

CHAPTER 14. CONDENSER WATER SYSTEMS

AS part of the vapor-compression cycle for mechanical refrigeration, the heat of compression produced must be rejected to complete the refrigeration cycle. Refrigerant systems may be cooled by air or water. In water-cooled systems, water flows through the condenser and is called **condenser water**. Condenser water systems are classified as (1) once-through systems (e.g., city water, well-water, or lake/groundwater systems), or (2) recirculating or cooling tower systems. This chapter focuses on open condenser water systems and evaporative coolers; for information on closed-loop systems used in ground-source heat pump loops, see [Chapter 49](#) of this volume and [Chapter 34 of the 2013 ASHRAE Handbook—HVAC Applications](#).

1. ONCE-THROUGH CITY WATER SYSTEMS

Once-through city water systems use water from the city's potable water supply and circulate through the refrigeration equipment condenser (e.g., walk-in cooler, computer room unit) to reject heat and discharge water directly to the sewer. Many municipalities prohibit this type of direct water cooling because of water conservation restrictions, although some localities allow its use as a standby or emergency condenser water system for critical refrigeration needs such as for computer rooms, research laboratories, or critical operating room or life support machinery. In addition, standards such as ASHRAE Standard 189.1 do not allow once-through city water for heat rejection. If city water is allowed for condenser water purposes, then allowed flow may be limited to less than 0.2 gpm per ton. The designer should contact the local water department to determine the viability of this system.

[Figure 1](#) shows a water-cooled condenser using city water. The return (leaving water) is run higher than the condenser so that the condenser is always full of water. Water flow through the condenser is regulated by a control valve in the supply or discharge line, usually actuated from condenser head pressure to (1) maintain a constant condensing temperature with load variations and (2) close when the refrigeration compressor turns off. City water systems should always include approved backflow prevention devices and open (air gap) drains. When more than one condenser is used on the same circuit, use individual control valves.

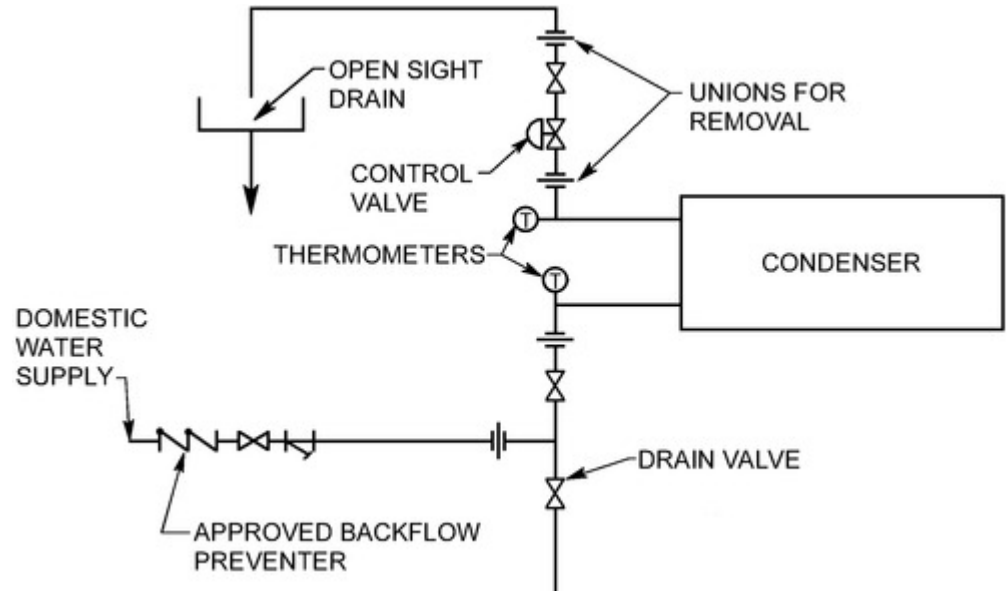


Figure 1. Condenser Connections for Once-Through City Water System

Piping materials for these systems are generally nonferrous, usually copper but sometimes high-pressure plastic, because corrosion-protective chemicals cannot be used. Scaling can be a problem with higher-temperature condensing surfaces when the water has a relatively high calcium content. In these applications, use mechanically cleanable straight tubes in the condenser. Piping should be sized according to the principles outlined in [Chapter 22 of the 2013 ASHRAE Handbook—Fundamentals](#), with velocities of 5 to 10 fps for design flow rates. A pump is usually not required where city water is used. **Well water** can be used in lieu of city water, connected on the service side of the pumping/pressure control system. Because most well water has high calcium content, scaling on the condenser surfaces can be a problem. Another once-through system uses lake or river water. Although these systems eliminate the need for a cooling tower, they require particular attention to filtering out sediment, particulates, and other materials that could foul the system. In the United States, special permitting is required from the local Department of Natural Resources (DNR) and the Environmental Protection Agency (EPA). Particular attention must be paid to the design of intake structures and keeping the velocity below 0.5 fps so as not to intake aquatic wildlife.

2. OPEN COOLING TOWER SYSTEMS

Open systems have at least two points of interface between the system water and the atmosphere; they require a different approach to hydraulic design, pump selection, and sizing than do closed hot- and chilled-water systems. Some heat conservation systems rely on a split condenser heating system that includes a two-section condenser. One section of the condenser supplies heat for closed-circuit heating or reheat systems; the other section serves as a heat rejection circuit, which is an open system connected to a cooling tower (see [Chapter 40](#)).

In selecting a pump for a cooling tower/condenser water system, consider the static head and the system friction loss. The pump inlet must have an adequate net positive suction head (see [Chapter 40](#)). In addition, continuous contact with air introduces oxygen into the water and concentrates minerals that can cause scale and corrosion on a continuing basis. Fouling factors and an increased pressure drop caused by aging of the piping must be taken into account in the condenser piping system design (see [Chapter 22 of the 2013 ASHRAE Handbook—Fundamentals](#)). Corrosion and erosion are not just limited to condenser water piping; the chiller condenser water bundle sees the same water. It is not uncommon to coat the condenser water box with epoxy paint or other material to prolong its life. Similarly, adding nylon tube inserts extends the life of the tube ends at the tube sheet walls.

The required water flow rate depends on the refrigeration unit used and on the temperature of the available condenser water. Cooling tower water is available for return to the condenser at a temperature several degrees above the design wet-bulb temperature, depending on tower performance. An approach of 7°F to the design wet-bulb temperature is frequently considered an economically sound design. In city, lake, river, or well water systems, the maximum water temperature that occurs during the operating season must be used for equipment selection and design flow rates and temperature ranges.

The required flow rate through a condenser may be determined with manufacturers' performance data for various condensing temperatures and capacities. With air-conditioning refrigeration applications, a return or leaving condenser water temperature of 95°F has been standard practice. If economic feasibility analyses can justify it, higher leaving-water temperatures (and lower condenser flow rates) may be beneficial to the chilled-water system.

[Figure 2](#) shows a typical cooling tower system for a refrigerant condenser. Water flows to the pump from the tower basin or sump and is discharged under pressure to the condenser and then back to the tower. When it is desirable to control condenser water temperature or maintain it above a predetermined minimum, water is diverted through a control valve directly back to the tower basin.

Piping from the tower sump to the pump requires some precautions because, at this point, the water is basically flowing due to gravity. The sump level should be above the top of the pump casing for positive prime, and piping pressure drop should be minimized such that there is always adequate net positive suction head (NPSH) on the pump. Not having adequate NPSH leads to pump cavitation and potential damage to the pump impeller, thereby requiring close attention, accurate head calculation, and appropriate pump selections, as discussed in the following sections. All piping must pitch up to the tower basin, if possible, to eliminate air pockets. It is not unusual to have this piping a diameter or two larger than the pump discharge or pressurized piping.

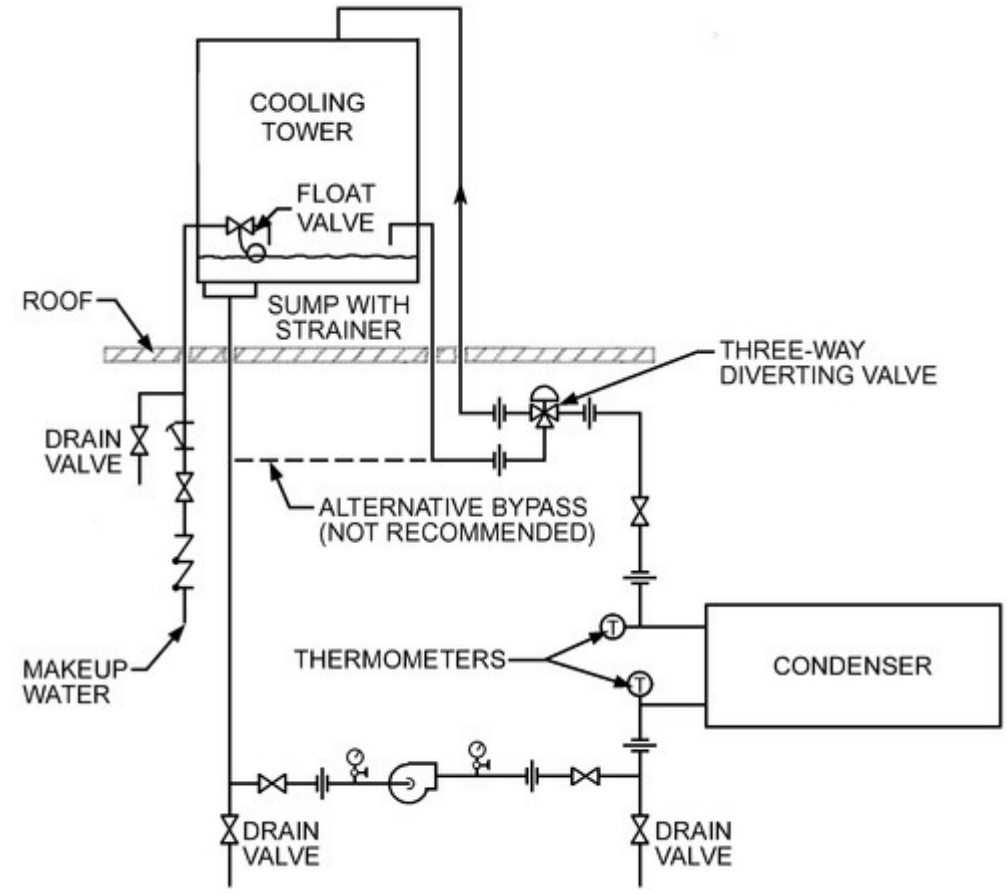


Figure 2. Cooling Tower Piping System

If used, suction strainers should be equipped with inlet and outlet gages to indicate through excessive pressure drop when cleaning is required. In-line pipe strainers are not recommended for cooling tower systems because they tend to become blocked and turn into a reliability problem in themselves. Many designers depend on large mesh screens in the tower sump and condenser heads designed with settling basins to remove particulate matter. If a strainer is deemed necessary, two-large capacity basket strainers, installed in parallel such that they can be alternately put into service and valved out for cleaning, are recommended.

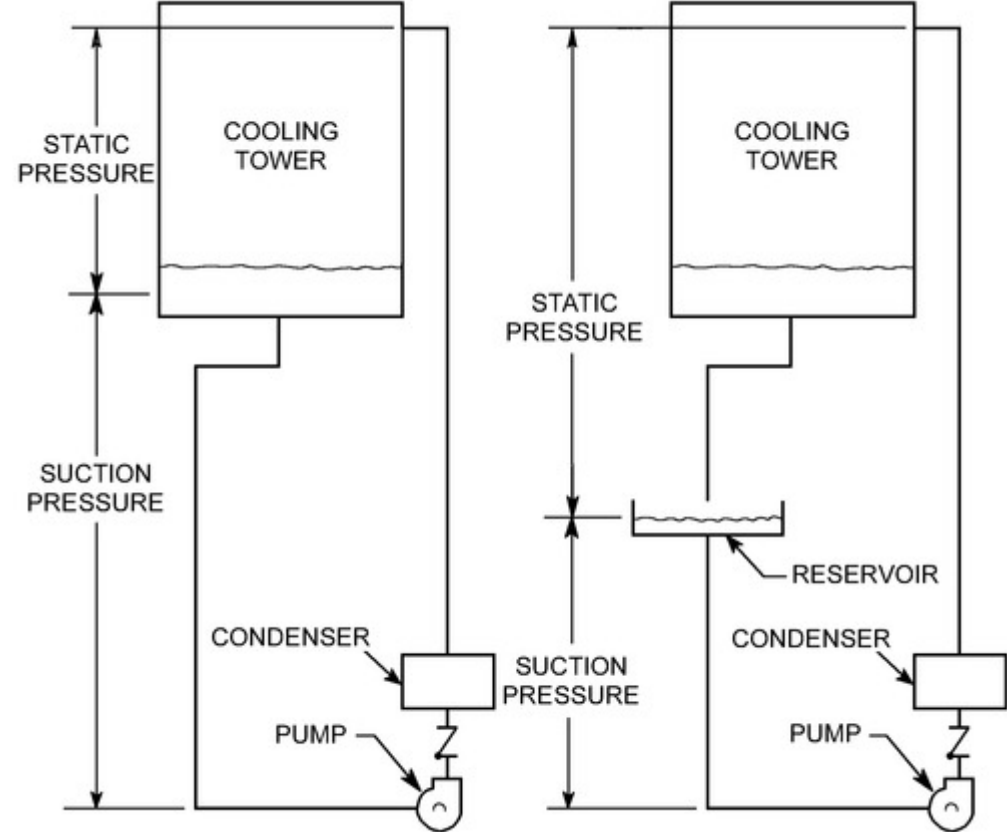
Air and Vapor Precautions

Both vapor and air can create serious problems in open cooling tower systems. Water vaporizes in the pump impeller if adequate net positive suction head is not available. When this occurs, the pump loses capacity, and serious damage to the impeller can result. Equally damaging **vaporization** can occur in other portions of the system where pressure in the pipe can drop below the vapor pressure at the operating water temperature. On shutdown, these very low pressures can result from a combination of static pressure and momentum. Vaporization is often followed by an implosion, which causes destructive water hammer. To avoid this problem, keep all sections of the piping system except the return line to the upper tower basin below the basin level. When this cannot be achieved, perform a thorough dynamic analysis of the piping system for all operating conditions; a soft start and stop control such as a variable-frequency drive on the pump motor is recommended as an additional precaution, and all actuated control valves should be slow closing.

Air release is another characteristic of open condenser water systems that must be addressed. Because the water/air solution in the tower basin is saturated at atmospheric pressure and cold-water basin temperature, the system should be designed to maintain the pressure at all points in the system sufficiently above atmospheric that no air will be released in the condenser or in the piping system (see [Figures 2 and 3 in Chapter 13](#)). Another cause of air in the piping system is **vortexing** at the tower basin outlet. This can be avoided by ensuring that the maximum flow does not exceed that recommended by the tower manufacturer. Release of air in condenser water systems is the major cause of corrosion, and it causes decreased pump flow (similar to cavitation), water flow restrictions in some piping sections, and possible water hammer. Antivortexing devices can be added to the piping to mitigate this occurrence. These features often are available on strainers and suction diffusers.

Pump Selection and Pressure Calculations

The elements of required pump head are illustrated in [Figure 3](#). Because there is an equal head of water between the level in the tower sump or interior reservoir and the pump on both the suction and discharge sides, these static heads cancel each other and can be disregarded. The elements of pump head are (1) static head from lower sump or interior reservoir level to the tower header; (2) friction loss in suction and discharge piping; (3) pressure loss in the condenser; (4) pressure loss in the control valves; (5) pressure loss in the strainer; and (6) pressure loss in the tower nozzles, if used. Added together, these elements determine the required pump total dynamic head. Normally, piping is sized for water velocities between 5 and 12 fps. As stated previously, piping on the discharge of the pump may see the higher velocities, and piping on the suction side should see the lower velocities. Refer to [Chapter 22 of the 2013 ASHRAE Handbook—Fundamentals](#), for piping system pressure losses. Friction factors for 15-year-old pipe are commonly used. Manufacturers' data contain pressure drops for the condenser, cooling tower, control valves, and strainers.



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