

Manometers

One of the earliest and most widespread method of measuring pressure is by using a barometer or manometer. These instruments measure a pressure difference using a column of liquid. While there are a number of types of manometer the basic technique is illustrated in Figure 1 in which the difference in the pressure in in two tanks of gas is measured. The pressure difference, $(p_2 - p_1)$, in the two gas tanks generates a

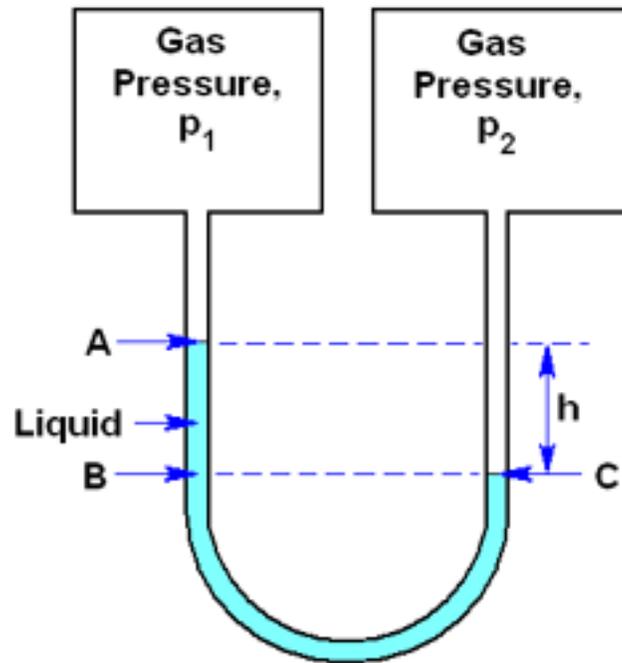


Figure 1: Basic liquid manometer for measuring a gas pressure difference.

difference, h , in the liquid levels on the two sides of the manometer or U-tube where

$$p_2 - p_1 = \rho gh \quad (\text{Kddb1})$$

where ρ is the liquid density. Consequently by measuring h accurately and knowing the liquid density we can calculate the desired pressure difference. In equation (Kddb1), in addition to neglecting the gravitational variations in the gas pressure, we have also neglected any **pressure differences across the menisci** at the points A and C. This second approximation is a serious problem in the design and use of manometers and there are several ways to mitigate it. One way is to use vertical tubes with a large enough internal diameter that any potential pressure difference is minimized. Another is to use vertical tubes with very accurately controlled internal diameters (and surface contact angles) so that the pressure differences due to **surface tension** at the points A and C are the same. This would then lead to the result (Kddb1). Another important consideration is to measure h as accurately as possible and, for this reason, laboratory manometers are often equipped with Vernier scales with which to measure h as accurately as possible. But it is also clear that it is still difficult to measure accurately elevation differences of the order of millimeters or, at the other end of the spectrum, to measure elevation differences greater than several meters. Consequently attention must be given to the choice of liquid in order to produce elevation differences that are both reasonable (of order 10 – 100cm) and large enough to measure accurately. Thus

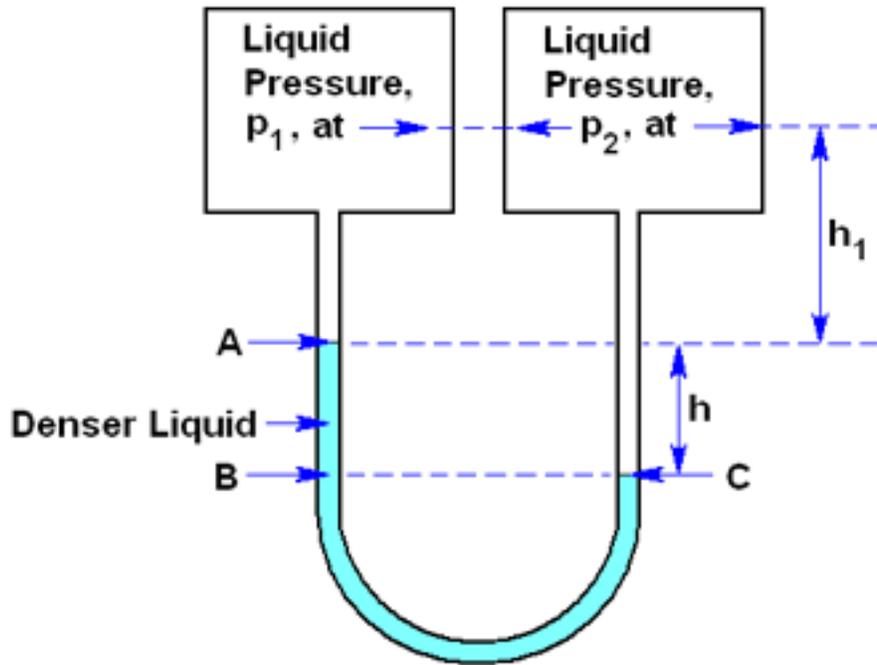


Figure 2: Basic liquid manometer for measuring liquid pressure differences.

water or alcohol are used for smaller pressure differences whereas mercury is used for larger pressure differences.

A simple manometer used in measuring the pressure difference between two tanks of liquid (rather than gas) is sketched in Figure 2. In this case the hydrostatic variation in pressure cannot be neglected and

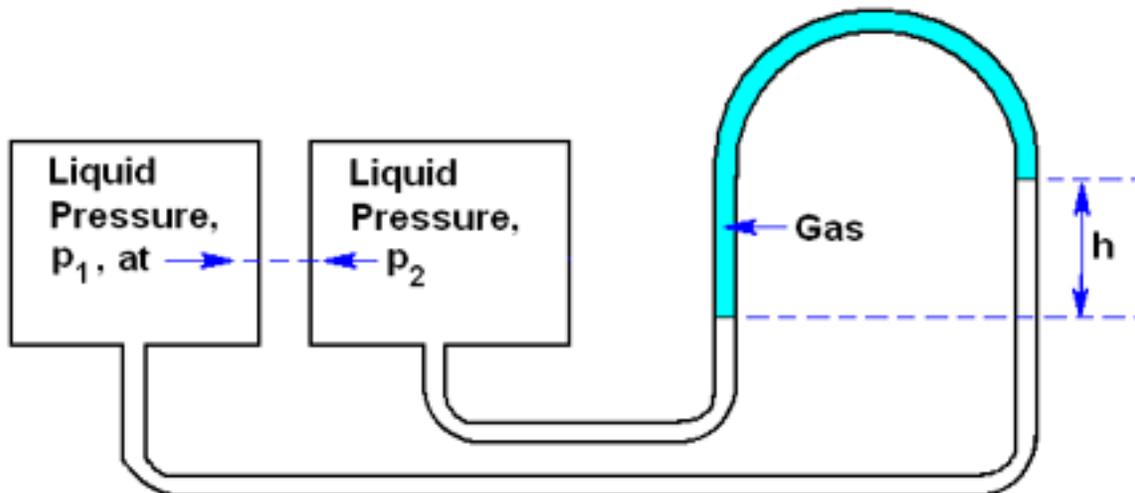


Figure 3: An inverted gas/liquid manometer.

the specific pressure difference that is sought will be the difference in pressures, $(p_2 - p_1)$, at the same horizontal level as shown in the sketch. Then proceeding along the fluid path the pressure at A will be $(p_1 + \rho_1 g h_1)$ (where ρ_1 is the density of the liquid in the tanks), then the pressure at B and at C will be $(p_1 + \rho_1 g h_1 + \rho g h)$ (where ρ is the density of the denser liquid in the manometer) and thence the pressure

in the right-hand tank will be given by

$$p_2 - p_1 = (\rho - \rho_1)gh \quad (\text{Kddb2})$$

Frequently mercury is used as the denser liquid to measure pressure differences in water tanks. If, however, this results in a elevation difference, h , that is too small to be measured accurately, an alternative arrangement is an “inverted gas/liquid manometer” which is shown schematically in Figure 3 and whose calibration is

$$p_2 - p_1 = \rho gh \quad (\text{Kddb3})$$

where ρ is the density of the liquid in the tanks. Clearly there are other possible configurations such as an inverted alcohol/water manometer.

The above manometers are usually adequate for the calibration of an instrument intended for the measurement of steady pressures. However the use of an instrument to measure unsteady, oscillating pressures requires a somewhat different calibration technique. In the case of instruments to be used to measure liquid pressures, this is done by mounting the transducer near the bottom of a vertical tube containing the appropriate liquid with an open free surface at the upper end of the tube. The tube is then mounted on a shake table capable of oscillating the tube over the full range of radian frequencies, ω , that the transducer will later experience in the intended experiment and with different amplitudes, a . If the vertical length of liquid in the tube above the transducer tap is ℓ then the transducer will experience an oscillating pressure amplitude of $\rho\omega^2 a\ell$ and the plot of this against the amplitude of the transducer signal (for a series of values of a) will represent the desired calibration. Repeating this same experiment for different frequencies, ω , will yield a family of calibration curves that will begin to deviate when the limit of the dynamic range of the transducer is approached.