

Training Session on Field Instruments at Paradip Refinery

**SH. K D AGHARA
SH. S P TANDON
SH. A K RAUT**

Instrumentation

Instrumentation is the technique for measuring the value of different process parameters like pressure, flow, level or temperature etc. and supplying a process variable signal (4mA to 20mA / 1- 5 V / 3 to 15 psi) that is proportional to the measured parameters. The output signals are standard signal used to provide indication, alarms, control, to drive final control element for automatic control & safety functions.

Brief about different aspects for various field instrumentation

- **Comparison of old and present installation**
- **Safety & Reliability**
- **Selection criteria :Process, Technology, Hazardous area.**
- **Maintenance provision.**
- **How to reduce source of error : Hook up, Location, QAP, Gap between licensor & OEM docs.**
- **Experience sharing of incidents**

Level measurement in Refining Industry

- Earlier about 80% level instruments were based on direct, float / displacer sensors. Present trend is use of GWR, Ultrasonic, DPT, Nucleonic, Balance ...
- Important to guards vessels / columns etc. against over filling & empty and proper Interface measurement.
- Higher performance & Lower maintenance.
- Selection criteria : Performance requirement, installation constraint, service, process condition .

Types of field instruments for

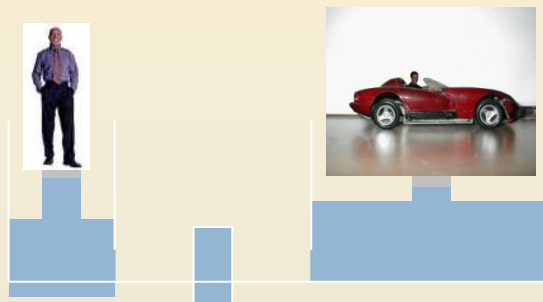
- **Pressure measurement**
- **Flow measurement**
- **Level measurement**
- **Temp measurement**
- **Control / ON-OFF valves**
- **Misc. Instrument hardwares.**

Process condition v/s type of instrument reference	Pressure	Capacitance	Ultrasonic	GWR	NC radar	Nuclear	Displacer	Magnetostri	Floats	Vibrating fo
Aeration	M	G	M	G	M	M	G	M	G	G
Agitation	G	M	P	M	M	G	G	M	M	G
Ambient temp changes	M	G	M	G	G	G	M	G	G	G
Corrosion	M	G	G	M	G	G	M	M	M	M
Density changes	M	G	G	G	G	M	M	M	M	G
Dielectric changes	G	P	G	G	G	G	G	G	G	G
Dust	G	G	P	G	M	G	P	G	P	P
Foam	G	M	P	M	M	G	G	G	G	M
High process temp limits	G	G	P	G	M	G	G	P	G	G
High vessel pressure limit	G	G	P	G	M	G	G	P	G	G
Internal obstruction	G	M	P	M	M	M	G	G	M	G
Low process temp limits	G	G	G	G	M	G	M	G	G	G
Low vessel pressure (Vacuum)	M	G	P	G	G	G	G	G	G	G
Noise	G	G	M	M	G	G	G	G	G	G
Product coating	P	P	M	M	G	M	P	P	M	M
Slurries	M	G	G	M	G	G	P	M	M	M
Solids	G	M	M	G	G	G	P	P	P	P
Vapors	P	M	M	G	G	G	G	G	G	G
Viscous, Sticky product	M	M	G	M	G	G	P	P	M	M
Good : This condition has no or little impact on performance of										
Moderate : This technology can handle this condition, but										
Poor : This technology does not handle this condition well.										

Key Points for successful commissioning

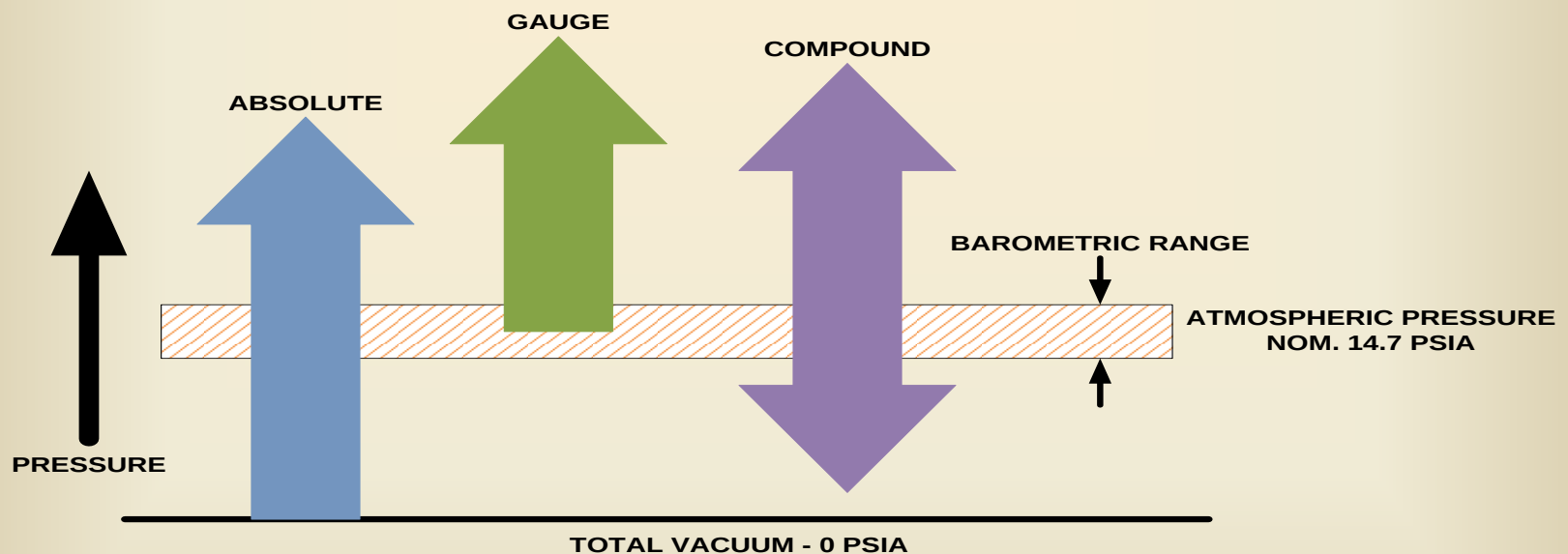
- Understand the source & types of problems associated with erection, installation, the first start up or any add on facility.
- List out the potential problem associated with the commissioning & used other's similar experience.
- Critical documents study.
- Take action for the ways to minimize the above & it's overall impact / consequences.
- Checklist preparation, compile & it's liquidation.
- Plan for 100 % Hydro testing of instrument Hook ups.
- Plan for 100 % loop checking.
- Witness 100 % interlock logics : Joint checking.

PRESSURE



Pressure measurement

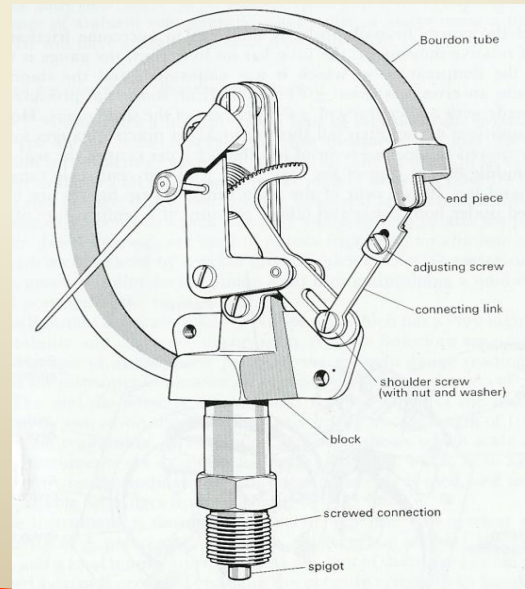
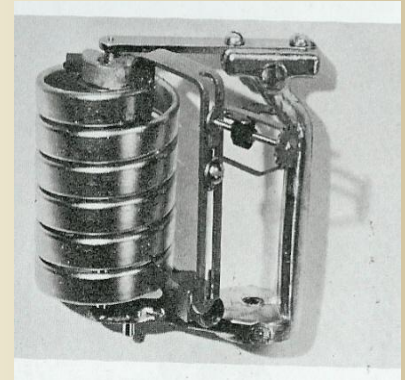
- Pressure, is force per unit area, thus it's closely related to the unit of force.



	Pascal	Bar	Torr	PSI
1atm	1.013×10^5	1.01325	760	14.695

Pressure Gauges

- A Bourdon gauge uses a coiled tube, which, as it expands due to pressure increase causes a rotation of an arm connected to the tube.
- Helical Pressure Element –
High Pressure, not as common



Pressure Gauge - Accessories

Snubber

Used for dampening and filtering and reducing the damaging effects of pulsation on a gauge. The snubber has a metal disc available in standard grades of porosity.



Pressure Limit Valve

Protects pressure instruments against surges and pulsations. Provides automatic positive protection and accurate, repeatable performance. Automatic pressure shut-off, built in snubber enhances instrument protecting performance.

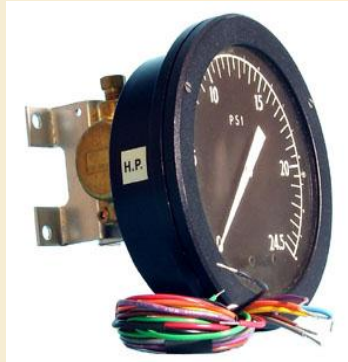


Siphon Tubes

Used to dissipate heat by trapping condensed liquid to keep high temperature steam or condensing vapor from damaging the pressure gauge.



Pressure Switches



Pressure Transmitters

- **Typical pressure ranges**
 - Wide ranges available. 0 to 0.3 PSIG up to 0 to 10,000 PSIG. (0-0.02 Bar up to 0-690 Bar)
- **Typical outputs:**
 - 4 to 20 milliamp (mA). Analogue signal.
 - Smart HART digital signal (rides on back of analogue signal).
 - Fieldbus digital serial signal.
- **Electrical connection**
 - ISO M20 (20mm)
 - 1/2" NPT

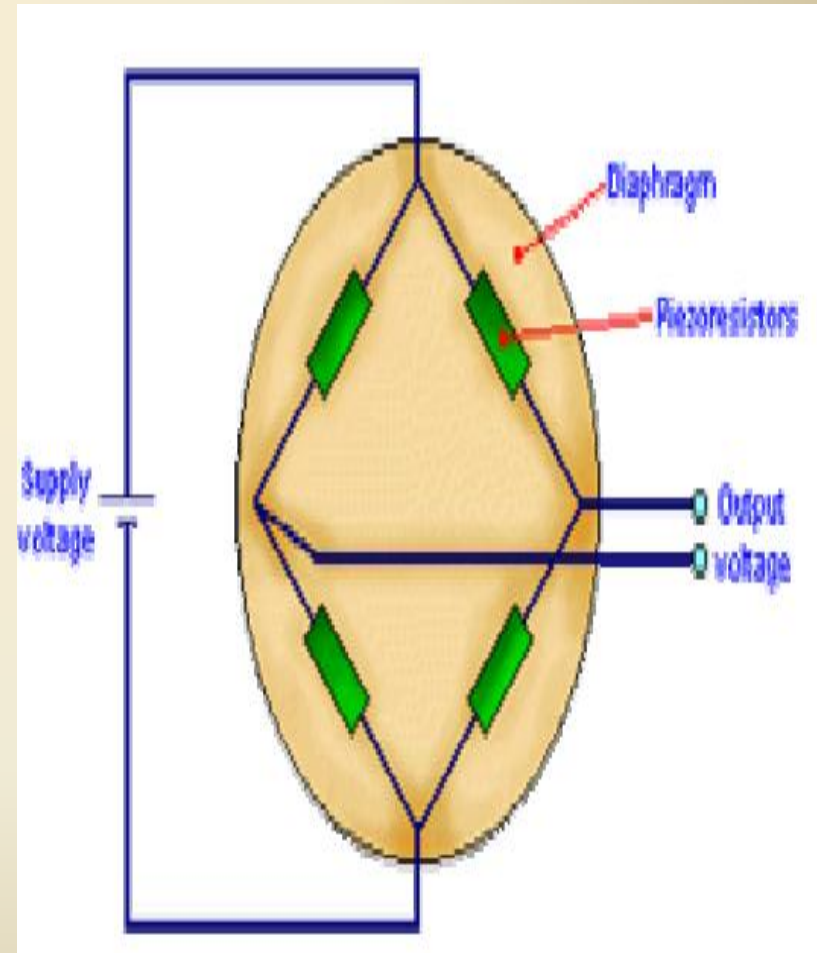


Piezoresistive & strain gauge sensors

When pressure is applied to the diaphragm it causes a strain in the resistors. The resistance of the piezoresistors changes in proportion to this strain, and hence the change in pressure .

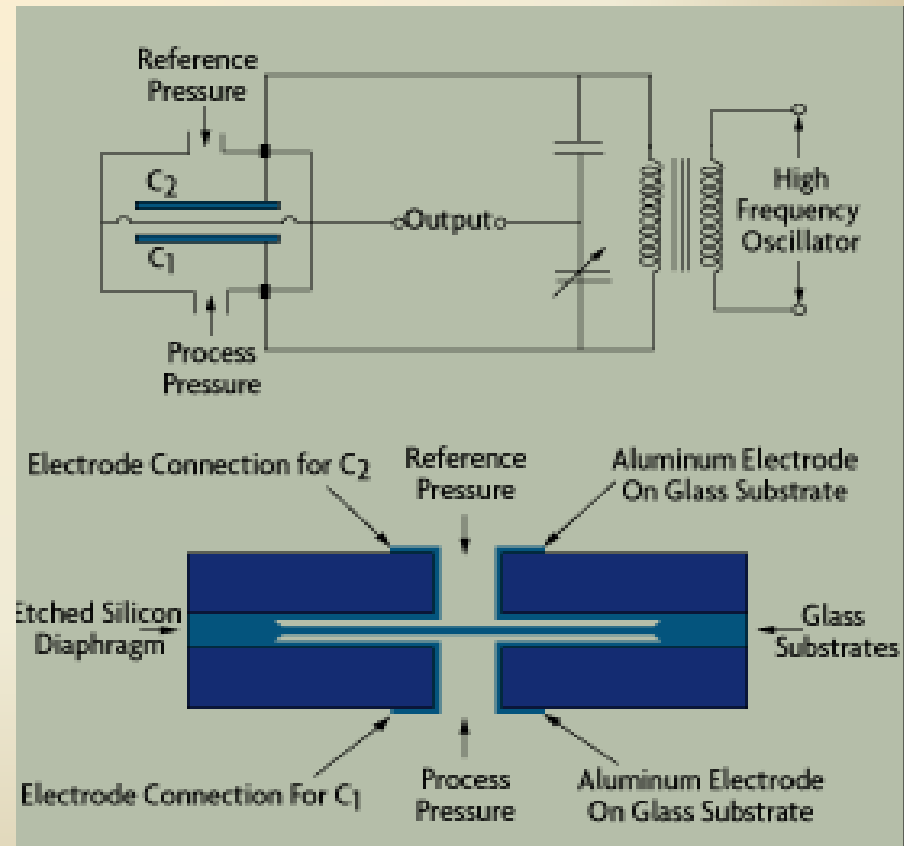
Uses : low pressure range ,high accuracy ,high repeatability .

Strain gauges for high pressure applications

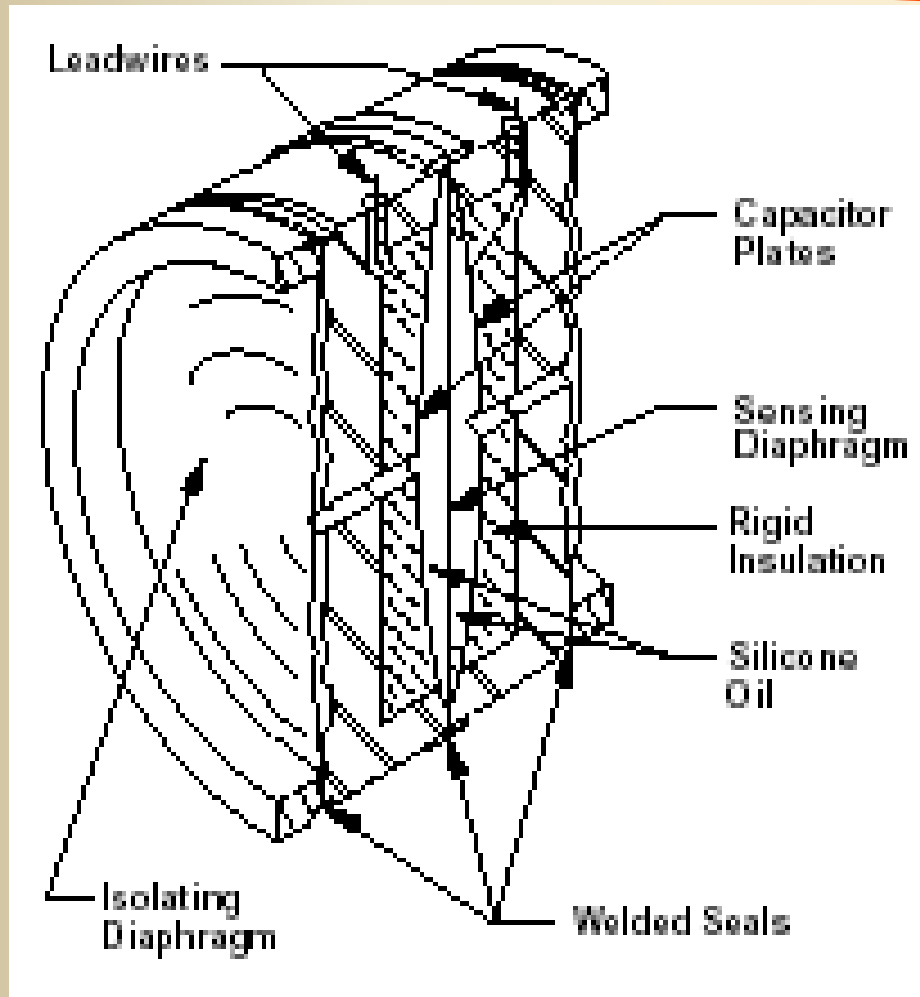


Pressure

- In a capacitance-type pressure sensor, a high-frequency, high-voltage oscillator is used to charge the sensing electrode elements. In a two-plate capacitor sensor design, the movement of the diaphragm between the plates is detected as an indication of the changes in process pressure.



Differential Pressure Transmitters



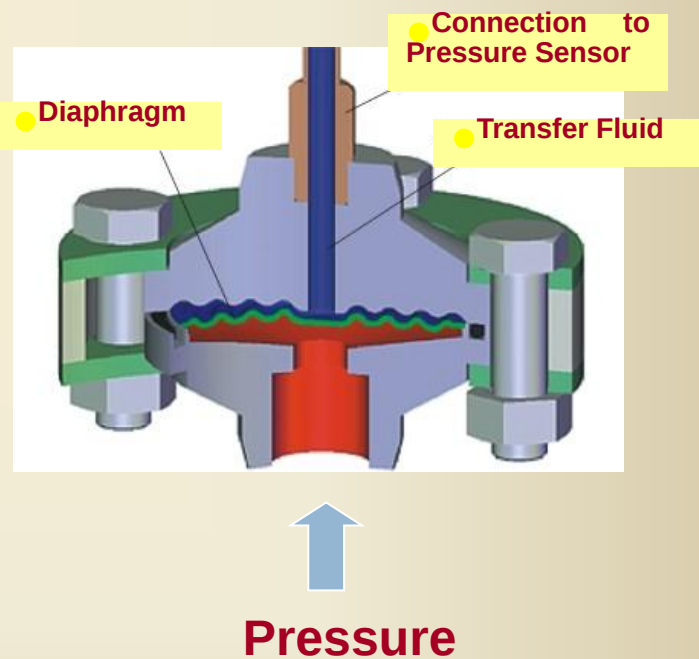
- Diagram shows a two-wire capacitance technique for DP measurement .
- Another common measuring technique is a strain gauge.
- Process pressure is transmitted through isolating diaphragms and silicone oil fill fluid to a sensing diaphragm.

The position of the sensing diaphragm is detected by capacitor plates on both sides of the sensing diaphragm.

Chemical seals



Flexible Stainless Steel Capillary

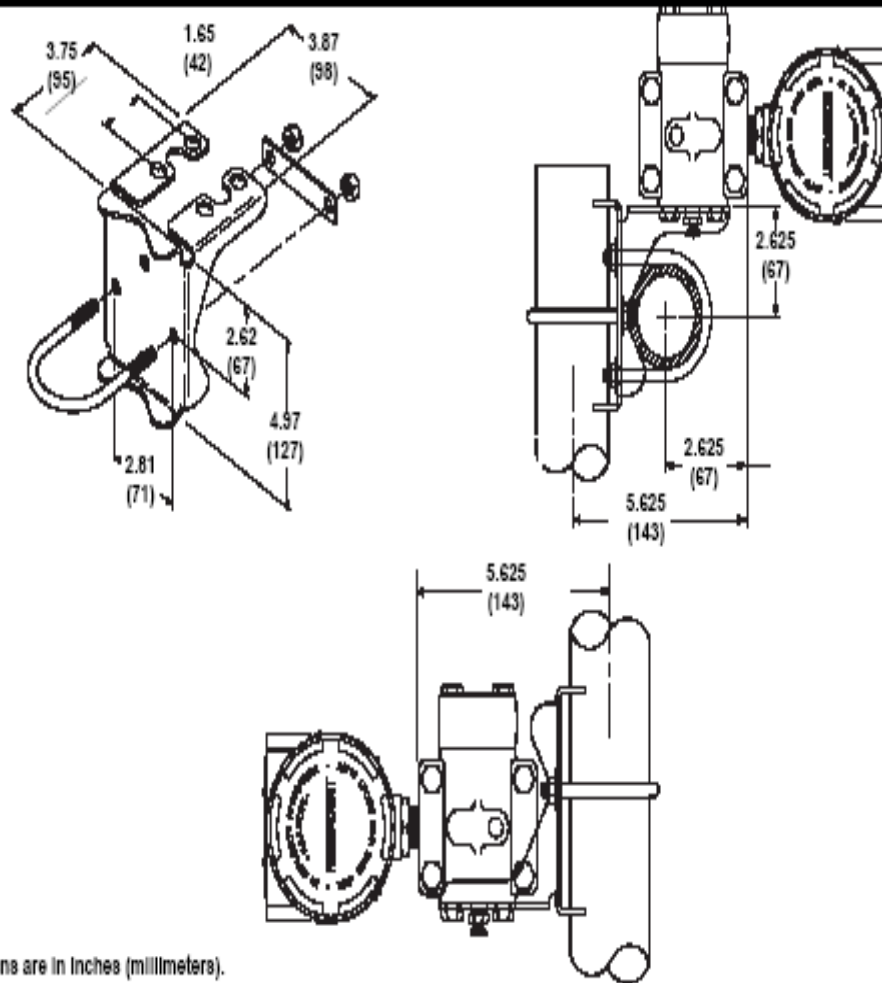


Chemical seals-Application

Application	Fill Fluid	Suitable Temperature for Pressures < 15 PSI	Suitable Temperature for Pressures > 15 PSI
General service	Silicone oil DC 200/50	-4° to 250° F	-4° to 392° F
	Silicone oil DC 200/10	-40° to 250° F	-40° to 400° F
Low temperature	Silicone Oil (4 cSt)	-130° to 176° F	-130° to 356° F
High temperature/ High vacuum	High-temperature oil (All threads welded during assembly)	4° to 392° F	-4° to 750° F (14° to 750° F with transmitters)
Oxygen/Chlorine service	Halocarbon 6.3	-40° to 176° F	-40° to 347° F
	Fluorolube FS-5	—	-40° to 392° F
Food and beverage	Glycerine *	—	60° to 462° F
	Glycerine/Water *	—	14° to 248° F
	Mineral Oil	-40° to 338° F	-4° to 482° F
	Food-Grade Silicone Oil	—	0° to 572° F
	Neobee M20	-10° to 200° F	-10° to 400° F

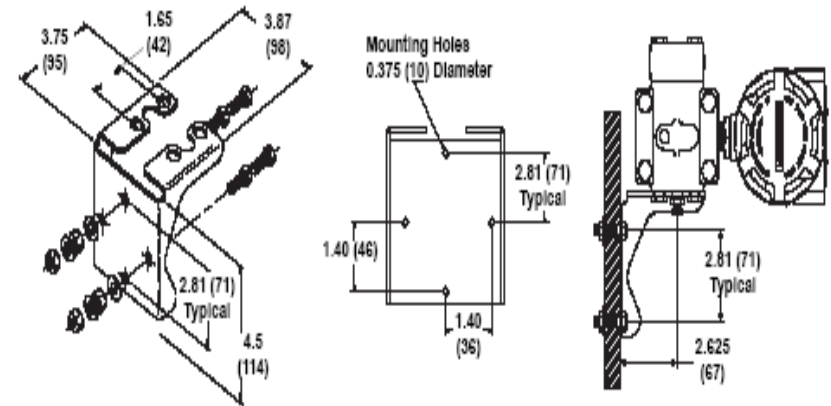
Installation

Mounting Bracket Option Codes B1, B4, and B7



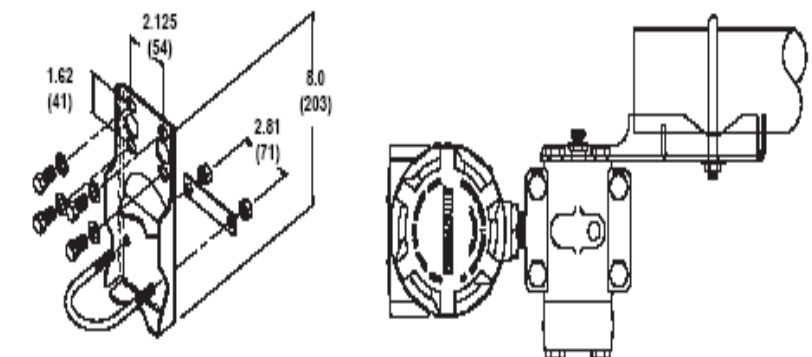
3051-3051B19A 1151-1151D, A06A

Panel Mounting Bracket Option Codes B2 and B5



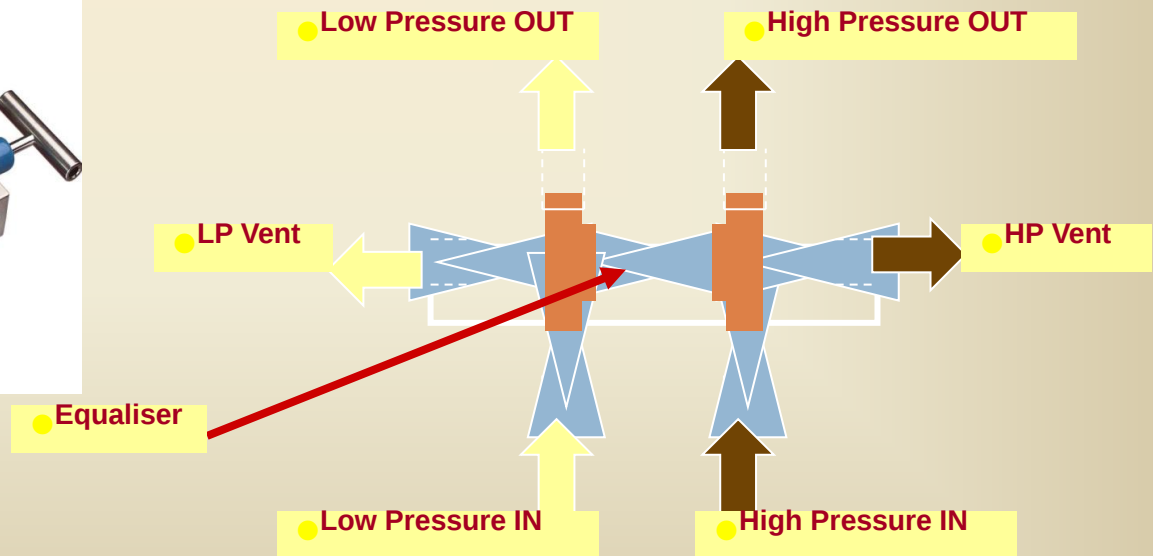
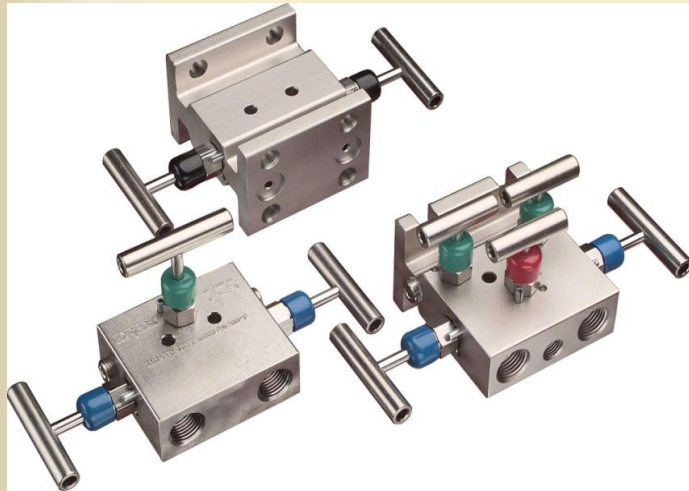
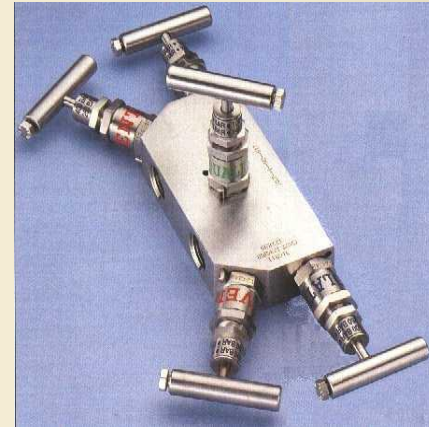
3051-3051A19A 1151-1151E06A

Flat Mounting Bracket Option Codes B3, B6, and B9

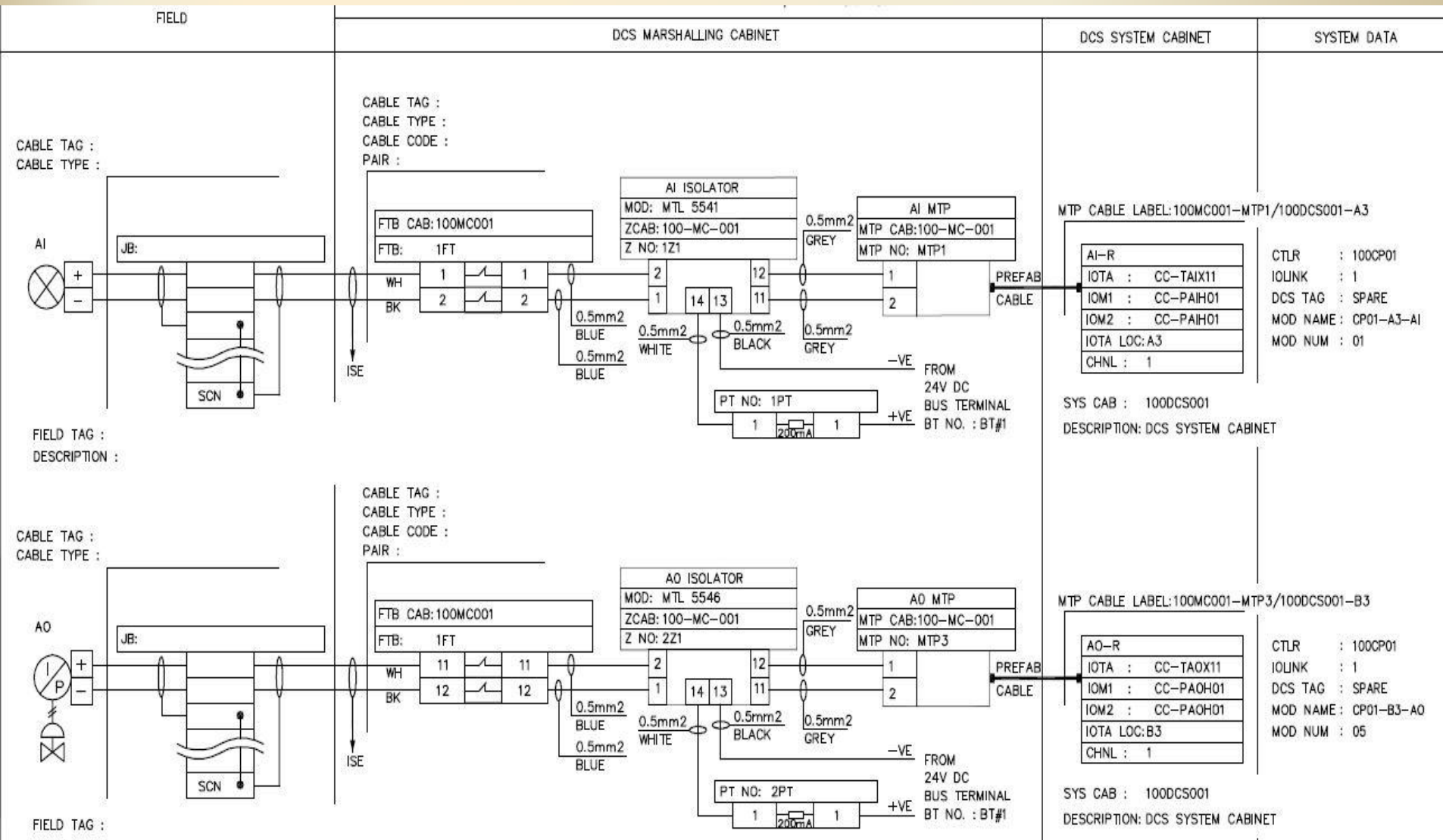


3051-3051H19B 1151-1151F06B

Manifolds



Typical Loop Drawing



FLOW



Flow Measurement

- **Volumetric Flow rate** :is the volume of fluid which passes through a given surface per unit time.
- Flow rate is determined by measuring the process stream velocity by restricting the flow using different measuring techniques. Velocity depends on the pressure differential that is forcing the stream of liquid or gas through a pipe. Because the pipe's cross-sectional area is known and remains constant, the average velocity is an indication of the flow rate. The basic relationship for determining the liquid's flow rate in such cases is:

$$Q = V \times A$$

where

Q = liquid flow through the pipe

V = average velocity of the flow

A = cross-sectional area of the pipe

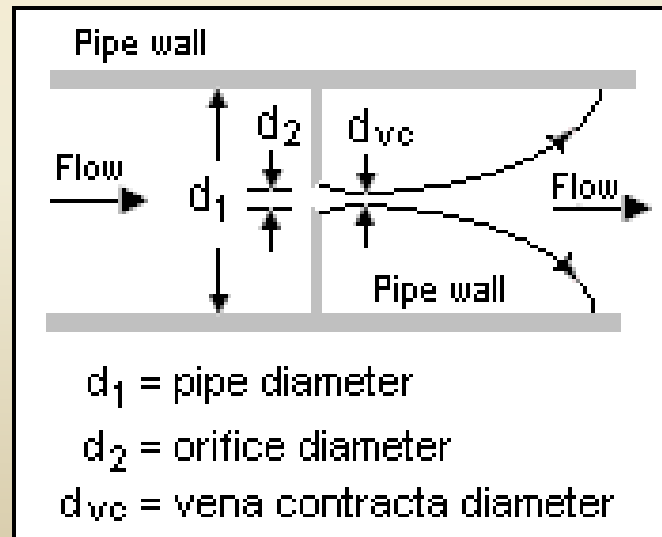
- Other factors that affect liquid flow rate include the liquid's viscosity and density, and the friction of the liquid in contact with the pipe.

Flow measurement techniques

- **Differential Pressure (Head) Type**
 - Orifice Plate - Concentric, Eccentric, Segmental, Quadrant Edge, Integral
 - Venturi Tube, Flow Nozzles
 - Pitot Tube, Averaging Pitot Tube (Annubar)
 - Variable Area (Rotameter)
 - Wedge Meter, V-Cone
- **Mass Type – measures the mass flow rate directly.**
 - Coriolis
 - Thermal
- **Velocity Type**
 - Magnetic
 - Ultrasonic - Transit Time, Doppler
 - Turbine
 - Vortex
- **Open Channel Type**
 - Weir
 - Parshall Flume
- **Other Types**
 - Positive Displacement
 - Target

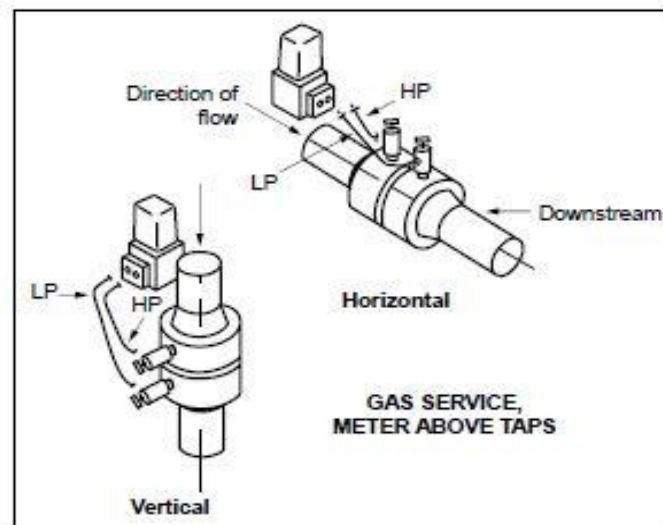
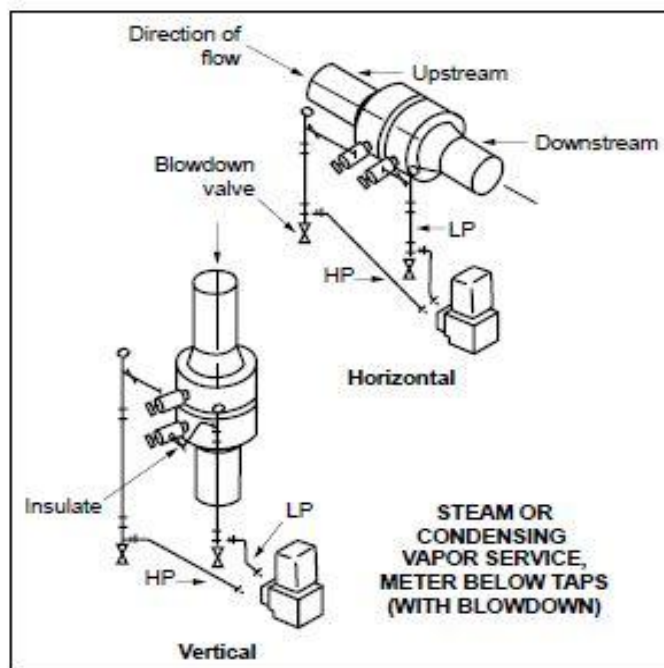
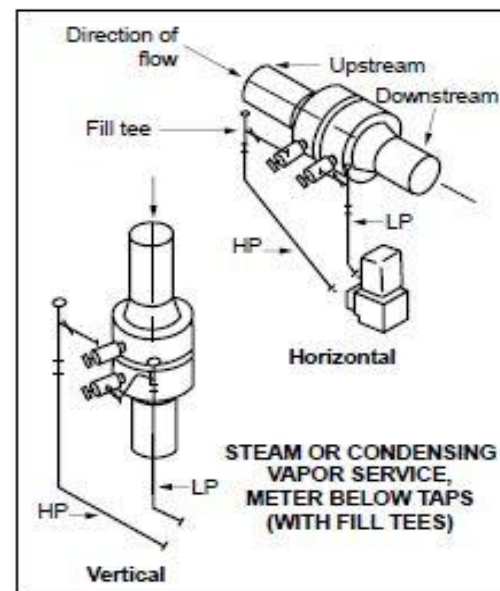
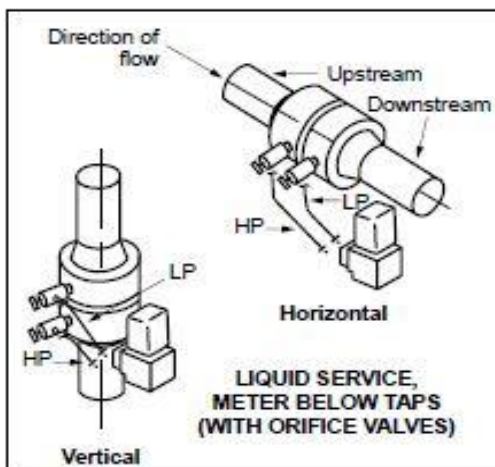
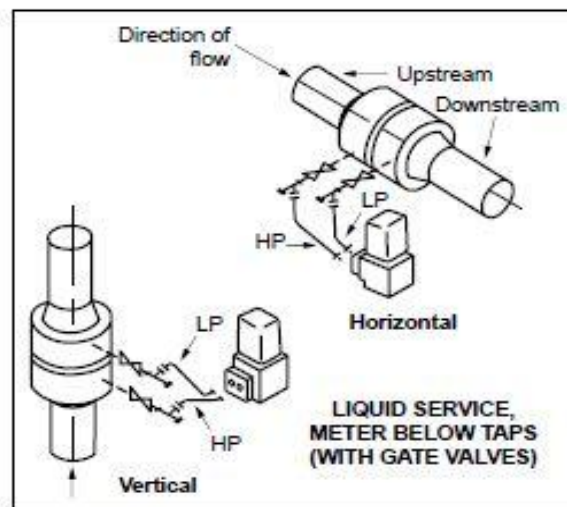
Orifice Plates

- An orifice plate is basically a thin metal plate with a hole bored in the centre. It has a tab on one side where the specification of the plate is stamped. The upstream side of the orifice plate usually has a sharp edge. When an orifice plate is installed in a flow line (usually clamped between a pair of flanges), increase of fluid flow velocity through the reduced area at the orifice develops a differential pressure across the orifice. This pressure is a function of flow rate.



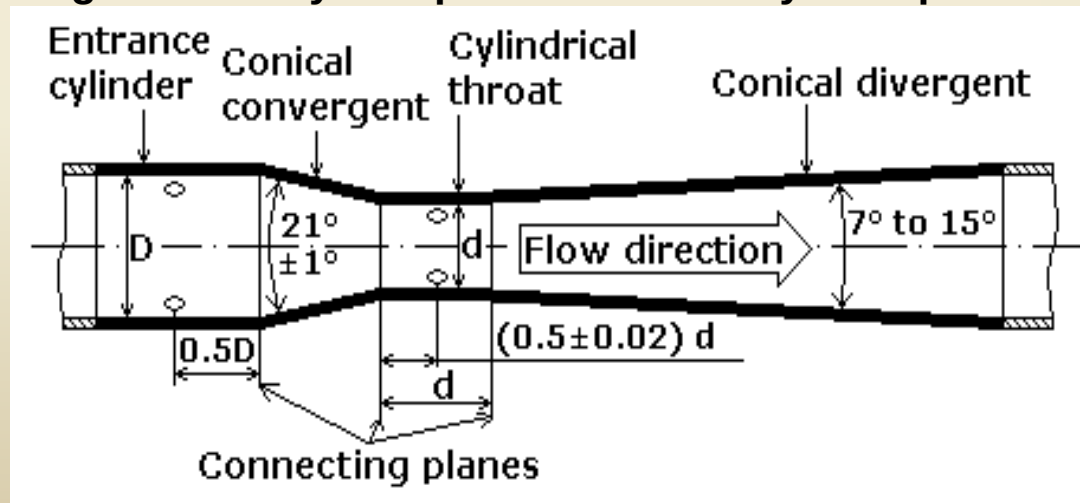


Orifice Plates Installation



Venturi Tubes

- For applications where high permanent pressure loss is not tolerable, a venturi tube is usually used. Because of its gradually curved inlet and outlet cones, almost no permanent pressure drop occurs. This design also minimizes wear and plugging by allowing the flow to sweep suspended solids through without obstruction.
- In a Venturi tube, the fluid is accelerated through a converging cone, inducing a local pressure drop. An expanding section of the meter then returns the flow to near its original pressure. These instruments are often selected where it is important not to create a significant pressure drop and where good accuracy is required.
- Used when higher velocity and pressure recovery is required.





Electromagnetic Flow meter

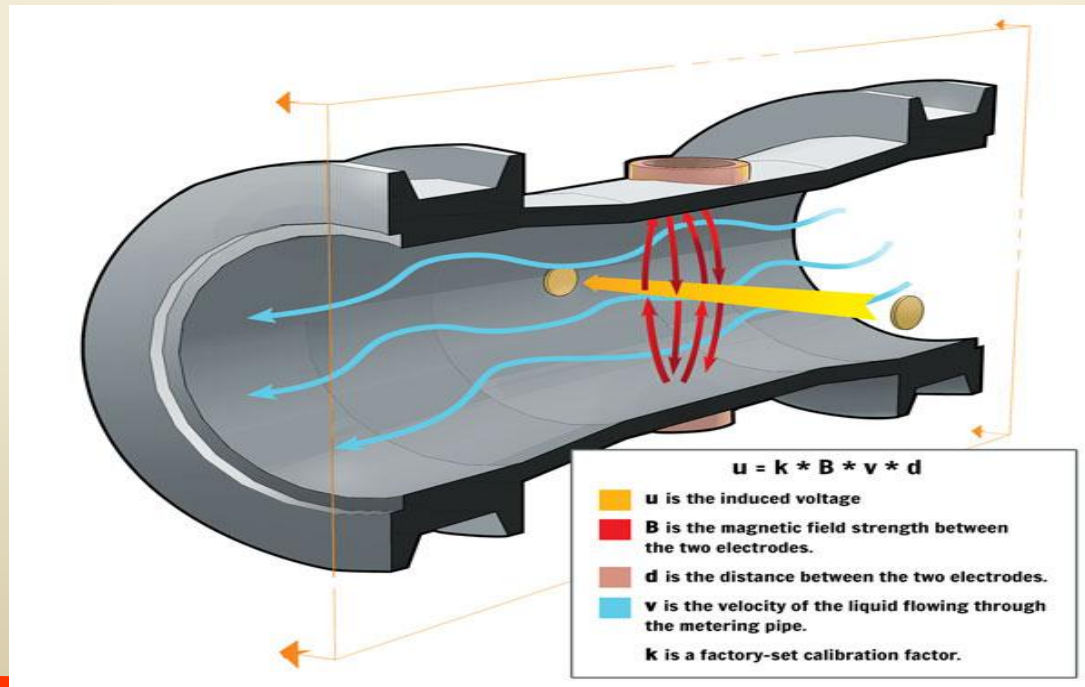
- Magnetic flow meters have been widely used in industry for many years.
- They are easy to install and use to the extent that existing pipes in a process can be turned into meters simply by adding external electrodes and suitable magnets.
- They can measure reverse flows and are insensitive to viscosity, density, and flow disturbances.
- Electromagnetic flow meters can rapidly respond to flow changes and they are linear devices for a wide range of measurements.
- As in the case of many electric devices, the underlying principle of the electromagnetic flow meter is Faraday's law of electromagnetic induction.

Electromagnetic Flow meter

- Principle of operation

When a conductive liquid flows through the magnetic field, a small voltage (u) is induced. This voltage is proportional to the velocity of the flow and is accurately measured by two stainless steel electrodes mounted opposite each other inside the metering pipe. The two electrodes are sent to signal conditioning circuit.

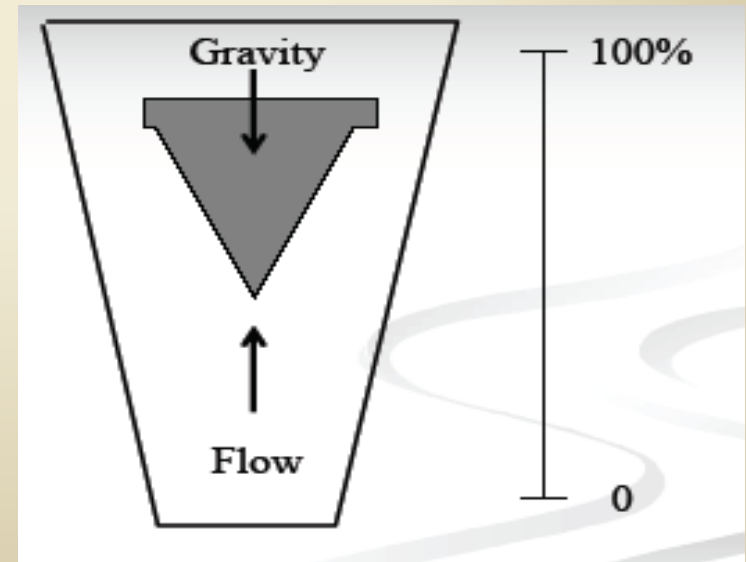
$$u = k * B * v * d$$





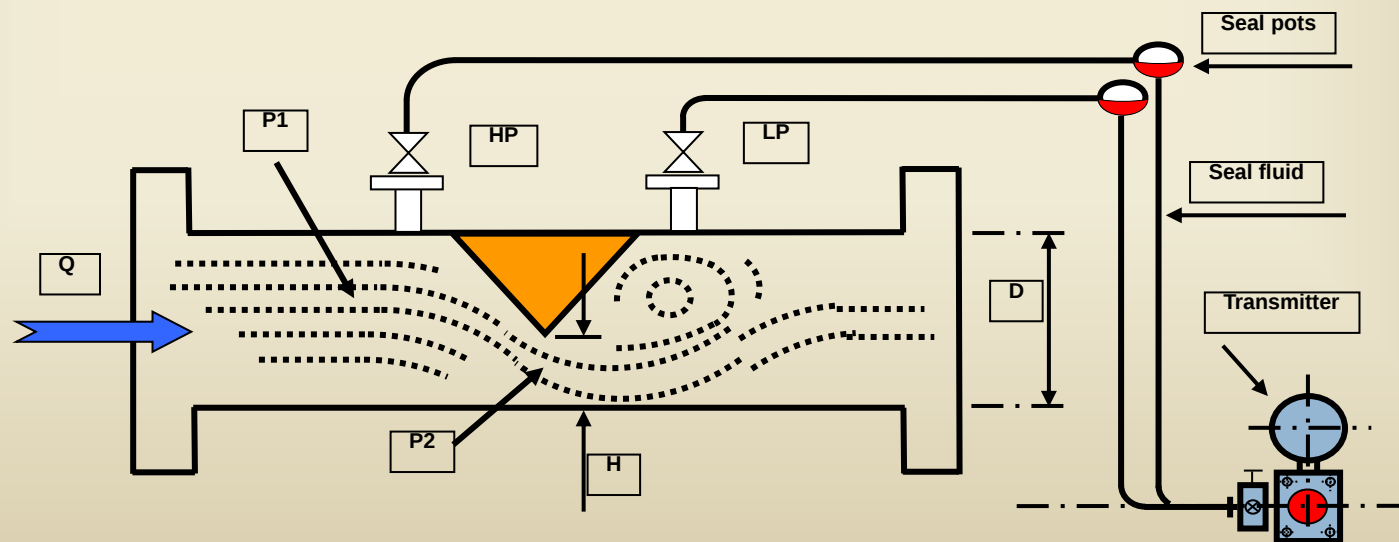
Rotameters : Variable area meter

- Fluid flow moves the float upward against gravity. Float will find equilibrium when area around float generates enough drag equal to weight - buoyancy.
- Some types have a guide rod to keep float stable.
- Low Cost
- Simple Reliable Design
- Can Measure Liquid or Gas Flows
- Tolerates Dirty Liquids or Solids in Liquid



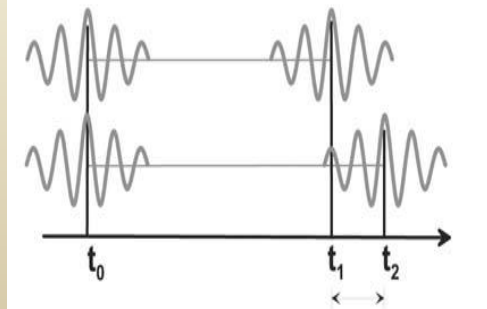
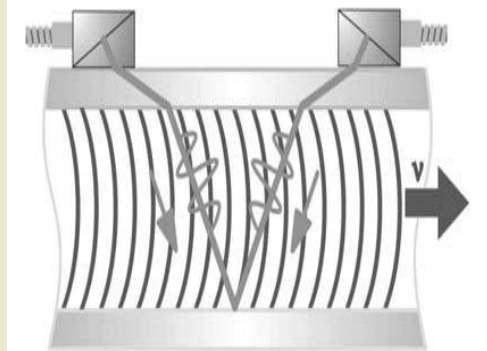
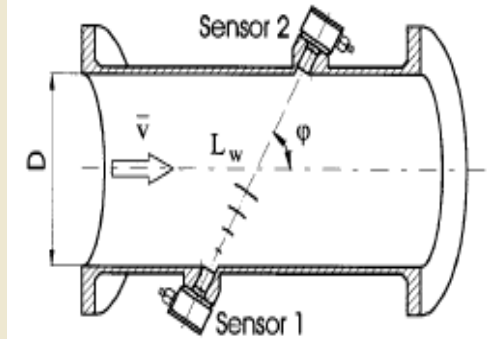
Wedge type flow measurement

- Wedge flow meters can be used on just about any liquid or gas, just like orifice plates. However they are generally chosen for dirty service applications, or high viscosity applications such as slurry or heavy oil, or where solids are present. For regular service applications consider other types of meters first unless wedge meters are specified by customer as preferred.
- Since they are a differential pressure device their sizing calculation is similar to that of other dP flow meters.



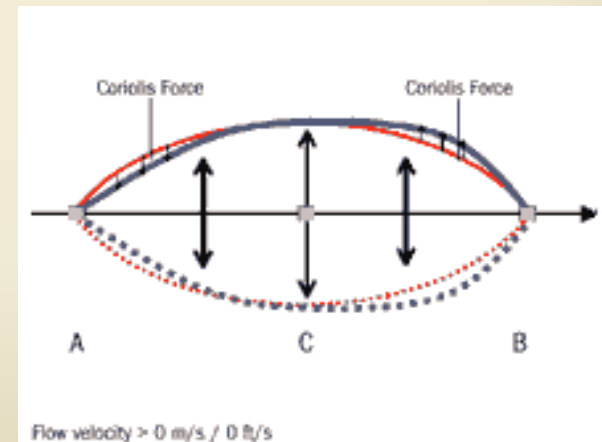
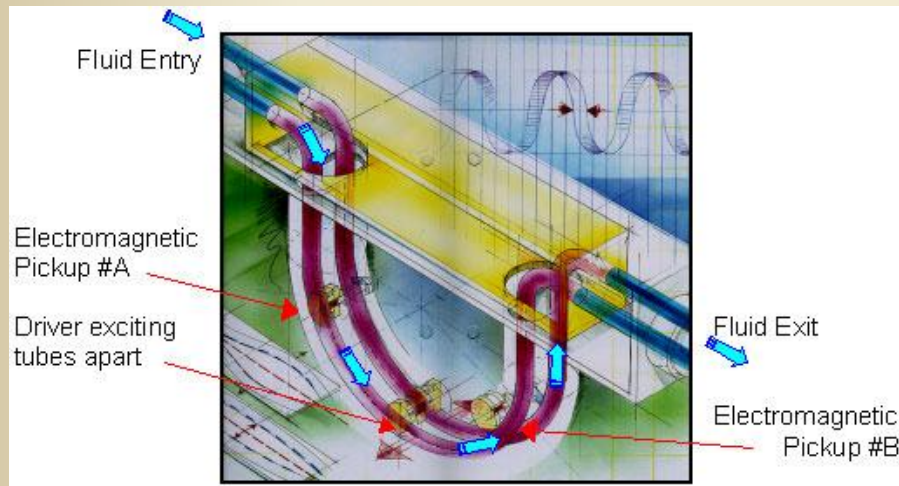
Ultrasonic Flow meter

- There are various types of ultrasonic flow meters in use for flow measurement:
- (1) *Transit time*: This is today's state-of-the-art technology and most widely used type.
- This type of ultrasonic flow meter makes use of the difference in the time for a sonic pulse to travel a fixed distance.
- First against the flow and then in the direction of flow.
- Transmit time flow meters are sensitive to suspended solids or air bubbles in the fluid.
- (2) *Doppler*: This type is more popular and less expensive, but is not considered as accurate as the transit time flow meter.
- It makes use of the Doppler frequency shift caused by sound reflected or scattered from suspensions in the flow path and is therefore more complementary than competitive to transit time flow meters.



Coriolis Mass Flow meter

- If a moving mass is subjected to an oscillation perpendicular to its direction of movement, Coriolis forces occur depending on the mass flow. This meter uses the Coriolis effect to measure the amount of mass moving through the element. The substance to be measured runs through a U-shaped tube that is caused to vibrate in a perpendicular direction to the flow. Fluid forces running through the tube interact with the vibration, causing it to twist. The greater the angle of the twist, the greater the flow



Comparison of Popular Flow Measurement Device

<i>Device Type</i>	<i>Liquids</i>	<i>Viscous Liquids</i>	<i>Slurries</i>	<i>Cost</i>	<i>% Full Scale Accuracy</i>
Head Type					
Orifice Plates	Yes	Limited	No	Low	1/4 to 2
Rotameters	Yes	Limited	Limited	Med	1/2 to 2
Venturi Tubes	Yes	Limited	Yes	High	1/4 to 3
Target Meters	Yes	Limited	Limited	Med	1/2 to 2
Velocity Type					
Magnetic	Yes	Yes	Yes	High	1/2 to 1
Vortex	Yes	Limited	No	Med	1/2 to 2
Displacement					
Turbine Meter	Yes	Limited	Limited	Med	1/4 to 1

LEVEL



Level Measurement Techniques

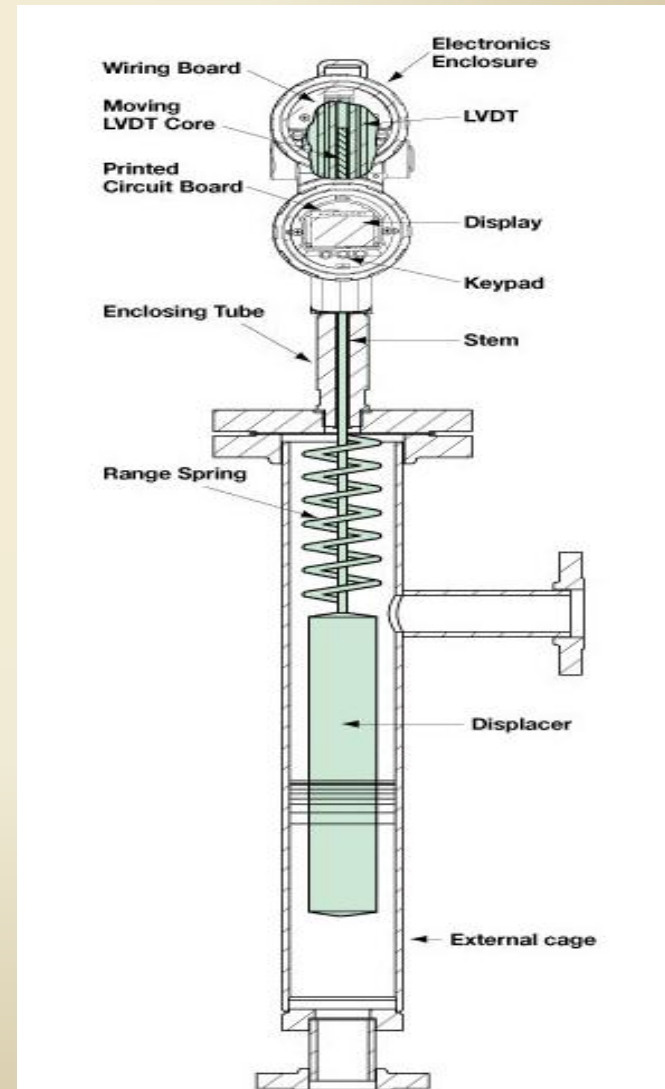
- Displacers / Floats
- Capacitance
- Ultrasonic
- Radar
- Nuclear
- Differential Pressure, and Bubbler level measurement technologies
- Level Gauges

DISPLACER TYPE LEVEL TX

- Displacers work on the Archimedes Principle, when a body is immersed in a fluid it loses weight equal to that of the fluid displaced. By detection of the apparent weight of the immersed displacer, a level measurement can be inferred.

These forces act upon the spring supported displacer causing vertical motion of the core within a linear variable differential transformer.

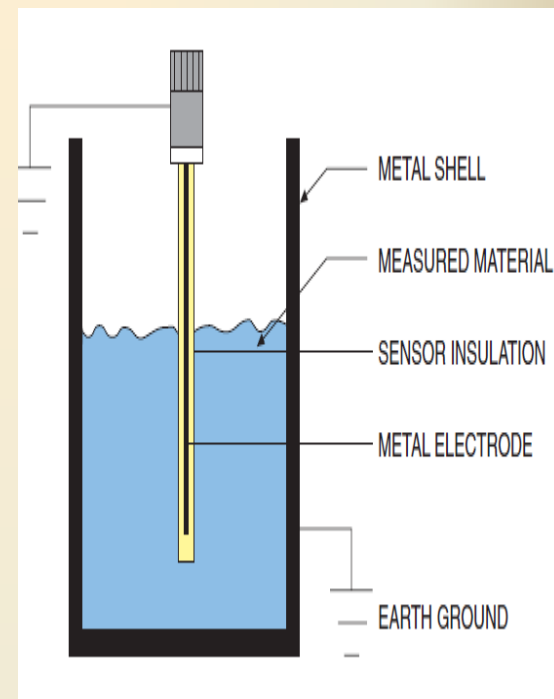
As the core position changes with liquid level, voltages are induced across the secondary windings of the LVDT. These signals are processed in the electronic circuitry and used to control the current in the 4-20 mA current loop.



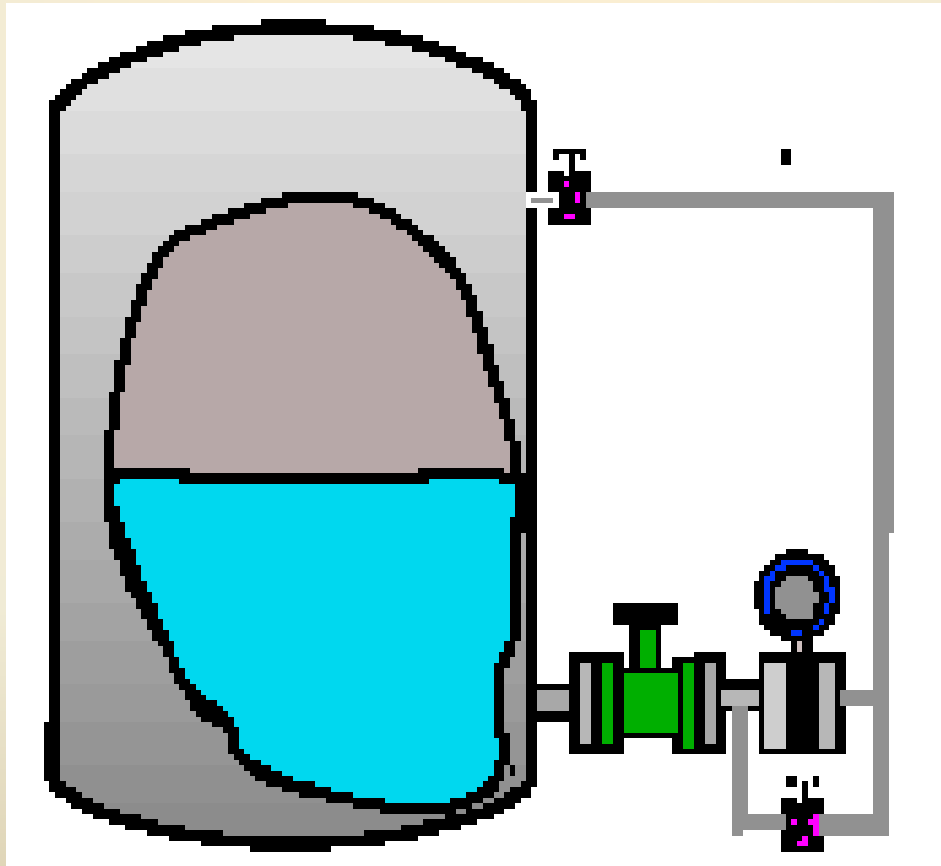
CAPACITANCE BASED LEVEL INSTRUMENT

A capacitor is formed when a level sensing electrode is installed in a vessel. The metal rod of the electrode acts as one plate of the capacitor and the tank wall (or reference electrode in a non-metallic vessel) acts as the other plate. As level rises, the air or gas normally surrounding the electrode is displaced by material having a different dielectric constant. A change in the value of the capacitor takes place because the dielectric between the plates has changed. RF (radio frequency) capacitance instruments detect this change and convert it into a relay actuation or a proportional output signal. The capacitance relationship is illustrated with the following equation:

$$C = 0.225 K \left(\frac{A}{D} \right)$$

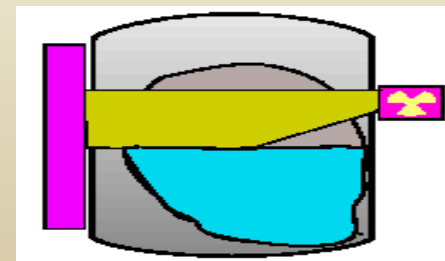


DIFFERENTIAL PRESSURE TYPE LEVEL INSTRUMENT



Principle of Operation of Nucleonic based Level

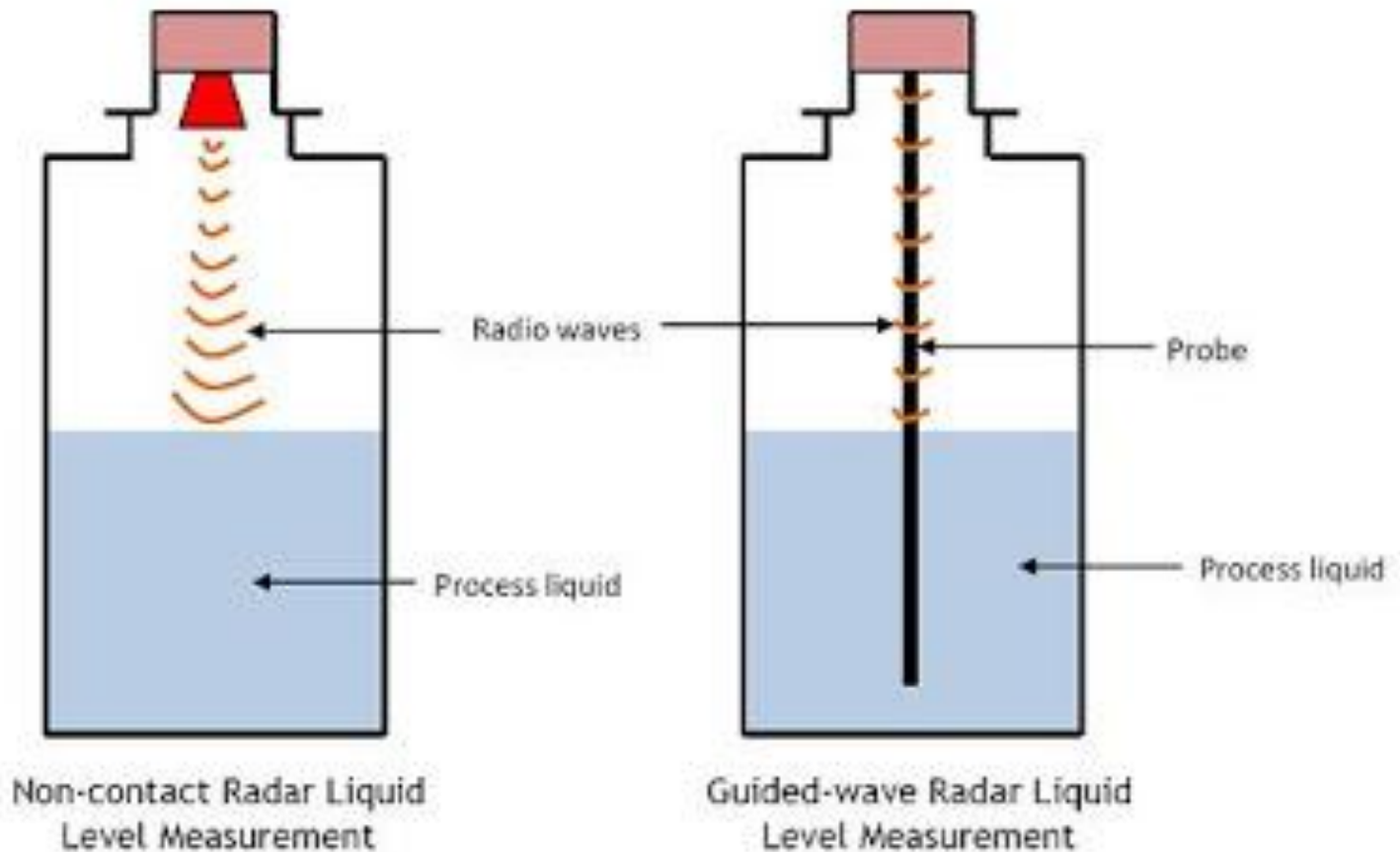
- Nucleonic based level instruments are used for point and continuous measurements, where most other technologies are not proven & unsuccessful. The radioisotopes used for level measurement emit energy at a fairly constant rate but in random bursts. Gamma radiation, the source generally used for nucleonic level gauging is similar to microwaves or even light . The short wavelength and higher energy of gamma radiation penetrates the vessel wall and process media. A detector on the other side of the vessel measures the radiation field strength and infers the level in the vessel.



Radar Based Level Measurement

- **Theory:** Radar level measurement is based on the principle of measuring the time required for the microwave pulse and its reflected echo to make a complete return trip between the non-contacting transducer and the sensed material level. Then, the transceiver converts this signal electrically into distance/level and presents it as an analogue and/or digital signal. The transducer's output can be selected by the user to be directly or inversely proportional to the span.
- The two technologies on the market are frequency modulated continuous wave (FMCW) or pulsed wave time of flight. Pulsed wave systems emit a microwave burst towards the process material, this burst is reflected by the surface of the material and detected by the same sensor which now acts as a receiver.

RADAR BASED LEVEL INSTRUMENT



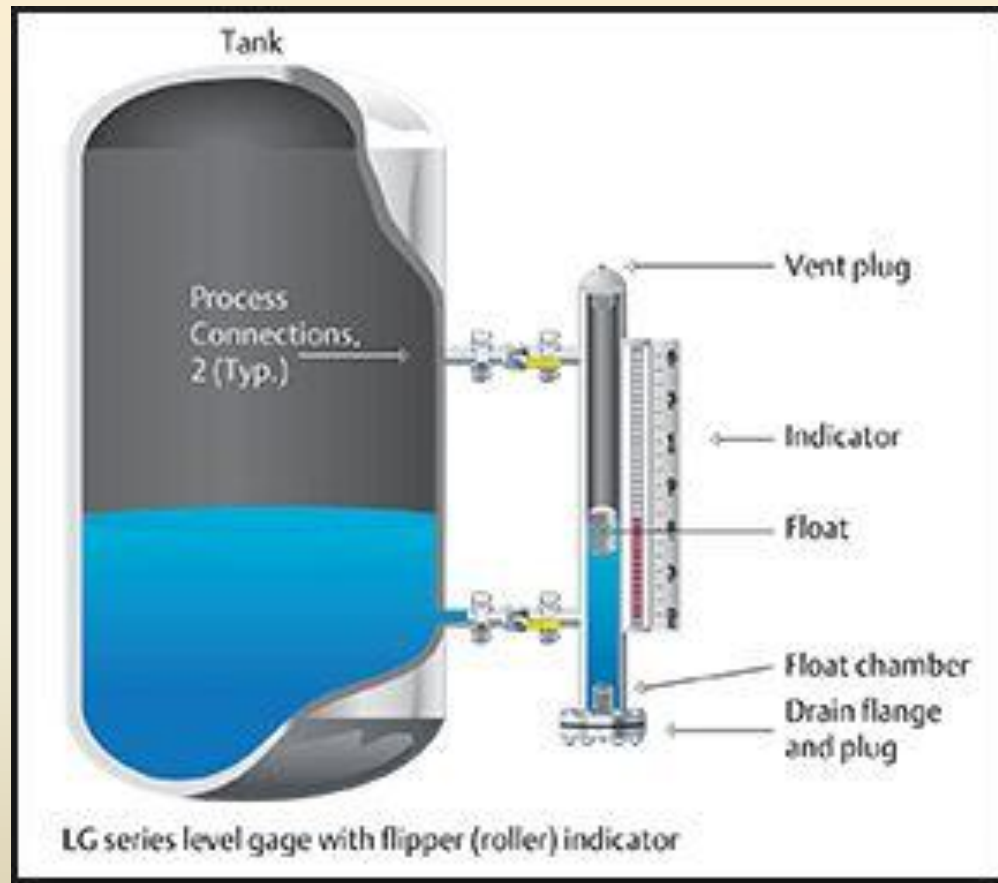
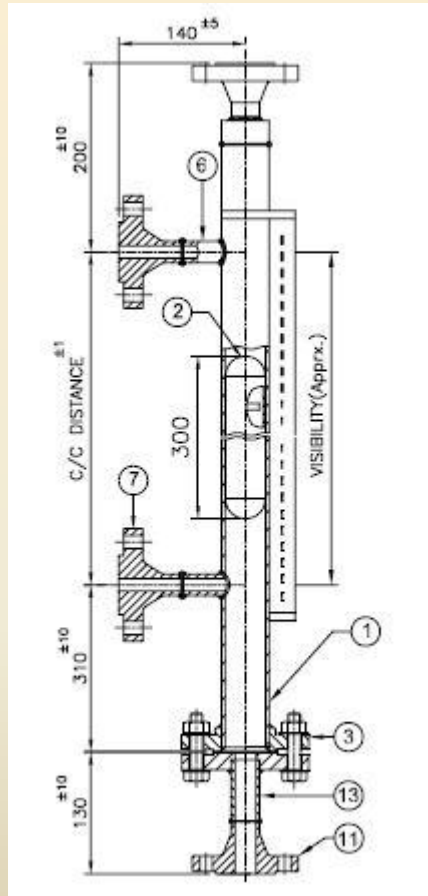




104-A
CORROSION MONITORING
CAPA

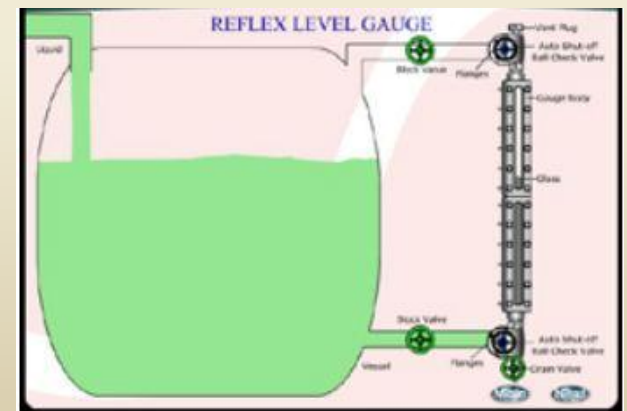
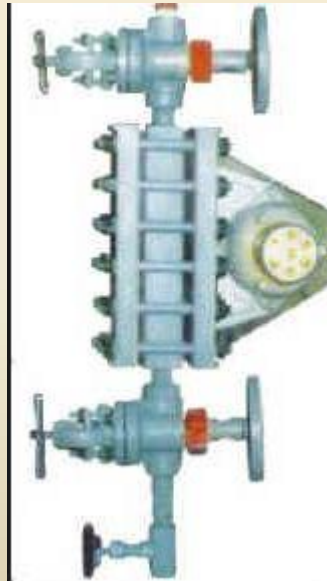
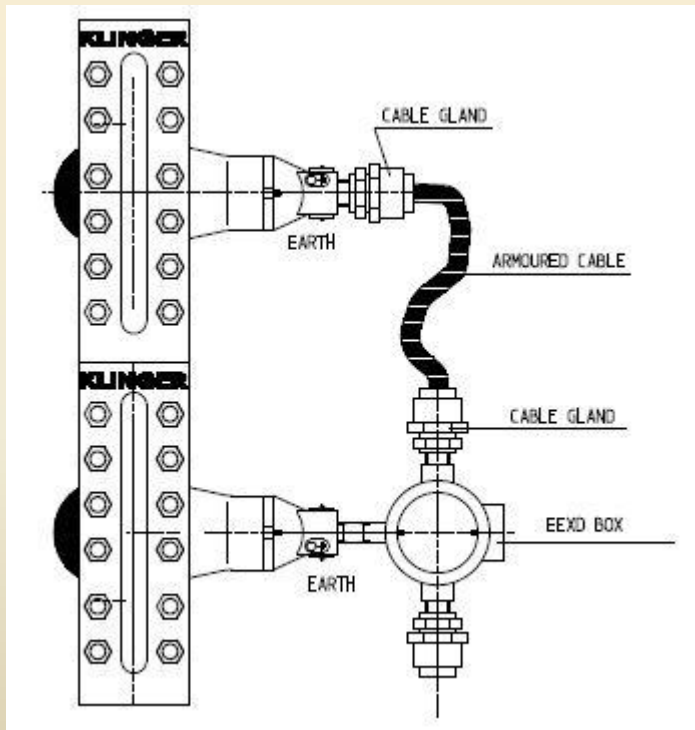
TYPES OF LEVEL GAUGES

- **Magnetic type :** Used for hydrogen, congealing, fouling and very high pressure applications



TYPES OF LEVEL GAUGES

- Transparent Type
- Reflex Type









TEMPERATURE

What temperature sensor should you use?

- What temperature sensor should you use? Should it be a contact or non-contact device? What process, temperature range, and environment will you be working in? What response time and accuracy does your application require? There's no shortage of questions. What you need are answers. Let us examine thermocouple, RTD, thermistor, and IR technologies.
- Selecting the right temperature sensor depends on the process being measured, the temperature range stipulated, the response time desired, the accuracy required, and the operating environment encountered. Another important factor to consider is price, which varies with the accuracy rate and the mounting style of the device.

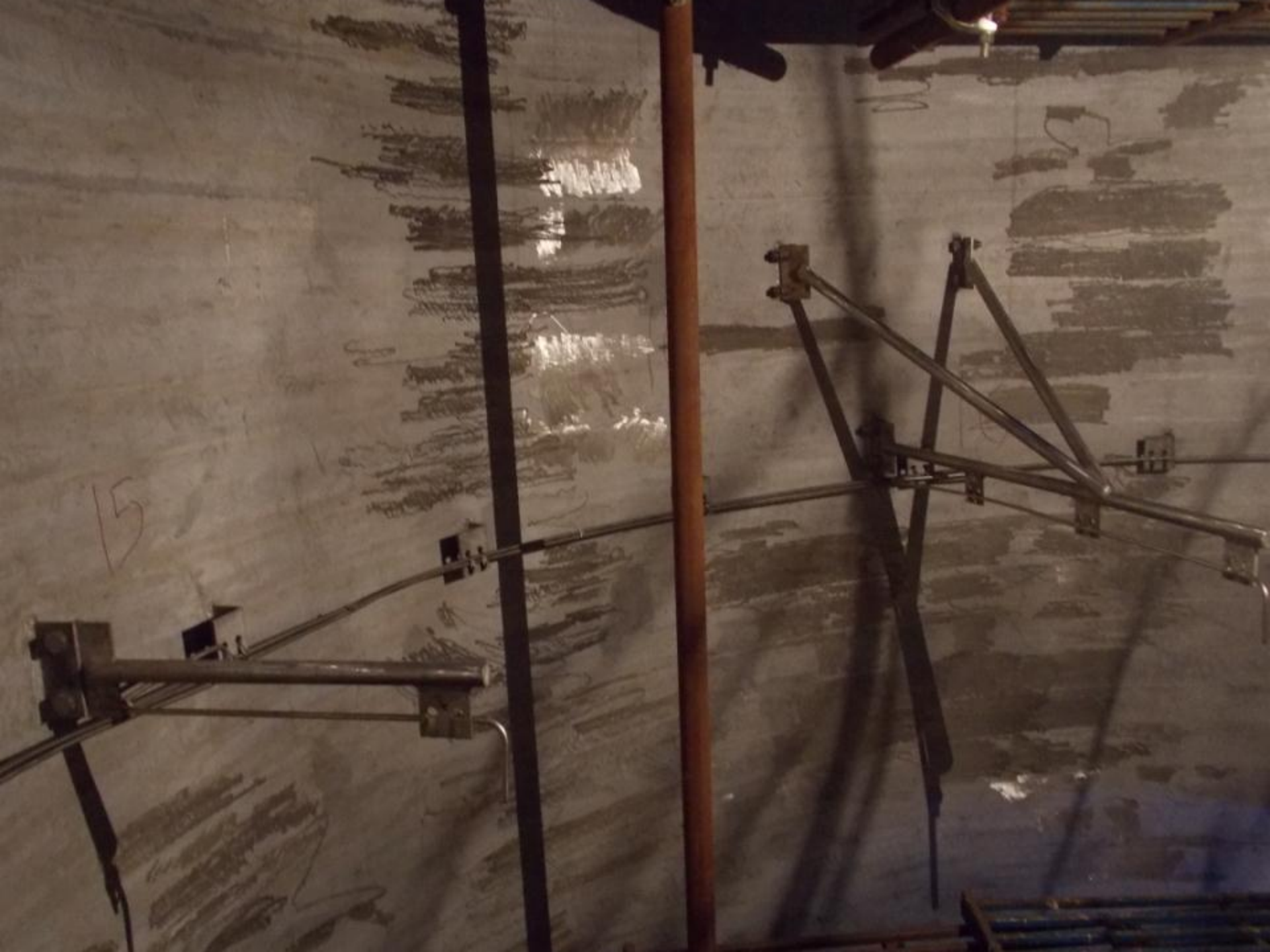
Thermocouples

- **Operating principle of the thermocouple:** If two dissimilar metals are joined at one end, a voltage (the Seebeck voltage) proportional to the temperature difference between the joined and open ends is generated. In an effort to maximize performance, numerous combinations of metals have been characterized to determine their output voltage vs. temperature transfer function. Of the few combinations selected as industry standards, two of the more popular are types K(Chromel-Alumel) and E.

Thermocouple Types

Standard Calibration		Material	Temp Range	Accuracy	Premium Grade	Accuracy
"J"	+	Iron	32 F to 1400 F	+/- 4 F or 0.75%	"JJ"	+/- 2 F or 0.4%
	-	Constantan				
"K"	+	Chromel	32 F to 2300 F	+/- 4 F or 0.75%	"KK"	+/- 2 F or 0.4%
	-	Alumel				
"T"	+	Copper	-320 F to 700 F	+/- 2 F or 0.75%	"TT"	+/- 1 F or 0.4%
	-	Constantan				
"E"	+	Chromel	32 F to 1600 F	+/- 3 F or 0.75%	"EE"	+/- 1.8 F or 0.4%
	-	Constantan				
"N"	+	Nicrosil	32 F to 2300 F	+/- 4 F or 0.75%	"NN"	+/- 4 F or 0.4%
	-	Nisil				





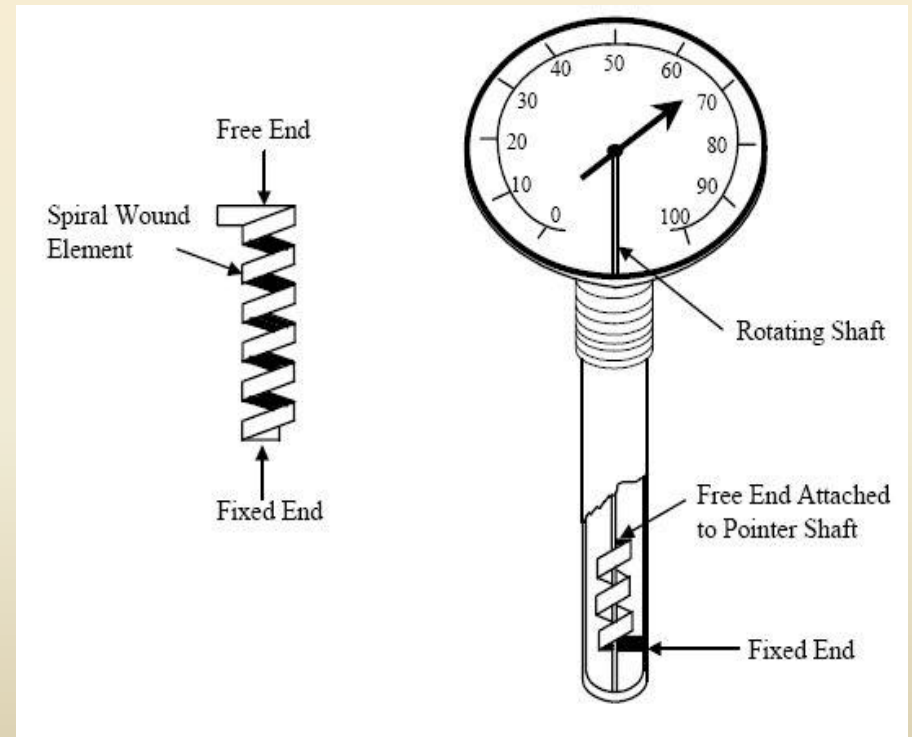
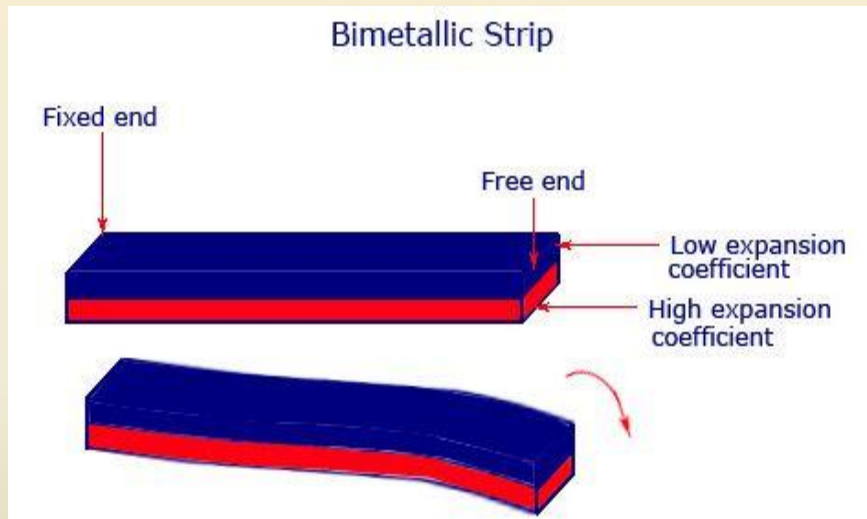


Comparison of RTDs and Thermocouples

Performance	RTDs	Thermocouple
Accuracy	*	
High Temp.		*
Linearity	*	
Meas.in gas/air		*
Noise immunity	*	
Vibration/Shock immunity		*

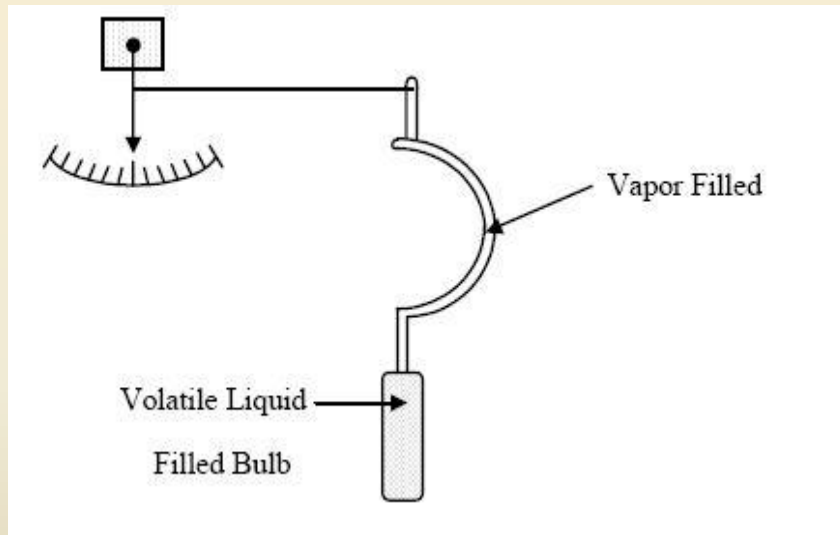
TEMPERATURE GAUGE BIMETALLIC

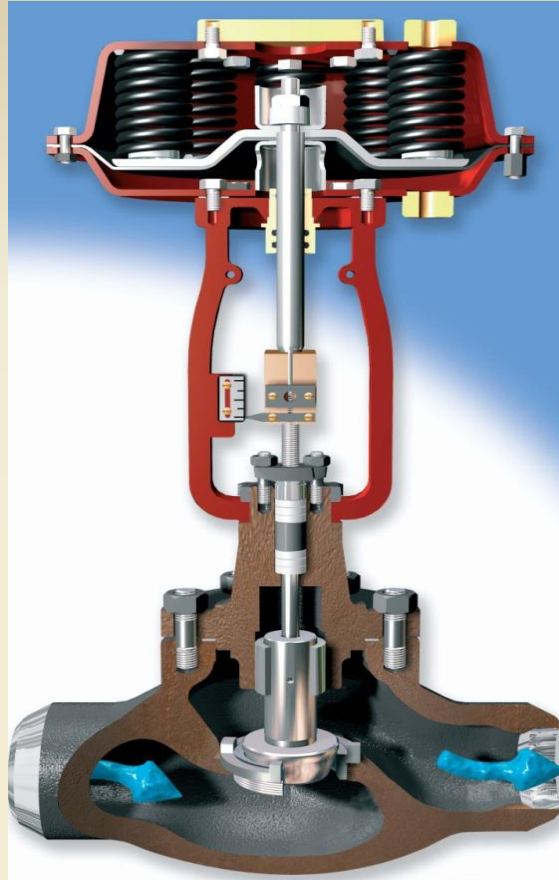
It employs a bimetal strip in form of helix (two metals having different coefficient of thermal expansion). Resultant expansion is proportional to temperature.



GAS FILLED TEMPERATURE GAUGE

If a local temperature measurement is in an inaccessible location so that a bimetallic TG can't be easily read, in that case a gas filled TG is recommended because its capillary tubing can be led to an indicator that can be installed/located in a convenient place.

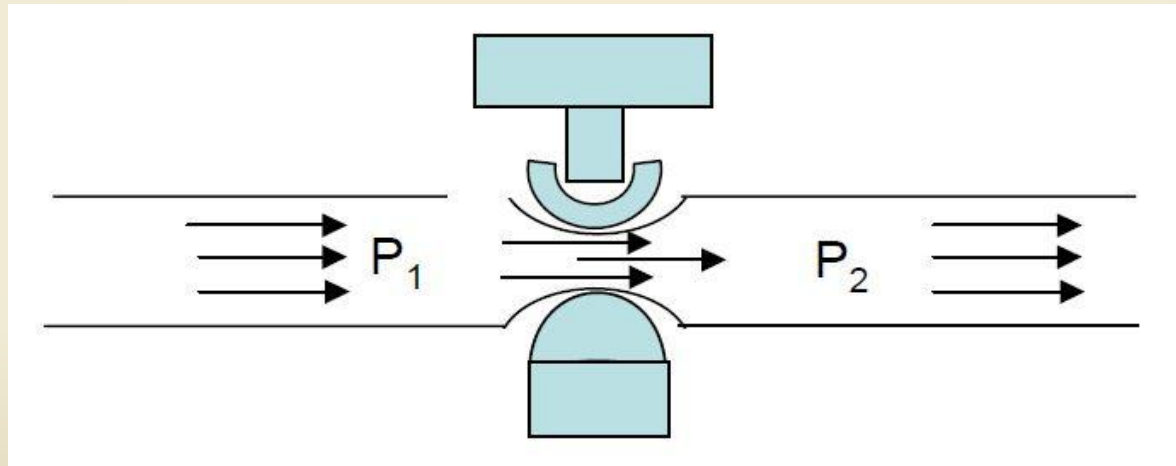




CONTROL VALVE

control valve

- Mechanical devices that fits in a pipeline creating an externally adjustable variable restriction.
- Specifically designed to direct, start, stop, mix, divert or regulate the flow, pressure, and temperature of a process fluid.

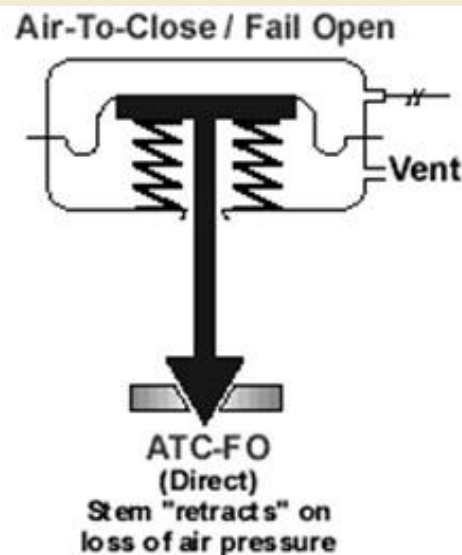
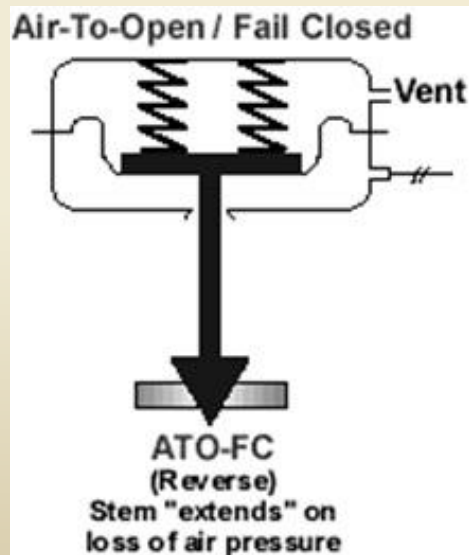


(Control valve adjusts the effective area of flow in the pipe)

- Pipe line flow depends on effective area x square root ($P_1 - P_2$)

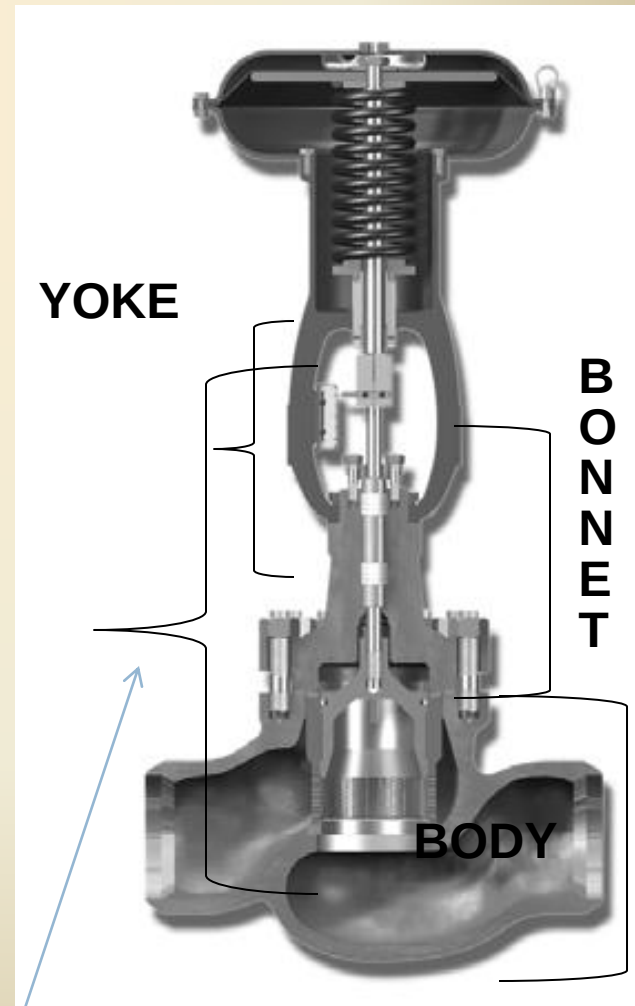
Action of Control valve

- Air-to-open (fail close): as the air P increases, the valve opening gets larger.
- Air-to-close (fail open): as the air P increases, the valve opening gets smaller.
- The fail safe selection should be made based on the safety consideration / as per P & ID's and design basis criteria.
 - Furnace fuel valve should be closed in case of utility failure
 - Coolant valve in exothermic reactor should be open in case of utility failure

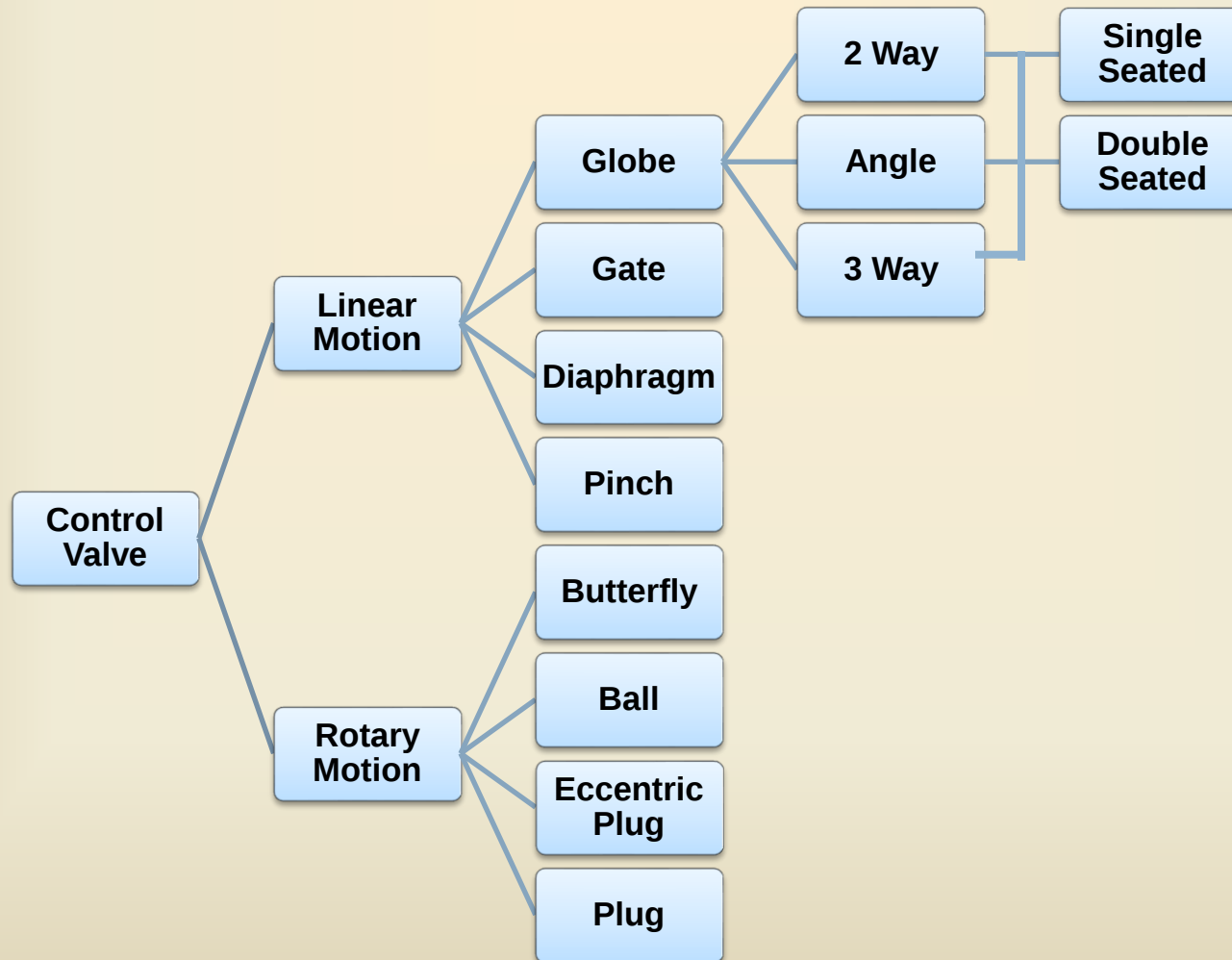


Major Parts of Control Valve

- **Body**
 - Main Pressure Boundary of the valve
 - Provides the pipe connecting ends & the fluid flow passage way
 - Support the seating surfaces & the valve closure member
- **Bonnet**
 - The portion of the valve pressure retaining boundary
 - Guides the stem & contains the packing box and stem seal
 - Provide the attachment of the actuator to the valve
- **Yoke**
 - Connects the Valve body or Bonnet with the actuating mechanism
- **Valve Stem** - The part that connects the actuator stem with the closure member.



Classification of Control Valves

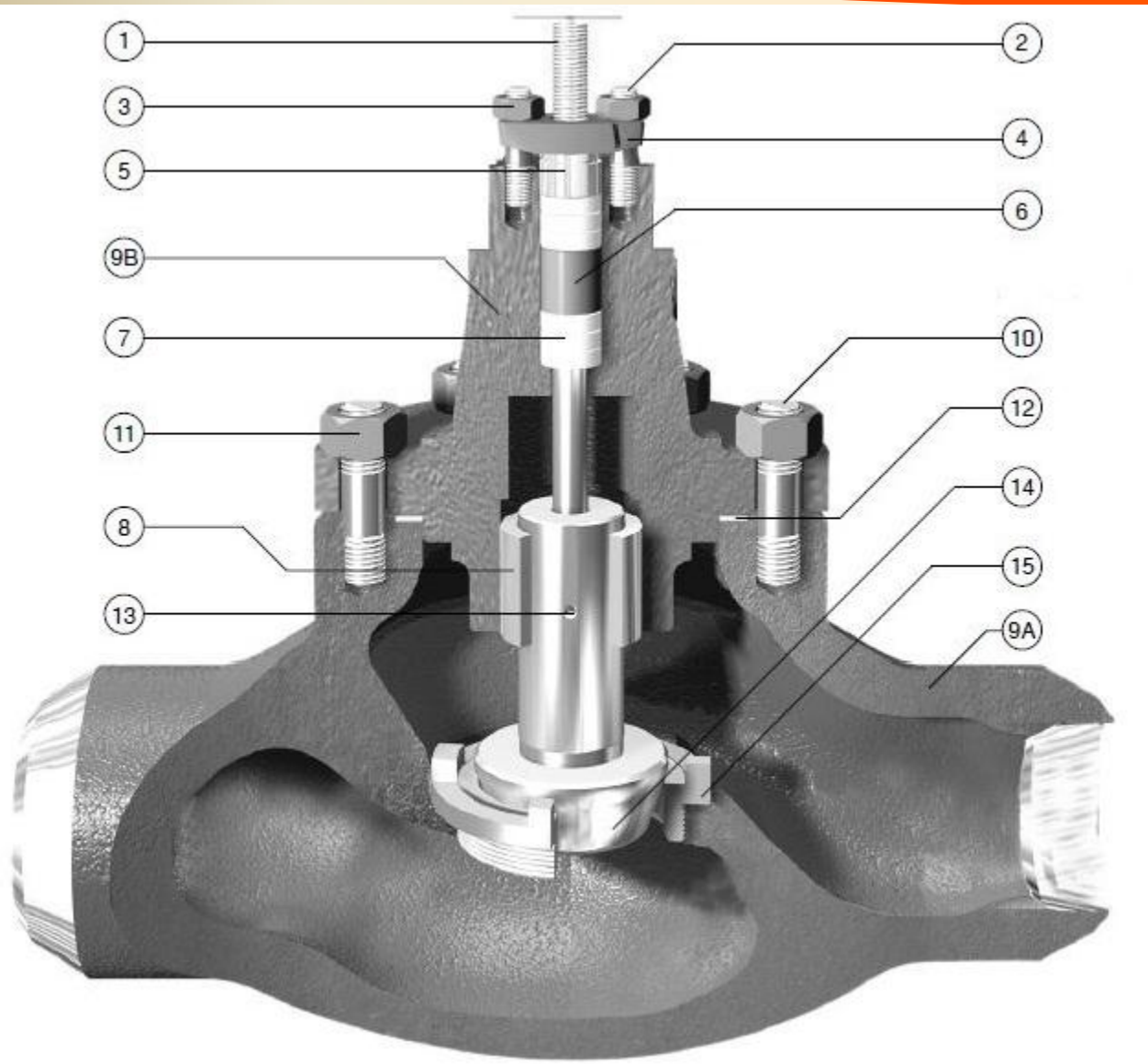


Globe Control valves

- Linear motion valve characterized by a globe sized body
- Most common, due in part of its design simplicity, versatility of application, ease of maintenance, and ability to handle a wide range of pressure and temperatures.
- can use for extremely high pressure drops and high temperature ranges.
- The main disadvantages of globe valves are the large size, weight, and more expensive



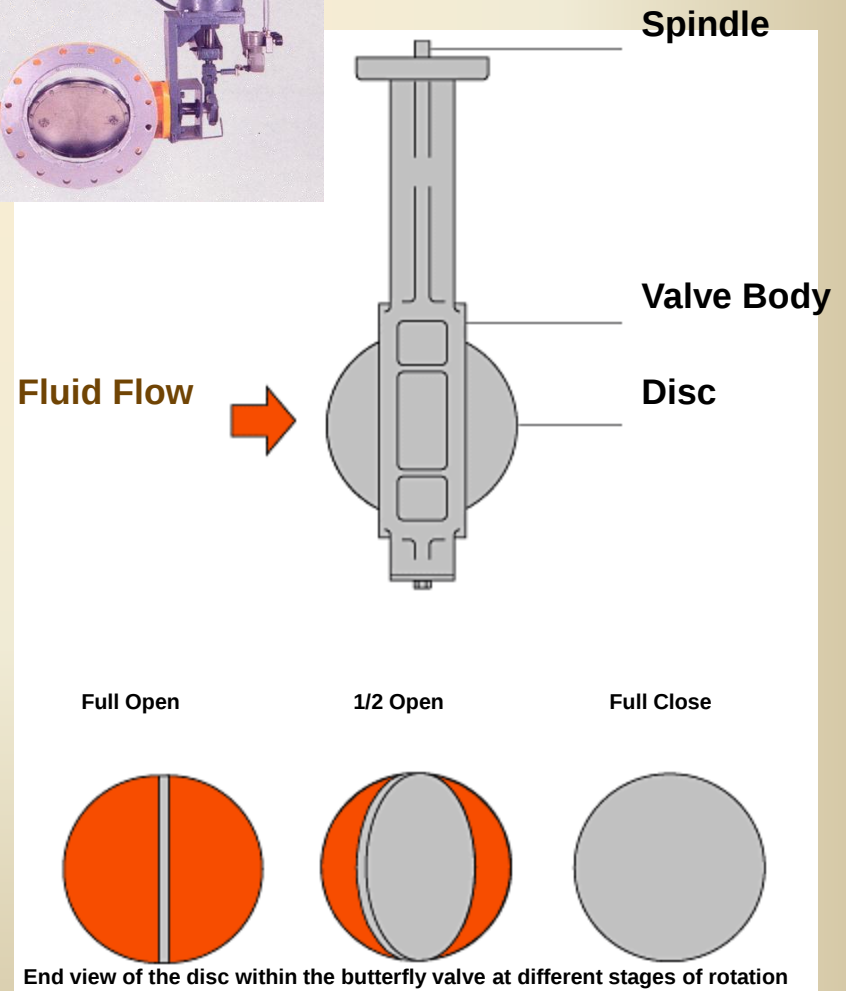
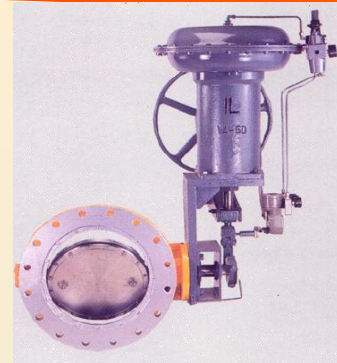
Globe Control Valve Body Disassembly



1. Plug Stem
2. Packing Flange Stud
3. Packing Flange Nut
4. Packing Flange
5. Packing Follower
6. Packing Spacer / Lantern Ring
7. Gland Packing
8. Guide Bush
- 9A. Body
- 9B. Bonnet
10. Body Stud
11. Body Nut
12. Body Gasket
13. Plug Pin
14. Valve Plug
15. Seat Ring

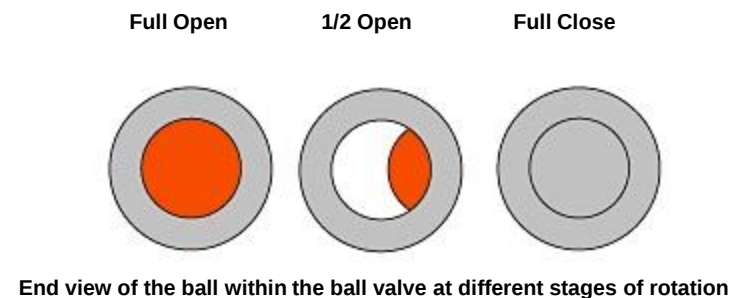
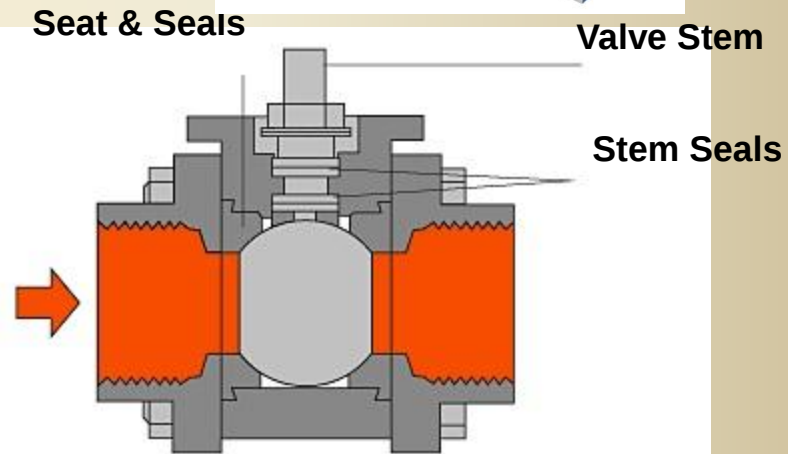
Butterfly Control Valves

- Damper valve , most economical valves, high torque required
- Disc that rotates on a shaft at right angles to the fluid flow, When open. In the closed position, the disc is rotated against a seat in the body of the valve.
- Used in Liquids & Gas Services



Ball Control Valve

- Tight shutoff, high capacity with just a quarter-turn to operate
- small in size and low in weight
- Rotation of the ball through 90° opens and closes the valve and allows fluid to flow directly through the orifice. In the closed position, the blank sides of the ball block the inlet and the outlet preventing any flow.



Trim

- Trim consists of the removable internal parts of the valve contacting the fluid (wetted parts) viz:
 - Plug
 - Cage
 - Seat Ring
 - Valve Stem
 - Stem / plug guides
 - Bushings

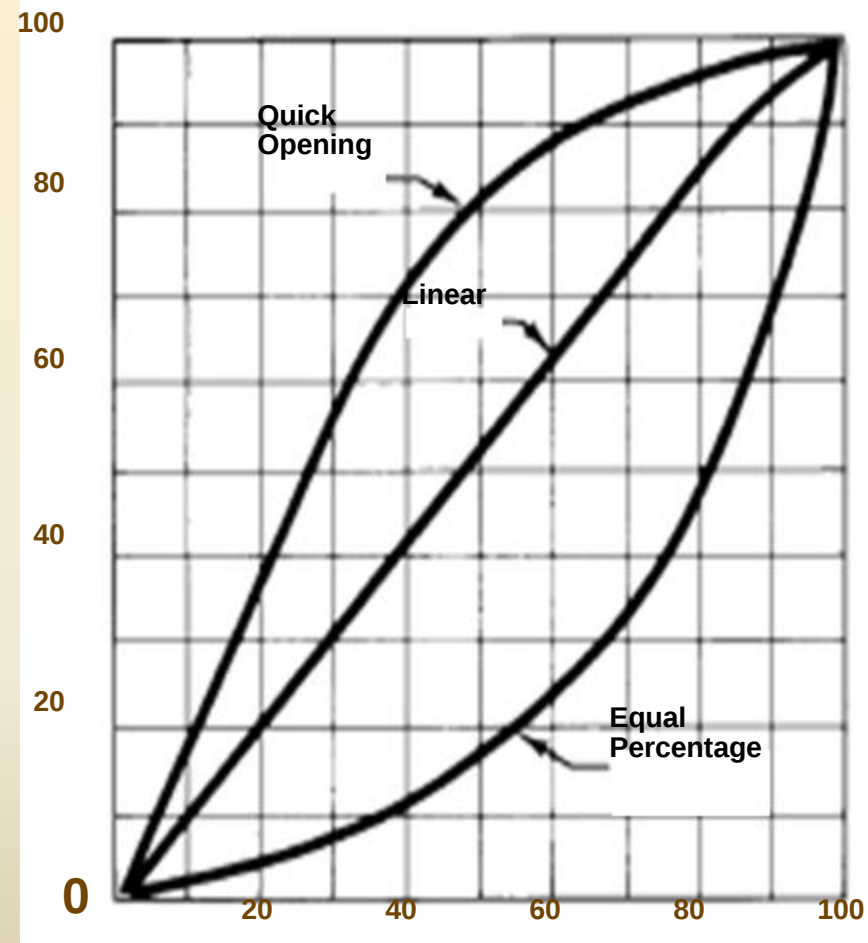
Note: Valve Body, bonnet assembly & bottom flange which are exposed in contact with fluid are not considered as trim.

Control Valve Flow Characteristics

Explains how the valve travel or stroke (openness) relates to the flow.

- Linear
- Equal Percentage
- Quick Opening

Percent of Maximum Flow



Percent of Valve Travel

Linear Characteristics

- Valve travel is directly proportional to the flow.
- Used in liquid level & flow loops.
- Used in systems where the pressure drop across the valve is expected to remain fairly constant.

Equal Percentage Characteristics

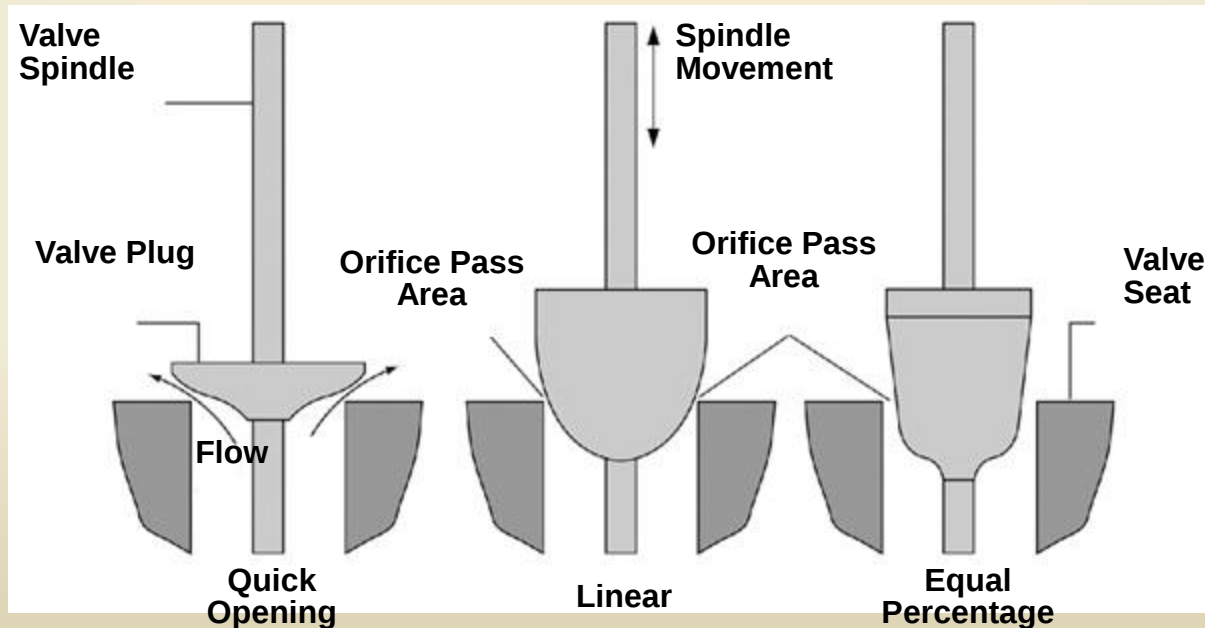
- Equal increments of valve travel produce equal percentage changes in the existing flow.
- Used in processes where large changes in pressure drop are expected.
- Used in processes where a small percentage of the total pressure drop is permitted by the valve.
- Used in temperature and pressure control loops.

Quick Opening Characteristics

- Large increase in flow with a small change in valve stroke.
- Used for frequent on-off service.
- Used for processes where "instantly" large flow is needed. (ie. safety systems or cooling water systems)

Constructional Difference in Plug

- A Cylindrical and / or contoured part which moves in the flow stream in linear motion
- Plug shapes determine valve flow characteristics.



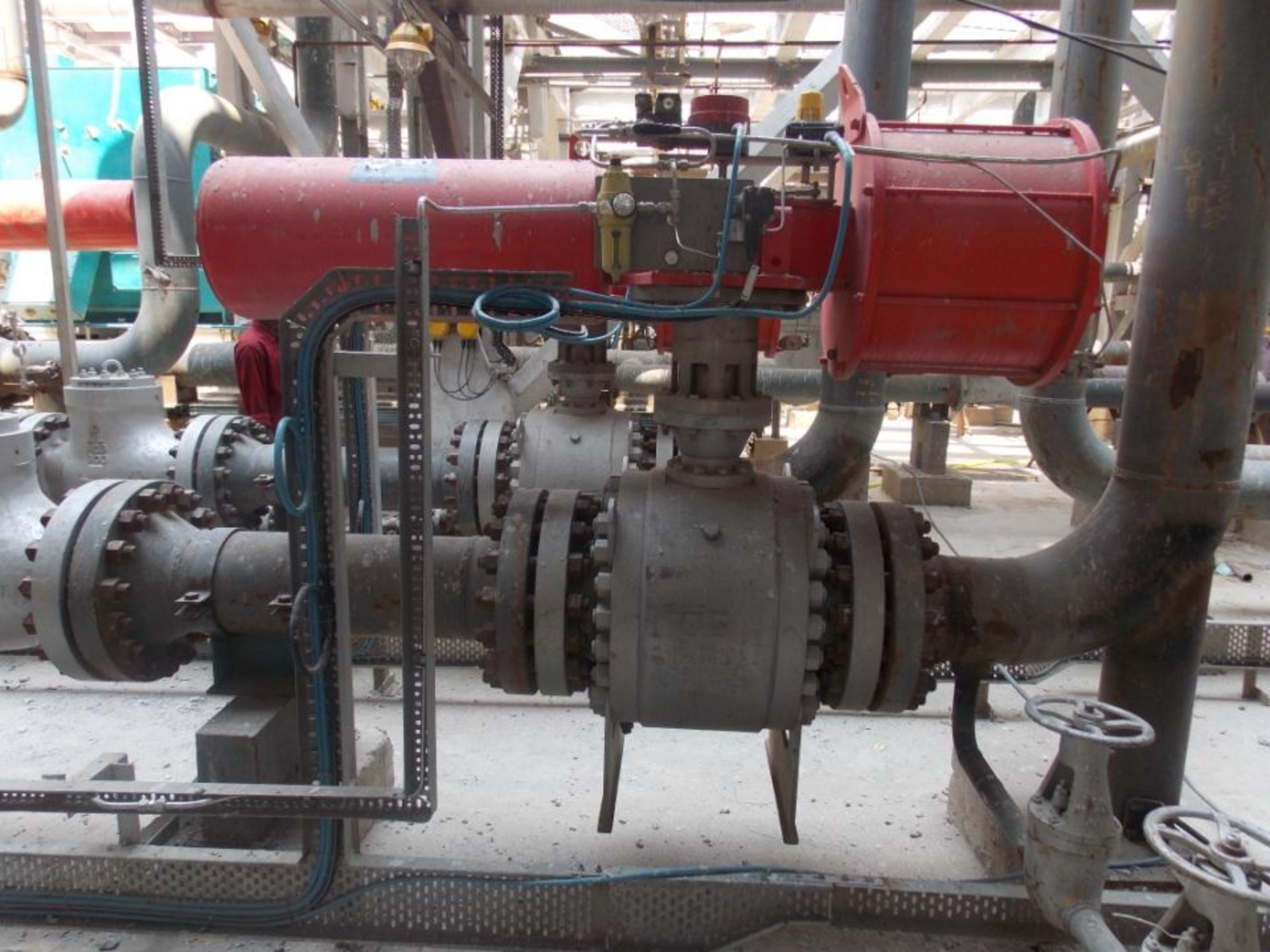
Valve flow coefficient : C_v

- Control valve flow coefficient
- Used to establish control valves flow capacity for a given travel
- C_v is defined as number of US gallons per minute of water flowing at 60°F that flows through valve (at Fully Open condition) with a pressure drop (upstream & down stream) of 1 Psi.





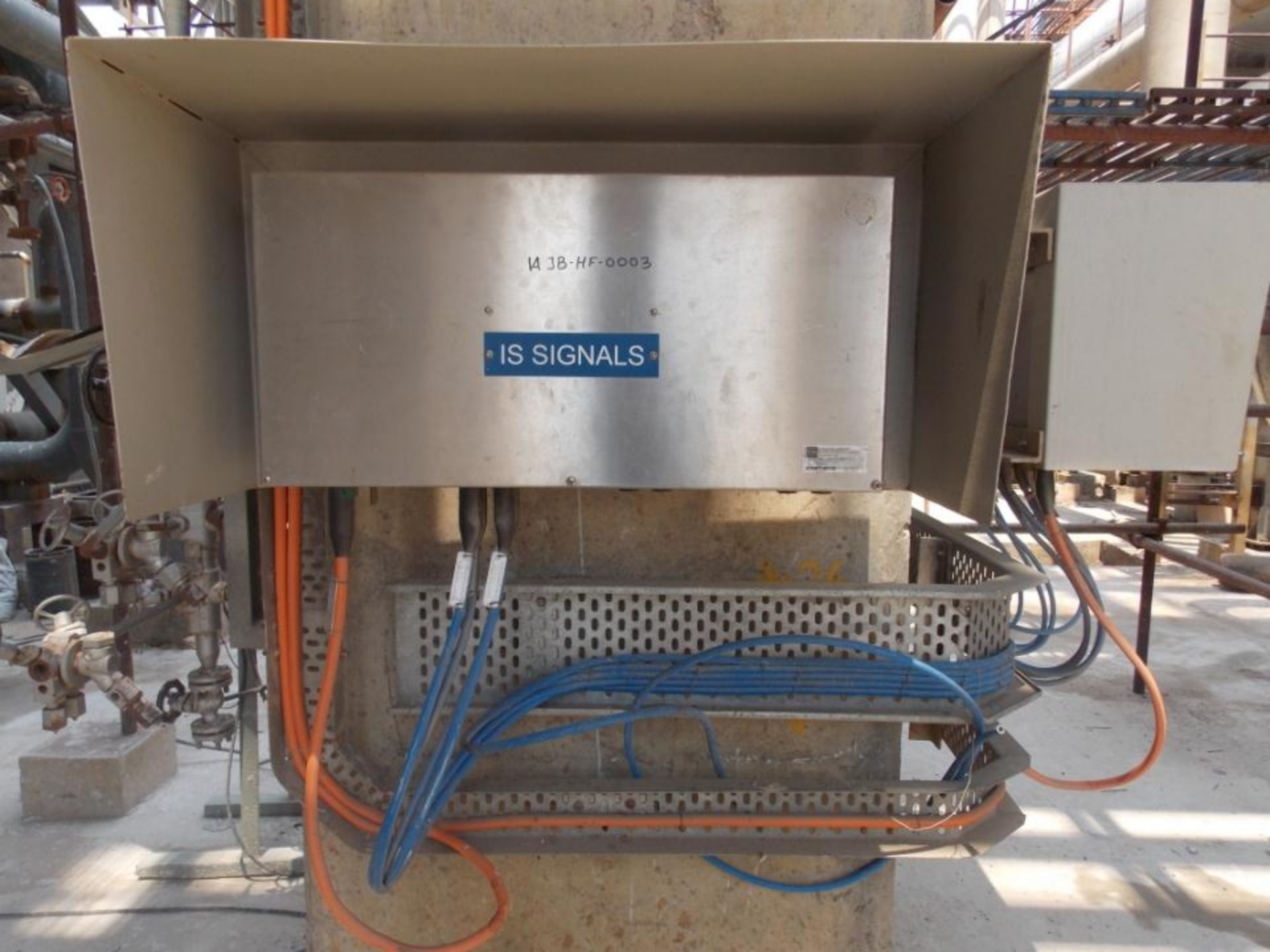






14 JB-HF-0003

IS SIGNALS









Key Points for successful commissioning

- Understand the source & types of problems associated with erection, installation, the first start up or any add on facility.
- List out the potential problem associated with the commissioning & used other's similar experience.
- Critical documents study.
- Take action for the ways to minimize the above & it's overall impact / consequences.
- Checklist preparation, compile & it's liquidation.
- Plan for 100 % Hydro testing of instrument Hook ups.
- Plan for 100 % loop checking.
- Witness 100 % interlock logics : Joint checking.

Process condition v/s type of instrument reference	Pressure	Capacitance	Ultrasonic	GWR	NC radar	Nuclear	Displacer	Magnetostrictive	Floats	Vibrating fork
Aeration	M	G	M	G	M	M	G	M	G	G
Agitation	G	M	P	M	M	G	G	M	M	G
Ambient temp changes	M	G	M	G	G	G	M	G	G	G
Corrosion	M	G	G	M	G	G	M	M	M	M
Density changes	M	G	G	G	G	M	M	M	M	G
Dielectric changes	G	P	G	G	G	G	G	G	G	G
Dust	G	G	P	G	M	G	P	G	P	P
Foam	G	M	P	M	M	G	G	G	G	M
High process temp limits	G	G	P	G	M	G	G	P	G	G
High vessel pressure limit	G	G	P	G	M	G	G	P	G	G
Internal obstruction	G	M	P	M	M	M	G	G	M	G
Low process temp limits	G	G	G	G	M	G	M	G	G	G
Low vessel pressure (Vacuum)	M	G	P	G	G	G	G	G	G	G
Noise	G	G	M	M	G	G	G	G	G	G
Product coating	P	P	M	M	G	M	P	P	M	M
Slurries	M	G	G	M	G	G	P	M	M	M
Solids	G	M	M	G	G	G	P	P	P	P
Vapors	P	M	M	G	G	G	G	G	G	G
Viscous, Sticky product	M	M	G	M	G	G	P	P	M	M

Good : This condition has no or little impact on performance of this technology

Moderate : This technology can handle this condition, but performance could be affected or special installation is needed.

Poor : This technology does not handle this condition well.

THANK YOU