Lecture 7

5. Pressure and Its Units

A Pressure is the ratio of a frce to the area on which the force acts. The SI pressure unit,N/m^2, is called a pascal (Pa), while in AE is called psi.

Some common nonstandard variations of pressure measurement used with the SI system are

a. Bars (bar): 100 kPa = 1 bar
b. Kilograms (force) per square centimeter (kg_f/cm^2)*—a very common measure of pressure but not standard in SI (often called just "kilos")
c. Torr (Torr): 760 Torr = 1 atm

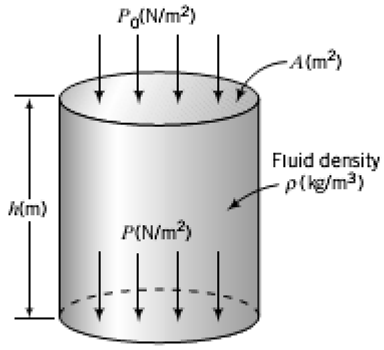
In the AE system pressure can be expressed in a variety of ways, including

a. Millimeters of mercury (mm Hg)
b. Inches of mercury (in. Hg)
c. Feet of water (ft H_2O)
d. Inches of water (in. H_2O)
e. Atmospheres (atm)
f. Pounds (force) per square inch (often called just "pounds") (psi)

The pressure at the bottom of the static (nonmoving) column of mercury exerted on the sealing plate is:

$$p = \rho g h + p_0$$

Where p = pressure at the bottom of the column of the fluid, ρ= density of fluid, g = acceleration of gravity, h = height of the fluid column, and p_0= pressure at the top of the column of fluid.



For Example, suppose that the cylinder of fluid in Figure above is a column of mercury that has an area of 1 cm^2 and is 50 cm high. The density of the Hg is 13.55 g/cm^3. Thus, the force exerted by the mercury alone on the 1 cm^2 section of the bottom plate by the column of mercury is:

$$F = \frac{13.55\text{ g}}{\text{cm}^3}\left|\frac{980\text{ cm}}{\text{s}^2}\right|50\text{ cm}\left|1\text{ cm}^2\right|\frac{1\text{ kg}}{1000\text{ g}}\left|\frac{1\text{ m}}{100\text{ cm}}\right|\frac{1\text{ N s}^2}{1\text{ kg m}} = 6.64\text{ N}$$

The pressure on the section of the plate covered by the mercury is the force per unit area of the mercury plus the pressure of the atmosphere:

$$p = \frac{6.64\text{ N}}{1\text{ cm}^2}\left|\left(\frac{100\text{ cm}}{1\text{ m}}\right)^2\right|\frac{(1\text{ m}^2)(1\text{ Pa})}{1\text{ N}}\left|\frac{1\text{ kPa}}{1000\text{ Pa}} + p_0 = 66.4\text{ kPa} + p_0\right.$$

If we had started with units in the AE system, the pressure would be computed as [the density of mercury is 845.5 lb_m/ft^3]:

$$p = \frac{845.5\text{ lb}_m}{1\text{ ft}^3}\left|\frac{32.2\text{ ft}}{\text{s}^2}\right|50\text{ cm}\left|\frac{1\text{ in.}}{2.54\text{ cm}}\right|\frac{1\text{ ft}}{12\text{ in.}}\left|\frac{(\text{s}^2)(\text{lb}_f)}{32.174\text{ (ft)(lb}_m)}\right.$$
$$+ p_0$$

$$= 1388\,\frac{\text{lb}_f}{\text{ft}^2} + p_0$$

Pressure, like temperature, can be expressed in either absolute (**psia**) or relative scales. Rather than using the word *relative*, the relative pressure is usually called **gauge pressure** (**psig**). The

atmospheric pressure is nothing more than the barometric pressure. The relationship between gauge and absolute pressure is given by the following expression:

$$p_{\text{absolute}} = p_{\text{gauge}} + p_{\text{atmospheric}}$$

$$p_{\text{vacuum}} = p_{\text{atmospheric}} - p_{\text{absolute}}$$

Measurement of Pressure

Pressure, like temperature, can be expressed using either an absolute or a relative scale.

The pressure of the atmosphere can be thought of as the pressure at the base of a column of fluid (air) located at the point of measurement (e.g., at sea level). A typical values are 760 mm Hg and 1 atm.

The relationship between relative and absolute pressure is given by the following expression:

Absolute Pressure = Gauge Pressure + atmospheric Pressure

The standard atmosphereis equal to

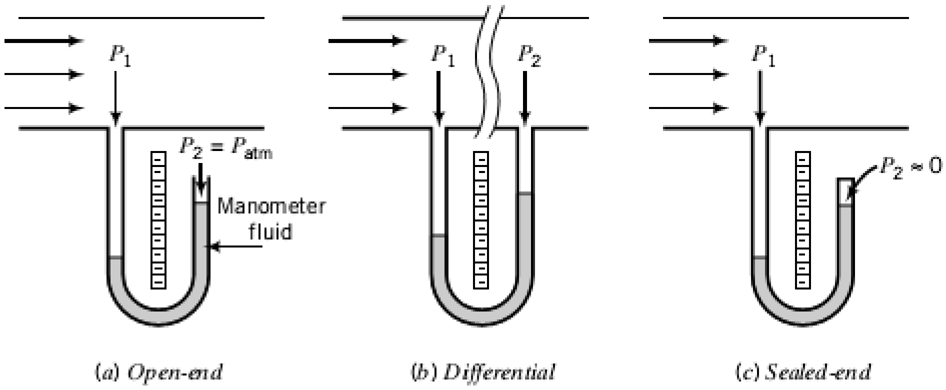
- ♦ 1.00 atmospheres (atm)
- ♦ 33.91 feet of water (ft H_2O)
- ♦ 14.7 pounds (force) per square inch absolute (psia)
- ♦ 29.92 inches of mercury (in. Hg)
- ♦ 760.0 millimeters of mercury (mm Hg)
- ♦ $1.013 * 10^5$ pascal (Pa) or newtons per square meter (N/m^2); or 101.3 kPa.

For Example, convert 35 psia to inches of mercury and kPa.

$$35\ \text{psia}\left|\frac{29.92\ \text{in.Hg}}{14.7\ \text{psia}}\right. = 71.24\ \text{in. Hg}$$

$$35\ \text{psia}\left|\frac{101.3\ \text{kPa}}{14.7\ \text{psia}}\right. = 241\ \text{kPa}$$

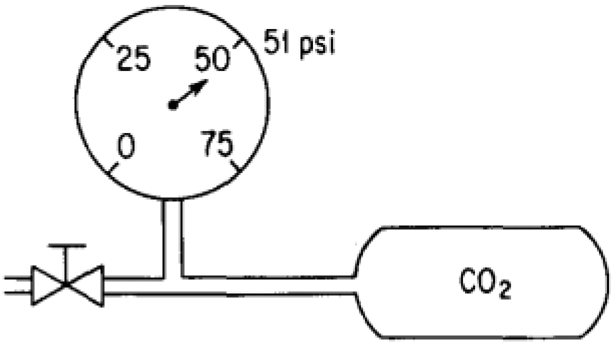
A manometer is a U-shaped tube partially filled with a fluid of known density (the manometer fluid). Manometers are used in several different ways, as shown in Figure.



a) **Open-end manometer**: one end is exposed to a fluid whose pressure is to be measured, and the other is open to the atmosphere. This type is used to measure a relative (gauge) pressure.
b) **Differential manometer**: is used to measure the pressure difference between two points in a process line.
c) **Sealed-end manometer**: has a near-vacuum enclosed at one end and used to to measure absolute pressure.

Example 20

The pressure gauge on a tank of CO_2 used to fill soda-water bottles reads 51.0 psi. At the same time the barometer reads 28.0 in. Hg. What is the absolute pressure in the tank in psia?



Solution

$$\text{Atmospheric pressure} = 28\ \text{in. Hg} \left| \frac{14.7\ \text{psia}}{29.92\ \text{in.Hg}} \right. = 13.76\ \text{psia}$$

The absolute pressure in the tank is

$$51.0\ \text{psia} + 13.76\ \text{psia} = 64.8\ \text{psia}$$