(2-5) Measurement of Pressure

(2-5-1) Atmospheric Pressure

The pressure of the air in the atmosphere was first measured by Evangelista Torricelli (1608-1647), a student of Galileo, by the use of a mercury **barometer.** A long narrow tube is filled to the top with mercury, chemical symbol Hg. It is then placed upside down into a reservoir filled with mercury, as shown in figure (2-2).

The mercury in the tube starts to flow out into the reservoir, but it comes to a stop when the top of the mercury column is at a height **h** above the top of the mercury reservoir, as also shown in figure (2-2). The mercury does not empty completely because the normal pressure of the atmosphere p_o pushes downward on the mercury reservoir. Because the force caused by the pressure of a fluid is the same in all directions, there is also force acting upward inside the tube at the height of the mercury reservoir, and hence there is also a pressure p_o acting upward as shown in figure (2-2). This force upward is capable of holding the weight of the mercury in the tube up to a height *h*. Thus, the pressure exerted by the mercury in the tube is exactly balanced by the normal atmospheric pressure on the reservoir, that is,

$$P_o = P_{Hg} \quad \dots\dots\dots\dots\dots\dots\dots (2-6)$$

But the pressure of the mercury in the tube P_{Hg}, given by equation (2-5),

$$P_{Hg} = \rho_{Hg} g h \quad \dots\dots\dots\dots\dots\dots\dots (2-7)$$

Substituting equation (2-7) back into equation (2-6), gives

$$P_o = \rho_{Hg} g h \quad \dots\dots\dots\dots\dots\dots\dots (2-8)$$

Equation (2-8) says that normal atmospheric pressure can be determined by measuring the height *h* of the column of mercury in the tube. It is found experimentally, that on the average, normal atmospheric pressure can support a column of mercury 76.0 cm high, or 760 mm high. The unit of 1.00 mm of Hg is sometimes called a torr in honor of Torricelli. Hence, normal atmospheric pressure can also be given as 760 torr. Using the value of the density of mercury of 1.360×10^4 kg/m^3, normal atmospheric pressure, determined from equation (2-8), is

$$P_o = \rho_{Hg} gh = \left(1.36 \times 10^4 \frac{kg}{m^3}\right)\left(9.8 \frac{m}{s^2}\right)(0.760\ m)$$
$$= 1.013 \times 10^5\ N/m^2 (Pa)$$

Thus, the average or normal atmospheric pressure acting on us at the surface of the earth is 1.013×10^5 Pa.

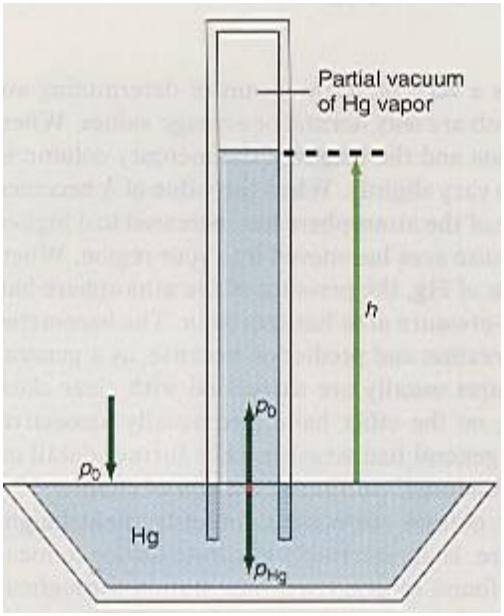

Figure 2-2 A mercury barometer

(2-5-2) Absolute Pressure

1) Now that we have discussed atmospheric pressure, it is obvious that the total pressure exerted at a depth h in a pool of water must be greater than the value determined previously, because the air above the pool is exerting an atmospheric pressure on the top of the pool. This additional pressure is transmitted undiminished throughout the pool. Hence, the total or *absolute pressure* observed at the depth h in the pool is the sum of the atmospheric pressure plus the pressure of the water itself, that is,

$$P_{abs} = P_o + P_w$$

Example 10: What is the absolute pressure at a depth of **3 m** in a swimming pool?

2) When the pressure of the air in an automobile tire is measured, the actual pressure being measured is called the **gauge pressure,** that is, the pressure as indicated on the measuring device that is called a gauge. This measuring device, the gauge, reads zero when it is actually under normal atmospheric pressure. Thus, the total pressure or absolute pressure of the air inside the tire is the sum of the pressure recorded on the gauge plus normal atmospheric pressure. We can write this mathematically as

$$P_{abs} = P_o + P_{gauge}$$

Example 11: A gauge placed on an automobile tire reads a pressure of **34 lb/in.²**. What is the absolute pressure of the air in the tire?

Example 12: In a test of lung's function a person is asked to blow air through one of the two ends of monometer containing water. If the difference between the two levels of water in the monometer is **80 cm,** find the pressure inside the lungs?