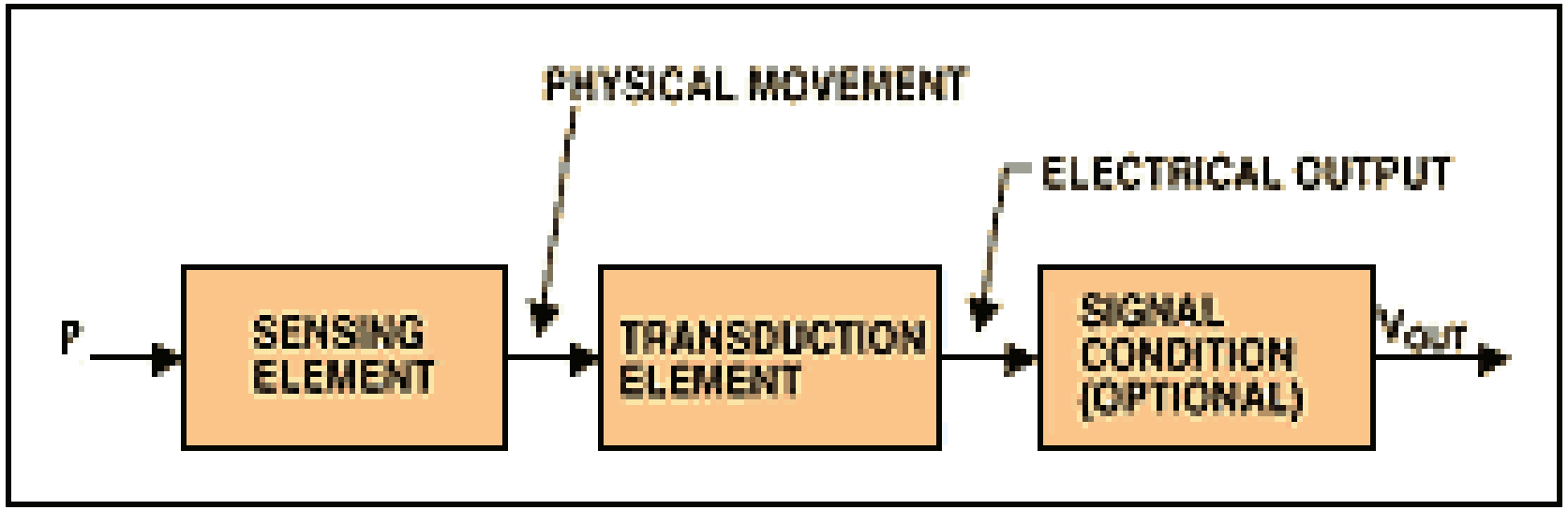
EIPC
NEE-403
Unit-2
Force, Pressure measurement

Pressure definition

- Pressure is the action of one force against another over, a surface. The pressure P of a force F distributed over an area A is defined as:

$$P = F/A$$

Typical pressure sensor functional blocks.



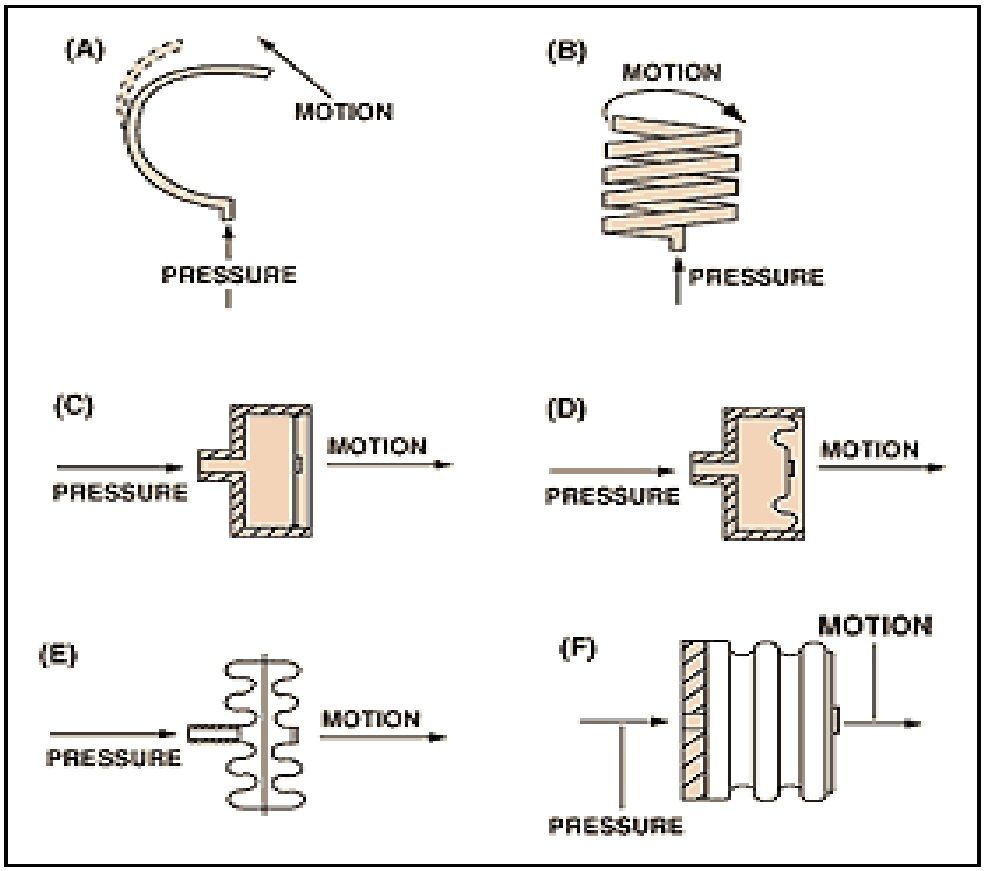
Sensing Elements

The main types of sensing elements are

- Bourdon tubes,
- diaphragms,
- capsules, and
- bellows .

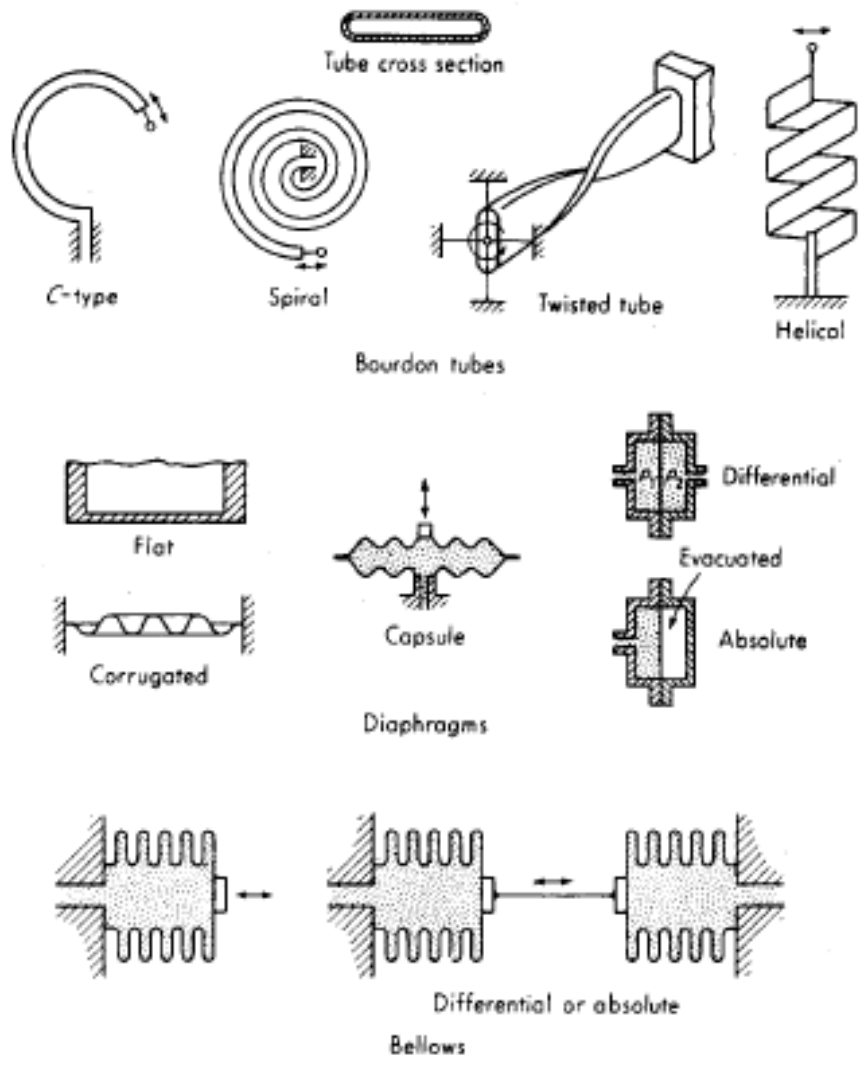
All except diaphragms provide a fairly large displacement that is useful in mechanical gauges and for electrical sensors that require a significant movement.

Sensing Elements

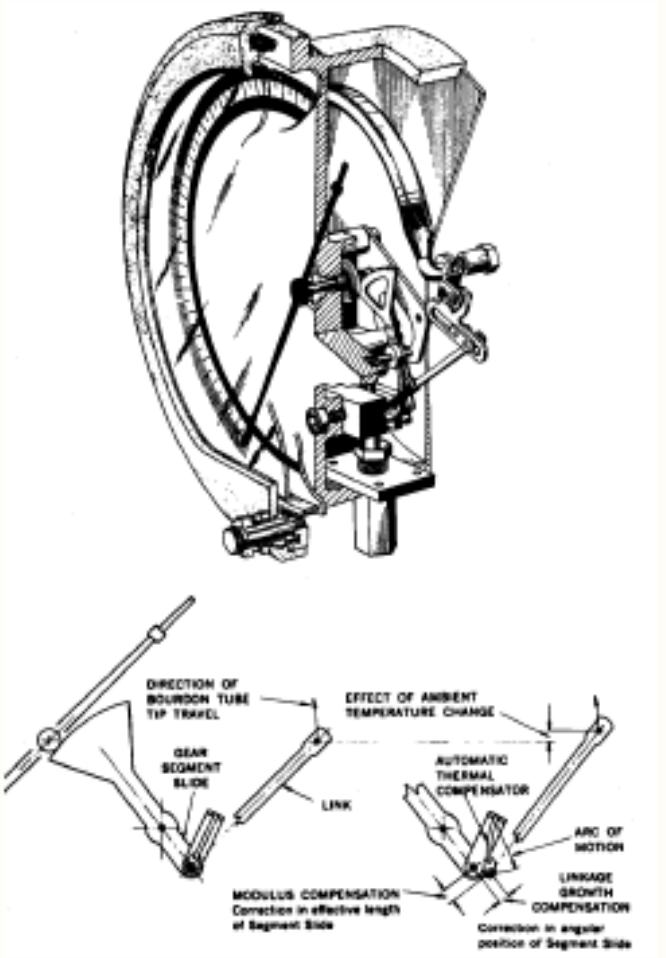


The basic pressure sensing element can be configured as a C-shaped Bourdon tube (A); a helical Bourdon tube (B); flat diaphragm (C); a convoluted diaphragm (D); a capsule (E); or a set of bellows (F).

- Elastic pressure transducers



Bourdon-tube gage (0.1% accuracy)



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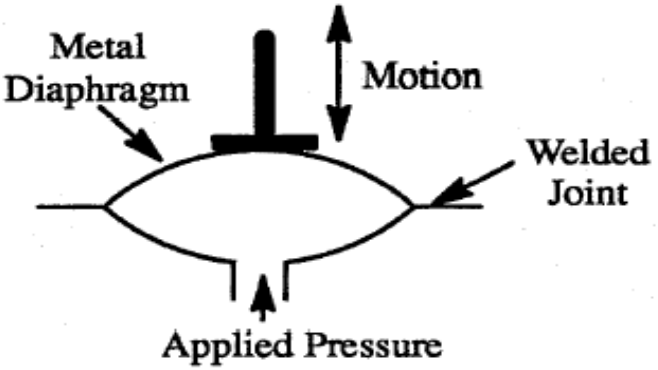
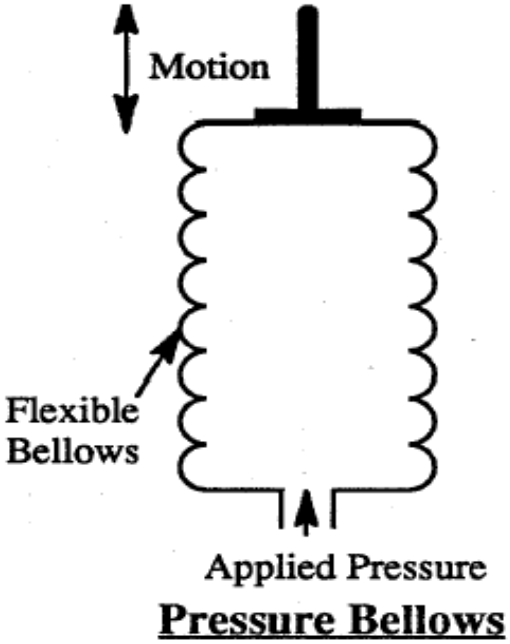
Primary Pressure Elements

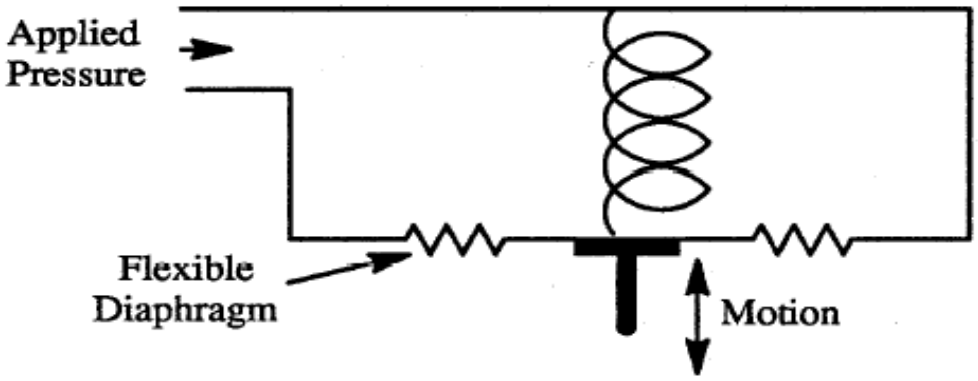
Capsule, Bellows & Spring Opposed Diaphragm



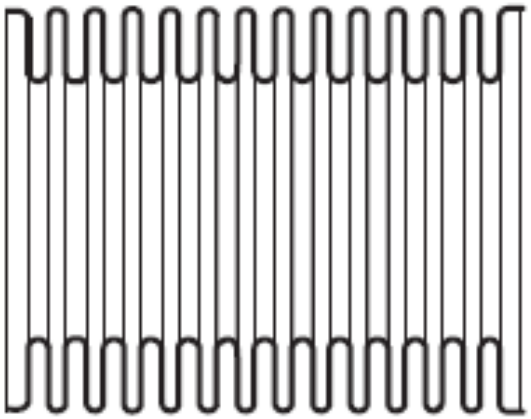
Pressure Capsule

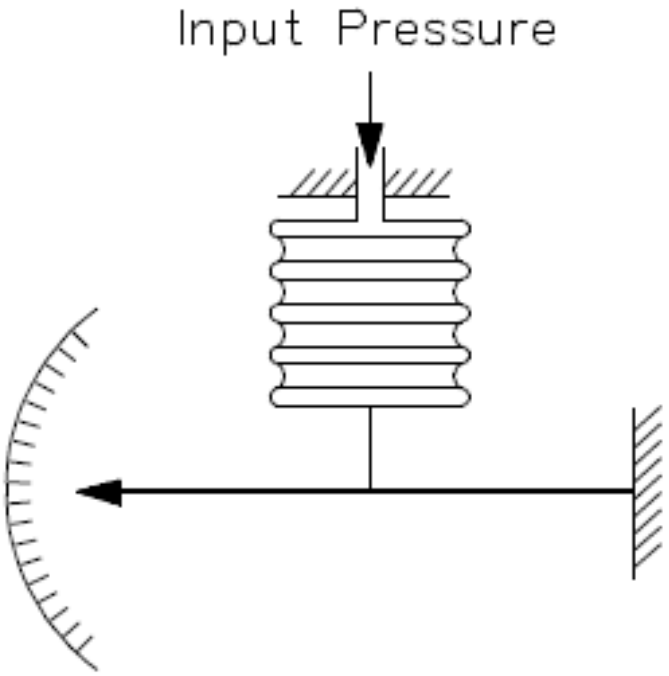


Pressure Bellows



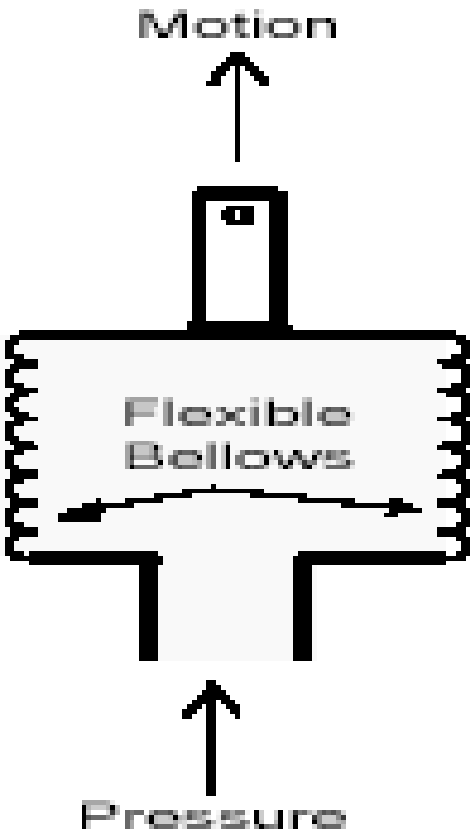
Bellows





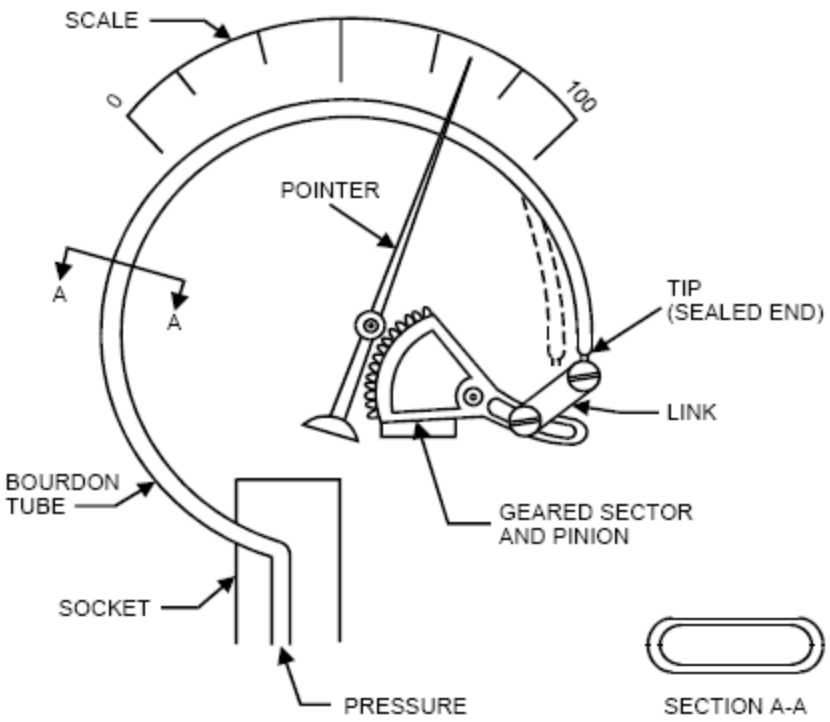
- Made of Bronze, S.S., BeCu, Monel etc..
- The movement is proportional to number of convolutions
- Sensitivity is proportional to size
- In general a bellows can detect a slightly lower pressure than a diaphragm
- The range is from 0-5 mmHg to 0-2000 psi
- Accuracy in the range of 1% span

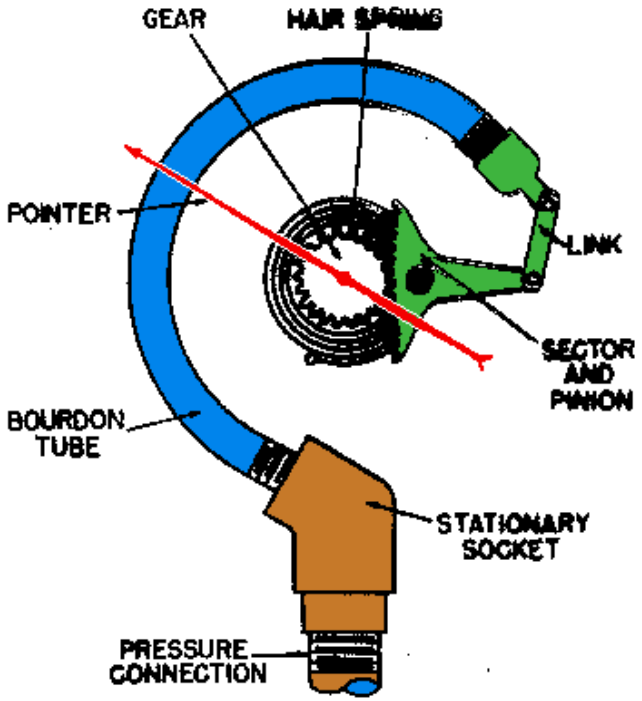
Bellows



Bellows Gauges

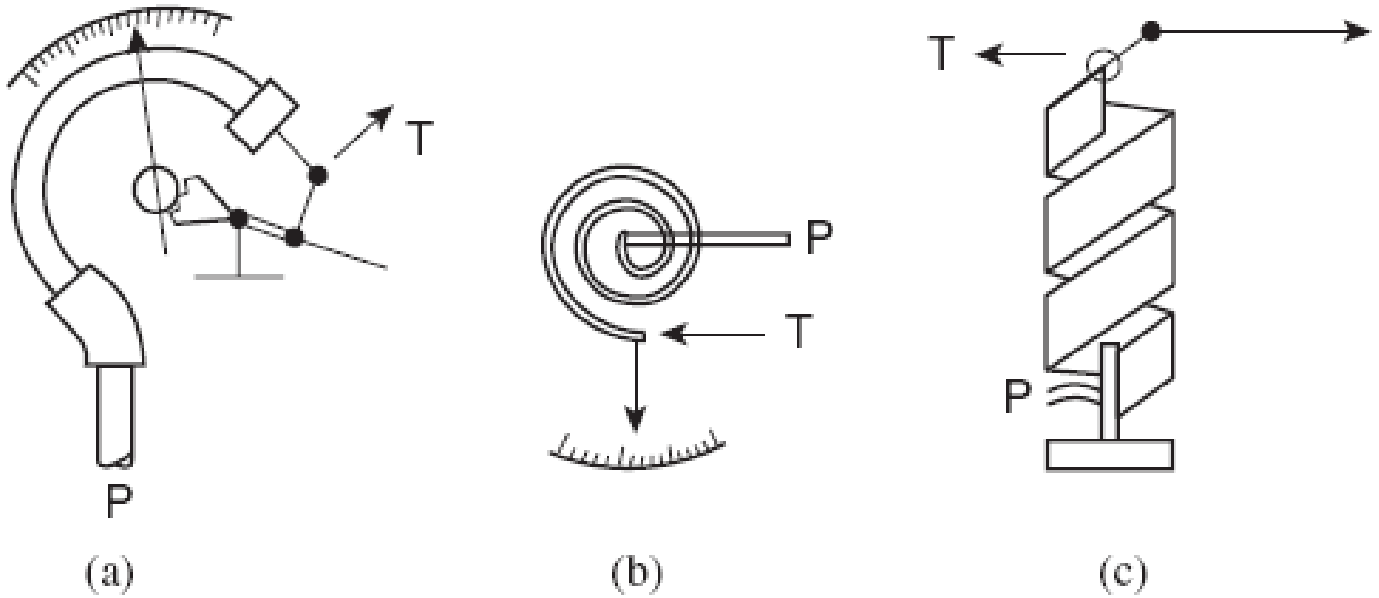
Bourdon Tube





Bourdon Tube Gauge

Bourdon Tubes

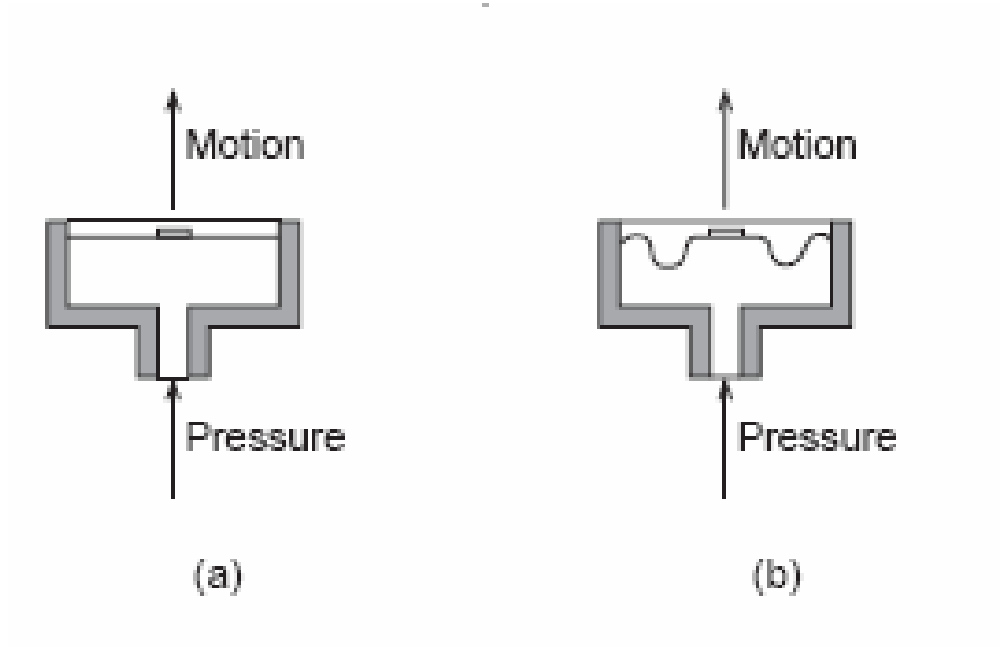


(a) (b) (c)

- (a) C-type tube.
- (b) Spiral tube.
- (c) Helical tube

Bourdon Tubes

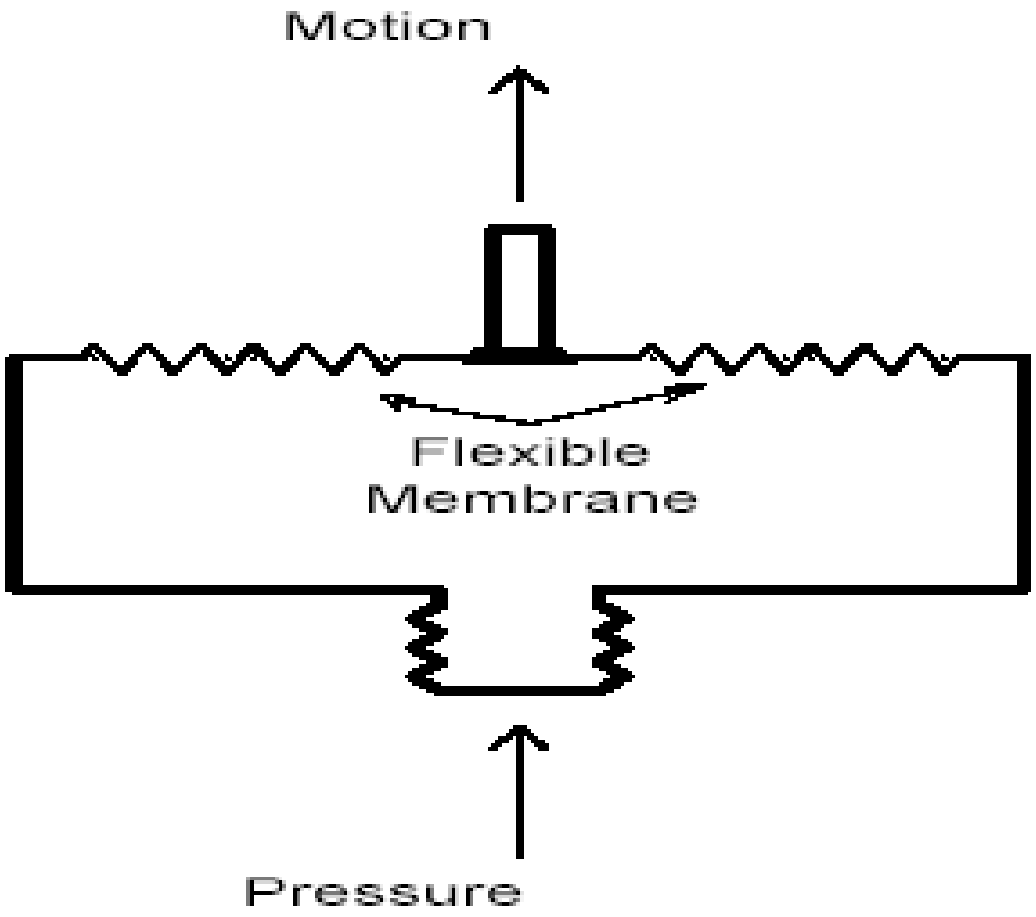
Diaphragm



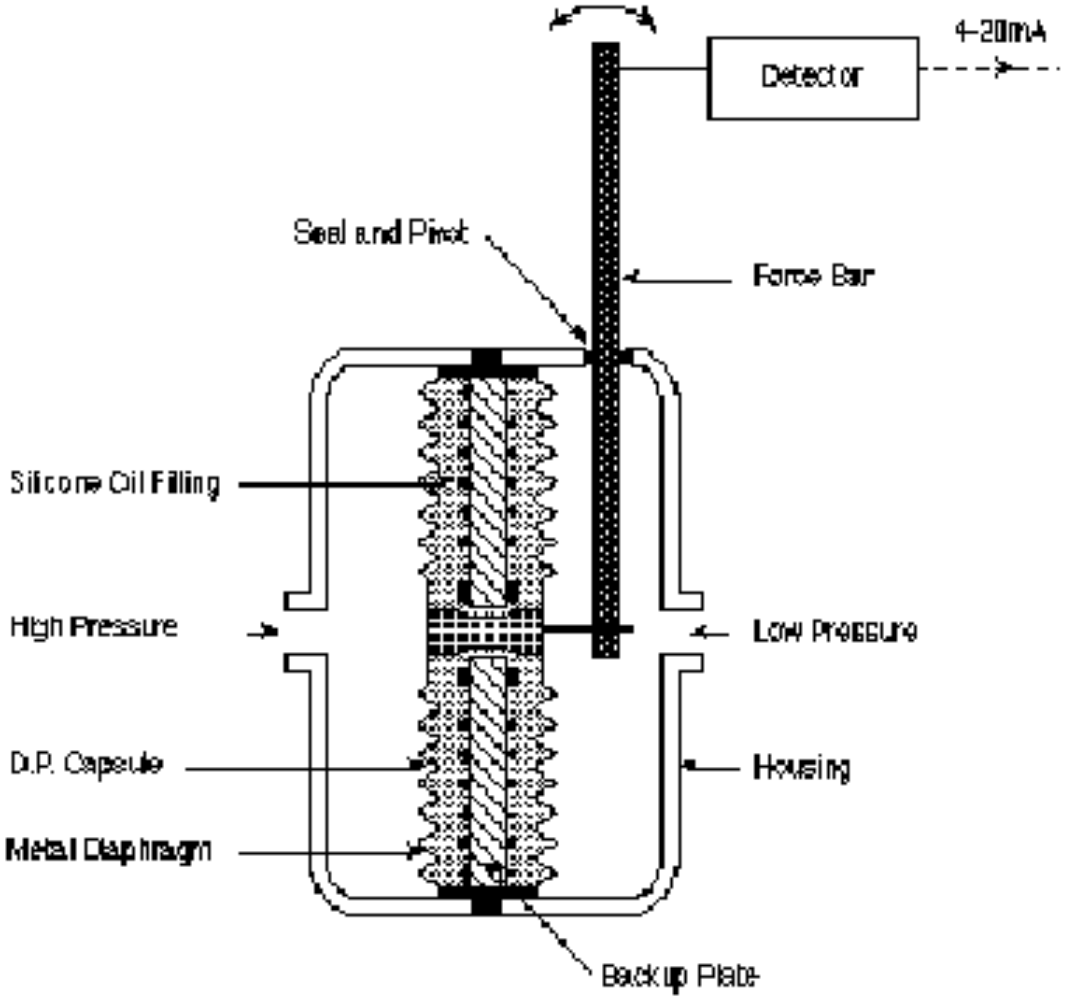
(a) flat diaphragm; (b) corrugated diaphragm

- A diaphragm usually is designed so that the deflection-versus-pressure characteristics are as linear as possible over a specified pressure range, and with a minimum of hysteresis and minimum shift in the zero point.

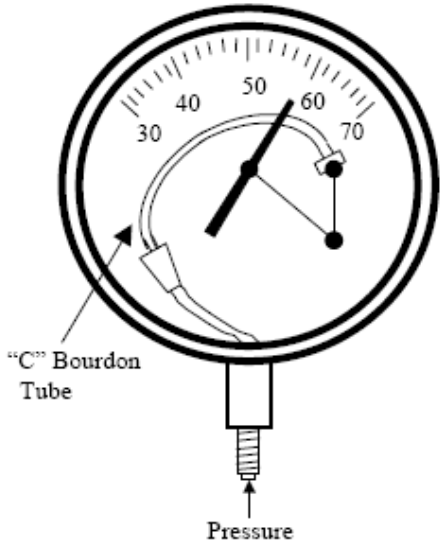
Diaphragm



Differential Pressure Cell



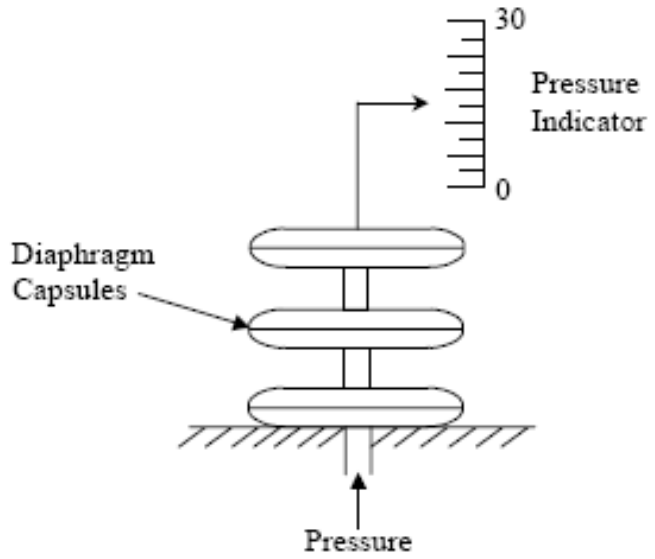
Pressure Gauges



Bourdon tube pressure gauge

- In "C" type Bourdon tube, a section of tubing that is closed at one end is partially flattened and coiled.
- When a pressure is applied to the open end, the tube uncoils.
- This movement provides a displacement that is proportional to the applied pressure.
- The tube is mechanically linked to a pointer on a pressure dial to give a calibrated reading.

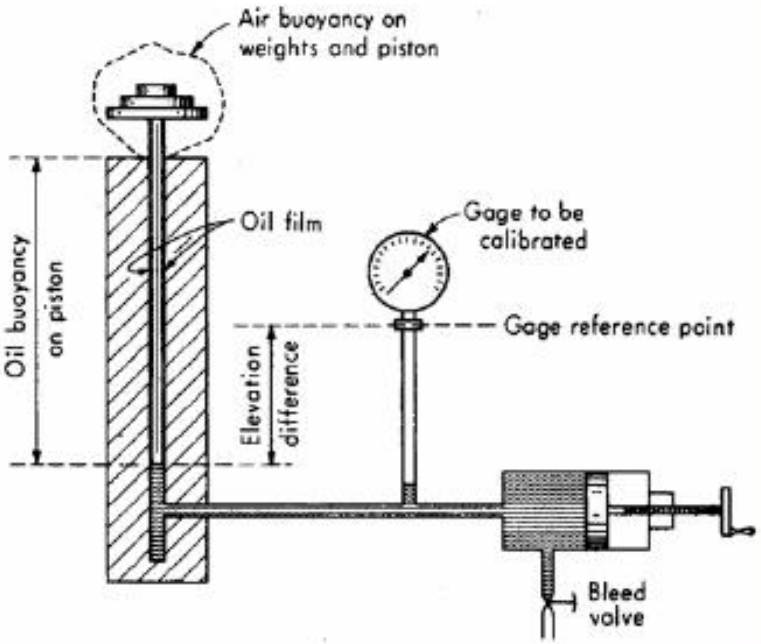
Pressure Gauges



Diaphragm-type pressure gauge

- To amplify the motion that a diaphragm capsule produces, several capsules are connected end to end.
- Diaphragm type pressure gauges used to measure gauge, absolute, or differential pressure.
- They are normally used to measure low pressures of 1 inch of Hg, but they can also be manufactured to measure higher pressures in the range of 0 to 330 psig.
- They can also be built for use in vacuum service.

Calibration of Pressure Sensing Devises



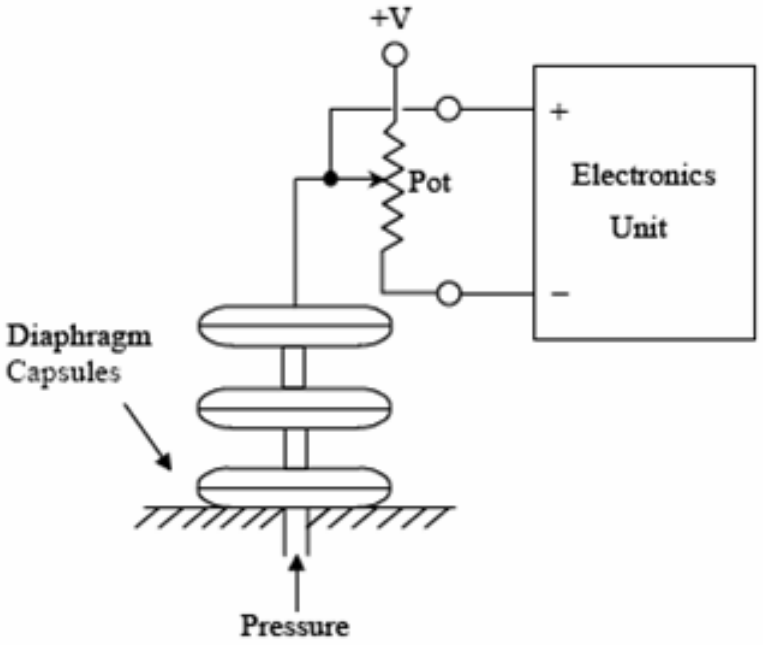
$$\text{Gauge pressure} = \frac{Mg_l\left(1-\frac{\rho_{air}}{\rho_{mass}}\right)+\pi DT}{A_{(20.0)}\cdot[1+(\alpha_p+\alpha_c)\cdot(\theta-20)]\cdot(1+\lambda P)} - (\rho_{fluid}-\rho_{air})\cdot g_l h$$

From Mechanical to Electronic

- The free end of a Bourdon tube (bellows or diaphragm) no longer had to be connected to a local pointer, but served to convert a process pressure into a transmitted (electrical or pneumatic) signal.
- At first, the mechanical linkage was connected to a pneumatic pressure transmitter, which usually generated a 3-15 psig output signal for transmission over distances of several hundred feet,
- The force-balance and later the solid state electronic pressure transducer were introduced.

Potentiometric type sensor

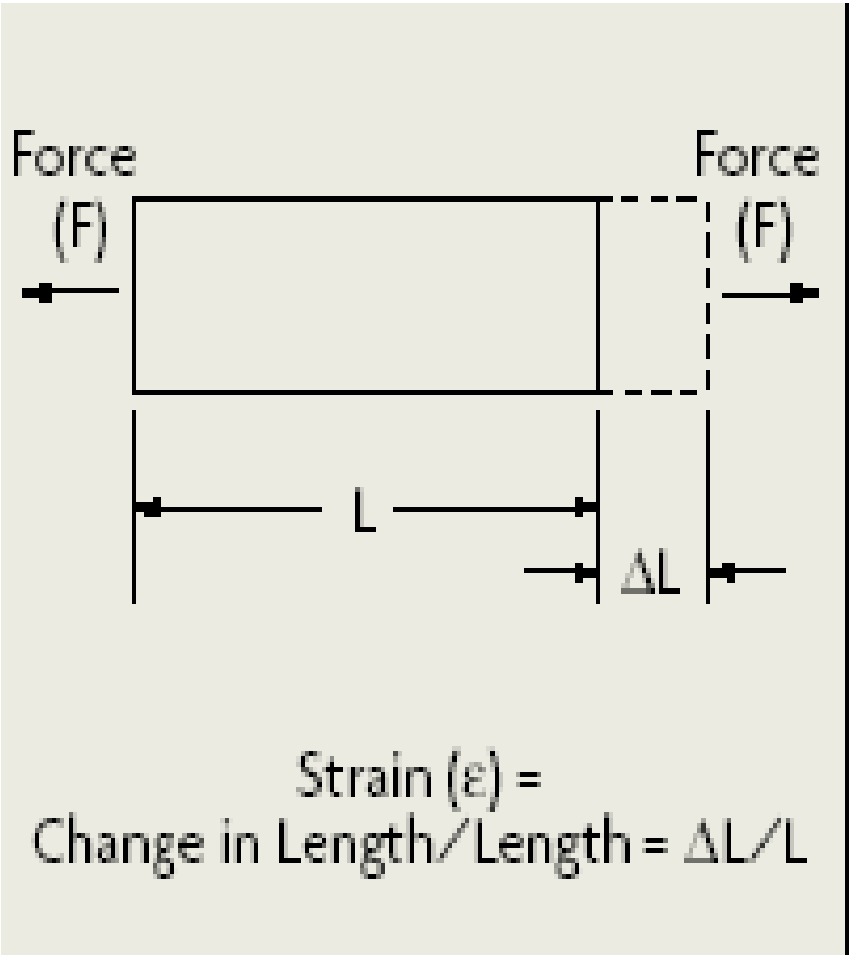
- A mechanical device such as a diaphragm is used to move the wiper arm of a potentiometer as the input pressure changes.
- A direct current voltage (DC) V is applied to the top of the potentiometer (pot), and the voltage that is dropped from the wiper arm to the bottom of the pot is sent to an electronic unit.
- It normally cover a range of 5 psi to 10,000 psi.
- Can be operated over a wide range of temperatures.
- Subject to wear because of the mechanical contact between the slider and the resistance element.
- Therefore, the instrument life is fairly short, and they tend to become noisier as the pot wears out.



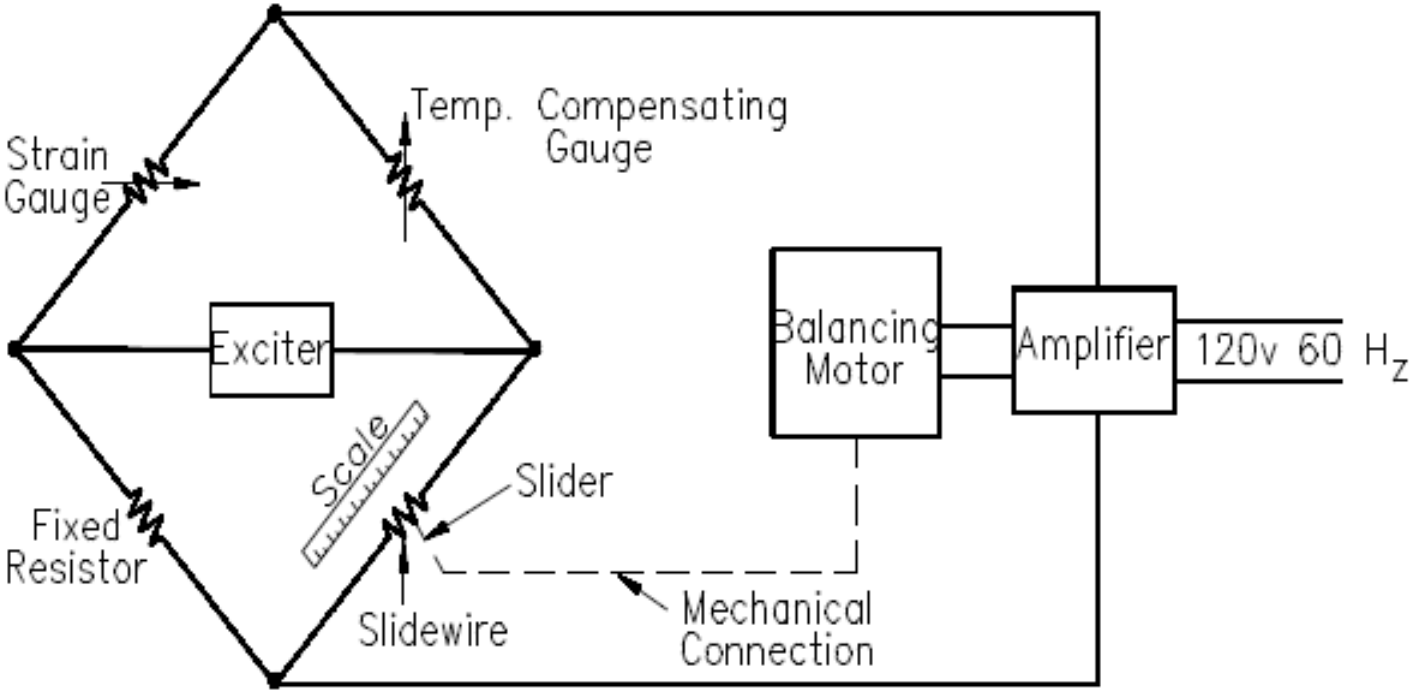
Strain Gage

- If a wire is held under tension, it gets slightly longer and its cross-sectional area is reduced. This changes its resistance (R) in proportion to the strain sensitivity (S) of the wire's resistance.

- The strain sensitivity, which is also called the gage factor (GF), is given by: GF = (Δ R/R)/(Δ L/L) = (Δ R/R)/ Strain

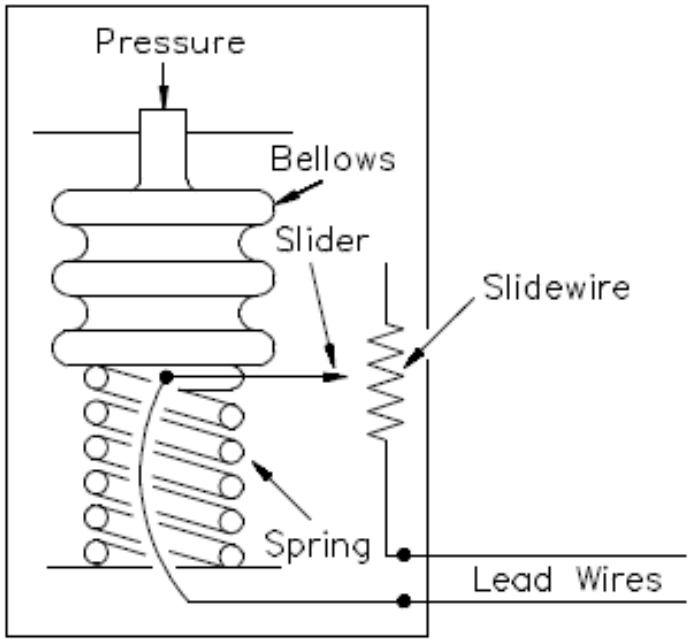


Strain Gauge Used in a Bridge Circuit

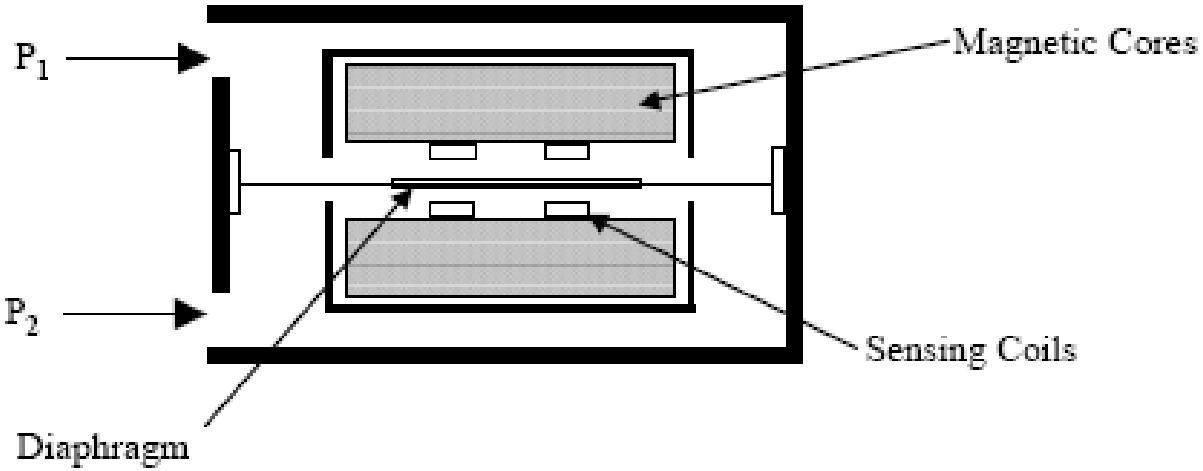


Bellows Resistance Transducer

- Bellows or a bourdon tube with a variable resistor.
- Bellow expand or contract causes the attached slider to move along the slidewire.
- This increase or decrees the resistance.
- Thus indicating an increase or decrease in pressure.



Inductance-Type Transducers

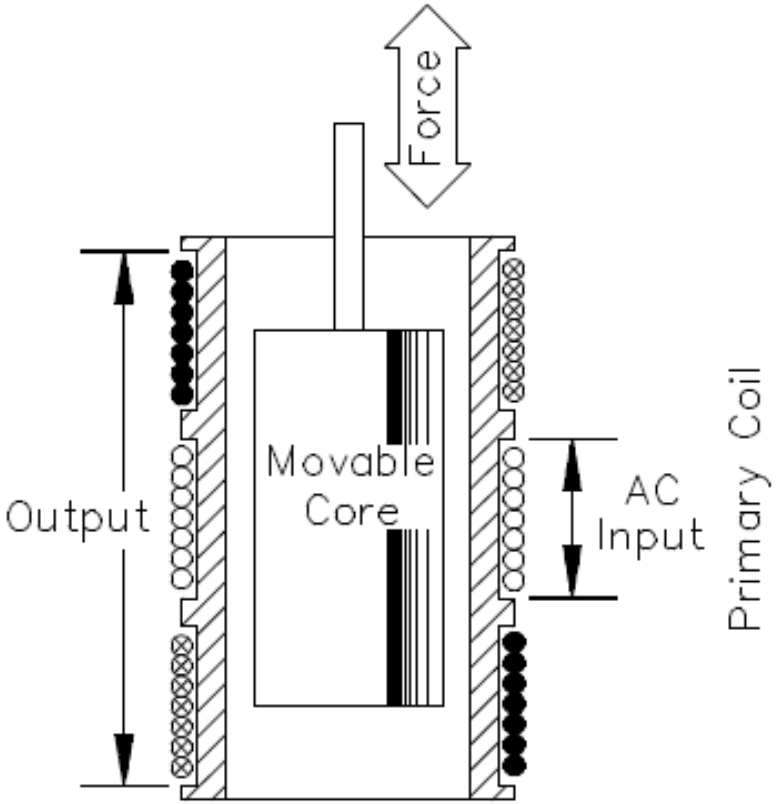


- The inductance-type transducer consists of three parts: a coil, a movable magnetic core, and a pressure sensing element.

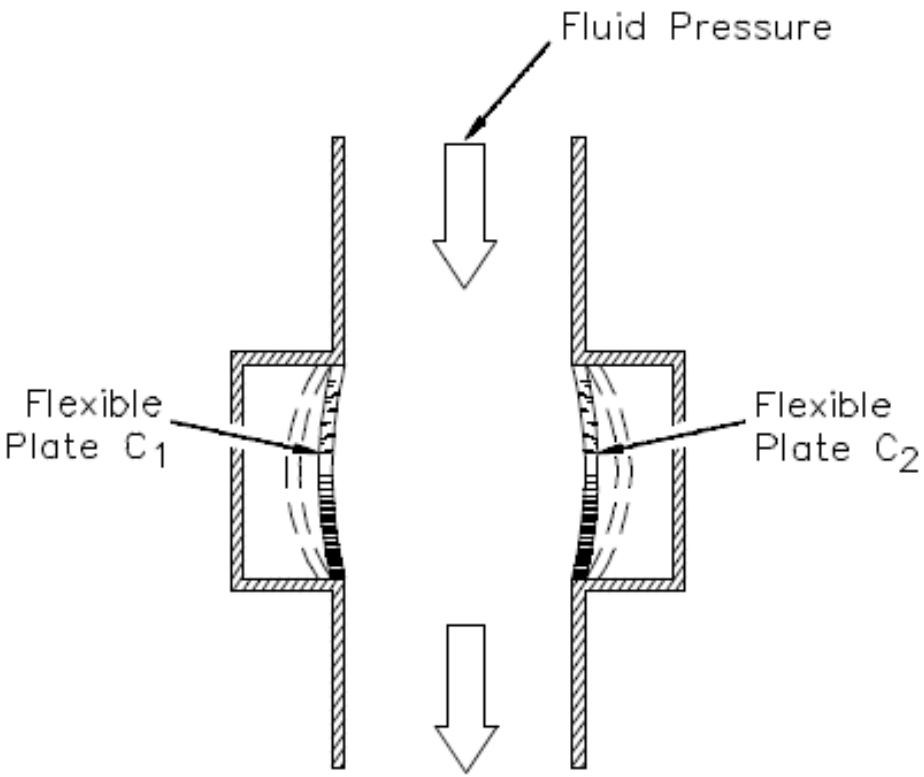
- An AC voltage is applied to the coil, and, as the core moves, the inductance of the coil changes.

LVDT

- Another type of inductance transducer, utilizes two coils wound on a single tube and is commonly referred to as a Differential Transformer or sometimes as a Linear Variable Differential Transformer (LVDT).



Capacitance



Piezoelectric

- When pressure, force or acceleration is applied to a quartz crystal, a charge is developed across the crystal that is proportional to the force applied.
-
- Piezoelectric devices can further be classified according to whether the crystal's electrostatic charge, its resistivity, or its resonant frequency electrostatic charge is measured.

- Depending on which phenomenon is used, the crystal sensor can be called electrostatic, piezoresistive, or resonant.

Electronic Pressure Sensor Range

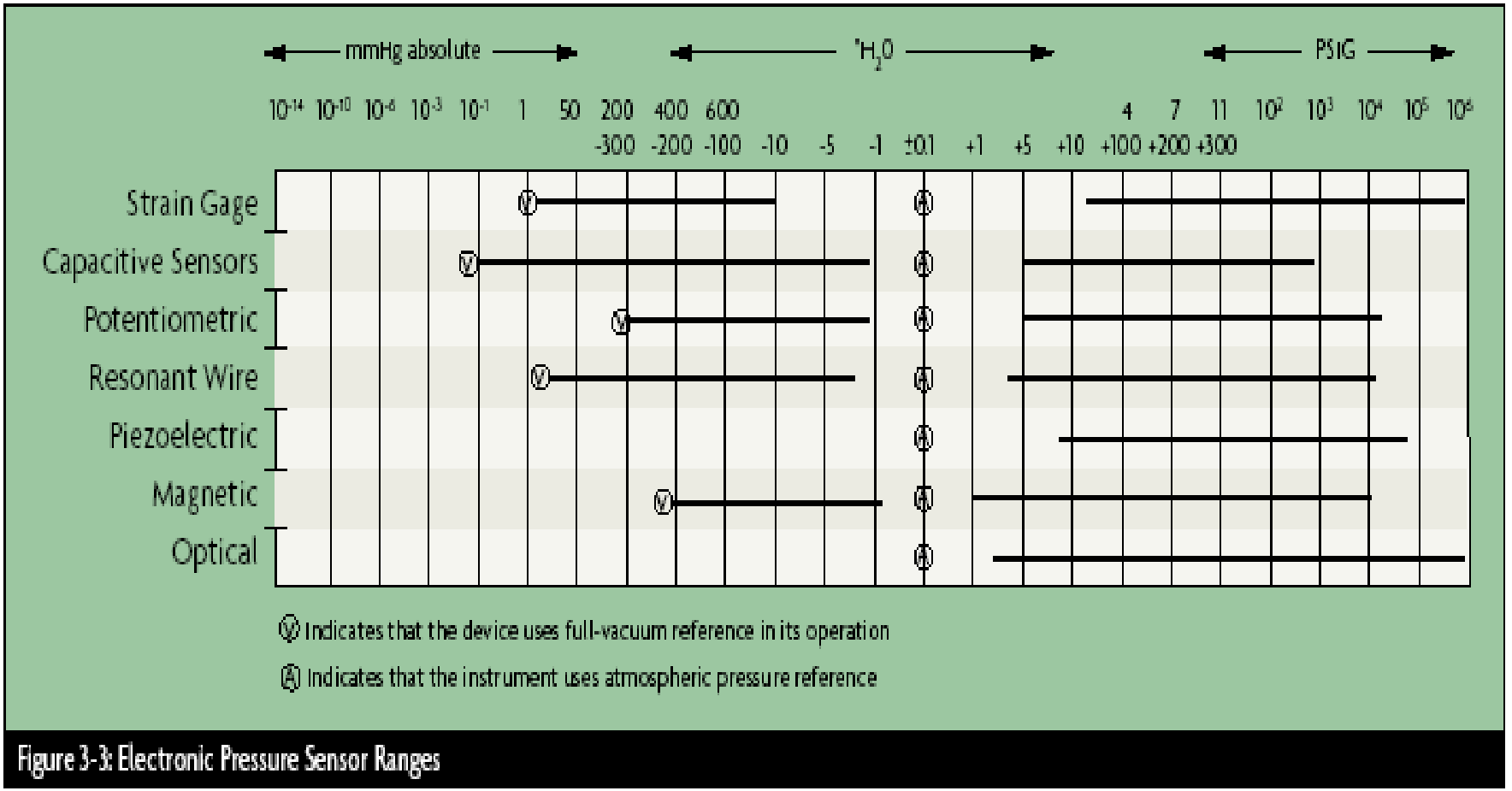


Figure 3-3: Electronic Pressure Sensor Ranges

Thank You