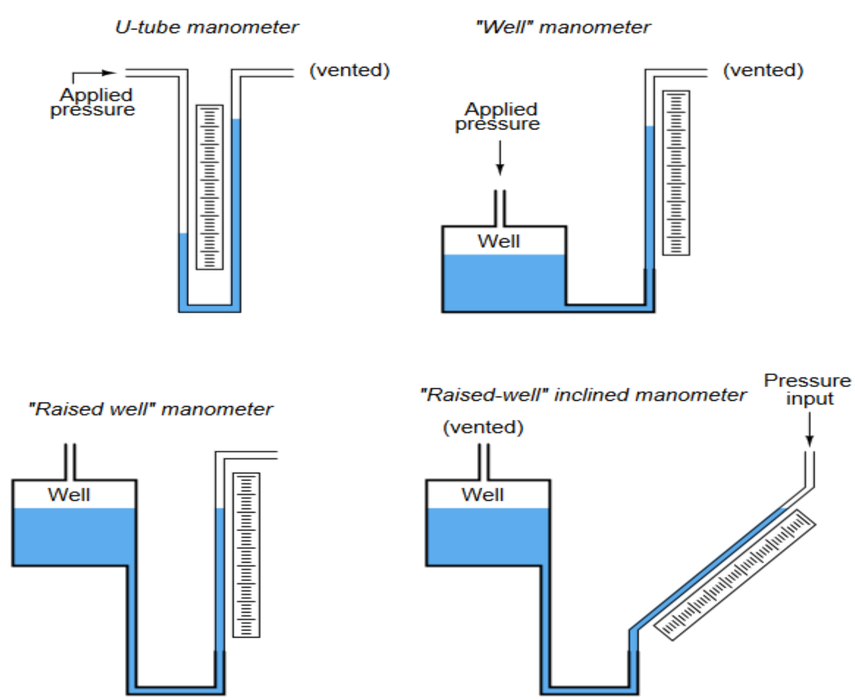
Pressure Measuring Instruments:

1. Manometer
2. Bourdon Tube.
3. Bellows.
4. Diaphragm.
5. Capsule.
6. Piezoresistive (strain gauge).
7. Differential Capacitance sensor.

Manometer

A very simple device used to measure pressure

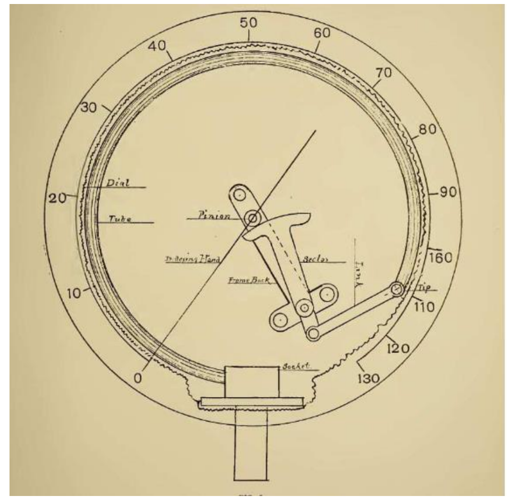
A fluid-filled tube where an applied gas pressure causes the fluid height to shift proportionately. This is why pressure is often measured in units of liquid height (e.g. inches of water, inches of mercury). As you can see, a manometer is fundamentally an instrument of differential pressure measurement, indicating the difference between two pressures by a shift in liquid column height.



$P_{high} - P_{low} = g \times$ difference in height of the liquid in the columns.

where g is the specific weight of the liquid in the manometer.

Bourdon Tube



The Bourdon tube pressure element is a very robust and time-tested design.

C-tube pressure gauge

Mechanism (taken from the rear of the gauge, behind the pointer and scale) reveals its

Mechanical Workings:

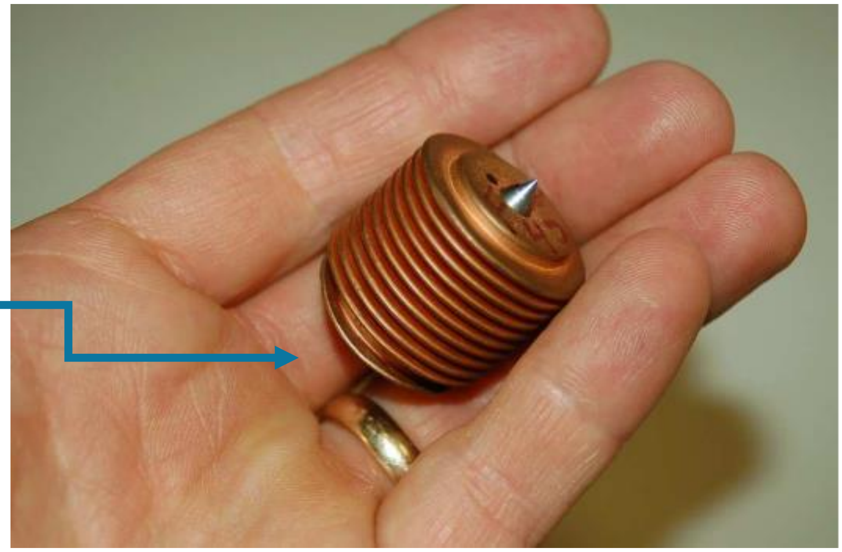
The dark, C-shaped tube is the bourdon tube sensing element, while the shiny metal parts are the linkage, lever, and gear assembly.

Spiral Bourdon tube

Designed to produce a wider range of motion than a C-tube bourdon.

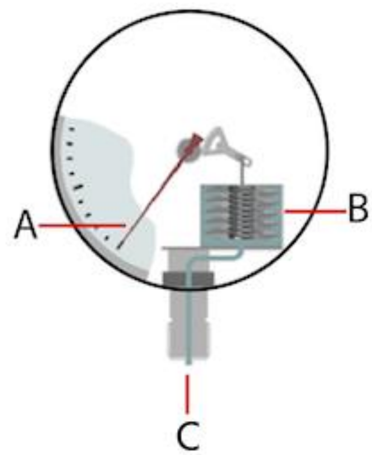
Bellows

Constructed from metal instead of fabric.



Mechanical Working:

A bellows pressure gauge consists of a flexible metal bellows that expand or contracts in response to changes in pressure. The expansion and contraction are converted into a readable measurement by a connected mechanical or digital display.



components: pointer (A), bellows (B), and inlet (C).

Advantages:

These gauges have High accuracy and durability, making them a popular choice in many industrial and laboratory settings.

It can measure absolute, differential, or positive and negative (vacuum) gauge pressure.

Applications:

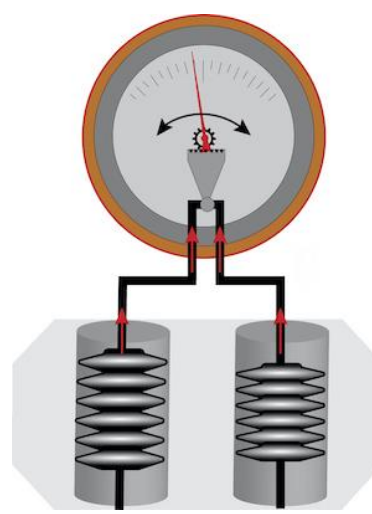
Low to intermediate system pressures:

HVAC (pressure of the refrigerant or air in the system)

Power transmission (measure the pressure of fluid (oil))

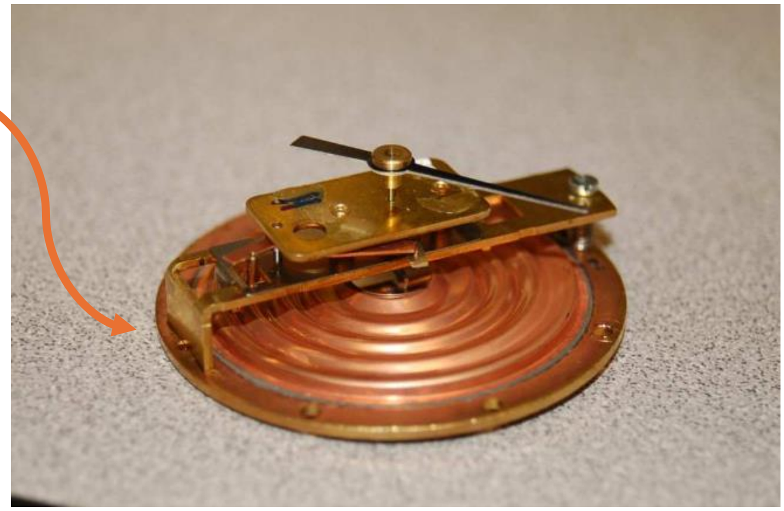
Aerospace (System fuel, pneumatic and hydraulic systems)

Electrical interrupters read the pressure of the insulated gas.



Diaphragm

uses the deflection of a thin, flexible membrane to measure fluid pressure in a system.



Mechanical Working:

Pressure inlet: media enters the pressure gauge at the pressure inlet.

Diaphragm: The media presses against and proportionally deflects the diaphragm. The diaphragm is a thin, circular, flexible, metal disc. It is typically made of stainless steel for corrosion and high-temperature resistance.

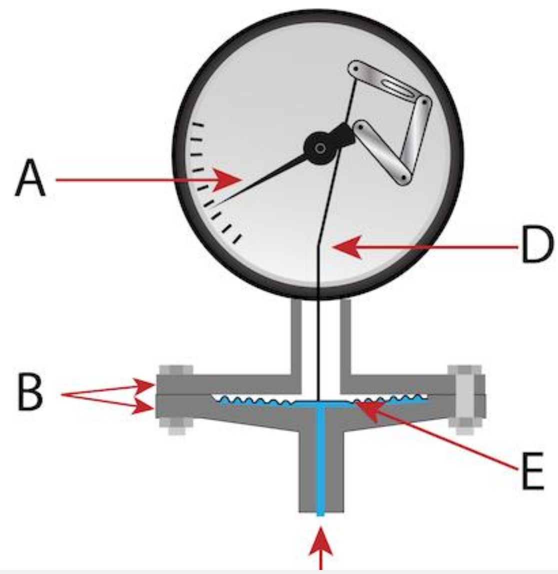


Figure 2: Operating principle of a diaphragm pressure gauge: pointer (A), upper and lower housing (B), pressure inlet (C), pressure element (D), and diaphragm (E).

The disc can be corrugated or smooth. Smooth discs are only suitable for small deflections and therefore are unlikely to operate well in industrial applications.

Housing: securing the diaphragm has upper and lower components. The lower housing connects to the pressure inlet and the upper housing supports the diaphragm in the case of high pressure.

Pressure element: Typically, the pressure element will be a rack and pinion setup or a bourdon tube setup. For the latter, the pressure element is filled with fluid to transfer pressure changes throughout the element.

Pointer: the movement of the pressure element proportionally translates to the pointer's movement so a user can read the system pressure from the pressure gauge.

Digital Diaphragm

It is a pressure sensor that utilizes a diaphragm with piezoresistive components. When a medium exerts pressure, the diaphragm bends, altering the cross-sectional area of the piezoresistive elements and leading to a change in their electrical resistance. This generates a voltage difference, which is then processed by the sensor's microprocessor to produce pressure reading on the digital display.

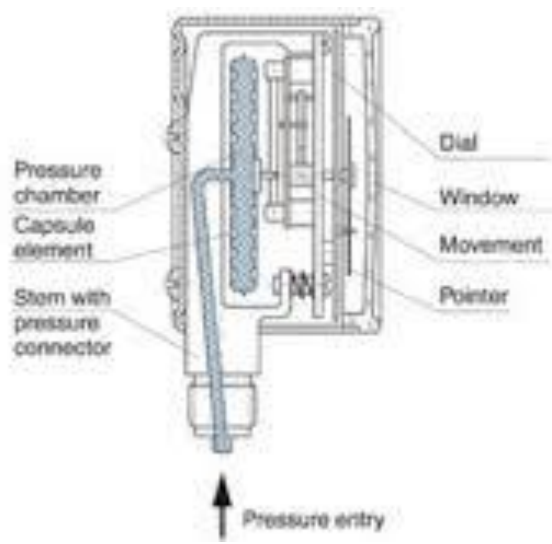
Diaphragm Applications:

- Chemical plants and Power plants.
- Pneumatic and Hydraulic systems.
- Pressure monitoring in gas and liquid storage tanks.
- Pressure measurement in HVAC systems, such as in boilers and air conditioning units.
- Pressure monitoring in medical equipment, such as in blood pressure monitors.
- Pressure monitoring in pipelines and other fluid transport systems.
- Pressure testing and calibrating in laboratory settings.

Capsule

The sensing element of a capsule pressure gauge consists of two corrugated diaphragms welded together at their periphery to form a capsule.

Mechanical Working:



The pressure to be measured is introduced into the capsule via an opening in the center of the first diaphragm. The center of the second diaphragm is connected to the transmission mechanism so that the deflection of the measuring element can be transmitted to the pointer.

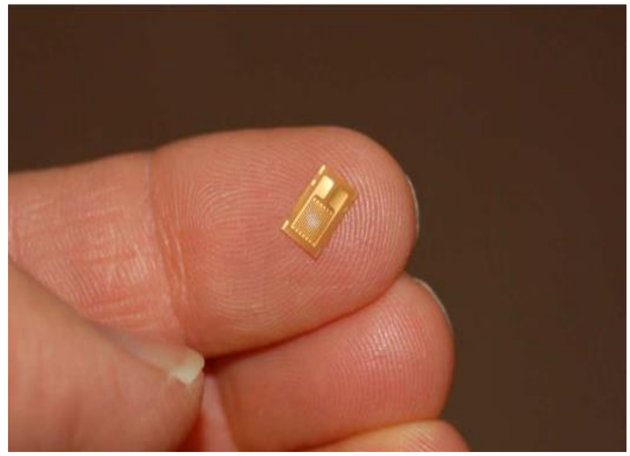
When the pressure rises inside the capsule, both diaphragms will slightly deform. By making use of two diaphragms, the total deflection of the measuring element is twice as large.

In the pressure gauge animation below, the pressure is going in and out of the capsule, turning the pointer to the right and back to the left.

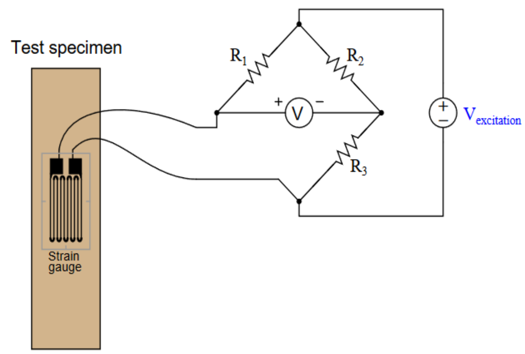
Applications

Only used for the measurement of Gas Pressures.

Piezoresistive (Strain Gauge)



Piezoresistive means "pressure-sensitive resistance," or a resistance that changes value with applied pressure. The strain gauge is a classic example of a piezoresistive element.



Working Principle:

Refers to the change in electrical resistance of a material when subjected to mechanical stress or strain. This phenomenon is observed in certain materials, such as silicon and germanium, which exhibit a change in resistance when deformed under pressure.

Advantages:

- High sensitivity
- Wide measurement range
- Fast response time
- Compact and lightweight

Disadvantages:

- Temperature dependence
- Long-term stability
- Cost

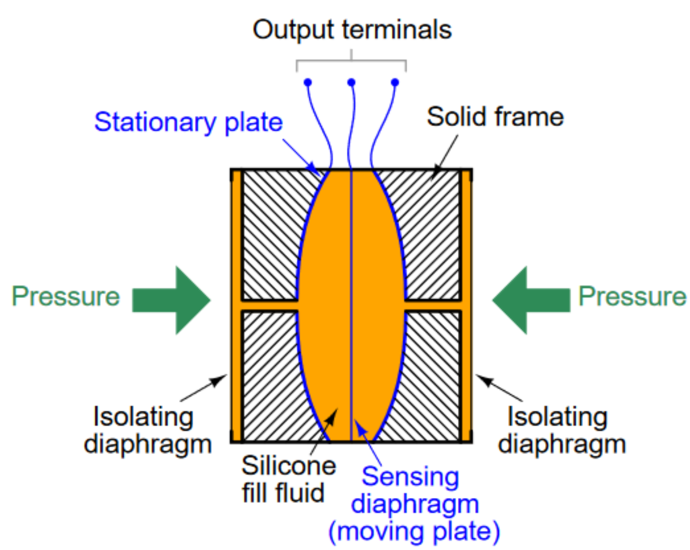
Differential Capacitance Sensor

One capacitor is charged positive with respect to ground, while the other is charged negative with respect to ground, as the AC voltage source alternates positive and negative. While one capacitor of the pressure sensor is charging, the other is discharging through R_{load}, producing an output voltage (V_{out}).

Working Principle:

If both Capacitances are equal, the output voltage will alternate equally between positive and negative values, having a DC average value of zero. If one capacitance is larger than the other, it will store additional charge on its plates, causing it to sway the output voltage of the Twin-T circuit in the direction of its polarity.

Thus, V_{out} becomes more positive as pressure increases on one side of the sensor, and more negative as pressure increases on the other side of the sensor.



Pressure Measurement:

Pressure is the primary variable for a wide range of process measurements. many types of industrial measurements are inferred from pressure, such as:

- **Flow** (measuring the pressure dropped across a restriction)
- **Liquid level** (measuring the pressure created by a vertical liquid column)
- **Liquid density** (measuring the pressure difference across a fixed-height liquid column)
- **Weight** (hydraulic load cell)

Pressure Expression:

Pressure(P): the amount of **force (F)** distributed across a given **area (A).**

$$\boldsymbol{P = F/A}$$

The mathematical relationship between vertical liquid height and hydrostatic pressure is quite simple, and may be expressed by either of the following formulae:

$$\boldsymbol{P = \rho g h}$$

Where,

P = Hydrostatic pressure in units of weight per square area unit: pascals (N/m2) or lb/ft2

ρ = Mass density of liquid in kilograms per cubic meter (metric) or slugs per cubic foot (British)

g = Acceleration of gravity (9.81 meters per second squared or 32.2 feet per second squared)

γ = Weight density of liquid in newtons per cubic meter (metric) or pounds per cubic foot (British)

h = Vertical height of liquid column

Specific Gravity of any liquid:

$$\boldsymbol{D}\ liquid\ /\ \boldsymbol{D}\ water$$

Ideal Gases Pressure given by:

$$P\,V = nRT$$

Where,

P = Absolute pressure (atmosphere)

V = Volume (liters)

n = Gas quantity (moles)

R = Universal gas constant (0.0821 L · atm / mol · K)

T = Absolute temperature (K)

$$\mathbf{P\,V \propto T}$$

Several “gas laws” are derived from this proportionality. They are as follows:

P V = Constant Boyle’s Law (assuming constant temperature T)

V ∝ T Charles’s Law (assuming constant pressure P)

P ∝ T Gay-Lussac’s Law (assuming constant volume V)

Units of Pressure & Conversion

	Complete Solutions		Answers
1. 99.6 kPa to atm	99.6 kPa X	$\frac{1\ atm}{101.3\ kPa}$	= 0.98 atm
2. 0.993 atm to mmHg	0.993 atm	$\frac{760\ \text{mmHg}}{1\ atm}$	= 754.68 mmHg
3. 745 mmHg to torr	745 mmHg	$\frac{1\ torr}{1\ mmHg}$	= 745 torr
4. 55.0 kPa to atm	55.0 kPa	$1\ \frac{atm}{101.3\ kPa}$	= 0.54 atm
5. 2.67 atm to mmHg	2.67 atm	$\frac{760\ mmHg}{1\ atm}$	= 2029.2 mmHg
6. 319 torr to mmHg	319 torr	$\frac{1\ mmHg}{1\ torr}$	= 319 mmHg
7. 5.0 atm to kPa	5.0 atm	$\frac{101.3\ kPa}{1\ atm}$	= 99.3 kPa
8. 263 mmHg to atm	263 mmHg	$\frac{1\ atm}{760\ mmHg}$	=0.35 atm
9. 21.9 kPa to torr	21.9 kPa	$\frac{7.5\ torr}{1\ kPa}$	= 164.25 torr
10. 748 torr to kPa	748 torr	$\frac{1\ kPa}{7.5\ torr}$	= 99.73 kPa

There are six terms applied to pressure measurements. They are as follows:

- **Total vacuum:** which is zero pressure or lack of pressure, as would be experienced in outer space.
- **Vacuum** is a pressure measurement made between total vacuum and normal atmospheric pressure (14.7 psi).
- **Atmospheric pressure** is the pressure on the earth's surface due to the weight of the gases in the earth's atmosphere and is normally expressed at sea level as 14.7 psi or 101.36 kPa. It is, however, dependent on atmospheric conditions. The pressure decreases above sea level and at an elevation of 5000 ft drops to about 12.2 psi (84.122 kPa).
- **Absolute pressure** is the pressure measured with respect to a vacuum and is expressed in pounds per square inch absolute (psia).
- **Gauge pressure** is the pressure measured with respect to atmospheric pressure and is normally expressed in pounds per square inch gauge (psi). shows graphically the relation between atmospheric, gauge, and absolute pressures.
- **Differential pressure** is the pressure measured with respect to another pressure and is expressed as the difference between the two values. This would represent two points in a pressure or flow system and is referred to as the delta P.

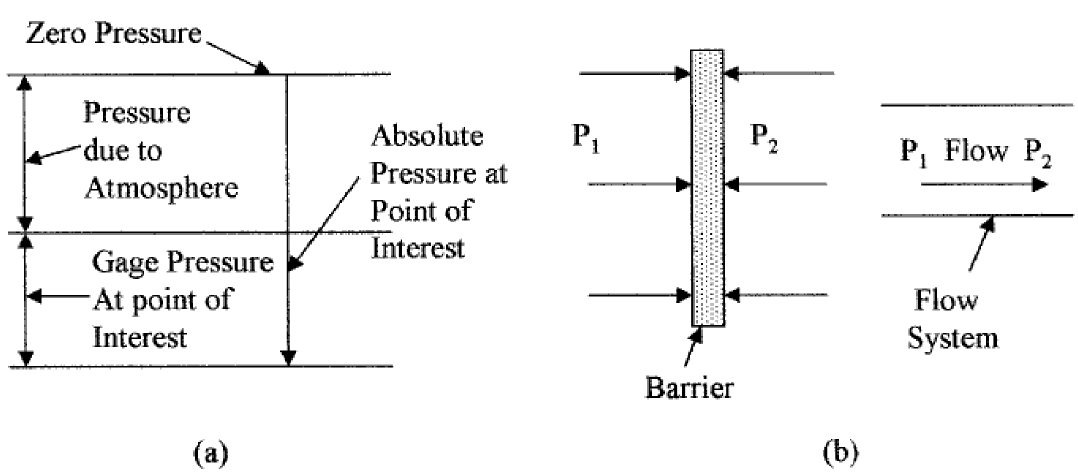


Figure 5.2 Illustration of (*a*) gauge pressure versus absolute pressure and (*b*) delta or differential pressure.