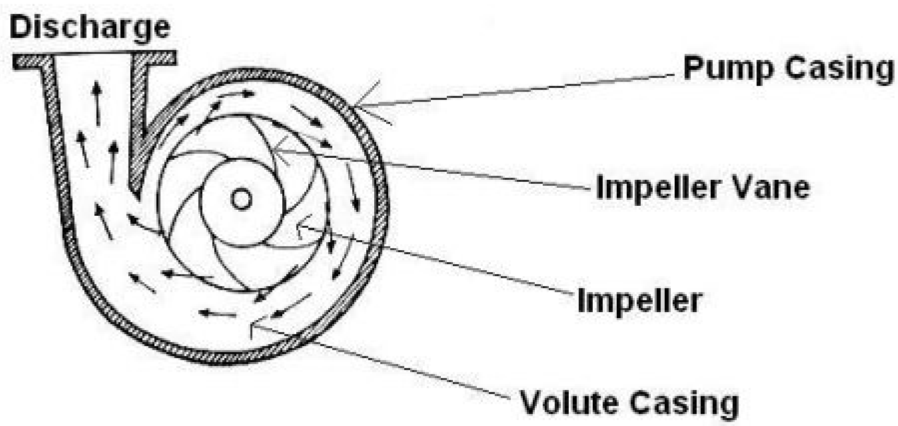
Centrifugal pump

How centrifugal pumps work

A centrifugal pump consists of an impeller attached to and rotating with the shaft and a casing that encloses the impeller.

In centrifugal pump, liquid is forced into the inlet side of the pump casing by atmospheric pressure or some upstream pressure. As the impeller rotates, liquid moves toward the discharge side of the pump. This creates a void or reduced pressure area at the impeller inlet. The pressure at the pump casing inlet, which is higher than this reduced pressure at the impeller inlet, forces additional liquid into the impeller to fill the void.



Pump selection criteria

<u>Pump capacity</u>

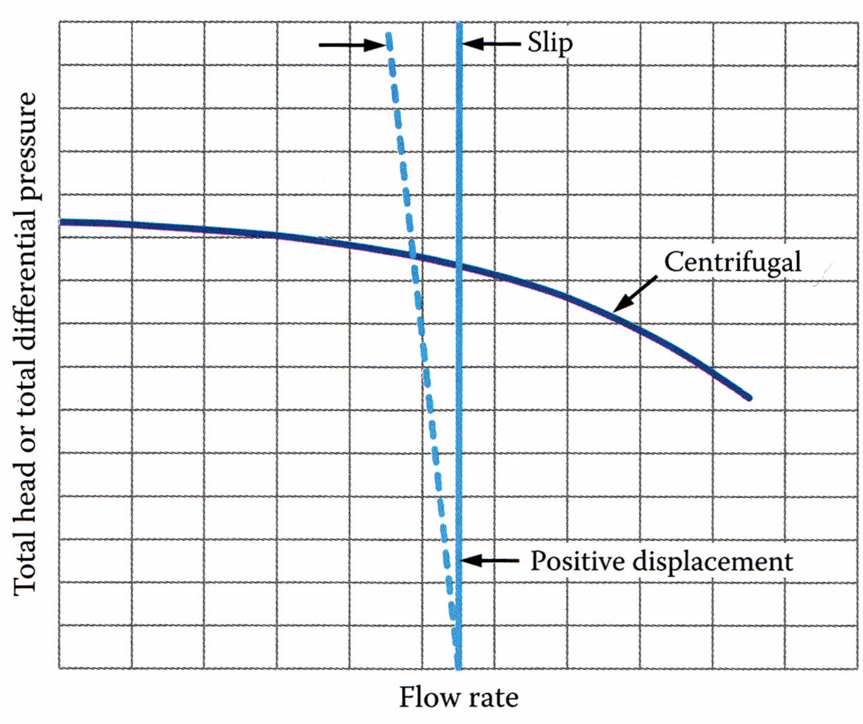
The two parameters that must determined to size a pump are the capacity and the total head.

Capacity or flowrate is usually expressed as:

- Gallons per minute (gpm)
- Cubic feet per second (cps)
- Cubic meter per second
- Liter per second

Total head, sometimes simply referred to as head, is abbreviated TH or H, measured in feet or meter.

Example of the head-capacity (H-Q) curve of a centrifugal pump is shown below.



Total head (TH)

The amount of head developed in the impeller is approximately:

$$H = \frac{V^2}{2g} \qquad (1)$$

V is the velocity at the tip of the impeller in m/s.
g is the acceleration of gravity.

The velocity at the tip of the impeller can also be expressed as:

$$V = \frac{\pi DN}{60} \qquad (2)$$

D is the impeller diameter in meter.
N is the pump speed in rpm.

From both equations above, we could write the head developed in the impeller is:

$$H = \frac{(\pi DN)^2}{60^2 \cdot 2g} \qquad (3)$$

Equation (3) shows that the head developed by a centrifugal pump is only a function of rpm and impeller diameter, and is not a function of specific gravity of the liquid being pumped.

A pump moving a liquid up a static distance of 100m always has required head of 100m (ignoring friction at this condition), regardless of the specific gravity of the liquid.

If the liquid is water, a pressure gauge located at the pump discharge could be calculate using Equation (4).

$$P = \rho g H$$

which means, for water, the pressure is 981 kPa. If the liquid being pumped up were oil, with specific gravity of 0.8, the pressure is 784.8 kPa.

The point of this is that the pump discharge pressure varies with the specific gravity of the liquid, while the head of liquid remains constant for liquids of different density.

This is why engineers should always convert pressure terms into unit of meter of head when dealing with centrifugal pumps.

A pump's head-capacity curves does not require adjustment when the specific gravity of liquid changes.

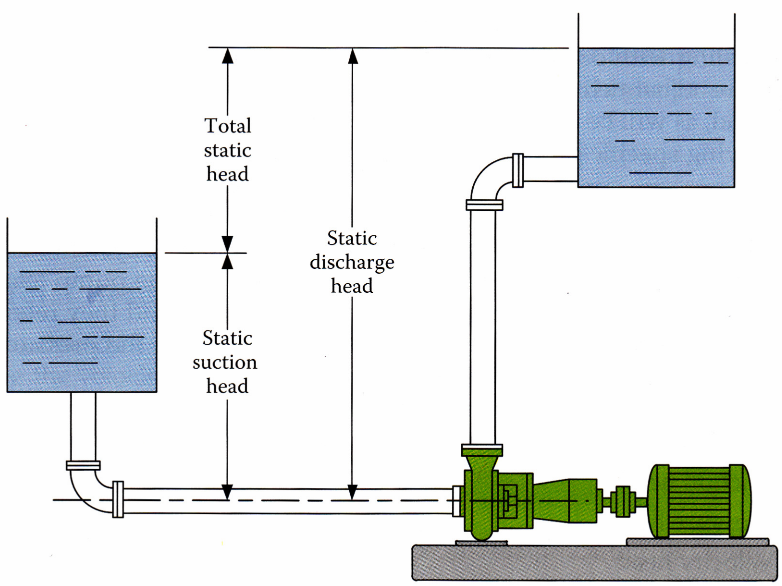
However, the head-capacity curve is affected by the viscosity of the pumped liquid.

There are four separate components of total head which are; static head, friction head, pressure head and velocity head.

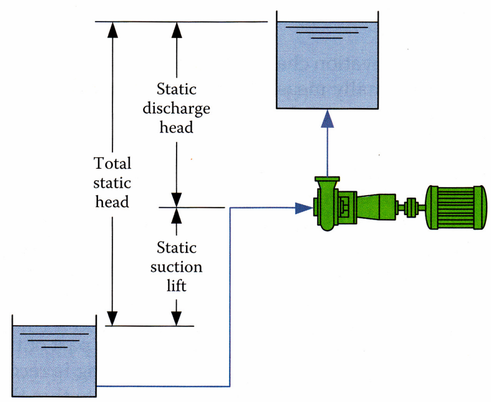
1. Static head

Static head is the total elevation change that the liquid must undergo. In most cases, static head is normally measured from the surface of the liquid in the supply vessel to the surface of the liquid in the vessel where the liquid is being delivered.

Below figure shows an example of a pump with a static suction head, static discharge head and total static head.



Static suction head, static discharge head, and total static head.



Static suction lift, static discharge head, and total static head.

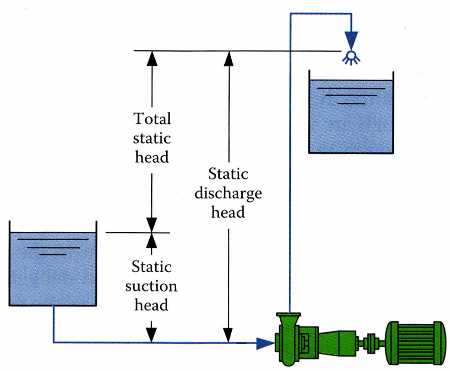
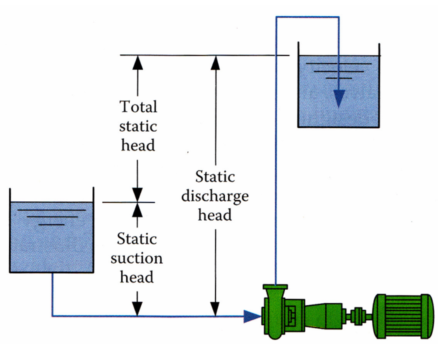
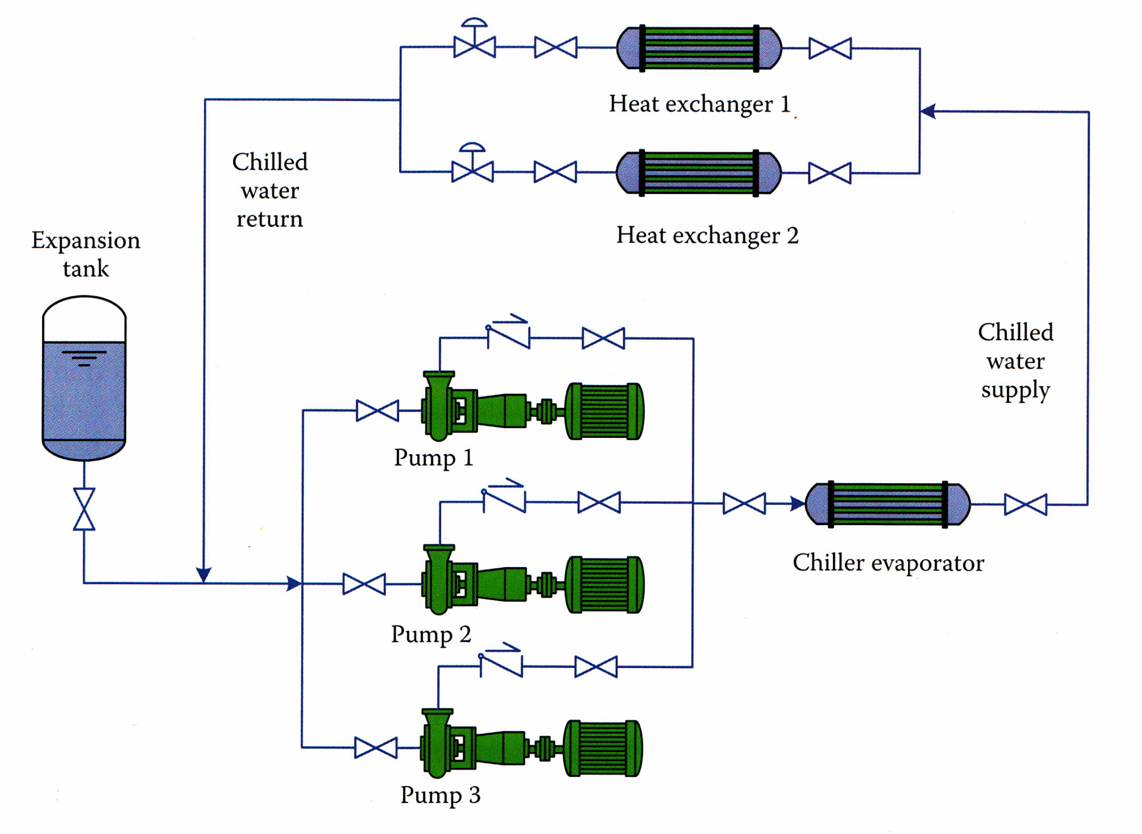


FIGURE 2.3
Recovered static head due to siphon effect moves reference point for static head to outlet of pipe.



Submerged return line moves reference point for static head to delivery vessel liquid surface.

Note that for a pump in a closed loop system (one where the return line goes directly back to the pump suction, as shown in below figure), the total static head is zero, since all of the static head from the pump to the high point in the piping system is recovered in the downhill leg of the system.



2. Friction head

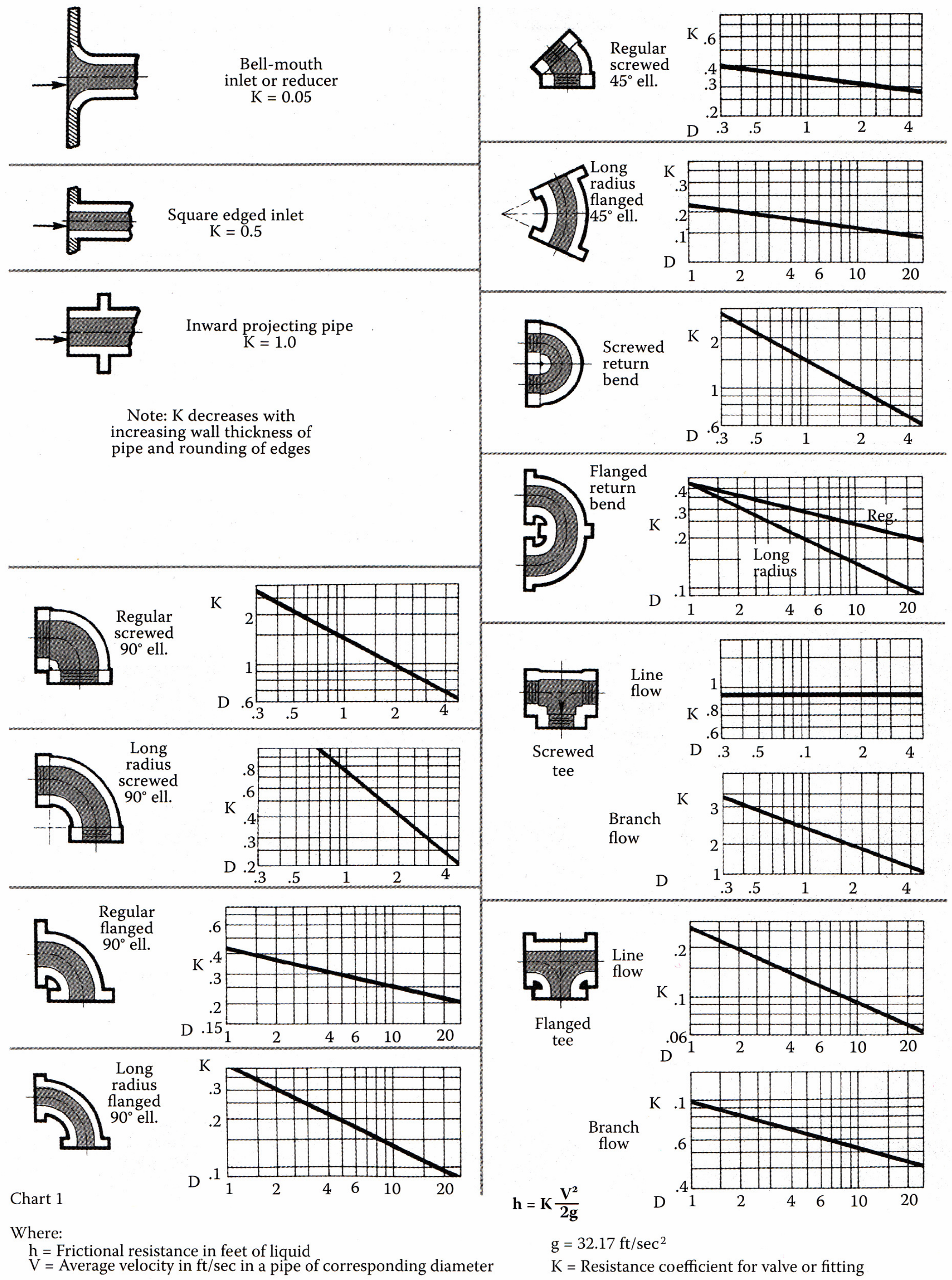
Friction head is the head necessary to overcome the friction losses in the piping, valves, fitting and components such as heat exchangers for the system in which the pump operates.

Major loss:

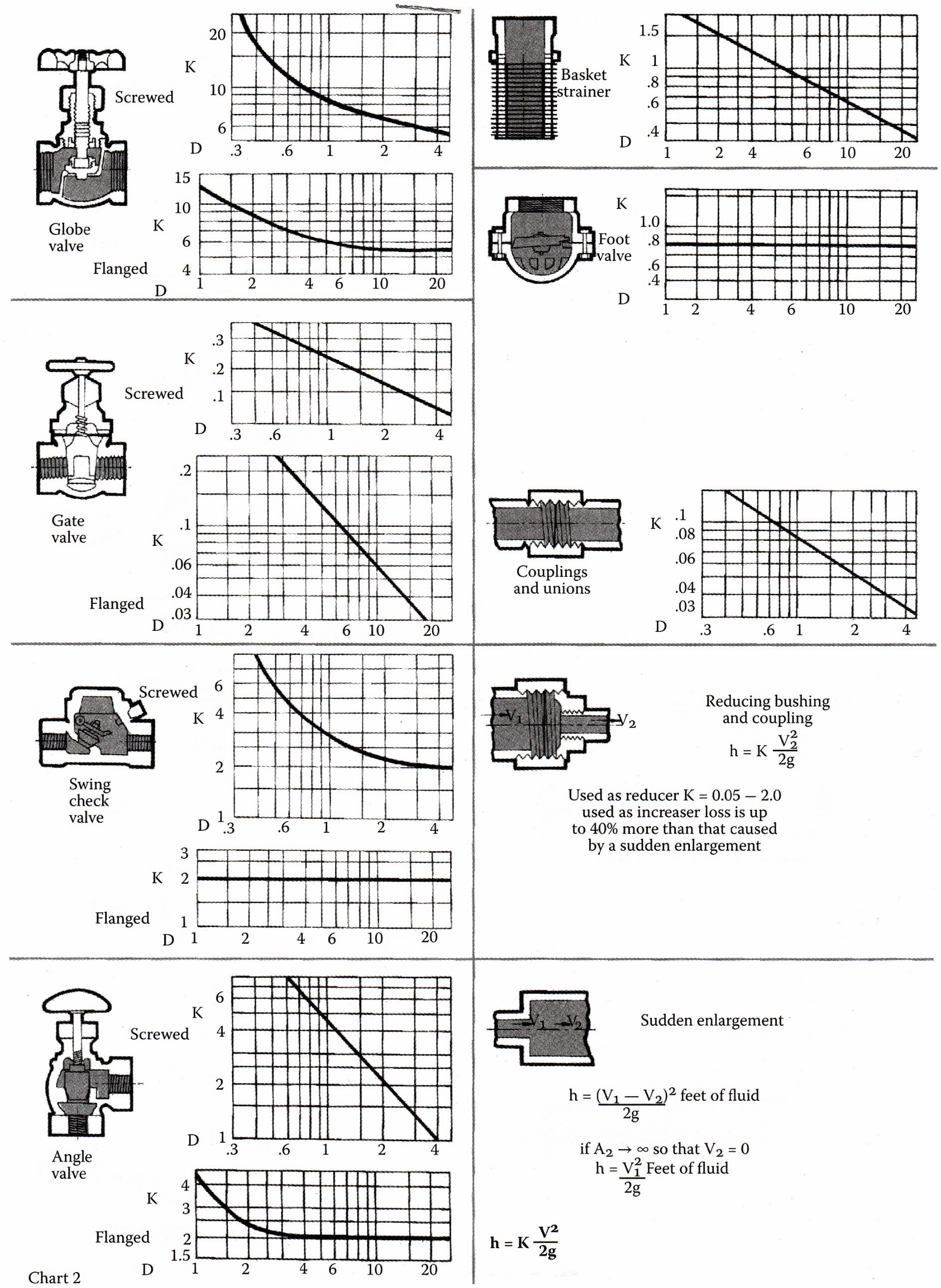
$$h_{major} = f \cdot \frac{L}{D} \cdot \frac{V^2}{2g}$$

Minor loss: (friction loss in valves and fittings)

$$h_{\min or} = K \cdot \frac{V^2}{2g}$$



Resistance coefficients (K) for valves and fittings. (From Hydraulic Institute, *Engineering Data Book*, 2nd edition. Parsippany, NJ, 1990; www.pumps.org. With permission.)



(Continued) Resistance coefficients (K) for valves and fittings. (From Hydraulic Institute, *Engineering Data Book*, 2nd edition. Parsippany, NJ, 1990; www.pumps.org. With permission.)

3. Pressure head

Pressure head is the head required to overcome a pressure or vacuum in the system upstream or downstream of the pump. It is normally measured at the liquid surface in the supply and delivery vessels.

If the pressure in the supply vessel from which the pump is pumping and the pressure in the delivery vessel are identical (for example, both are atmospheric tanks), then there is no required pressure head adjustment to total head (TH).

Likewise, there is no pressure adjustment to TH for a closed loop system.

If the supply vessel is under vacuum or under pressure different than that of the delivery vessel, a pressure head adjustment to TH is required. The pressure or vacuum must be converted to feet or meter.

$$\text{Pressure head} = \frac{\text{Pressure (Pa)}}{\rho \text{g}}$$

If the suction vessel is under vacuum, the amount of vacuum (equivalent to gauge pressure, converted to feet or meter) must be added to the delivery vessel gauge pressure to get the total pressure adjustment to TH.

If the suction vessel in under positive pressure, then the suction vessel pressure should be subtracted from the delivery vessel pressure to get the adjustment to TH.

4. Velocity head

Velocity head is the energy of a liquid as a result of its motion at some velocity.

The formula for velocity head is: $H_V = \frac{V^2}{2g}$

The value of velocity head is different at the suction and discharge of the pump, because the size of the suction piping is usually larger than the size of the discharge piping.