MVPS's Rajarshi Shahu Maharaj Polytechnic, Nashik

Mechanical Engineering Department

Mechanical Engineering Measurement
(22443)
Class: ME4I

Unit 03: Pressure and Temperature measurement

Course Outcome:
Students should able to use relevant pressure and temperature measuring instruments.

Unit Outcome:
Students should able to

3a. Select the pressure gauge for pressure measurement in given situation with justification.
3b. Choose the relevant instruments to measure temperature of given system with justification.
3c. Select the relevant pyrometer for given application with justification.
3d. Describe with sketches the procedure for measurement of temperature and pressure using given device.

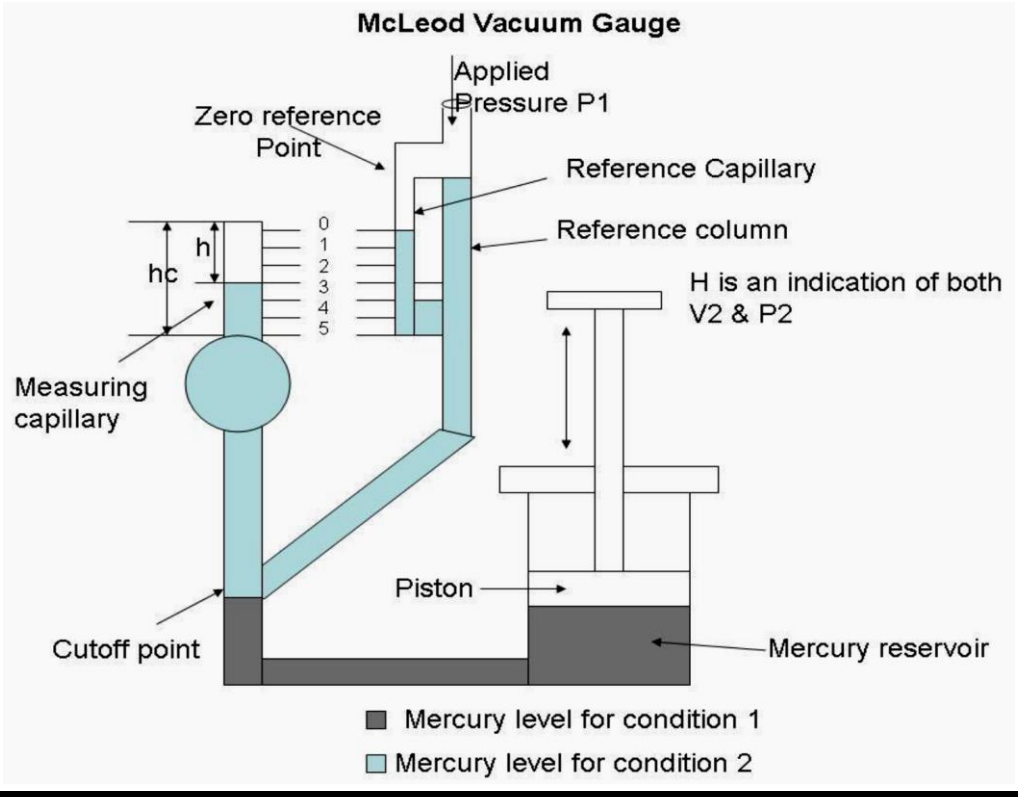
Pressure Measurement

Low Pressure measurement	High Pressure measurement
1.Mcleod gauge	1. Depends on Elastic element
2. Thermal conductivity gauge	a) Bourdon tube
a) Pirani gauge	b) Bellow type
b) Thermocouple	c) Diaphragm
3.Ionisation gauge	i. Metallic type
	ii. Slack diaphragm
	2. Piezo electric pressure transducer

1) Explain with neat sketch working of Mc Leod gauge

Working Principle: "Compressing a known volume(V1) of low pressure gas to a high pressure and measuring the resulting volume(V2) and pressure change(P2) one (P1) can calculate by Appling **Boyles Law."**

Range: 10^{-1} to 10^{-5} torr.



 The gas enters the gauge through the open capillary tube and fills the tubes down to the level of mercury in the reservoir.

 The pressure is equal through the tubes and the bulb. Mercury is pumped up from the reservoir.

 As the mercury raises the cut-off, it traps the gas inside the bulb.

 The mercury is then pumped higher in the open end capillary tube until all the gas in the bulb is compressed into the bulb.

 Operator allows the mercury to rise until it reaches zero reference line on the closed capillary tube. The mercury rises faster in the open capillary tube.
The compression of gas in closed capillary tube makes the pressure of trapped gas higher than the measured pressure. This pressure difference causes difference in the mercury level in the two tubes

It is working is based on **Boyles law**
Mathematically P1V1=P2V2
Where P1=Unknown pressure of gas, V1= Initial volume of gas, P2=Final pressure, V2=Final volume of gas

P1= P2V2/ V1

Advantages
It is independent of the gas composition.
It serves as a reference standard to calibrate other low pressure gauges.
A linear relationship exists between the applied pressure and h
There is no need to apply corrections to the McLeod Gauge readings.

Disadvantages
The gas whose pressure is to be measured should obey the Boyle's law
Moisture traps must be provided to avoid any considerable vapor into the gauge.
It measures only on a sampling basis.
It cannot give a continuous output.

Applications

1. Measurement of very low pressure (below a 1 micron)

2) Thermal conductivity Gauge

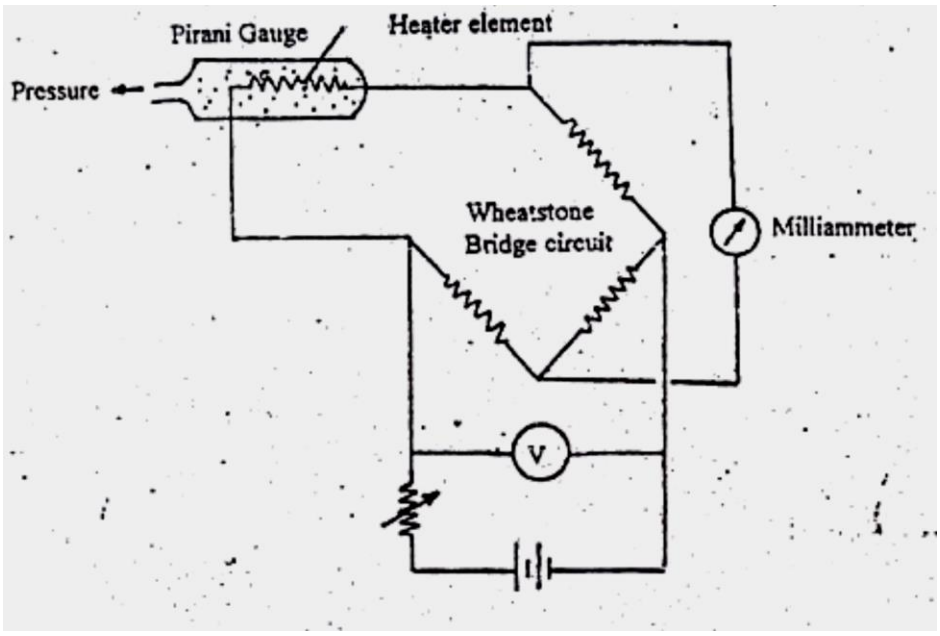
a) Pirani Gauge
Working Principle: "As surrounding pressure changes the filament temperature and it changes thermal conductivity hence temperature and resistance**."**
 It is a low pressure measuring device. Thermal conductivity is the ability of material to carry heat by conduction.

 It does not change in pressure takes place until it drops below 1 mm of Hg. In this low pressure, there is direct relationship between pressure and conductivity of gas.

 This relationship is used to measure the low pressure hence called thermal conductivity gauges.

 In a balanced bridge circuit four resistances are connected. One resistance is connecting to source of which pressure is to be measured. At low pressure density of gas changes and hence its ability to carry away heat is also reduced.

 At low pressure thermal conductivity is proportional to density hence temperature of sensing arm resistance is changed and circuit is imbalanced resulting in deflection.



Construction:

1. Consists of platinum filament wire enclosed in a chamber connected to unknown pressure source.
2. Filament forms an arm of W-bridge.
3. Compensating resistance is placed in opposite arm

Working:

1. Due to constant current, filament gets heated.
2. At low pressure, thermal conductivity gets reduces.
3. Temperature variation leads to resistance variation of filament which unbalances the W- bridge.
4. Change in resistance of wire filament gives value of unknown pressure.
5. Range is between 10^{-5}mm to 10 mm of Hg.

Advantages

1. Simple in Design.
2. Less Cost.
3. Good Accuracy.
4. Simple Measurement.

Disadvantages

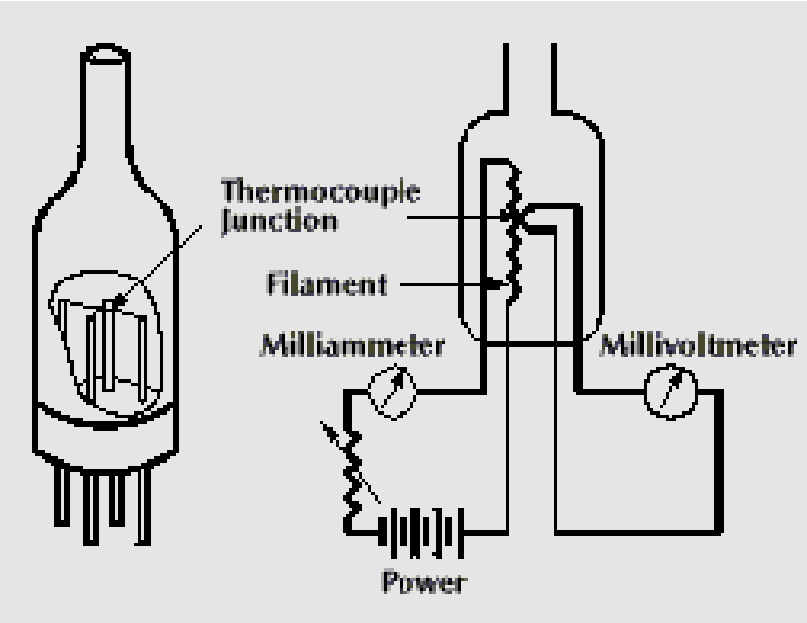
1. Depends on nature of gas.
2. Non Linear Scale.
3. Damaged by organic vapours.

Applications

1. Measurement of very low pressure (below a 1 micron)

b) Thermocouple vacuum gauge (same as Pirani gauge)

Working Principle: "As surrounding pressure changes the filament temperature and it changes thermal conductivity hence temperature and resistance**."**



RANGE 10^{-4} to 1 TORR

Construction is same as Pirani gauge.

Advantage:

- Rugged and inexpensive construction
- Convenient and continuous reading
- Remote measurementand control can be possible

Disadvatages:

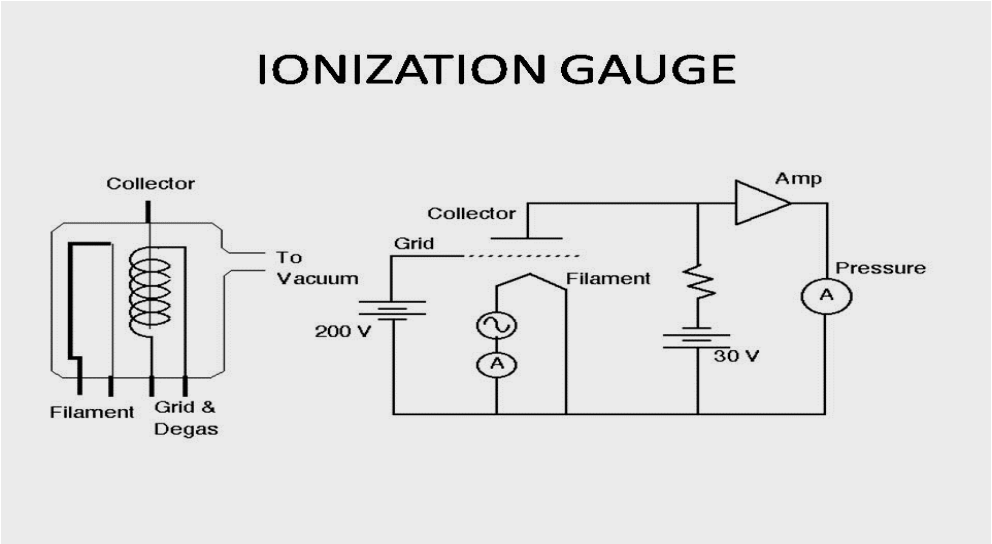
- Required electrical power
- Narrow reading range
- Need individual and frequent calibration for different gases.

3) With a neat sketch explain working of ionization gauge for pressure measurement.

Working Principle: "Flow of electrons from grid to plate or vice versa creates variation in current that is measurable at output**."**

 The construction of a hot cathode type ionization gauge consists of a basic vacuum triode.

 It is useful to measure pressure ranging from 10^{-3} to 10^{-8} mm of Hg.



 Ionization is the process of removing electron from an atom producing a free electron and positively charged ion.

 It may be produced by the collision of high speed electrons from the atom.
Pressure of gas is proportional

 The grid is maintained at a large positive potential with respect to the cathode and the plate.

 The plate is at a negative potential with respect to the cathode.

 This method is also known as the external control type ionization gauge as the positive ion collector is external to the electron collector grid with reference to the cathode.

 The positive ions available between the grid and the cathode will be drawn by the cathode, and those between the grid and the plate will be collected by the plate.

Advantages

1. Linear scale. 2. Continues measurement of pressure is possible.

3. Simple in design. 4. High sensitivity.

Disadvantages

1. Short Life. 2. Require careful control.

3. Difficult to maintain the constant current.

4. Decomposition of some gases take place.

Applications

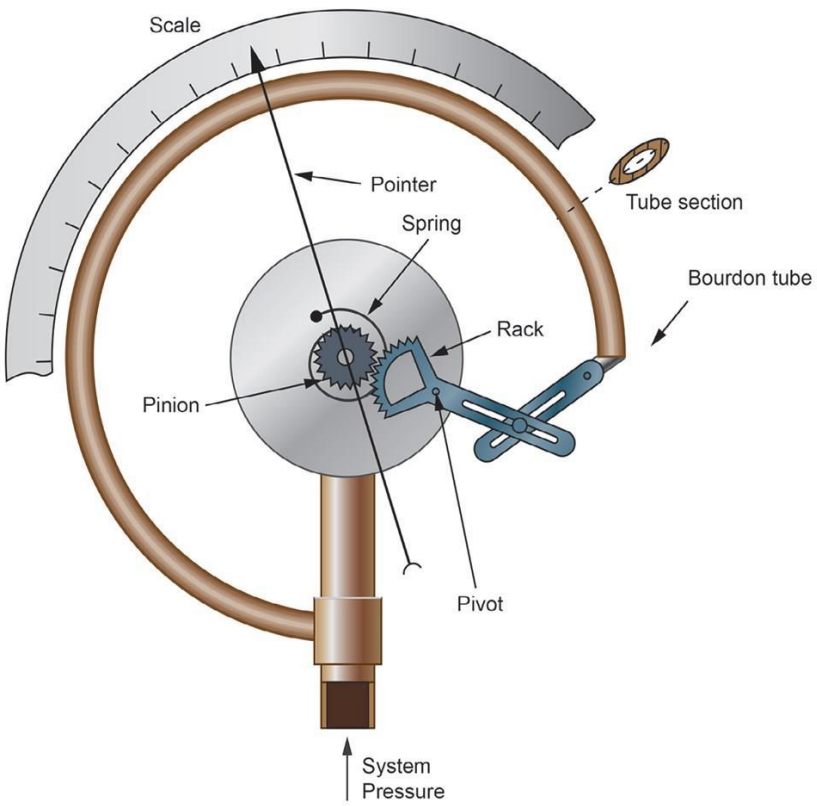
1. To measure the very low pressure 1 micron and below.

HIGH PRESSURE MEASUREMENT

1) Depends Upon Elastic Element

a. Explain with the neat sketch pressure measurement using Bourdon Gauge.

Working Principle: "If a curved or twisted tube is held and pressurized at its open end, produces movement at its closed end (Tip Travel)**."**



Construction

1. Consists of elliptical c/s bourdon tube bend into arc of circle.

2. Materials for Tube: Brass, Bronze, SS, Monel, Beryllium copper, Inconel X, Ni-Span C, Bourdon tube can be C shaped, helical, Spiral and twisted tube.

3. Open end of tube is fixed, and pressure is applied to this end.

4. Closed end is free and connected to mechanical linkages. (Sector & pinion)

5. Pointer is pivoted on pinion.

6. Pointer can move on a indicating scale.

Working

1. Applied pressure tends to change cross section of tube from elliptical to circular.

2. This makes the tube straighten itself with increase in radius of curvature. This causes free end of tube to move.

3. Displacement of tube rotates pinion through mechanical linkages and sector of a gear.

4. Movement of pointer over calibrated scale directly indicates pressure in terms of N/m or m head of mercury.

5. High Range (Min span 100kPa to max span 690 MPa).

Advantages

1. It can measure both static & dynamic pressure.
2. Simple in design.
3. Easy portability
4. Compact size.

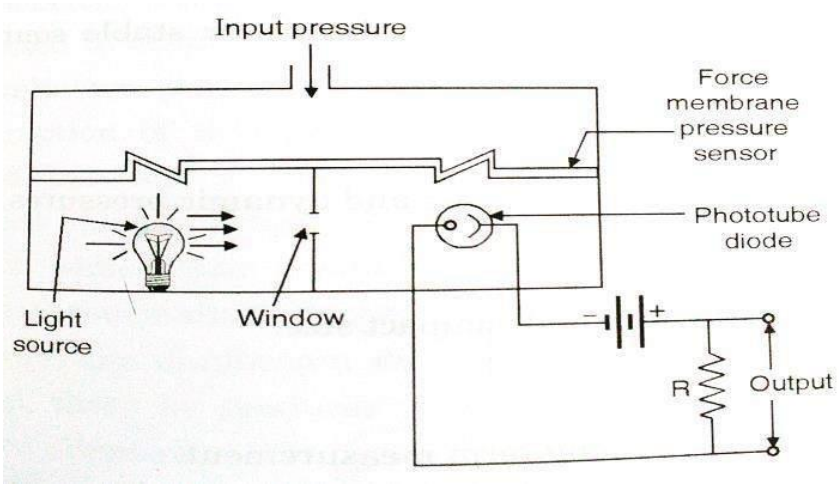
Disadvantages

1. Depends upon the elasticity of tube.
2. It has wear and tear.
3. Gear and sector arrangement require.
4. Pointer bend problem.

Applications

1. It can measure low pressure as well as High pressure.

4) Photoelectric pressure transducer



Working Principle: "Variation of window size results variation of light beams emitting on photodiode hence output reading changes**."**

 It consist of port for input pressure, Pressure sensing member like diaphragm, light source, a small window, a photo tube with output circuit.

 The function of pressure sensing element is to control the aperture of small window. The amount of output is entirely depending upon the amount of incident light falling on phototube.

 When the pressure to be measured is applied through port to the pressure sensing member, it changes the position of window.

 As the light source and phototube are separated by a window it changes the amount of light falling on phototube, causing change in the current.

 This change in current is approximately linear with displacement of window i.e. applied pressure.

 The current in phototube is amplified by a suitable output circuit.

- A meter connected across output terminal can directly calibrate in terms of pressure measurement.
- An A.C Modulated light or stable source of light can be used for incident light.

Advantages

1. It can measure both static & dynamic pressure.
2. It is highly efficient
3. Easy portability
4. Compact size.

Disadvantages

1. Depends upon the light source.
2. It cannot repair.
3. Less diaphragm life.
4. Requires external source.

Applications

1. It can measure very low pressure.

5) Difference between Diaphragm and Bellow Element.

Sr.No.	Parameters	Diaphragm	Bellow
1	Working Primciple	The deflection of diaphragm is proportional to applied pressure.	A bellow gauge contains an elastic element that is convoluted unit which expands and contracts axially with changes in pressure. The pressure to be measured is applied to the outside or inside of bellow.
2	Construction	A thin member of sheet metal made to precision dimensions either in shape of membrane or circular disc.	Bellow gauges are made of brass, phosper bronze, stainless steel, beryllium copper or other metal that is suitable for the intended purpose the gauge.
3	Pressure range	0-50 N/m^2 to 0-200N/m^2	Vacuum and low pressure measurement
4	Application	Industrial process pressure measurement, Manifold pressure measurement	Abroad ship, also some type of recording device.

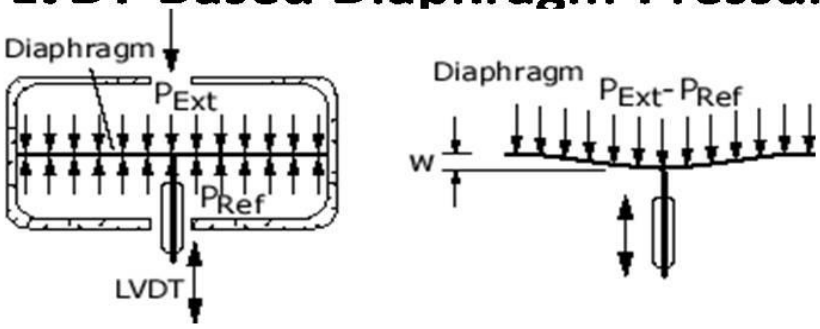
- **Diaphragm Pressure gauge:**

- The diaphragm is a thin member of sheet metal made to precise dimension either in the shape of membrane or circular disc.
- If unknown pressure is applied on one side of diaphragm it gets deflected.
- The deflection of diaphragm is proportional to applied pressure.
- The measure of the deflection is calibrated in terms of pressure.

TYPES

- Flat type
- Disc type
- Corrugated type
- Capsule

LVDT-Based Diaphragm Pressure Gage



The commonly used materials for making the diaphragm are polythene, neoprene, animal membrane, silk, and synthetic materials.

The common range for pressure measurement varies between 50 Pa to 0.1 MPa.

Advantages:

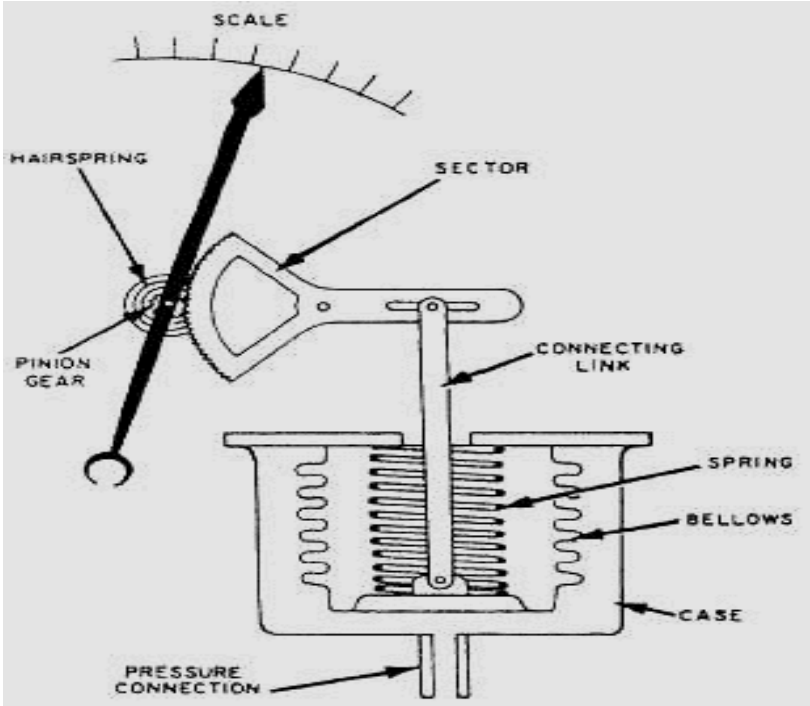
- They have moderate cost and simple in construction.
- Good linearity.
- Easy calibration with dead weight tester.
- Connectivity to strain, capacitance and other electrical sensor.
- They can measure gauge, absolute and differential pressure.

Limitations:

- Cannot avoid overloading.
- Cannot tolerate vibrations and shocks.
- Difficult to repair.
- Range limited to relatively low to medium pressure.

- **Bellows pressure gauge:**

- Bellows are pressure sensing elastic elements used for measurement of low and medium pressure.
- When number of circular plates welded together in such a way that they can be expanded or contracted by the applications of pressure.



Working:

- Pressure to be measured is applied from bottom which is fixed, expansion of bellows take place to upper side to which rod is connected.
- The displacement of rod is directly proportional to the pressure inside the bellows.
- This displacement is transferred to pointer moving over a calibrated scale.

Advantages:

- Simple and rugged construction.
- Good for low to moderate pressure measurement.
- Can used for measurement of gauge, absolute and differential pressures.
- Relatively less expensive.

Disadvantages:

- Not suitable for very high pressure.
- Friction and dirt may affect sensitivity.
- For more accurate result, spring arrangement is necessary.

• How pressure is measured by piezoelectric transducer? Explain.

The main principle of a piezoelectric transducer is that a force, when applied on the quartz crystal, produces electric charges on the crystal surface.

The charge thus produced can be called as piezoelectricity. Piezo electricity can be defined as the electrical polarization produced by mechanical strain on certain class of crystals.

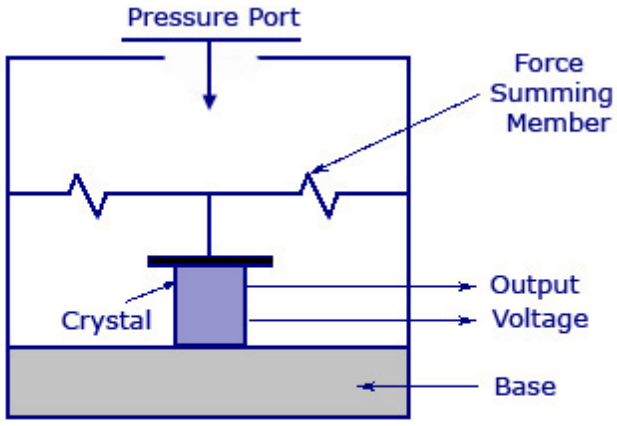
The rate of charge produced will be proportional to the rate of change of force applied as input. As the charge produced is very small, a charge amplifier is needed so as to produce an output voltage big enough to be measured.

The device is also known to be mechanically stiff. For example, if a force of 15 KN is given to the transducer, it may only deflect to a maximum of 0.002mm. But the output response may be as high as 100KHz.This proves that the device is best applicable for dynamic measurement.

The figure shows a conventional piezoelectric transducer with a piezoelectric crystal inserted between a solid base and the force summing member.

If a force is applied on the pressure port, the same force will fall on the force summing member.

Thus a potential difference will be generated on the crystal due to its property. The voltage produced will be proportional to the magnitude of the applied force.



Piezo-Electric Transducer