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CLOSING THE LOOP – WHICH METHOD IS BEST FOR YOUR SYSTEM?

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Which Method is Best for Your System?

Abstract

Closed loop cooling systems deliver many benefits compared to traditional open loop systems, such as reduced system fouling, reduced risk of fluid contamination, lower maintenance, and increased system reliability and uptime. Several methods are used to close the cooling loop, including the use of an open circuit cooling tower coupled with a plate & frame heat exchanger or the use of a closed circuit cooling tower. This study compares the total installed cost of open circuit cooling tower / heat exchanger combinations versus closed circuit cooling towers, including equipment, material, and labor costs. Additionally, this study will contrast the operational and maintenance aspects of the two alternatives to help system designers and operators make the best heat rejection choice for their next project.

Open Cooling Loops

Evaporatively cooled, open cooling loops are the most common and efficient method of heat rejection available today. Open circuit cooling towers enable direct contact of water with the cooling air over a heat transfer surface known as “fill.” The fill, typically fabricated of plastic, provides a large volume of surface area for the water and air to mix. A small portion of the water is evaporated, cooling the remaining water towards the wet bulb temperature, which is always equal to or less than the dry bulb temperature of the entering air, providing a psychrometric advantage over traditional dry cooling. It takes approximately 1,000 BTU (0.293 kWh) of heat to evaporate one pound (0.23 kg) of water in this process, reducing the volume of cooling air that must be used versus air cooled alternatives which transfer only 1.05 BTU per pound of air per degree Fahrenheit (4396 J/kg·°C).

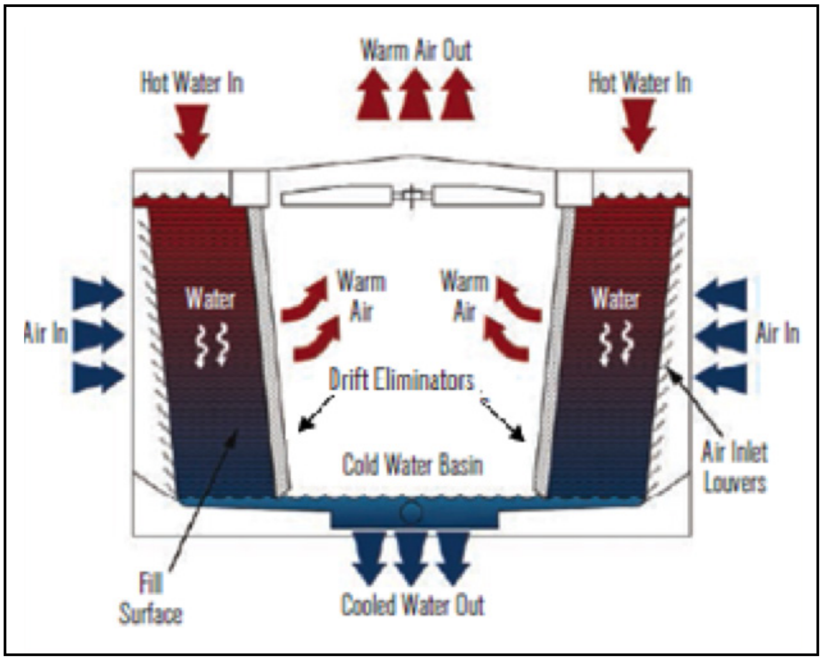


Figure 1 Induced Draft Crossflow Cooling Tower Schematic

Open circuit cooling towers are available in many configurations as well as capacities. Axial fan, induced draft crossflow designs as shown in Figure 1 offer low fan energy and great access to key components for maintenance, such as the fan and water distribution systems. Axial fan, induced draft counterflow designs (Figure 2) also offer low fan energy and a compact footprint, especially in the smaller tonnage range though maintenance access is reduced versus crossflow arrangements. Centrifugal counterflow designs, illustrated in Figure 3, are available for indoor applications, which can be an advantage for units located in cold weather areas or high security applications, and are capable of handling external static pressure. Centrifugal fan designs are generally quieter than their axial fan counterparts but low sound axial fan units are also available. Attenuation packages are available for all types of units for especially sound sensitive applications.

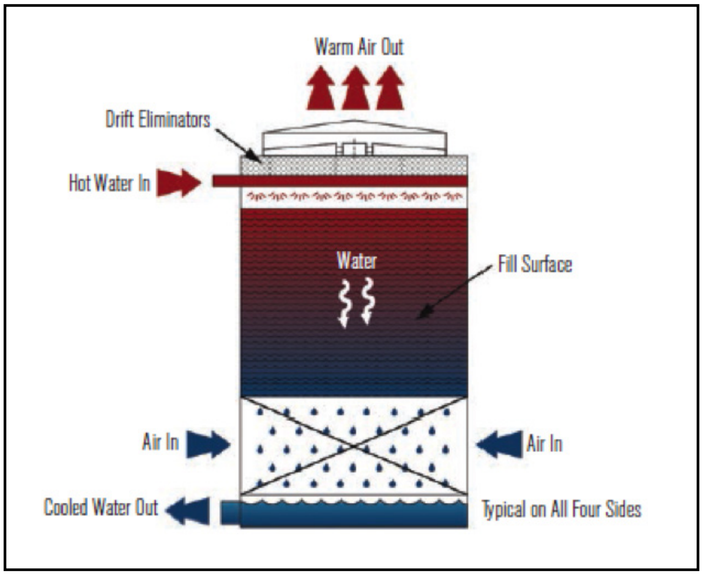


Figure 2 Induced Draft Axial Fan Counterflow Cooling Tower

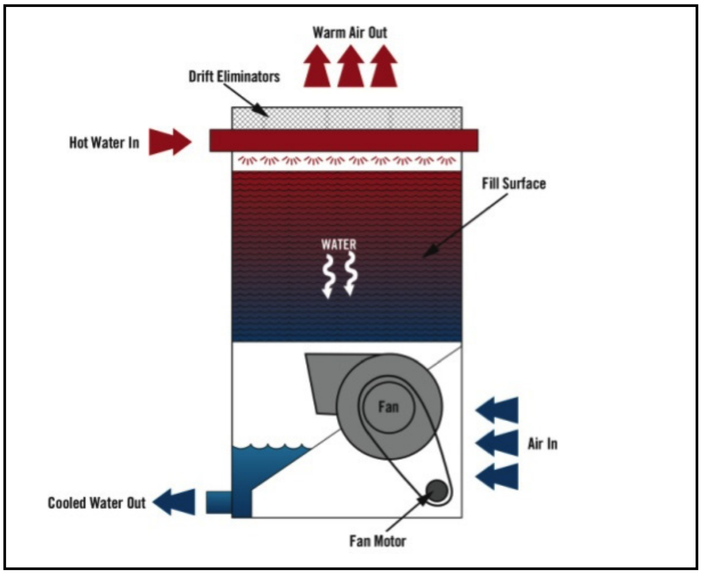


Figure 3 Forced Draft, Centrifugal Fan, Counterflow, Open Circuit Cooling Tower

Being open directly to the atmosphere, however, allows the cooling water in an open circuit cooling tower to potentially be exposed to airborne contaminants. A small portion of the recirculating water must also be bled from the system to keep the level of minerals in the water under control, which are left behind from the evaporated water. To maintain peak system efficiency over time, the cooling loop must be properly treated and kept clean, in some cases with the help of side stream filtration. Keep in mind that cooling towers recycle more than 98% of the recirculating water, resulting in tremendous reductions in both water and energy use versus either once through or air cooled systems.

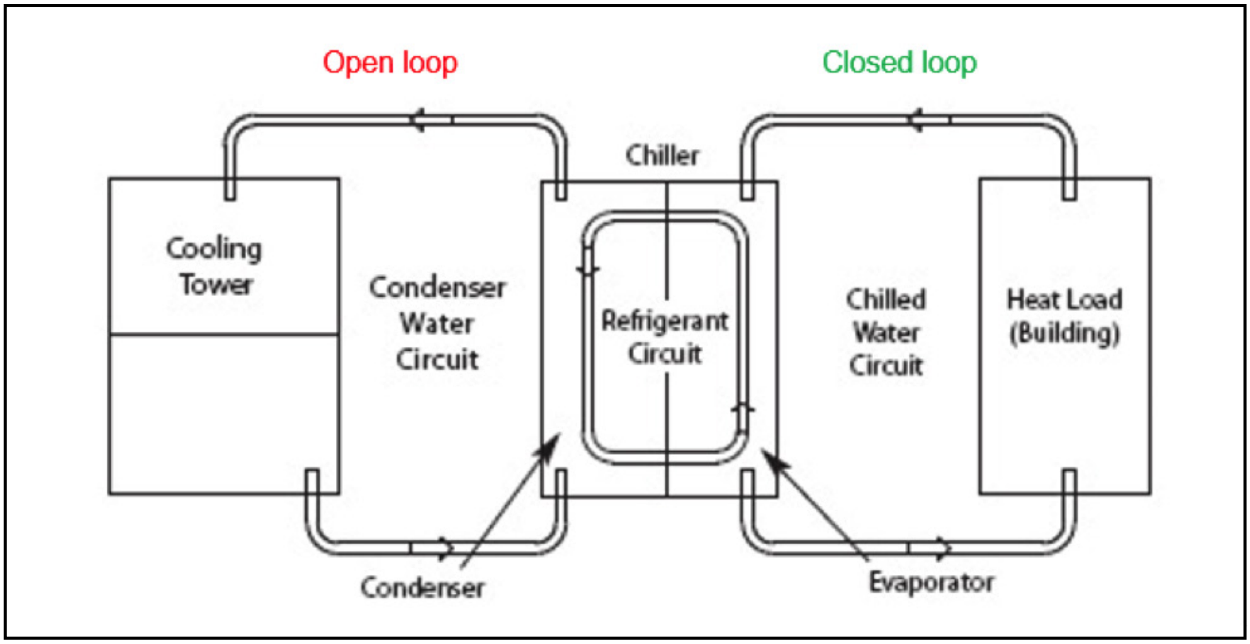


Figure 4 Typical Water Cooled Chiller System

Besides the cooling tower, system components, such as the shell and tube condenser in the water cooled chiller system shown in Figure 4, are subject to fouling from the open loop water (reference Figure 5). As an example, the standard fouling factor for the closed loop evaporator (chilled water) side of the chiller is 0.0010 hr-ft^2-°F/BTU (0.000441 °C-m^2/W), while the fouling factor for the condenser on the open loop side is 0.0025 hr-ft^2-°F/BTU (0.00018 °C-m^2/W) per AHRI 550 / 590, the rating standard for chillers. Over time, fouling may approach or even exceed this level on the open loop side, at which point heat exchanger cleaning must be considered to restore performance to an acceptable level. In a poorly maintained system, the fouling factor for the condenser can reach many times this value, resulting in extremely poor performance and significantly higher energy consumption.

Figure 5 Shell & Tube Heat Exchanger Before and After Cleaning

Closing the Cooling Loop

System designers can also choose to “close the loop” when designing a heat rejection system. Closed loop cooling systems contain process fluids in a clean, closed loop isolated from the external environment. Many traditional open loop cooling systems, such as water cooled chillers and many process heat exchangers, can benefit by “closing the loop.” Other systems, such as water source heat pumps, water cooled VRF, modular chillers, and air compressor installations must utilize a closed loop for proper long term operation due to the use of relatively small, distributed heat exchangers with tight heat transfer passageways. These small heat exchangers are typically coaxial tube-in-tube or brazed plate designs, as shown in Figure 6, which are difficult or impossible to clean, either mechanically or chemically. Even a small amount of fouling or scale in these high performance units can have an outsized negative impact on their thermal efficiency.

Figure 6 Examples of Heat Exchangers with Small Passageways – Brazed Plate (left) and Coaxial Tube-In-Tube (right) Heat Exchangers

Whatever the application, the benefits of closing the loop include:

- **Higher Operational Efficiency:** Closed loop systems prevent oxygen and debris from entering the process cooling system, reducing the buildup of corrosion and environmental contaminants as well as limiting the risk of organic growth. Reducing the fouling of heat transfer surfaces help to maintain high thermal performance resulting in up to a 30% system energy saving versus traditional open loop designs. In addition, closed loops often have lower pumping power requirements than traditional open loops.

- **Lower Maintenance and Water Related Costs:** Closed loop systems deliver reduced maintenance and downtime costs due to significantly lower fouling as described above. They can also reduce water and water treatment costs due to the lower open circuit spray water volume, generally higher allowable cycles of concentration, and a reduced need for side-stream filtration as compared to traditional open circuit systems.

- **Greater Reliability:** Reduced fouling translates into reduced wear and tear on many system components leading to extended maintenance intervals as well as fewer unplanned shutdowns.

- **Longer System Lifetime:** As a clean system does not have to work as hard as a dirty system, reduced operational stress on the system can extend the life of mechanical equipment and pipework. Reduced system maintenance requirements can also contribute to extended equipment lifetimes.

- **Location Flexibility:** The closed loop allows System Designers to locate the heat rejection at grade or even below the load, providing design flexibility and potentially lower installation costs. Architects can also take advantage of this feature to help the heat rejection equipment better “blend” with the aesthetics of the building.

These advantages can be especially beneficial on critical applications where system downtime can be costly or interfere with life safety systems, such as data centers, 911 Emergency Call Centers, and large petrochemical facilities.

How to Close the Loop?

Many options are available to close the heat rejection loop, including:

- **Dry Coolers:** Dry coolers, which are typically finned tube heat exchangers, can cool the process fluid within 10°F to 15°F (5.6°C to 8.3°C) of the entering dry bulb temperature of the air, so in warm climates the process temperatures can be quite high. Relatively large amounts of air need to be moved at a high fan energy cost with this technology.

- **Adiabatic Fluid Coolers:** Air is adiabatically cooled towards the wet bulb temperature of the air by being pulled through wetted pads before entering a finned tube heat exchanger. This lowers the process fluid temperature that is achievable and reduces the required fan energy but adds cost and complexity.

- **Ground Source Heat Exchangers:** These heat exchangers, typically made of plastic, are placed underground, typically in wells or submerged in lakes, where they rely on the low ground temperatures to either reject or absorb heat. Large amounts of piping as well as ground space is required. The “free cooling’ from the ground is offset by the significant capital costs for the ground source heat exchanger, well fields, etc. Hybrid ground source systems, which incorporate a fluid cooler to supplement the cooling effect of the ground, can reduce initial cost while still achieving high energy efficiency at lower risk.[1]

- **Direct Cooling or Condensing of the Process Fluid:** Rather than using an intermediate cooling fluid, some systems pipe the fluid or gas to be cooled directly to the heat rejection device, such as an air cooled condenser, evaporative condenser, or oil cooler. However, this method often increases the process fluid / gas volume in the system which can be a detriment in some cases.

**Figure 7 Some Options to Close the Loop -
Dry Cooler, Adiabatic Fluid Cooler, and Ground Source Heat Exchanger, Respectively**

The two most efficient options in terms of both first cost and system energy consumption are the use of an open circuit cooling tower + heat exchanger combination and a closed circuit cooling tower, often called a “fluid cooler.” Both have been successfully applied on closed loop cooling systems for many decades. Each alternative can be designed to supply the same process fluid temperature to the system, so the efficiency of the process (less the heat rejection system) is identical. So given these two alternatives, what are the key considerations to determine the best choice for your next project?

Certified Thermal Performance

When comparing any heat rejection alternative, first be sure to “level the playing field” and specify independently certified thermal performance whenever possible. Doing so will allow for fair comparisons of the alternatives while helping to assure design efficiency is achieved in the operating system. Open and closed circuit cooling towers are certified per CTI Standard 201 RS (ECC Certification in Europe) while plate & frame heat exchangers are certified per AHRI 400 (reference Figure 8). Each program has many participating manufacturers offering a wide array of certified models. As an alternative to independent thermal certification, a field performance test can be specified as is often the case with custom field erected cooling towers. Check the manufacturers’ websites for specific wording for your project specifications.

[1] Assessment of Hybrid Geothermal Heat Pump Systems, US DOE, DOE/EE-0258, http://www.eren.doe.gov/femp, December 2001.

Figure 8 Specify Certified Thermal Performance

Open Circuit Cooling Tower + Plate & Frame Heat Exchanger Combinations

Systems utilizing open circuit cooling tower + plate & frame heat exchanger combinations keep the process fluid in a clean, closed loop as shown in Figure 9. The high performance refrigerant condenser tubes are protected from scaling and fouling. Note that the other side of the heat exchanger is connected to an open loop through the cooling tower, which was discussed earlier (contrast to the typical water cooled chiller system diagram in Figure 4).

Plate and frame heat exchangers typically have high overall heat transfer coefficient (“U”) values. Pressure drops are generally reasonable, usually 10 psi (69 kPa) or less on each side of the heat exchanger. These heat exchangers have small passageways between the plates resulting in high fluid velocities which can help to minimize any buildup of contaminants on the open loop side. However, because of the high “U” values, even a small amount of fouling can have an outsized impact on thermal performance and the small passageways can be prone to clogging on the open loop side.

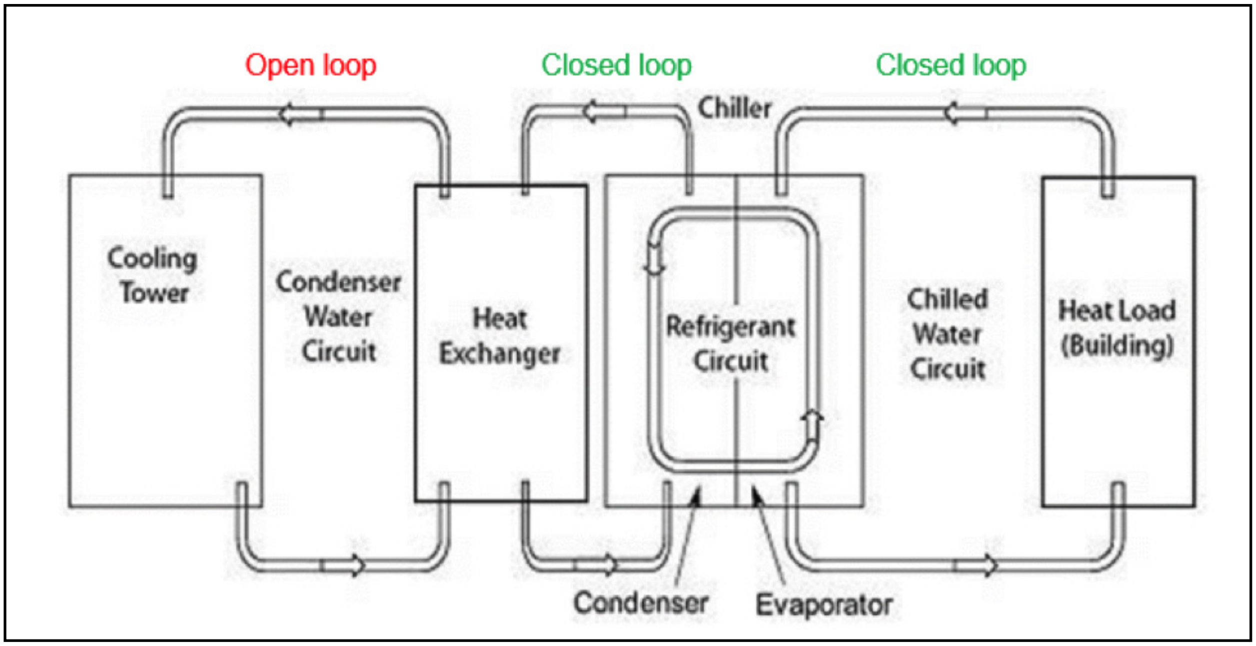


Figure 9 Water Cooled Chiller System with Open Circuit Cooling Tower + Plate & Frame Combination

The heat exchanger is typically located in an equipment room and as such does not need glycol for freeze protection in colder climates. Because they are connected to an open loop, plate & frame heat exchangers are designed to be taken apart for inspection and cleaning (see Figure 10). Designers need to allow adequate room for dismantling and cleaning the plate pack and be sure to include a floor drain nearby. New gaskets are generally required when reassembling the plate pack. Maintenance personnel must also follow the proper plate pack tightening procedure to ensure proper thermal performance and pressure drop are achieved after reassembly. The open circuit cooling tower must be properly maintained and the recirculated system water properly treated as previously discussed.

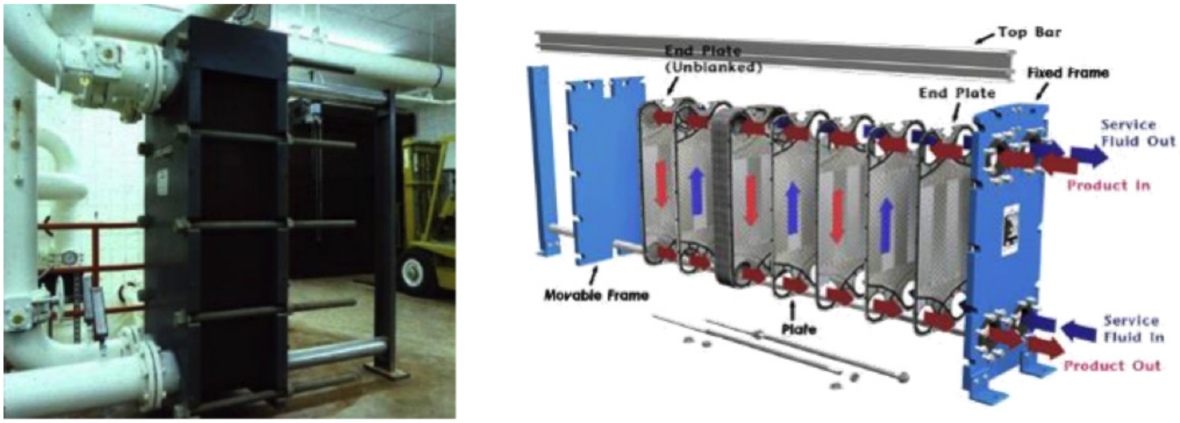


Figure 10 Typical P&F Heat Exchanger Installation and Exploded View Showing Plate Pack

When sizing such a system, be sure to account for the approach across the heat exchanger (leaving process fluid temperature minus the entering cooling fluid temperature), which is typically 2°F (1.1°C) to 3°F (1.7°C). This results in a larger cooling tower than if the cooling tower were used to directly cool the load. For example, if the system requires 85°F (29.4°C) cooling fluid with a 10°F (5.6°C) range, or temperature drop, through the cooling tower, typical open loop conditions would be 95°F (35.0°C) fluid in, 85°F (29.4°C) fluid out, at a 78°F (25.6°C) entering wet bulb. To supply the same fluid temperature to the system when using a heat exchanger with a 3°F (1.7°C) approach, the cooling tower must be sized for 92°F (33.3°C) fluid in, 82°F (27.8°C) fluid out, at a 78°F (25.6°C) entering wet bulb. These conditions will result in a larger physical size and/or high fan horsepower for the cooling tower.

Figure 11 Open Circuit Cooling Towers Available in a Wide Variety of Sizes and Configurations

Finally, note that there is a balance point between the approach on the cooling tower (the water temperature leaving the cooling tower minus the entering wet bulb temperature of the air) and the approach on the heat exchanger given a fixed process supply temperature to the system and a fixed design wet bulb for the site. The closer the approach on either the cooling tower or heat exchanger, the larger that particular device will be. A closer approach on the heat exchanger will increase the size of the heat exchanger while reducing the size of the cooling tower. Conversely, selecting the cooling tower for a closer approach (colder water temperature off the cooling tower) reduces the required size of the heat exchanger. Designers can evaluate a grid of approaches to arrive at the optimum point for first cost and operating cost. For instance, the Designer can evaluate heat exchangers with 2°F, 3°F, and 4°F (1.1°C, 1.7°C, and 2.2°C respectively) approaches versus the corresponding cooling tower selections and evaluate key items that can impact the project such as:

- Length, width, and height of each component
- Weight of each component
- Cooling tower fan horsepower and pumping head
- Pressure drop across each side of the heat exchanger
- Cost for the cooling tower and heat exchanger

Open Cooling Loops

As an alternative to the use of an open circuit cooling tower + heat exchanger combination, a closed circuit cooling tower, or fluid cooler, can be used to close the cooling loop. These devices combine the function of a heat exchanger and cooling tower in a single, compact unit while keeping the process fluid in a clean, closed loop. In contrast to the system shown in Figure 9, both the chilled water and condenser loops illustrated in Figure 12 are closed loop.

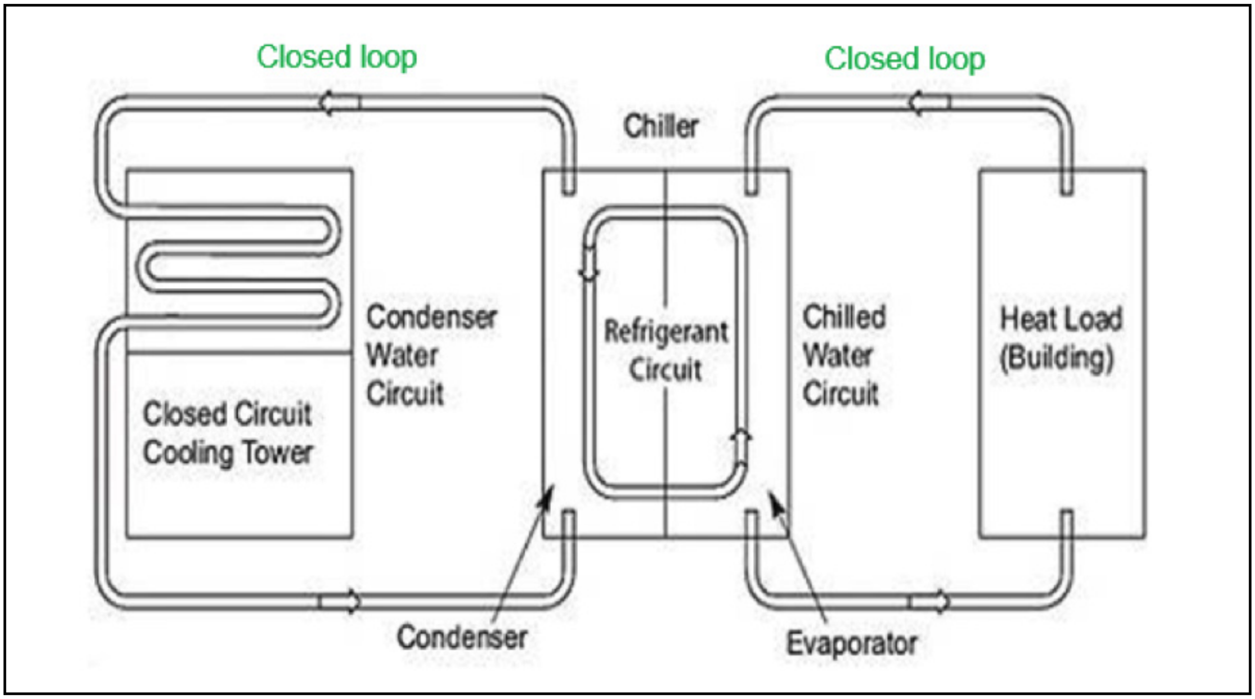


Figure 12 Water Cooled Chiller System with Fluid Cooler (Closed Circuit Cooling Tower)

Units are equipped with an integral spray pump to recirculate water over the coil from the basin (note that this is an open loop). The size of the equipment room can be reduced as the heat exchanger, typically a tubular coil as shown in Figure 13, is located in the fluid cooler, rather than inside the building. However, this does make the fluid cooler heavier than an open circuit cooling tower, resulting in the need for additional structural grillage to support the unit.

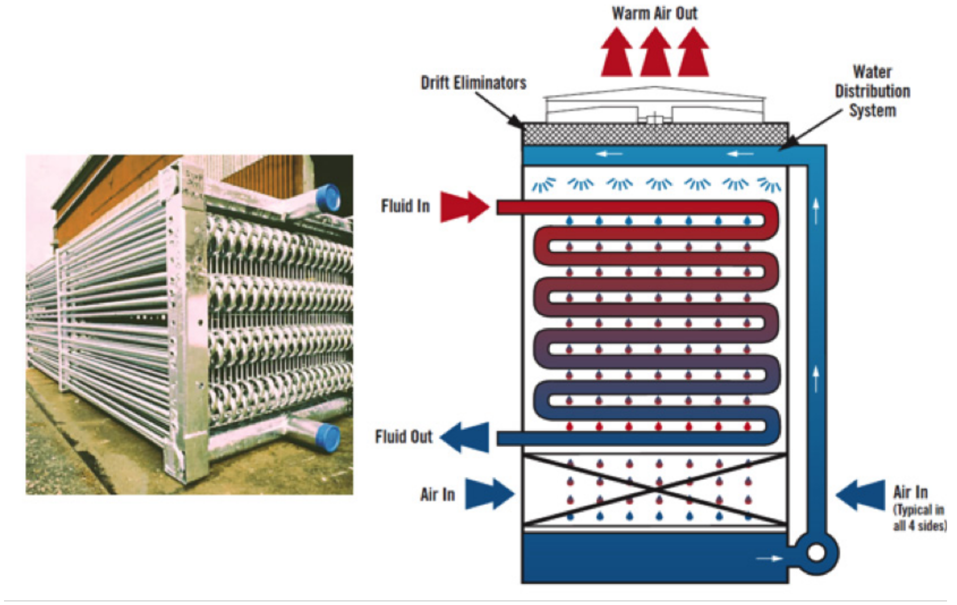


Figure 13 Induced Draft Counterflow Fluid Cooler Showing Tubular Heat Exchanger

Fluid coolers, like open circuit cooling towers, are available in many configurations and capacities. Axial fan, induced draft counterflow designs, as shown in Figure 13, offer low fan energy and a relatively compact footprint, especially in lower tonnage applications. Centrifugal fan, forced draft counterflow designs (Figure 14) are available for indoor applications, which like their open circuit counterparts, can be an advantage for units located in cold weather areas or high security applications, and are capable of handling external static pressure. Centrifugal fan designs are also quieter than their axial fan counterparts. Low sound fan options can lower the sound levels of axial fan designs. Attenuation packages are available for all types of units for especially sound sensitive applications.

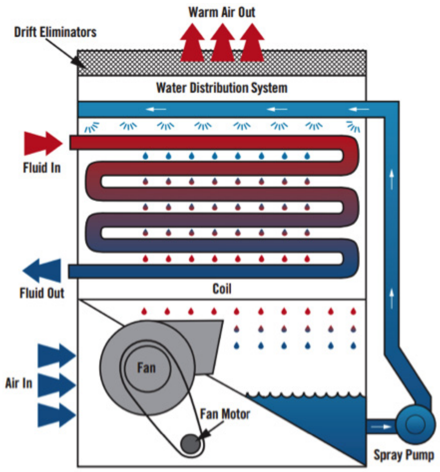


Figure 14 Forced Draft, Centrifugal Fan, Counterflow Fluid Cooler

Another category of fluid coolers incorporate open circuit heat transfer surface, or fill, into the design to improve thermal performance, lower fan horsepower, and reduce unit size and footprint. The coil/fill design illustrated in Figure 15 offers great access to key components for maintenance, such as the fan and water distribution systems. In this design, the spray nozzles can be inspected and maintained while the unit is in operation, which is an important advantage for many projects.

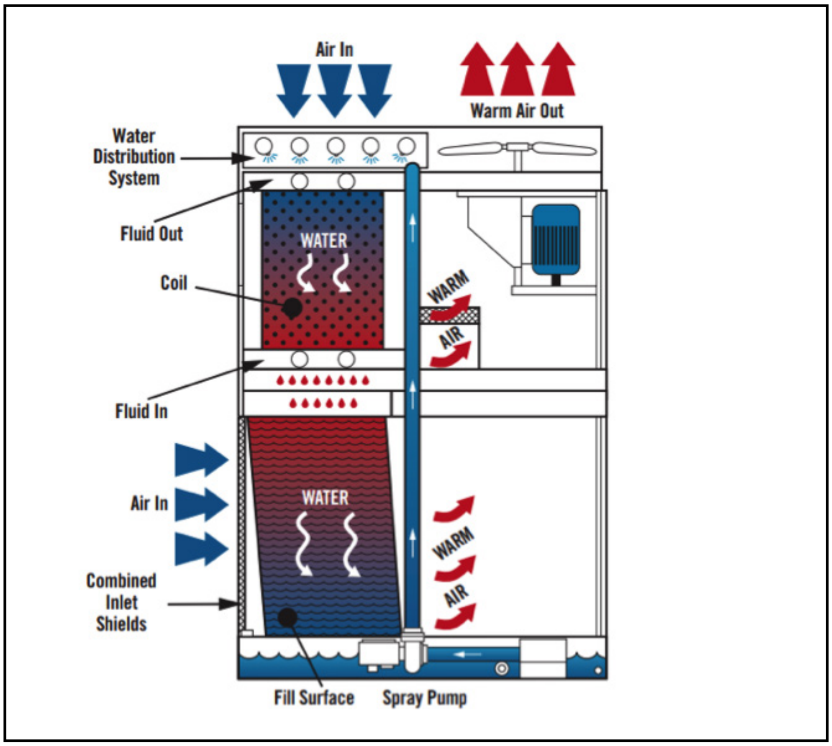


Figure 15 Induced Draft, Axial Fan Coil / Fill Fluid Cooler

Pressure drops through the heat exchanger, typically 10 psi (69 kPa) or less, are often similar to or less than that of plate & frame heat exchangers. The relatively lower fluid cooler heat transfer coefficient is also less susceptible to external fouling on the open loop side. In addition, unlike plate & frame heat exchangers, the open loop side of the heat exchanger can be readily inspected for scale and fouling, which can be controlled through the water treatment program.

As the open loop water volume in a fluid cooler is less than that in a similar system based on an open circuit cooling tower, the water treatment is typically easier and less costly. The spray water stays within the fluid cooler casing so only the materials of construction of the unit need to be protected, rather than the numerous materials used in the larger system, such as copper tubes in a chiller condenser or black steel piping.

Because of the simpler, direct piping arrangement, economization, or free cooling, can be implemented more easily. An additional advantage of fluid coolers over open circuit cooling towers is that they can often be operated dry in cooler weather and/or periods of low heat load. This can save water and water treatment chemicals during such periods. Coupled with the lower open circuit water volume, water and water treatment costs can often be reduced by 20% or more compared to open circuit cooling towers. Dry operation also reduces concerns, on the part of some operators, with unit icing when operating wet in very cold weather. Note that whether the project utilizes open circuit or closed circuit cooling towers, the proper cold weather operating procedures need to be followed.

Figure 16 Closed Circuit Cooling Tower Installations

Installation Case Studies

The previous discussion reviewed the characteristics of each closed loop heat rejection alternative. To supplement this information, a study was commissioned to better understand both the total installed cost and the energy use of the two evaporative heat rejection alternatives on buildings with different load profiles (sizes) in two climate zones. The studies were conducted by IMEG, formerly known as KJWW, an independent consulting engineering firm. The results of the study were analyzed with the goal of developing guidance for System Designers and Operators to help them make the best heat rejection choice for their future projects.

The study examined the following cases:

- **Two HVAC systems with closed heat rejection loops**
    - Water-cooled chiller
    - Water source heat pump

- **Two heat rejection alternatives**
    - Open circuit cooling tower coupled with a plate & frame heat exchanger
    - Fluid cooler

- **Building type/size**

    - **Water-cooled chiller**
        - 250 ton (878 kW) Office (10 story)
        - 400 ton (1405 kW) Hotel (13 story)
        - 750 ton (2635 kW) Hospital (15 story)

    - **Water-source heat pump**
        - 250 ton (878 kW) Condominium (multi-story)
        - 400 ton (1405 kW) Condominium (multi-story)

- **Climate zones**
    - ASHRAE Zone 3A (Dallas)
    - ASHRAE Zone 5A (Chicago)

The analysis of each system captured all components as illustrated in the sample diagrams in Appendix A for water cooled chiller systems (less the chiller) and Appendix B for water source heat pump loops. Note that only the heat rejection subsystem was costed as the remainder of the cooling system was identical regardless of the choice of heat rejection since both alternatives provided the chiller or water source heat pumps with the same design cooling temperature and heat rejection capacity (process flow rates were adjusted for aqueous glycol solutions as appropriate).

The following elements were considered as part of installation costs:

- **Equipment**
    - Cooling towers
    - Heat Exchangers
    - Pumps
    - Water treatment panels
    - Centrifugal separator
    - Etc.

- **Plumbing**
    - Piping
    - Valves
    - Strainers
    - Glycol
    - Etc.

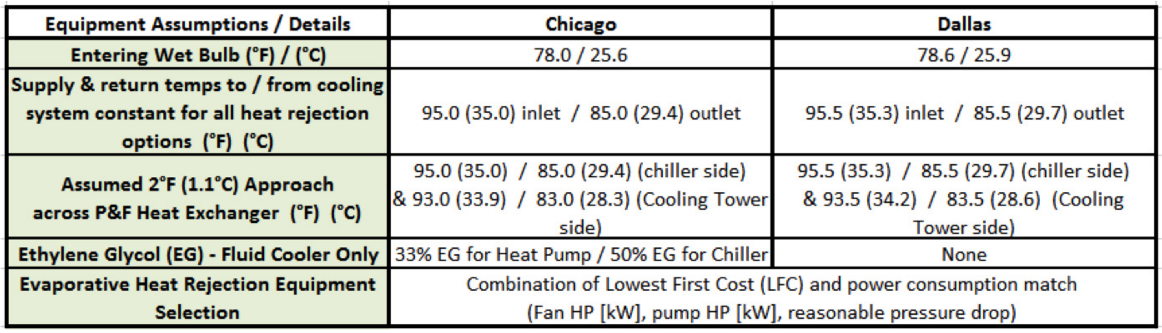
- **Electrical**
    - Wiring
    - Breakers
    - Conduit
    - Disconnects
    - Variable Speed Drives
    - Etc.

- **Instrumentation / Measurement Equipment**
    - Pressure gauges
    - Flowmeters
    - Temperature probes
    - Etc.

- **Structural steel support for the cooling towers**

- **Real estate** (i.e., space in the mechanical room)

Costs were obtained from RSMeans data along with supplier quotes for the heat rejection equipment. Evaporative heat rejection equipment sizing was driven by compliance with energy code, low first cost, and power consumption match as detailed in Figure 17. For the Chicago cases with fluid coolers, the heat pump loops utilized a 33% ethylene glycol solution while the chiller loop utilized a 50% ethylene glycol solution. The use of an aqueous glycol solution was taken into account in the selection of the fluid coolers. A higher flow rate was required for the chiller condenser and water source heat pump loops to provide the same heat rejection capability.



Equipment Assumptions / Details	Chicago	Dallas
Entering Wet Bulb (°F) / (°C)	78.0 / 25.6	78.6 / 25.9
Supply & return temps to / from cooling system constant for all heat rejection options (°F) (°C)	95.0 (35.0) inlet / 85.0 (29.4) outlet	95.5 (35.3) inlet / 85.5 (29.7) outlet
Assumed 2°F (1.1°C) Approach across P&F Heat Exchanger (°F) (°C)	95.0 (35.0) / 85.0 (29.4) (chiller side) & 93.0 (33.9) / 83.0 (28.3) (Cooling Tower side)	95.5 (35.3) / 85.5 (29.7) (chiller side) & 93.5 (34.2) / 83.5 (28.6) (Cooling Tower side)
Ethylene Glycol (EG) - Fluid Cooler Only	33% EG for Heat Pump / 50% EG for Chiller	None
Evaporative Heat Rejection Equipment Selection	Combination of Lowest First Cost (LFC) and power consumption match (Fan HP [kW], pump HP [kW], reasonable pressure drop)	

Figure 17 Equipment Sizing Assumptions

The evaporative heat rejection equipment was outfitted as follows:

- Galvanized steel construction with Type 304 stainless steel cold water basin
- Electric water level control
- Sump sweeper piping
- Access platforms with ladder, safety cage, and safety gate
- Access door platform and ladder
- Internal basin walkway as appropriate
- Electric basin heater (sized for 0°F [-17.8°C] Dallas and -20°F [-28.9°C] Chicago)
- Bottom outlet (open circuit cooling tower only)
- Equalizer (open circuit cooling tower only)

Plate & frame heat exchangers were selected using a 2°F (1.1°C) approach and a 10 psi (69 kPa) pressure drop limit across each side.

Piping run diameters and lengths were based on the associated building size corresponding to the load. Costs used were those to the end user including labor, materials, and freight. Location multipliers were used to adjust labor and material costs for the two cities studied.

Total Installed Cost

An example of this cost breakdown is shown in Figure 18 for a 250 ton (878 kW) Office Building with a water cooled chilled water system. The equipment only cost for the fluid cooler option was more than that for the cooling tower + heat exchanger, yet when all of the other costs for piping, electrical, instrumentation, etc. are included, the installed cost favors the fluid cooler version. While the structural cost for mounting the unit was less with the open circuit cooling tower, the larger equipment room to accommodate the plate & frame heat exchanger and loss of rentable space more than offsets this added cost.

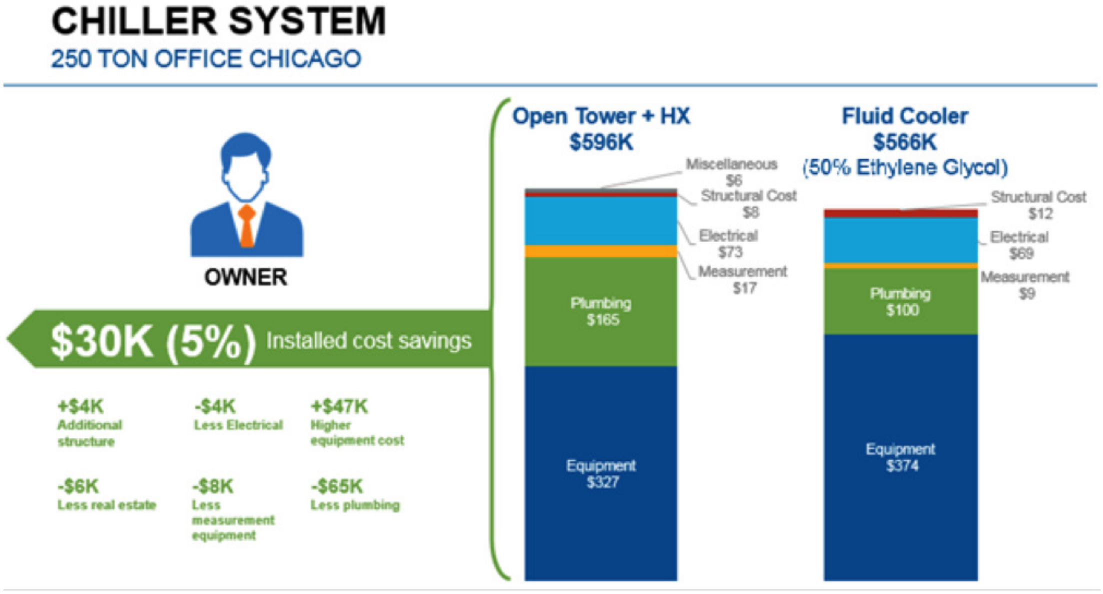


Figure 18 250 Ton Water Cooled Chiller System Installed Cost

The summary results for all water cooled chiller systems studied are shown in Figure 19. While installed costs were generally similar, fluid cooler based designs were lower cost in most cases, except for the 400 ton (1405 kW) Hotel and 750 ton (2635 kW) Hospital cases in Chicago, due to the simpler, more compact nature of the fluid cooler based system (versus having to design, layout, and pipe an open circuit cooling tower + heat exchanger system). The Chicago designs utilizing fluid coolers all called for glycol in the condenser loop for freeze protection, which also necessitated the use of a larger fluid cooler; however, note that the 250 ton (878 kW) Chicago Office case still offered savings despite the use of glycol.

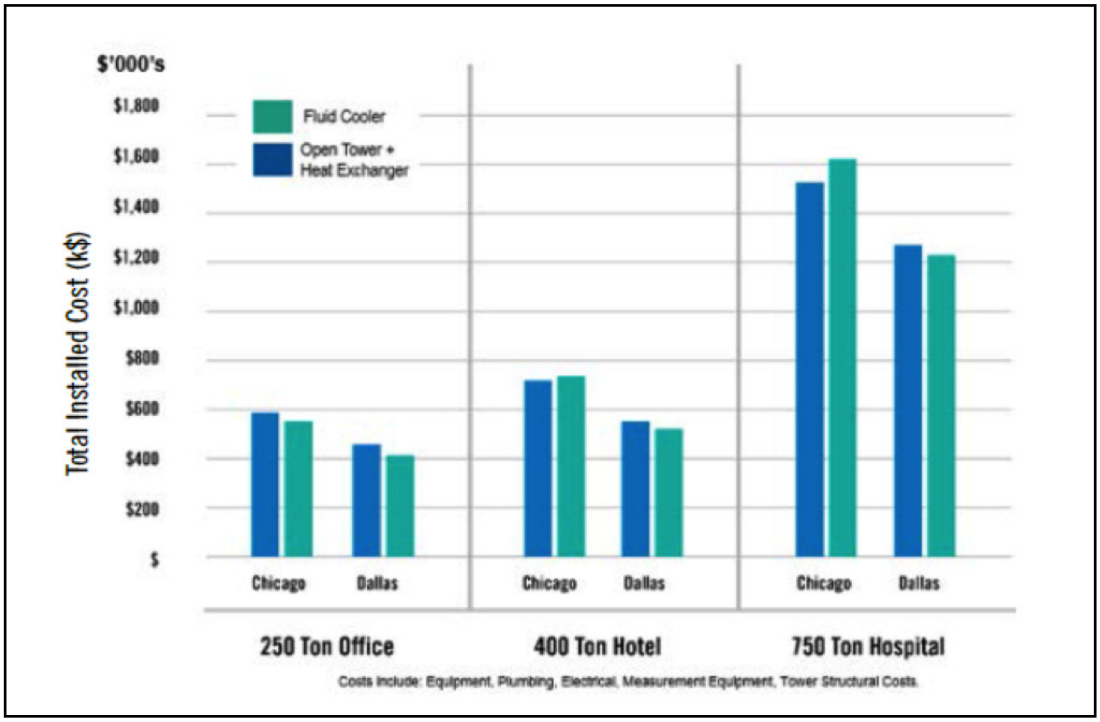


Figure 19 Water Cooled Chiller System with Fluid Cooler

An example of the cost breakdown for a water source heat pump system is shown in Figure 20 for a 400 ton (1405 kW) Condominium. As with the chiller system example described earlier, the equipment only cost for the fluid cooler option was more than that for the cooling tower + heat exchanger. However, once the costs for piping, electrical, instrumentation, etc. are included, the installed cost once again favors the fluid cooler version, despite the requirement for aqueous glycol in the cooling loop. While structural costs for mounting the fluid cooler were greater than required for the open circuit cooling tower, the larger equipment room to accommodate the plate & frame heat exchanger and loss of rentable space again offsets this added cost.

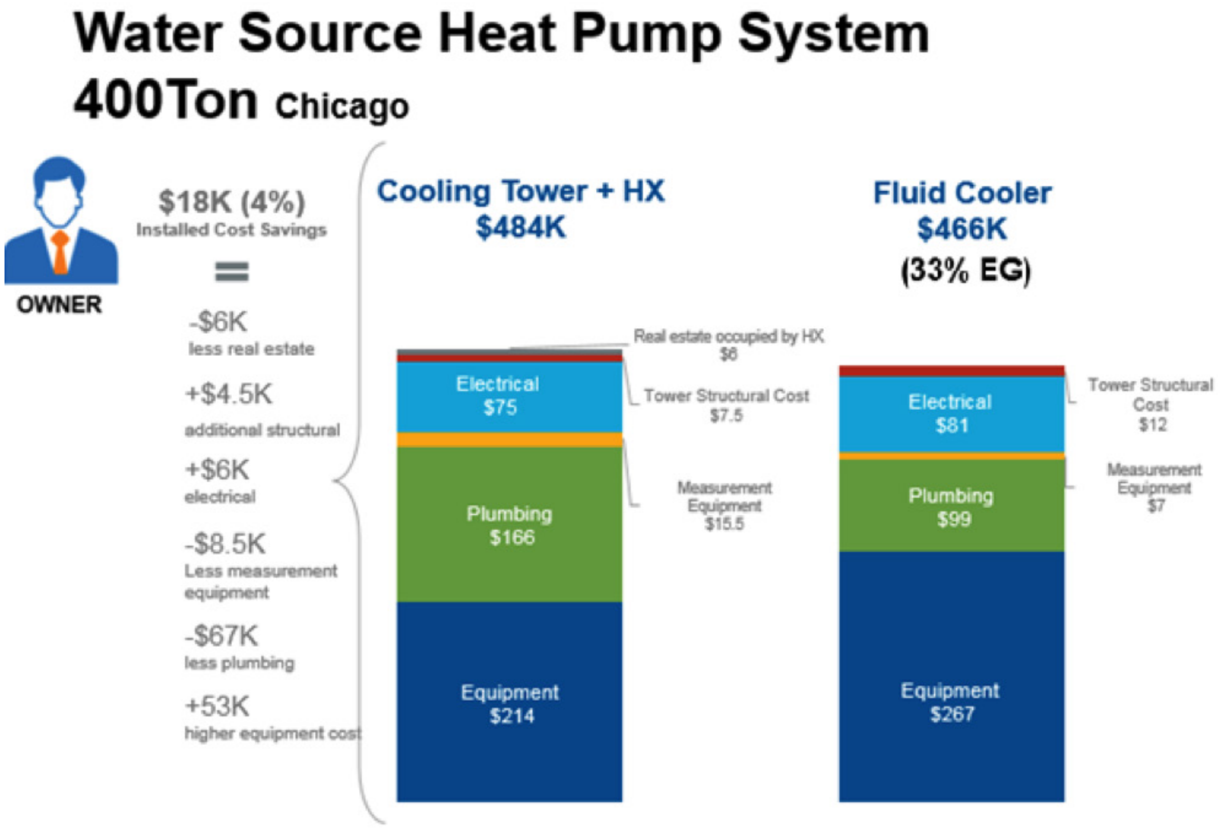


Figure 20 400 Ton Water Source Heat Pump System Installed Cost

Results for the 250 ton (878 kW) and 400 ton (1405 kW) water source heat pump systems, often used in condominium buildings, are shown in Figure 21. In both cases, the equipment only costs for the fluid cooler were once again more than the open circuit cooling tower + heat exchanger combination. However, in all cases, the installed cost of the fluid cooler based system was less than the alternative, despite the use of glycol in the fluid coolers located in Chicago. Note also that the fluid coolers in both cities utilized positive closure damper hoods, which are required by Code to reduce heat loss when the system is in boiler mode.

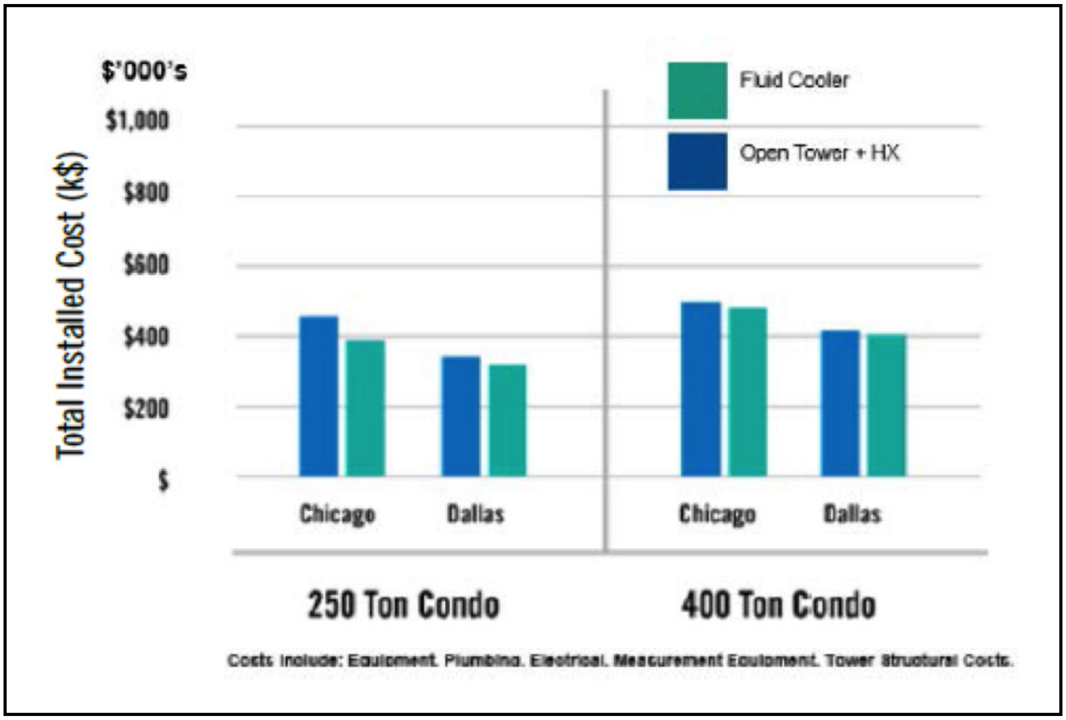


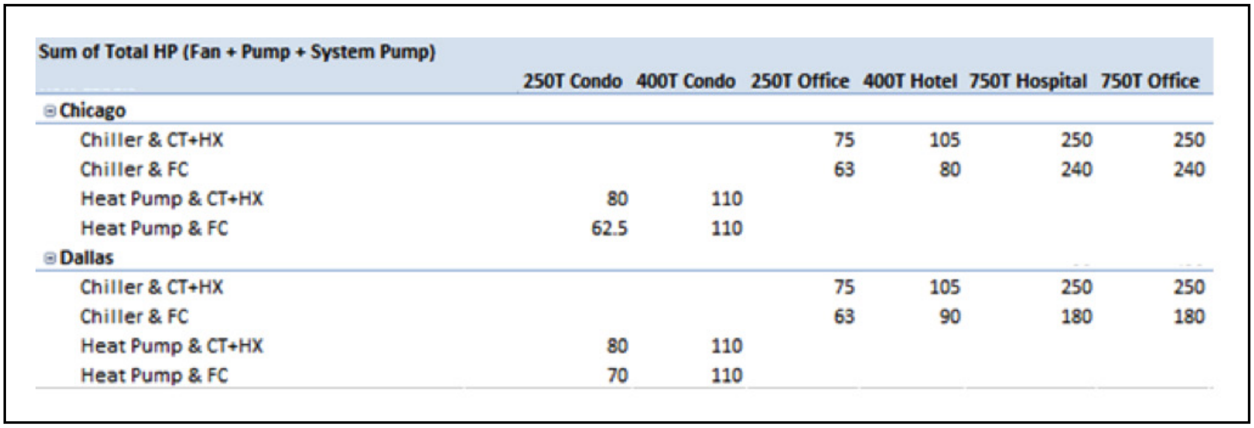
Figure 21 Summary Results for Water Source Heat Pump Systems

In addition to the total installed cost, the fluid cooler option benefits from the flexibility of dry operation and other water related efficiencies not offered by the open tower and heat exchanger option. As mentioned earlier, this option also saves space within the building by eliminating the need for a larger mechanical room to accommodate the heat exchanger.

Heat Rejection System Energy

The study also looked at the connected horsepower of each heat rejection system, which included the cooling tower fan, the heat exchanger pumps (including the spray pump for each fluid cooler), and the system pump, which reflected the pressure drops through the heat exchangers. From the summary of motor data for each heat rejection system shown in Figure 22, the fluid cooler based systems had the same or lower connected energy as the cases equipped with open circuit cooling towers + heat exchangers for the building designs evaluated.

For instance, for the 400 ton (1405 kW) chiller system on a Chicago hotel, the cooling tower + heat exchanger based system had a total of 105 horsepower (78.3 kW) while the fluid cooler based system had only 80 horsepower (59.7 kW). For the 400 ton (1405 kW) water source heat pump system in Chicago, both alternatives had a total of 110 connected horsepower (82.0 kW). Note that the spray pumps on fluid coolers were often lower horsepower than the pumps between the cooling towers and heat exchangers, which generally must handle much longer piping runs as well as the pressure drop of the heat exchanger. The fluid cooler spray pump only needs to transport the recirculating water from the fluid cooler basin to the low pressure spray distribution system, where the nozzles spray the water over the evaporative heat exchanger (reference Figures 13, 14, and 15).



Sum of Total HP (Fan + Pump + System Pump)	250T Condo	400T Condo	250T Office	400T Hotel	750T Hospital	750T Office
⊟ **Chicago**						
Chiller & CT+HX			75	105	250	250
Chiller & FC			63	80	240	240
Heat Pump & CT+HX	80	110				
Heat Pump & FC	62.5	110				
⊟ **Dallas**						
Chiller & CT+HX			75	105	250	250
Chiller & FC			63	90	180	180
Heat Pump & CT+HX	80	110				
Heat Pump & FC	70	110				

Figure 22 Summary of Connected Horsepower for Each System

In addition, the study found that the process fluid pressure drops of the two alternatives were generally similar. The pressure drop limit for the plate & frame heat exchanger selections was 10 psi (69 kPa) on each side of the exchanger. A 10 psi (69 kPa) limit was also used for the fluid cooler heat exchanger pressure drop. However, the pressure drop through the fluid coolers could vary greatly depending on the specific model chosen and were often less than 10 psi (69 kPa). Because of the multiple sizes, types, and quantity of plates available on plate & frame heat exchangers, the plate & frame selections could be “fine-tuned” and optimized very close to the 10 psi limit in all of the cases.

Heat rejection fan and system pump horsepower (kW) levels will be dependent on the specific equipment models selected, the distance from the load to the heat rejection devices, etc. As such, horsepower levels should be evaluated on a case-by-case basis. Often the fan horsepower of the cooling towers, whether open or closed circuit, can be reduced by judicious selection of units with additional heat transfer surface area. While more costly, paybacks of less than two years are frequently possible for these lower horsepower models.

The connected horsepower analysis only provides an indication of the relative energy use of the two alternatives. While full energy analyses were not performed using annual weather data and typical building load profiles, evaluating annual energy use for each heat rejection alternative is a significant opportunity for future study. Such a study could also include examining the energy benefits of closing the loop on traditional open circuit cooling tower applications such as water cooled chillers versus the additional cost to close the loop.

Summary

Closed loop cooling systems offer many advantages over traditional open loop cooling systems in terms of maintaining high system efficiency over time, ongoing maintenance requirements, and application flexibility. The use of energy efficient evaporative heat rejection, whether open or closed circuit, offers the highest overall system efficiency compared to air cooled alternatives. When choosing between an open circuit cooling tower + heat exchanger combination and a fluid cooler, be sure to evaluate the space available in the equipment room, the availability of maintenance staff, water treatment requirements, and other installation and operational considerations. Lastly, be sure to compare the total installed cost, rather than simply the initial heat rejection equipment cost, of these two alternatives. Often the fluid cooler based system will often offer the lowest total installed cost for the Owner while reducing logistics management for the Contractor thanks to the simpler system design.

References

AHRI 550 / 590 (IP) Standard for Performance Rating of Water-chilling and Heat Pump Water-heating Packages Using the Vapor Compression Cycle, 2015

ANSI/ASHRAE/IES Standard 90.1-2016 Energy Standard for Buildings Except Low-Rise Residential Buildings (I-P Edition)

“Assessment of Hybrid Geothermal Heat Pump Systems”, US DOE, DOE/EE-0258, http://www.eren.doe.gov/femp, December 2001

“Cold Weather Operation of Cooling Towers”, Lindahl, P., ASHRAE Journal, pages 26 – 35, March 2014

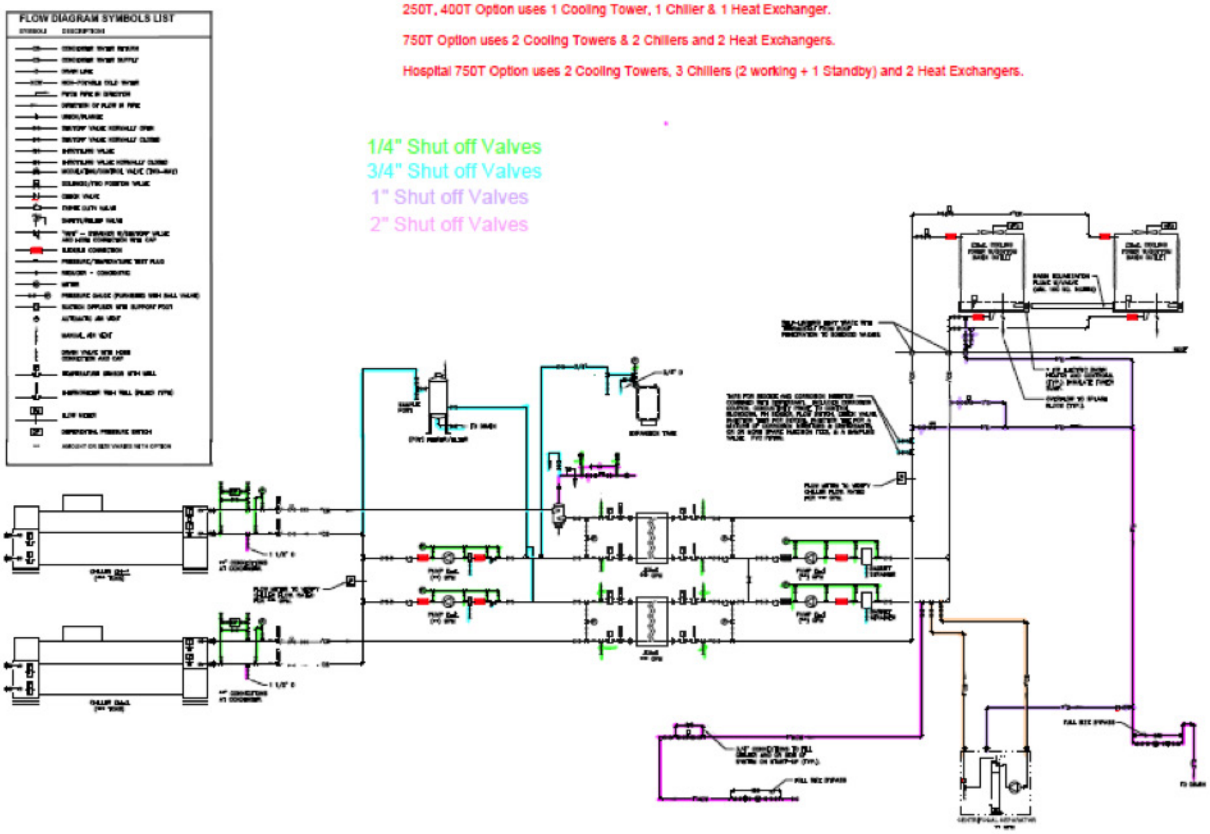
RS Means, 2016 Cost Data

“Saving Energy with Cooling Towers”, Morrison, F., ASHRAE Journal, pages 34-40, February 2014

“Saving Water with Cooling Towers”, Morrison, F., ASHRAE Journal, pages 20-33, August 2015

Appendices

Appendix A Diagrams for Water Cooled Chiller Systems



Note:

250T, 400T Option uses 1 Cooling Tower, 1 Chiller & 1 Heat Exchanger.

750T Option uses 2 Cooling Towers & 2 Chillers and 2 Heat Exchangers.

Hospital 750T Option uses 2 Cooling Towers, 3 Chillers (2 working + 1 Standby) and 2 Heat Exchangers.

① CONDENSER WITH HEAT EXCHANGER WATER FLOW DIAGRAM

Water Cooled Chiller System with Cooling Tower + Heat Exchanger

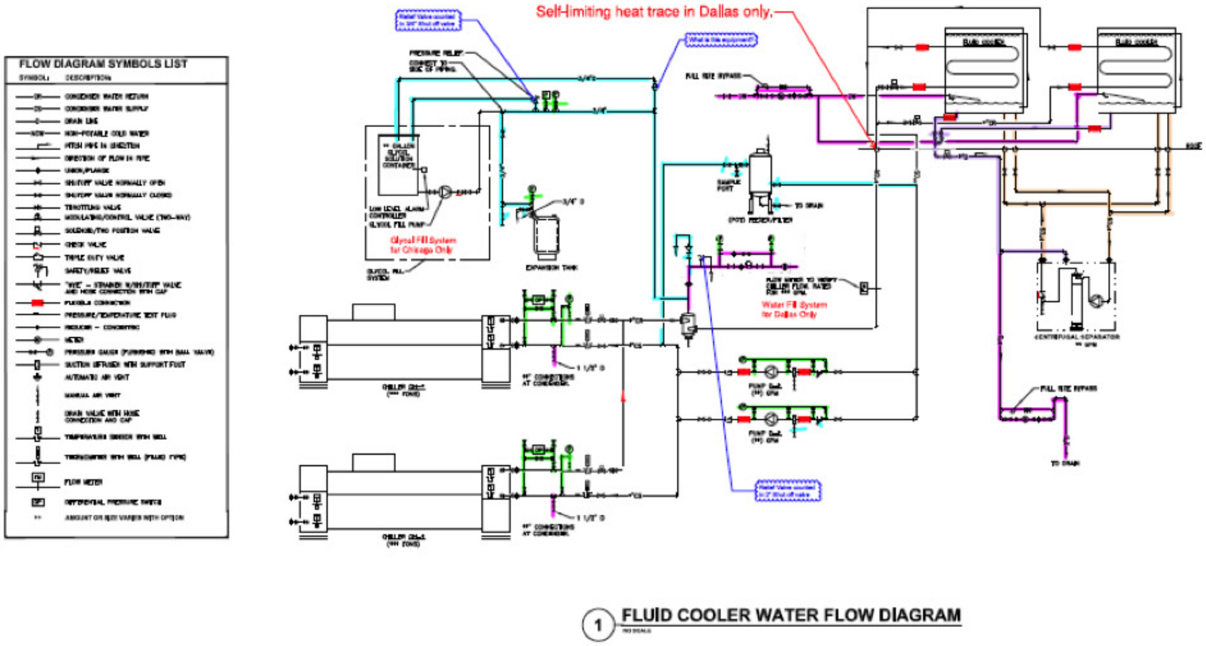
1/4" Shut off Valves
3/4" Shut off Valves
1" Shut off Valves
2" Shut off Valves

Note:

250T, 400T Option uses 1 Fluid Cooler, 1 Chiller.

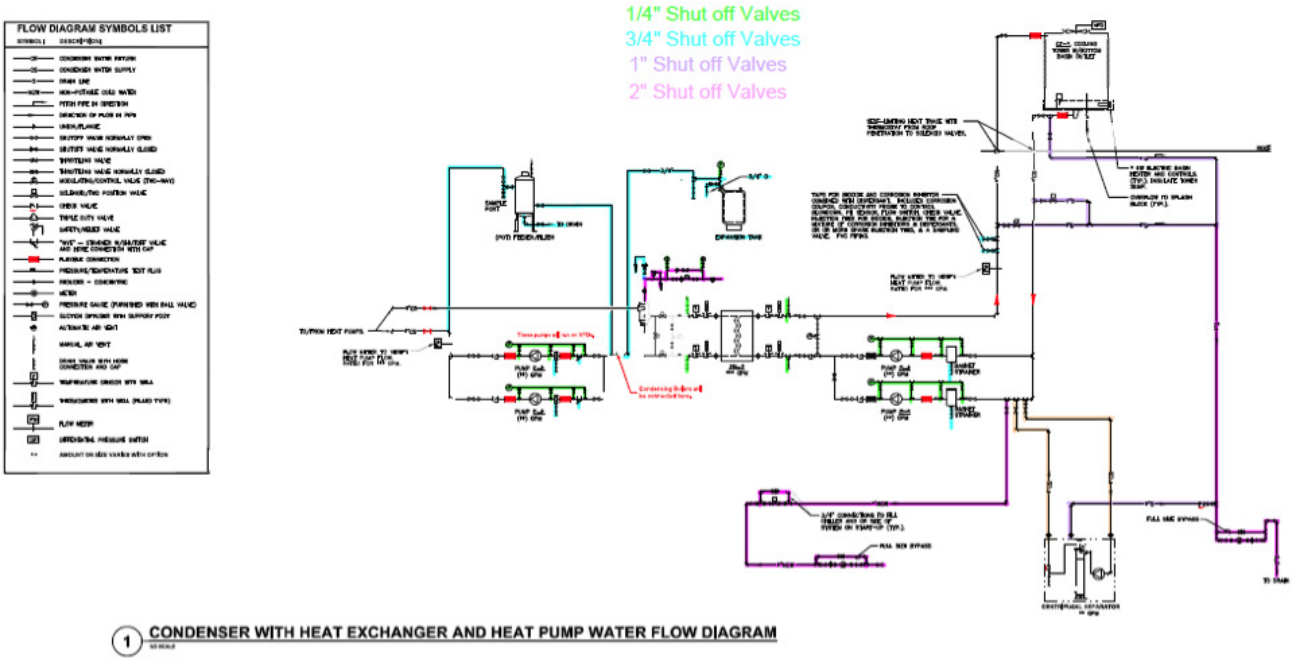
750T Option uses 2 Fluid Coolers & 2 Chillers.

Hospital 750T Option uses 2 Fluid Coolers, 3 Chillers (2 working + 1 Standby).

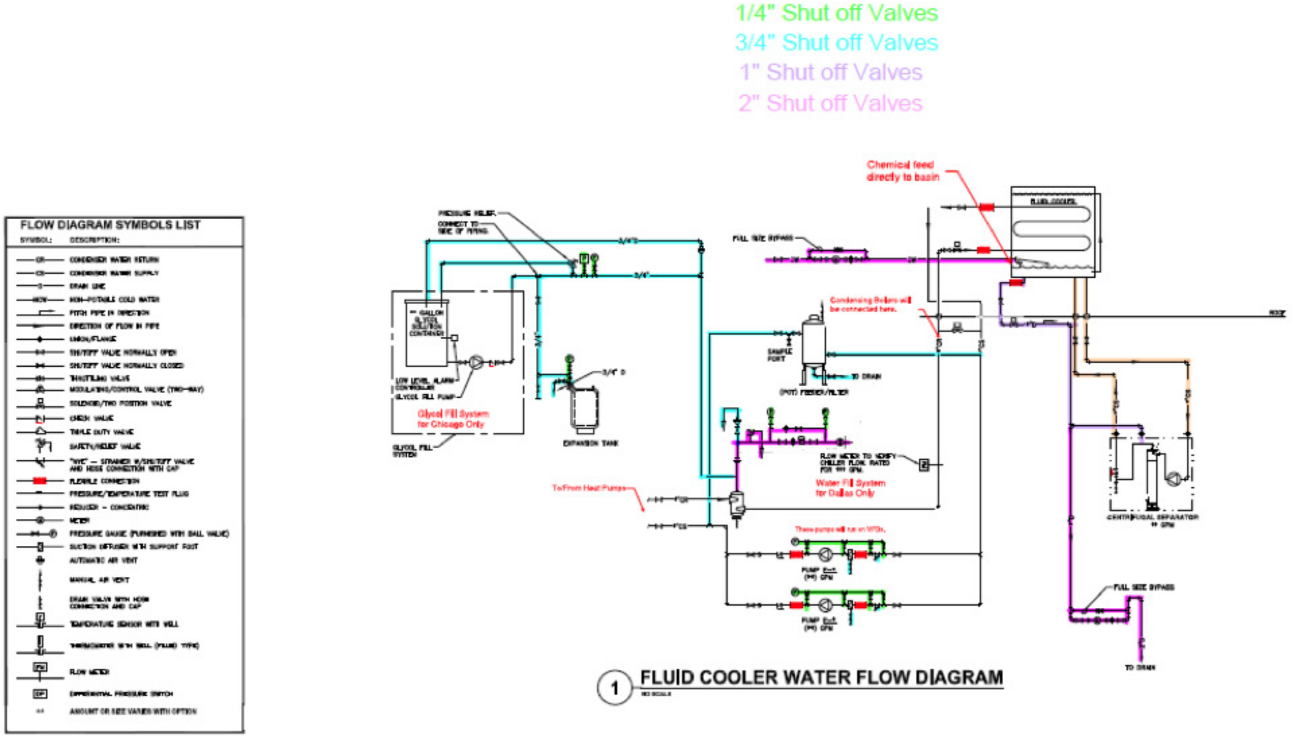


Water Cooled Chiller System with Fluid Cooler

Appendix B Diagrams for Water Source Heat Pump Loops



Water Source Heat Pump Loop with Cooling Tower + Heat Exchanger



Water Source Heat Pump Loop with Cooling Tower + Heat Exchanger

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