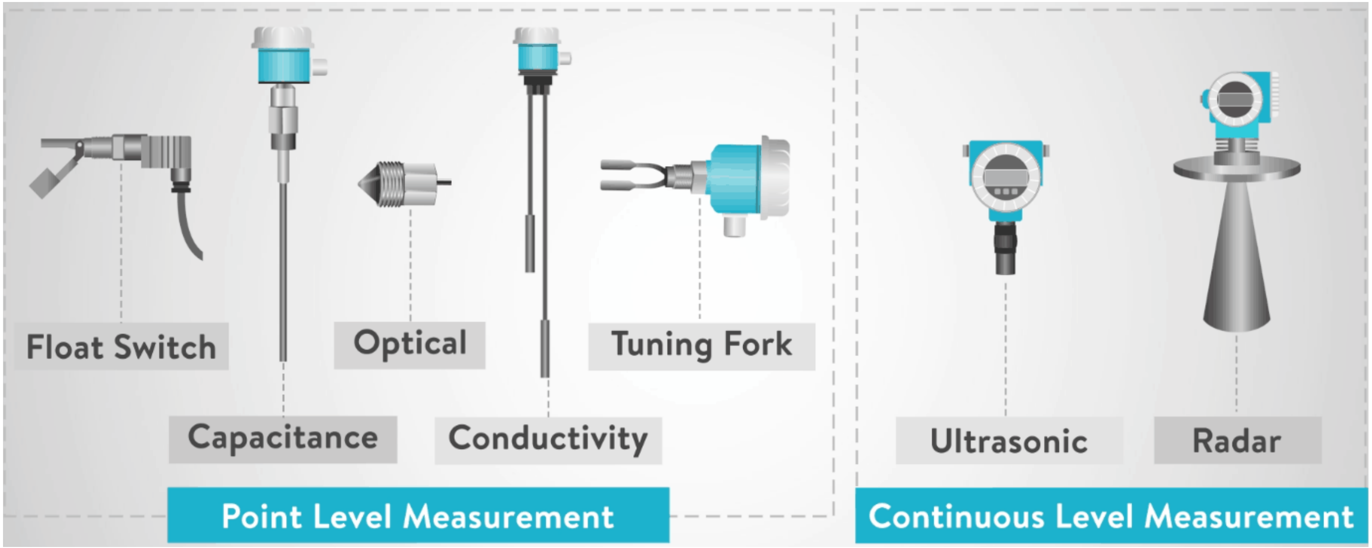
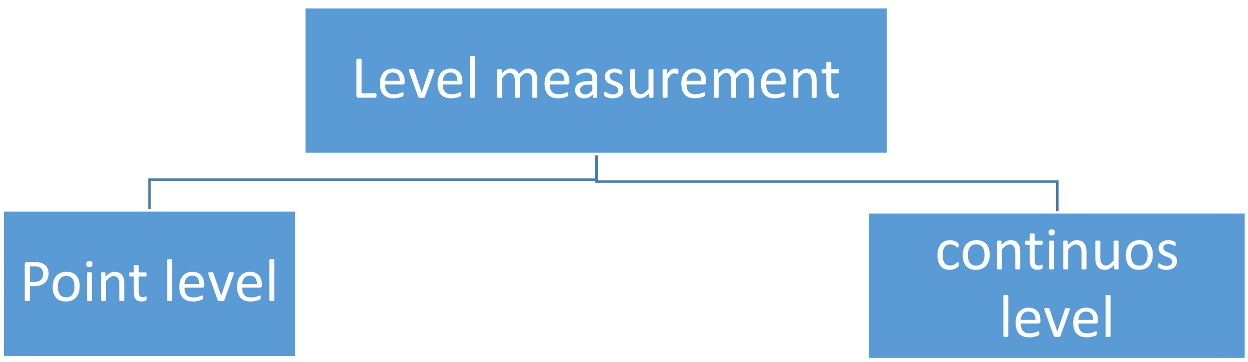
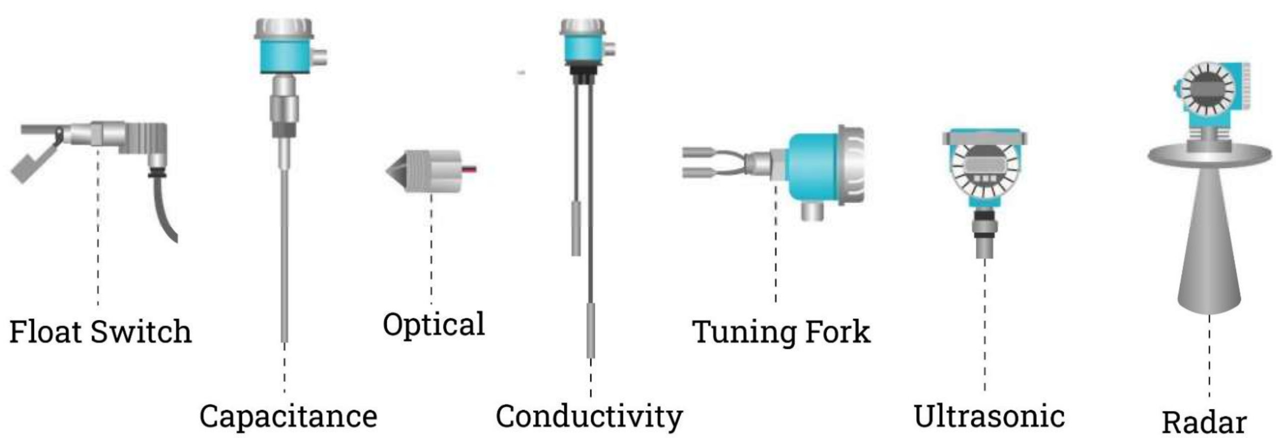
⑤ Level Measurements





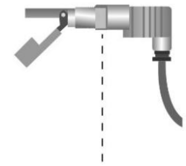
1. Float Switch
2. Capacitance
3. Optical
4. Conductivity
5. Tuning Fork
6. Magnetic

7. Ultrasonic
8. Radar
9. Displacer
10. Hydrostatic
11. Diff Pressure



① Float Switch:

Float switches use a float, a device that raises or lowers when a product is applied or removed, opening or closing a circuit as the level rises or falls, moving the float.



Advantages:	Disadvantages:
• Non – Powered. • Direct indication. • Inexpensive	• Must touch the liquid. • Have moving Parts. • Large in siza.

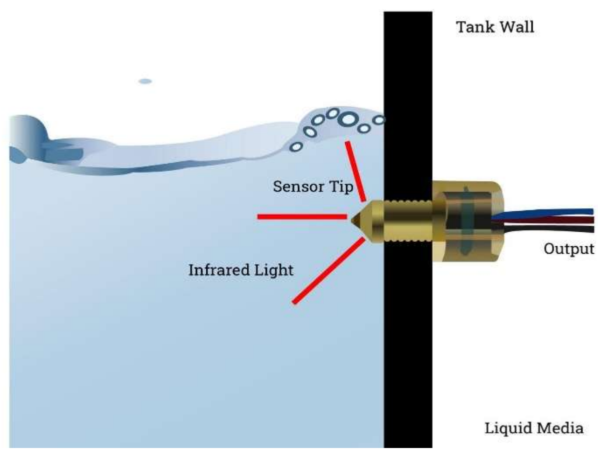
② Capacitance:

A capacitance level sensor is a proximity sensor that emits an electrical field and detects a level based on the effect on its electrical field. (# low farad at empty tank)

Advantages:	Disadvantages:
• Small. • Less expensive. • Accurate. • No moving parts. • For liquids & Solids.	• Must touch the liquid. • Have to be calibrated. • Detect certain liquids.

③ Optical:

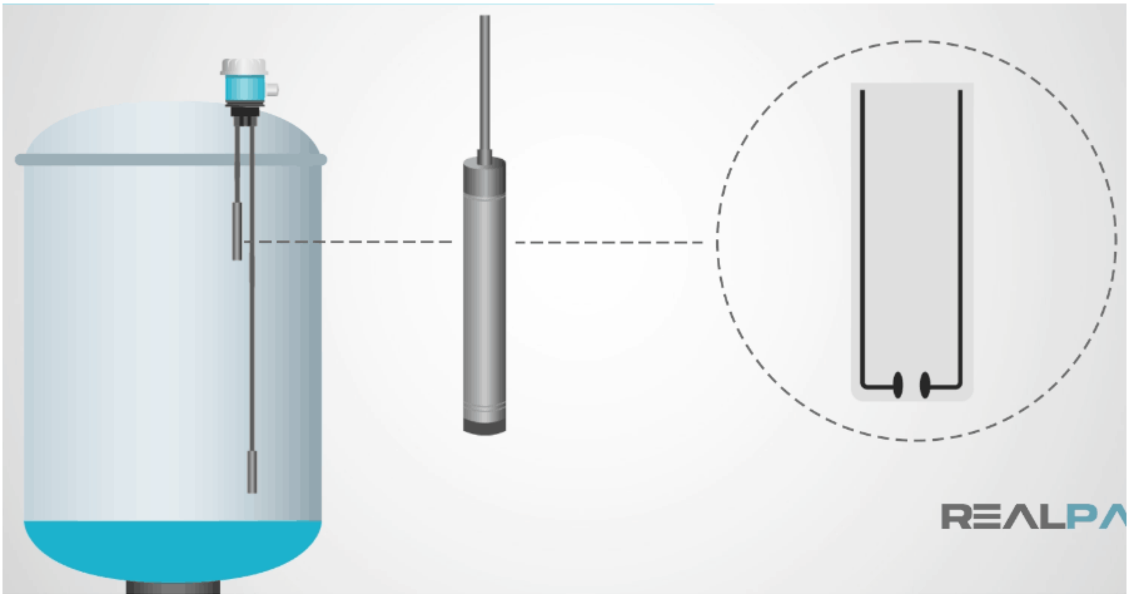
Optical sensors convert light rays(infra-red) into electrical signals, translating the physical quantity of light into a measurement.



Advantages:	Disadvantages:
• Small. • No moving parts. • Can used in liquids • Not affected by high pressure or temperature.	• Required cleaning.

④ Conductivity:

A conductivity or resistance sensor reads conductivity with a probe. The probe has two electrodes and uses alternating currents to power them. When a liquid covers the probe, the electrodes connect to an electric circuit, causing current to flow and signaling a high or low level.



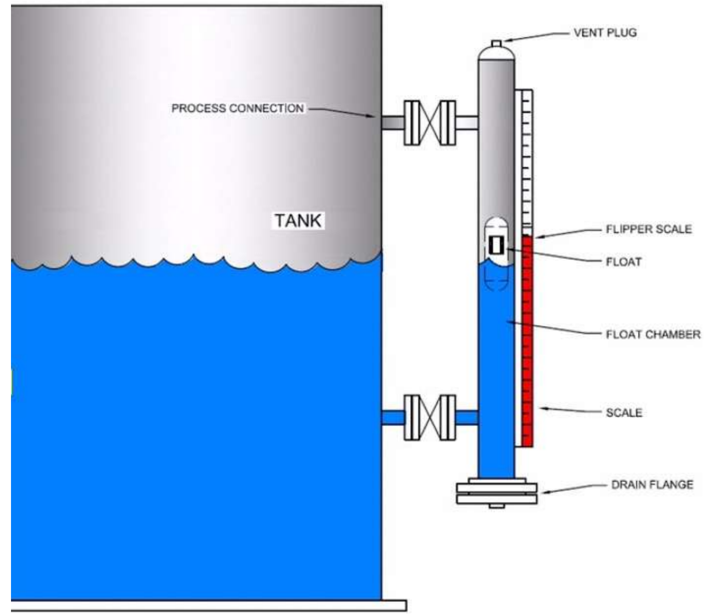
Advantages:	Disadvantages:
• Low cost. • No moving parts. • Easy to use.	• Must touch product. • Only for conductive liquid. • Probe will erode overtime.

⑤ Tuning Fork:

They employ a sensing element in the shape of a fork with two tines. The fork vibrates at the frequency of its natural resonant frequency. Therefore, the frequency of the fork detecting the level will change as the level changes.

Advantages:	Disadvantages:
• Inexpensive and small. • simple to install. • used in the mining, food and beverage, and chemical processing industries.	• Must touch product.

⑥ Magnetic:



The strength of the magnetic coupling between the float and the indicator must be directly proportional to the distance separating them. We must not allow any dirt or debris in the chamber, it can be lodged between the float and the inner wall, and it could prevent the float from following the change in the liquid level so the measurement will be badly affected. The magnetic level indicator is designed for specific liquid density so if the float is not properly manufactured or the density of the process fluid changes then there will be an error in the measurement. We must not use the magnetic level indicator for the process fluid that has less specific gravity than that of the float.

The magnetic level indicator must be made of stainless steel or other materials that could be compatible with the process fluid. The float must be selected according to the density of the liquid. The length of the magnetic level indicator must be suitable for the level range of the application. It must not be used for the liquid-liquid interface. We must make sure that the float and the chamber are designed according to the design pressure and temperature.

In a magnetic level, indicator floats are used to indicate the level, this type of level measurement is done with the attraction between two magnets. This device has a magnet that is enclosed in a float and it also has a second magnet which is called the magnet follower and it is in a non-ferrous metal tube. The magnet in the float attracts the magnet in the tube as the float raises and lowers with the level of the process liquid and this would cause the magnet inside the tube to raise and lower. By checking the position of the magnet the level of the liquid in the tank can be determined.

Advantages:	Disadvantages:
• It is cheap • Easy to install • High accuracy • It is not affected by material characteristics s conductivity and dielectric constant. Used for { Waste treatment , Chemical industry, pet chemistry, Power stations, Food and beverage indu	

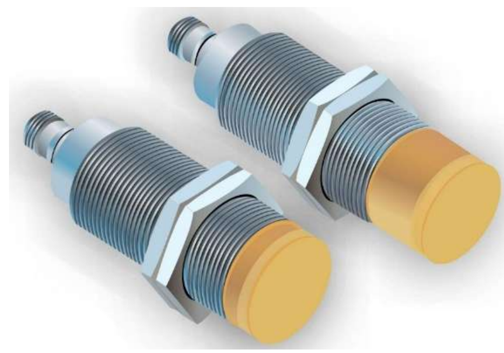
⑦ Ultrasonic:

Ultrasonic-level sensors generate and receive ultrasonic waves using the time it takes to reflect and measure distance. Ultrasonic sensors have no moving parts, are compact, extremely reliable, non-invasive (non-contact), unaffected by the properties of the material they are sensing, and self-cleaning due to vibrations produced. They are, however, costly and may be affected by the environment.

work by transmit & receive ultrasonic waves (Time α Level).

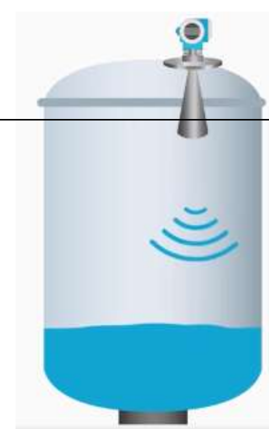
Advantages:	Disadvantages:
• Non-contact • Self-cleaning • used in Solid	• More expensive. • Negative effects of environment. • Need to be calibrated (Zero Trim).

⑧ Radar:

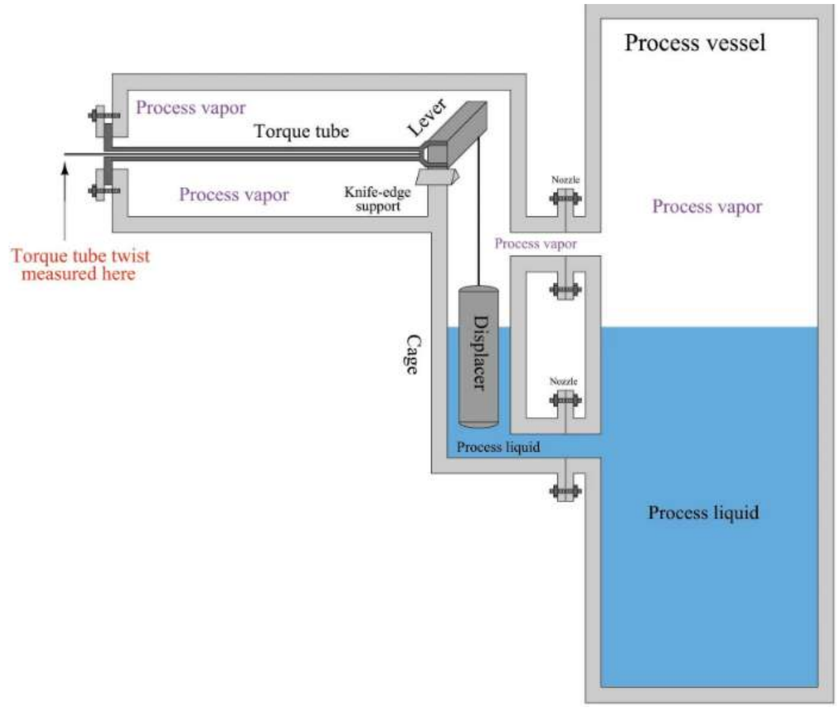


These sensors use an antenna on the radar sensor to transmit microwaves. The product being sensed reflects these microwaves to the antenna, and the time between signal emission and reception is proportional to the product level. Radar sensors offer many benefits. They are not affected by temperature, pressure, or dust and can measure liquids, pastes, powders, and solids. They are also very accurate and do not require calibration, and they are non-invasive because they do not have to touch the product. They are, however, expensive and have a limited detection range. Radar sensors, like ultrasonic sensors, are ideal for hot liquid storage tanks. # work by transmit & receive high frequency electromagnetic waves (Time α Level).

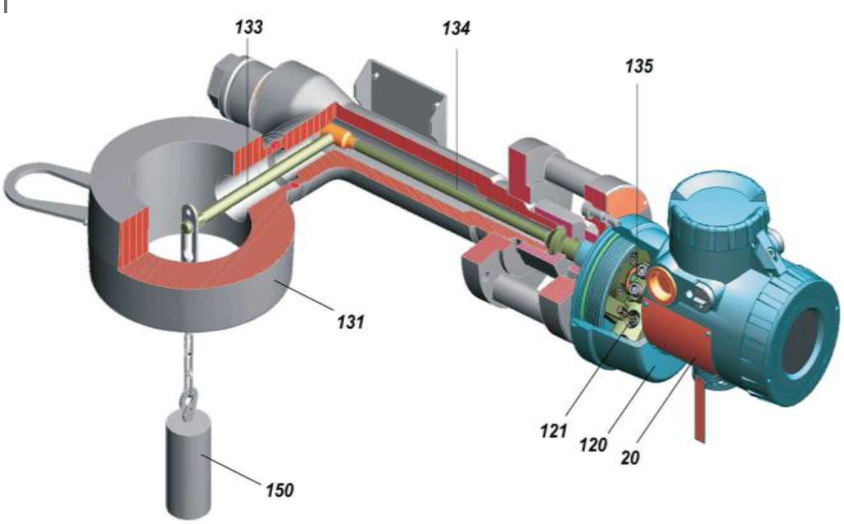
Advantages:	Disadvantages:
• Accurate • No Calibration. • Non-touchable(Non-invasive). • Non-affected by (Temp, Pressure or dust). • Measure liquids , powders , solids.	• More expensive. • Limited detection range.

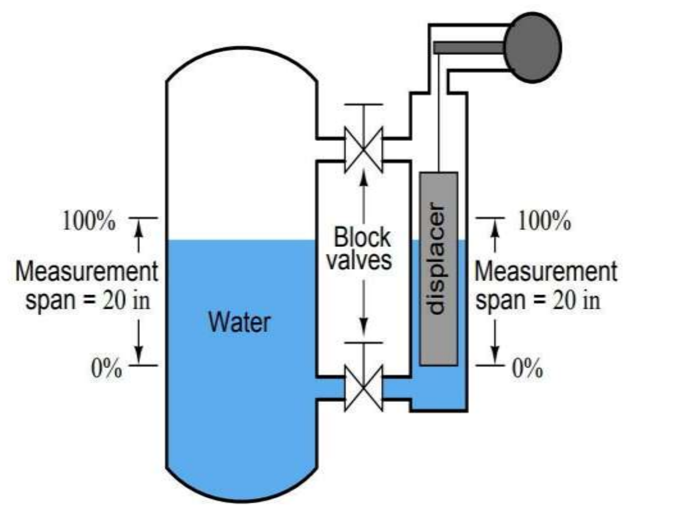


⑨ Displacer:



Displacer level sensor use Archimedes' Principle to observe liquid level by unendingly measurement the load of a displacer rod immersed within the process liquid.
The displacer is cylindrical in form with a continuing cross-sectional area and created long or short as needed. Normal heights range from fourteen inches to one hundred twenty inches.
As liquid level can increase, the displacer rod experiences a bigger buoyant force, creating it appear lighter to the sensing instrument, that interprets the loss of weight as a rise in level and transmits a proportional o/p signal.
As liquid level decreases, the buoyant force on the displacer rod decreases with a corresponding weight increase that is understood as decreasing level by the level detector that then provides a corresponding signal output.

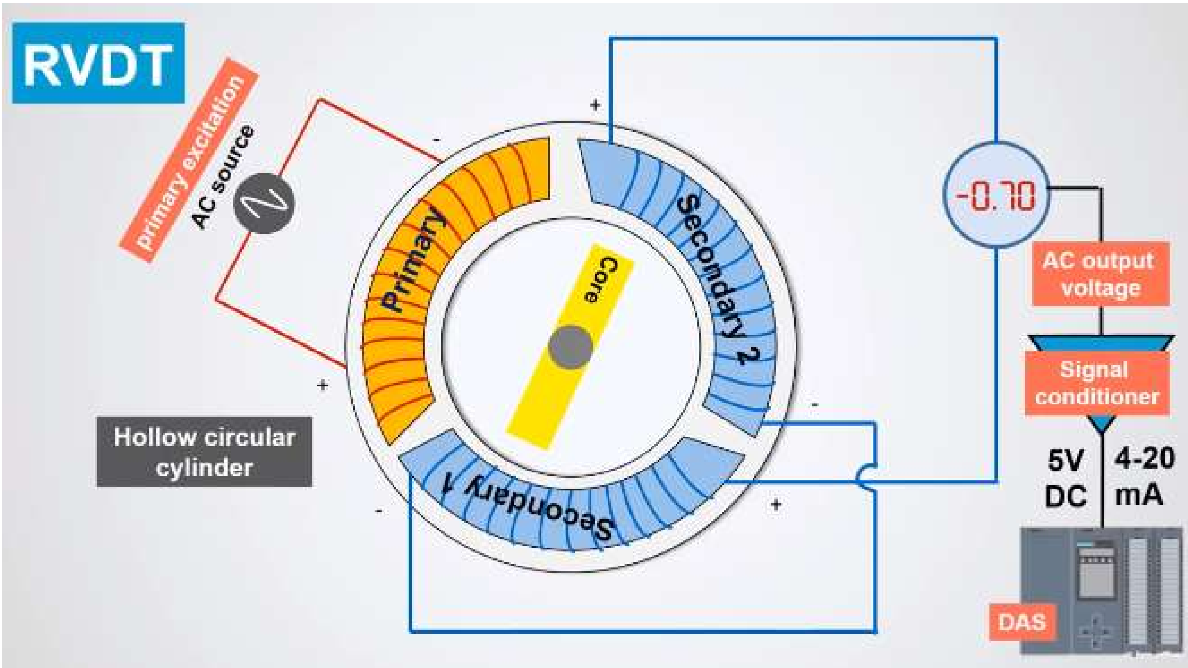




Transmission level and torque tube transmit movement of the displacer and convert it rotor motion.
(RVDT) transfer it to electrical signal (4:20 mA).

RVDT : Rotary Variable Differential Transformer

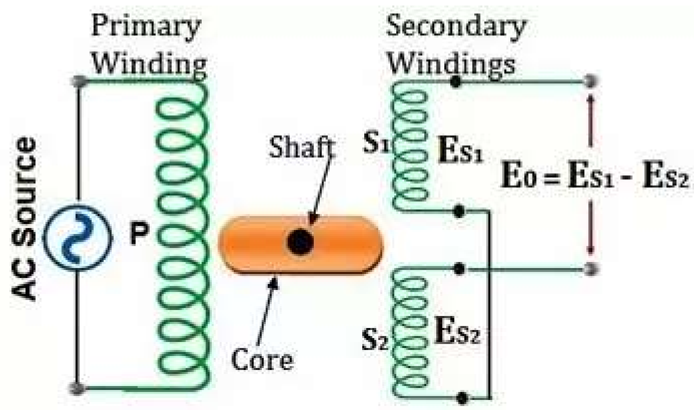
➤ RVDT:



(RVDT) is an electro-mechanical transducer that provides a variable AC output voltage that is proportional to the angular displacement of its input shaft. As RVDT is an AC-controlled device, there is no electronic component inside it. Also, the electrical output of RVDT is obtained by the difference in secondary voltages of the transformer, so it is also called a Differential Transformer.

RVDT is an electro-mechanical inductive **transducer** that converts angular displacement into the corresponding electrical signal. It is the most widely used inductive sensor due to its high accuracy level. Since the coil of RVDT is designed to measure an angular position, it is also known as an **angular position sensor**. Unlike LVDT, RVDT is also a passive differential transducer.

The design and construction of RVDT is similar to LVDT. The only difference is the shape of the core in transformer windings. LVDT uses the soft iron core to measure the linear displacement whereas RVDT uses the Cam-shaped core (Rotating core) for measuring the angular displacement.



The working principles of RVDT and LVDT both are the same and based on the mutual induction principle. When AC excitation of (5-15) Volt at a frequency of 50-400 Hz is applied to the primary windings of RVDT a magnetic field is produced inside the core. This magnetic field induces a mutual current in secondary windings. Then due to transformer action, the induced voltages in secondary windings (S_1 and S_2) are E_{s1} and E_{s2} respectively. Hence the net output voltage will be the difference between both the induced secondary voltages.

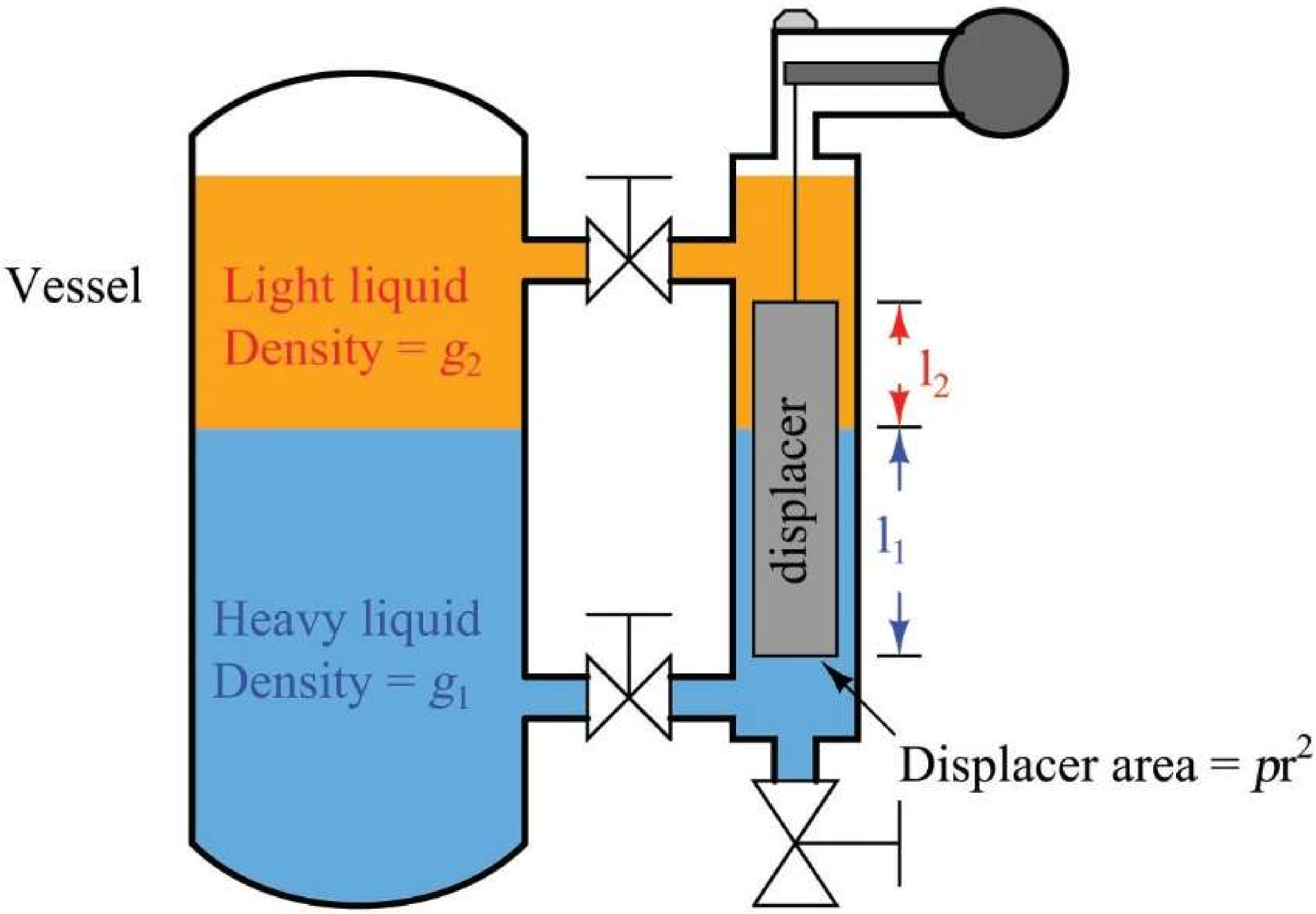
Hence Output will be **$E0 = Es1 – Es2$.**

Now according to the position of the core, there are three cases that arise. So Let's discuss these three cases one by one in detail.

- **Case 1: When the core is at the Null position:** When the core is at the null position then the flux linkage with both the secondary windings will be the same. So the induced emf (**E_{s1} and E_{s2}**) in both the windings will be the same. Hence the Net differential output voltage $E_0 = E_{s1} – E_{s2}$ will be zero ($E_0 = E_{s1} – E_{s2} = 0$). It shows that no displacement of the core.
- **Case 2: When the core rotates in the clockwise direction:** When the core of RVDT rotates in the clockwise direction. Then, in this case, the flux linkage with S_1 will be more as compared to S_2. This means the emf induced in S_1 will be more than the induced emf in S_2. Hence $E_{s1} > E_{s2}$ and Net differential output voltage $E_0 = E_{s1} – E_{s2}$ will be positive. This means the output voltage E_0 will be in phase with the primary voltage.
- **Case 3: When the core rotates in the anti-clockwise direction:** When the core of RVDT rotates in the anti-clockwise direction. Then, in this case, the flux linkage with S_2 will be more as compared to S_1. It means the emf induced in S_2 will be more than the induced emf in S_1. Hence $E_{s1} < E_{s2}$ and Net differential output voltage $E_0 = E_{s1} – E_{s2}$ will be negative. This means the output voltage E_0 will be in phase opposition (180 degrees out of phase) with the primary voltage.

➢ Displacement interface level measurement:

Displacer level instruments may be used to measure liquid-liquid interfaces just the same as hydrostatic pressure instruments. One important requirement is that the displacer always be fully submerged ("flooded"). If this rule is violated, the instrument will not be able to discriminate between a low (total) liquid level and a low interface level. This criterion is analogous to the use of compensated-leg differential pressure instruments to measure liquid-liquid interface levels: in order for the instrument to solely respond to changes in interface level and not be "fooled" by changes in total liquid level, both process connection points must be submerged.



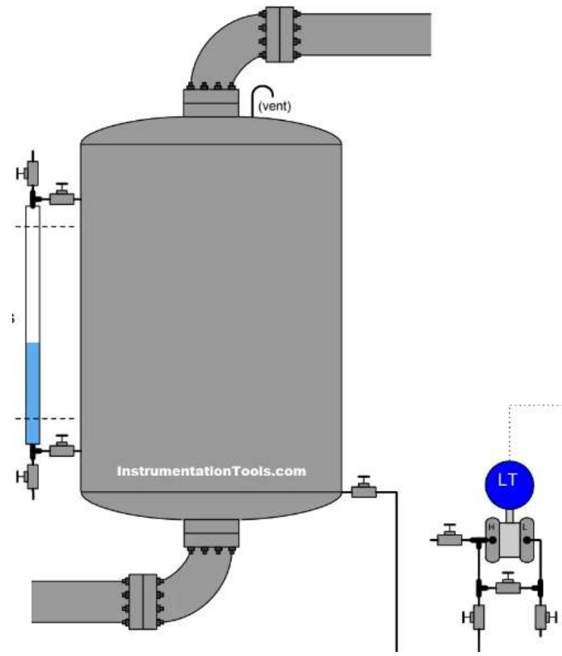
For example:

Light liquid has SG = 0.85 &&& Heavy liquid has SG = 1.1

SG: Specific gravity

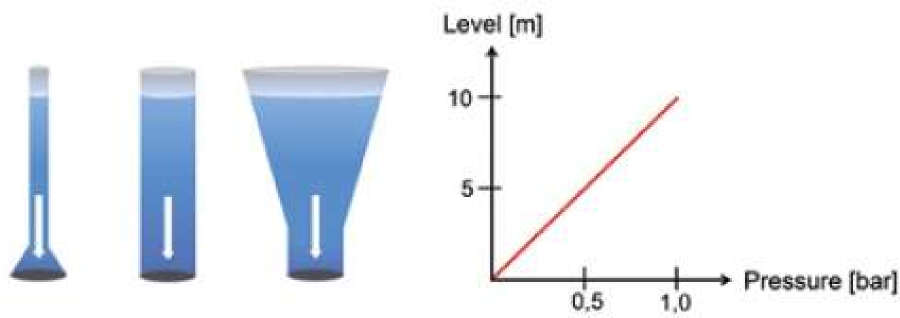
The specific gravity of an object is the density of that object divided by the density of water. The density of water is 1,000 kilograms per meter cubed

⑩ Hydrostatic:



Hydrostatic pressure sensors are used for the measurement of level or filling height of a liquid. Hydrostatic pressure measurement is suited for level measurement due to the hydrostatic effect of non flowing fluids.

$$P = \rho g h$$



Hydrostatic pressure and level measurement enjoys a consistently high popularity due to it’s high robustness, high reliability and simple installation of this technology.

Advantages:	Disadvantages:
• Highly Accurate (0.25%). • Ideal for wide range of liquids. • Ranges up to 30 M water. • Used in sea water, oil, chemical, …	• Need to calibrate (Span Setting). • Unsuitable for bulk material

Note : Accurate measurement requires either media with constant density or continuous density measurement of the medium

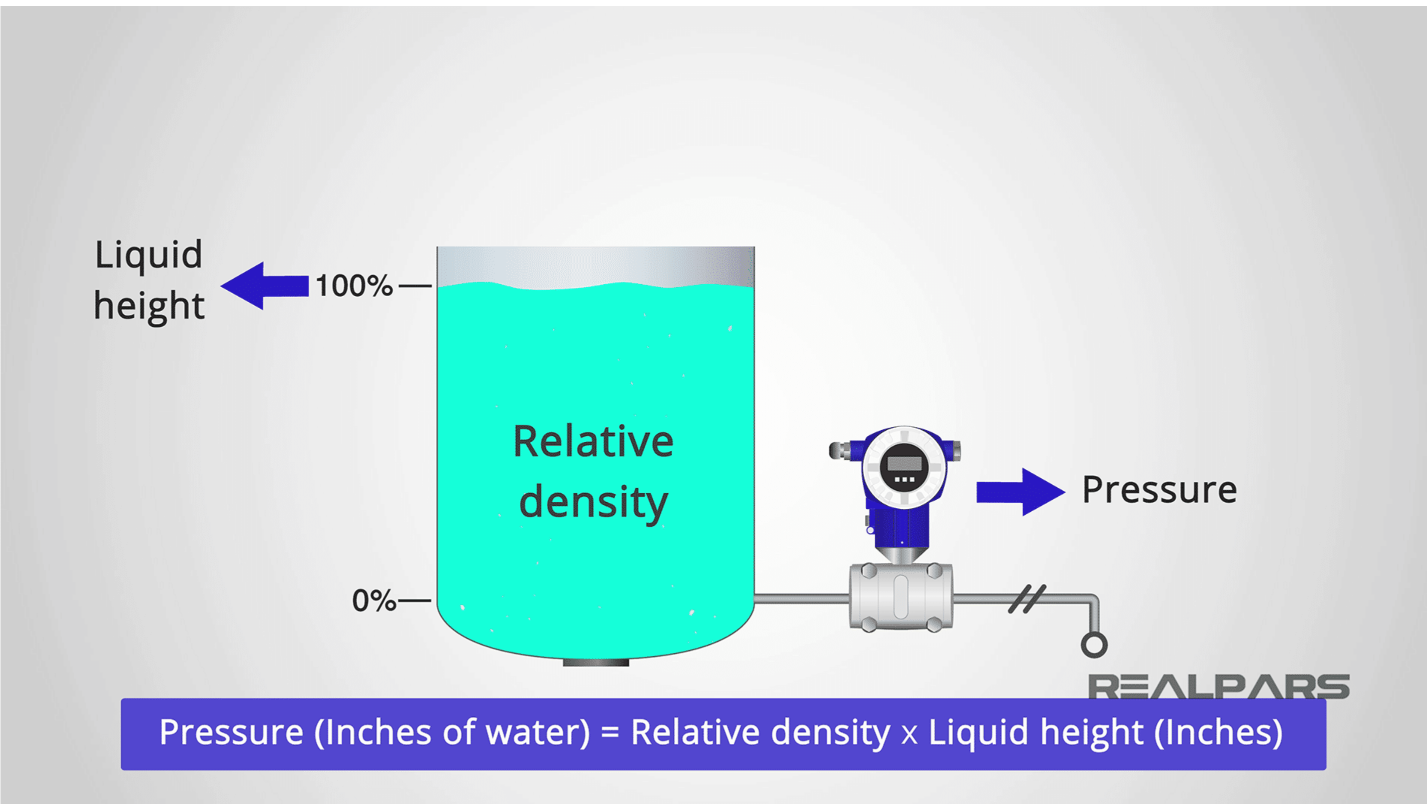
⑪ Differential Pressure:

Differential Pressure Transmitter can be used to measure the vessel level. We said earlier that the pressure at the bottom of a vessel is directly related to the level of the liquid in the vessel. In that case, if we connect a Differential Pressure Transmitter to the reference, or zero percent point of that vessel, we can use the pressure measurement to determine the level.

Another variable that has a major effect on the pressure at the reference point of the vessel is the relative density of the liquid in that vessel. Relative density is also called specific gravity.

There is a relationship between pressure, relative density, and liquid height. That relationship can be expressed as:

Pressure (inches of water) = Relative density × Liquid height (inches)

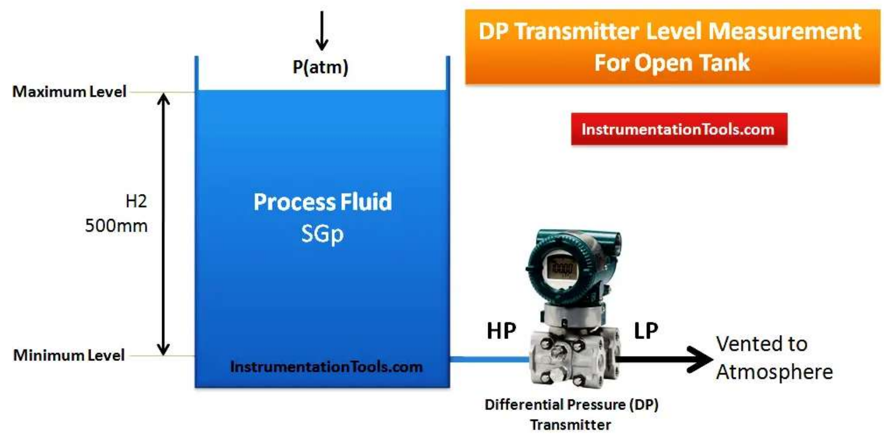


we can measure the level of an open vessel using a differential pressure transmitter

>>> The High-Pressure Port is connected at the 0 meters point and the Low-Pressure Port is vented to atmosphere.

Δp transmission

- **Open Vessel**
- **Closed Vessel**
  - Dry leg
  - Wet leg



At Zero level = 0 mmwc

At Span level = H x Specific gravity

= 500 mmwc

Then Range = 500 – 0 = 500 mmwc

So, we have to set Lower Range Value (LRV) = 0 mmwc and Upper Range Value (URV) = 500 mmwc in the DP Transmitter using HART communicator.

When zero suppression is used then H1 height always filled with process fluid.
At zero level (LRV) = H1 x specific gravity

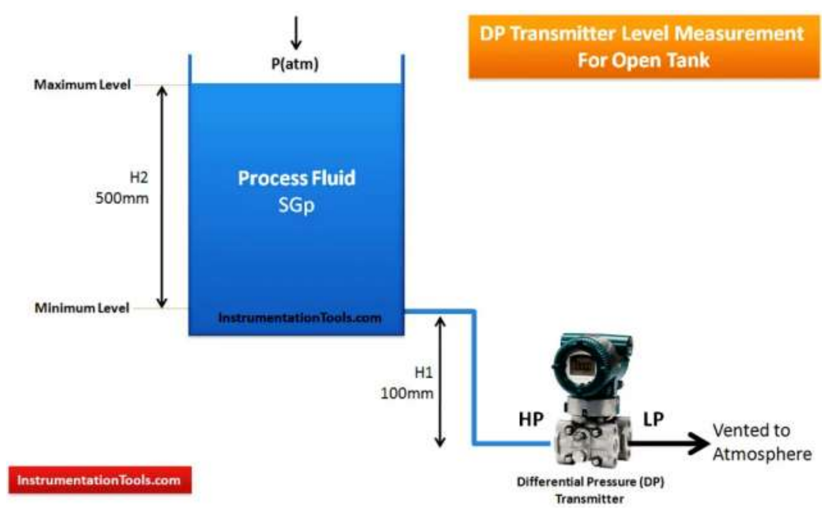
= 100 x 1.0

= 100 mmwc

At 100% level (URV) = (H1 + H2) x specific gravity

= (100 + 500) x 1.0

Range = URV – LRV = 600 – 100 = 500 mmwc



So, we have to set Lower Range Value (LRV) = 100 mmwc and Upper Range Value (URV) = 600 mmwc in the DP Transmitter using HART communicator.

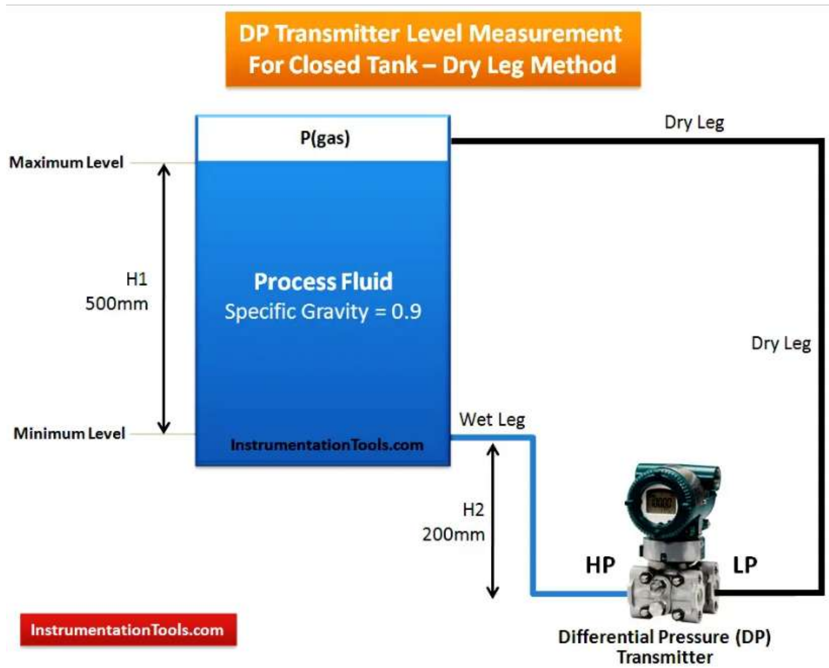
➢ Closed Vessel:

- In closed tank DP level measurement, LP leg is connected to the top of tank.

There are two methods in closed tank DP Level Measurement.

Dry leg method:

- Dry leg method is used in normal close tank where vapor is not condensate and temperature of process is equal to atmospheric.
- Simply when LP side of the DP transmitter is filled with any gas/air then we call it as Dry Leg & we apply Dry Leg Method for calculations.



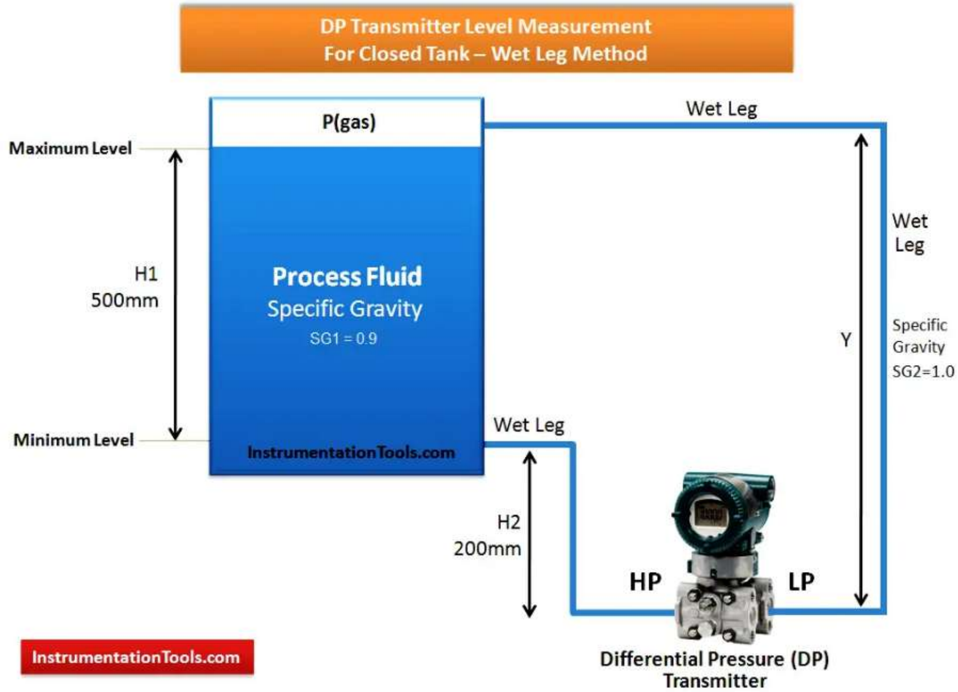
At zero level (LRV) = pressure acting on HP leg – Pressure acting on LP leg
=H2 x specific gravity – 0
= 200 x 0.9 – 0
= 180 mmwc

At 100 % level (URV) = pressure acting on HP leg – Pressure acting on LP leg
= (H2+H1) x specific gravity – 0
= (200 + 500) x 0.9 – 0
= 630 mmwc

Range = URV – LRV = 630 – 180 mmwc = 450 mmwc
So, we have to set Lower Range Value (LRV) = 180 mmwc and Upper Range Value (URV) = 630 mmwc in the DP Transmitter using HART communicator.

Wet leg method:

Wet leg method is used where vapor has a tendency to make the condensate and temperature of process is high or low from the atmospheric.



- For DP Transmitter Configuration, we have to find out Zero Level & Span Level. Accordingly, we have to configure Lower Range Value (LRV) and Upper Range Value (URV) using HART communicator.

Y = H1 +H2 = 500 + 200 = 700 mm

- <u>At zero level (LRV)</u> = pressure acting on HP leg – Pressure acting on LP leg

= H2 x SG1 – Y x SG2
= 200 x 0.9 – 700 x 1.0
= 180 – 700
= – 520 mmwc

- <u>At 100 % level (URV)</u> = pressure acting on HP leg – Pressure acting on LP leg

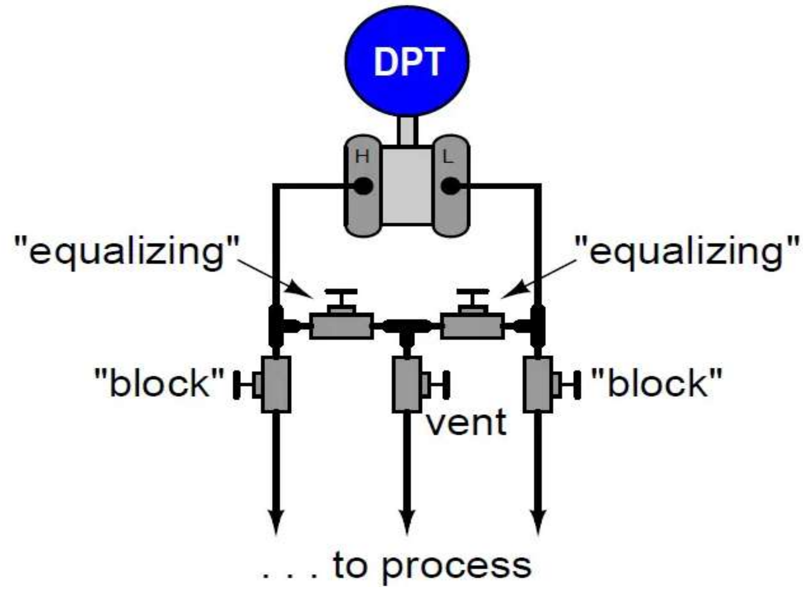
= (H2+H1) x SG1 – Y x SG2
= (200 + 500) x 0.9 – 700 x 1.0
= 630 – 700
= -70 **mmwc**

<u>Range</u> = URV – LRV = -70 – (-520) = 450 mmwc

So, we have to set Lower Range Value (LRV) = -520 mmwc and Upper Range Value (URV) = -70 mmwc in the DP Transmitter using HART communicator.

➢ Differential Pressure Transmitter with 5 Way Manifold Valve:

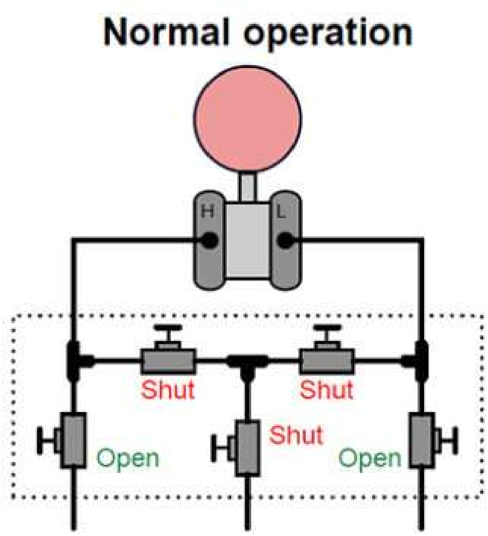
Some differential pressure transmitters are equipped with 5 way valve manifolds. These valve networks allow for blocking, equalizing, and bleeding of the transmitter's two pressure ports, the valves being arranged in this pattern:



What can be done with this manifold that cannot be done with a three-valve manifold?

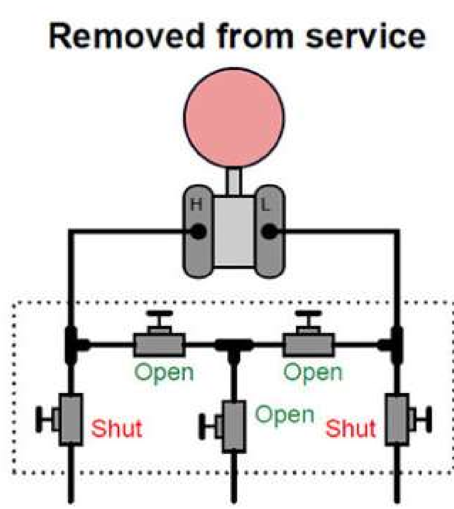
❖ *Normal valve positions:*

- Both block valves open.
- Both equalizing valves closed.
- Vent valve closed.



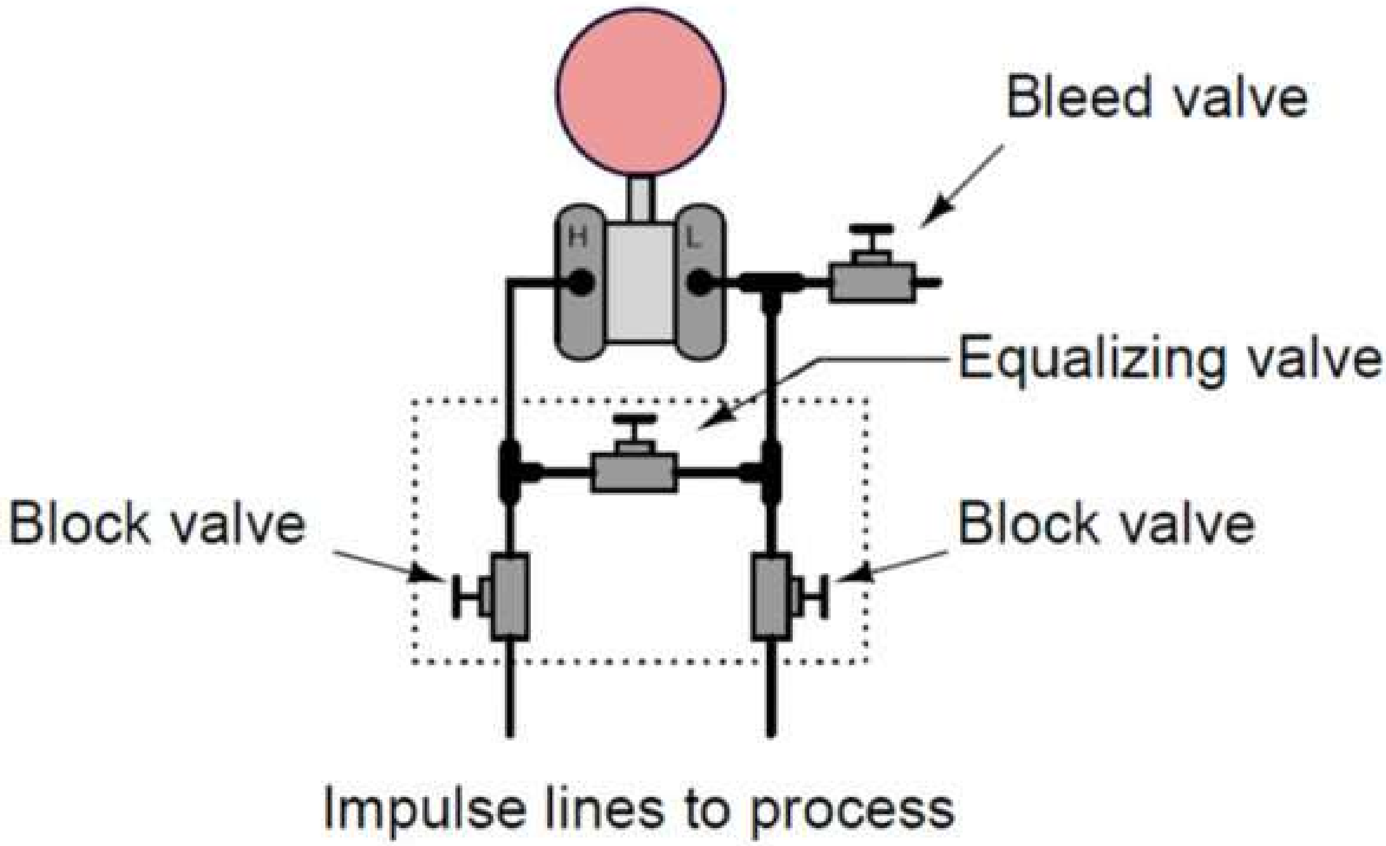
❖ *Removing differential pressure transmitter from service:*

- Close one block valve.
- Open both equalizing valves (which one first does not matter).
- Close the other block valve.
- Open the vent valve.
- Tag all valves, notifying of transmitter's planned return time/date.
- Disconnect the transmitter from the manifold.



Restoring the transmitter back to service is as simple as reversing all the steps taken to remove it from service (i.e. go through the list backwards, doing the reverse of each instruction).

❖ *Difference between 5-valve manifold and 3-valve manifold?*



One feature that 5-valve manifolds provide over 3-valve manifolds is the ability to route a vent tube to a remote (safer) location, for use with particularly hazardous process fluids.

5-valve manifolds allow for in-place transmitter calibration, provided one of the ΔP transmitter's sides has an atmospheric vent. By connecting the calibrating pressure source to the vent line, one can route the calibrating pressure to either side of the transmitter (only), while keeping the other side vented.