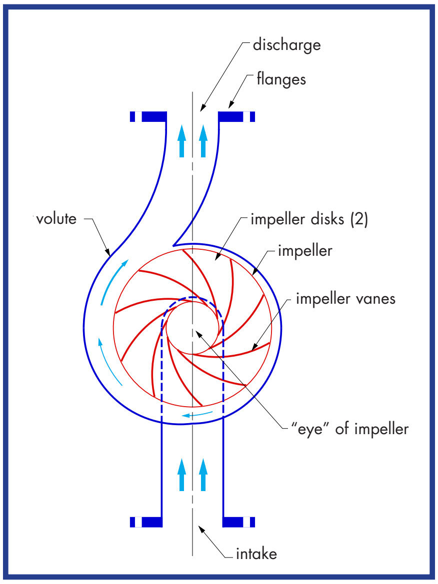
Circulators

6.1 Introduction

The circulator is the heart of a hydronic circuit. It adds head to the fluid, which creates the pressure differential that forces fluid to move through the circuit. The circulators used in hydronic systems are classified as centrifugal pumps. Figure 6.1 shows a cross section of such a pump.

Figure 6.1



Circulators operate as follows: Fluid enters the inlet port and is channeled through the intake volute to the "eye" of the spinning impeller. Curved vanes on the impeller push the fluid outward between two disks. This is where mechanical energy, called head, is transferred to the fluid. The fluid discharges from the perimeter of the impeller and is gathered up by the outlet volute (the chamber in which the impeller spins). The fluid is then routed out the discharge port, its pressure having been raised, but its flow rate unchanged.

When the inlet and discharge ports are aligned along a common centerline, the circulator is called an "inline circulator." Some circulators that have their inlet port parallel to the impeller shaft and are called "end suction circulators." Most circulators used in residential and light commercial systems use the inline configuration. The end suction configuration is more common in larger floor-mounted circulators.

6.2 Circulator performance

The ability of a circulator to move fluid cannot be expressed by a single number. Instead it's given as a graph called a pump curve. An example is shown in Figure 6.2.

Pump curves show how much head the circulator adds to the fluid as it flows through at a specific rate. For example, the circulator represented by the pump curve in Figure 6.2 adds 11 feet of head to a fluid flowing through at 8 gpm. A circulator always operates at some combination of flow rate and head represented by a point on its pump curve.

The head added to a fluid by a circulator, operating at some specific flow rate, does *not*, for all practical purposes, depend on the fluid itself. For example, a circulator pumping a 50 percent glycol solution at 8 gpm would add the same amount of head as it would pumping pure water at 8 gpm. However, the *pressure increase* of the glycol solution, as it flows through the circulator, will not be the same as for water. The pressure increase for either fluid can be calculated using Formula 6.1:

where:

Formula 6.1

$$\Delta P = \left(\frac{H_{added} \times D}{144}\right)$$

ΔP = pressure increase due to head added by circulator (psi)

H_{added} = head added by circulator (feet of head)

D = density of fluid (lb/ft.^{3})

Because the density of a glycol solution is slightly higher than that of pure water, the pressure increase across the circulator would be slightly higher for the glycol solution than for pure water.

To find the flow rate a circulator will produce in a specific pipe system, the system curve is overlaid on (drawn over) the pump curve. The intersection of the curves is where the head supplied by the circulator exactly equals the head removed by fluid friction. It's called the "operating point." The flow rate at the operating point is found by drawing a line straight down to the horizontal axis as shown in Figure 6.3. Using this method the system curve of any piping circuit can be overlaid on the pump curve of any circulator to find what the flow rate would be if such a combination were to be used. It's a powerful design tool that eliminates a lot of guess work.

6.3 Measuring the flow rate through a circulator

The fact that a circulator always operates along its pump curve makes it possible to determine the flow rate through it without using a flow meter. All that's required is an accurate measurement of the pressure increase across the circulator and a copy of the circulator's pump curve.

The procedure is as follows:

1. Measure the pressure increase across the circulator using gauges on, or very close to, the inlet and outlet flanges. Some larger circulators come with their flanges already drilled and tapped for these gauges. Another option is to install a single pressure gauge on a tee between two ball valves. The other sides of the ball valves are teed into the piping adjacent to the inlet and outlet flanges. Open one ball valve to read

Figure 6.2

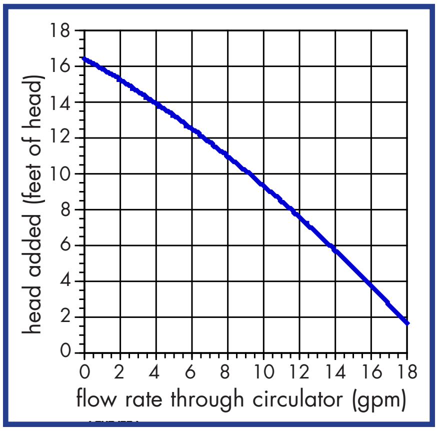
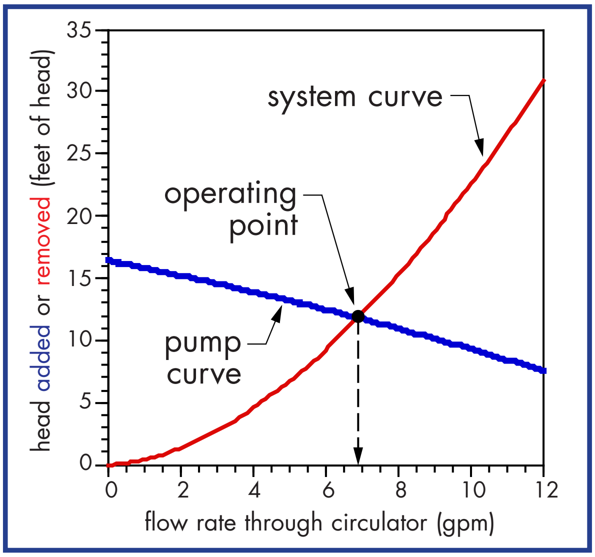


Figure 6.3



inlet pressure. Close it. Then open the other valve to read outlet pressure.

2. Convert this pressure increase to an equivalent amount of head gain using the Formula 6.2.

where:

Formula 6.2

$$H_{added} = \Delta P_{across\ circulator} \times \left(\frac{144}{D}\right)$$

H_{added} = head added to fluid by circulator (feet of head)

ΔP = pressure increase measured across circulator (psi)

D = density of the fluid (lb./ft.^{3})

To use this formula, you need to estimate the density of the fluid being pumped. A graph of the density of water at various temperatures is given in Figure 29.3. You can look up the density of antifreeze solutions on technical sheets supplied by the antifreeze manufacturer.

3. Find the calculated value of head on the vertical axis of the pump curve graph, then draw a horizontal line from that point over to the pump curve. The intersection of this line and the curve is the operating point of the circulator.

4. Finally, draw a line straight down from the operating point and read the operating flow rate on the horizontal axis.

6.4 Circulator efficiency

The efficiency at which a circulator converts the electrical energy supplied to its motor into head depends on where it operates along its pump curve. Peak efficiency occurs near the center of the pump curve. When selecting a circulator for a piping circuit the operating point should fall within the center third of the pump curve to achieve reasonably good efficiency.

6.5 Cavitation

One thing circulators don't handle well is when the fluid they're trying to move flashes into a vapor as it enters their impellers. This can happen at fluid temperatures above *and below* 212 degrees F depending on the pressure in the system. Water boils whenever its pressure drops below its vapor pressure. (Figure 23.1 shows the vapor pressure of water at various temperatures.)

The vapor pockets formed when the water boils at the eye of the impeller collapse as they flow out through the impeller vanes. This collapse happens with incredible speed and can actually erode hardened metal surfaces if it persists. A pump experiencing severe cavitation will make rumbling and popping sounds. If left unchecked, severe cavitation can destroy the impeller and parts of the volute in a short period of time. The performance of a cavitating circulator will also be a fraction of its normal performance. Cavitation simply must be avoided in all hydronic systems.

Guidelines for avoiding cavitation:

- Don't allow the system to operate with abnormally low pressure upstream of the circulator. At any given temperature, the lower the pressure, the closer the water is to boiling as it enters the circulator. Most systems should be fine if kept within the normal 10 to 20 psi (boiler pressure) operating range. Slightly higher pressures are fine as long as the relief valve doesn't prematurely open.
- Mount the circulator so it pumps away from the expansion tank connection point. This allows the pressure differential created by the circulator to be added to the static pressure in the system. If the circulator pumps toward the expansion tank its pressure differential will show up as a decrease in pressure at the worst possible spot — the eye of the impeller. This is a very cordial invitation for cavitation to occur.
- Don't operate the system at excessively high temperatures. Personally, I seldom find any reason to operate a residential or light commercial hydronic heating system with supply temperatures in excess of 200 degrees F. The higher the water temperature, the greater the chances the circulator could experience cavitation.
- Always install the circulator with a minimum of 10 pipe diameters of straight pipe on its inlet side. This reduces turbulence entering the impeller. Never install a throttling valve or other piping component with high flow resistance near the inlet of a circulator.
- All other factors being equal, lower RPM circulators are less prone to cavitation than higher RPM circulators. Circulators with "steep" pump curves that are improperly applied are also more susceptible to cavitation than circulators with relatively "flat" pump curves.

Section 24 gives additional information about how to predict and avoid cavitation.

Figure 6.4A (DOs)

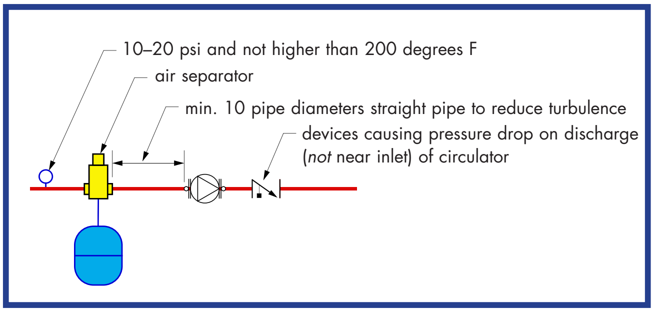


Figure 6.4B (DON'Ts)