Table 1 .... Chilled Water Coil Performance

Coil Circuiting	Chilled Water Inlet Temp, F	Coil Pressure Drop, psi	Chilled Water Flow, gpm ton	Chilled Water Temp Rise, F deg
Full	45	1.0	2.2	10.9
½	45	5.5	1.7	14.9
Full	40	0.5	1.4	17.1
½	40	2.5	1.1	21.8

Based upon cooling air from 81.4 F db, 67.4 F wb to 57.7 F db, 56.4 F wb.

several methods. The *equivalent length* method assigns an equivalent length for each size and type of fitting and valve. Multiplying this length by the friction rate at the particular water quantity and size pipe gives the pressure loss through the fitting in feet of water. Equivalent lengths of commonly used valves and fittings are given in Table 4 of Chapter 75.

The *velocity head* method assigns a constant for each type of obstruction to flow which, when multiplied by the velocity head ($h = V^2/2g$), gives the pressure loss through the obstruction in feet of water.

Hydrostatic Pressure

Every piping system has at least one point where air pressure is exerted upon the surface of the water. This point is the reference point (or reservoir) of the system. When the pump is not operating, the hydrostatic pressure (measured in feet of water) at any point in the system is the vertical distance between the reference point and the required point. When the pump is operating, the pressure will either increase or decrease depending upon the relationship of the pump, expansion tank, and point of measurement.

In a closed system, a pump must overcome only the frictional resistance of the system. The discharge reservoir of the system is also the suction reservoir, so there is no difference in elevation, or *lift*, for the pump to overcome.

In an open system, however, the suction reservoir may be at a different elevation than the discharge reservoir and the pump must overcome the sum of the frictional losses of the system and the hydrostatic lift, or difference in elevation between the two reservoirs.

The preceding discussion is based on the premise that all piping in the system is full of water. The system must be designed so there is no point in the system at which the pressure is below the saturation pressure of water, to avoid flashing in the water circuit, with resultant problems of pump cavitation, water hammer, and erratic flow. Proper location of expansion tanks and proper design pressure in compression tanks will aid in eliminating these problems.

Pipe Sizing

The design of all piping systems is limited by the maximum velocity of flow which is permissible. This maximum velocity is established by limitations of noise generated by water (and entrained air), and erosion of piping by entrained sand, slag, air, etc. Erosion of piping is also dependent upon the hours of operation per year and the desired system life in years. The recommended maximum velocity for typical summer air conditioning systems of average cleanliness is 10 fps. If long hours of operation or unusual water conditions are expected, this velocity should be reduced accordingly to about 6 fps. The velocity at suction connections to open tanks with little submergence should be less than 4 fps.

Piping system design is also limited by friction loss. City water piping must be sized so as to provide the required flow rates at a pressure loss within the pressure available after all other losses (condenser pressure drop, static lift, meter drops) have been deducted from city main pressure. Recirculating pump systems are sized to provide a reasonable balance between increased pumping horsepower due to high friction loss and increased piping first cost due to large pipe sizes. This balance point is usually taken as a maximum friction loss of 10 ft per 100 ft of equivalent length, and the range from 4 to 7 ft per 100 ft is most commonly used.

Pump Selection

Pumps are discussed in detail in Chapter 41 of the 1961 Guide And Data Book.

Circulating pumps for chilled and condenser water are usually direct-driven single-stage centrifugal pumps. Small pumps (5 hp and below) are usually end-suction type and may be either close-coupled type or with separately mounted motor. Larger pumps are more frequently double-suction horizontally split casing type with separately mounted motors, although close-coupled end-suction pumps as large as 75 hp are occasionally used.

Centrifugal pumps are generally very trouble-free and the additional expense to provide stand-by or multiple pumps is difficult to justify on an average air-conditioning installation. Some industrial processing or critical comfort air-conditioning applications require stand-by protection, which should be provided to a similar extent at all equipment in the system. Depending upon the system arrangement, a net savings in investment and pumping cost may be available by use of multiple pumps or 2-speed motors.

If a pump is to handle hot water or is to operate under vacuum with cold water, special attention should be given to pump selection to avoid cavitation. If the absolute pressure at the pump inlet minus the *net positive suction head* rating of the pump is approximately equal to or less than the saturation pressure corresponding to the temperature of the water being pumped, cavitation is likely to occur. This can be avoided by making a more favorable pump selection, or increasing the pump inlet pressure by improving the arrangement or sizing of piping.

In most applications a 5 or 10 percent variation in water quantity has a very minor effect on system performance, and for this reason it is not necessary to include any safety factor. It is, however, good practice to select pumps which will not overload the pump motor at 110 percent of design flow. Pumps which are to be used at constant flow rates may be selected on the *steep* part of the pump curve as shown in Fig. 1, so that a relatively large change in pumping head will have less effect on flow rate. Pumps which are to be used with throttling-type control valves should be selected with flat performance curves as shown in Fig. 2 to limit the increase in pump pressure as the flow is reduced. Points *A* and *B* on Figs. 1 and 2 are the full design flow and minimum operating flow points respectively. If the pump head at shut-off is greater than the maximum pressure differential at which the control valves will operate

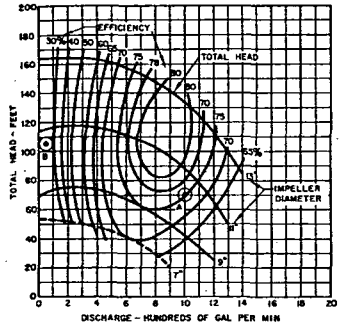


Fig. 1 .... Typical Steep Characteristic Pump Curve

satisfactorily, the use of 3-way valves or a pressure-actuated bypass valve should be considered.

Expansion Tanks

In a closed piping system, provision must be made for expansion or contraction of water due to temperature change, and addition of make-up water to replace pump gland leakage and blow-down losses. An open expansion tank is preferred for this function, and must be located to provide the best possible air venting and maintain a positive pressure on the pump suction to prevent cavitation or leakage of air into the system through the pump gland. This location will generally be at the top of the return main closest to the pump suction. If it is impracticable to install a tank in this location because of difficulty in protecting the tank from freezing, obtaining city water supply or providing overflow drain, a pressure tank (closed expansion tank) may be installed at any convenient point in the system, but preferably on the suction side of the pump.

The variation in volume of the water in the system can be obtained by calculating the total volume of the system including piping and heat exchangers, and multiplying this volume by the percent increase in volume, as obtained from Fig. 16 of Chapter 8. This change generally will be about 1 percent for chilled water systems and 3 percent for hot water systems. If necessary, open expansion tanks need not be sized to handle the entire water volume variation, but can be made any convenient size, recognizing that water will drain out the overflow when the system warms up. The equalizer line from an open expansion tank to the system should be 1 in. minimum size and must not be provided with a shutoff valve. On chilled water systems, the sides and bottom of the tank, as well as the equalizer line, will frequently require insulation if sweating is to be avoided.

The capacity of a closed expansion tank must be sufficiently large to accommodate the maximum variation in water volume that can occur. The capacity of closed expansion tanks may be calculated by use of Equations 4 and 5 of Chapter 8.

Piping Materials

It is customary for recirculating water systems to be provided with water treatment to control corrosion, and galvanized or wrought iron pipe is not generally required. Piping 2½ in. or smaller is normally either hard-drawn copper tubing

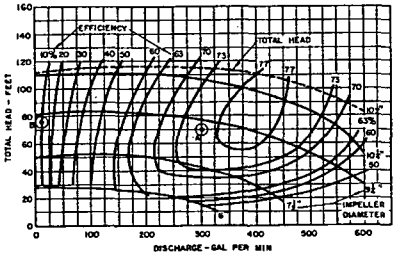


Fig. 2 .... Typical Flat Characteristic Pump Curve

or black steel; piping 3 in. or larger will generally be black steel. Steel pipe 3 in. and above is generally welded; 2½ in. and below, screwed with malleable iron fittings, although welding is acceptable. With proper workmanship and supervision, takeoffs in welded piping may be made by welding directly into the piping without using weld tee fittings, providing the take-off is smaller than the run.

The use of plastic piping is increasing. It is particularly suitable for condenser water and condensate drain piping. It is not generally applied to hot water piping because of the loss of strength at higher temperatures. Detailed information concerning usage and installation practice is available from manufacturers.

The allowable working pressure of pipe and fittings changes with wall thickness, diameter, and operating temperature. Standard weight, butt-welded steel pipe and type *L* hard copper tubing are suitable for applications up to approximately 250 psi at 250 F. Valves and fittings are generally available in both 125 psi and 250 psi construction. Piping for applications above these ranges should be selected for the specific conditions involved.

For information on pipe, tube, and fittings, see Chapter 50 of the 1961 Guide And Data Book.

Service Valves

Service valves should be installed wherever they will be needed to perform routine servicing or where their omission would cause undue hardship in the event of failure of some part of the system. It is not unreasonable to expect a small system to be drained in order to repack the pump gland or clean tubes, and even large systems with roof-located equipment may be treated in this manner. In order to justify the use of a service valve, the savings in time, inconvenience, and possible damage to portions of the building should be greater than the initial cost of the valve.

Service or shutoff valves should be of a low friction loss type to minimize pumping expense. Gate valves and lubricated type plug or ball cocks are preferred for this service.

Balancing Valves

Balancing valves should be installed where necessary to regulate the flow of water through the system. They will be required where the pressure from pump or main is sufficient to cause excessive flow through the system, or where the branches of a parallel flow system have unequal pressure drops at design flow rate.

Balancing valves must have a pressure loss proportional to valve opening, such as is provided by a globe valve or square-