Pumping of Liquids

5.1 Introduction

Pupmps are devices for supplying *energy* or *head* to a flowing liquid in order to overcome head losses due to friction and also if necessary, *to raise* liquid to a higher level.

For the pumping of liquids or gases from one vessel to another or through long pipes, some form of mechanical pump is usually employed**. The energy required by the pump** will depend on the height through which the fluid is raised, the pressure required at delivery point, the length and diameter of the pipe, the rate of flow, together with the physical properties of the fluid, particularly its *viscosity* and *density*. The pumping of liquids such as sulphuric acid or petroleum products from bulk store to process buildings, or the pumping of fluids round reaction units and through heat exchangers, are typical illustrations of the use of pumps in the process industries. On the one hand, it may be necessary to inject reactants or catalyst into a reactor at a low, but accurately controlled rate, and on the other to pump cooling water to a power station or refinery at a very high rate. The fluid may be a gas or liquid of low viscosity, or it may be a highly viscous liquid, possibly with non-Newtonian characteristics. It may be clean, or it may contain suspended particles and be very corrosive. All these factors influence the choice of pump.

Because of the wide variety of requirements, many different types are in use including centrifugal, piston, gear, screw, and peristaltic pumps, though in the chemical and petroleum industries the centrifugal type is by far the most important.

5.2 The Total Head (Δh)

The head imparted to a flowing liquid by a pump is known as the total head (Δh). If a pump is placed between points ① and ② in a pipeline, the head for steady flow are related by: -

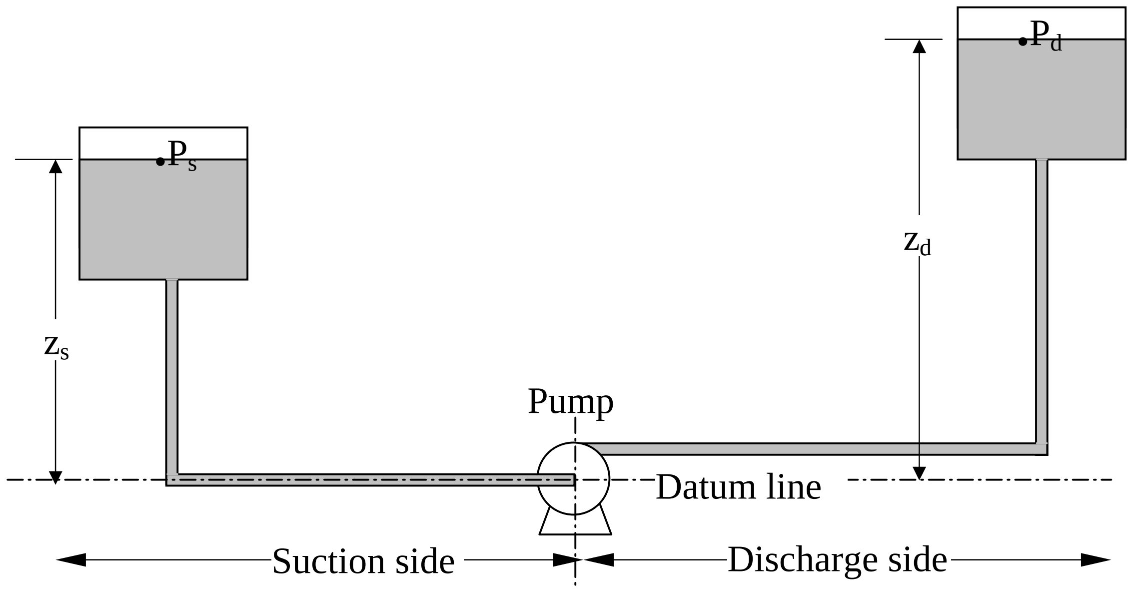

Figure (1) Typical pumping system.

$$\Delta h = \frac{\eta\, Ws}{g} = \left(\frac{P_2}{\rho\, g} + \frac{u_2^2}{2\alpha_2\, g} + z_2\right) - \left(\frac{P_1}{\rho\, g} + \frac{u_1^2}{2\alpha_1\, g} + z_1\right) - h_F$$

$$\Rightarrow \Delta h = \frac{\Delta P}{\rho\, g} + \frac{\Delta\, u^2}{2\alpha\, g} + \Delta z + h_F$$

5.3 System Heads

The important heads to consider in a pumping system are: -

1- Suction head
2- Discharge head
3- Total head
4- Net positive suction head (NPSH)

The following definitions are given in reference to typical pumping system shown in preceding Figure, where the datum line is the centerline of the pump

1- Suction head (h_s)

$$h_s = z_s + \frac{P_s}{\rho\, g} - (h_F)_s$$

2- Discharge head (h_d)

$$h_d = z_d + \frac{P_d}{\rho\, g} + (h_F)_d$$

3- Total head (Δh)

The total head (Δh), which is required to impart to the flowing liquid is the difference between the discharge and suction heads. Thus,

$$\Delta h = h_d \text{ - } h_s$$

$$\Rightarrow \Delta h = (z_d - z_s) + (\frac{P_d \text{ - } P_s}{\rho\, g}) + [(h_F)_d + (h_F)_s]$$

where,

$$(h_F)_d = 4 f_d \left(\frac{L}{d} + \sum \frac{Le}{d}\right)_d \frac{u_d^2}{2\, g}$$

$$(h_F)_s = 4 f_s \left(\frac{L}{d} + \sum \frac{Le}{d}\right)_s \frac{u_s^2}{2\, g}$$

The suction head (hs) decreases and the discharge head (hd) increases with increasing liquid flow rate because of the increasing value of the friction head loss terms (hF)s and (hF)d. Thus the total; head (Δh) which the pump is required to impart to the flowing liquid increases with increasing the liquid pumping rate.

Note:

If the liquid level on the suction side is below the centerline of the pump, z_s is negative.

4- Net positive suction head (NPSH)

Available net positive suction head

$$NPSH = z_s + \left(\frac{P_s - P_v}{\rho\, g}\right) - (h_F)_s$$

This equation gives the head available to get the liquid through the suction piping.