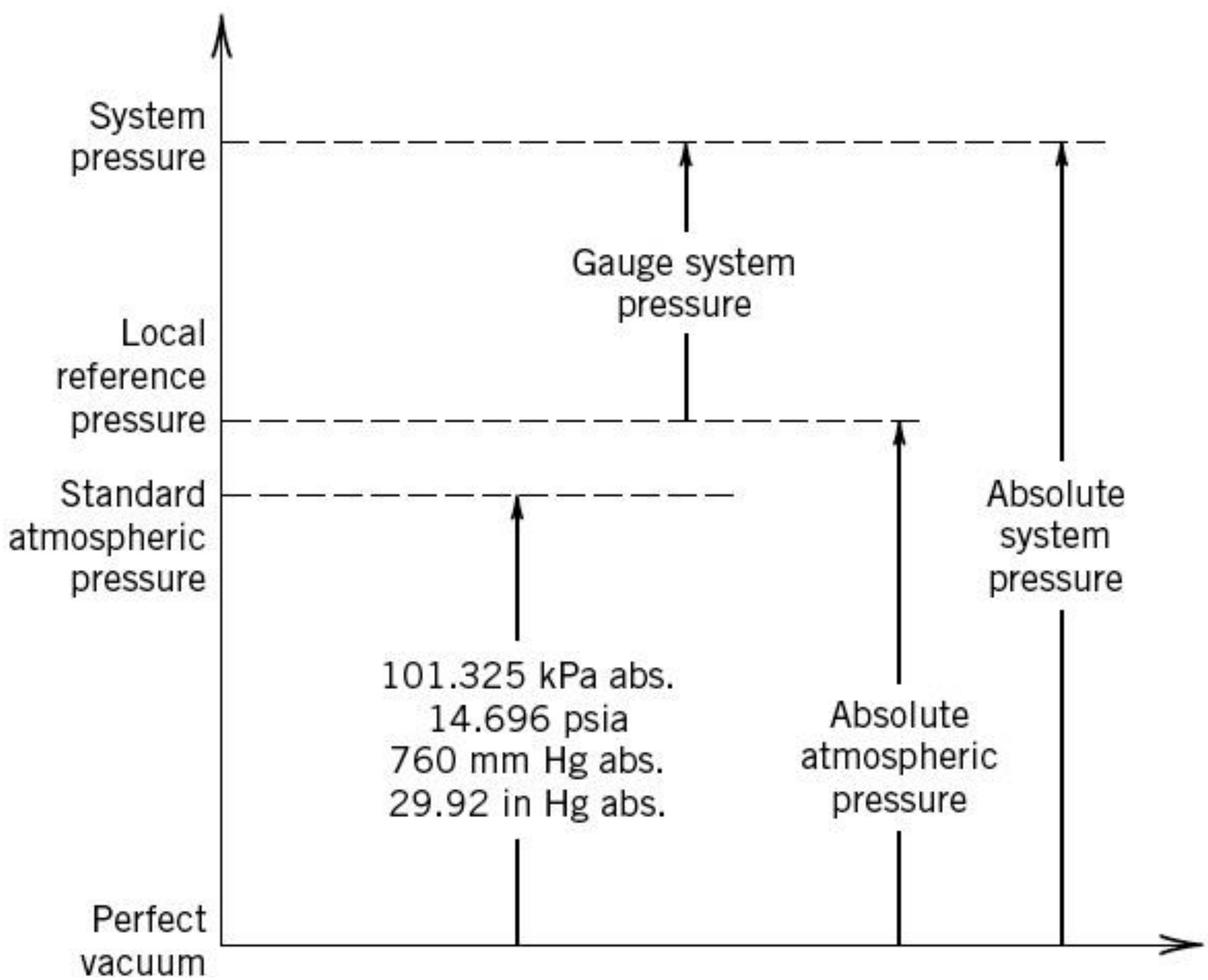
PRESSURE MEASUREMENT

Pressure is a force per unit area exerted by a fluid perpendicular to a boundary (as opposed to shear stress, which is exerted parallel to the boundary.) A more precise term is *hydrostatic pressure.*

Since almost all pressure sensors measure a pressure difference, we need to distinguish between <u>absolute</u> and <u>gauge</u> pressures:

$$P_g = P_{abs} - P_0 \quad (8.1^1, 9.1^{2,3})$$



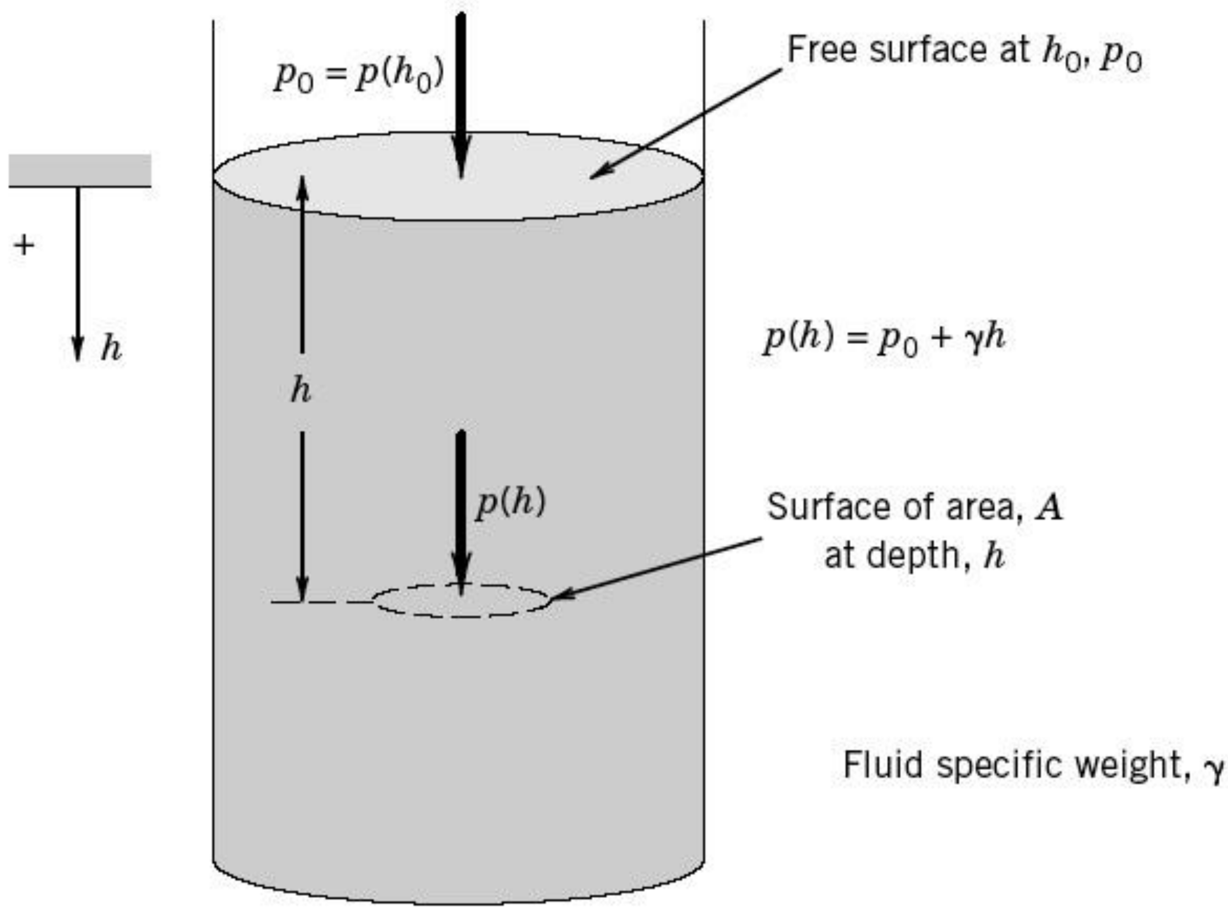
The <u>hydrostatic pressure</u> at any point in a fluid is related to the pressure at any other point by the weight of the fluid between the two points:

$$p(h_2) - p(h_1) = \gamma(h_2 - h_1)$$

We frequently express pressure in terms of an equivalent head of fluid:

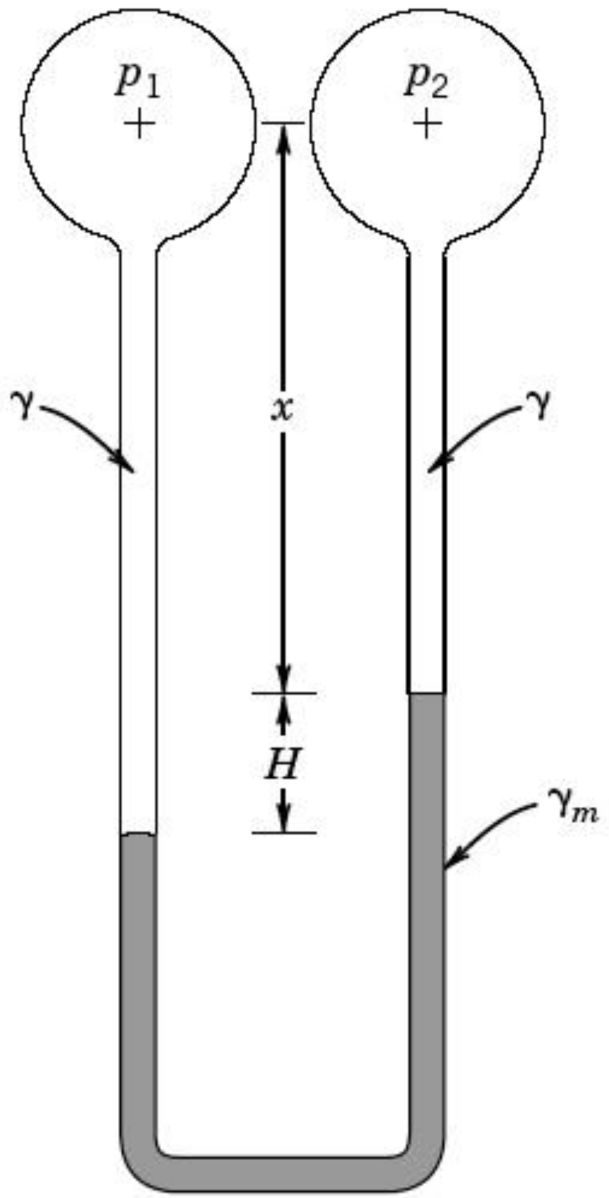
$$h = \frac{p(h) - p(h_o)}{\gamma}$$

$$p(h) = p(h_o) + \gamma h$$



Pressure Reference Instruments

Reference instruments are those which utilize directly the weight of a column of fluid. Pressure can be calculated from the geometry of the instrument and the specific weight of the fluid. They can be made quite precise but do not generally provide an electrical output. The most common instrument is the *manometer,* which measures a difference between two pressures:



$$p_1 - p_2 = (\gamma_m - \gamma) H$$

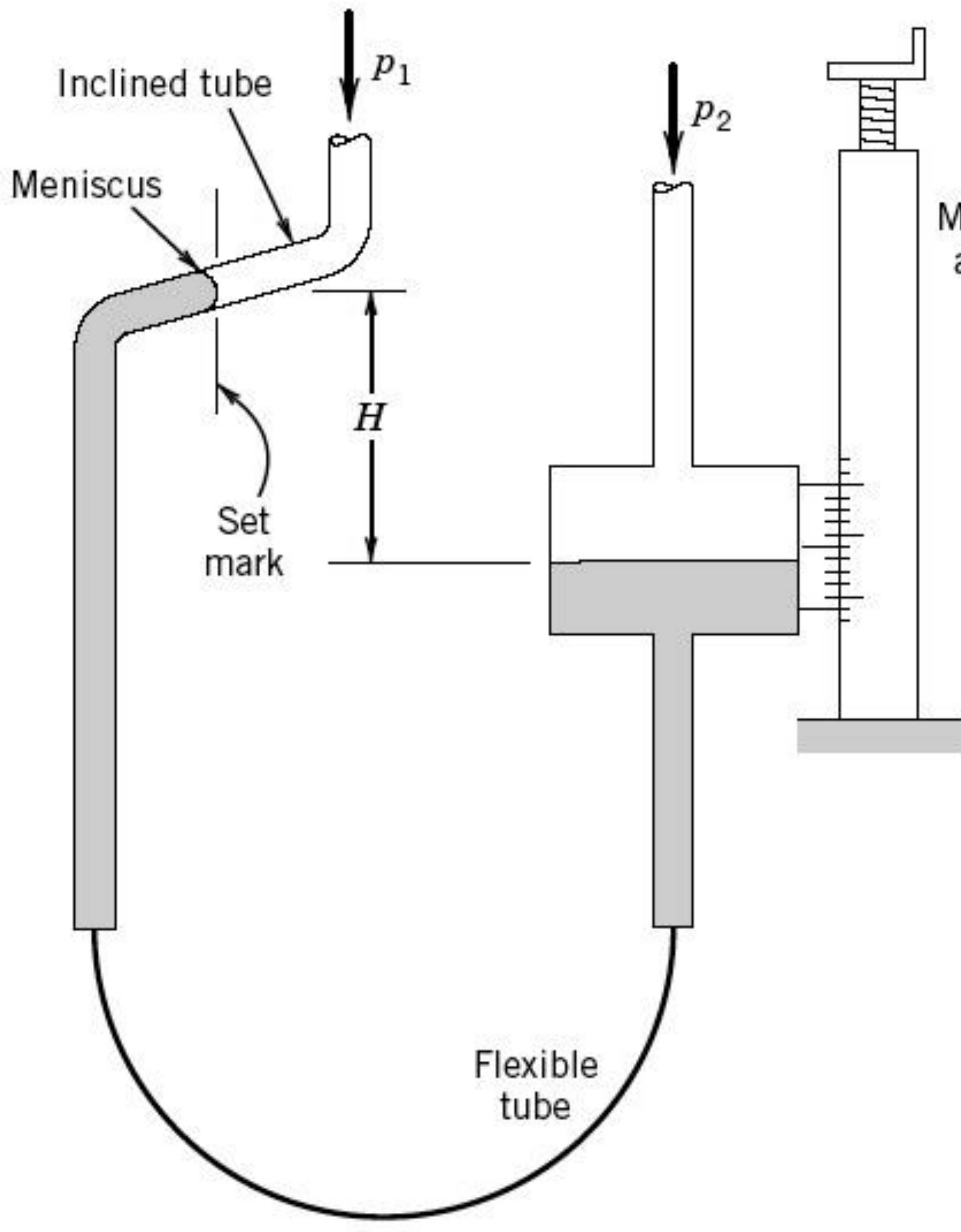
$$H = K (p_1 - p_2)$$

$$\text{where } K = \frac{1}{\gamma_m - \gamma}$$

The *static sensitivity* K can be controlled within limits by selecting the manometer fluid, although the density of most gases at

atmospheric pressure is much less than that of any liquid.

We can also increase the static sensitivity by using a <u>micromanometer</u>, which improves the precision of measuring H:



Another technique which increases static sensitivity is inclining the sensing tube.

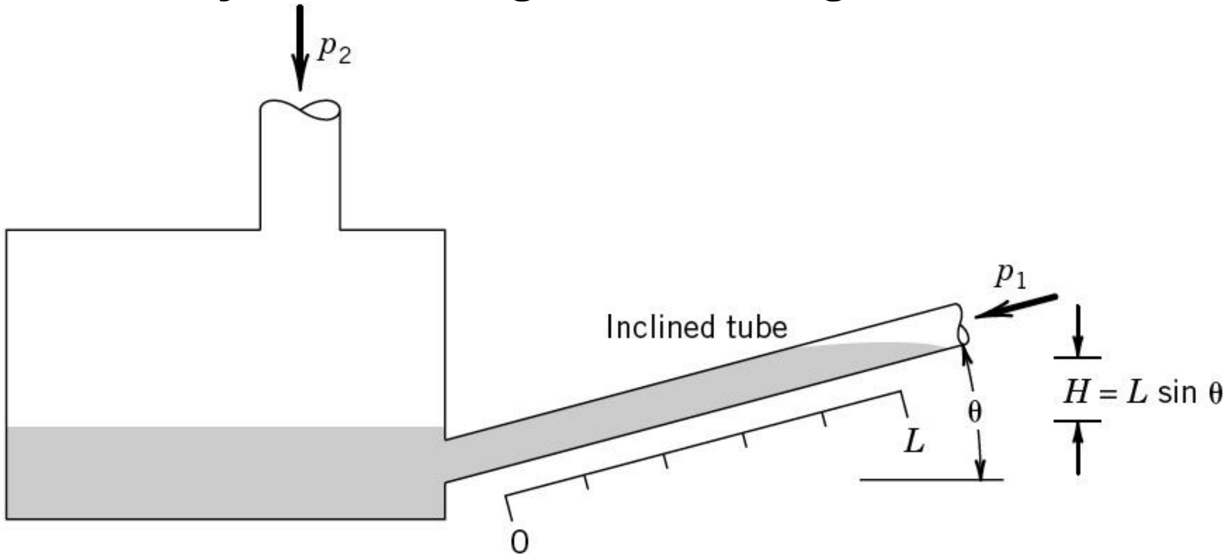


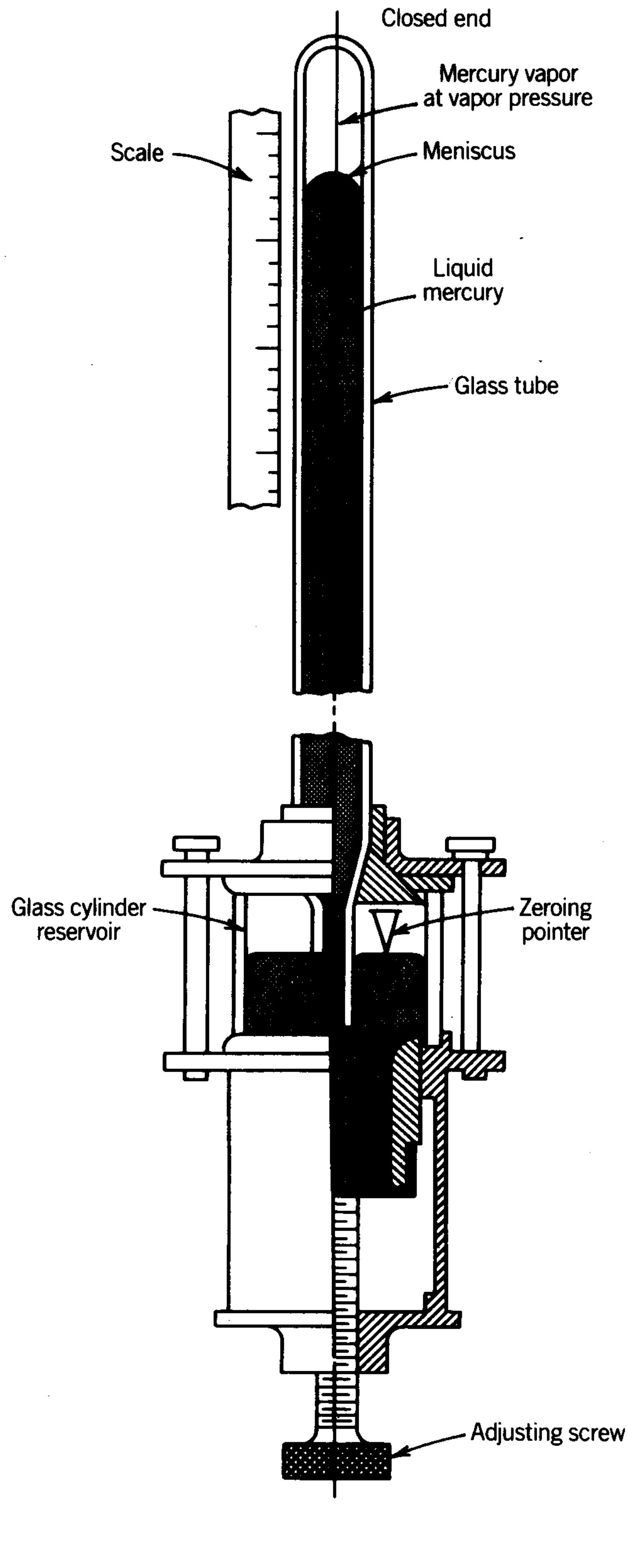
Figure 9.7 Inclined tube manometer.

Advantages and disadvantages of manometers:

Advantages	**Disadvantages**
Linear	**No electrical output**
No calibration required	**Poor sensitivity (gases)**
Good precision	**Poor dynamic response**
Relatively inexpensive	

A Barometer

measures the difference between ambient pressure and the vapor pressure of mercury (at 25^o C, the vapor pressure is .002 mmHg, which is about 10^{-4} atm). If ambient temperature is measured, the result can be corrected for the vapor pressure as well as the dependence of specific weight on temperature.



<u>Deadweight testers</u> are used to calibrate other pressure transducers. They are null rather than deflection instruments.

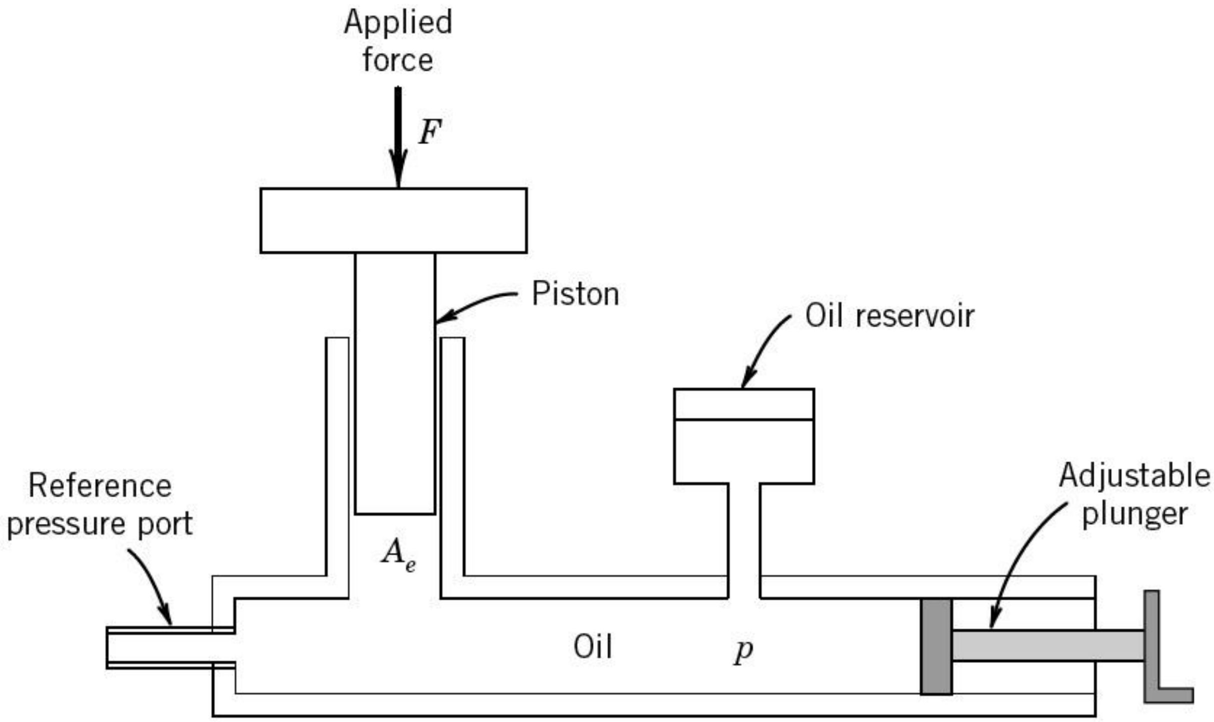


Figure 9.8 Deadweight tester.

The primary error in their use comes from friction between the piston and cylinder. This can be minimized by spinning the piston during the measurement (dynamic friction is less than static) and by proper design. The clearance between piston and cylinder must be small enough to prevent leakage but large enough to limit friction. The pressure is therefore:

$$p = \frac{F}{A_e} + \sum \text{errors}$$

Pressure Transducers

Almost all pressure transducers operate on the basis of elastic deflection - the applied pressure causes some component to deform or deflect.

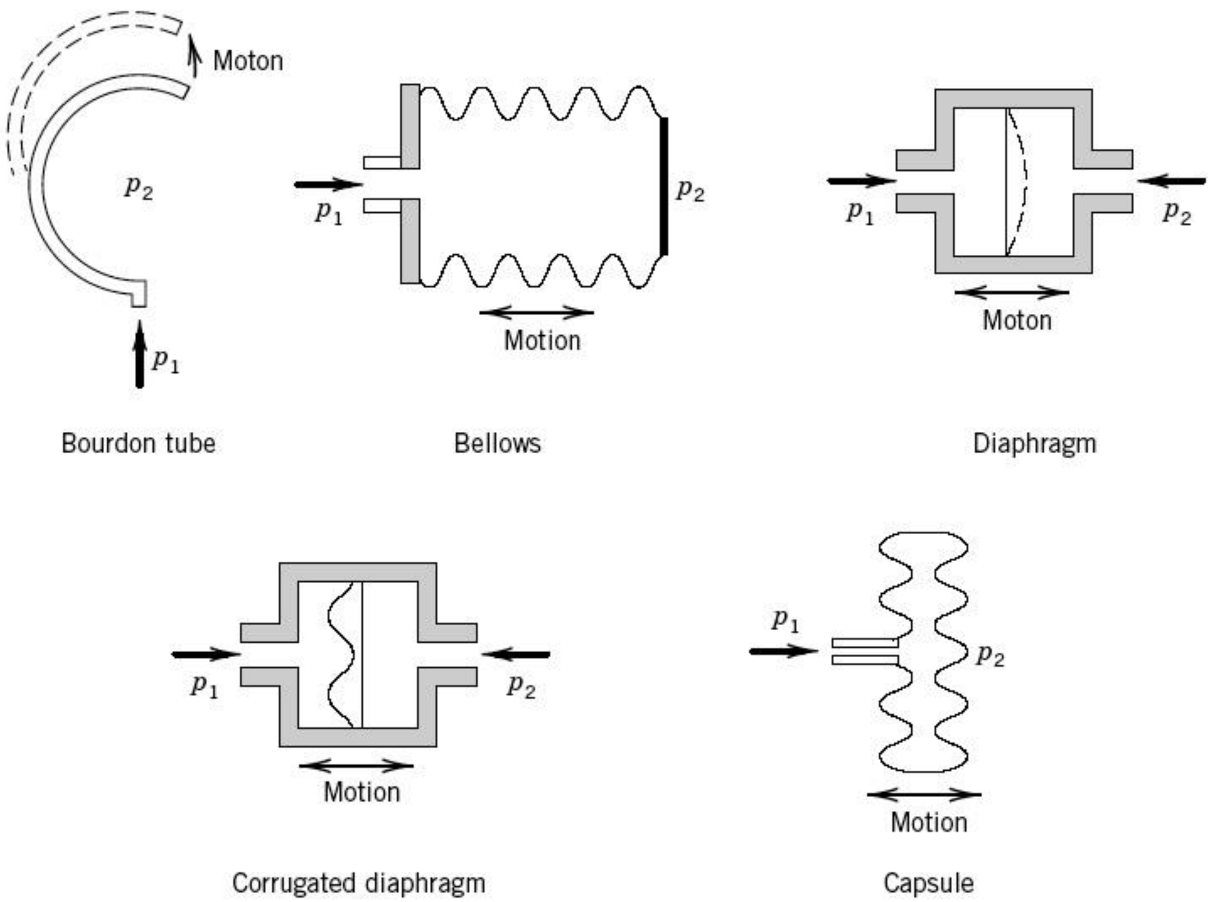


Figure 9.9 Elastic elements used as pressure sensors.

<u>The Bourdon Tube</u> forms the basic element of most dial pressure gauges.

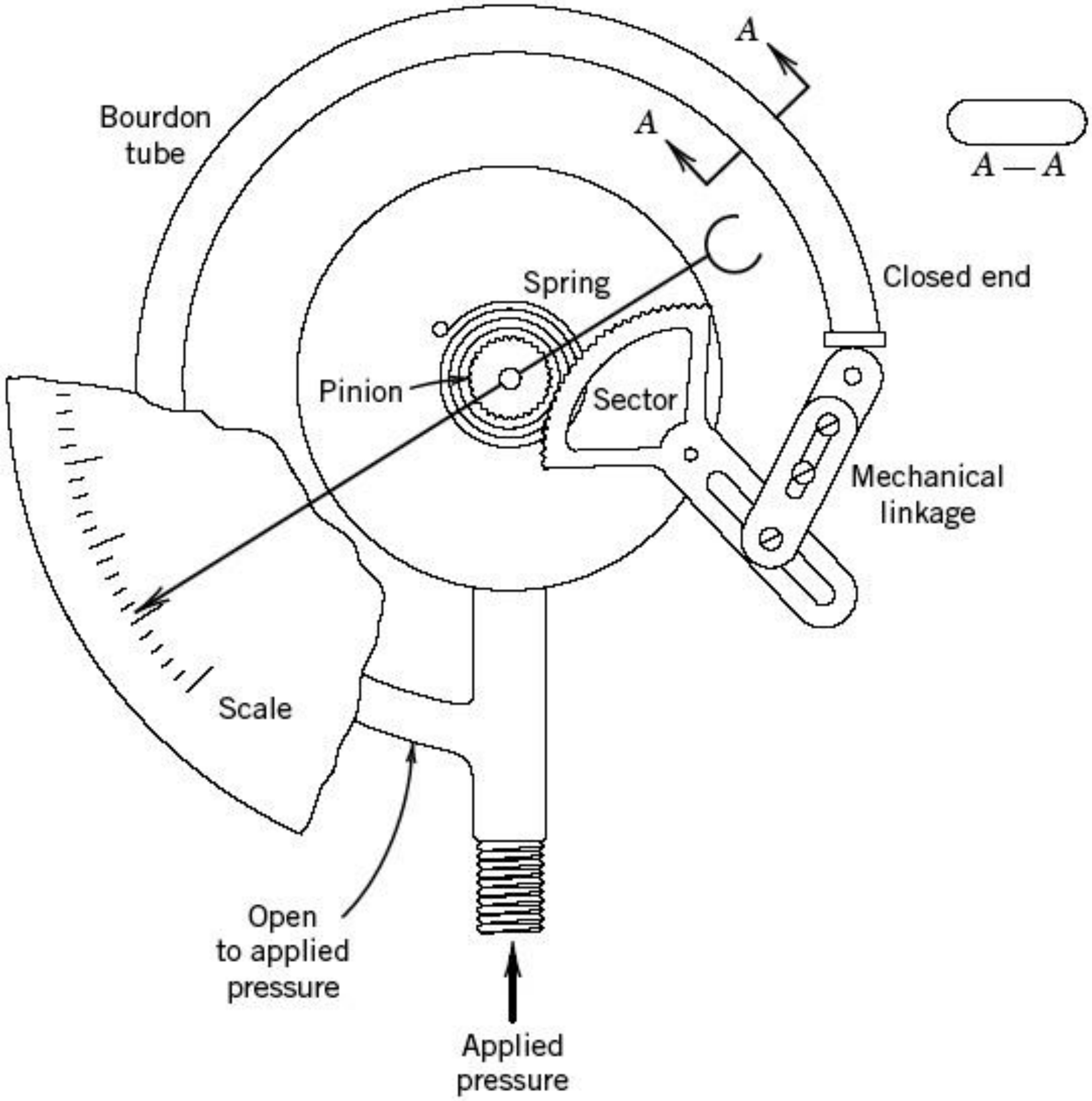


Figure 9.10 Bourdon tube pressure gauge.

Static sensitivity can be controlled by varying the dimensions of the tube. It is possible, though not common, to convert the mechanical output to an electrical signal by bonding strain gages to the tube. Bourdon tube gages can be made quite precise by using large diameter dials.

<u>Bellows and capsule elements</u> are frequently used when an electrical output is desired.

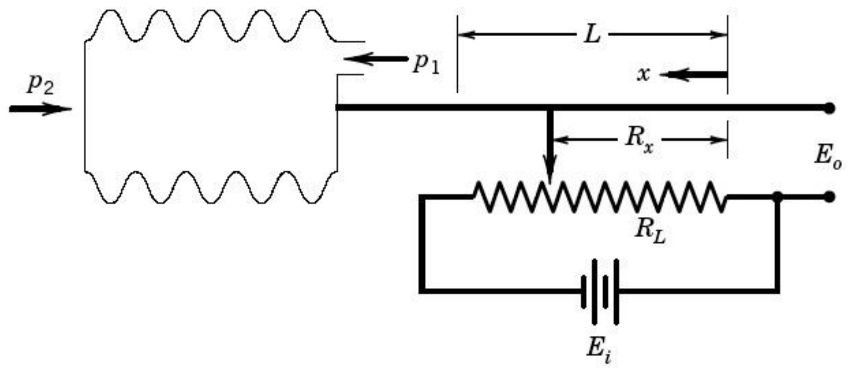


Figure 9.11 Potentiometer pressure transducer.

Figure 9.11 Potentiometer Pressure transducer.

Diaphragm elements are the most commonly used transducers with an electrical output. This is the type we are using in the lab.

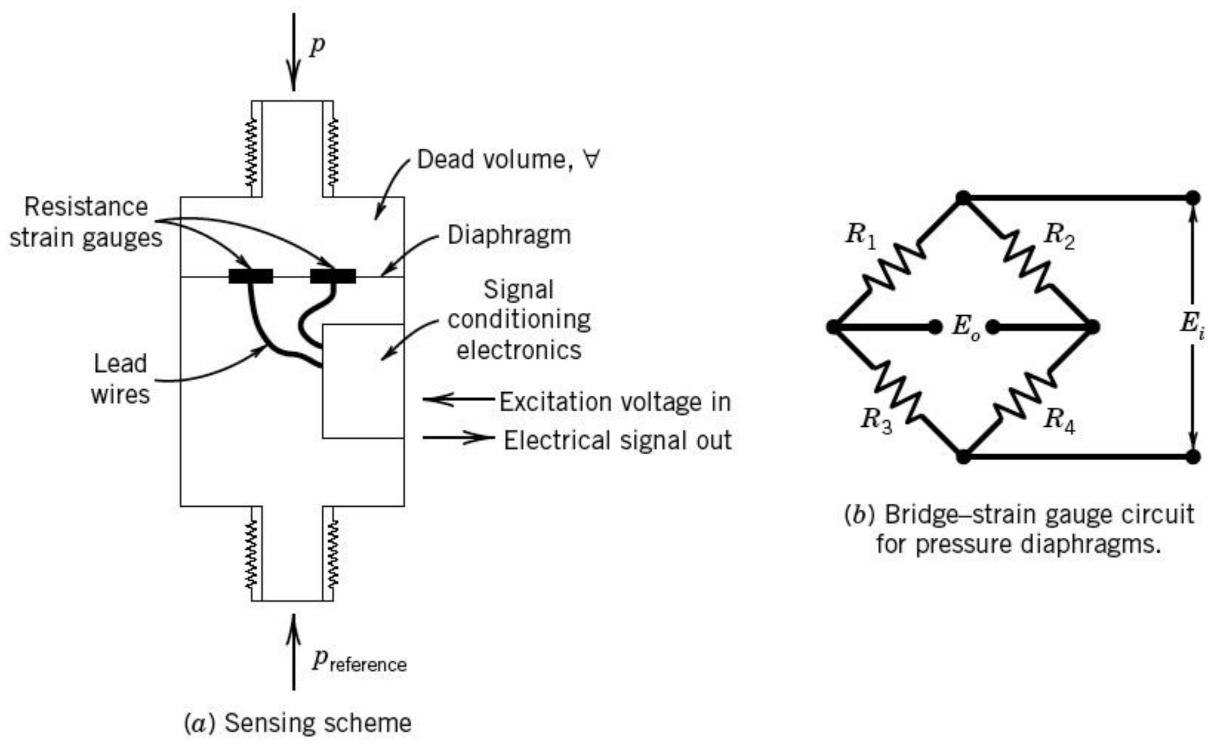


Figure 9.13 Diaphragm pressure transducer.

Several methods can be used to sense diaphragm deflection:

- **Resistance**
  - **Bonded strain gauge**
    - **metallic wire**
    - **Piezoresistive**
  - **Unbonded strain gauge**
    - **metallic wire**
- **Capacitance**

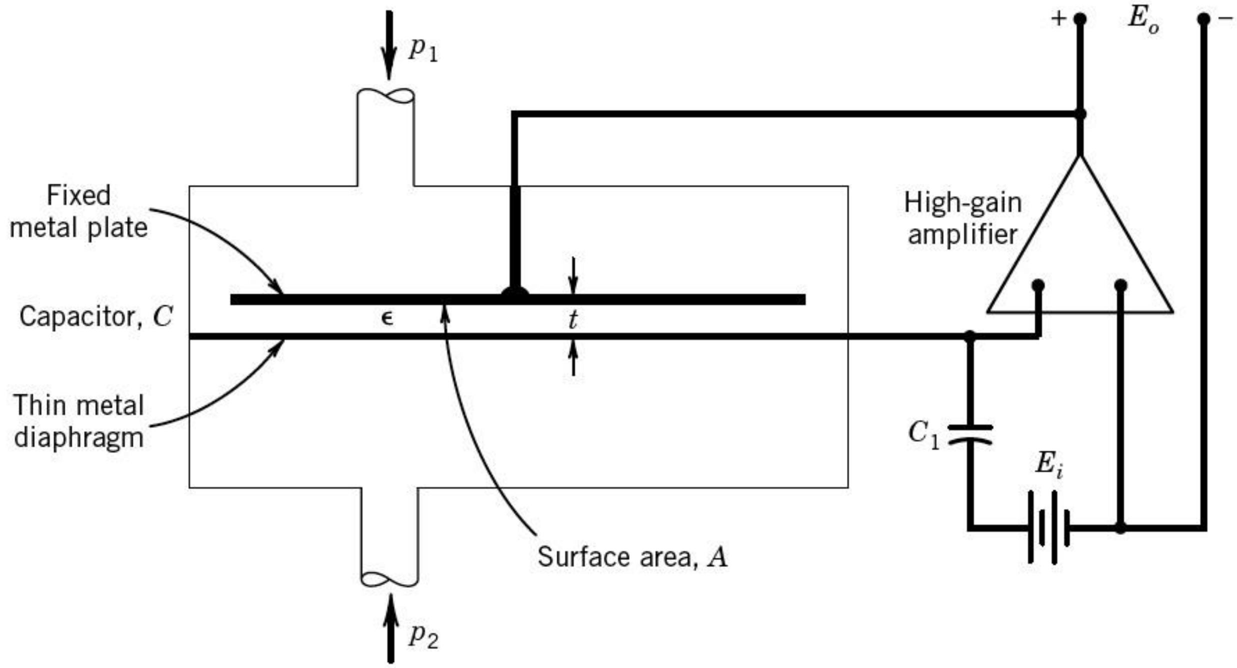


Figure 9.14 Capacitance pressure transducer.

- # Piezoelectric

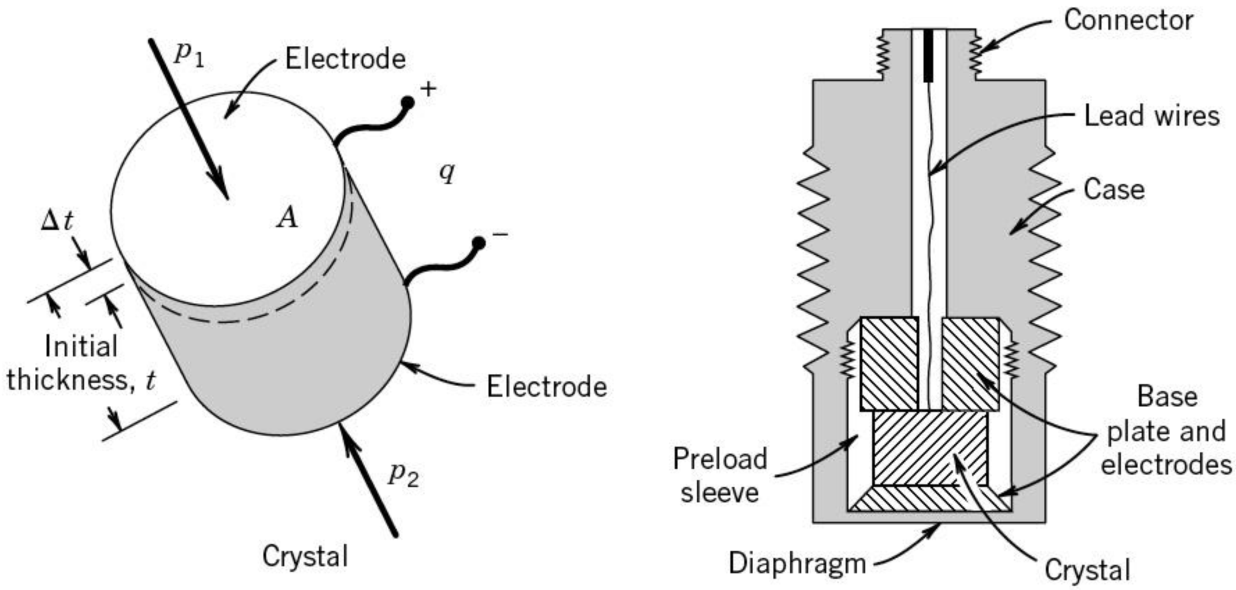


Figure 9.15 Piezoelectric pressure transducer.

<u>Elastic deflection transducers</u> are by definition deflection sensors, hence they load the system and care must be take to keep their input impedance high enough to minimize loading effects. We can define input impedance:

$$Z_i = \frac{\Delta P}{\Delta V}$$

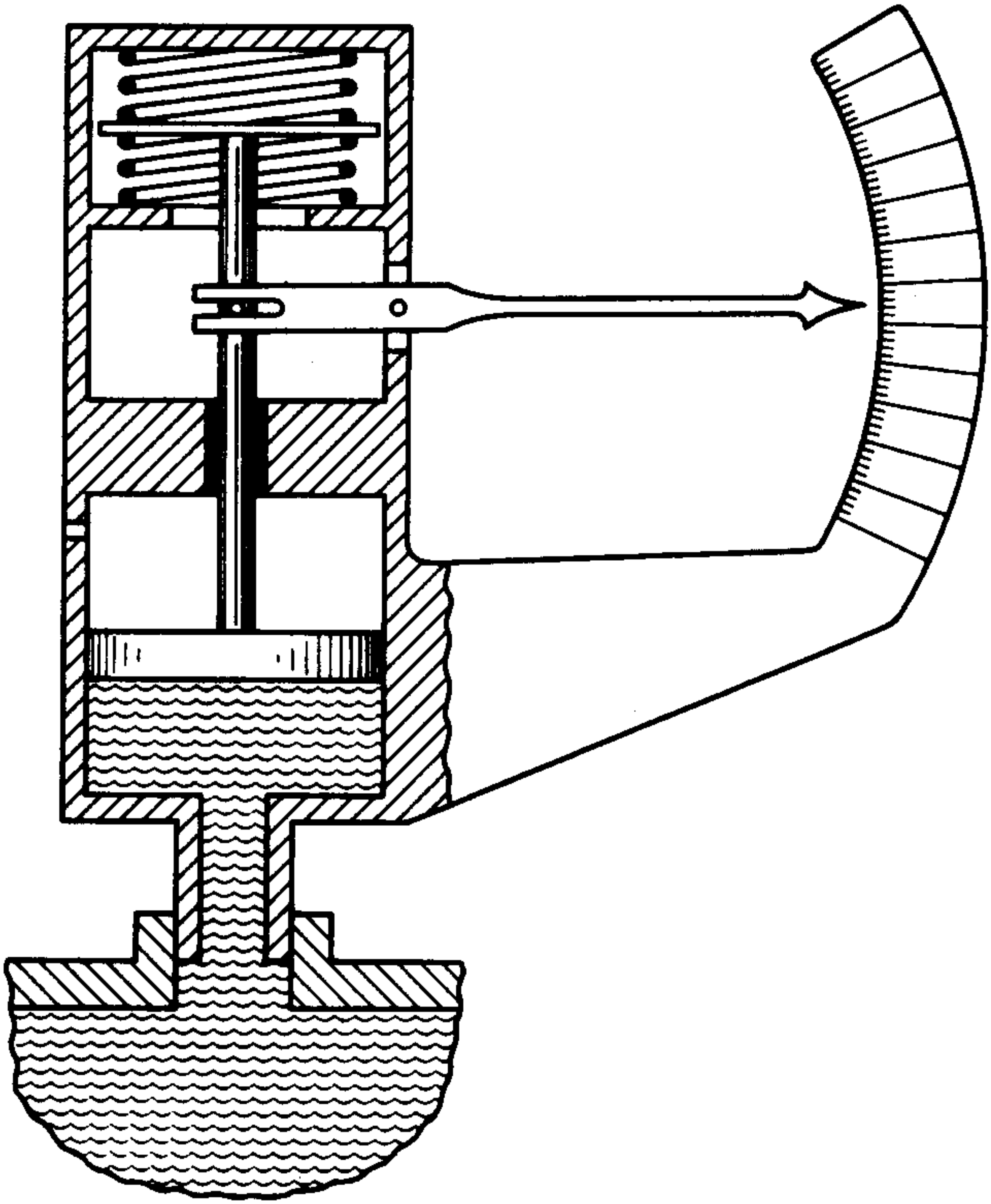
Unfortunately the static sensitivity of the device is proportional to the amount of deflection which occurs:

$$K \sim \frac{\Delta V}{\Delta P}$$

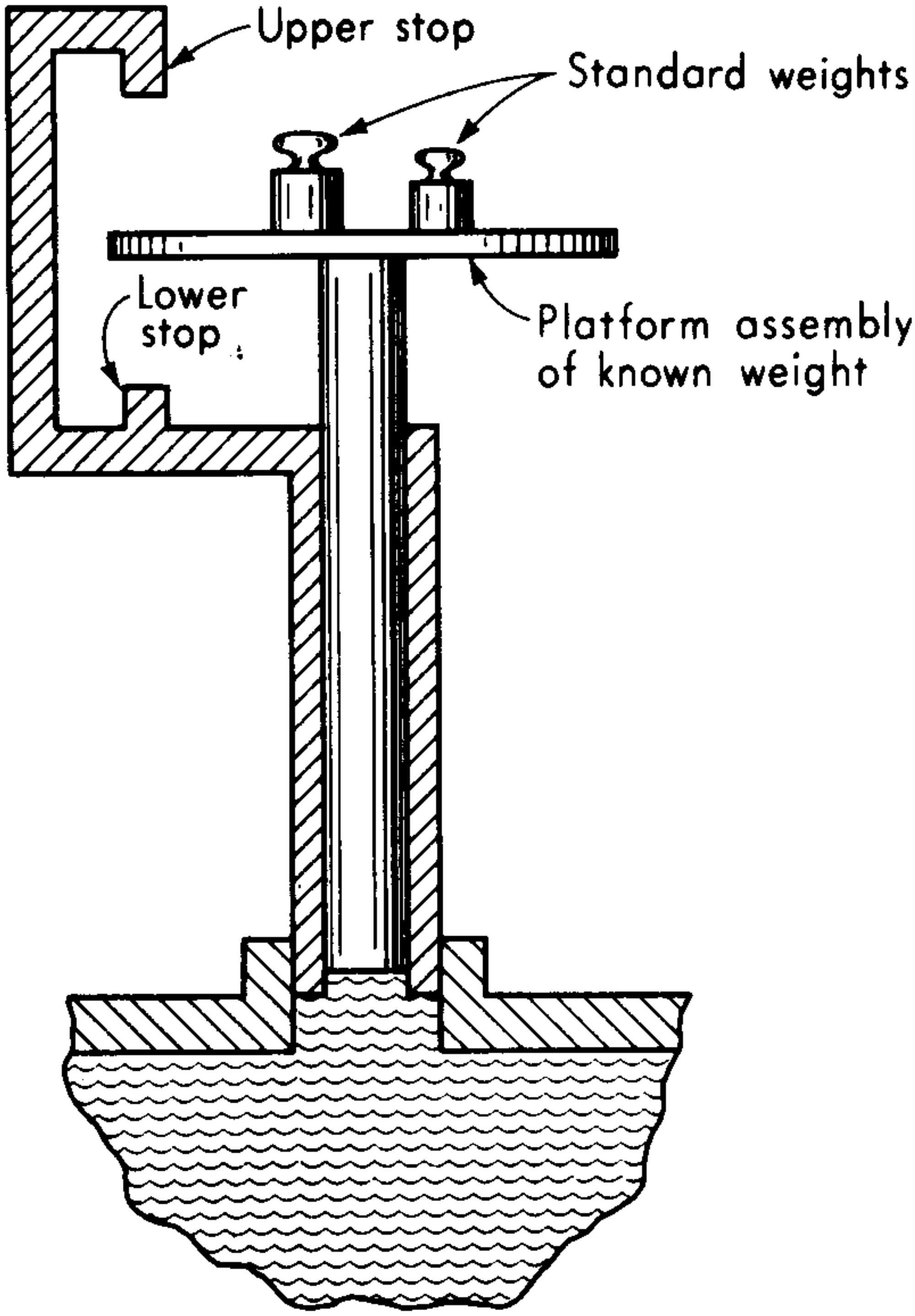
so that the input impedance is inversely proportional to static sensitivity:

$$Z_i \sim \frac{1}{K}$$

Deflection Instrument



Null Instrument



Figures from Doebelin