CH0302 Process Instrumentation

Lecture 11 – Pressure and Level Measurements

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Introduction – Pressure and Level Measurments

- Pressure Definitions and units
- Classification of pressure measuring instruments
- Working principles of pressure measuring instruments
- Measuring elements for gauge, vacuum pressure and absolute pressure
- Indicating elements in pressure measuring instruments

Introduction – Pressure and Level Measurements

- Pressure measurement for corrosive fluids
- Level Measurements
- Classifications of Level measuring instruments

Introduction – Pressure Measurements

- Pressure Definitions and units
- Classification of pressure measuring instruments
- Working principles of pressure measuring instruments
- Measuring elements for gauge, vacuum pressure and absolute pressure
- Indicating elements in pressure measuring instruments

Pressure – Definitions and units

Pressure is defined as the ratio of force and unit area

Pressure is a derived quantity
Commonly used unit for pressure in industrial gauges kg/cm^2, and lb/in^2 (psia and psig)

Other units of pressure used in engineering calculations N/m^2 (Pa), atm, bar, m of H_2O, mm of Hg, Torr and so on.

http://coin-trip39.deviantart.com/art/Under-Pressure-321890896

Pressure – Definitions and units

Hydrostatic pressure

Head

Atmospheric pressure

Gauge pressure

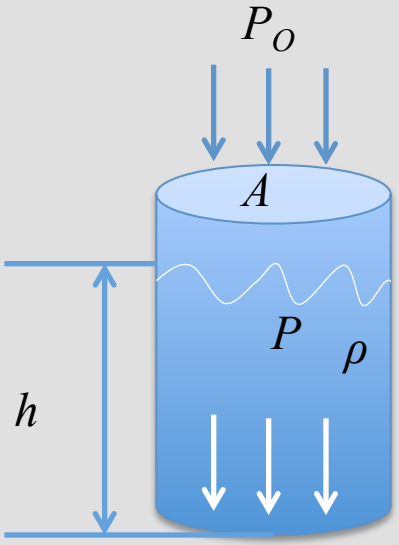
Vacuum pressure

} Types of pressures

Pressure – Definitions and units

Hydrostatic Pressure

Suppose a vertical column of fluid is considered $h(m)$ and has a uniform cross sectional area (m^2). Further that the fluid has a density (ρ) *in* kg/m^3 and that of pressure (P_o) in N/m^2 is exerted on the upper surface of the column. The pressure (P) of the fluid at the base of the column – hydrostatic pressure of the fluid.

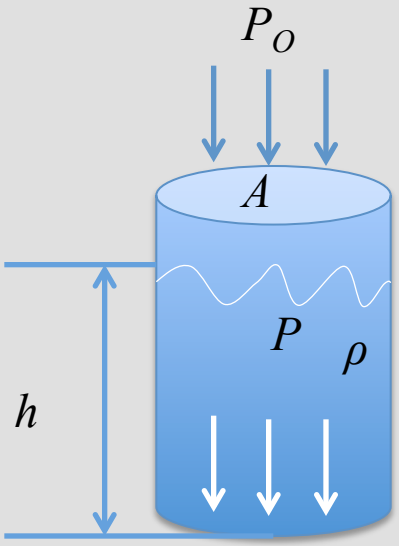


$$P = Po + \rho gh$$

Pressure – Definitions and units

Head

- A pressure may be expressed as a head of particular fluid.
- That is height of column of this fluid that would exert pressure at its base.
- If the pressure at the top is zero then we have



$$P = \cancel{P_O} + \rho g h$$

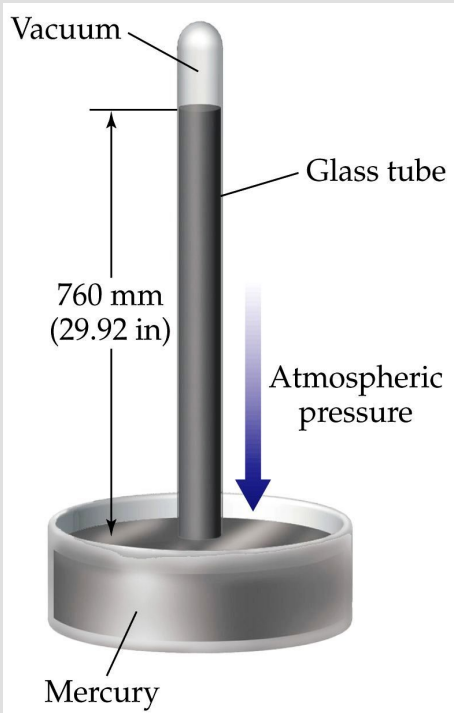
$$P = \rho g h$$

Pressure – Definitions and units

Standard atmospheric pressure

Standard atmospheric pressure is defined as the pressure (in a standard gravitational field equivalent to 1 atm at 0°C

Barometer is the instrument that measures atmospheric pressure

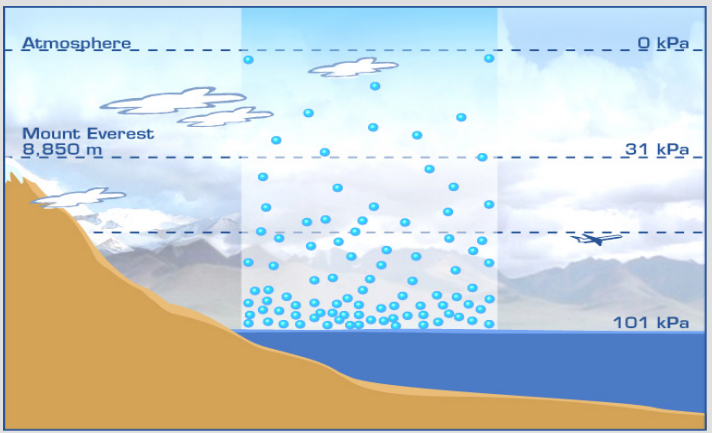


http://ap-physics.david-s.org/simple-mercury-barometer/

Pressure – Definitions and units

Atmospheric pressure – From Sea level

1 atm	101.325 kPa
	33.91 ft of water
	760 mm of Hg
	14.7 lb_f/in^2
	1.01325 bar
	10,332.274 kg/m^2



http://socratic.org/questions/why-is-atmospheric-pressure-measured-at-sea-level

Pressure – Definitions and units

Absolute pressure ($P_{absolute}$)

$$P_{absolute} = P_{atmosphre} + P_{gauge}$$

0 – 680 atm

Pressure – Definitions and units

Vacuum Pressure (P_{vacuum})

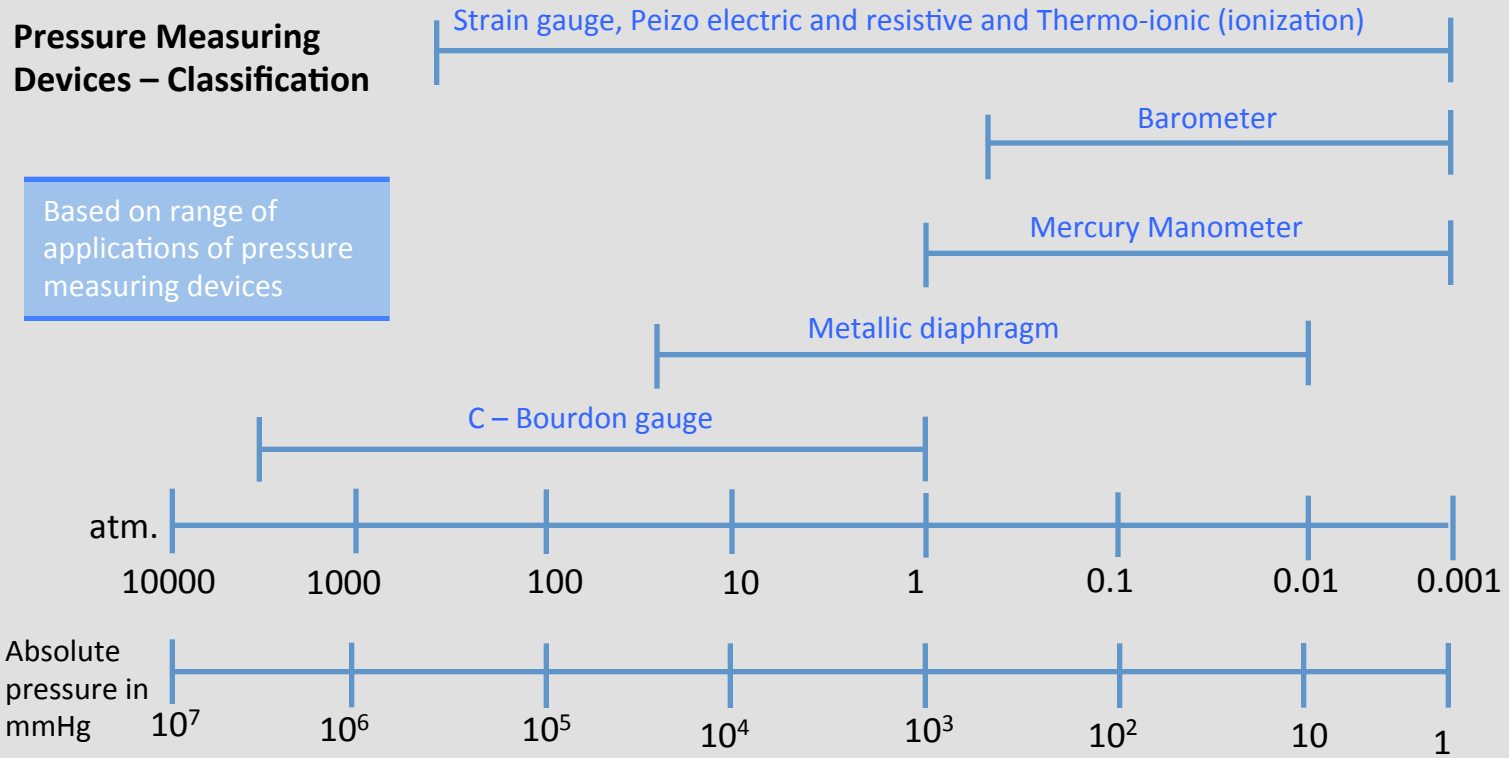
$$P_{Vacuum} = P_{atmospher} + P_{gauge}$$

-1 to 6.8 atm

Introduction – Pressure Measurements

Pressure Measuring Devices – Classification

Based on range of applications of pressure measuring devices

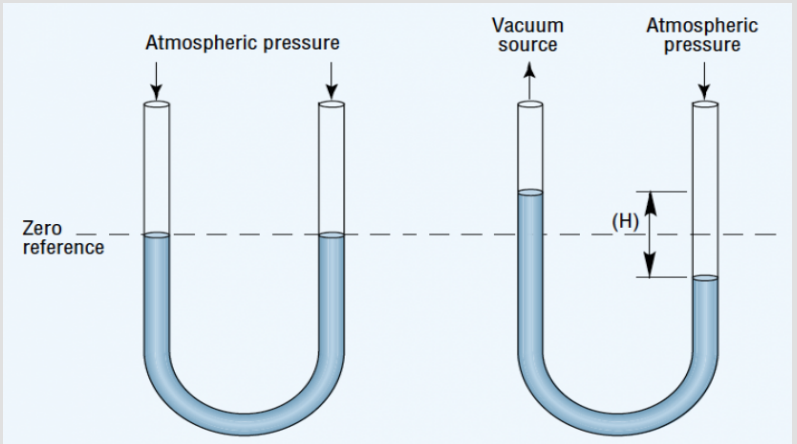


Pressure Measuring Devices - Classification

Based on method adopted

1. Those that are based on the measurement of height of a liquid column. Examples are U-tube, Inclined, Well and Enlarged tube manometers

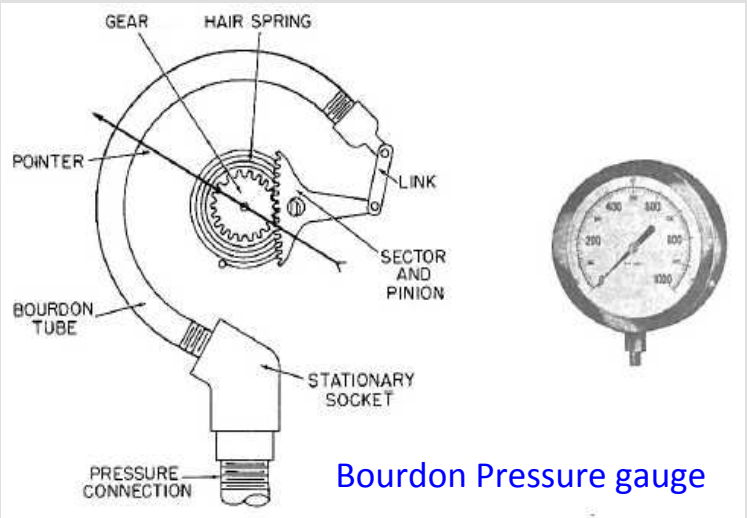
U – tube manometer



Pressure Measuring Devices - Classification

Based on method adopted

2. Those based on measurement of distortion of an elastic pressure chamber. Examples are Bourdon, Diaphragm and Bellow gauges.

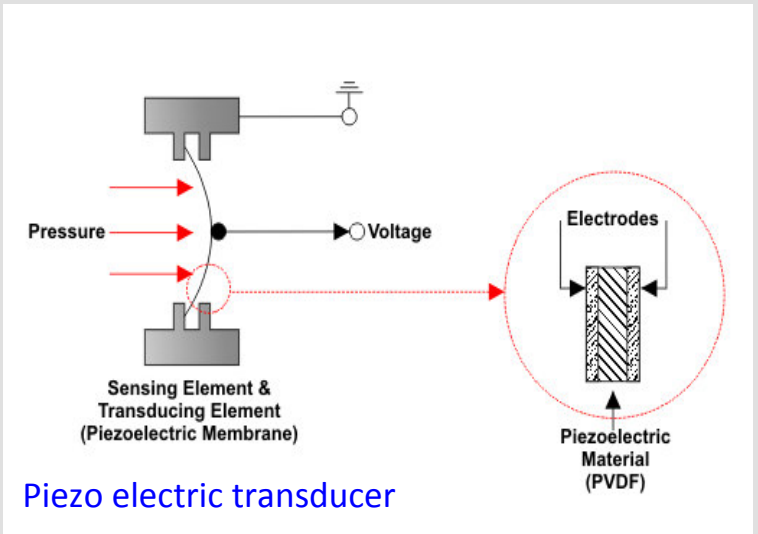


Bourdon Pressure gauge

Pressure Measuring Devices - Classification

Based on method adopted

3. Electrical sensing devices



Piezo electric transducer

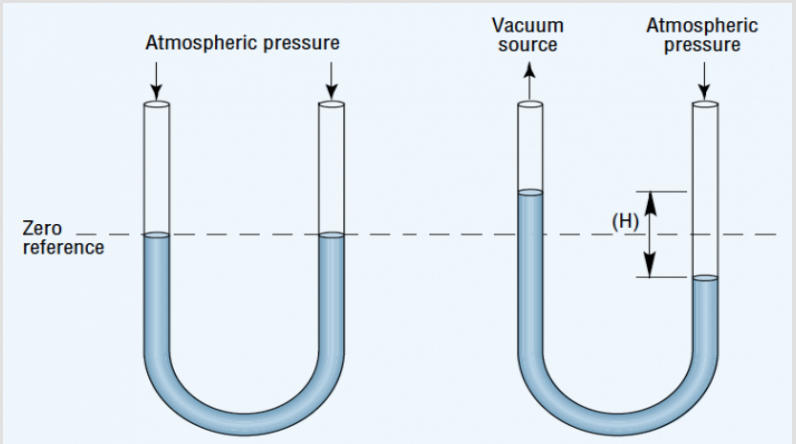
Pressure Measuring Devices
- Liquid column type

Devices that are based on the measurement of height of a liquid column.

Working Principle

Pressure being measured is balanced against the pressure exerted by a column of fluid

If the density of the liquid is known, the height of the liquid column is the measure of pressure

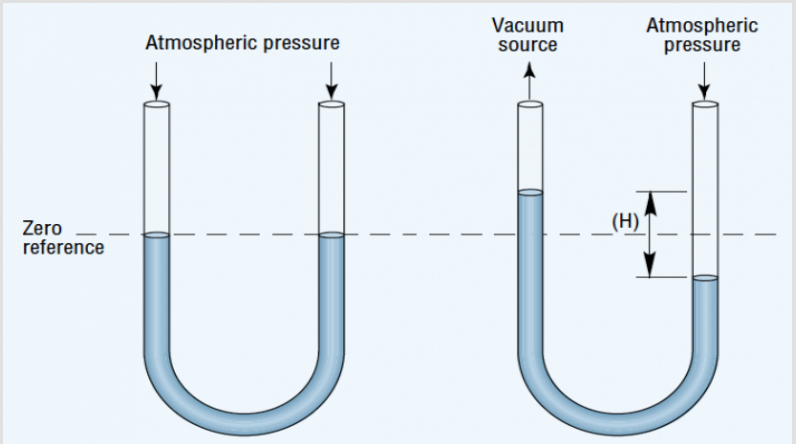


Pressure Measuring Devices
- Liquid Column type

Devices that are based on the measurement of height of a liquid column.

Working Principle

Depending upon the pressure range manometric fluids such as H_2O, Hg and CCl_4 are used.



Pressure Measuring Devices - Diaphragm type (Mechanical or Elastic)

Devices based on measurement of distortion of an elastic pressure chamber

Working Principle

The measured pressure deforms some elastic materials (usually metallic or non metallic) within its elastic limit.

The magnitude of deformation is approximately proportional to the applied pressure.

Pressure Measuring Devices - Classification

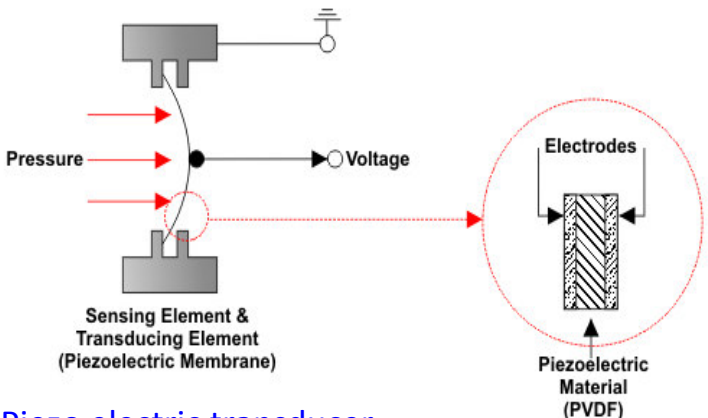
Based on method adopted (Electrical type)

Electrical sensing devices change in electrical resistance is proportional pressure

Working Principle

When a wire or other electrical conductor is stretched elastically, its length is increased, its diameter decreased.

Both these dimensional changes result in the electrical resistance of the conductor.



Piezo electric transducer

Pressure Measuring Devices - Classification

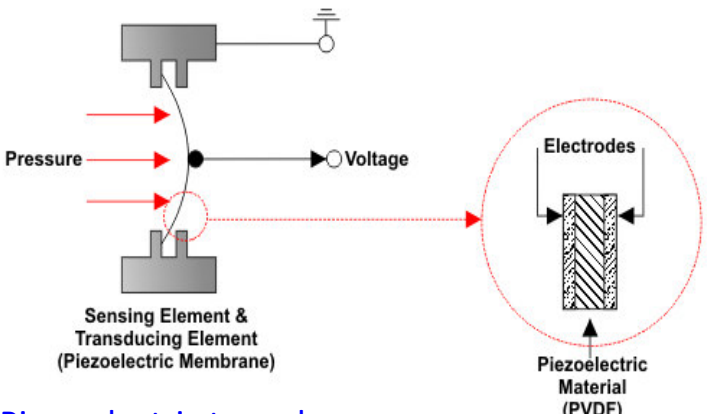
Based on method adopted

Working Principles

Device utilizing resistance wire grids for measuring small distortions in electrically stretched materials are commonly called strain gauges.

Examples are Strain gauge, piezo electric and peizo resistive transducers.

Electrical sensing devices change in electrical resistance is proportional pressure



Piezo electric transducer

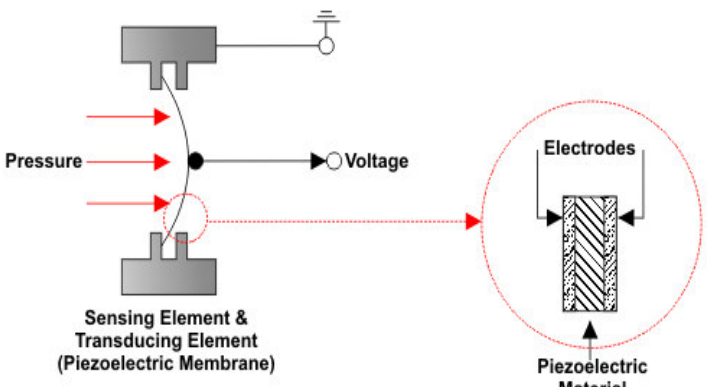
Pressure Measuring Devices - Classification

Based on method adopted

Working Principles

Pressure Transducers – these are electrical devices that transforms pressure energy into an electrical signal.

Electrical sensing devices change in electrical resistance is proportional pressure



Piezo electric transducer

Pressure Measuring Devices

Measuring elements (Gauge and Vacuum)

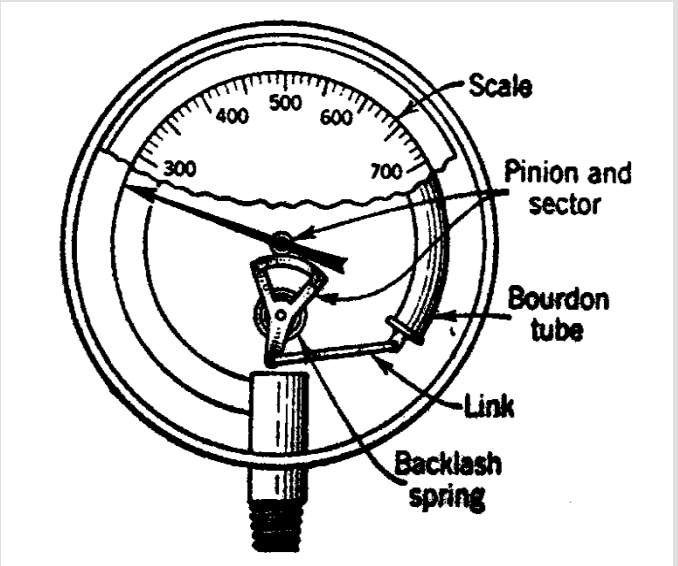
1. Pressure spring or Bourdon type
2. Bellows
3. Diaphragm (Metallic and non metallic)
4. Enlarged leg differential pressure
5. Bell differential pressure
6. Bellows differential
7. Ring and tilting type

Pressure Measuring Devices

Measuring elements (Gauge and Vacuum)

1. Pressure spring or Bourdon type

   40 atm – 681 atm



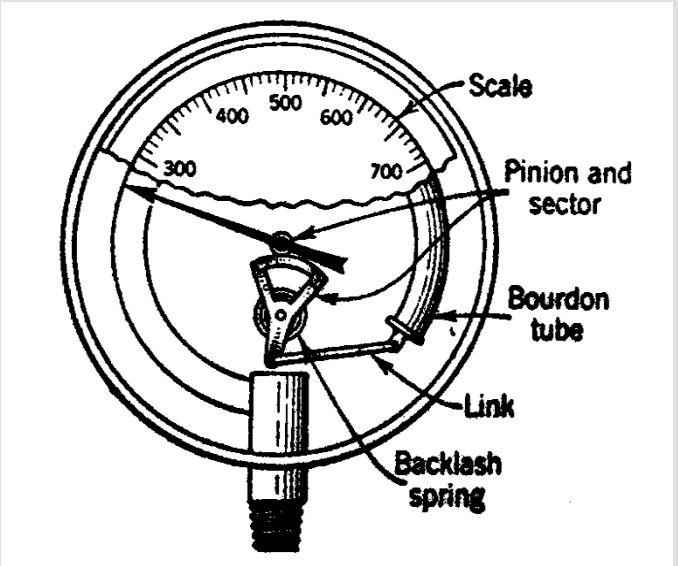
Pressure Measuring Devices

Measuring elements (Gauge and Vacuum)

1. Pressure spring or Bourdon type

The pressure spring employs a bourdon, spiral or helical tube made of bronze, beryllium copper and steel alloy.

Literally thousands of industries uses this type of pressure gauge.

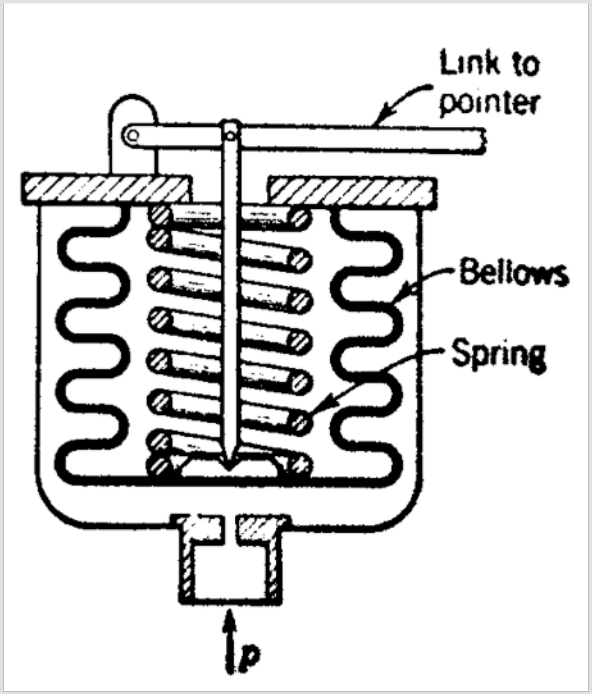


Pressure Measuring Devices

Measuring elements (Gauge and Vacuum)

2. Bellows

   Commonly used to measure pressure range between (0.02 atm – 6.08 atm)



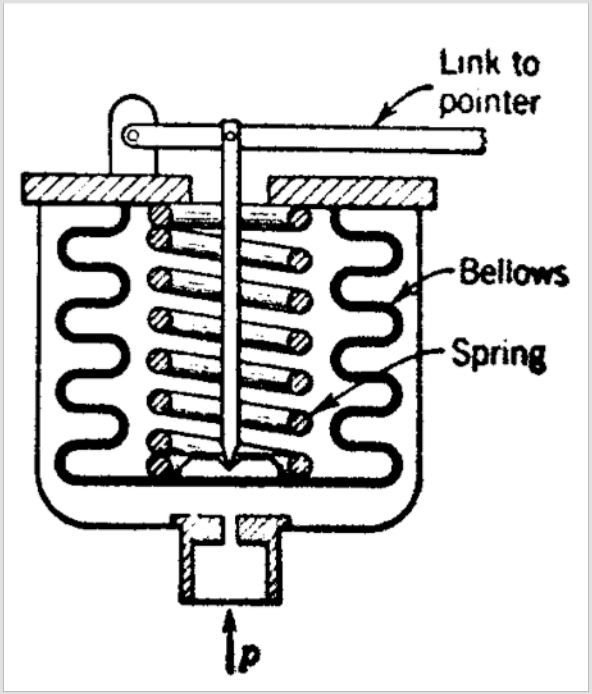
Pressure Measuring Devices

Measuring elements (Gauge and Vacuum)

2. Bellows

Commonly used bellows are brass or phosphor bronze.

Usually the pressure range of the system is determined mainly by the effective area of the bellows and spring gradients.

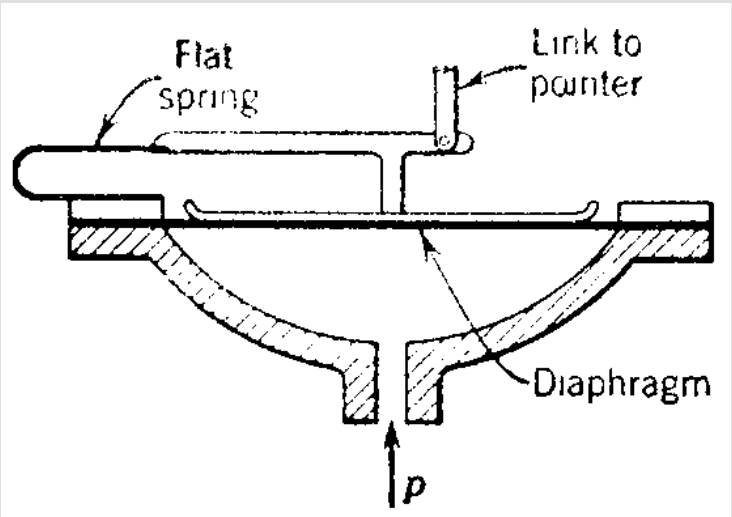


Pressure Measuring Devices

Measuring elements (Gauge and Vacuum)

3. Diaphragm (Metallic and Non-Metallic)

   Normally used to measure the pressure range between (0.06 atm – 0.3 atm)



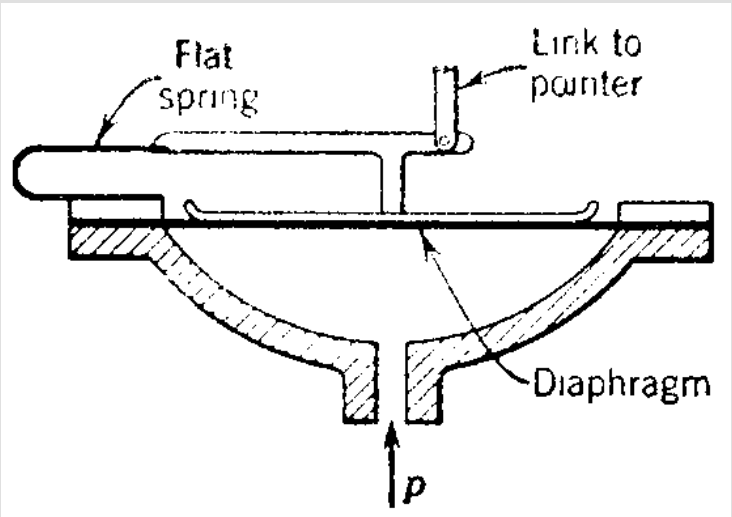
Pressure Measuring Devices

Measuring elements (Gauge and Vacuum)

3. Diaphragm (Metallic and Non-Metallic)

   Metallic type uses bronze or brass

   Non-metallic uses a flexible thin neoprene material



Pressure Measuring Devices

Measuring elements – Absolute pressures

1. Bourdon type
2. Diaphragm type

} Mechanical or elastic type

3. Pirani Vacuum gauge
4. Thermocouple type
5. Thermionic type

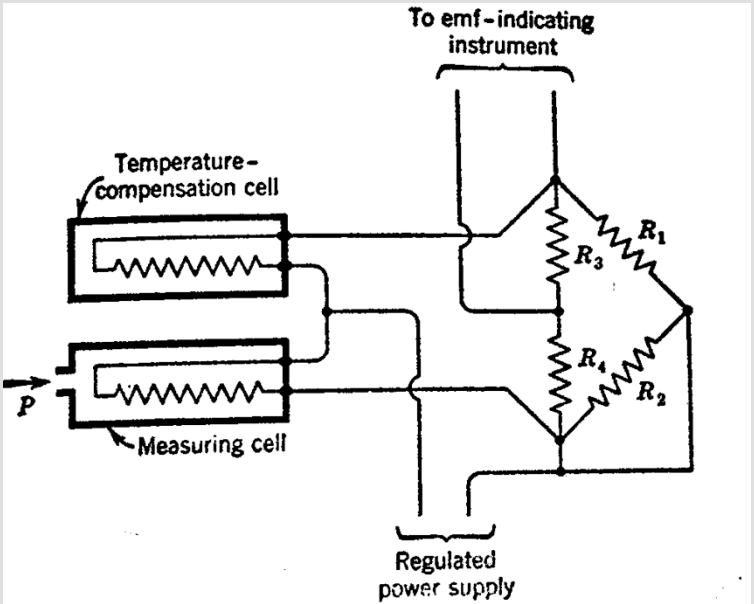
} Electrical type

Pressure Measuring Devices

Measuring elements – Absolute pressures

1. Pirani gauge

This gauge operates on the principle that heat loss by conduction and convection from a heated resistance wire depends on the pressure of the gas surrounding the wire. The change in resistance is measured through bridge circuit.



Pressure Measuring Devices

Indicating elements

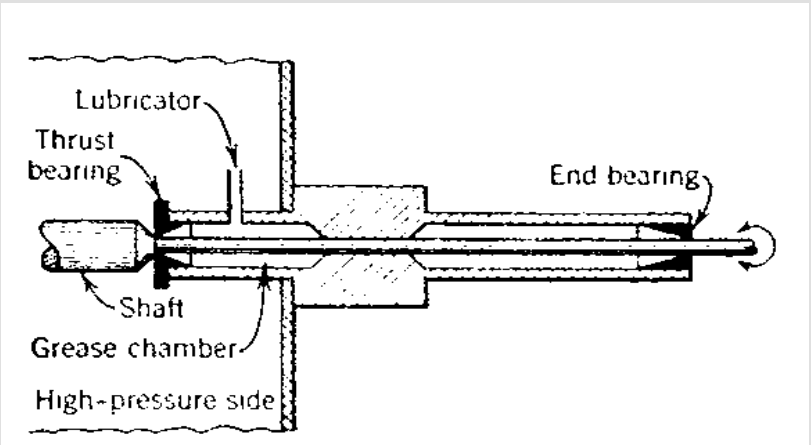
1. Pressure tight shaft
2. Torque – tube shaft
3. Inductance bridge
4. Resistance rod
5. Magnetic clutch
6. Pneumatic balance

Pressure Measuring Devices

Indicating elements

1. Pressure tight shaft

   Mechanical means for transmitting motion of bellows f the differential – pressure meter are the pressure tight shaft and the torque tube.

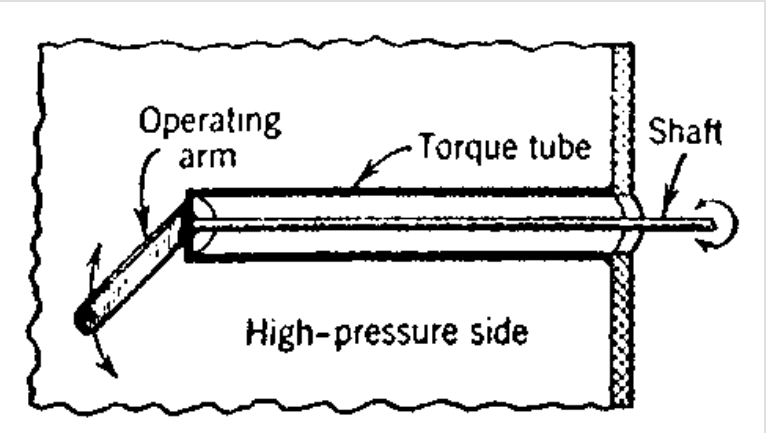


Pressure Measuring Devices

Indicating elements

2. Torque – tube shaft

- Often employed in bellows type pressure gauge or meter.
- The outer tube made of thin metal tube is clamped rigidly to the meter housing.
- The force of the bellows causes the free end of the torque tube to twist.
- The inner shaft rotates in the same direction resulting in indication of pressure through dial scale.



Pressure Measuring Devices

An industrial real time example of pressure measurement is available in this following web link provided M/s. Endress+Hauser
a global player in instrumentation for process industries

http://www.in.endress.com/en/Tailor-made-field-instrumentation/pressure

Pressure measurements in corrosive fluids

- In nearly all the pressure gauges, the fluid in which the pressure is measured is conducted to the inside of pressure measuring element and is in direct contact with measuring element.
- This creates problem of handling high temperature corrosive sludge or semi solid materials.
- To meet this problem some systematic arrangement of pressure measurement for devices are adopted and few such are listed in next slide.

Pressure measurements in corrosive fluids

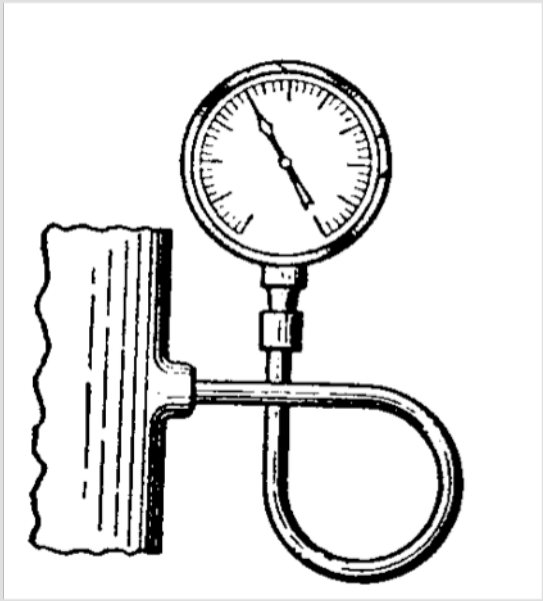
1. Siphoning
2. Diaphragm seal
3. Liquid seal
4. Purge system

Pressure measurements in corrosive fluids

1. Siphoning

This type of arrangement is effective in protecting a pressure-gauge element from high temperatures of steam.

The brass coil traps condensed steam and limits the temperature rise in the gauge.



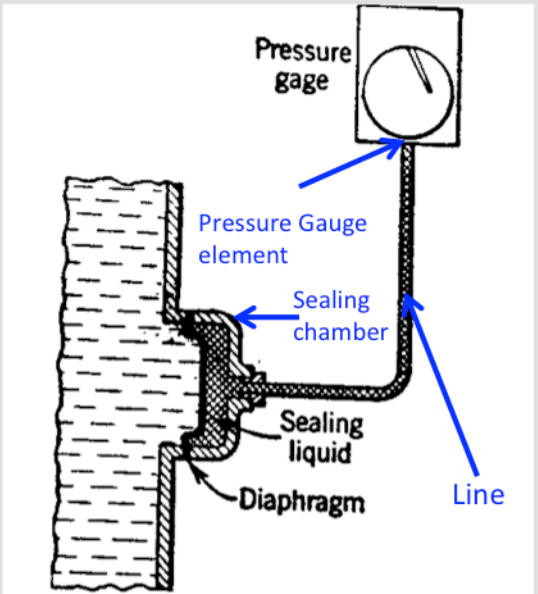
Pressure measurements in corrosive fluids

2. Diaphragm seal

This is simple but effective device.

The unit is usually made of bronze or cast iron with a neoprene or thin metal diaphragm.

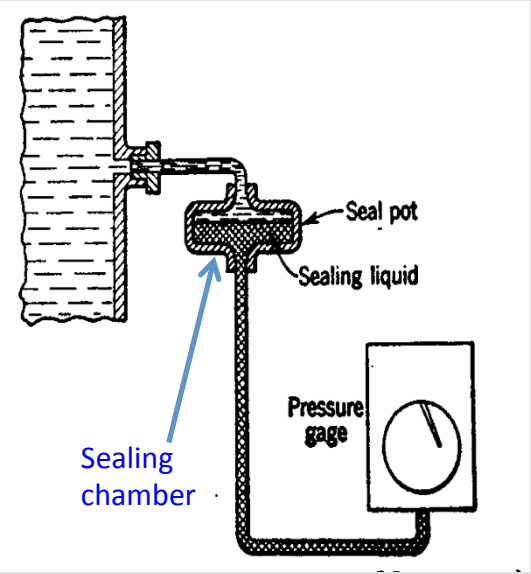
The system is filled with a liquid such as glycerin.



Pressure measurements in corrosive fluids

3. Liquid seal

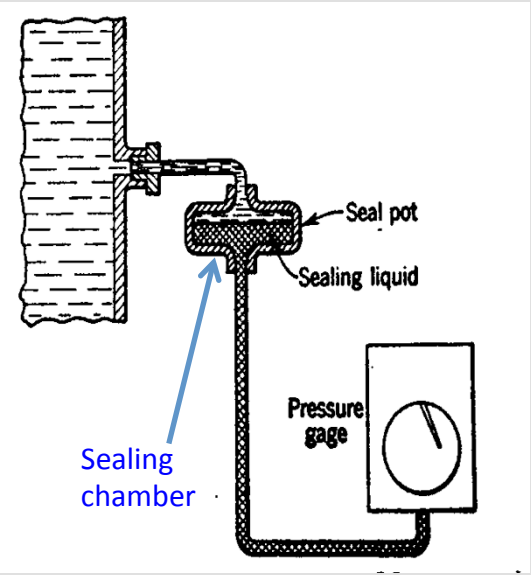
A sealing chamber, usually of bronze or cast iron, is interposed in the gauge line between the pressure gauge and the point of measurement. The pressure gauge element and, line and sealing chamber are filled with a suitable liquid.



Pressure measurements in corrosive fluids

3. Liquid seal

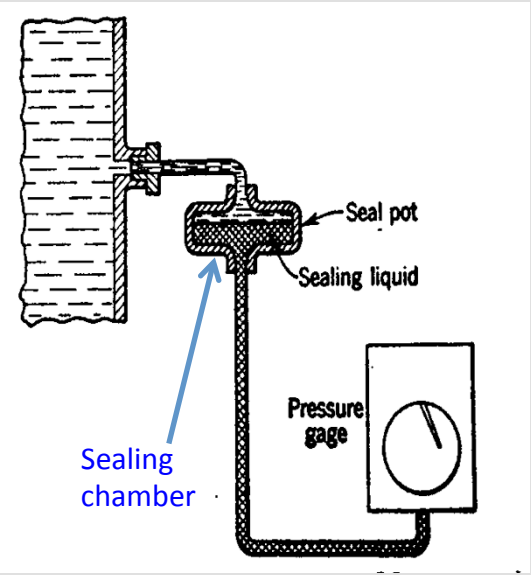
When the gauge and line are below the point of measurement, the sealing liquid must have a density greater than that of the fluid at point of measurement.



Pressure measurements in corrosive fluids

3. Liquid seal

When the gauge and line are above the point of measurement, the sealing liquid must have density less than the fluid at point of measurement.

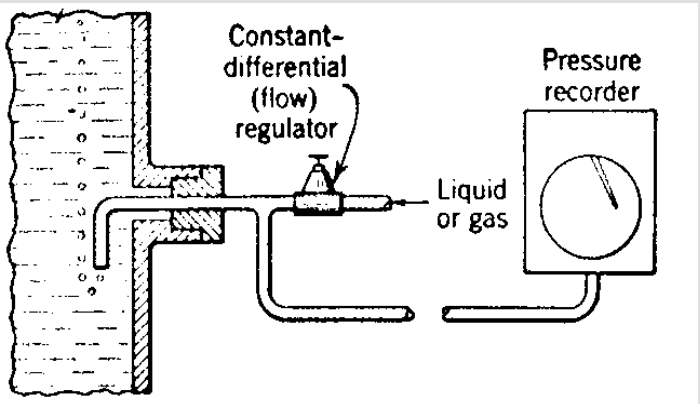


Pressure measurements in corrosive fluids

4. Purge System

It is useful when small and continuous flow of air or other gas through the measuring line is sufficient to maintain the line from sludge.

Air is supplied at necessary pressure through a constant flow regulator, which contains an orifice and a differential-pressure controlling means.



References

1. Donald P. Eckman, (2004) *Industrial Instrumentation*, CBS Publishers, Pp. 1- 27.
2. Pieter R. Wiederhold, *Water Vapor Measurement and Instrumentation*
3. www.wikipedia.com

Thank You