CHAPTER 44

CENTRIFUGAL PUMPS

2020 ASHRAE Handbook—HVAC Systems and Equipment

NOTE: All information it has been extracted from 2020 ASHRAE Handbook—HVAC Systems and Equipment already, and any pictures will be added to this document will be taken from the internet for better understanding, furthermore any other information adopted from other standards, must be mentioned the names of standards here for your reference.

Other Standards for Your Reference:

American Society of Plumbing Engineers (ASPE), **Volume 4 Chapter 1**.

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1. INTRODUCTION

Centrifugal pumps provide the primary force to distribute and recirculate hot and chilled water in a variety of space conditioning and plumbing systems.

The pump provides a predetermined flow of water to the space load terminal units or to a thermal storage chamber for release at peak loads.

The effect of centrifugal pump performance on the application, control, and operation of various terminal units is discussed in Chapter 13.

Other hydronic systems that use pumps include:

(1) Condensing water circuits to cooling towers (Chapters 14 and 40).
(2) Water-source heat pumps (Chapter 9).
(3) Boiler feeds (Chapter 11).
(4) Condensate returns (Chapter 11).
(5) Water treatment and service water heating systems.

NOTE: Chapter 9 & 11 & 14 & 40 must be to refer it for more information all these chapters in the ASHRAE Handbook – HVAC Equipment & Application 2020.

Boiler feed and condensate return pumps for steam boilers **should be selected based on the boiler manufacturer's requirements.**

2. CENTEIRFUGAL PUMPING

In a centrifugal pump, an electric motor or other power source **rotates the impeller at the motor's rated speed.** Impeller rotation adds energy to the fluid after it is directed into the center or eye of the rotating impeller. The fluid is then acted on by centrifugal force and rotational or tip-speed force, as shown in the vector diagram in Figure 1. These two forces result in increased fluid velocity.

The pump casing is designed for maximum conversion of velocity energy of the fluid into pressure energy, either by the uniformly increasing area of the volute or by diffuser guide vanes (when provided).

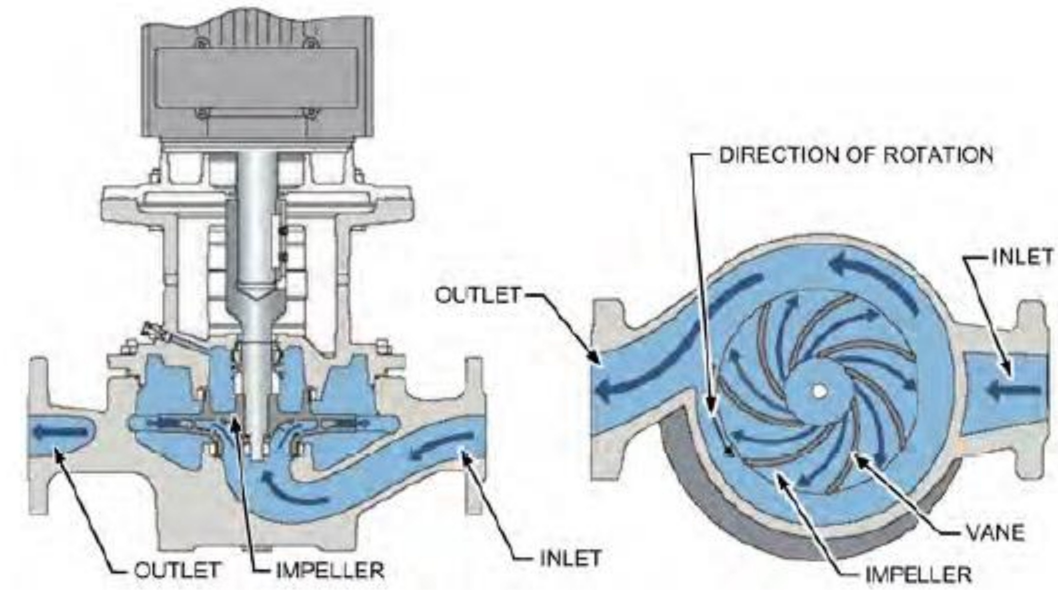


Figure 1 Centrifugal Pump

3. CONSTRUCTION FEATURES

The construction features of a typical centrifugal pump are shown in Figure 2. These features in the Table -1 change or vary according to manufacturer and type of pump:

Table 1 Construction Features

Sr.	Components	Definition or Properties
1	Materials.	• *Centrifugal pumps are generally* available in stainless steel-fitted, bronze-fitted, or iron-fitted construction. • The term "**fitted**" refers to the materials of impeller and wear rings (if used) and the shaft sleeve. • *The choice of material* depends on those parts in contact with the liquid being pumped. • *The casing is typically* cast iron. Stainless steel-fitted, bronze-fitted, and iron-fitted constructions are all appropriate for general water applications. • *All-bronze construction* is often used in potable water applications.
2	Mechanical seals	• Are devices that prevent fluid leakage along rotating shafts. • *They are used mostly in* clean hydronic applications, **either as unbalanced or balanced (for higher pressures) seals.** • *Balanced seals are used* for high-pressure applications, particulate- laden liquids, or for extended seal life at lower pressures. • **Inside seals** operate inside the mechanical seal chamber, whereas **outside seals** have the rotating element outside the box. • Pressure and temperature limitations vary with the liquid pumped and the style of seal.
3	Shaft sleeves	• **Shaft sleeves** protect the motor or pump shaft.

4	Wear rings	• (if present) prevents wear to the impeller and/or casing and are easily replaced when worn. • **Using wear rings is optional,** *because improved casting abilities and part tolerances have reduced the need for them.* • ***Wear rings are intended*** *for applications with abrasive solutions*, **which are not typical in HVAC systems**.
5	Ball bearings	• **Are most frequently used**, except in low-pressure circulators, *where motor and pump bearings are the sleeve type.*
6	Balance ring	• Placed on the back of a single-inlet enclosed impeller reduces the axial load, thereby decreasing the size of the thrust bearing and shaft.

NOTES:

- ***Normal operating speeds of motors*** are 600 to 3600 rpm.
- **The pump manufacturer can help determine the optimum pump speed for** a specific application by considering pump efficiency, the available pressure at the inlet to prevent cavitation, maintenance requirements, and operating cost.

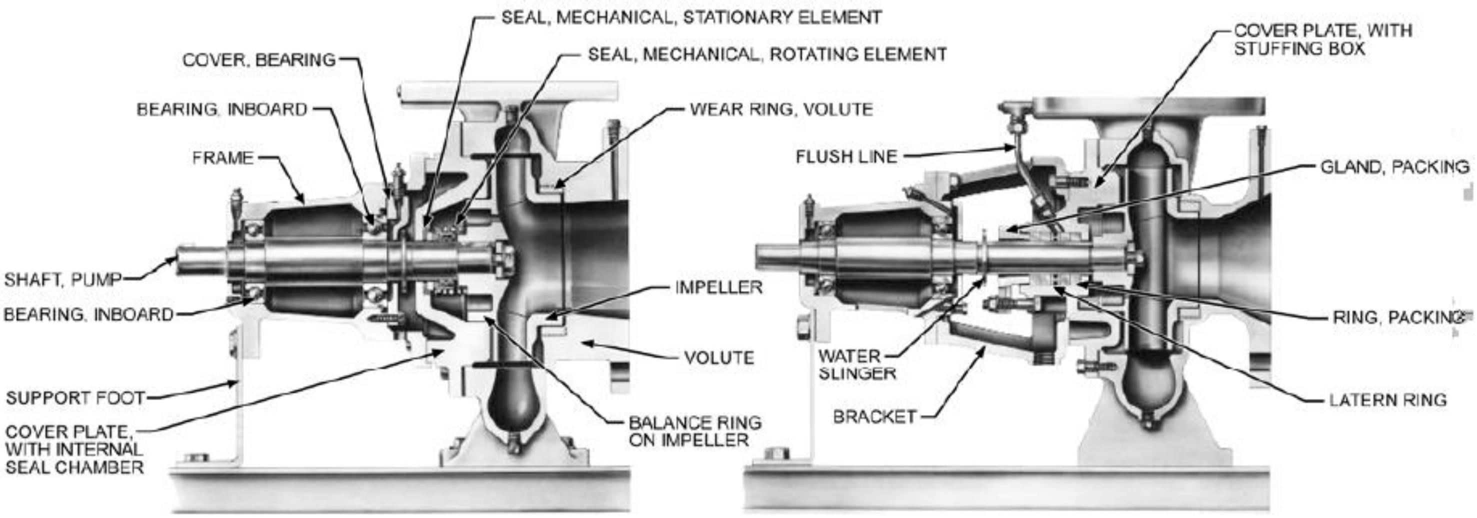


Figure 2 Cross Section of Typical Overhung-Impeller End-Suction Pump

4. PUMP TYPES

Centrifugal pumps **used in hydronic systems are** single stage or multistage. **(These terms refer** to the number of impellers in the pump housing).

A centrifugal pump has either a volute or diffuser casing as shown in figure 3. **Pumps with volute casings** collect water from the impeller and discharge it perpendicular to the pump shaft. **Casings with diffusers** discharge water parallel to the pump shaft. *All pumps described in this chapter have volute casings* **except the vertical turbine pump, which has a diffuser casing.**

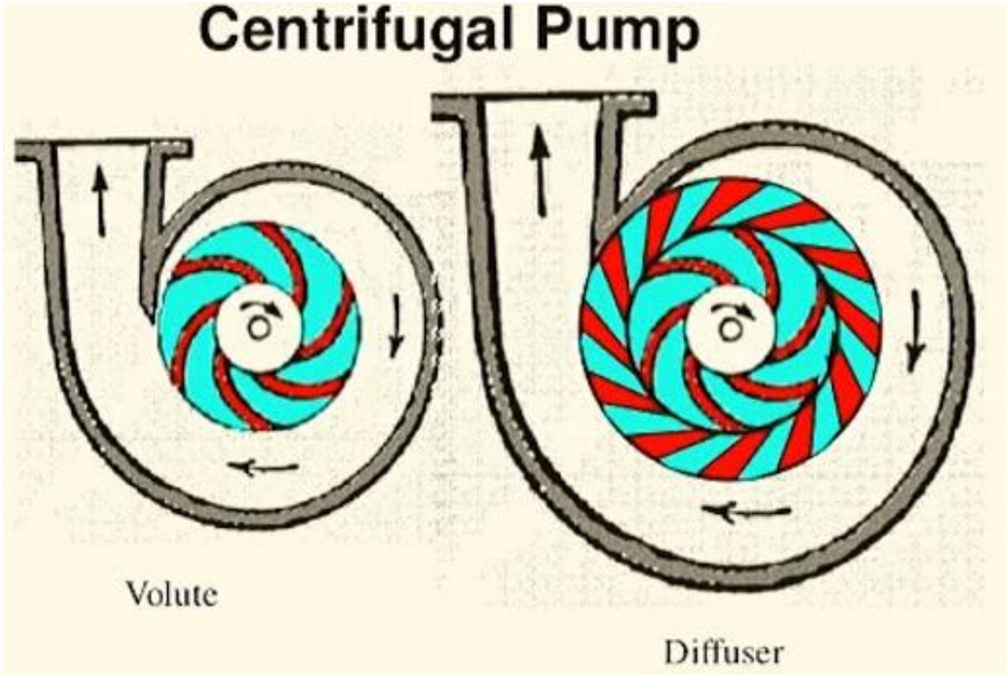


Figure 3 Volute and Diffuser Casing
https://www.youtube.com/watch?v=A42DqcbJttw

Pumps may be classified as close-coupled or flexible-coupled **to the electric motor** as shown in Table – 2. **The close-coupled pump** has the impeller mounted on a motor shaft extension, and **the flexible-coupled pump** has an impeller shaft supported by a frame or bracket that is connected to the electric motor through a flexible coupling.

Close-coupled pumps have an end-suction inlet for horizontal mounting or a vertical in-line inlet **for direct installation in the piping.**

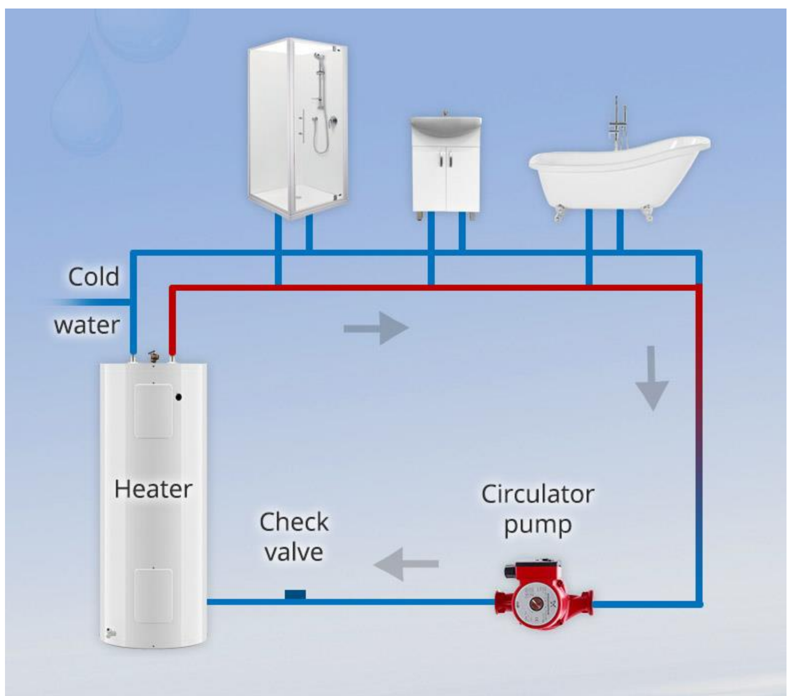
Base-mounted pumps are (1) end-suction, frame-mounted or (2) double-suction, horizontal or vertical split case units.

Double-suction pumps can also be arranged vertically on a support frame with the motor vertically mounted on a bracket above the pump.

Pumps may also be classified by their mechanical features and installation arrangement. And pumps are usually labeled by their mounting position **as either horizontal or vertical**.

Table 2 Types of Pumps

Sr.	Pump	Definition
1	Circulator Pump	• ***A circulator pump*** is a low-pressure, low-capacity, in-line centrifugal pump, with or without an electric motor, consisting of an in-line casing that houses one impeller, which is intended for pipe mounted, installation in heating systems or cooling distribution systems. Shown in Figure -4

		• ***This pump may have a*** wet rotor or may be driven by a close-coupled or flexible-coupled motor. • ***Circulator pumps are commonly used*** **in** residential and commercial buildings to circulate source water and to recirculate the flow of terminal coils to enhance heat transfer and improve the control of large systems.  *Figure 4 Circulator Pump*  *Figure 5 Example 1* *https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.*

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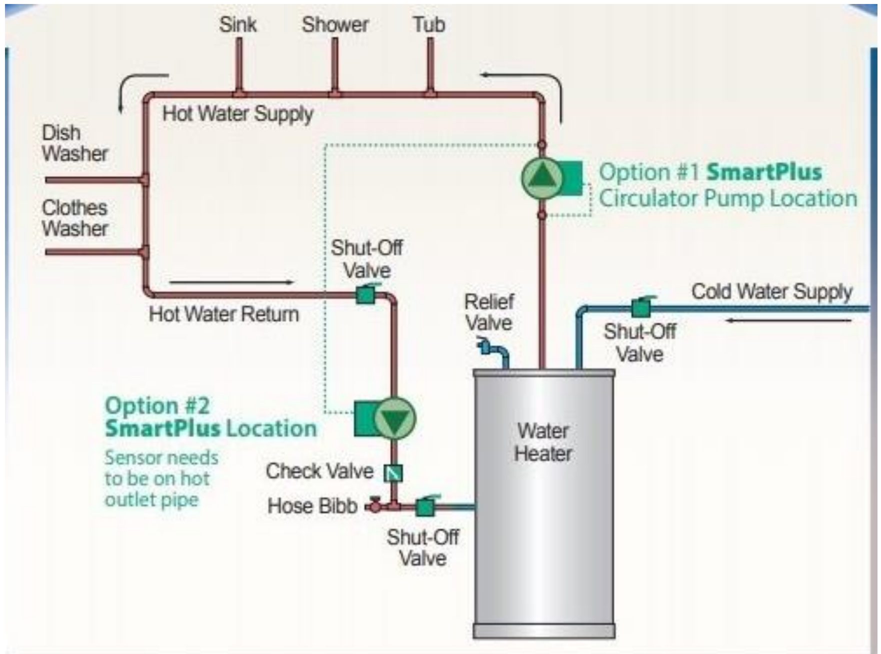
<tr><td>2</td><td></td><td>

Figure 6 Example 2
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<tr><td>2</td><td>Close-Coupled, Single-Stage, End-Suction Pump</td><td>

The close-coupled pump is mounted on a horizontal motor supported by the motor or pump foot mountings (Figure 7).
Mounting usually requires a solid concrete pad.
The impeller is directly mounted on the motor shaft, eliminating the need for flexible couplings.
This compact pump has a single horizontal inlet and vertical discharge.
It may have one or two impellers.

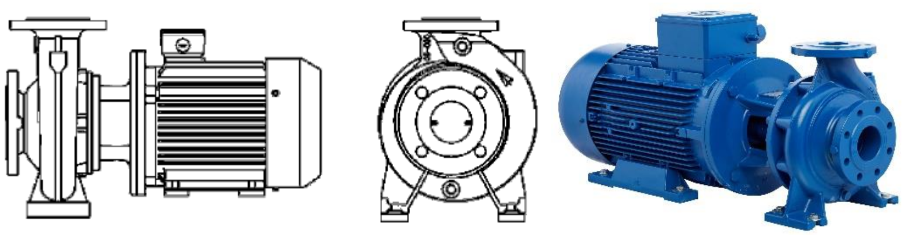

Figure 7 Close-Coupled, Single-Stage, End-Suction Pump</td></tr>
<tr><td>3</td><td>Frame-Mounted, End-Suction Pump on Base Plate (flexible-coupled)</td><td>

Typically, the motor and pump are mounted on a common, rigid base plate for horizontal mounting (Figure 8).
Mounting requires a solid concrete pad.
The motor is flexible-coupled to the pump shaft and should have an Occupational Safety and Health Administration (OSHA)-approved guard.
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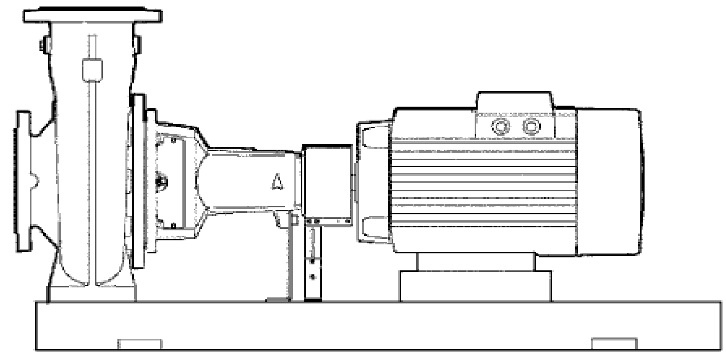
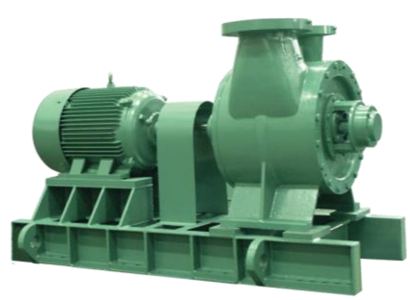
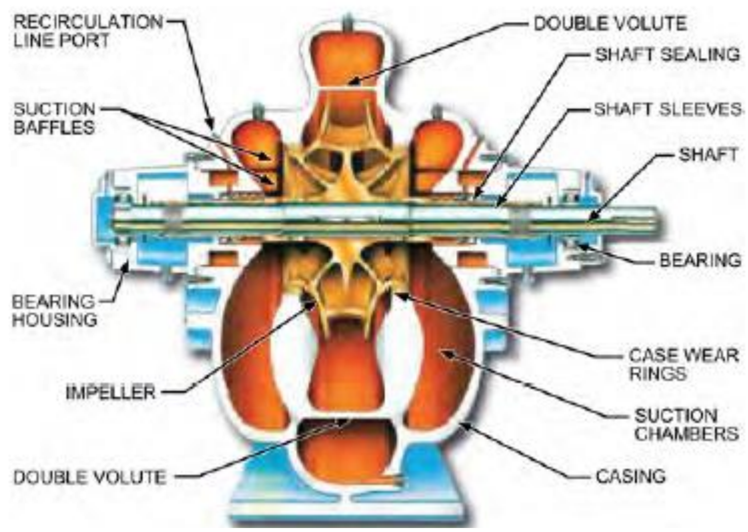
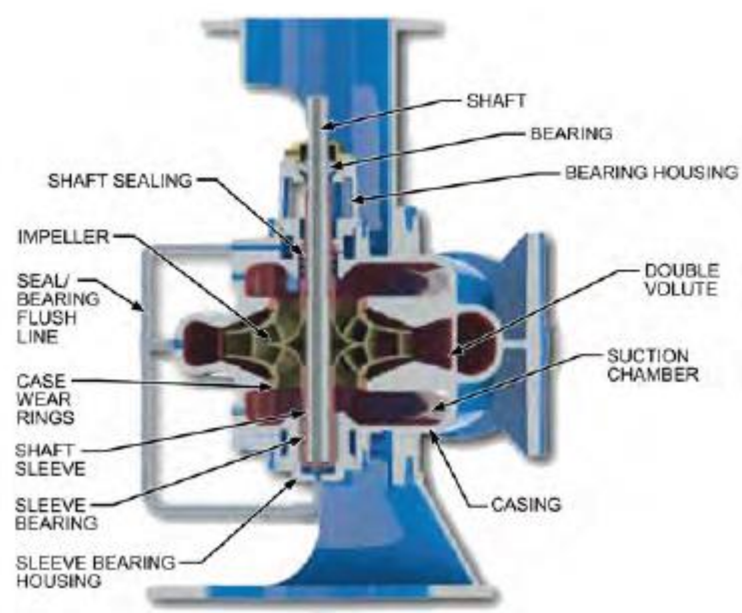
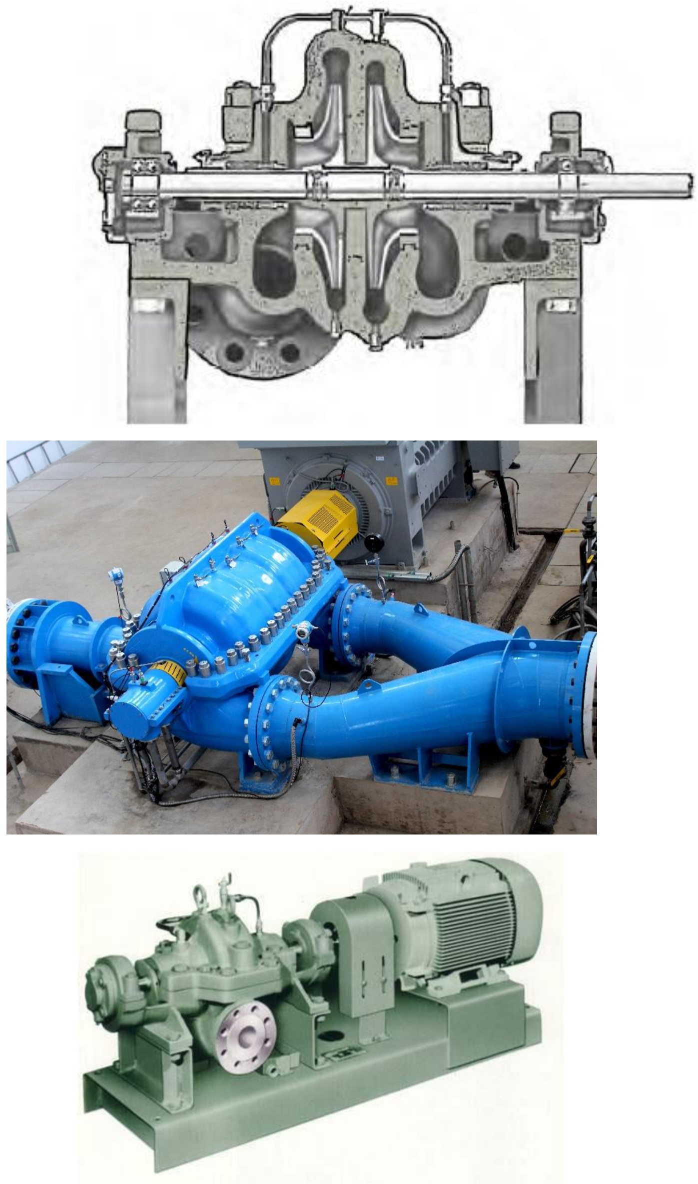
		• <u>For horizontal mounting</u>, **the piping is horizontal on the suction side and vertical on the discharge side.** • This pump **has a single suction.**   *Figure 8 Frame-Mounted, End-Suction Pump on Base Plate (flexible-coupled)*
4	Base-Mounted, Horizontal (Axial) or Vertical, **Split-Case, Single-Stage, Double-Suction Pump**	• The motor and pump are mounted on a common, rigid base plate for horizontal mounting (Figures 9 and 10). • **<u>Mounting requires a solid concrete pad</u>** and **<u>rigid steel base plate,</u>** <u>which may or may not require grouting</u>. • *A split case allows complete access to the impeller for maintenance.* • The motor is flexible-coupled to the pump shaft**<u>, and the coupling should have an OSHA-approved</u>**. • *This pump may have* <u>one or two double-suction impellers</u>.  *Figure 9 Horizontal Spilt Case Pump*  *Figure 10 Vertical Spilt Case Pump*

		 *Figure 11 Vertical Spilt Case Pump*  *Figure 12 Base-Mounted, Horizontal (Axial), Split-Case, Single-Stage, Double-Suction Pump*  *Figure 13 Base-Mounted, Vertical, Split-Case, Single-Stage, Double-Suction Pump*

5	Base-Mounted, Horizontal, **Split-Case, Multistage Pump**	• The motor and pump are mounted on a common, rigid base plate for horizontal mounting (Figure 14). • **Mounting requires a solid concrete pad**. • **The motor is flexible-coupled to the pump shaft, and the coupling should have an OSHA-approved guard**. • **Piping is horizontal on both the suction and discharge sides**. • *The split case* allows complete access to the impellers for maintenance. • *This pump has a* single suction and may have one or more impellers for multistage operation.  *Figure 14 Base-Mounted, Horizontal, Split-Case, Multistage Pump*

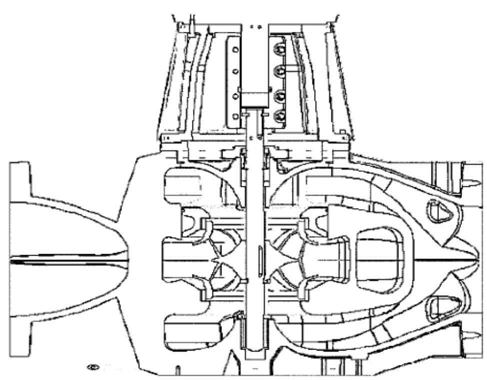
6	**Vertical In-Line Pump**	• This close-coupled pump and motor are mounted on the pump casing. • **The unit is compact and depends on the connected piping for support.** • Mounting requires adequately spaced pipe hangers and, sometimes, vertical casing support. • *The suction and discharge piping* ***are horizontal.*** • *The pump* ***has a single or double suction impeller.***  *Figure 15 Vertical In-Line Pump*
7	**Vertical In-Line** Split-Coupled Pump	• **The suction and discharge flanges of this pump are oriented in the horizontal plane,** on a common centerline. • *The motor is installed* vertically. • *Removing the coupler allows access* to replace the mechanical seal between the motor shaft and pump shaft without moving the motor. • *This pump can be either* single or double suction (see Figures 10 and 11.  *Figure 16 Vertical In-Line Split-Coupled Pump*

Figure 17 Vertical In-Line Pump (Single Suction Impeller)

8	**Vertical Turbine**, Single- or Multistage, Sump-Mounted Pump	• Vertical turbine pumps have a motor mounted vertically on the pump discharge head for either wet-sump or can-type mounting (Figure 12). • This single-suction pump may have one or multiple impellers for multistage operation. • **Mounting requires a solid concrete pad or steel sole plate above the wet pit with accessibility** *to the screens or trash rack on the suction side for maintenance.* • Can-type mounting requires a suction strainer. • **Piping is horizontal on the discharge side and vertical on the suction side.** • **The sump should be designed according to Hydraulic Institute (HI) recommendations.**  *Figure 18 Vertical Turbine Pump*

5. PUMP PERFORMANCE CURVES

- Performance of a centrifugal pump is commonly shown by a **manufacturer's** performance curve (Figure 19) and ***the figure displays*** the pump power required for a liquid (water) with a specific gravity of 1.0 over a particular range of impeller diameters and flows.
- The curves are based on standard test procedures developed by the Hydraulic Institute (2008-2010) and the International Organization for Standardization (ISO).
- **The tests are performed by** the manufacturer for a given pump volute or casing and several impeller diameters, normally from the maximum to the minimum allowable in that volute.
- *The tests are conducted at* a constant impeller speed **for various flows**.
- *The curve is sometimes* called the head-capacity curve (HQ) for the pump.

- *The discharge head of the centrifugal pump, sometimes* called the total dynamic head (TDH), **is measured in feet of water flowing at a standard temperature and pressure.**
- *TDH represents the* **difference in total head between the suction side and the discharge side of the pump.** This discharge head decreases as the flow increases (Figure 20). Motors are often selected to be non-overloading at a specified impeller size and maximum flow to ensure safe motor operation at all flow requirements.
- *The pump characteristic curve may be further described as* flat or steep (Figure 21). Sometimes these curves are described as a normal rising curve **(flat),** a drooping curve **(steep),** or a steeply rising curve.
- The pump curve is considered flat if the pressure at shutoff is about **1.10 to 1.20 times** the pressure at the best efficiency point.
- **Flat characteristic pumps** are usually installed in closed systems with modulating two-way control valves.
- **Steep characteristic pumps** are usually installed in open systems, such as cooling towers (see Chapter 14), where higher head and constant flow are usually desired.

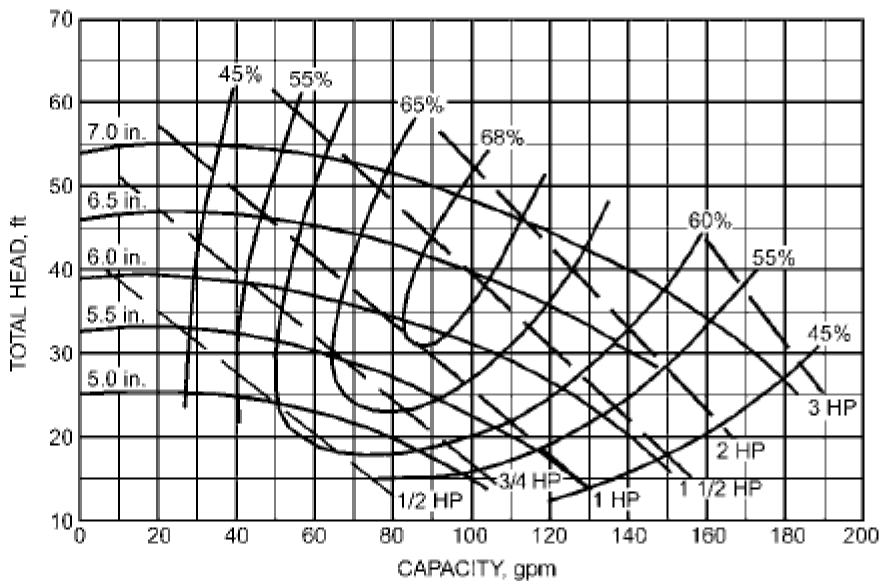


Figure 19 Typical Pump Performance Curve

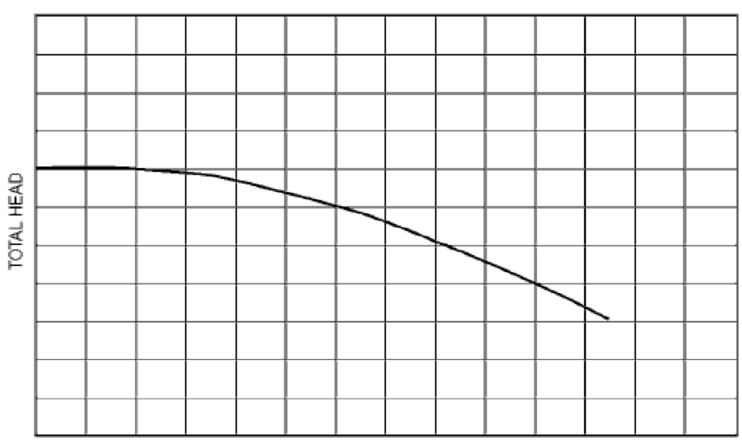


Figure 20 Typical Pump Curve

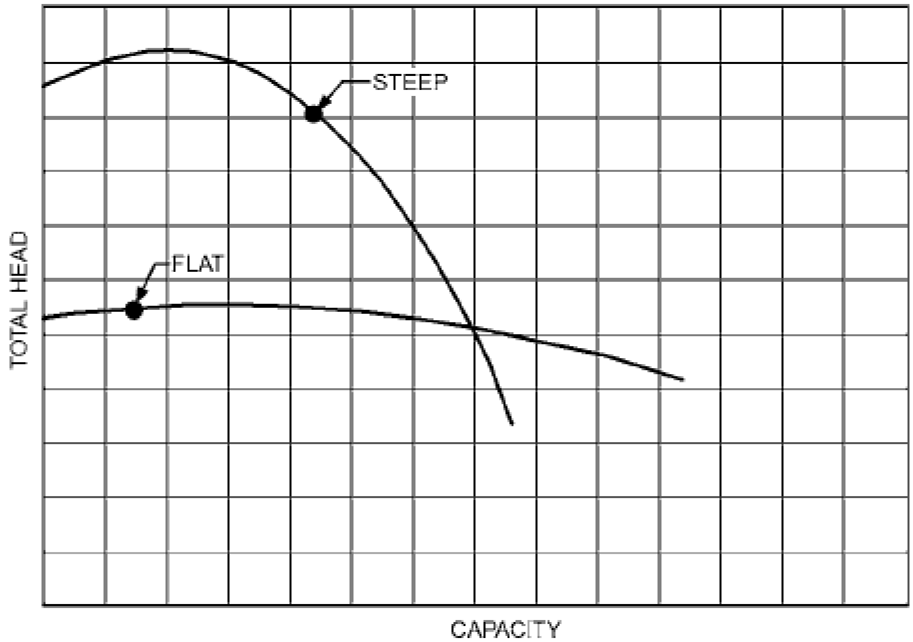


Figure 21 Flat Versus Steep Performance Curves

Pump manufacturers may compile performance curves for **a particular set of pump volutes in a series** (Figure 22).

The individual curves are shown in the form of an envelope consisting of the maximum and minimum impeller diameters and the ends of their curves.

This set of curves is known as **a family of curves.**

A family of curves is useful in determining the approximate size and model required, **but the particular pump curve** (Figure 19) **must then be used to confirm an accurate selection**.

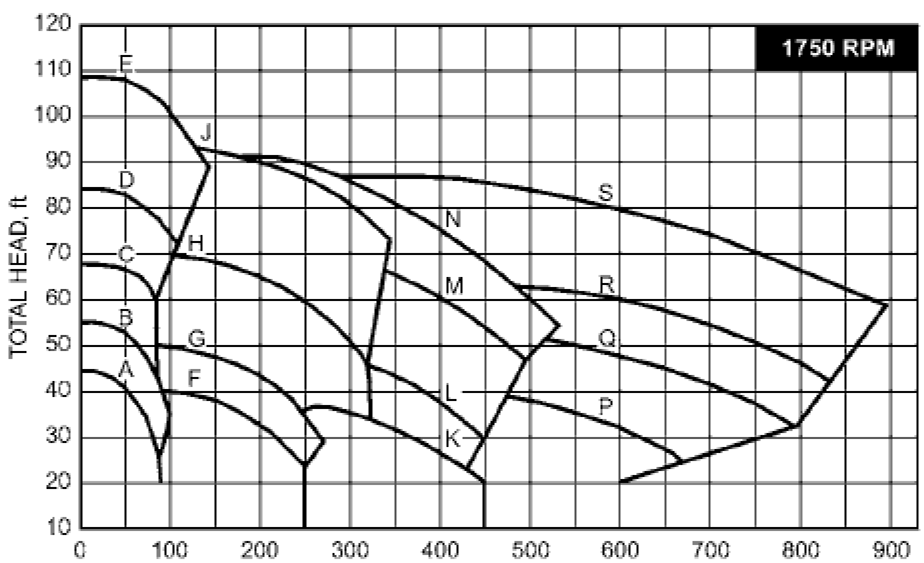


Figure 22 Typical Pump Manufacturer's Performance

NOTE:

Many pump manufacturers and HVAC software suppliers offer electronic versions for pump selection. **Pump selection software typically allows the investigation of different types of pumps and operating parameters. Corrections for fluid specific gravity, temperature, and motor speeds are easily performed and** then you can extract report has all details of pump.

You can visit to this link and check, this for example:
https://crane.pump flo.com/app/user/login.aspx?ReturnUrl=%2fapp%2fstorefront.aspx%3fsid%3dcrane&sid=crane

6. HYDRONIC SYSTEM

Pressure drops caused by the friction of a fluid flowing in a pipe may be described by the Darcy-Weisbach equation:

$$\Delta p = f \frac{L}{D} \frac{\rho}{g} \frac{V^2}{2} \qquad (1)$$

Equation (1) **shows that pressure drop in a hydronic system** due (pipe, fittings, and equipment).

The design of the system (*including the number of* terminals and flows, the fittings and valves, and the length of pipe mains and branches).

Equation (1) may also be expressed in head or specific energy form:

$$\Delta h = \frac{\Delta p}{\rho} = f \frac{L}{D} \frac{V^2}{2g} \qquad (2)$$

where

Δh = head loss through friction, ft (of fluid flowing)
Δp = pressure drop, lb/ft^2
ρ = fluid density, lb/ft^3
f = friction factor, dimensionless
L = pipe length, ft
D = inside diameter of pipe, ft
V = fluid average velocity, ft/s
g = gravitational acceleration, 32.2 ft/s^2

7. PUMP POWER

The theoretical power to circulate water in a hydronic system is the **water horsepower (whp)** and is calculated as follows:

$$\text{whp} = \frac{\dot{m} \Delta h}{33{,}000} \qquad (3)$$

where

$\dot{m}$ = mass flow of fluid, lb/min
Δh = total head, ft of fluid
33,000 = units conversion, ft·lb/min per hp

At 68°F, water has a density of 62.3 lb/ft3, and Equation (3) becomes.

$$\text{whp} = \frac{Q\Delta h}{3960} \qquad (4)$$

where

Q = fluid flow rate, gpm

3960 = units conversion, ft·gpm per hp

Figure 23 shows how water power increases with flow. **At other water temperatures or for other fluids,** Equation (4) is corrected by multiplying by the specific gravity of the fluid.

The **brake horsepower** (bhp) required to operate the pump **is determined by the manufacturer's test of an actual pump running under standard conditions to produce the required flow and head as shown in** Figure 13.

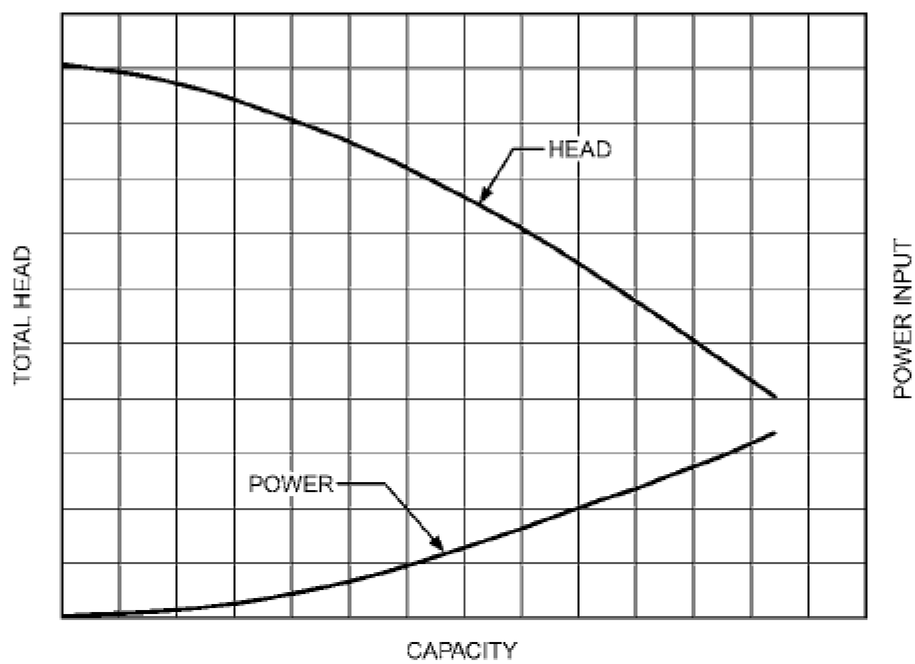


Figure 23 Typical Pump Water Power Increase with Flow

8. PUMP EFFICIENCY

Pump efficiency is determined by comparing the output power to the input power:

$$\text{Efficiency} = \frac{\text{Output}}{\text{Input}} = \frac{\text{whp}}{\text{bhp}} \times 100\% \qquad (5)$$

Figure 24 shows a typical efficiency versus flow curve. The pump manufacturer usually plots the efficiencies for a given volute and impeller size on the pump curve **to help the designer select the proper pump** (Figure 25).

The best efficiency point (BEP) is the optimum efficiency for this pump, operation above and below this point is less efficient. The locus of all the BEPs for each impeller size lies on a system curve that passes through the origin (Figure 26).

For hydronic systems, basing centrifugal pump selection on the highest efficiency at the highest possible application flow and head point may not result in the most efficient overall pump selection, because this is often a rare operating point.

In addition, centrifugal pumps selected at a motor synchronous speed and then fitted with a **reduced-diameter impeller** to meet the highest flow and head point **may not be optimal**.

Centrifugal pumps have the highest efficiency at the maximum impeller diameter, and new hydronic system pumps serving variable-flow systems exceeding 5 hp are required by ASHRAE Standard 90.1 to be variable speed so they can operate at or below the motor synchronous speed.

Selecting pumps at the maximum impeller diameter and using reduced speed to reach the highest flow and head operating point, and all other operating points, often results in **the highest overall pump efficiency and lowest power requirement.**

With variable- speed operation, ensure the speed at the minimum flow and head operating point exceeds the motor minimum speed.

Motor suitability for operation below 30 to 50% of the motor synchronous speed **should be verified with the motor manufacturer.**

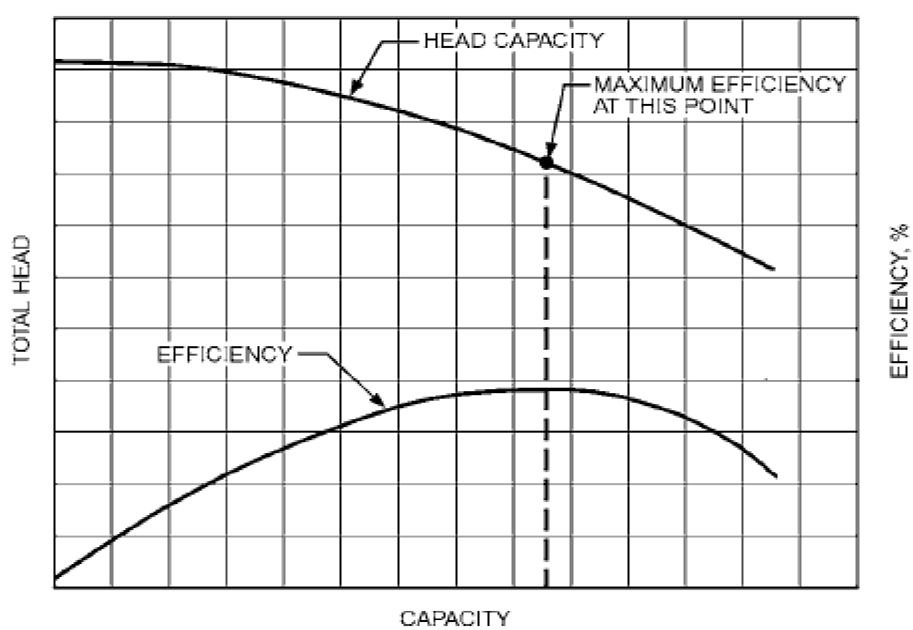


Figure 24 Pump Efficiency Versus Flow

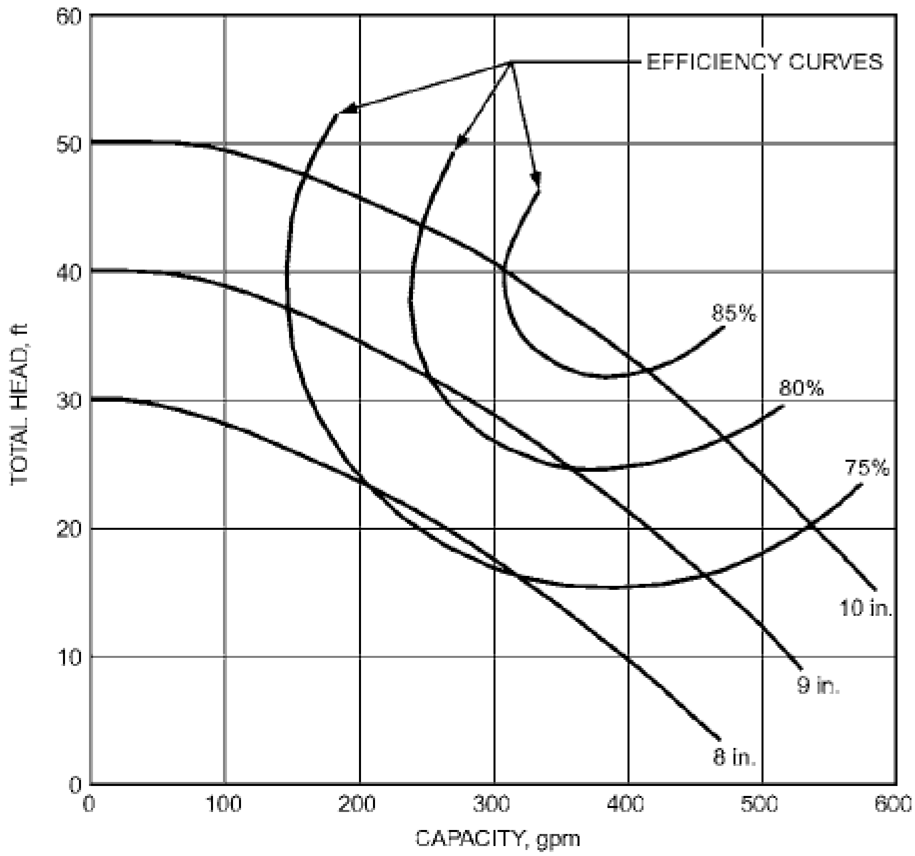


Figure 25 Pump Efficiency Curves

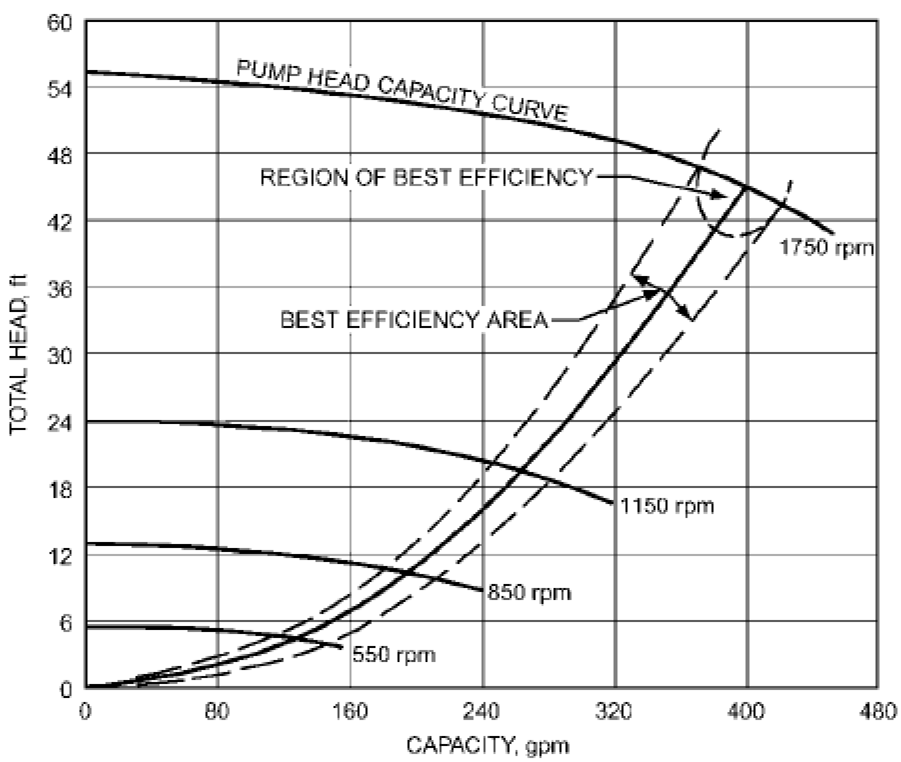


Figure 26 Pump Best Efficiency Curves

9. AFFINITY LAWS

The centrifugal pump, which imparts a velocity to a fluid and converts the velocity energy to pressure energy, can be categorized by a set of relationships called **affinity laws** (Table 1).

The affinity laws are useful for estimating pump performance at different rotating speeds or impeller diameters D based on a pump with known characteristics.

The following two variations can be analyzed by these relationships:

- By changing speed and maintaining constant impeller diameter, pump efficiency remains the same, but head, capacity, and brake horsepower vary according to the affinity laws.
- By changing impeller diameter and maintaining constant speed, the pump efficiency for a diffuser pump is not affected if the impeller diameter is changed by less than 5%. However, efficiency changes if the impeller size is reduced enough to affect the clearance between the casing and the periphery of the impeller.

Table 3 Pump Affinity Laws

Pump Affinity Laws

Function	Speed Change	Impeller Diameter Change
Flow	$Q_2 = Q_1\left(\frac{N_2}{N_1}\right)$	$Q_2 = Q_1\left(\frac{D_2}{D_1}\right)$
Head	$h_2 = h_1\left(\frac{N_2}{N_1}\right)^2$	$h_2 = h_1\left(\frac{D_2}{D_1}\right)^2$
Horsepower	$\text{bhp}_2 = \text{bhp}_1\left(\frac{N_2}{N_1}\right)^3$	$\text{bhp}_2 = \text{bhp}_1\left(\frac{D_2}{D_1}\right)^3$

10. RADIAL THRUST

Hydraulic radial force in the plane of the impeller, generated by the interaction between the impeller and the pump casing or the diffuser (Figure 27).

Figure 28 shows the typical change in radial thrust with changes in the pumping rate. Specifically, radial thrust decreases from shutoff to the design capacity (if chosen at the BEP) and then increases as flow increases.

The radial forces at extremely low flow can cause severe impeller shaft deflection and, ultimately, shaft breakage. This danger is even greater with high pressure pumps.

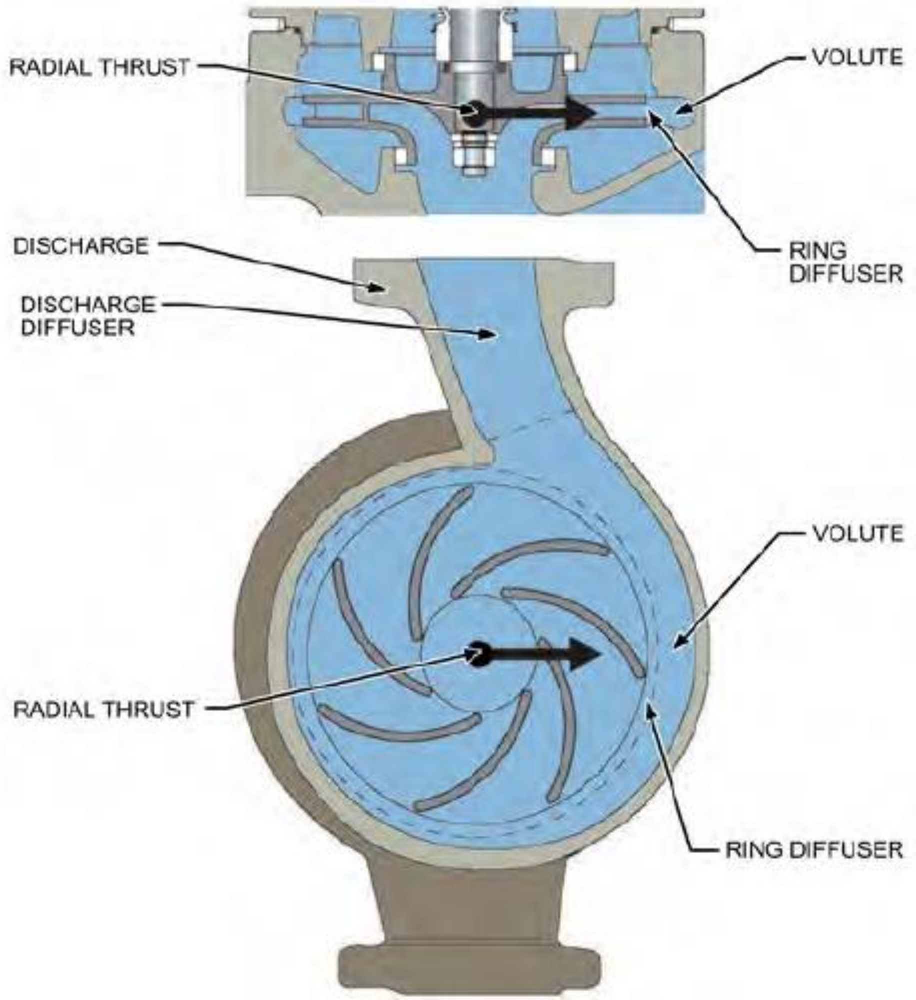


Figure 27 Radial Thrust

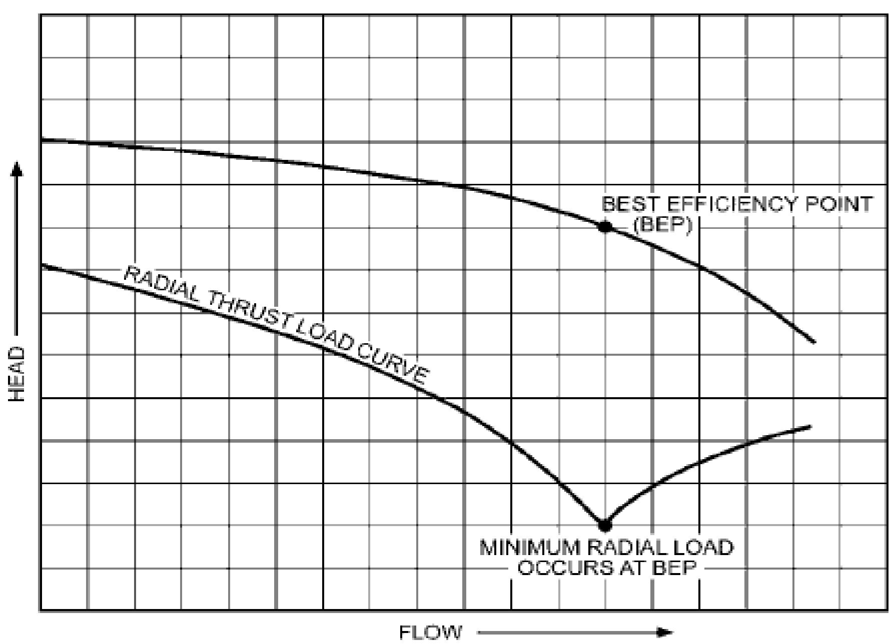


Figure 28 Radial Thrust Versus Pumping Rate

11. NET POSITIVE SUCTION CHARACTERISTICS (NPSH)

- Particular attention **must be given to the pressure and temperature of the water as it enters the pump**, **especially in** condenser towers, steam condensate returns, and steam boiler feeds.
- Cavitation occurs when the liquid in a pump turns to a vapor at low pressure. It occurs because there is not enough pressure at the suction end of the pump, or insufficient Net Positive Suction Head available (NPSHA). **When cavitation takes place, air bubbles are created at low pressure**.
- The amount of pressure in excess of the vapor pressure required to prevent vapor pockets from forming is known as the net positive suction head required (NPSHR).
- ***NPSHR*** is a characteristic of a given pump and varies with pump speed and flow.
- ***NPSHR*** is determined by the manufacturer and is included on the pump performance curve.
- **NPSHR is particularly important when a pump is operating with hot liquids or is applied to a circuit having a suction lift.**
- The vapor pressure increases with water temperature and reduces the net positive suction head available (NPSHA).
- **Each pump has its NPSHR**, **and the installation has its NPSHA**, which is the total useful energy above the vapor pressure at the pump inlet.

The following equation 6 may be used to determine the NPSHA in a proposed design (Figure 29):

$$\text{NPSHA} = h_p + h_z - h_{vpa} - h_f \qquad (6)$$

where

h_p = absolute pressure on surface of liquid that enters pump, ft of head
h_z = static elevation of liquid above center line of pump (h_z is negative if liquid level is below pump center line), ft
h_{vpa} = absolute vapor pressure at pumping temperature, ft
h_f = friction and head losses in suction piping, ft

To determine the NPSHA in an existing installation, the following equation 7 may be used (see Figure 30):

$$\text{NPSHA} = h_a + h_s + \frac{V^2}{2g} - h_{vpa} \qquad (7)$$

where

h_a = atmospheric head for elevation of installation, ft
h_s = head at inlet flange corrected to center line of pump (h_s is negative if below atmospheric pressure), ft
$V^2/2g$ = velocity head at point of measurement of h_s, ft

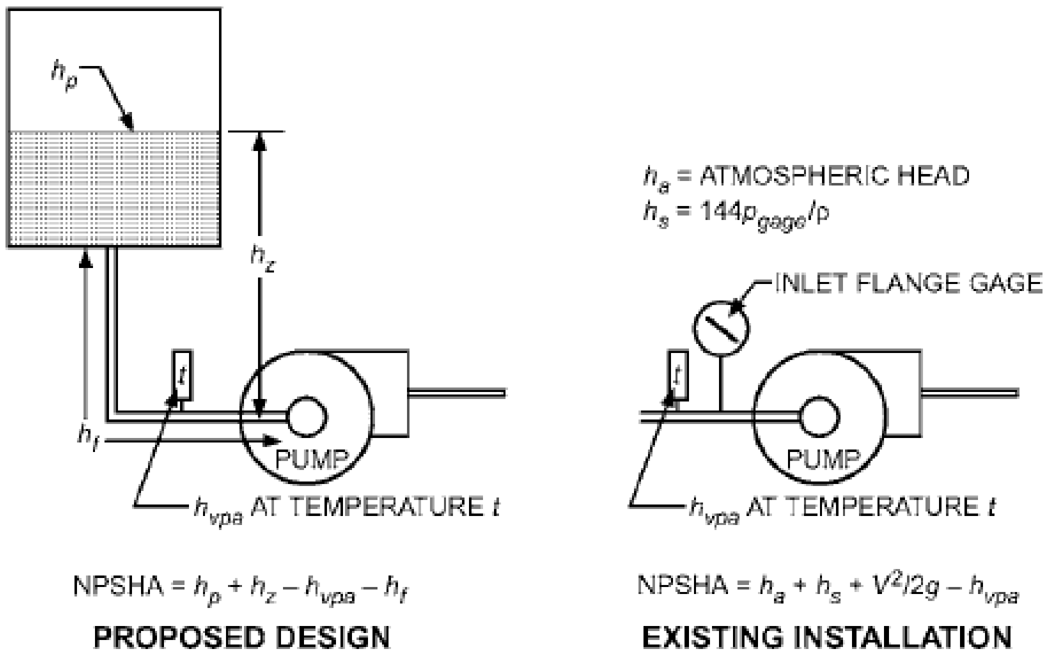


Figure 29 Net Positive Suction Head Available

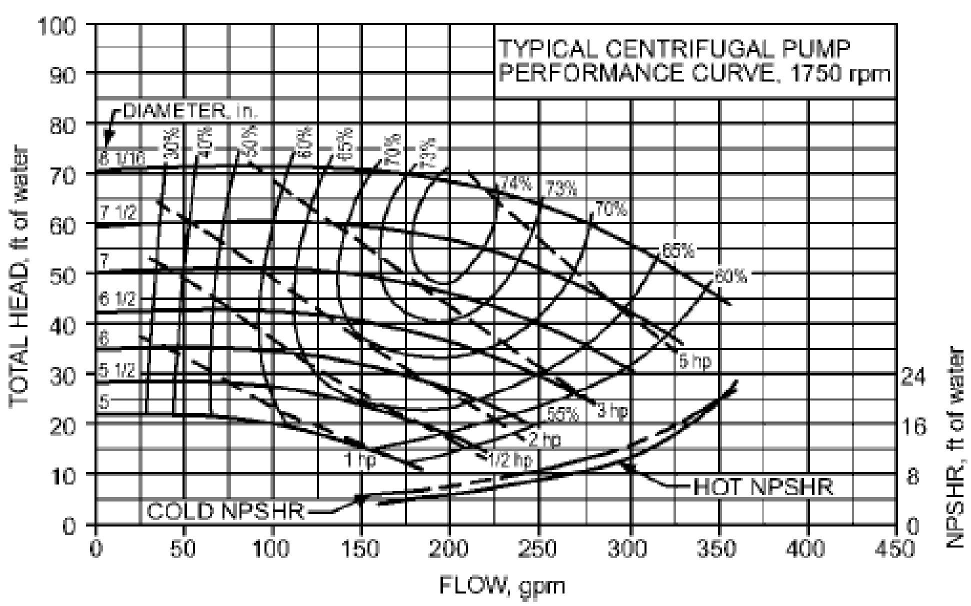


Figure 30 Pump Performance and NPSHR Curves

- **If the NPSHA is less than the pump's** NPSHR, cavitation, noise, inadequate pumping, and mechanical problems will result. **For trouble-free design, the NPSHA must always be greater than the pump's NPSHR.**
- In closed hot and chilled water systems where, sufficient system fill pressure is exerted on the pump suction, NPSHR is normally not a factor.
- Cooling towers and other open systems **require calculations of NPSHA**.

- Figure 30 shows pump curves and NPSHR curves.

12. SELECTION OF PUMPS

A substantial amount of data is required to ensure that an adequate, efficient, and reliable pump is selected for a particular system. **The designer should review the following criteria:**

- Design flow.
- Pressure drop required for the most resistant loop.
- Minimum system flow.
- System pressure at maximum and minimum flows.
- Type of control valve: two-way or three-way
- Continuous or variable flow.
- Pump environment.
- Number of pumps and standby.
- Electric voltage and current.
- Electric service and starting limitations.
- Motor quality versus service life.
- Water treatment, water conditions, and material selection.

However, **if the designer is confident in the calculated design friction head loss for the system, the pump should be selected as near the BEP as possible.**

If the pump is installed with a variable frequency drive (VFD), selecting the duty point slightly to the right of the BEP is even better.

13. ARRANGEMENT OF PUMPS

In a large system, a single pump may not be able to satisfy the full design flow and yet provide both economical operation at partial loads and a system backup. **The designer may need to consider the following alternative pumping arrangements and control scenarios:**

- **Multiple pumps in parallel or series.**
- **Standby pump.**
- **Pumps with two-speed motors.**
- **Primary-secondary pumping.**
- **Variable-speed pumping.**
- **Variable-speed distributed pumping.**

Now we will explain all arrangements of pumps at below in the Table - 4:

Table 4 Arrangements of pumps

<table>
<tr><th>Sr.</th><th>Arrangement of pump</th><th>Definition</th></tr>
<tr><td>1</td><td>Duty Standby</td><td>

- HVAC pumping systems are often designed for **duty-standby** operation wherein pumps (typically two or more) are installed, with only one pump operating at a time.
- **The other pump is on standby, available to provide 100% flow redundancy** in case the duty pump experiences **failure** or **is shut off for maintenance**.

</td></tr>
<tr><td>2</td><td>Parallel Pumping</td><td>

- If the building does not require critical HVAC pumping service, **then a duty-standby arrangement may not be required and designing multiple pumps in parallel** may be more cost effective.
- The appropriate level of redundancy should be discussed with the owner.
- **For example,** a flow capacity split of 50:50 results in each pump being sized for 50% of the peak design flow; if one of the pumps were unavailable, **the remaining pump could provide approximately 70% of the peak design flow rate** (depending on the pump and system curves):

$$\text{Flow redundancy} = \frac{Q_{n-1}}{Q_{design}}$$

where

n = number of pumps
Q_{n-1} = flow rate at $n-1$
Q_{design} = peak design flow rate

- **This approach can reduce costs** for equipment, pump installation, and electrical infrastructure.
- A control strategy should also be considered for any parallel pumping application to optimize operation and sequencing of the multiple pumps and further minimize operational cost.
- An example of possible flow redundancy by application is shown in Table 5.

Table 5 Flow Redundancy

Application	Proposed Flow Redundancy	Flow Capacity Split (for Two-Pump System)
Generic duty	70%	50:50
High comfort sensitivity	85%	70:70
Mission critical	100%	100:100

</td></tr>
</table>

Operation:

- The piping of parallel pumps (Figure 31) should permit running either pump.
- **A check valve is required in each pump's discharge** to prevent backflow when one pump is shut down.
- **Hand valves and a strainer** allow one pump to be serviced while the other is operating.
- **A strainer protects a pump by** preventing foreign material from entering the pump.
- **Using gages or a common gage with a trumpet valve**, which includes several valves as one unit, or pressure taps allows checking pump operation.
- **Parallel pumps are often used** for hydronic heating and cooling.
- **In this application**, both pumps operate during the cooling season to provide maximum flow and pressure, but only one pump operates during the heating season.

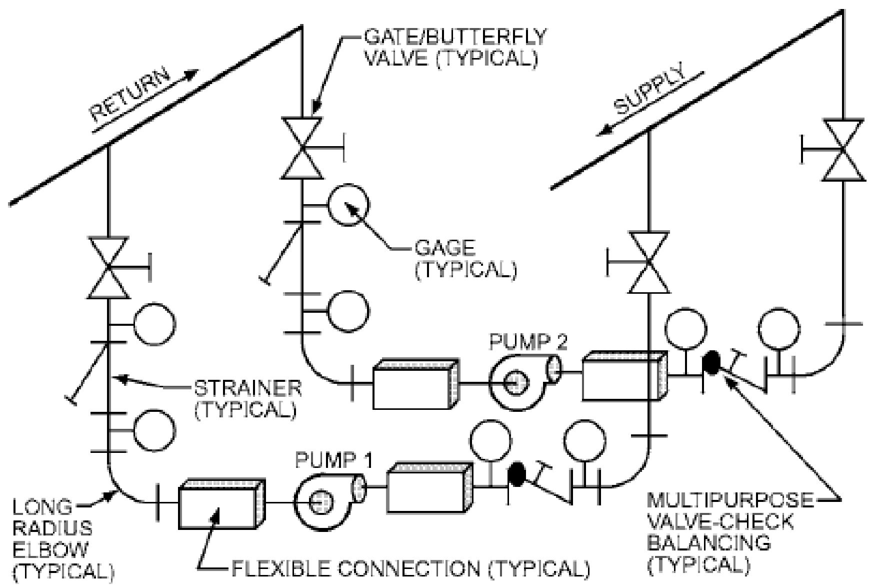


Figure 31 Typical Piping for Parallel Pumps

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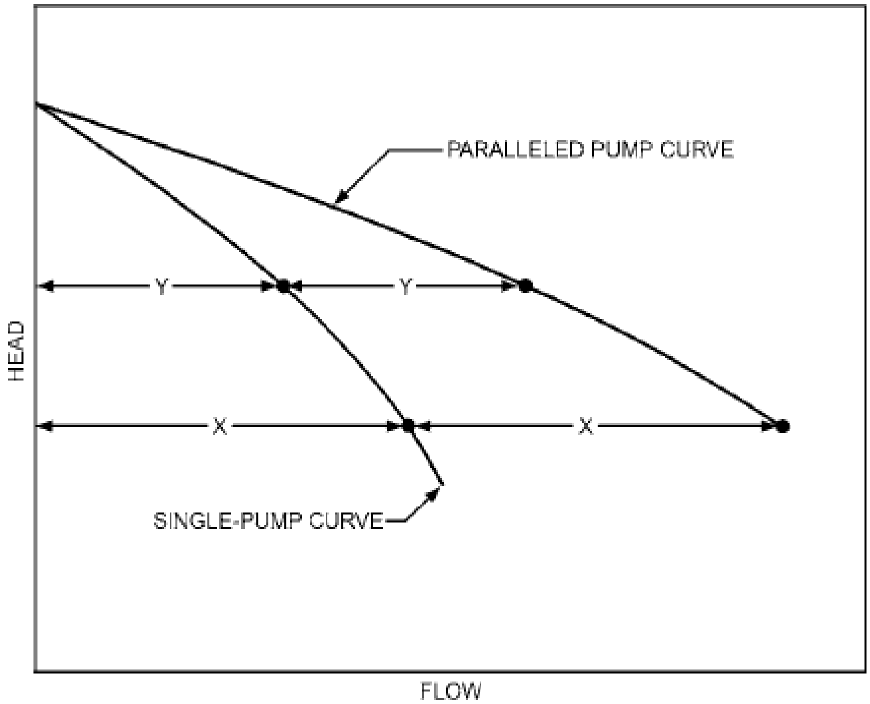
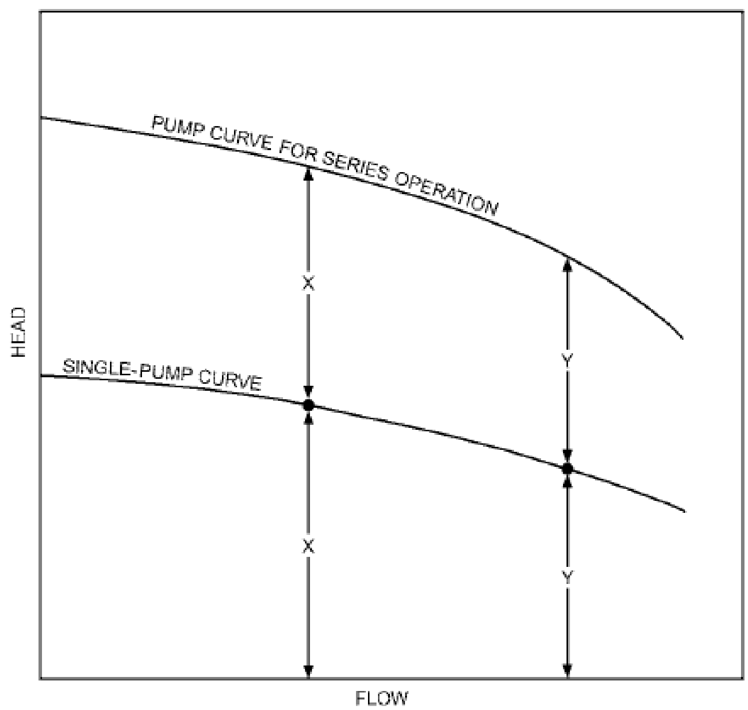
		 *Figure 32 Pump Curve Construction for Parallel Operation* **NOTE: Here the flowrate increases and the head constant**
3	Series Pumping	• **When pumps are applied in series**, each pump operates at the same flow rate and provides its share of the total pressure at that flow (Figure 33).  *Figure 33 Pump Curve Construction for Series Operation*

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- Piping for series **pumps should allow running either pump** (Figure 34).
- A bypass with a hand valve **allows servicing one pump while the other is in operation.**
- **A strainer prevents** foreign material from entering the pumps.
- **In designing systems with multiple pumps**, operation in either parallel or series **must be fully understood and considered by both designer and operator**.

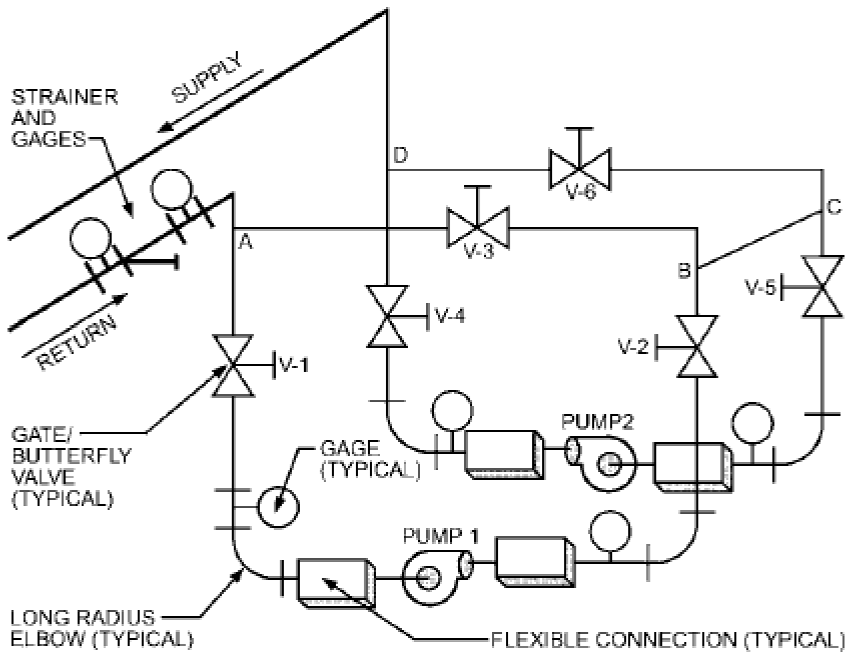

Figure 34 Typical Piping for Series Pumps

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</tr>
<tr>
<td>4</td>
<td>Standby Pump</td>
<td>

- **A backup or standby pump of equal capacity and pressure** installed in parallel to the main pump is recommended to operate during an emergency or to ensure continuous operation when a pump is taken out of operation for routine service.
- **A standby pump** installed in parallel with the main pump

</td>
</tr>
<tr>
<td>5</td>
<td>Primary-Secondary Pumping</td>
<td>

- **In a primary-secondary or compound pumping arrangement**, a secondary pump is selected to provide the design flow in the load coil from the common pipe between the supply and return distribution mains (Figure 35).
- The pressure drop in the common pipe should not exceed 1.5 ft.
- **In circuit A of the figure**, a two-way valve allows a variable flow in the supply mains by reducing the flow; **a secondary pump provides a constant flow in the load coil.**
- **In circuits B and C of the figure**, three-way valves provide a constant flow regardless of the load.

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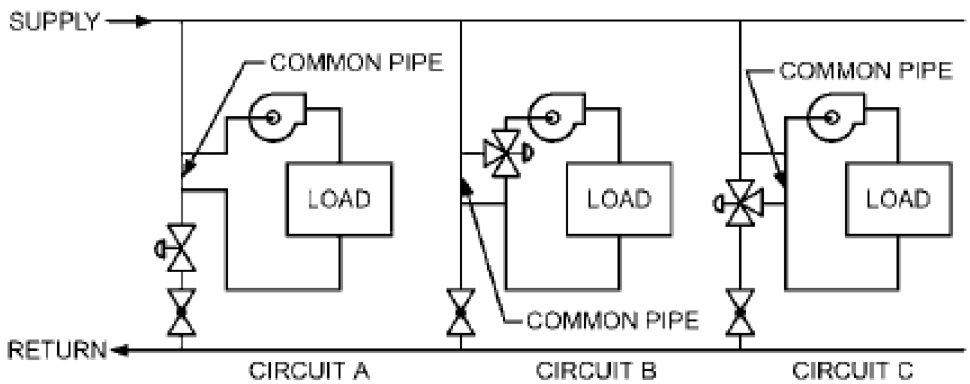
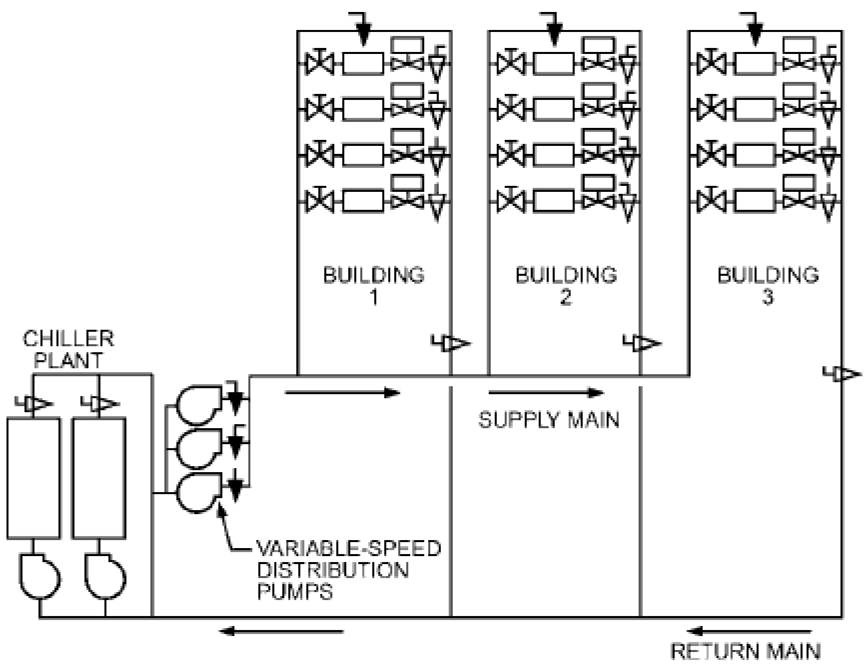
		 *Figure 35 Primary-Secondary Pumping*
6	Variable-Speed Central Pumping	• **In a variable-speed pumping arrangement**, **constant flow** pump(s) recirculate the chiller or boiler source in a primary source loop, and a variable-speed distribution pump located at the source plant draws flow from the source loop and distributes to the load terminals as shown in Figure 36. • **Two-way control valves** are installed in the load terminal return branch to vary the flow required in the load.  *Figure 36 Variable-Speed Central Pumping*
7	Variable-Speed Distributed Pumping	• **In a variable-speed distributed pumping arrangement,** constant flow pump(s) recirculate the chiller or boiler source in a primary source loop, and a variable-speed zone or building pump draws flow from the source loop and distributes to the zone load terminals as shown in Figure 37.

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		• **Two-way control valves** in the load terminal return branch vary the flow required in the load.

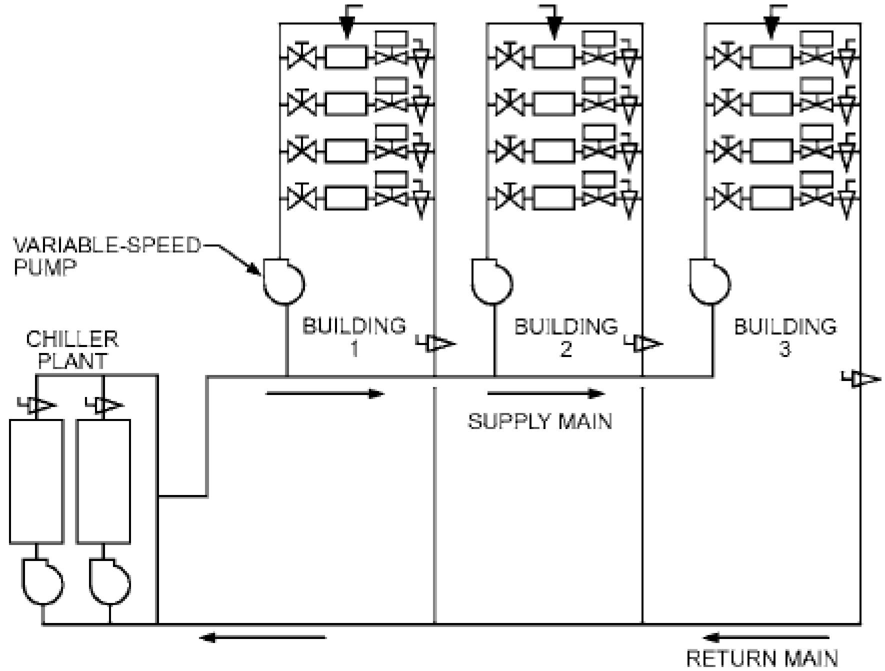

Figure 37 Variable-Speed Distributed Pumping

14. ENERGY CONSERVATION IN PUMPING

- Pumps for heating and air conditioning **consume appreciable amounts of energy.**
- For an electric-driven, constant speed pump, the equipment efficiency is:

$$\eta_e = \eta_p \eta_m \qquad (9)$$

where

η_e = equipment efficiency, 0 to 1
η_p = pump efficiency, 0 to 1
η_m = motor efficiency, 0 to 1

- For a variable-speed pump, the variable-speed drive efficiency η_v *v* (0 to 1) must be included in the **equipment efficiency equation**:

$$\eta_e = \eta_p \eta_m \eta_v \qquad (10)$$

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15. INSTALLATION, OPERATION

1- Pumps may be base-plate-mounted (Figure 38), either singly or in packaged sets, or installed in-line directly in the piping system (Figure 39). **Pumping equipment, accessories, electrical controls, and/or packaged systems**, must comply with applicable seismic requirements for anchorage and equipment seismic certifications, as described in local building codes.

2- **A concrete pad provides a secure mounting surface** for anchoring the pump base plate and raises the pump off the floor to permit housekeeping. **The minimum weight of concrete that should be used is 2.5 times the weight of the pump assembly**. **The pad should be at least 4 in. thick and 6 in. wider than the pump base plate on each side.**

3- In applications where the pump bolts rigidly to the pad base, level the pad base, anchor it, and fill the space between pump base and the concrete with a non-shrink grout. Grout prevents the base from shifting and fills in irregularities. **Pumps mounted on vibration isolation bases require special installation** (see the section on Vibration Isolation and Control in Chapter 49 of the 2019 *ASHRAE Handbook—HVAC Applications*).

4- Support in-line pumps independently from the piping so that pump flanges are not overstressed.

5- Once the pump has been mounted to the base, check the alignment of the motor to the pump. Align the pump shaft couplings properly and shim the motor base as required. Incorrect alignment may cause rapid coupling and bearing failure.

6- **Pump suction piping should be direct and as smooth as possible. Install a strainer (coarse mesh) in the suction to remove foreign particles that can damage the pump**. Use a straight section of piping at least 5 to 10 diameters long at the pump inlet and long radius elbows to ensure uniform flow distribution. **Suction diffusers may be installed in lieu of the straight pipe requirement where spacing is a constraint**. Eccentric reducers at the pump flange **reduce the potential of air pockets forming in the suction line**.

7- If a flow-measuring station (venturi, orifice plate, or balancing valve) is located in the pump discharge, **allow 10 diameters of straight pipe between the pump discharge and the flow station for measurement accuracy.**

8- **Pipe flanges should match the size of pump flanges.** Mate flat face pump flanges with flat-face piping flanges and full-face gaskets. **Install tapered reducers and increasers on suction and discharge lines to match the pipe size and pump flanges.**

9- **If a fine mesh screen is used in the strainer at initial start-up to remove residual debris, replace it with normal-sized screen after commissioning to protect the pump and minimize the suction pressure drop.**

10- Install shutoff valves in the suction and discharge piping near the pump to permit removing and servicing the pump and strainer without draining the system. Install a check valve in the pump discharge to prevent reverse flow in a nonrunning pump when multiple pumps are installed.

11- **Where seismic considerations allow**, install vibration isolators in the pump suction and discharge lines to reduce transmission of vibration noise to building spaces (Figure 39). Properly located pipe hangers and supports can reduce transmission of piping strains to the pump.

12- Investigate alternatives to conventional fittings. **A suction diffuser in the pump inlet** **is an alternative to an eccentric reducer and contains a strainer.** **Separate strainers can be specified with** **screen size.** **A multipurpose valve in the pump discharge** **is an alternative way to combine the functions of shutoff, check, and balancing valves.**

13- **Each pump installation** **should include pressure gages and a gage cock to verify system pressures and pressure drop.** **As a minimum, pressure taps with an isolation valve and common gage** **should be available at the suction and discharge of the pump.** An additional pressure tap upstream of the strainer allows checking for pressure drop.

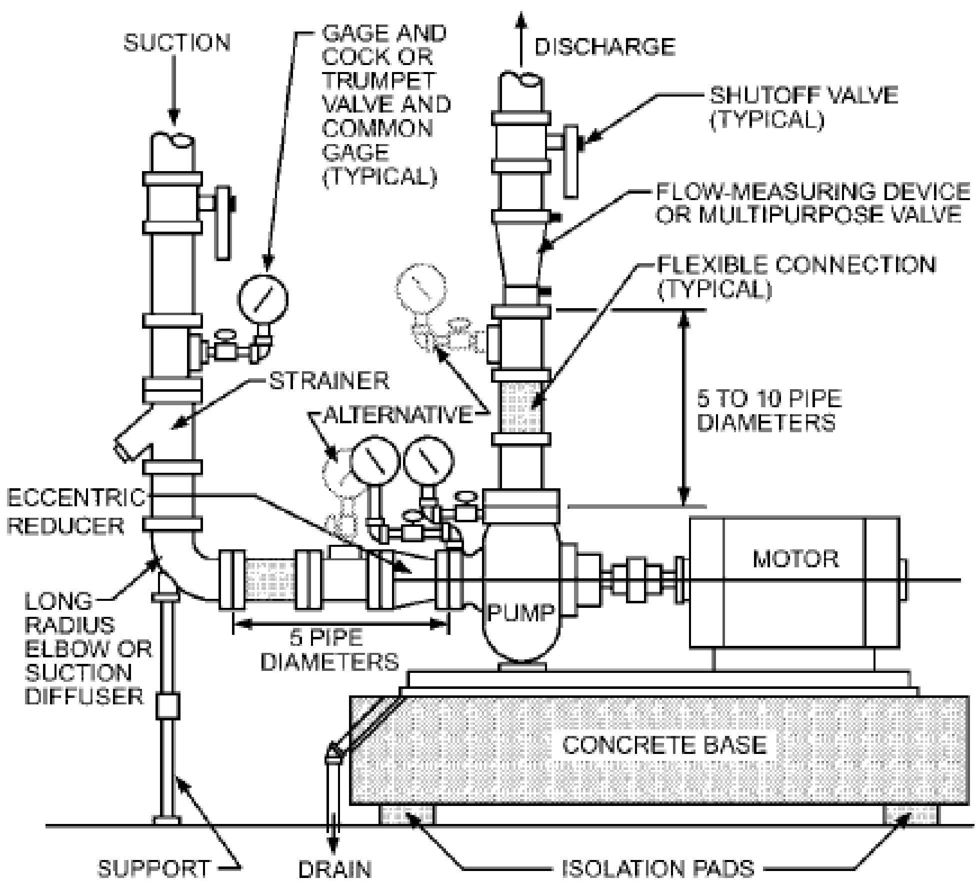

Figure 38 base-Plate-Mounted Centrifugal Pump Installation

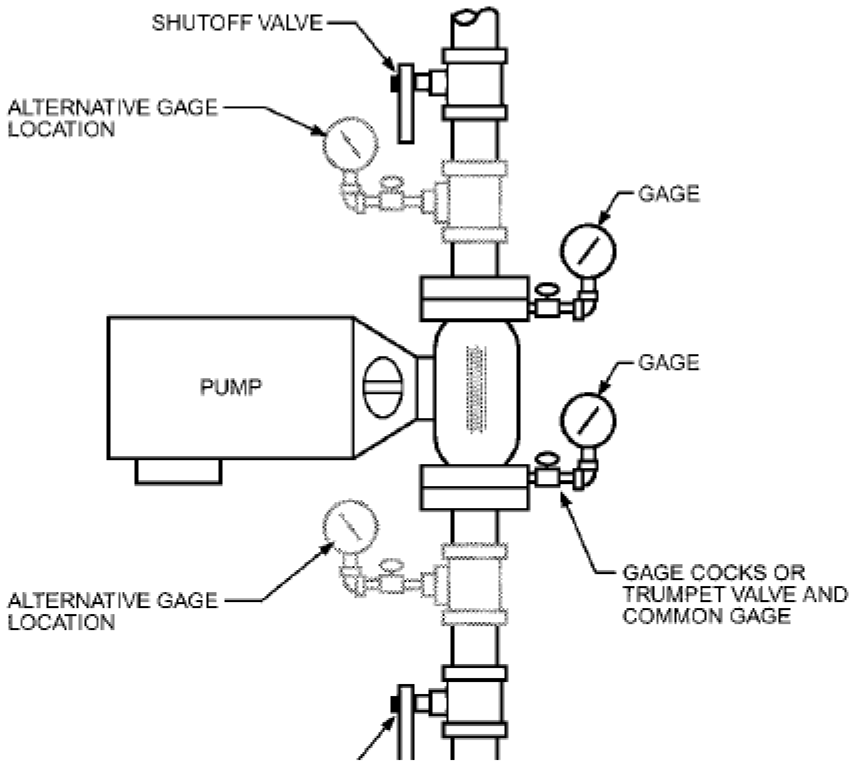

Figure 39 In-Line Pump Installation

16. Commissioning Base-Mounted Centrifugal Pumps

1. Turn off power and tag disconnect off.
2. Remove coupling guard.
3. Check alignment. See instruction manual for alignment guidelines.
4. Rotate shaft several revolutions to ensure there is no binding.
5. Replace coupling guard.
6. Pressurize pump by opening suction and discharge valves.
7. Loosen vent plug on top of casing to release air. When all air is released, tighten vent plug.
8. Close discharge valve.
9. Bump motor and check rotation. Rotation arrow is located on pump casing.
10. Turn on power to pump. Slowly open discharge valve until specified total head is achieved.
11. If the baseplate is not grouted, there might be some vibration. Loosen baseplate mounting bolts one at a time. When vibration stops or is reduced, shim and retighten bolt.

17. TROUBLESHOOTING

Table 6 lists possible causes and recommended solutions for pump or system noise.
Table 7 lists possible causes and recommended solutions for inadequate circulation.

Table 6 Pumping System Noise Analysis Guide

Possible Cause	Recommended Action
Shaft misalignment	• Check and realign
Worn coupling	• Replace and realign
Worn pump/motor bearings	• Replace, check manufacturer's lubrication recommendations • Check and realign shafts
Improper foundation or installations	• Check foundation bolting or proper grouting • Check possible shifting caused by piping expansion/contraction. • Realign shafts
Pipe vibration and/or strain caused by pipe expansion/ contraction	• Inspect, alter, or add hangers and expansion provision to eliminate strain on pump(s)
Water velocity	• Check actual pump performance against specified, and reduce impeller diameter as required • Check for excessive throttling by balance valves or control valves
Pump operating close to or beyond end point of performance curve	• Check actual pump performance against specified, and reduce impeller diameter as required
Entrained air or low suction pressure	• Check expansion tank connection to system relative to pump suction • If pumping from cooling tower sump or reservoir, check line size • Check actual ability of pump against installation requirements • Check for vortex entraining air into suction line

Table 7 Pumping System Inadequate/No-Flow Analysis

Possible Cause	Recommended Action
Pump running backward (three-phase)	• Reverse any two motor leads
Broken pump coupling	• Replace and realign
Improper motor speed	• Check motor nameplate wiring and voltage
Pump (or impeller diameter) too small	• Check pump selection (impeller diameter) against specified requirements
Clogged strainer(s)	• Inspect and clean screen
Clogged impeller	• Inspect and clean
System not completely filled	• Check setting pressure release valve • Vent terminal units and piping high points
Balance valves or isolating valves improperly set	• Check setting and adjust as required
Air-bound system	• Vent piping and terminal units • Check location of expansion tank connection line relative to pump suction • Review provisions to eliminate air
Air entrainment	• Check pump suction inlet conditions to determine if air is being entrained from suction tanks or sumps
Insufficient NPSHA	• Check NPSHA of pump • Inspect strainers and check pipe sizing and water temperature