below the dewpoint of the air in the space, and moisture will condense on any exposed piping and begin to drip. This usually further saturates the insulation on the piping and the wet insulation becomes cold enough to cause moisture to condense on the insulation. This continues until the drip hits something or someone important.

High chilled water temperature:
Normally chilled water is delivered into the piping system at a temperature between 42°F and 46°F. This is the water temperature that should be present at the supply connection on the air handler. Some buildings vary the temperature of chilled water with outdoor temperature change. This is called reset. In an effort to save energy, a building may install a control system that resets the chilled water temperature upward as the outdoor temperature drops. The theory is, that as outdoor temperatures decrease there is less of a need for cooling and the cooling requirements can be met with higher temperature water or less water. They may deliver 42°F water at 95° outdoor temperatures and 50° water at 65° outdoor temperatures. Unfortunately, in a retail store the load on a 65°F day may be almost as great as the load on a 95°F day. When the building resets the chilled water temperature, the store receives insufficient cooling.

We have also seen high chilled water temperatures caused by situations where one tenant, with a booster pump has an air handler that is piped backwards. This tenant draws 55°F water from the return main and discharges 65°F water into the supply main. The result is that the supply water temperature reaching all tenants downstream is several degrees higher than it should be. This reduces the capacity of the air handlers downstream.

Change-over problems:
As stated earlier, some buildings utilize the same piping systems and coils for both heating and cooling. Almost all buildings in seasonal climates shut down their chilled water supply when outdoor air temperatures drop below 50°F. Some buildings specify dates in their leases when chilled water will be available. During certain times of the year, in certain geographic locations, heating is required in the morning, cooling is required in the afternoon and the outdoor temperatures in the afternoon are above 65°F. Two pipe systems cannot be switched quickly from hot water to chilled water. This is due to a number of issues. If a building has a two pipe system, or management provides chilled water between certain dates, there will probably be certain times when the most heavily lit and most densely populated stores in that building cannot be cooled sufficiently. Economizers work, but as outdoor temperatures rise above 55°F it becomes impossible to cool a retail store with outside air only.

Winter freeze-ups:
The most devastating problem that can occur with a chilled water air handler is freezing of the chilled water coil. As water within a finned coil freezes, it expands. As it expands, because the water is trapped within the tubes of the coil, it expands the tubes. The tubes, limited in their ability to expand then split. The tubes actually appear to have blisters, which popped open. Usually, when a coil freezes, the splits are so numerous that the coil cannot be repaired and must be replaced.

Freeze-up occurs due to many situations. Usually, the coil is exposed to outdoor air at temperatures lower than 32°F. The source may be an outdoor air damper that gets stuck in the open position, or the heating coil may have been installed downstream of the cooling coil, and the minimum outdoor air brought in for ventilation purposes is enough to freeze the coil. Sometimes, the heating system fails, and the entire space drops below 32°F causing the coil to freeze.

One sure way to prevent freeze-ups is to drain the chilled water coil after each cooling season, and valve the coil off. If there's no water, there can be no freeze damage. In addition, every chilled water air handler installed in an area where outdoor air temperatures drop below 32°F should be equipped with a freeze-stat. This control is wired to shut down the fan, close the outdoor air dampers, and bring on heat (if possible) to prevent the coil from freezing. In extremely frigid areas, a run-around cycle with a separate pump is used to keep the water in the coil moving fast enough that it cannot freeze. Another sure method of freeze protection is to circulate a mixture of propylene glycol and water that has a freeze point lower than the coldest outdoor ambient temperatures experienced in a particular geographic location. If you maintain stores that are served by chilled water systems, and the circulated fluid is water, I strongly recommend that you make certain that they are drained each winter. Otherwise, sooner or later a component will fail leaving you with a burst coil and a soggy mess when the system is filled in spring.

Troubleshooting:
With some very basic information, the facilities manager can troubleshoot and diagnose chilled water systems. Back in HVAC 101, you learned that the definition of a BTU (British Thermal Unit) is the amount of heat required to raise the temperature of one pound of water one degree Fahrenheit. Now that useless bit of information comes in handy. Let's say the entering water temperature is 45°F and the leaving water temperature is 55°F. (Most chilled water systems are designed for a 10°F to 12°F rise through the air handler.) If we know the flow rate in gallons per minute, and we know that water weighs approximately 8.3 pounds per gallon, and there are 60 minutes in an hour, we can determine the amount of heat in BTU's per hour that are being transferred by the air handler to the chilled water. A ton of air conditioning is defined as 12 000 BTU's per hour, and therefore we can determine the number of tons of cooling that we are using.

Here's an example. If the chilled water temperature rises 10°F as it flows through the air handler, and the flow rate is 50 gallons per minute, we get the following: 50 GPM X 60 minutes per hour X 8.3 lb./gallon X 10°F= 249,000 BTU's per hour. If we divide by 12,000 BTU's per ton we get 20.75 tons. The flow rate can usually be obtained by installing a differential pressure gage across the balancing valve that is installed on the system. If we can't obtain the flow rate, the relationship above still gives us information about the system. Most chilled water air handlers are designed for a leaving air temperature between 50°F and 55°F. If the leaving air temperature is above 55°F <u>and</u> the difference between the entering and leaving chilled water is greater than 10°F, you are not getting enough chilled water from the building system. If the entering chilled water temperature is around 45°F and the difference between the entering and leaving chilled water is significantly less than 10°F, you are not getting good heat transfer from the coil. This could be due to low airflow, or a dirty coil. If the leaving air temperature is 55°F or less, the entering chilled water is around 45°F, and the difference between entering and leaving chilled water is around 10°F, and the blower motor is drawing its rated current, most likely the air handler is undersized for the space it is cooling.

If you look at the mechanical plans for a store, you will find that the mechanical engineer usually lists a schedule for each chilled water air handler, specifying the entering and leaving chilled water temperatures, the flow rate, and the leaving air temperature. Compare this information with the temperature readings taken by a technician in the field and you will be able to determine the cause of an insufficient cooling problem on a chilled water system. You will also be armed with the knowledge and information you require to discuss the situation with the building Management Company if it turns out that you're not receiving enough flow, or the chilled water temperature is too high. You don't need to be an HVAC technician or an engineer to deal with these issues. Like most things, all you need is a little knowledge and the correct methodology.