MECHANICAL SYSTEM SOLUTIONS: CHILLED WATER

Ali Buron, PE
Associate, Mechanical Engineer

BAIRD, HAMPTON & BROWN
building partners

Mechanical System Solutions

The Components to Keeping your Facility Running Successfully

At BHB, we understand that the least glamorous aspects of a building are often the most vital. Regardless of the type of facility you operate, it goes without saying that you want your occupants to be comfortable. Selecting the best HVAC system for your building and maintaining it properly is paramount to successful operations; in some facilities such as healthcare or food service you may even face legal requirements that a certain temperature be maintained for safety reasons.

From industrial warehouses to museums housing precious artifacts, every building owner will be faced with the following considerations when choosing an HVAC system:

- Initial cost to install
- Maintenance requirements
- Operating cost
- Available space for indoor or outdoor equipment
- Efficiency
- Acoustics

Our team of mechanical engineers kicks off each project by establishing a thorough understanding of your facility's intended use, space requirements, and any special prerequisites. We will also work with our in-house civil, electrical, and structural engineers to verify that site utilities are suited to the building's requirements and equipment can be safely supported. After our engineering analysis, we will design a system to meet the unique needs of your building.

There are many different options when it comes to commercial HVAC systems. In this four-part series, we dive into the following:

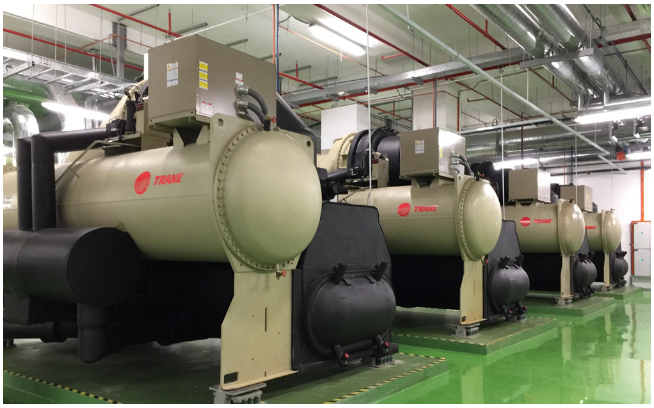
- Variable refrigerant flow (VRF)
- Geothermal heat pumps
- Direct expansion rooftop units (DX RTUs)
- Chilled water systems

Chilled Water Systems

Overview

Chilled water systems work similarly to direct expansion (DX) systems with the exception that instead of refrigerant, water flows through the system. The chiller uses an internal refrigeration cycle to chill water in a chiller barrel. Once inside the chiller barrel, the chiller removes heat from the water through heat transfer to a colder internal refrigerant loop. Water is then pumped through the chilled water system where it eventually passes through air handling unit coils and the water removes heat from the air stream, cooling the building.

The two main types of chillers used in commercial construction are air-cooled chillers and water-cooled chillers. Air-cooled chillers are located outside the building and remove heat from the chilled water by rejecting the heat directly to the atmosphere. Water-cooled chillers can be installed outside, but are typically found inside of the building. They remove heat from the chilled water by rejecting the heat to a separate condenser water loop. The condenser water is piped to a different heat exchanger, a cooling tower, that uses evaporation to ultimately reject the heat to the atmosphere. Though both chillers reject heat to outside, the water-cooled chiller uses the evaporation of water in the cooling tower to transfer large amounts of heat with lesser energy required to initiate the process.



Water-cooled chiller and storage tank located inside of an industrial building

Air-cooled chiller located on the roof of a large industrial building

Chilled water systems are typically used in medium and large sized commercial buildings, where it is more cost-effective to use a centralized system and the required maintenance can be performed by building personnel. Smaller facilities can also benefit from the operating efficiency of chillers, but the first cost of a chilled water system for smaller projects is often enough to dismiss it in favor of less costly alternatives.

Advantages and Disadvantages

Advantages

Efficiency

Chilled water systems are more energy efficient and thus more cost-effective to operate than direct expansion (DX) air conditioning systems. This can be a significant advantage in large commercial buildings where the extra efficiency yields monthly operating cost savings. Therefore, they often allow a good return on investment in a relatively quick time frame.

The efficiency of an air-cooled chiller is dependent on the temperature of the ambient air being used as the heat sink. Therefore, the warmer the outside temperature, the harder the chiller refrigerant cycle needs to work in order to reject heat to the air. As stated before, water-cooled chillers use the evaporation of water in the air to reject heat, which is still affected by ambient conditions, but can be accommodated with additional cooling tower surface area or larger cooling tower fans that still consume less energy than the chiller itself.

Water is better at absorbing heat than air and carries more heat per kilogram. It also uses less space than air for a given mass. In fact, if equal masses of water and air were to absorb the same temperature rise, water absorbs over four times as much heat. When chilled water is used, indoor heat can be removed with a smaller fluid mass, and hydronic piping is more compact than air ducts. Also, compared to refrigerant, water is plentiful and inexpensive, further contributing to the overall cost savings of a chilled water system.

Water-cooled chillers generally operate around 0.50 to 0.60 kW per ton of cooling produced. With different piping techniques (like series, counterflow arrangements), this can be as low as 0.35 kW per ton with certain variable speed chillers. Air-cooled chillers generally operate at a higher load demand, as high as 1.1 kW per ton of cooling, depending on ambient conditions. So, a decision needs to be made - does it make sense to introduce a cooling tower for your system to get the increased operating efficiency? Each project will be different, but our engineers can help with the cost payback analysis to help you decide.

Reliability

Year-round availability of heating and cooling at each zone independent of the mode of operation in other building spaces makes for a reliable system and comfortable environment for building occupants. Individual room temperature control allows each thermostat to be adjusted to a different temperature (within a finite range) with greater ease than the DX options available, offering greater system flexibility to change as the needs of the facility change. In addition, thermostats can be set to maintain a dead-band between heating and cooling to prevent simultaneous heating and cooling, further reducing operating cost. There are also no seasonal changeover requirements.

Life Expectancy

The ASHRAE Handbook estimates that the median life of a chilled water system is about 25 years with proper repair and preventative maintenance. Typically chillers, especially water-cooled, have a longer lifetime expectancy than that of packaged DX equipment, which is estimated to have a median lifespan of 15 years.

Disadvantages

Initial Cost

Chillers require a higher initial investment than other systems. However, as previously discussed, they allow for a more efficient system and therefore save money on energy consumption throughout the lifetime of the system. According to manufacturing company Daikin Industries, the expected cost per ton of cooling for a chilled water system can be between $9,000 and $12,000 per ton.

Ease of Maintenance

With chilled water systems, the terminal equipment that actually cools the air in the spaces and buildings, can either be installed in central mechanical rooms or above the ceilings in the spaces they serve. This can provide for easier maintenance because equipment is readily accessible or centralized. Also, the terminal equipment is generally a fan and coil, so the major equipment is located outside or in a central plant. With the chiller, pumps, chemical feed, and controls located in a central plant in the building, major service and maintenance can be done with minimal impact to the building occupants.

Redundancy

Due to the higher initial cost of a chilled water system, redundancy is typically only built into the system at the request of the owner. This can allow for a single mode of failure. If the chiller were to malfunction, all zones would lose temperature control. For many projects, redundancies may be required to ensure that systems do not experience any downtime. Multiple chillers and pumps can be used to split the total building load so only a portion of the building would be down if a chiller were to fail.

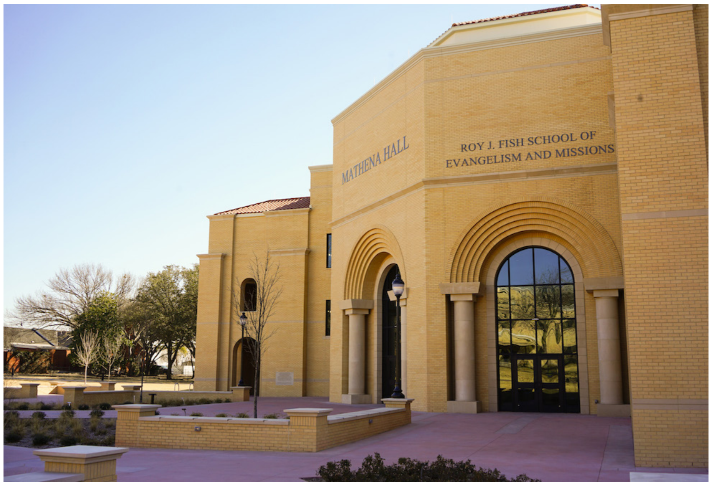
If redundancy is a requirement for the project, we will plan for the additional infrastructure very early in the design phase. For a smaller up-front cost, we can plan for future equipment in the design without compelling the project to spend the additional capital now. This would be handled with room in the central plant that is dedicated to future chillers or pumps, and piping and valves would be in place to allow these future components to be easily added when the time is right. Even an air-cooled chiller, mounted remotely away from the chiller plant, can help avoid operational issues in the event of a chiller failure.

Summary

Chillers are used in a variety of comfort air conditioning and process cooling applications. Chilled water systems are especially suited to applications with large consistent cooling loads, and where maximizing equipment service life and using energy and operational workforce efficiency are important.

Case Studies

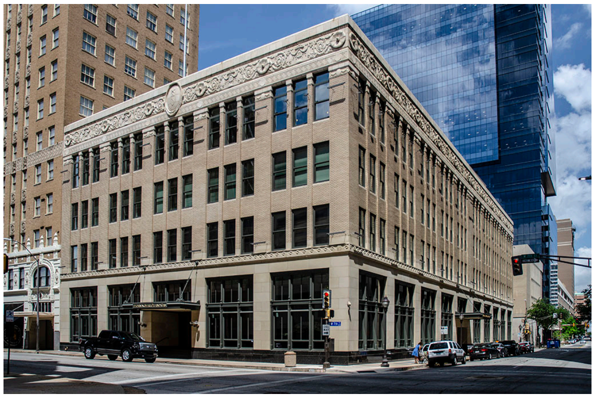
Southwestern Baptist Theological Seminary



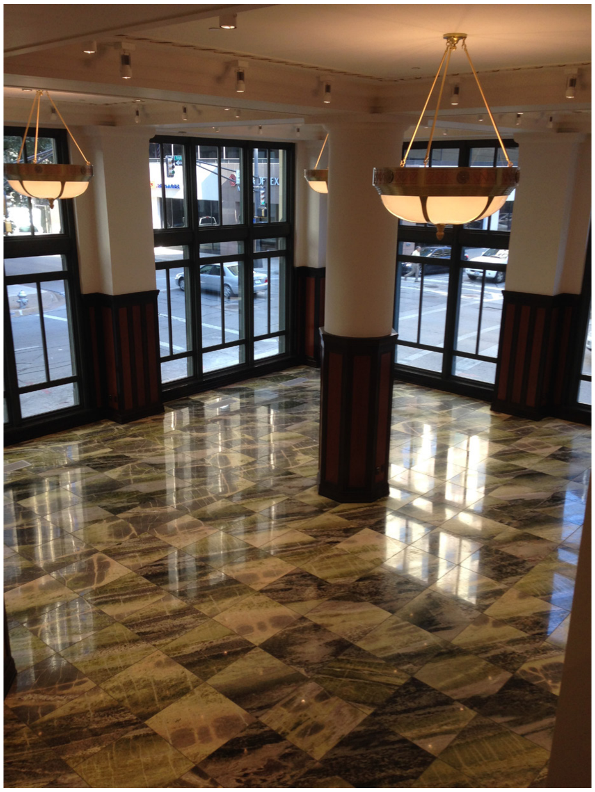
In preparation for the addition of a new 100,000 square-foot office and education building to the existing campus of 22 conditioned buildings, SWBTS involved BHB to determine if sufficient capacity existed for the addition, as well as any potential for reductions in energy consumption by the chiller plant. The Seminary used two existing chiller plants, with a combined total of more than 2,000 tons of cooling capacity. BHB broke this task into several distinct phases - initial site investigations, analysis and simulations, and finally delivering recommendations to the owner.

After monitoring the health of their system over time, we determined that the flow rates of several buildings were unusually high due to wild AHU coils (those which fail to control the flow), leaking two-pipe system bypass valves, and constant volume pumps – all symptoms of an aging system. Energy modeling of the chilled water distribution system confirmed that the flow rate was indeed the source of the system's limitations, rather than total chiller capacity. We proposed several potential modifications to the system, including repair of existing bypass valves, the addition of variable frequency drives (VFDs) to existing pumps, and connecting the two distribution systems to add redundancy. Although some upfront capital would be needed, much of the improvements could be paid for with cost savings from previous energy reduction measures. The end goal of our presented plan was to reduce the Seminary's chilled water flow rates and increase their temperature difference when cooling.

400 West 7th Street – Historic Star-Telegram Building/Office Renovation



The approximately 180,000 SF building was originally constructed in three phases: the original 60,000 SF four-story building; the 1946 addition of 50,000 SF; and the final 1968 expansion of 75,000 SF. BHB began working with MorningStar Oil & Gas on the building's renovation in 2011.



The building had significant loads and a designated mechanical space which made it a perfect candidate for a central chilled water system. It was also finished out in phases, which allowed us to make provisions for estimated future demands of the building. As part of this project, we installed new chilled water infrastructure and a new 75-ton chiller. As the building was finished out, and loads increased, we eventually replaced an existing 400-ton chiller with a new 300-ton chiller. Replacement allowed us to adjust to better fit building loads that have changed and improve performance. It also allowed us to operate closer to peak efficiency, as opposed to incorrectly sized units that are forced to operate at low loads for extended periods of time. It also saved on the cost of installing extra capacity.

We strategically selected differently sized equipment to provide better part-load capability and efficiency. With the use of multiple chillers, we were able to also provide a wider range of operation without cycling on and off. Equipment operation was staged to match load profile and allowed select pieces of equipment to be taken off-line for maintenance.

As part of the equipment replacement, we installed variable-frequency drives on the chilled and condenser water pumps, which allowed for flexibility in control and energy efficiency of chiller and plant operation.

By selecting ancillary equipment, automatic control, and facility management, we were able to customize the plant without sacrificing the standardization, flexibility, and performance required of the primary cooling equipment.