(*v*) These gauges must be carefully installed—in particular absorbed gases must be eliminated.

Some ionization gauges like the one manufactured by Philips use cold cathodes and therefore they do not have the disadvantages which are associated with gauges using hot cathodes. These gauges use cold cathodes and a high accelerating potential which is of the order of 2000 *V*. They use a superimposed magnetic field which causes the electrons which are emitted from the cold cathode to follow a long helical path while travelling to the anode. The long path results in more collisions with the gas molecules thereby producing greater ionization. Philips cold cathode gauges are used in the pressure range of 10×10^{-6} torr to 10×10^{-3} torr.

9.19. CALIBRATION OF PRESSURE MEASURING EQUIPMENT

Laboratory standards for calibrating pressure measuring instruments are Manometers and Dead Weight Testers.

9.19.1. Manometers. Low pressure gauges such as manometers and straight bellows types are usually calibrated by comparison method using precision manometers. Not all manometers can be used for calibration purposes. In general, designs incorporating float mechanism are unsuitable because they give low accuracy on account of the fact that reading is dependent upon the dimensions of tubes which are not accurately known. Also they have frictional errors.

Simple U-tube manometers fitted with antiparallax devices and moving reservoir type manometers with vernier scales are used for calibration.

A wide range of pressures may be accommodated by using different liquids for different ranges. In order to get high magnification, two liquids having nearly the same density should be used. For accurate work corrections for change in the value of *g* due to change in altitude and change in the value of density of liquids due to change in temperature, must be applied. Calibration manometers may use a liquid of lower density than that used for the gauges being calibrated to produce greater motion of the liquid in the capillary of calibration unit. This technique increases accuracy of calibration.

When manometers are used for calibration purposes, a source of variable pressure is required. This can be provided by a compressed air supply and sensitive pressure regulator. Variable pressure may also be obtained from adjustable liquid heads. Manometers are used upto a pressure of 200 kN/m^2. Above this pressure dead weight testers are used.

9.19.2. Dead Weight Tester. A dead weight tester is shown in Fig. 9.47. The apparatus is used for calibration of gauge. The chamber and cylinder of the tester are filled with clean oil. The gauge to be tested is fixed at its appropriate place and piston is inserted in the cylinder. A weight is placed on the piston. The

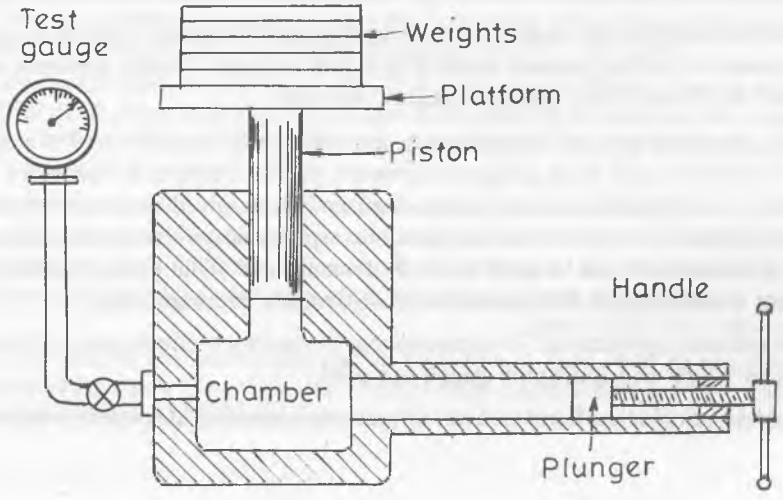

Fig. 9.47. Dead weight tester.

pressure is exerted on the fluid and this pressure is transmitted to the gauge deflecting its pointer. The weights may be adjusted to get the desired setting of the gauge pointer. The plunger is forced in by moving the handle, thereby varying the pressure. The handle is moved till enough pressure is built up to lift the piston weight combination. The piston weight combination floats freely under these conditions. Therefore equilibrium is established with fluid force balanced against the gravitational force of the weights plus the friction drag.

$$\therefore \qquad PA = Mg + F$$

Hence, $$\text{pressure } P = \frac{Mg + F}{A} \qquad ...(9.55)$$

where M = mass, kg ;

g = acceleration due to gravity, m/s^2 ;

F = friction drag, N ;

and A = effective area of piston cylinder combination, m^2.

The accuracy of dead weight testers is affected by three factors.

(*i*) *Friction force between the piston and cylinder.* The friction force is reduced by having good surface finish and fit between the cylinder and the piston. The friction force is also reduced by rotation of piston so that kinetic friction is applied rather than static friction with the probability of stick-slip conditions.

(*ii*) *Uncertainty of value of effective area A.* The area upon which the weight force acts is neither the area of piston nor the area of cylinder. The value of effective area is somewhere inbetween these two values. The effective area depends upon the clearance spacing and viscosily of oil. If the clearance is small, the effective area becomes more close to the area of the piston. At high pressures there can be elastic deformation of the cylinder which increases the clearance spacing which increases the error of the tester.

(*iii*) *Uncertainty of value of gravitational constant g.* The tester is calibrated initially by the manufacturer for a particular value of g, usually the standard 9.80665 m/s^2. But since the local value of g is different from this, corrections should be applied to get better accuracy.

Many types of pressure measuring devices such as industrial pressure gauges, piezoelectric pressure transducers, engine indicators etc. may be calibrated by Dead Weight Testers. It should be noted that Manometers and dead weight testers are suitable for static calibration only.

9.20. RANGES AND APPLICATIONS OF PRESSURE MEASURING DEVICES

The principal methods for making static measurements of pressure depend upon either the deformation of elastic elements or on the pressure exerted by liquid columns. Elastic elements are more compact than liquid columns and hence have quicker dynamic response.

Dynamic measurement of pressure may be made with capacitive, strain gauge or piezo-electric transducers. Capacitive and strain gauge transducers are fast and act as secondary transducers for elastic members. However, the masses and mechanical displacments involved are smaller than those of similar elastic elements with mechanical outputs. Thus the dynamic response of the electric transducer is better. Strain gauge and capacitive transducers can be used for both dynamic and static pressure measurements. Piezoelectric transducers are however used for measurement of dynamic pressure only.

For low pressure applications, *i.e.* measurement of vacuum McLeod gauge, thermocouple gauge, Pirani gauge, Kundsen gauge and Ionization gauge are used.

The ranges over which different classes of pressure measuring elements are normally used are indicated in Fig. 9.48.

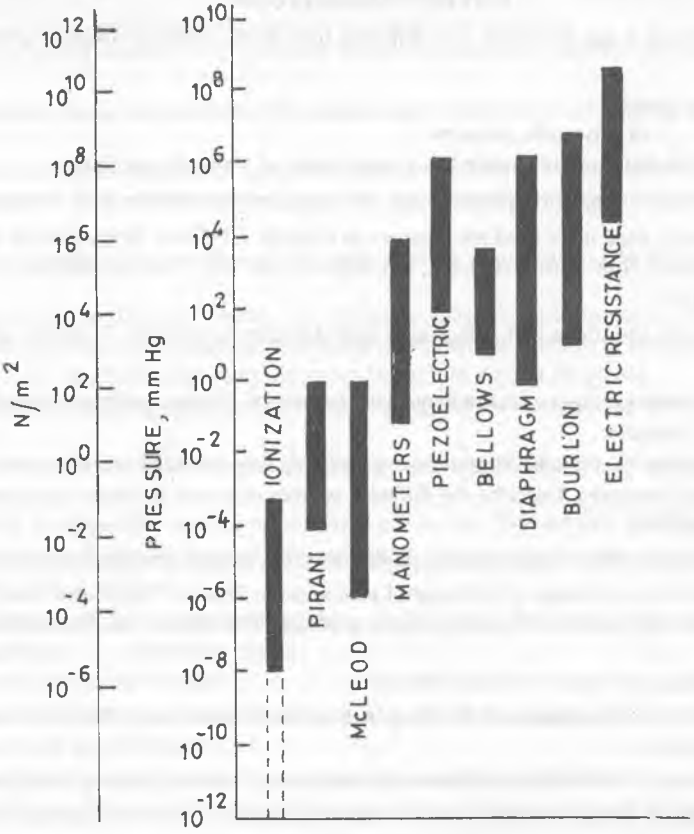

Fig. 9.48. Summary of applicable range of pressure gauges.

UNSOLVED PROBLEMS

1. A U-tube manometer uses mercury as the manometer fluid. What is the height to which the mercury will rise in the narrow limb if a differential pressure of 100 kN/m^2 is applied ? The wide and the narrow limb diameters are 150 mm and 5 mm respectively. The density of mercury is 13.6×10^3 kg/m^3. **[Ans.** 749 mm]
2. A manometer uses transformer oil of specific gravity 0.8 as the manometric liquid. However, the scale is graduated in mm of water. If the diameter of one leg is 2 mm and of the other 20 mm, calculate the angle to the horizontal at which the tube and the scale must be inclined to give a reading of 5 mm on the scale for pressure difference equivalent of 1 mm head of water. **[Ans.** 14.3°]
3. A well type U-tube manometer using mercury as the measuring fluid has a well 30 mm in diameter and a tube 1 mm in bore. If a scale correctly graduated in millimeters is used, and the datum level is at 0 mm, calculate the reading on the scale when a pressure difference of 1 m of mercury is applied across the manometer. State the percentage error in the reading, and calculate actual error in pascal and bar units.
[Ans. 998.9 mm, 146 Pa, 1.46×10^{-3} bar]
4. A manometer has a well 20 mm in diameter, and the bore of tube of the other leg is 4 mm. It is proposed to use a scale graduated accurately in cm to measure pressure heads in mm directly *i.e.*, 1 cm scale division indicates 1 mm pressure head change. Calculate the angle at which the tube must be inclined with horizontal to do this.
[Ans. 5.5°]