Ministry Of Higher Education and Scientific Research

Salahaddin University - Erbil

College of Engineering

Aviation Engineering Department

Measurements and Instrumentation

Spring semester

salar.sherwani@su.edu.krd

salar.saber@mail.ru

Second year

Lecture: 5

Pressure Measurements

Lecturer:

Dr. Salar Saber Kartas

Erbil 2023

3. Pressure Measurements

3.1. Introduction

Pressure measurement is a very common requirement for most industrial process control systems and many different types of pressure-sensing and pressure-measurement systems are available. However, before considering these in detail, it is important to explain some terms used in pressure measurement and to define the difference between **absolute pressure, gauge pressure and differential pressure.**

Absolute pressure: This is the difference between the pressure of the fluid and the absolute zero of pressure.

Gauge pressure: This describes the difference between the pressure of a fluid and atmospheric pressure. Absolute and gauge pressure are therefore related by the expression:

$$\text{Absolute pressure} = \text{Gauge pressure} + \text{Atmospheric pressure}$$

Thus, gauge pressure varies as the atmospheric pressure changes and is therefore not a fixed quantity.

Differential pressure: This term is used to describe the difference between two absolute pressure values, such as the pressures at two different points within the same fluid (often between the two sides of a flow restrictor in a system measuring volume flow rate).

In most applications, the typical values of pressure measured range from 1.013 bar (the mean atmospheric pressure) up to 7000 bar. This is considered to be the ‘normal’ pressure range, and a large number of pressure sensors are available that can measure pressures in this range. Measurement requirements outside this range are much less common. Whilst some of the pressure sensors developed for the ‘normal’ range can also measure pressures that are either lower or higher than this, it is preferable to use special instruments that have been specially designed to satisfy such low- and high-pressure measurement requirements.

The discussion below summarizes the main types of pressure sensor that are in use. This discussion is primarily concerned only with the measurement of static pressure, because the measurement of dynamic pressure is a very specialized area that is not of general interest. In general, dynamic pressure measurement requires special instruments, although modified versions of diaphragm-type sensors can also be used if they contain a suitable displacement sensor (usually either a piezoelectric crystal or a capacitive element).

3.2.Pressure Measurements

- General theory (Pascal's law)

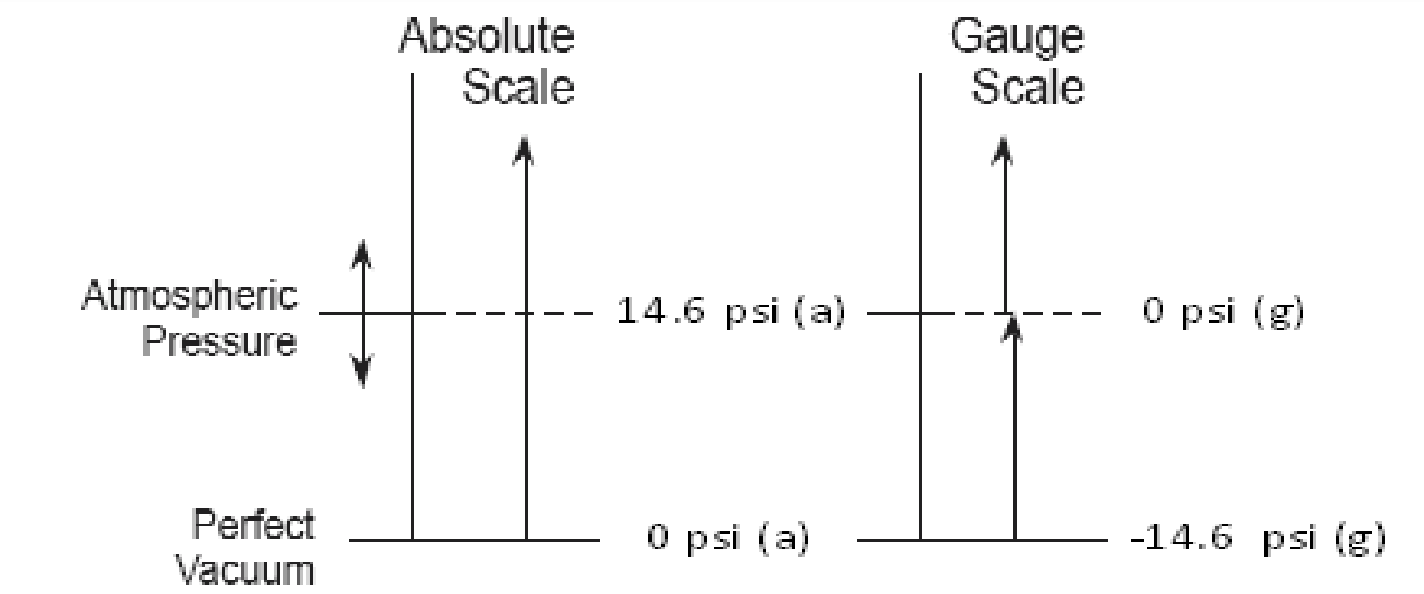
$$\text{Pressure} = \frac{\text{Force}}{\text{Area}}$$

- Pressure units are pounds per square inch (PSI), (bar),(Pa) or millimeter water (mm H2O).

- Atmospheric pressure = 14.6 psi
  = 1.01325 bar
  = 10.33 ct.,m H2O
  = 101325 Pa
  = 760 MM PT. CT.

3.3.Pressure Scales

- Gauge and Absolute pressure



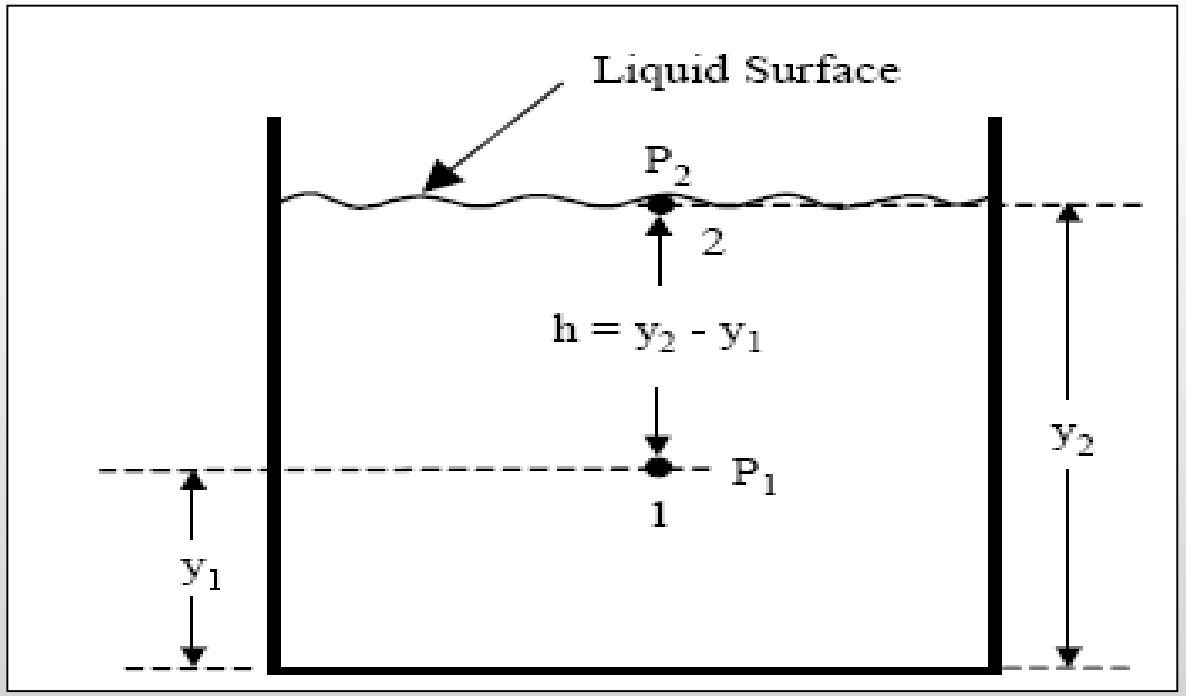
$$P_a = P_g + P_{atm} \qquad \text{(when } P_g > P_{atm}\text{)}$$

$$P_a = P_g + P_{atm} \qquad \text{(when } P_g < P_{atm}\text{)}$$

3.4. Pressure in a Fluid

- Liquids are uncompressible. For an opened vessel,

$P_a = P_{atm} + \rho g h$ → Pascal's law



Pressure in a Fluid

- Pascal's law indicates that the shape of the open tank does not affect the pressure and that the pressure is influenced only by the depth (h) and the density (ρ).
- Application: Hydraulic press.
- The pressure at every point on the same line is equal:

$$P_1 = P_2$$

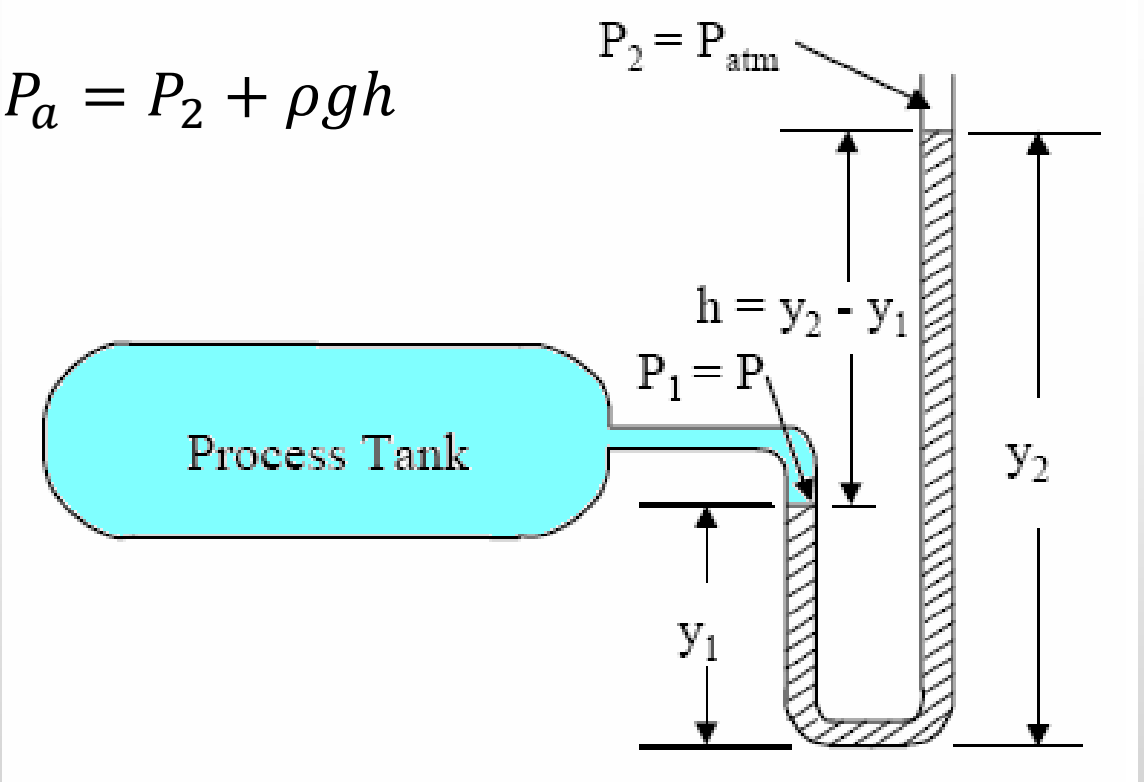
So that $F_2 = (A_2/A_1)F_1$

- The hydraulic press is a force amplifier where the gain is **(A_2 / A_1).**

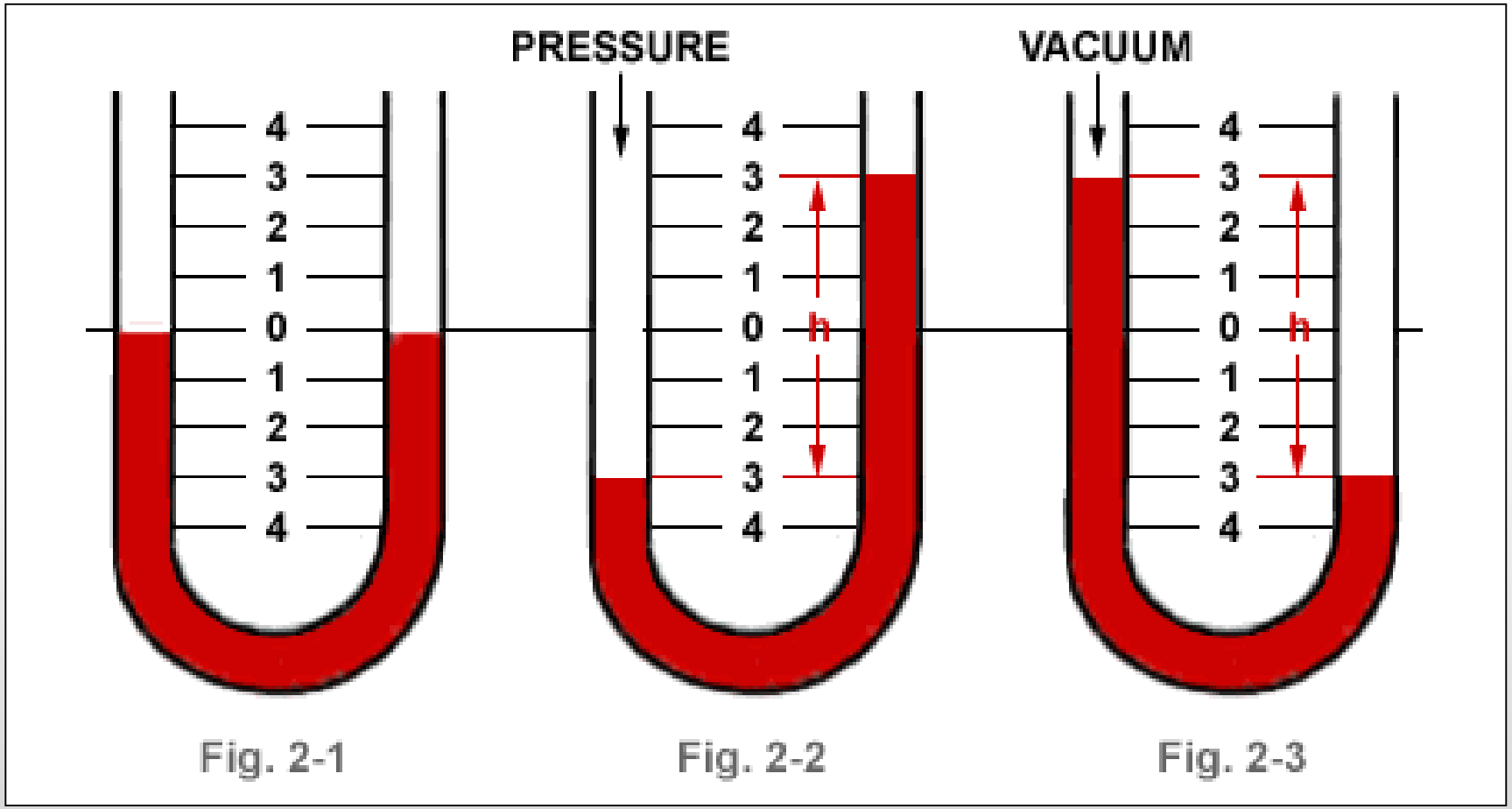
3.5.Manometers

Can provide a very accurate measurement of pressure Used as calibration standards for other pressure measurement devices.

$$P_a = P_2 + \rho g h$$



Manometers



Pressure Gauges

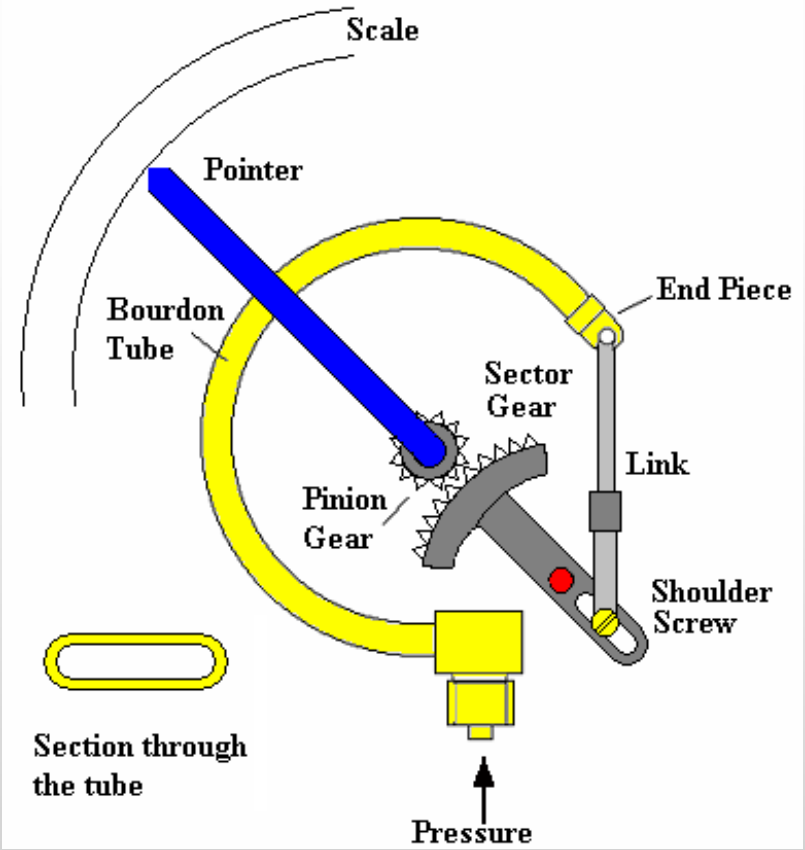
- Pressure gauges are used for local indication
- Pressure gauges consist of a dial or indicator and a pressure element.
- A pressure element converts pressure into a mechanical motion.
- Most mechanical pressure elements rely on the fact that pressure acts on a surface area inside the element to produce a force that causes a mechanical deflection.

3.6.Bourdon Tube

❖ A Bourdon tube is an elastic element in instrumentation that allows monitoring pressures of all levels used in industry. It senses changes in pressure and converts these changes into mechanical movement. A Bourdon tube is usually connected to a pressure gauge, which displays the change in pressure on a graduated scale.

How a Bourdon Tube works

❖ Bourdon tubes are circular-shaped tubes with oval cross sections. The outward pressure on the oval cross section forces it to become rounded. 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 reading.



Bourdon Tube

Diaphragm

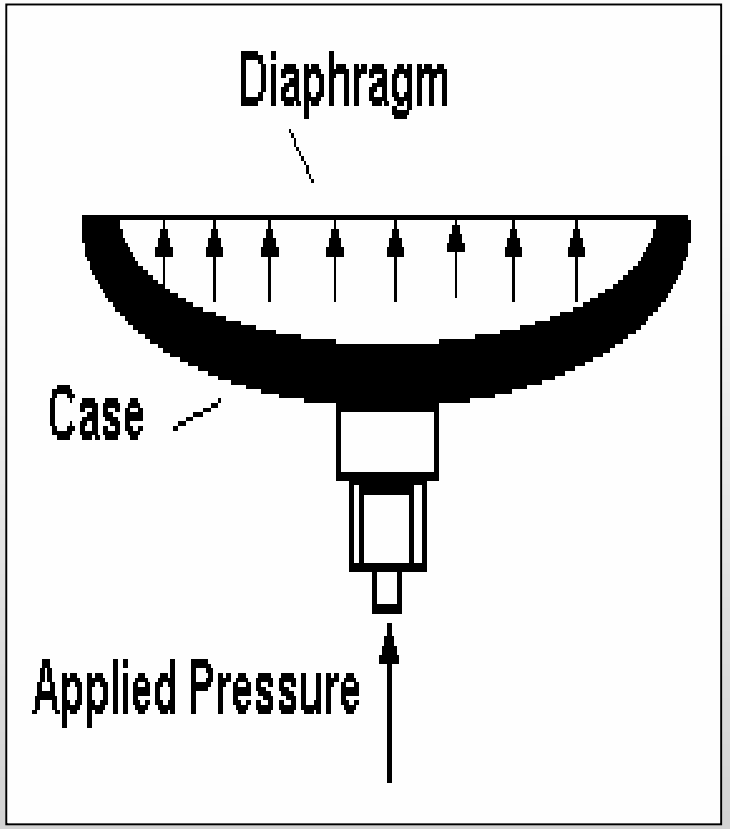
❖ A diaphragm is a flexible membrane that expands when pressure applied . In pressure-measuring instruments, the diaphragms are normally metallic. When two are fastened together they form a container called a capsule. Pressure applied inside the diaphragm capsule causes it to expand and produce motion along its axis.

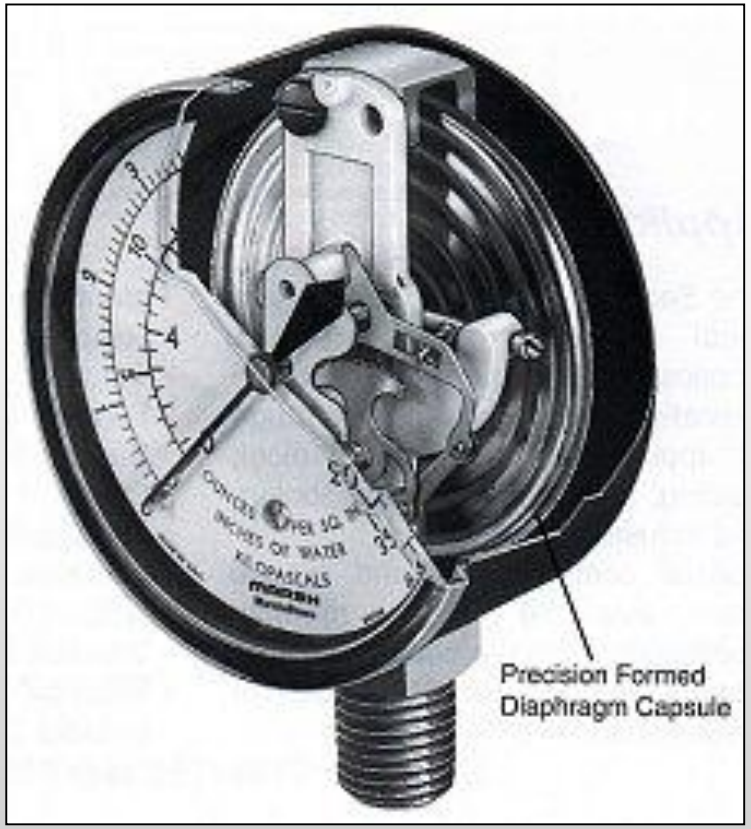
❖ **Where can use Diaphragm:**

1. Low pressure;
2. Overload protection;
3. Critical media.

❖ **what is it made :**

1. PTFE;
2. Gold;
3. Hastelloy.



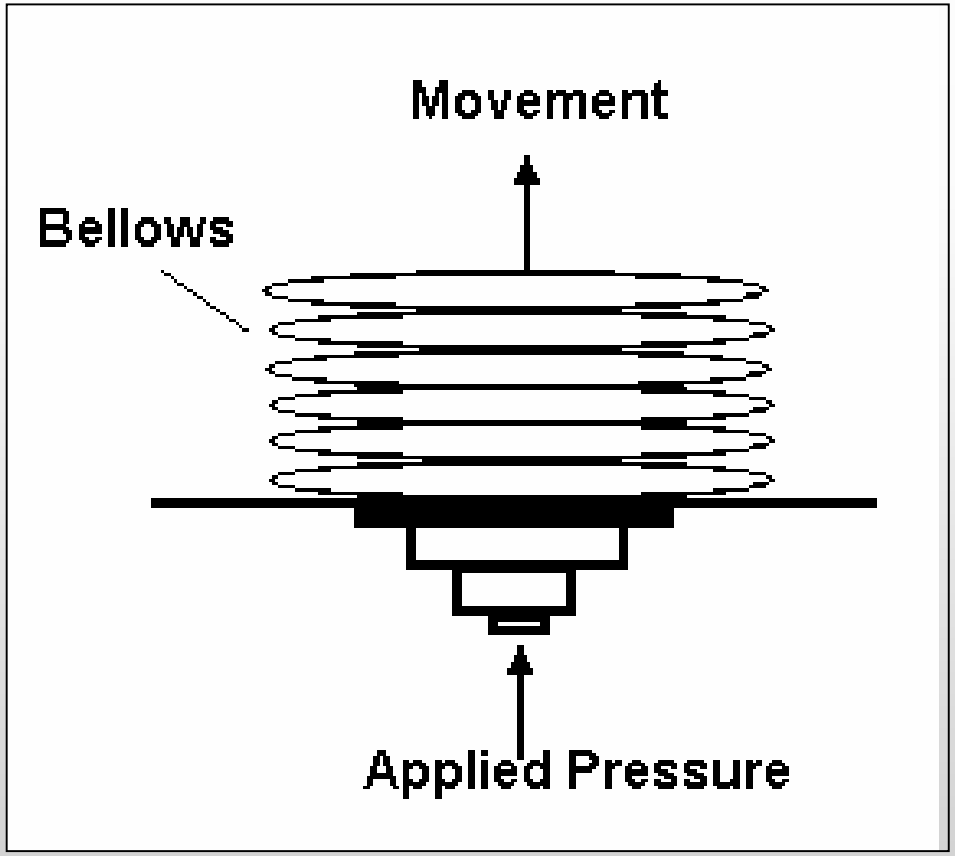


Bellows

❖ The bellows pressure element converts a pressure into a physical displacement. It is very similar to a diaphragm-type gauge the difference is that typically the movement in a bellows is much more of a straight-line expansion.

❖ **What type Bellows are there:**

1. Brass spring;
2. Phosphor bronze spring;
3. Stainless steel spring.



3.7. Differential Pressure Gauges

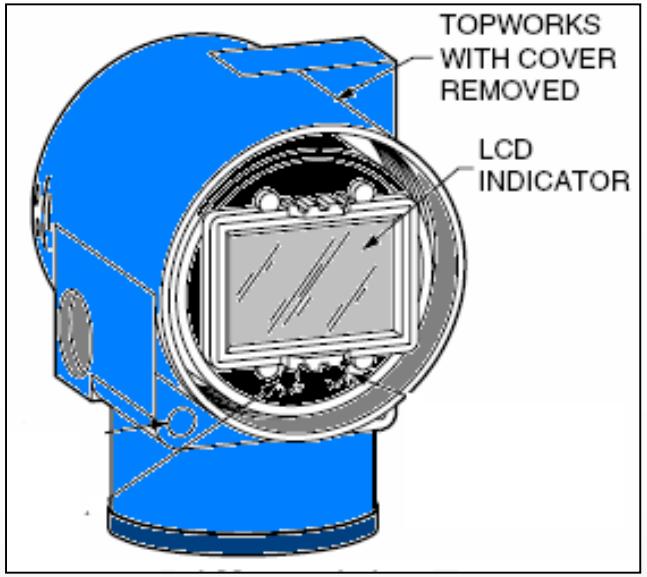
❖ Measures the difference between two pressures. The measuring element is formed by two diaphragms, acting on the same movement. In this way the pointer senses only the difference between the two pressures.

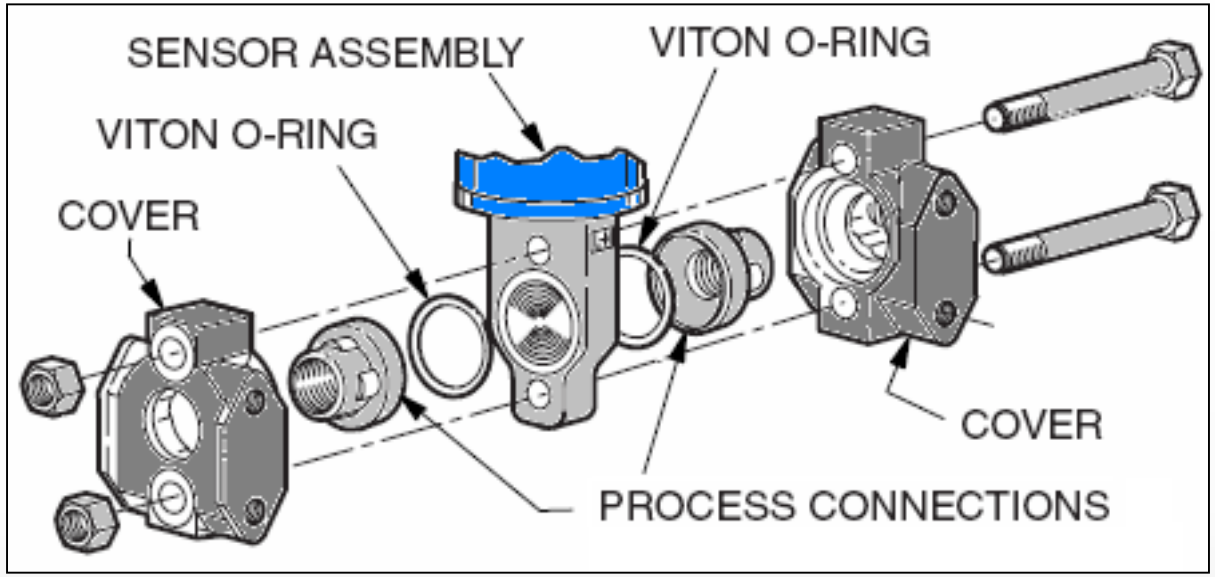
3.8. Smart Differential Pressure Transmitter

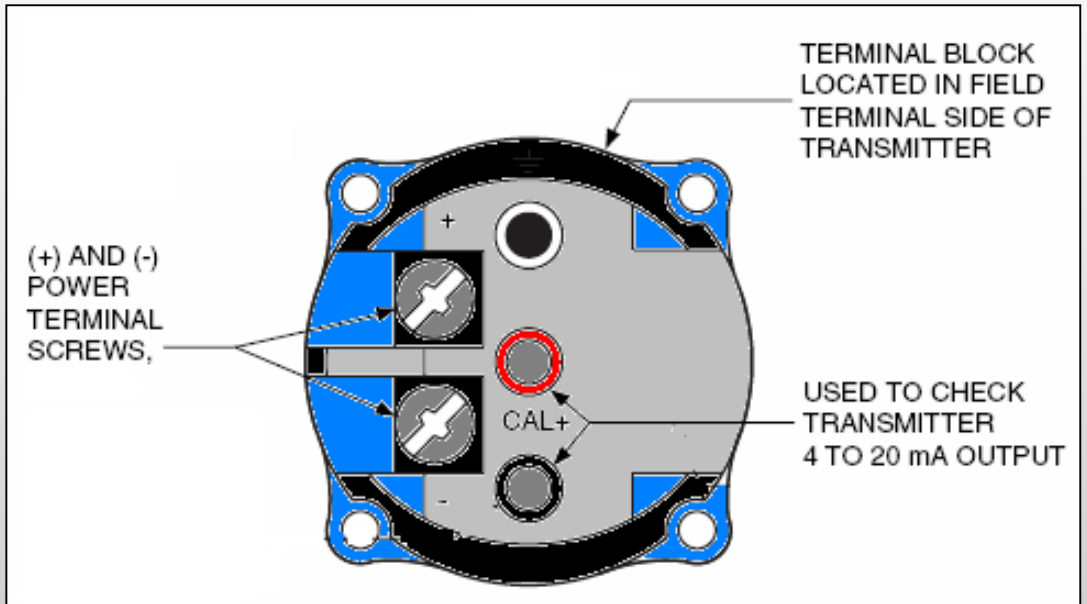
- Capable of measuring differential pressure (that is, the difference between a high pressure input and a low pressure input) and therefore called DP transmitters or DP cells.
- The DP transmitter consists of:
  1) Body containing display, electronic module & power module.
  2) Manifold with isolation, bypass & vent valves.
  3) The transducer (DP cell) inserted in a pressure capsule .
- A pressure capsule has to be used to obtain maximum sensitivity.
- A pressure capsule has a sensitivity range that closely matches the anticipated pressure of the measured fluid.

3.7.Differential Pressure Transmitter

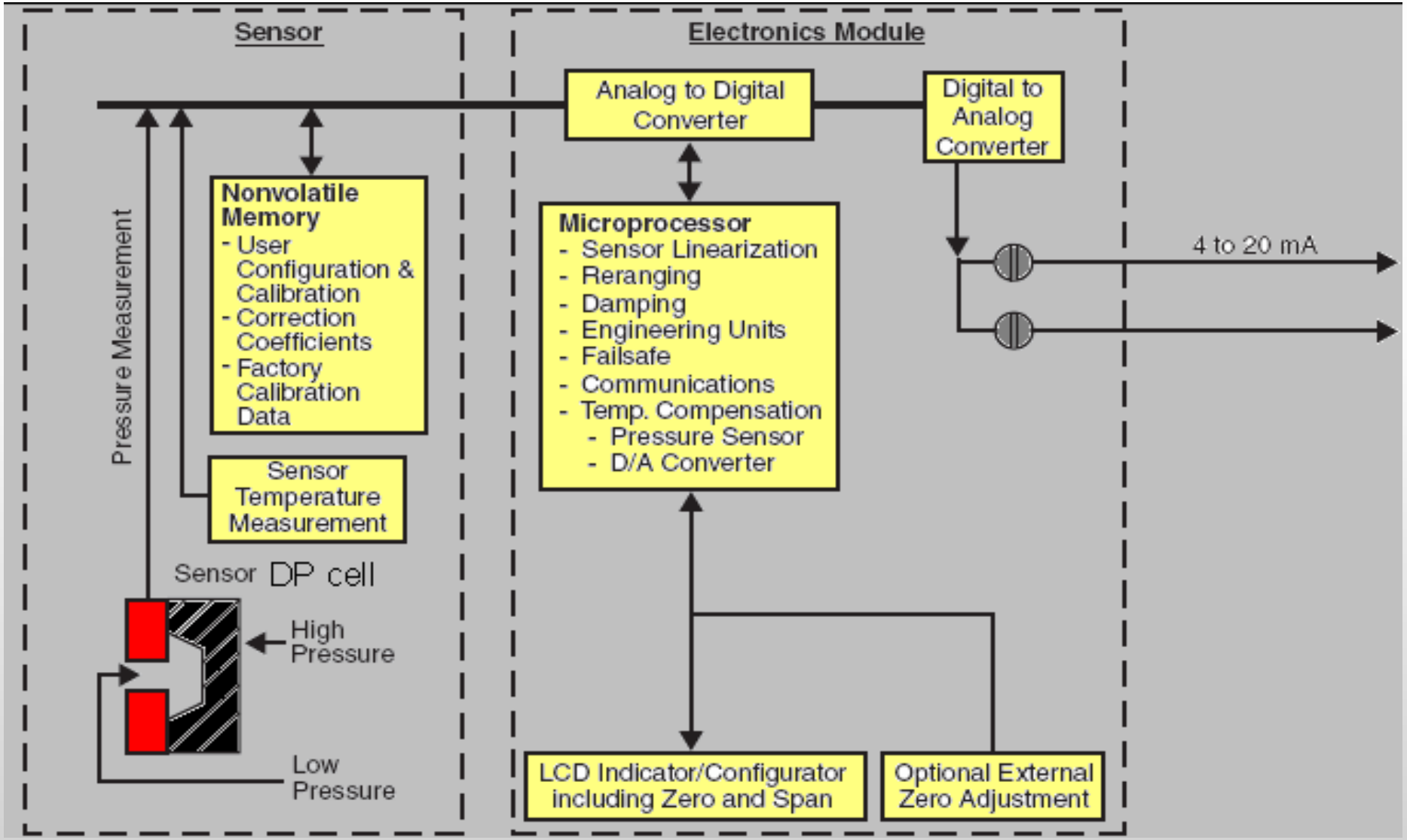
3.7.Differential Pressure Transmitter







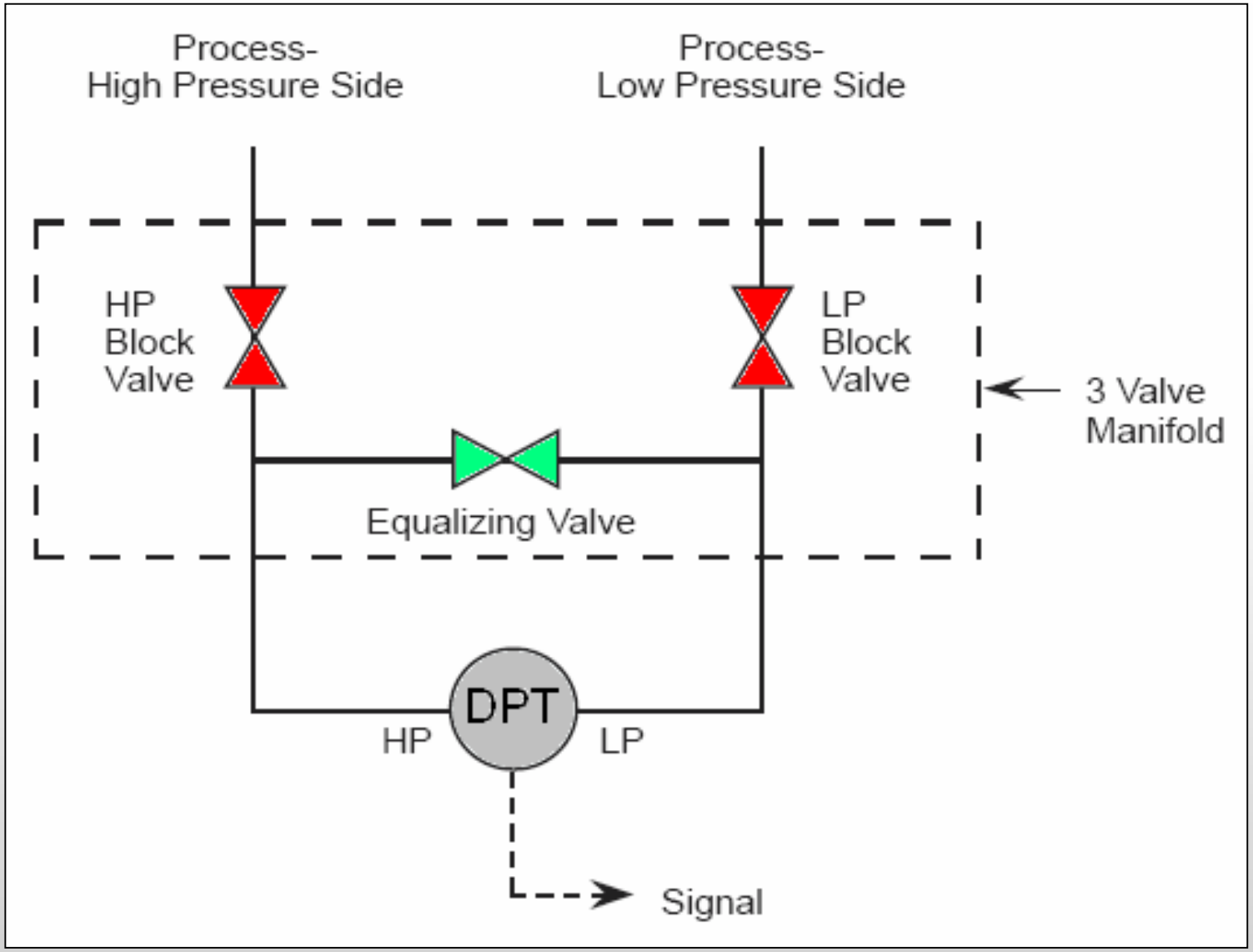
Transmitter Functional Block Diagram



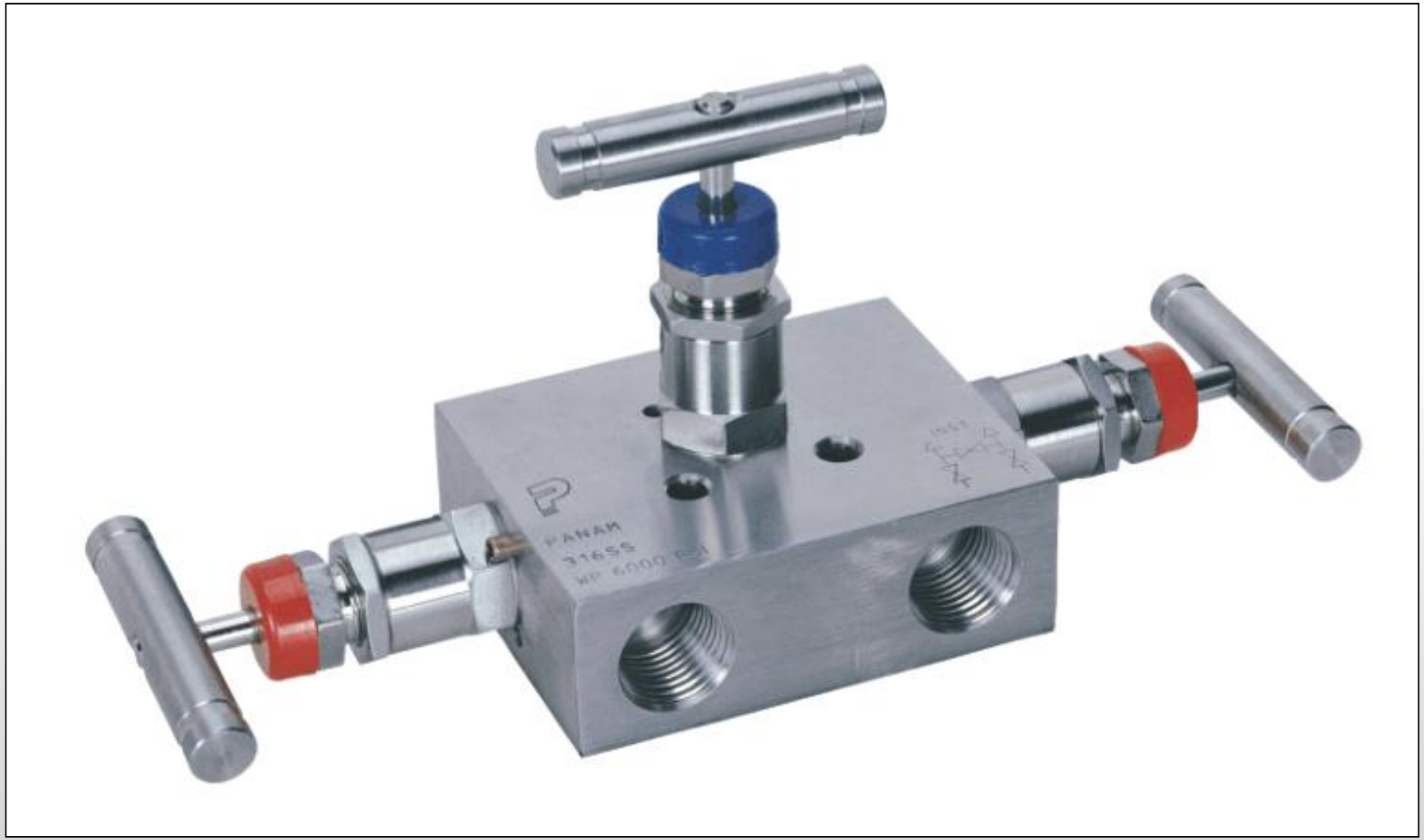
3.9.Three Valve Manifold

- If the process pressure is accidentally applied to only one side of the DP capsule during installation or removal of the DP cell from service, over ranging of the capsule would occur and the capsule could be damaged causing erroneous indications.
- A three-valve manifold is a device that is used to ensure that the capsule will not be over-ranged during bringing the transmitter in/out of the service.
- Allows isolation of the transmitter from the process loop.
- Consists of two block valves - high pressure and low pressure block valve - and an equalizing valve.
- During normal operation, the equalizing valve is closed and the two block valves are open.

Three Valve Manifold



Three Valve Manifold



Question Five lecture

1. Define absolute pressure, gauge pressure and differential pressure?
2. What is measuring pressure and writing a formal?
3. What is a pressure scale?
4. What is the pressure in a liquid?
5. What are Manometers and draw?
6. What is it Bourdon Tube and how a work?
7. Where can use the diaphragm and what is it made of?
8. What are Bellows and what type are there?