SKN3022
PROCESS INSTRUMENTATION
CHAPTER IV

SENSORS/TRANSDUCERS

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SENSOR (TRANSDUCER)

SELECTION OF TRANSDUCER

- **Criteria that requires to be considered when selecting a transducer:**

1. **Identification of an input type.**
    - ***Example:*** **a pressure sensor must be able to detect an instantaneous pressure and must not be sensitive to any temperature changes.**
2. **Does not change the state of the process to be measured.**
3. **Suitable with the process and visual display unit to be used.**

4. **High accuracy.**
5. **High precision.**
6. **Has a linear amplitude.**
7. **Has a stable response frequency.**
8. **Must not be induced by phase distortion or time lag between input signal and output signal.**
9. **Has high resistance against outside elements without effecting the accuracy in certain limits.**
10. **Easy to obtain at a low price.**
11. **Safe to be used.**

Operation principles of sensors/transducers in the process industry

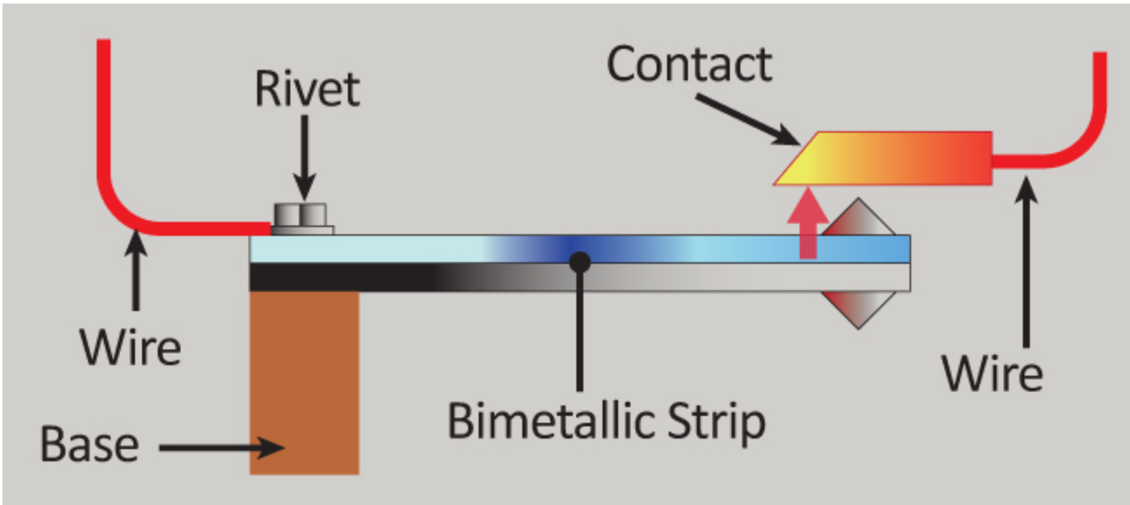
Temperature Sensors

- Several type of temperature sensors commonly employed by the industry:
  1. Bimetallic sensor
  2. Thermocouple
  3. Resistive Temperature Detector (RTD)
  4. Thermistor
  5. Radiation Pyrometer
  6. Integrated Circuit Sensor (ICS)

1. BIMETALLIC SENSOR

- **Normally used as circuit breaker to protect electrical system from excess electrical current in the circuit.**
- **Usually employed in the "ON/OFF" process system.**
- **Circuit breaker is commonly connected in series with the protected circuit, allowing *bimetallic strip* physically connected with one/more circuit bay.**
- **Comprise from two basic material bearing two different "*thermal expansion coefficient*" *and bonded together*.**

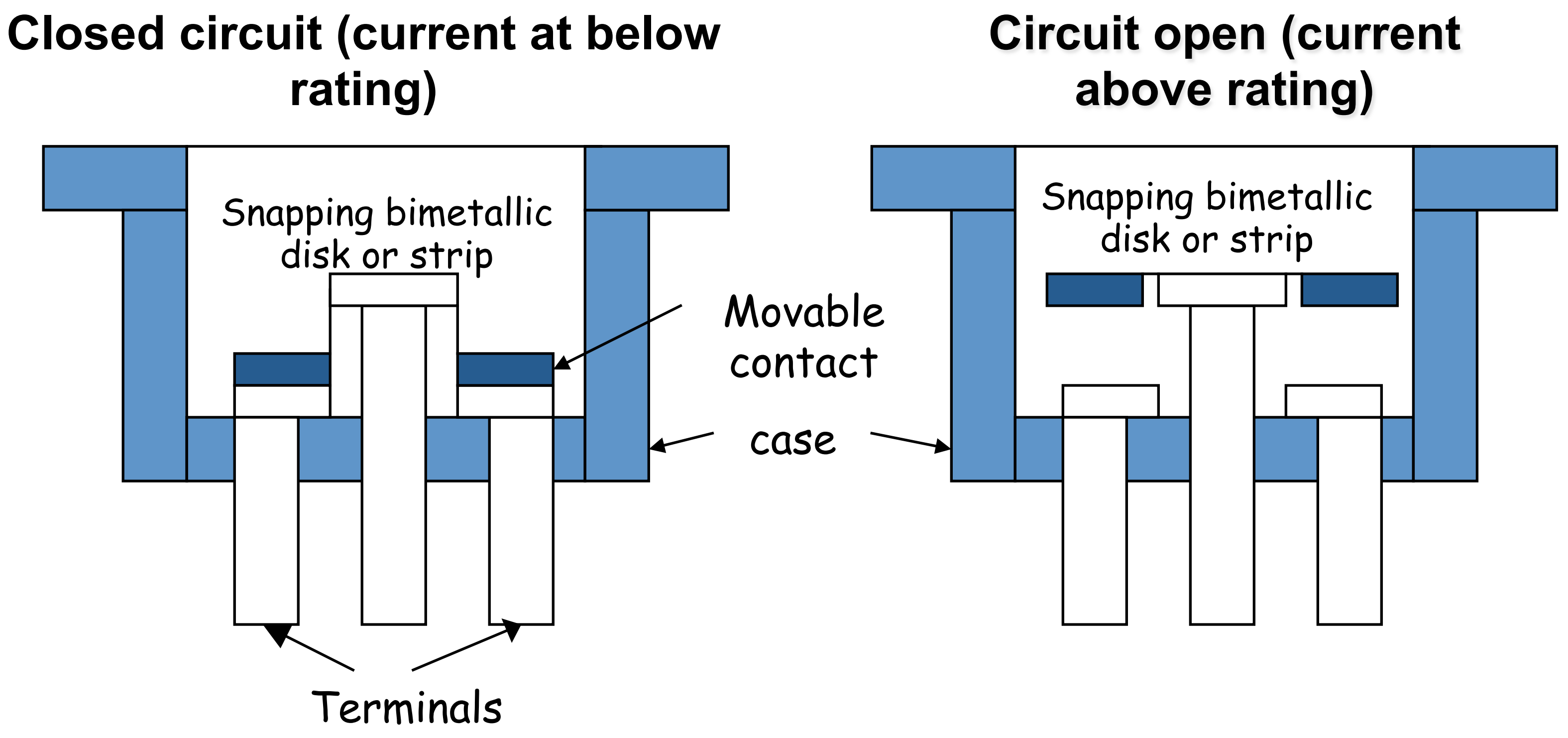
The principle behind a bimetallic strip thermometer relies on the fact that different metals expand at different rates as they warm up. By bonding two different metals together, you can make a simple electric controller that can withstand fairly high temperatures. This sort of controller is often found in ovens. Here is the general layout:



Two metals make up the bimetallic strip (hence the name). In this diagram, the grey metal would be chosen to expand faster than the blue metal if the device were being used in an oven. In a refrigerator, you would use the opposite setup, so that as the temperature rises the blue metal expands faster than the grey metal. This causes the strip to bend downward, making contact so that current can flow. By adjusting the size of the gap between the strip and the contact, you control the temperature. You will often find long bimetallic strips coiled into spirals. This is the typical layout of a backyard dial thermometer. By coiling a very long strip it becomes much more sensitive to small temperature changes. In a furnace thermostat, the same technique is used and a mercury switch is attached to the coil. The switch turns the furnace on and off.

OPERATION PRINCIPLE

- **When the electrical current flows through the bimetallic strip, the resistance in the strip will significantly produce heat. In the normal operation of the circuit, heat released does not sufficient to separate the contacting point.**
- **If the current flow exceeding the allowable limit, heat released from the system will increase and subsequently displaced the original position of the strip and continually deflected. This will certainlly separate the contact point and creating an *open-circuit* system and stop the flow of current.**

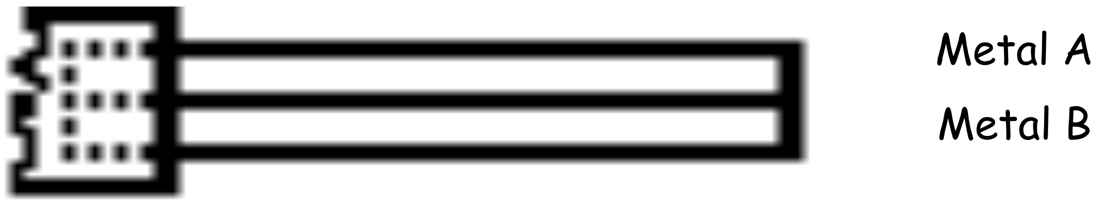


Bimetallic Thermostat Used As A Circuit Breaker

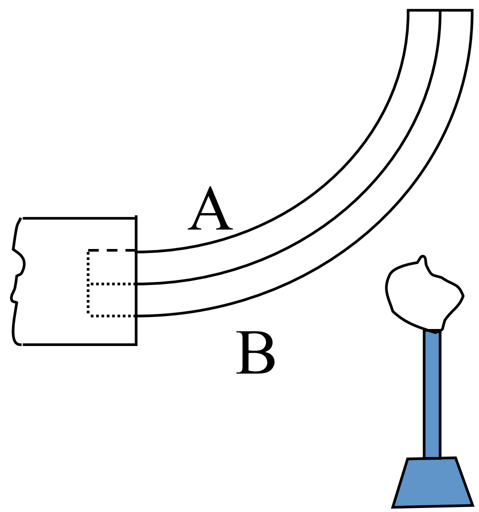
Thermal Expansion Coefficient

Materials	Expansion Coefficient
Aluminium	$25 \times 10^{-6} /°C$
Copper	$16.6 \times 10^{-6} /°C$
Steel	$6.7 \times 10^{-6} /°C$

Without Heat



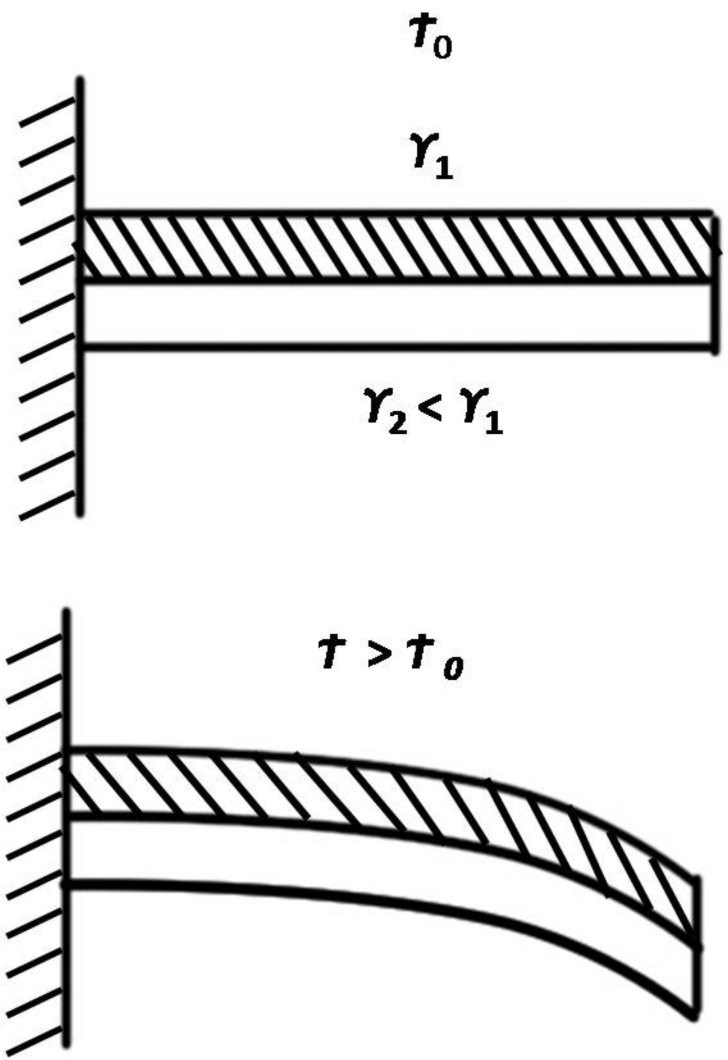
Heat Applied



Metal A (low expansion)

Metal B (high expansion)

The different rate at which metals expand when heated is the principle of the bimetallic strips.



A bimetal strip will curve when exposed to a temperature change because of different thermal expansion coefficients. Metal thickness has been exaggerated in this view.

- Thermal expansion formula

  $L = L_0 [1+\gamma\Delta T]$

  Where;

  $\Delta T = T-T_0$

  L_0 = initial length

  L = final length

  γ = thermal expansion coefficient

Example

- How much will an aluminium rod of 10-m length at 20°C expand when the temperature is changed from 0 to 100°C?.

Solution:

First, find the length at 0°C and at 100°C; then find the difference. Using previous equation.

at 0°C:

L_1 = (10)[1+(25x10^{-6}/°C)(0°C – 20°C) = 9.995m

at 100°C:

L_2 = (10)[1+25x10-6/°C)(100°C – 20°C) = 10.02m

Thus, the expansion is $L_2 – L_1$ = 0.025m = 25mm

ADVANTAGES AND DISADVANTAGES OF BIMETALLIC SENSOR

Advantages

- Durability
- Cheap
- Simple Design

Disadvantages

- Not accurate
- Difficult to calibrate
- Limited in application

2. THERMOCOUPLE

- **Consists of a pair of wires of different metal types where ends of each wires are connected.**
- **Both these ends are known as "cold-junction" and "hot – junction".**
- **When one of the edges is heated, current will flow continuously in the circuit.**
- **This characteristic is known as the thermoelectric effect where the electric voltage which is proportionate to temperature will be produced when there is a temperature difference between the "hot junction" and "cold junction"**

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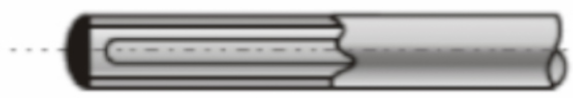
where a is a constant (V/K).

- **Thermocouples are coated with metal tubes for protection.**

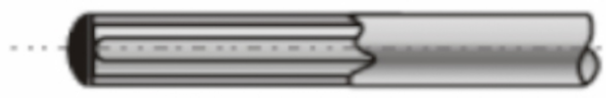
Hot End Junctions

Insulated Junction

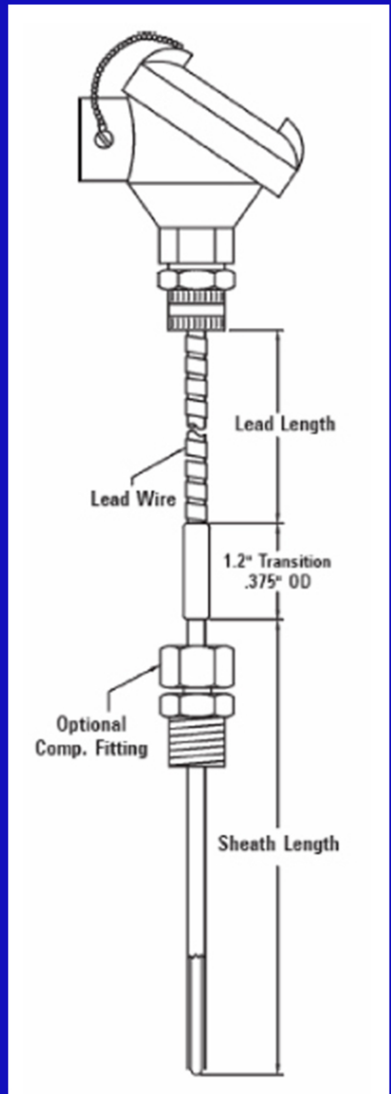


Insulated hot ende junction are suitable for most applications, espeially where low EMF pick-up is essential. High insulation resistanc is enhanced due to extreme compaction of the high purity MgO powder insulation.

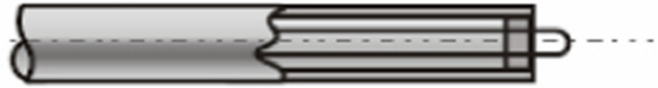
Bonded Junction



Bonded or grounded junctions offer a slightly faster temperature response than the insulated junction type. Not recommended for multi-point instrumentation.



Exposed Junction

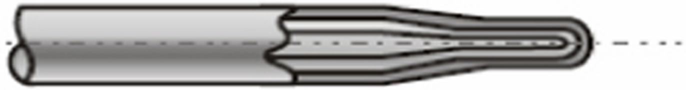


Bare or exposed junction thermocouples provide extremely fast temperature response. Although the exposed MgO is completely moisture sealed, it is not recommended for corrosive environments or temperatures in excess of 300ºC

Extended Tip Junction

Extended tip junction can also be provided to special order. Their solid end makes this type of construction ideal for spot welding or peening to the contact surface. The standard version has a pointed tip 15 mm long. Other shapes can be provided

Reduced Tip Junction



Reduced tip junctions are ideal for applications where low mass and extremely fast response times are required, together with good mechanical strength. Reduced tip can be provided on 1.0 to 6.0 mm diameter thermocouples.

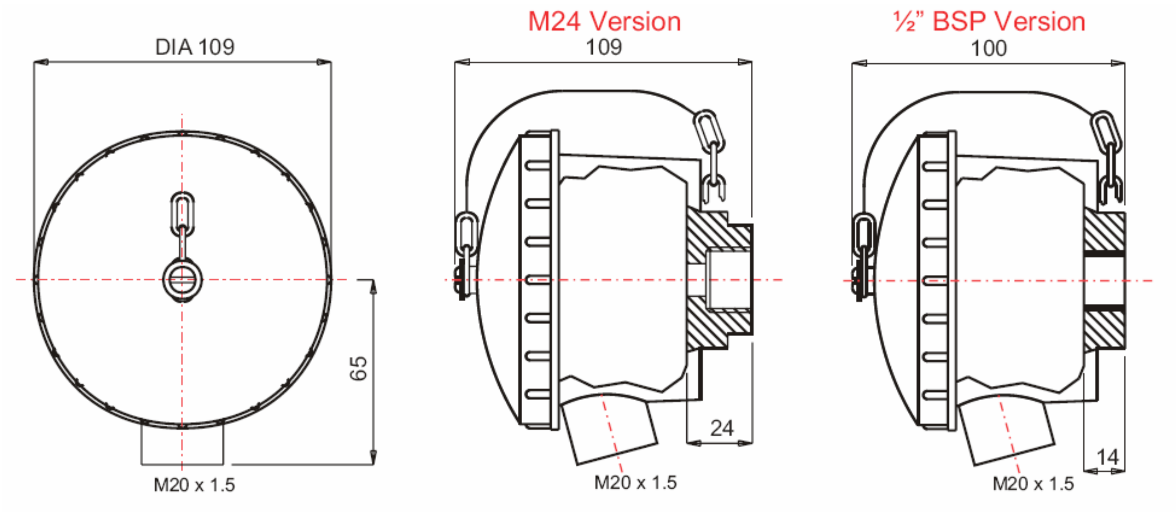
Compression Seal

Sliding Compression Fitting

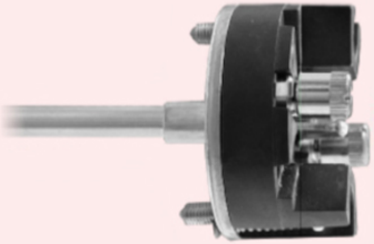
Fittings

A wide range of termination glands and adjustable compression fittings are available to suit thermocouples of all diameters.

Connection Head



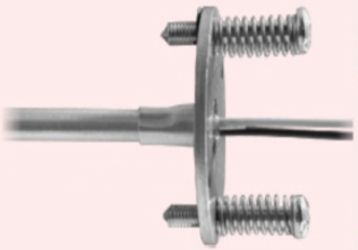
Cold End Terminations

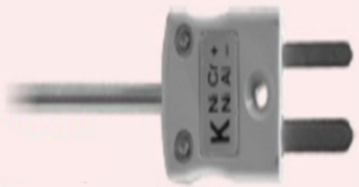

Rayton Block


P4 Plug


C Pot


PS1 Pot


Transmitter Baseplate


P3 Plug


A Pot

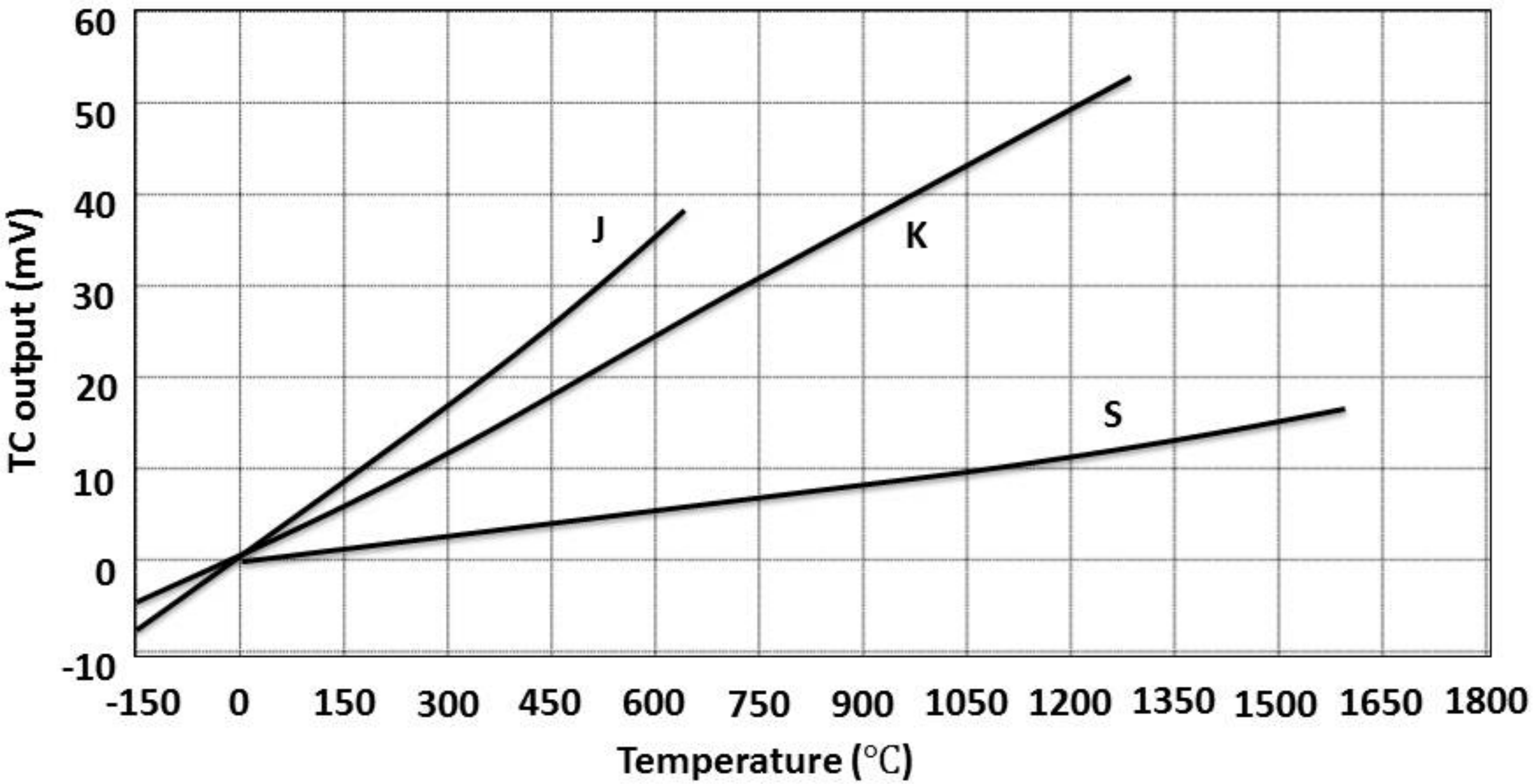

B Pot

STANDARD TERMOCOUPLE

- The type of material used for both wires in the thermocouple determines the type.

Type	Material	Typical Range
J	Iron-constantan	- 190° - 760°
T	Copper-constantan	- 200° - 371°
K	Chromel-alumel	- 190° - 1260°
E	Chromel-constantan	- 100° - 1260°
S	90% Platinum+10% Rhodium-Platinum	0° - 1482°
R	7% Platinum+13% Rhodium-Platinum	0° - 1482°

- Normally a table is provided with each thermocouple to show the output of the thermocouple.



These curves of thermocouple voltage versus temperature for a 0 °C reference show the different sensitivities and nonlinearities of three types.

Thermocouple Types

Type	Conductor Materials	Standard Tolerances
K	Nickel-Chromium/ Nickel-Aluminium	40°C to 333°C : ± 2.5°C 333°C to 1200°C : ± 0.75%
J	Iron/ Copper-Nickel	-40°C to 333°C : ± 2.5°C 333°C to 750°C : ± 0.75%
T	Copper/ Copper-Nickel	-40°C to 133°C : ± 1°C 133°C to 350°C : 0.75%
E	Nickel-Chromium/ Copper-Nickel	-40°C to 333°C : ± 2.5°C 333°C to 900°C : ± 0.75%
N	Nickel-Chromium/ Nickel-Silicon	40°C to 333°C : ± 2.5°C 333°C to 1200°C : ± 0.75%
B	Platinum-30%Rhodium/ Platinum-6%Rhodium	0 to 600°C : ± 1.5°C 600°C to 1700°C : ± 0.25%
R	Platinum-13%Rhodium/ Platinum	0 to 600°C : ± 1.5°C 600°C to 1600°C : ± 0.25%
S	Platinum-10%Rhodium/ Platinum	0 to 600°C : ± 1.5°C 600°C to 1600°C : ± 0.25%

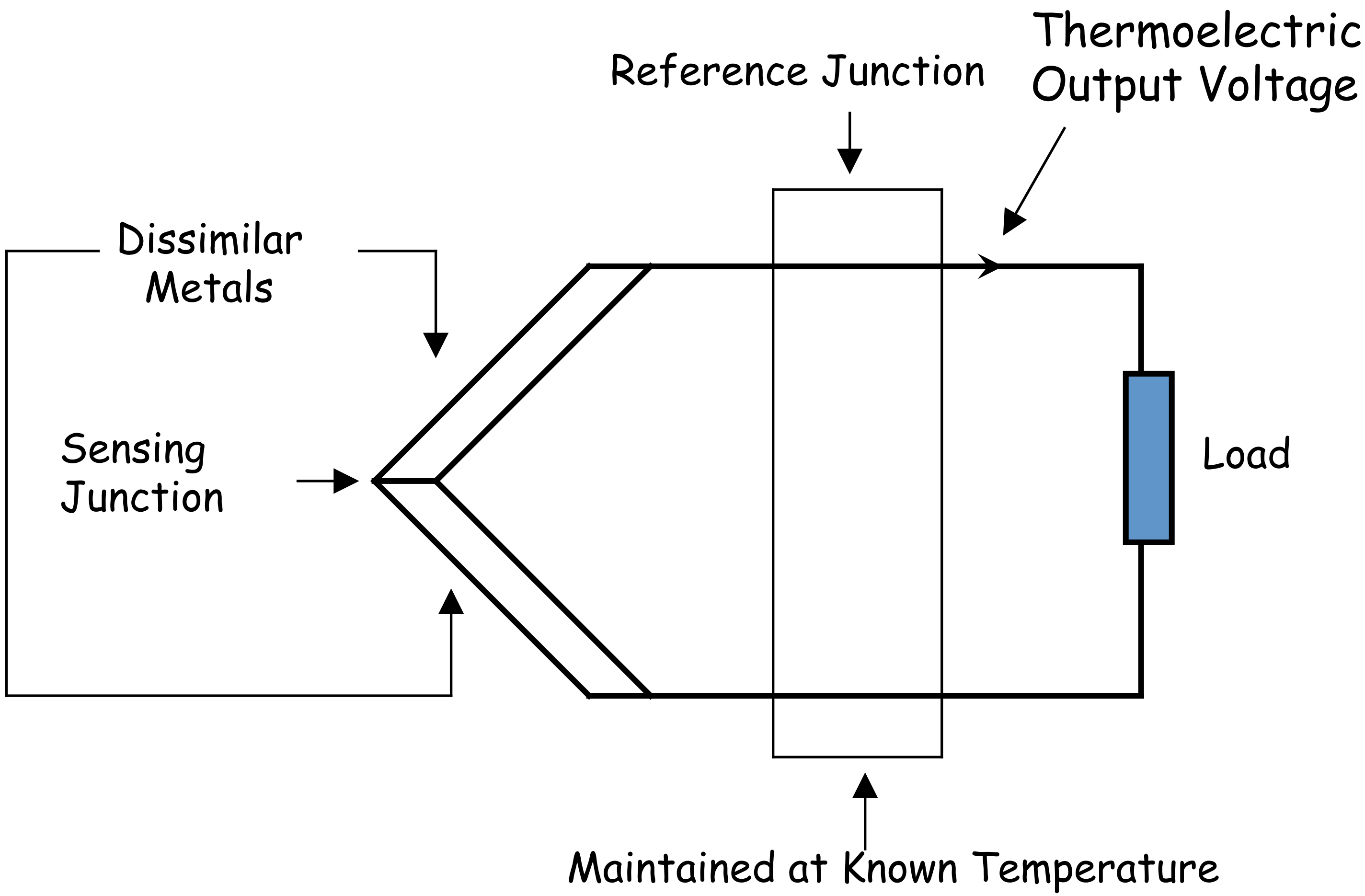
ADVANTAGES AND DISADVANTAGES OF STANDARD THERMOCOUPLE:

Advantages

- Small size, cheap price
- Large range
- Durable
- Satisfactory accuracy
- Large range of signal transmission

Disadvantages

- Stray pickup
- Easy to rust
- Amplifier needed



Basic Thermocouple Circuit

BRIDGE CIRCUIT

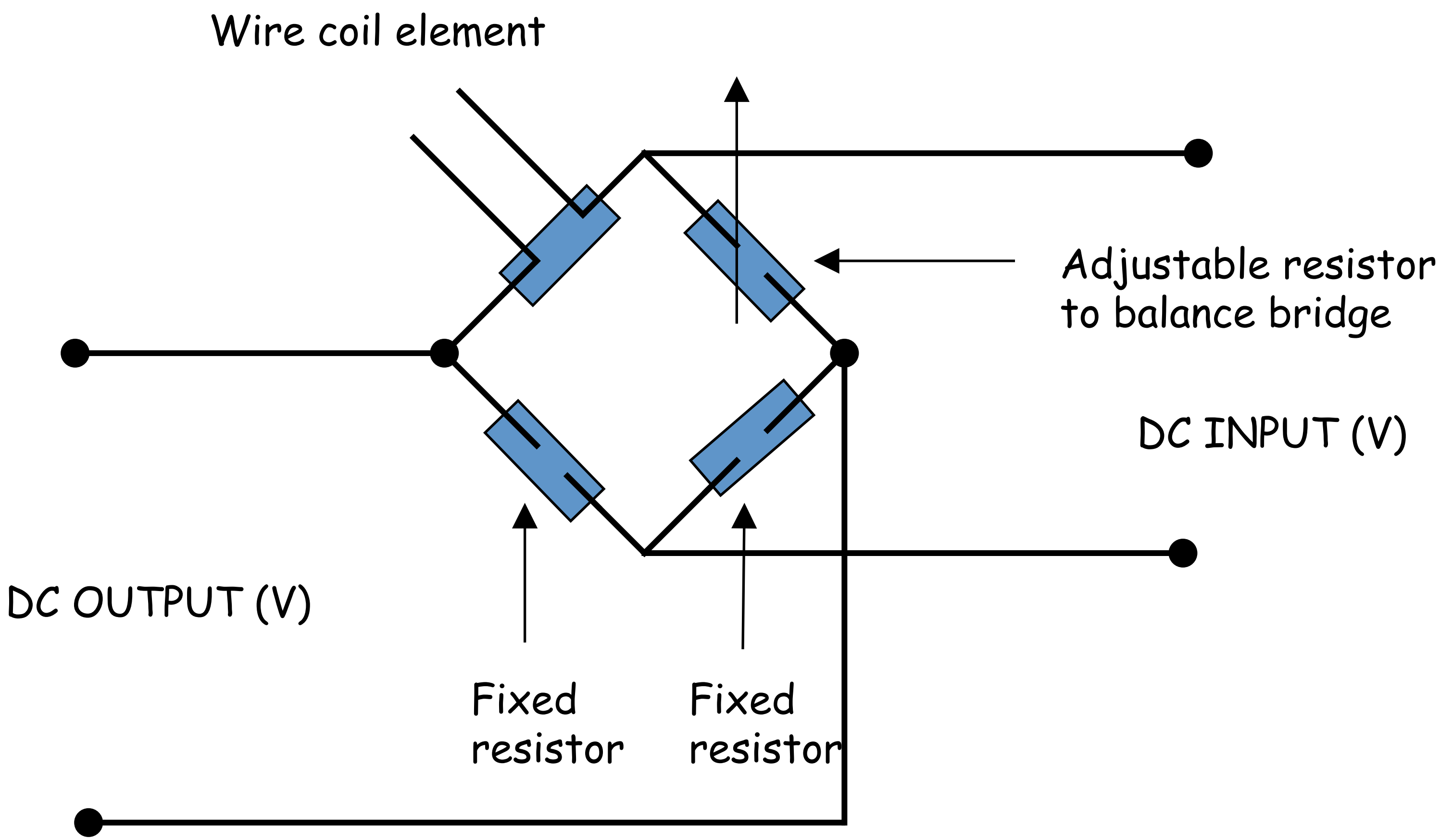
Wheatstone Bridge

- Used to change any difference.
- Simplest bridge circuit and normally used.
- The output voltage shows the difference between voltage at point a (V_a) and point b (V_b).
- Output voltage (V_o) = $V_a - V_b$.
- Uses 'voltage divider':

$$V_a = \frac{R_3}{R_1 + R_3} \bullet V$$

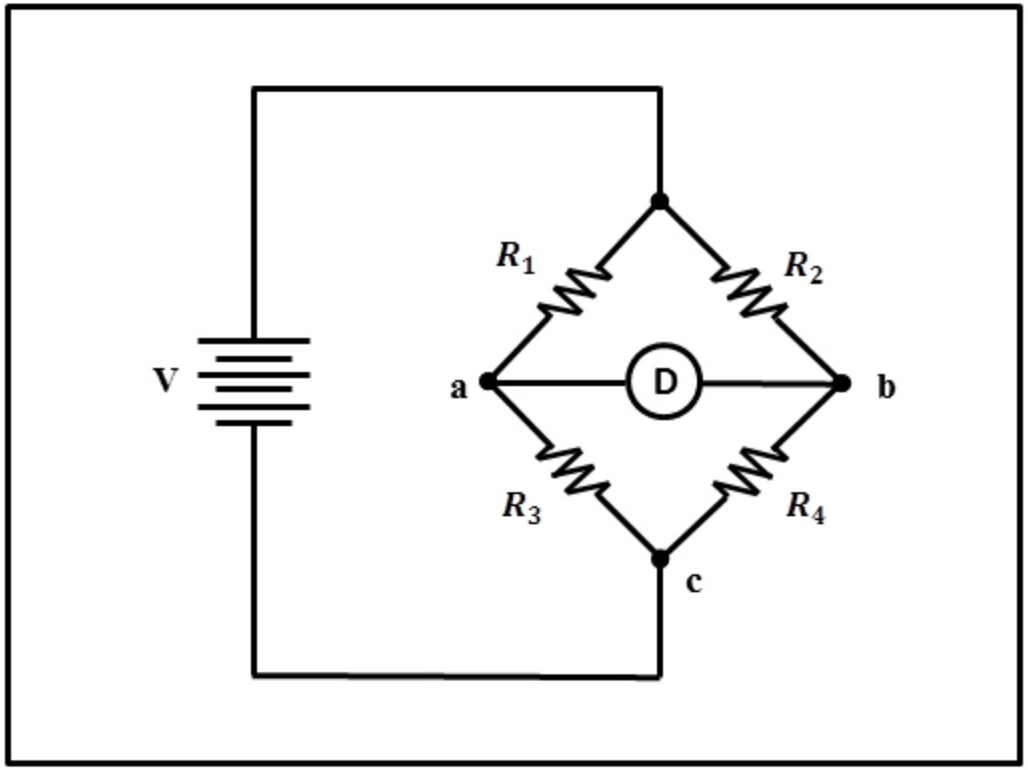
$$V_b = \frac{R_4}{R_2 + R_4} \bullet V$$

V= bridge supply voltage



WHEATSTONE BRIDGE (DC input, Null Deflection Type)

The basic dc Wheatstone bridge



- **For null deflection type:**
  $V_0 = V_a - V_b = 0$
  $V_a - V_b = 0$

- **Input of V_a and V_b :**

$$\frac{R_3}{R_1 + R_3} \bullet V - \frac{R_4}{R_2 + R_4} \bullet V = 0$$

$$V\left(\frac{R_2R_3 + R_3R_4 - R_1R_4 - R_3R_4}{(R_1 + R_3) \bullet (R_2 + R_4)}\right) = 0$$

$$\therefore \quad R_2R_3 - R_1R_4 = 0$$

$$R_2R_3 = R_1R_4$$

Example 1:

If the output voltage of a Wheatstone Bridge is zero with R_1 = 1000 Ω , R_2 = 842 Ω and R_3 = 500 Ω, determine R_4 in null state condition.

$$R_1 R_4 = R_2 R_3$$

$$R_4 = \frac{R_2 R_3}{R_1} = \frac{(500\,\Omega)\cdot(842\,\Omega)}{1000\,\Omega} = 421\,\Omega$$

Example 2:

A Wheatstone bridge has $R_1 = R_2 = R_3 = 120\ \Omega$ and $R_4 = 121\ \Omega$. If the voltage is V, determine the output voltage.

$$V_0 = V\left[\frac{R_2R_3 - R_1R_4}{(R_1 + R_3)\cdot(R_2 + R_4)}\right]$$

$$V_0 = 10\left[\frac{(120)(120) - (120(121))}{(120 + 120)\cdot(120 + 121)}\right]$$

$$V_0 = -20.7\text{mV}$$

3. RESITIVE TEMPERATURE DETECTOR (RTD)

- Resistivity of a metal has relation to temperature. i.e. when temperature increases, resistance increases.
- $$R \cong R_0(1 + aT)$$

where: R : resistance

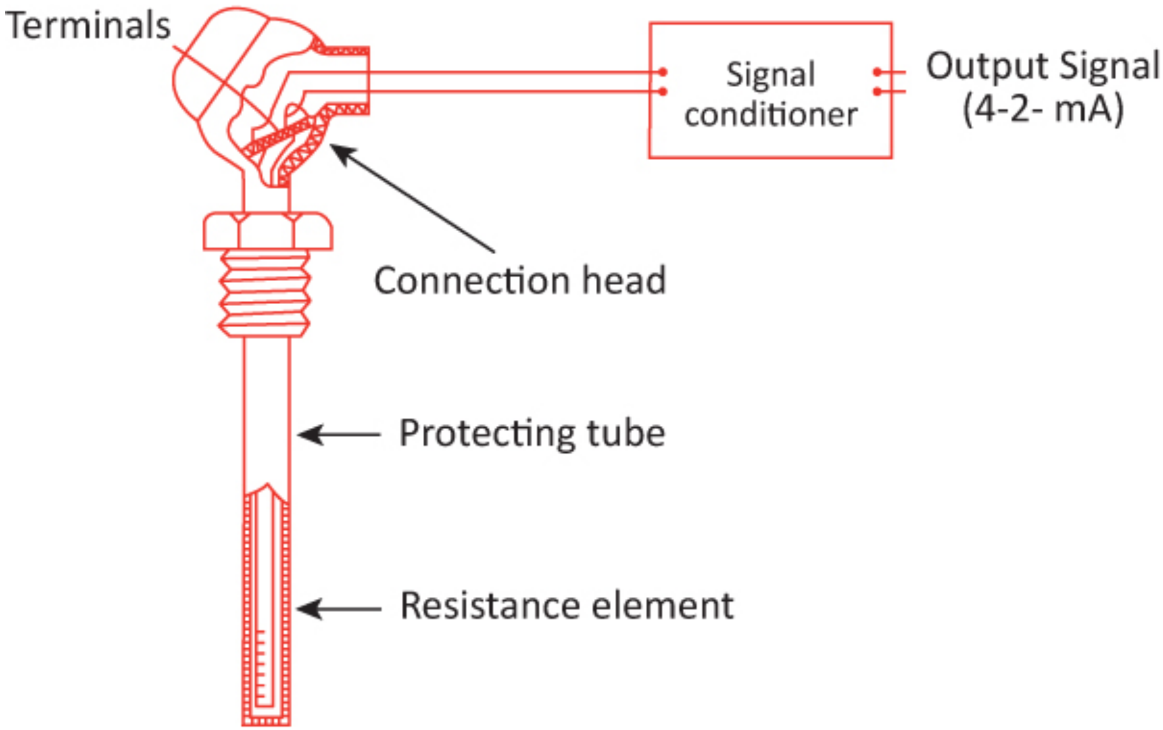
R_0 : resistance at 0 Kelvin

a : constant

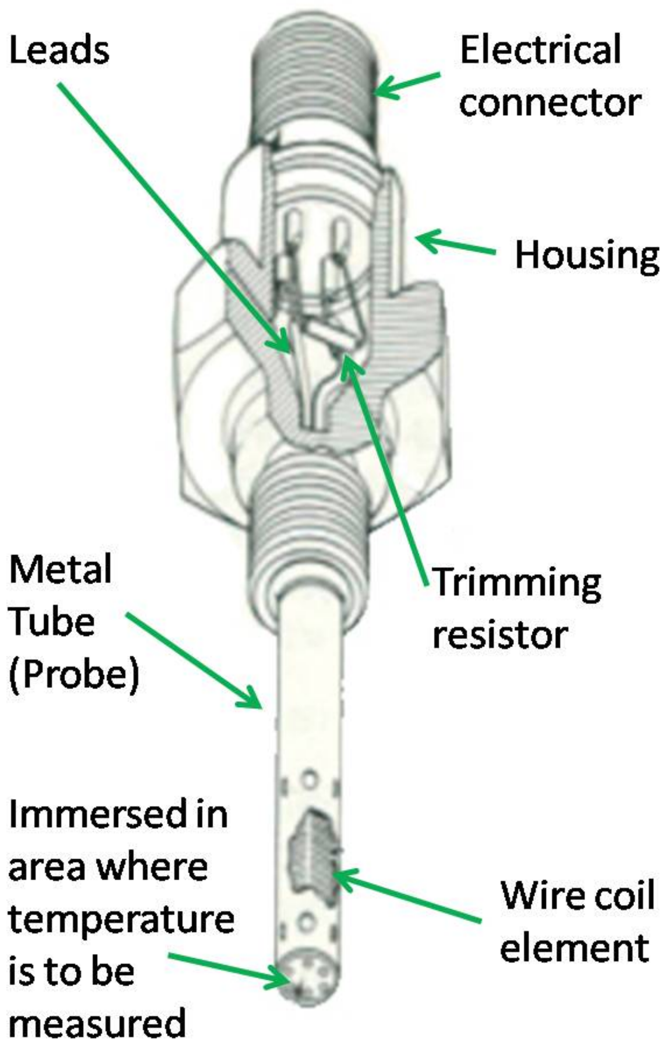
T : temperature

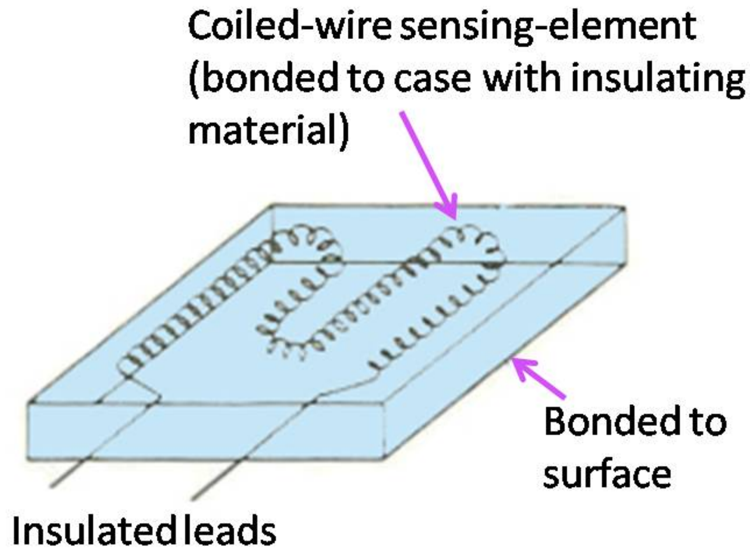
- The temperature sensor element is a thin wire coil (normally nickel or platinum) which is located at the end of the tube.

- **The range of RTD depends on the type of metal used where the range for platinum is -100° - 650° C and the range for nickel is -180° – 300° C.**
- **Nickel type RTD is cheaper than platinum but it is having lesser linearity.**
- **RTD sensor requires a Wheatstone Bridge signal modifier to change the resistance to standard voltage.**


Terminals
Signal conditioner
Output Signal (4-2- mA)
Connection head
Protecting tube
Resistance element

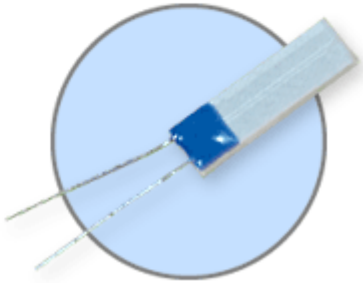
RTD Sensor


Leads
Electrical connector
Housing
Metal Tube (Probe)
Trimming resistor
Immersed in area where temperature is to be measured
Wire coil element

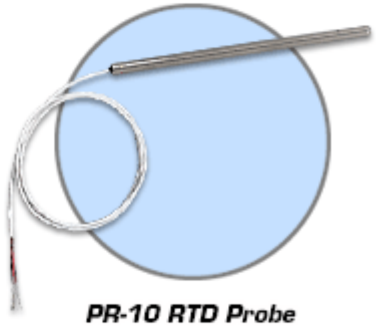

Coiled-wire sensing-element (bonded to case with insulating material)
Bonded to surface
Insulated leads

Resistance Thermometers

1PT100G RTD Elements



TFD RTD Surface Element



PR-10 RTD Probe

General Description

Platinum Resistance Sensors offer the highest standard of accuracy and stability of any temperature sensor. They also exhibit good linear response, covering a temperature range from -200ºC to +650ºC. They are easy to apply and require no special cables or cold junction reference. Platinum resistance sensors are finding increasing favour in industry, where their high accuracy, repeatability and stability are vital. Minerally insulated RTDs are manufactured from superior grade materials.

RTD Elements

The RTD element is the simplest form of RTD. It consists of a piece of wire wrapped around a ceramic or glass core. Because of their compact size, RTD elements are commonly used when space is very limited.

RTD Surface Elements

A surface element is a special type of RTD element. It is designed to be as thin as possible thus providing good contact for temperature measurement of flat surfaces.

RTD Probes

The RTD probe is the most rugged form of RTD. A probe consists of an RTD element mounted inside a metal tube, also known as a sheath. The sheath protects the element from the environment. OMEGA offers a wide variety of probes in various configurations.

- It is possible to express the resistance of a particular metal sample at a constant temperature analytically using the following equation.

$$R = \rho \frac{l}{A} (T = cons\tan t)$$

Where,

R = sample resistance (Ω)

ρ = resistivity (Ω.m)

l = length (m)

A = cross-sectional area (m^2)

ADVANTAGES AND DISADVANTAGES

Advantages

- Large temperature range
- High accuracy
- High precision
- Good linearity
- Small size

Disadvantages

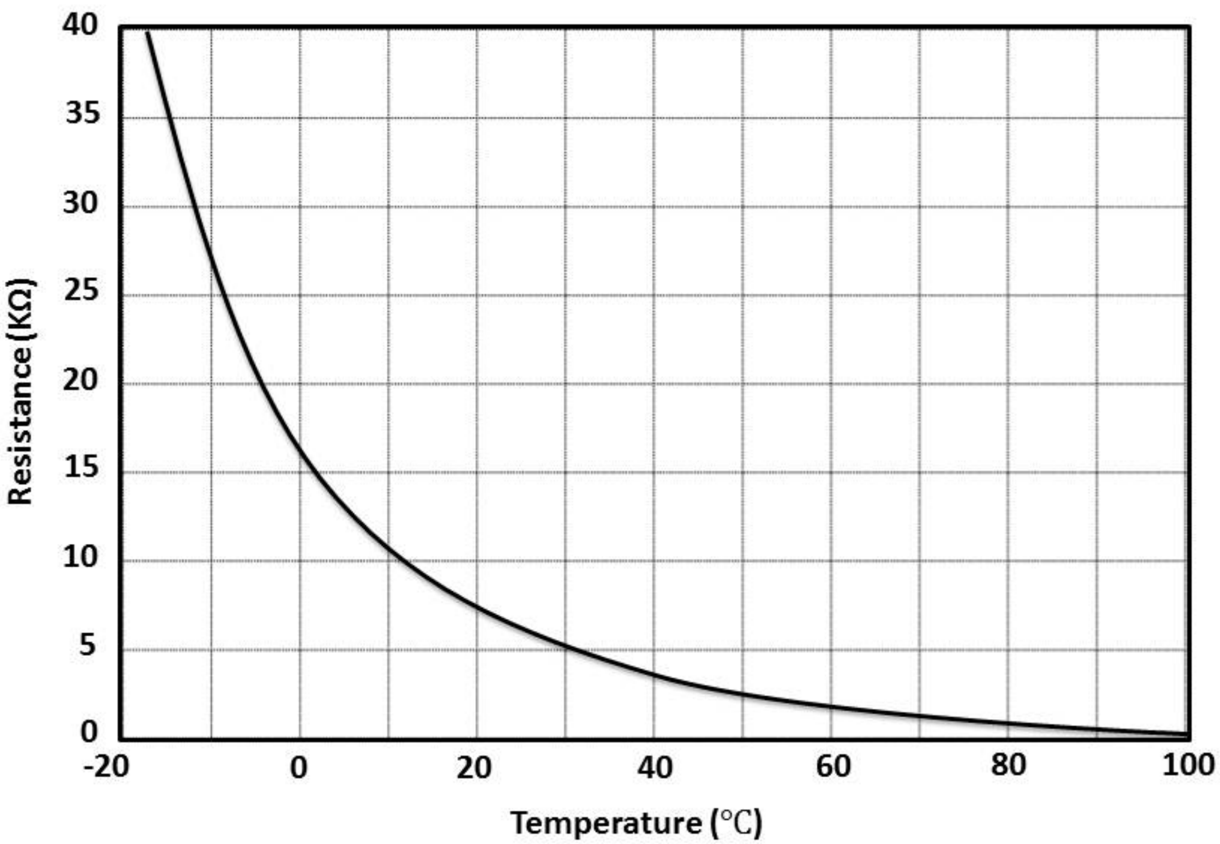
- Low response time due to the protection tube
- Difficult to fix

4. Thermistor

- This sensor consists of a semiconductor which undergoes a large change of resistance when there is a change in temperature.
- The semiconductor material consists of a mixture of a few metal oxides which were sintered at a high temperature.
- A thermistor can be fabricated in many forms due to its semiconductor behaviour. e.g. disk, rod, bead and others where the diameter can range from 1 mm to a few centimetres.
- Has a negative temperature coefficient. i.e. resistance decreases with increasing temperature.

$$R = R_0 \exp\left[\beta(1/T) + (1 + T_0)\right]$$

A Simple Application of Themistor



Thermistor resistance versus temperature is highly nonlinear and usually has a negative slope.

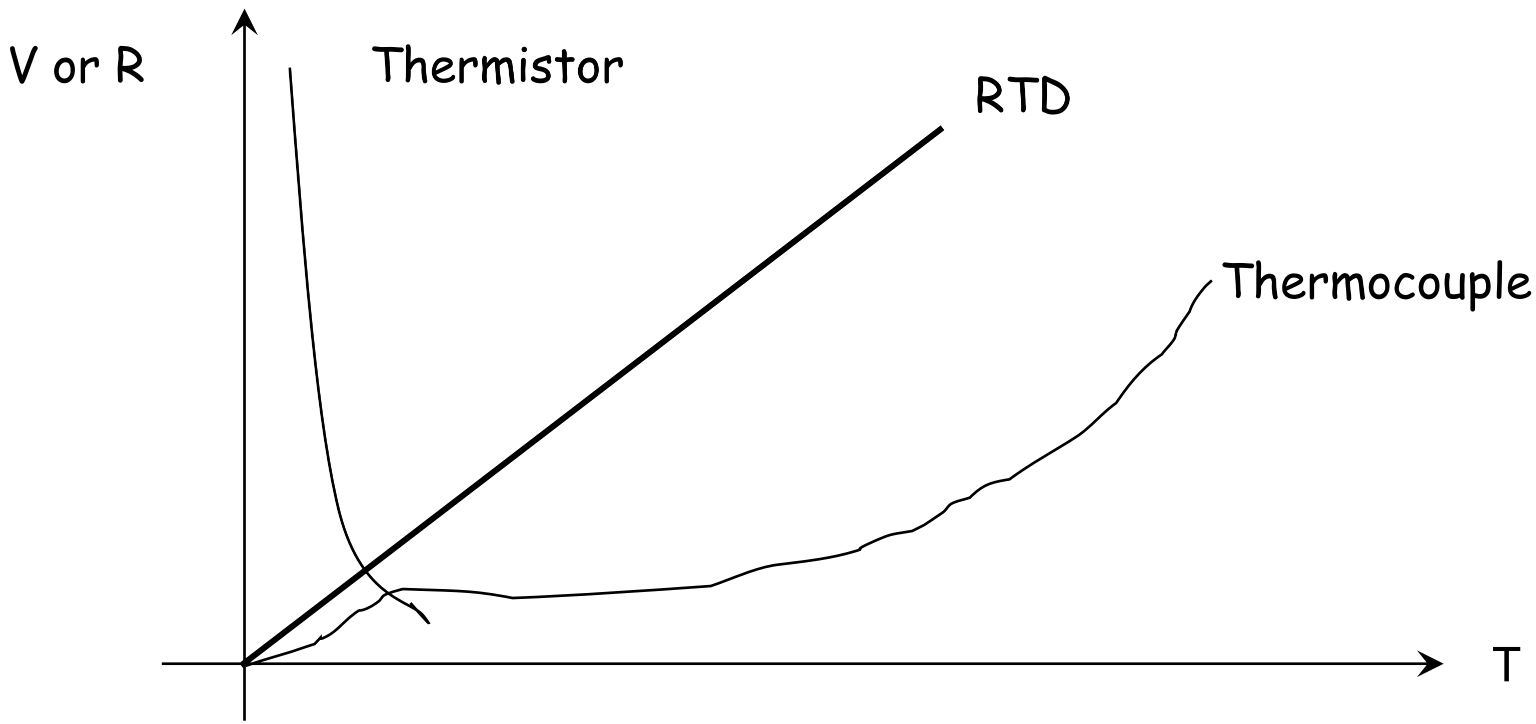
ADVANTAGES AND DISADVANTAGES

Advantages

- Relatively low cost
- Their small size

Disadvantages

- Non-linear
- The size reduction also decreases its heat dissipation capability



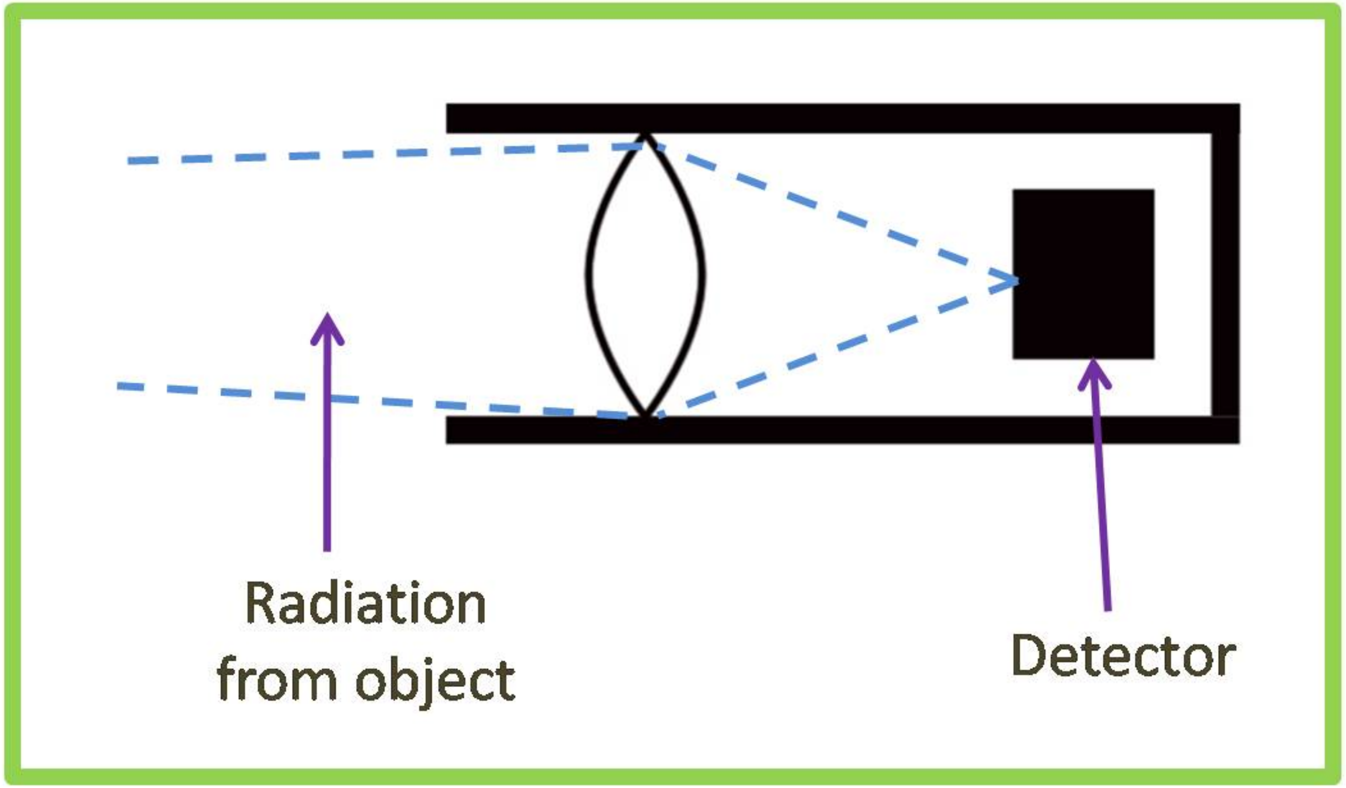
Relative response for Thermistor, RTD and Thermocouple

5. RADIATION PYROMETER

- Measures temperature by detecting thermal radiation from an object without touching the object.
- Consists of an optic system which accumulates visible infrared energy and focuses the energy to the detector.
- The detector will convert the energy to electricity, where the electric energy is proportionate to temperature.
- Radiation emission:

$$E \,\alpha\, T^4 \left(W/m^2\right)$$

where, T is the temperature of the object in Kelvin.

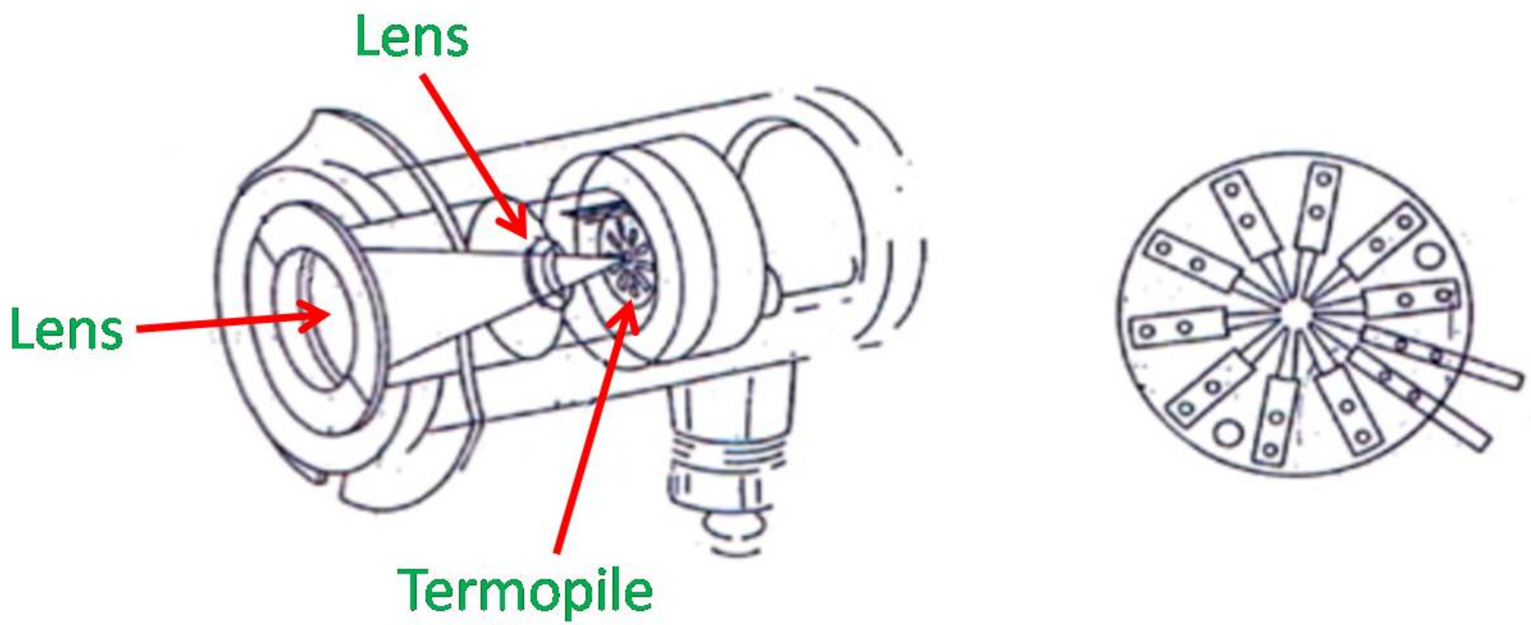


Structure of the radiation pyrometer

- **Thermopile is normally used to detect infrared energy where it normally consists of a few small thermocouples.**
- **These small thermocouples are connected serially to increase sensitivity of the pyrometer where the effect of serial connection will increase the sensitivity of sensor as much as *n* times.**

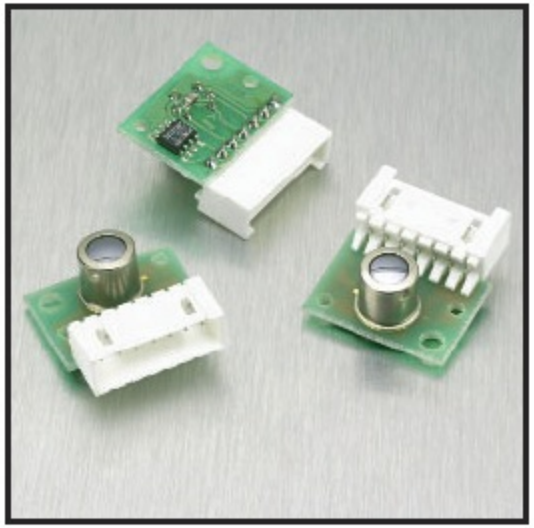
- **Radiation pyrometers have one major advantage in that they do not require to be in contact with the hot body in order to measure its temperature. Thus, there is no disturbance at all of the measured system.**

- **Furthermore, there is no possibility of contamination, which is particularly important in the food and many other process industries.**



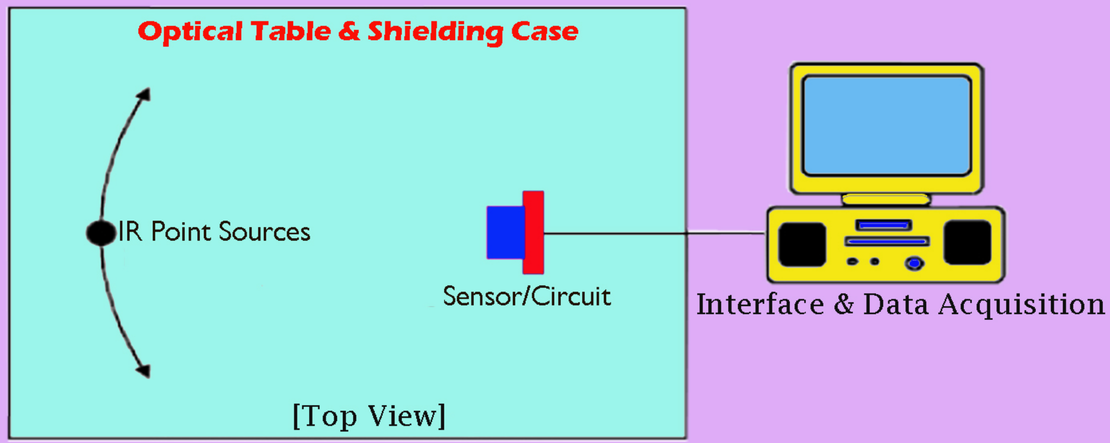
Pyrometer With A Thermopile Sensor

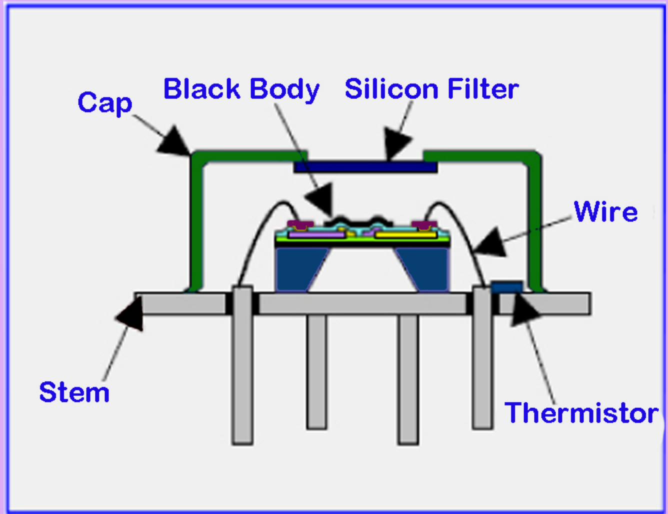
Dual and Quad Element Thermopile Detectors

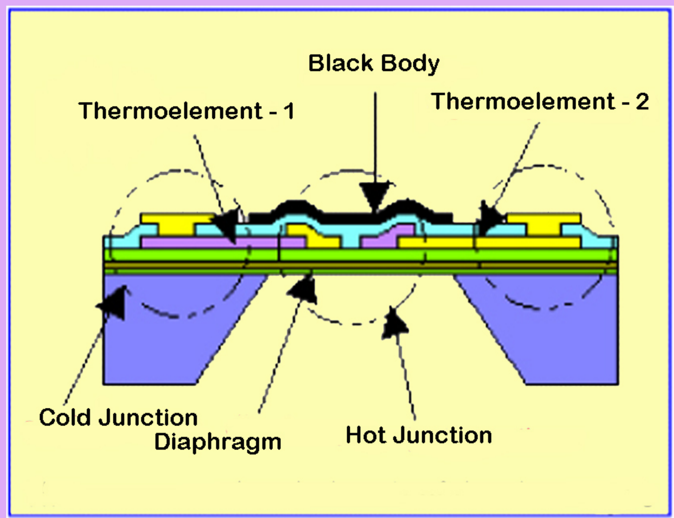


Thermopile Arrays

Thermopile TPMI Modules

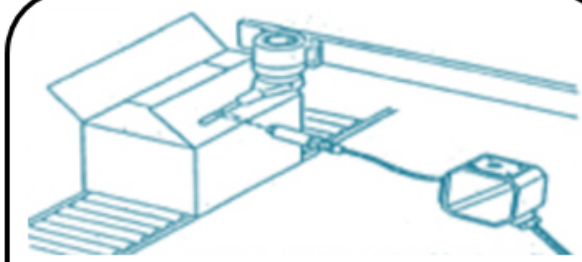




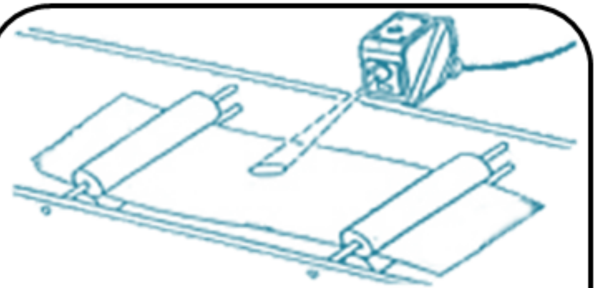


Physical Construction of Thermopile

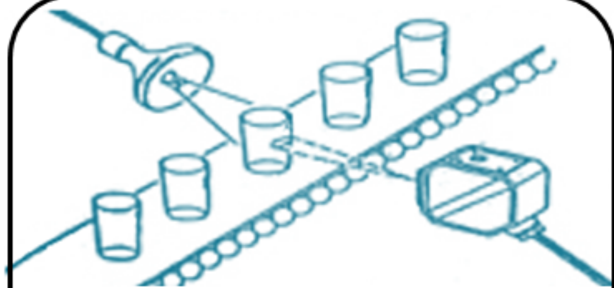
Examples of Pyrometer Applications



Existence/Absence of Hot melt

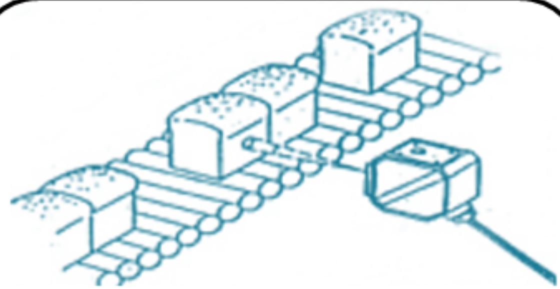


Preheating Temperature of Resin

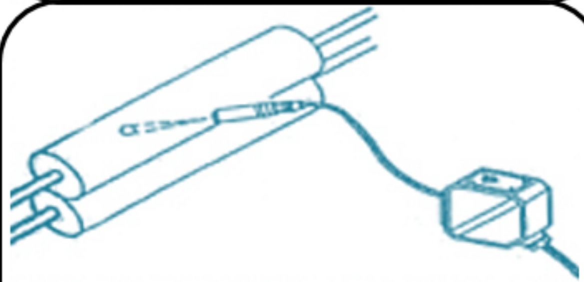


Transparency Transit Counting

Preheating of PC Board



Temperature Control Food Industry

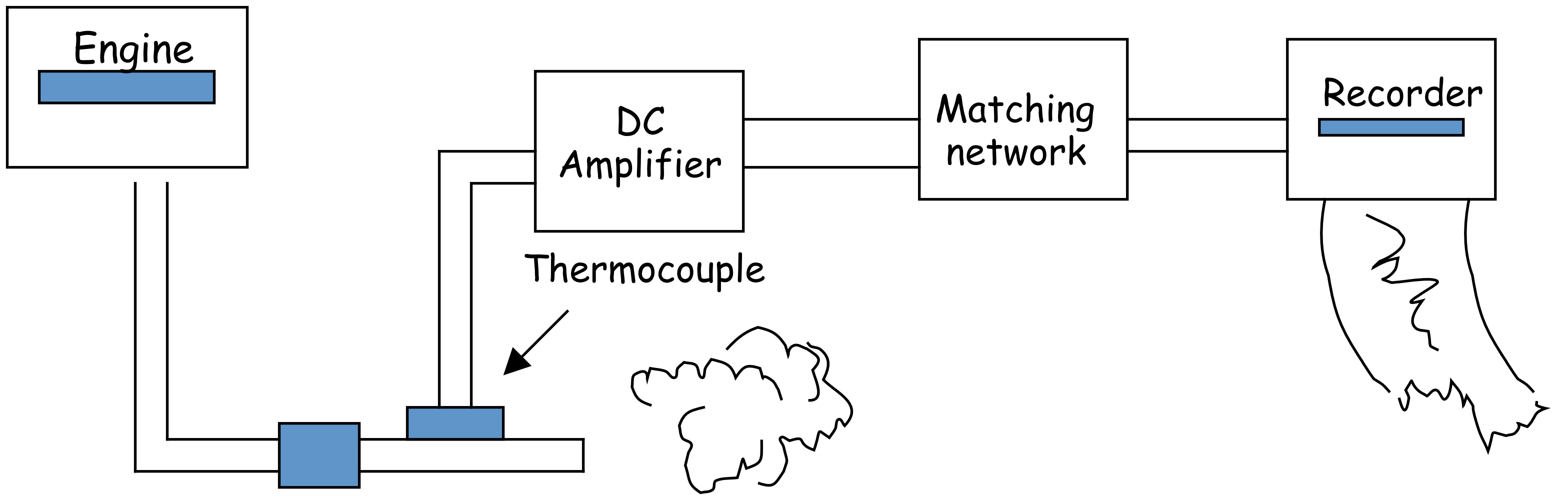


Comparison Between Temperature Sensors

Type of Temperature Sensor	Advantages	Disadvantages
Thermocouple	▪Self-powered ▪Simple ▪Rugged ▪Low cost ▪Ease of installation ▪Wide variety ▪Wide temperature range	▪Non-linear ▪Low voltage ▪Reference required ▪Least stable ▪Least sensitive
RTD	▪Most stable ▪Most accurate ▪Reasonably linear (more linear than thermocouple)	▪Expensive ▪Small ΔR ▪Slow response ▪Current Source required ▪Self-heating
Thermistor	▪High output ▪Fast response ▪Two-wire Ohm measurement ▪Small size	▪Non-linear ▪Limited temperature range ▪Current source required ▪Self-heating
Radiation Pyrometer	▪No physical contact fast response ▪Ability to measure high temperature and temperature of small objects	▪High cost ▪Non-linear response
Integrated Circuit Sensor	▪Inexpensive ▪Most linear ▪Highest output	▪$T < 200°C$ ▪Power Supply required ▪Slow ▪Self-heating

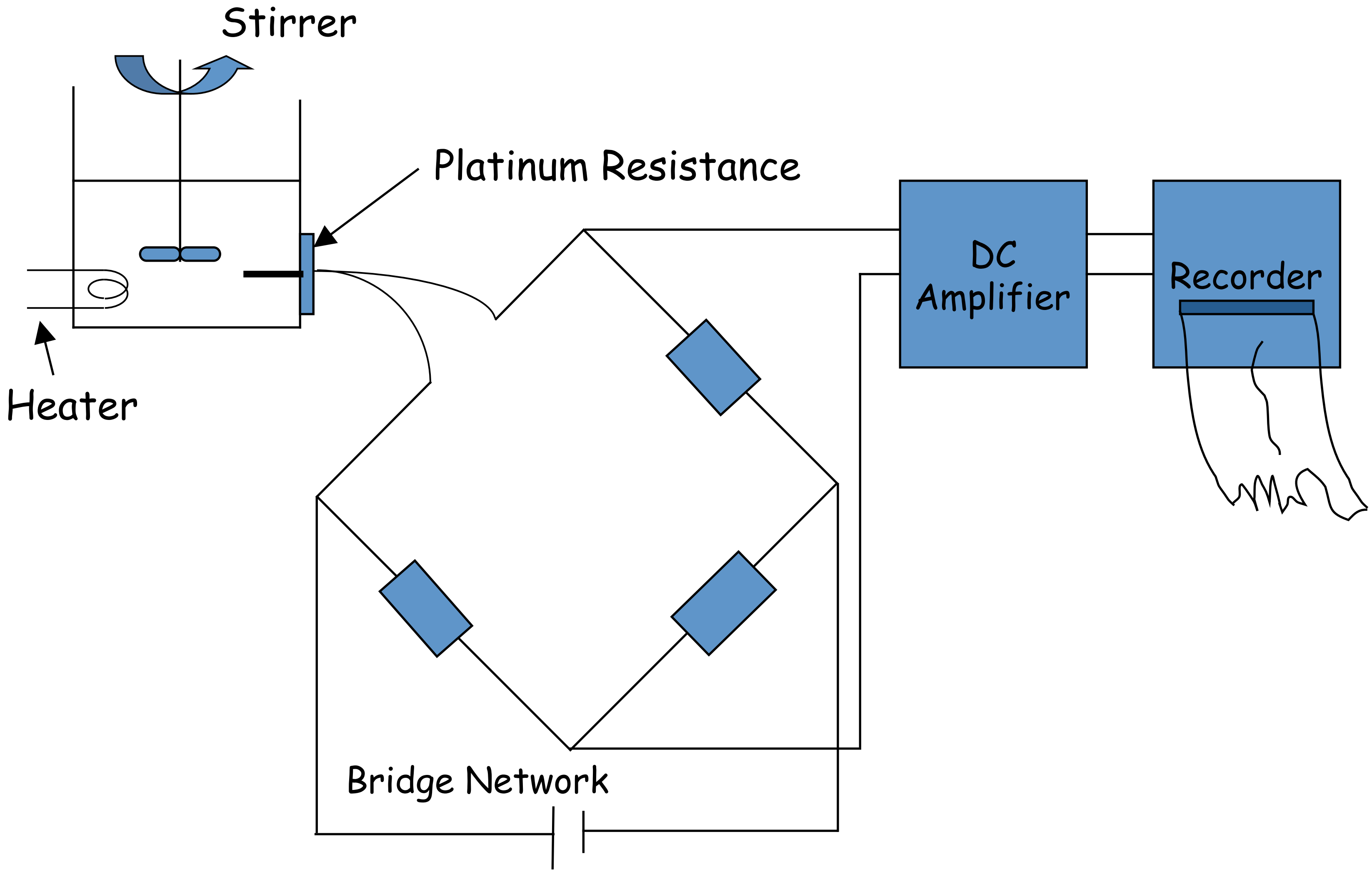
EXAMPLES OF TEMPERATURE MEASUREMENT SYSTEMS

- **Measurement of exhaust gas temperature in the engine.**



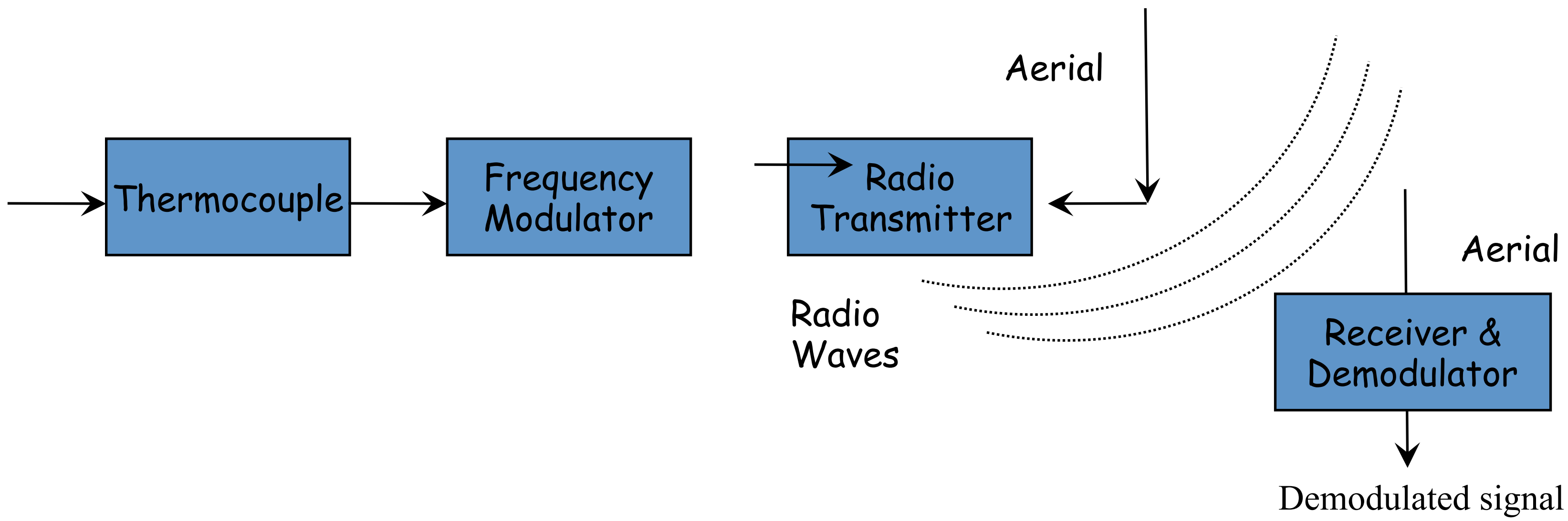
- **The above diagram shows a typical exhaust gas temperature control using a thermocouple. A DC amplifier is used to amplify the thermocouple output to a suitable value to be connected to a "matching network".**

- **Temperature measurement in a hot water tank.**
- **A platinum resistance thermometer is placed in a liquid filled tank. The resistance change will be changed to voltage through a "bridge network". A DC amplifier produces enough voltage for the recorder to operate. A stirrer is used to keep the temperature uniform.**



Stirrer
Platinum Resistance
Heater
DC Amplifier
Recorder
Bridge Network

• Telemetry In Temperature Measurement



- **Sometimes temperature measurement from a distance is needed and this is when the telemetry comes in. Voltage from a thermocouple is used to modulate the frequency to high wave radio frequency. This radio wave is transmitted and received by the radio frequency receiver where a demodulator is used to get the initial temperature reading.**

PRESSURE SENSOR

Can be divided into three types:

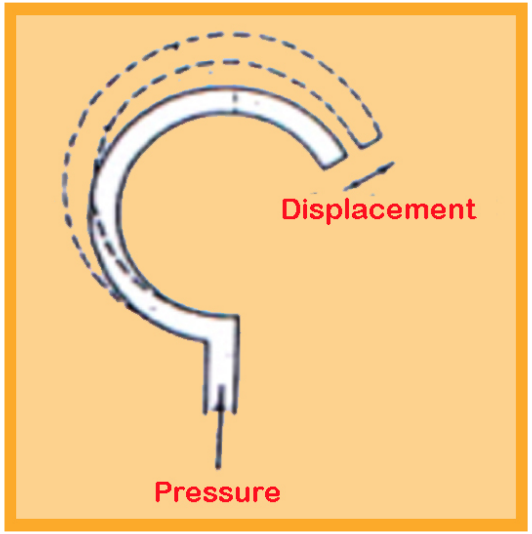
1. Deflection type
2. Strain gauge type
3. Piezoelectric type

Typical Pressure Detector System

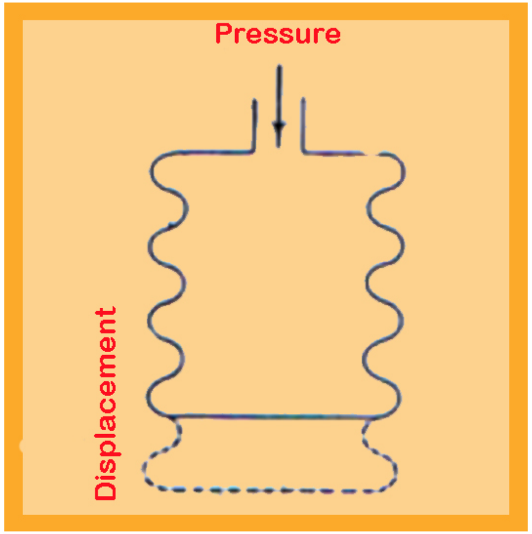
1. DEFLECTION TYPE PRESSURE SENSOR

- This sensor uses an elastic material to convert pressure to displacement e.g. stainless steel, brass.
- The displacement will be proportionate to the value of pressure exerted.
- Suitable to be used in an automatic control system.
- The main element used is in the shape of Bourdon tube, bellow or diaphragm.
- The secondary element is the element that will convert the displacement to electrical signals where the displacement can be detected through resistivity change, inductance or capacitance.

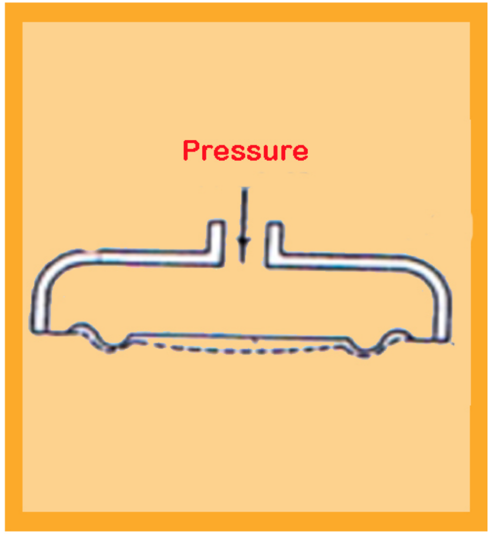
a) A Circular Bourdon Pressure Element

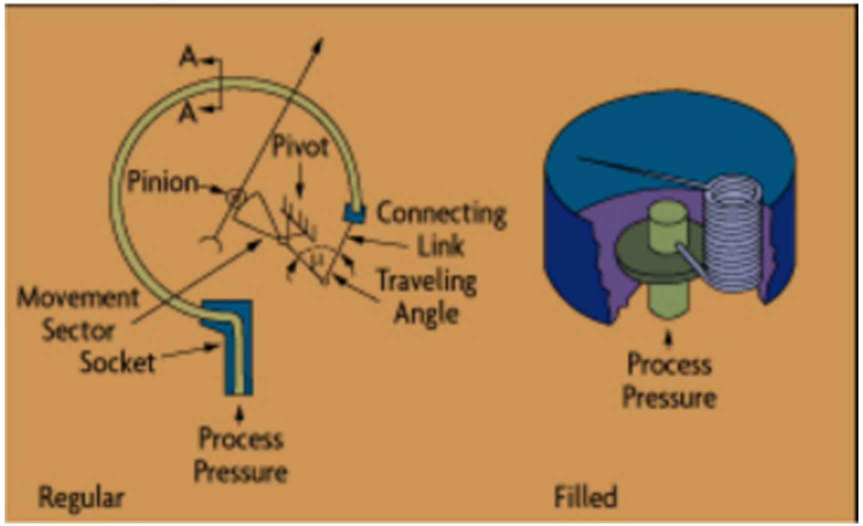


b) A bellows Pressure Element



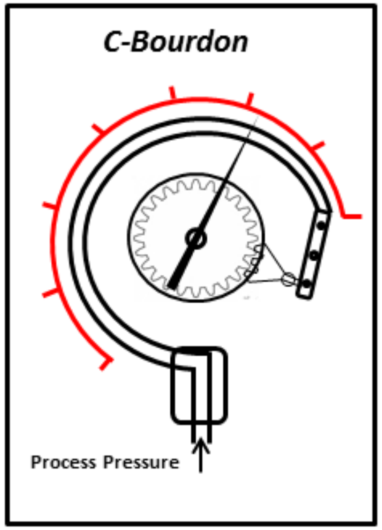
c) A diaphragm Pressure Element

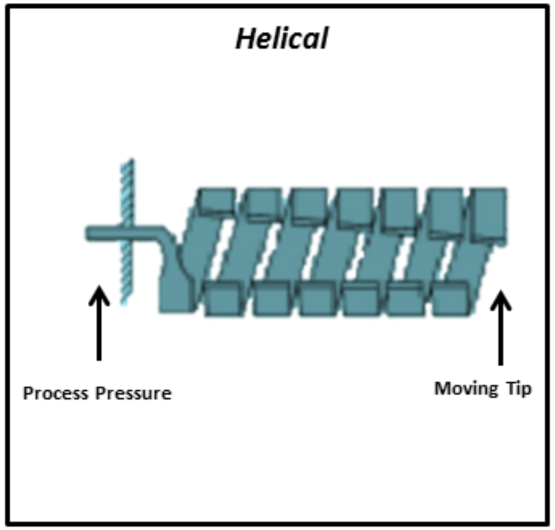


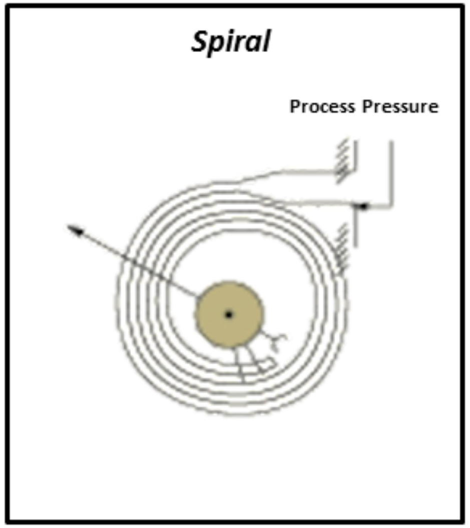


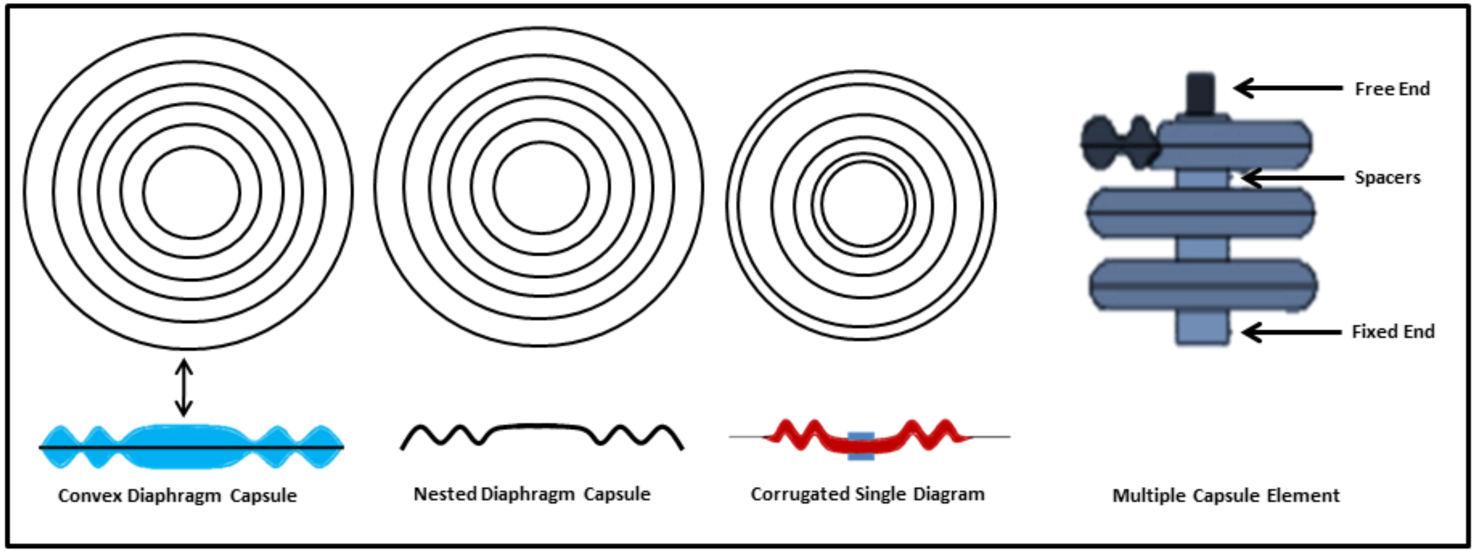
The Main Typical Element Used In A Deflection Type Pressure Sensor

Basic Form of Mechanical Pressure Sensors









Example :

i. Bellow-resistance pressure sensor

- The pressure is proportionate to the resistivity.
- The resistance change is detected by displacement of sliding contact in the resistance element.

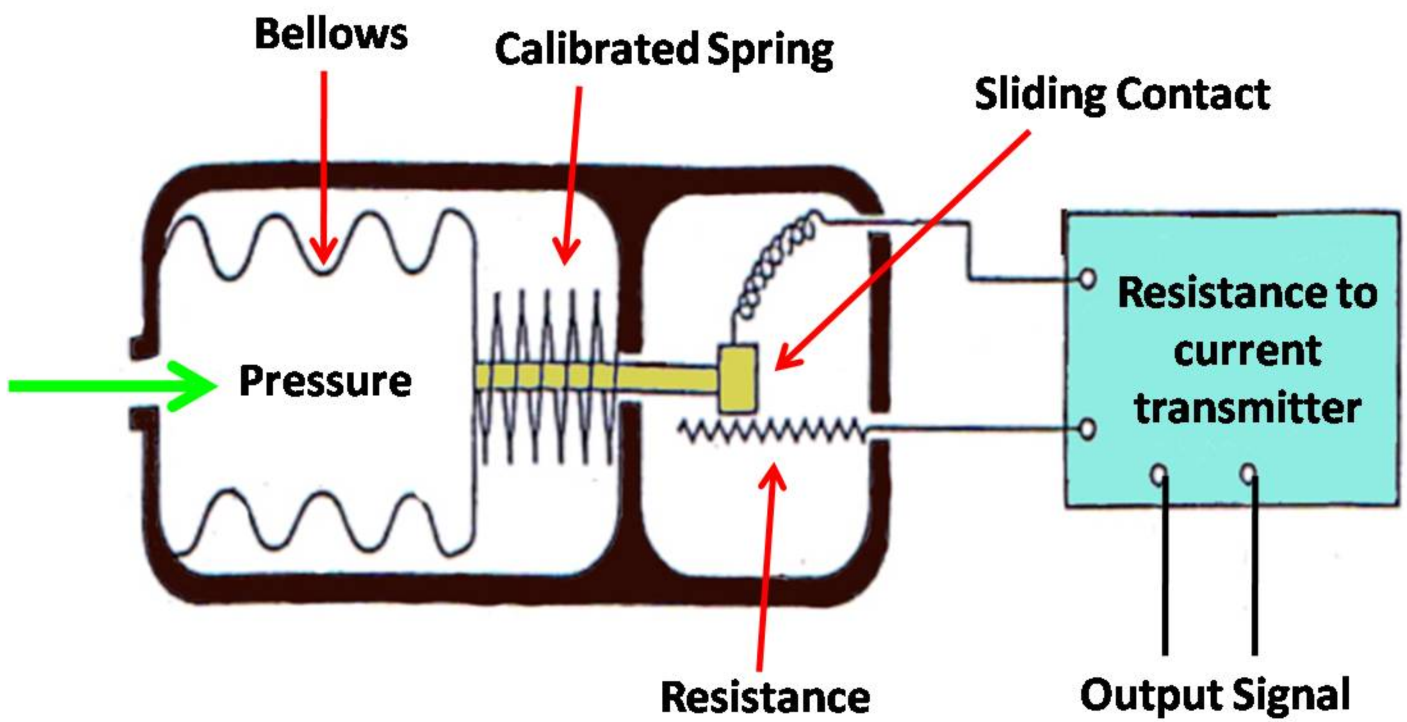
ii. Bellow-inductance pressure sensor

- The pressure is proportionate to the inductance change which is detected from the displacement of the core in the wire coil.

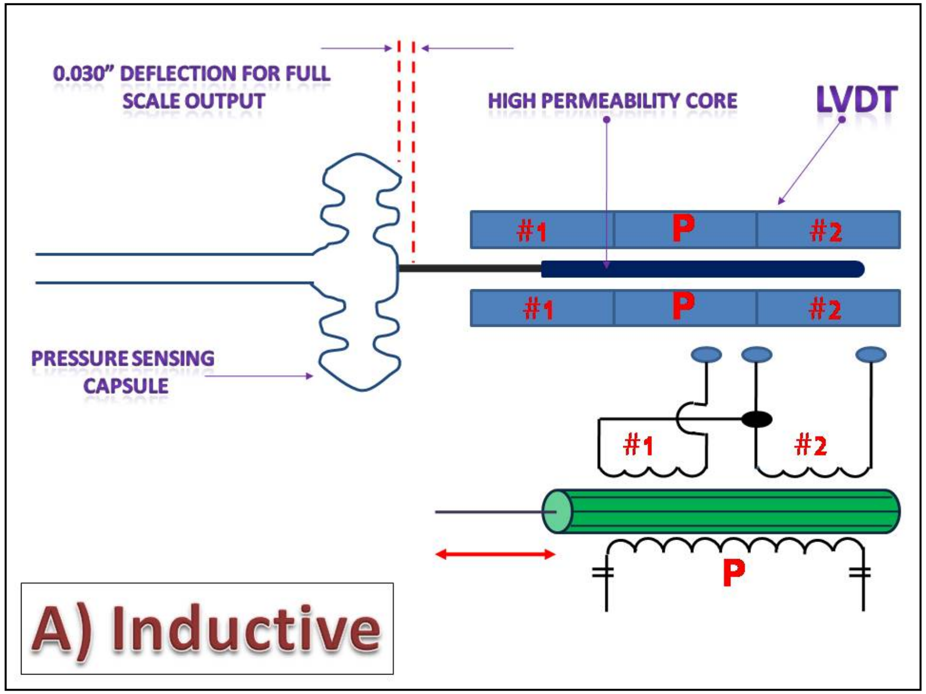
- **The core movement will produce AC signal output which will give the value and direction of inductance.**
- **LVDT (linear variable differential transformer) demodulator is used to convert the AC output to DC.**

iii. Diaphragm-capacitance pressure sensor

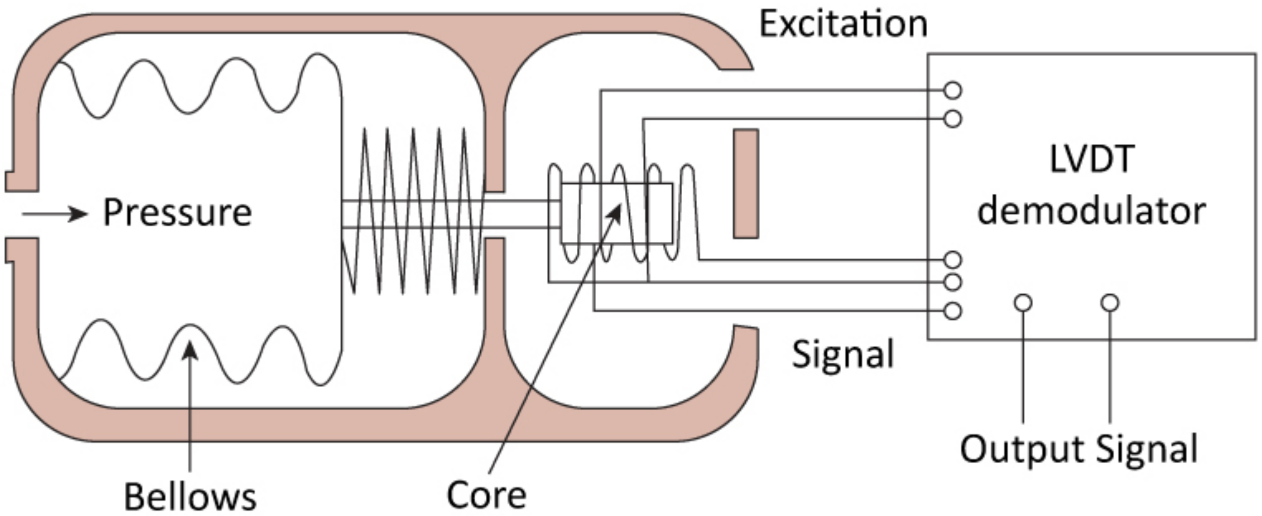
- **The pressure is proportionate to the capacitance change at the output through dielectric change.**
- **Pressure from the sensor element causes the diaphragm to move towards the plate and produces dielectric change.**

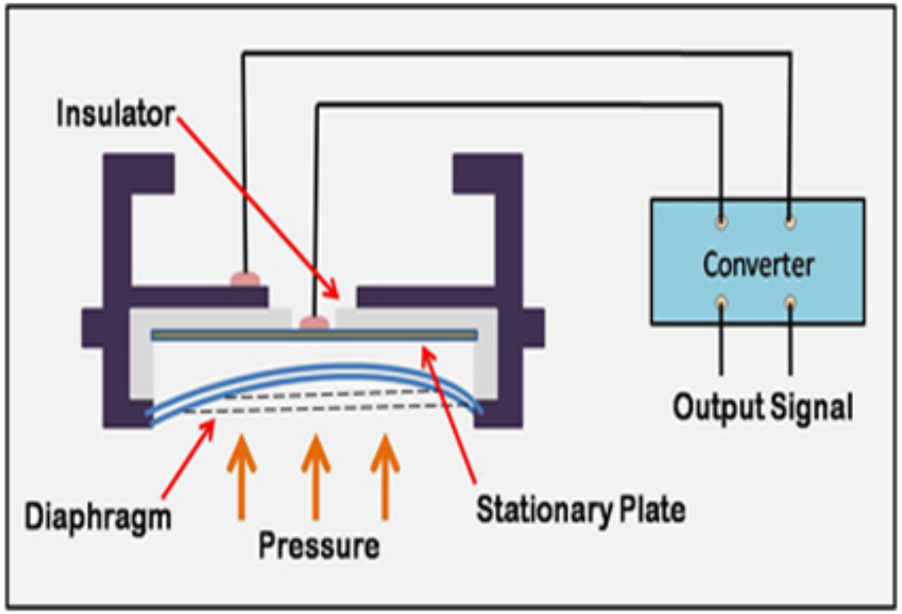


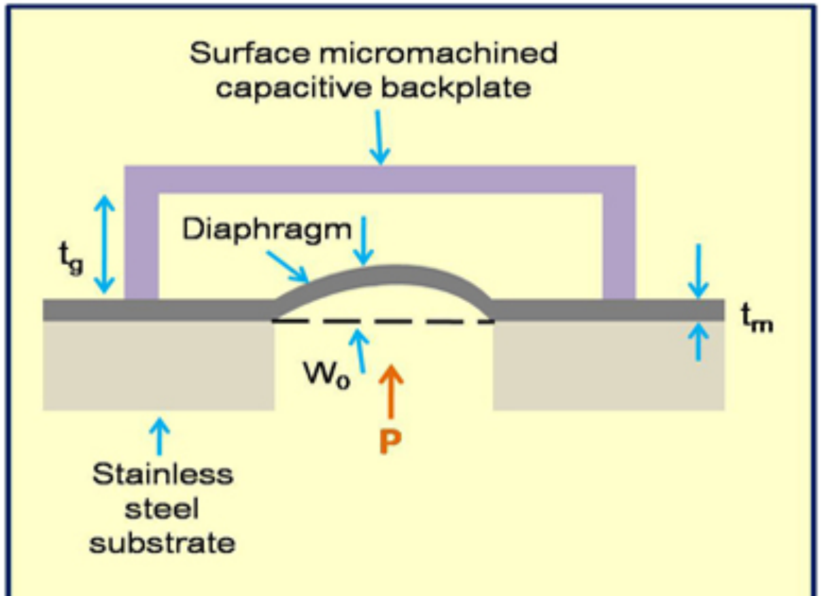
A Bellows – Resistance Pressure Sensor



A Bellows – Inductance Pressure Sensor

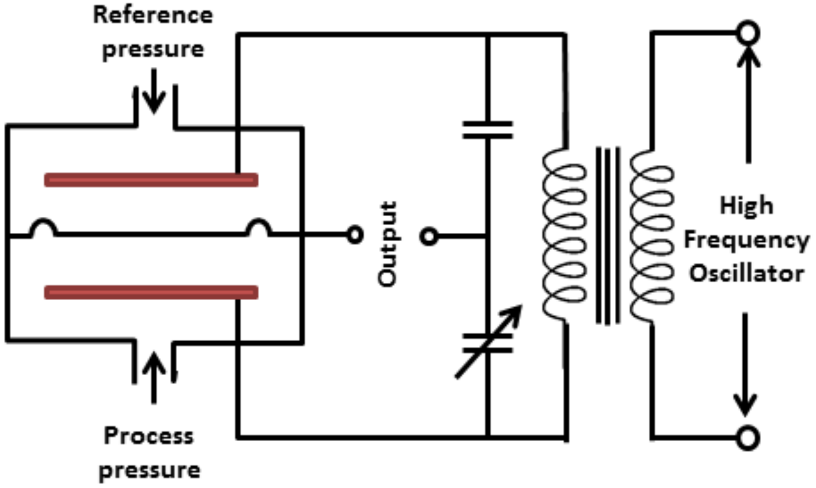


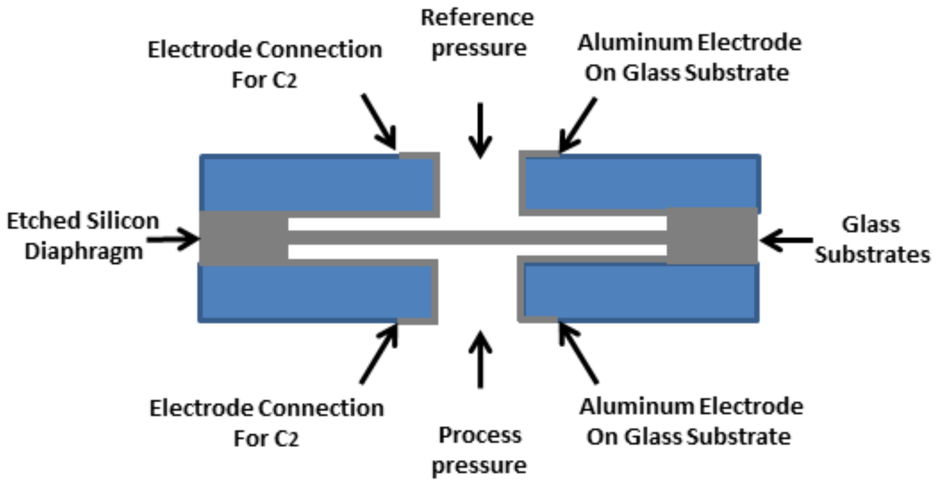




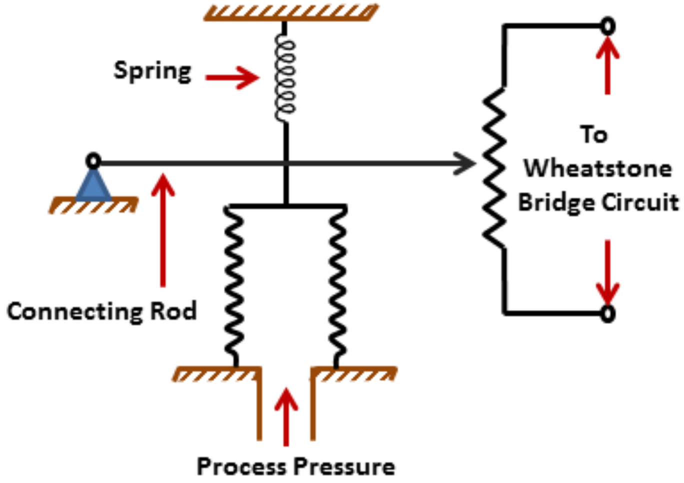
A schematic diagram of the side view of the capacitive pressure sensor

A Diaphragm – Capacitance Pressure Sensor





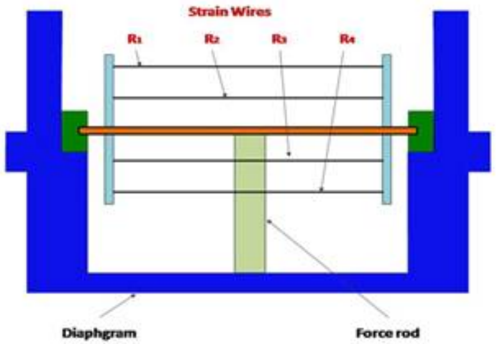
Capacitance Type



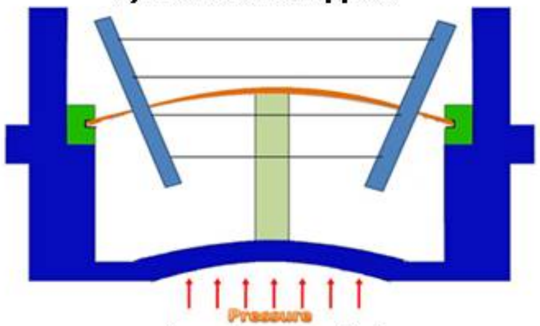
Resistance Type

2. STRAIN GAUGE PRESSURE SENSOR

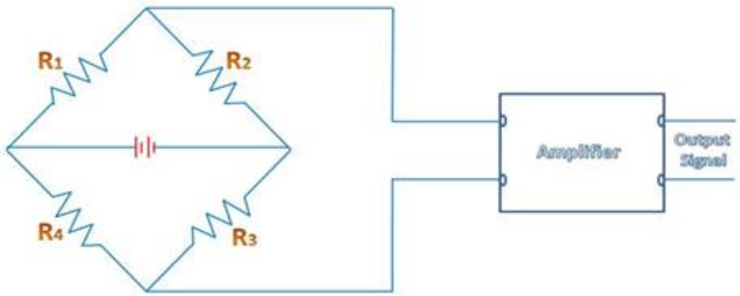
- Strain gauge is a type of resistive transduction.
- Pressure measurement is obtained from displacement of elastic element.
- Pressure is measured through force that is exerted on the diaphragm where the force will be detected by the strain gauge and resistance change will be produced.
- Wheatstone Bridge circuit is used to detect the change in pressure and an amplifier is used to amplify the small output signals.



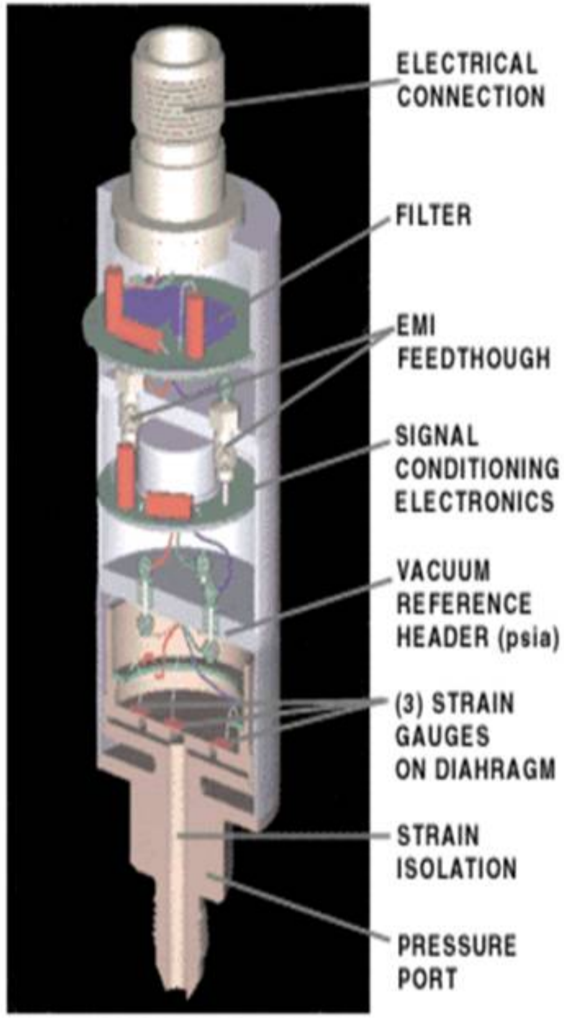
a) Pressure not applied



a) Pressure applied



a) Wheatstone bridge and amplifier

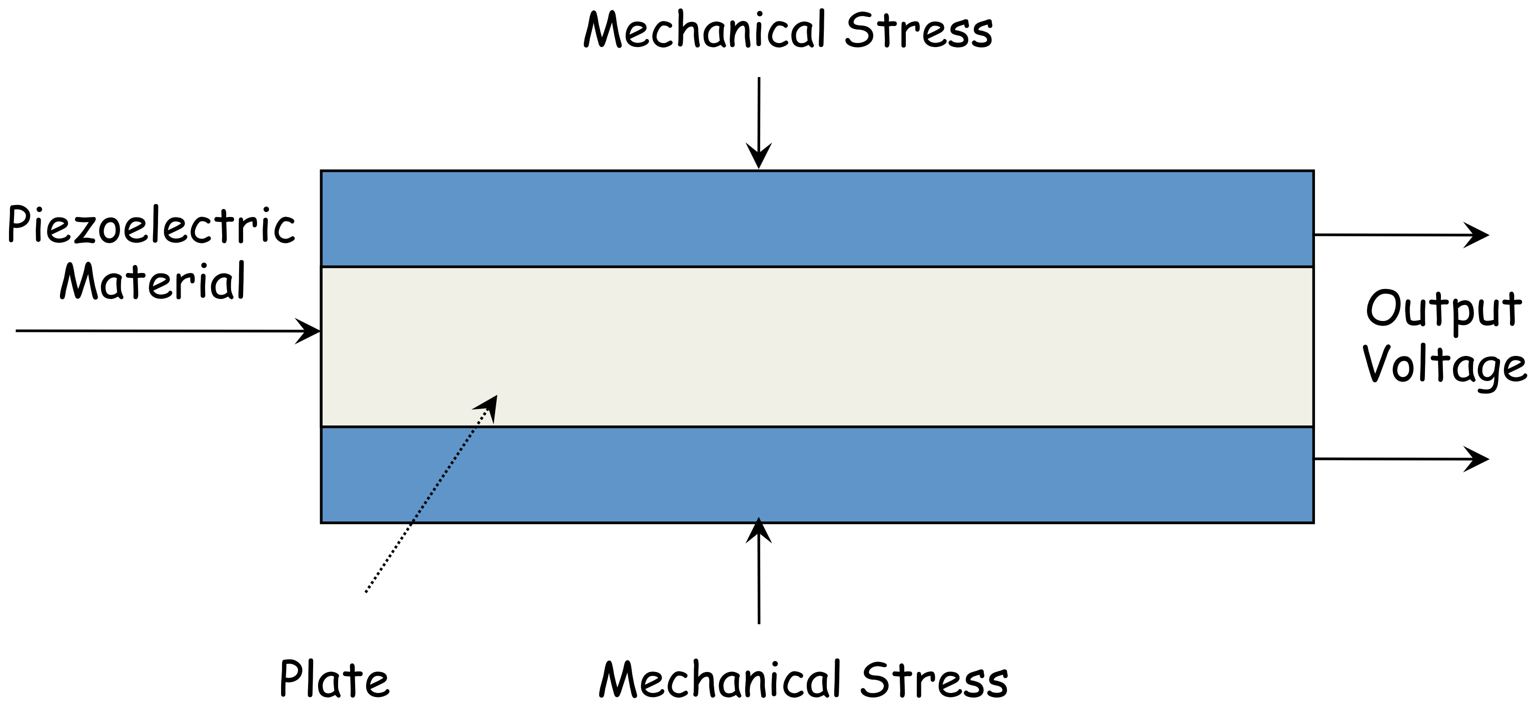


PRESSURE TRANSDUCER

Strain Gauge Pressure Sensor

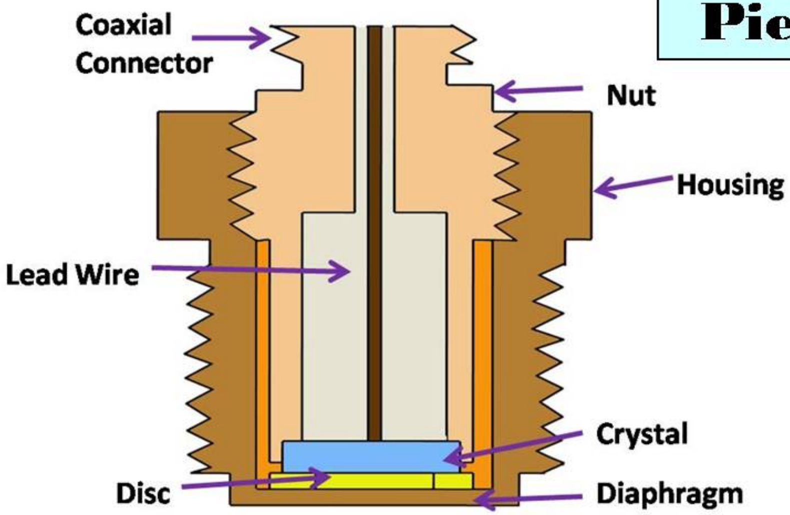
3. PIZOELECTRIC PRESSURE SENSOR

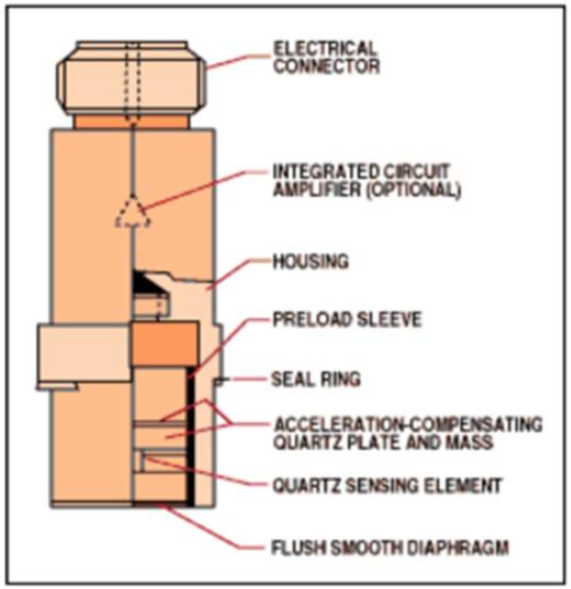
- This sensor consists of a piezoelectric crystal (made from quartz) which functions as a force-sensitive voltage source where the piezoelectric material will be in between two plates (see the following figure).
- Pressure exerted on the crystal surface is proportionate to the voltage produced by the crystal.
- This sensor does not require any voltage supply.
- This sensor is suitable for fast changing pressure measurement (dynamic pressure).

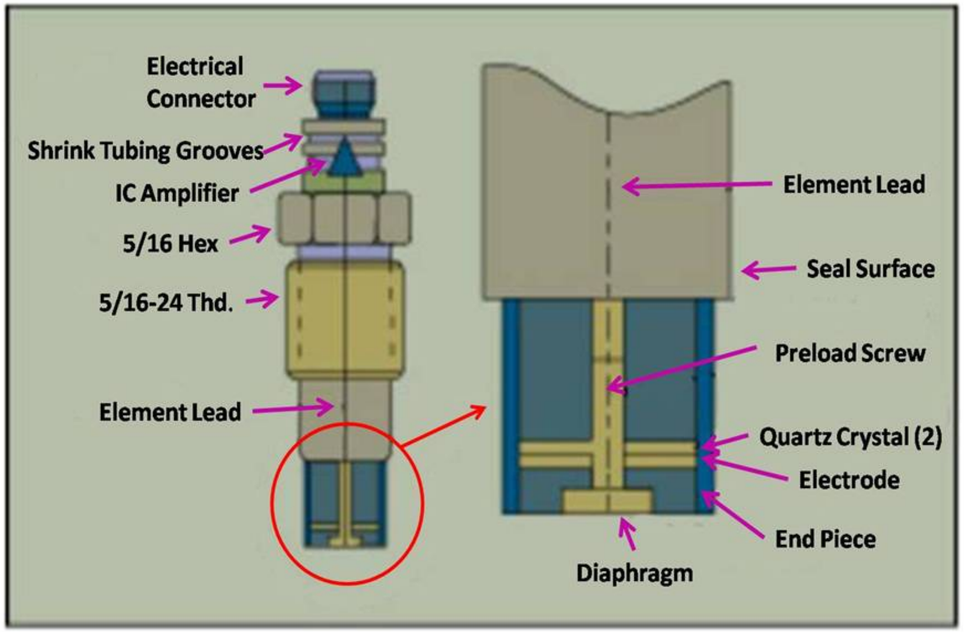


Piezoelectric Pressure Sensor

Piezoelectric Pressure Sensor

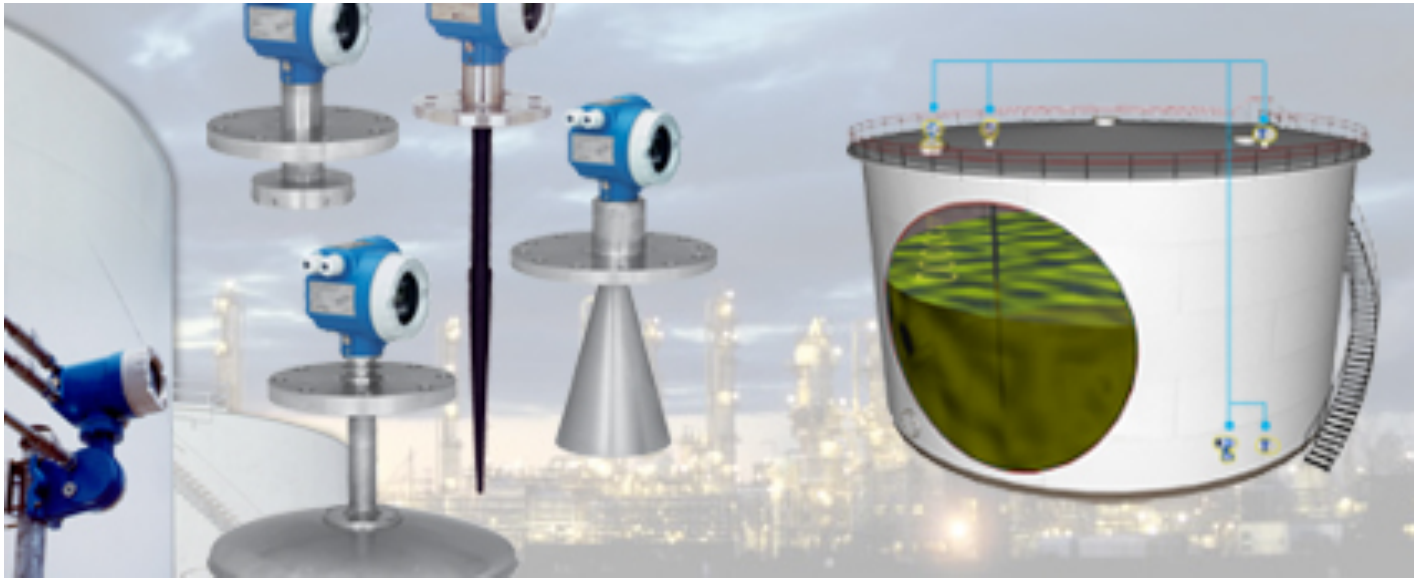






LEVEL SENSOR

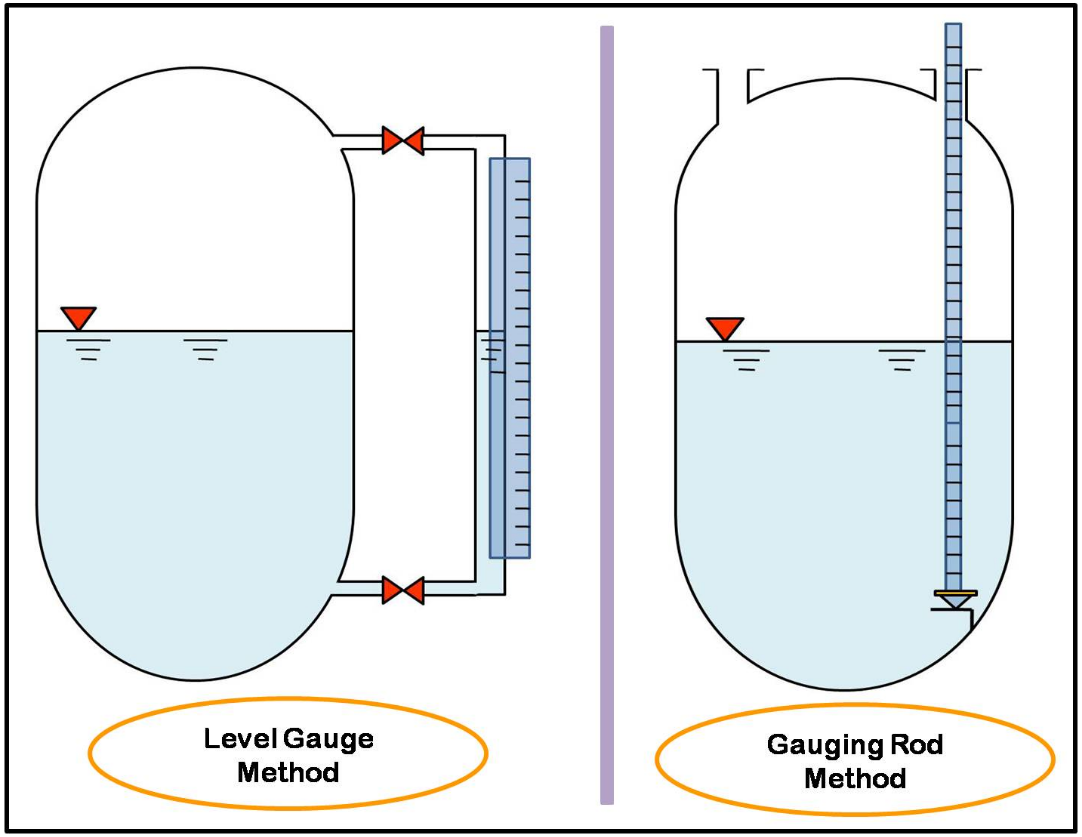
- Level measurement is important because by using the correct techniques, it can benefits in terms of economic, product's quality, equipment's and worker's safety and reduce losses.
- There are 2 types of level measurement known as direct and inferential measurement.
- Direct measurement is easy, simple and is used for the purpose of local indication.
- Inferential measurement is used when remote reading is considered necessary.

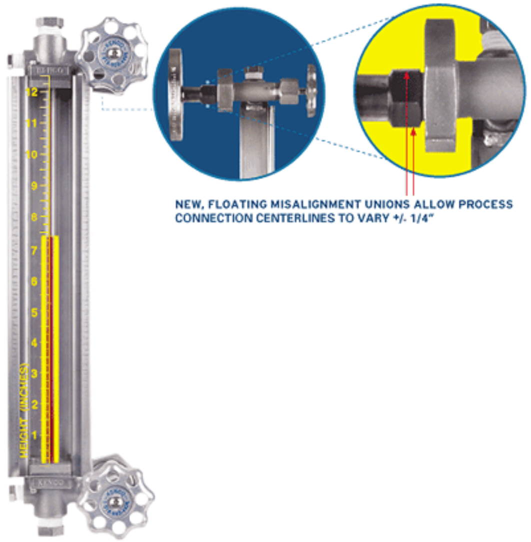


Examples of Direct Measurement

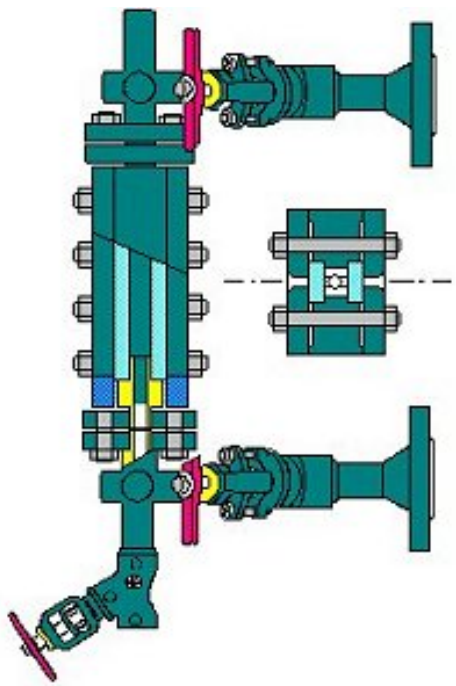
1. **GAUGING GLASS**
   - Transparent glass tube which is connected to a vessel and the values can be read directly.
   - Cheap and easy to install.
   - For visible liquid.
   - No signal transmission.

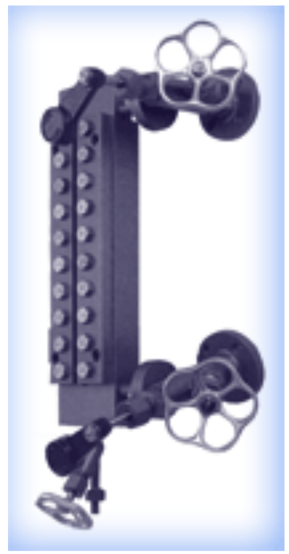
2. **GAUGING RODE**
   - Rode that had been calibrated is put into a vessel.
   - Easy to use.
   - Can be used for liquid or solid medium.

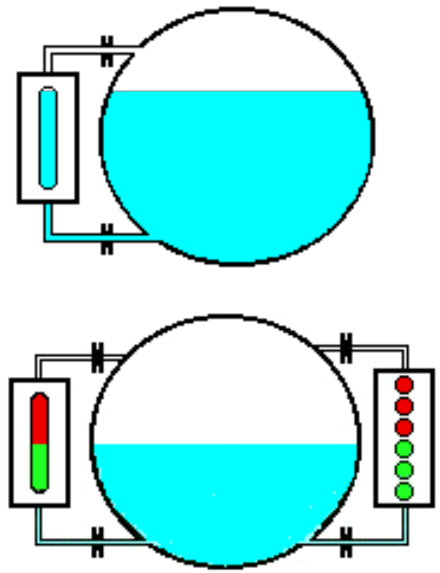




Level Gauge and Gauging Rod Method







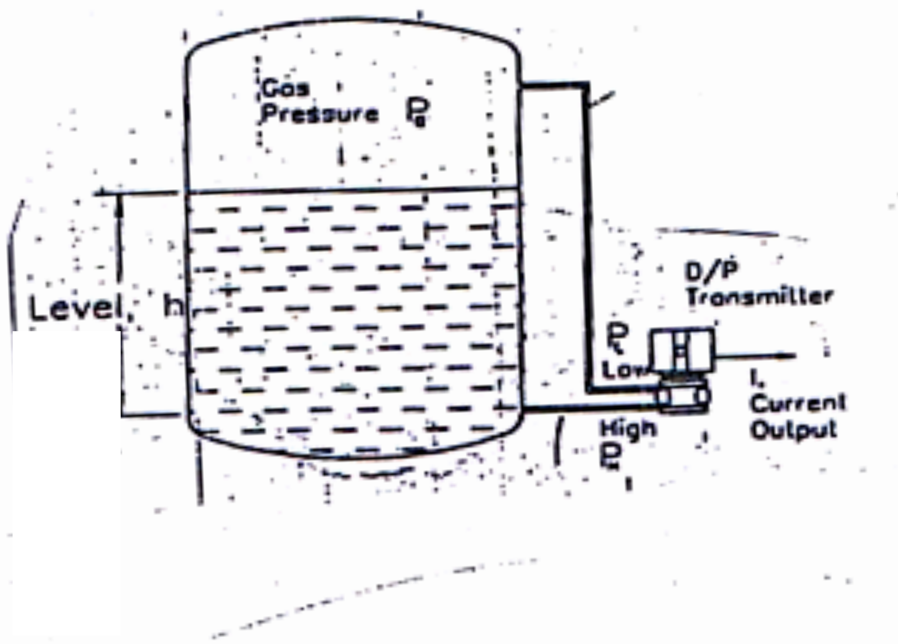
Typical Application of Glass Level Gauges

Examples of Screen Measurement

1. **BUYONCY TYPE SENSOR**
   - Float of hollow metal or plastic ball is used.
   - When fluid increases, the float will rise and moves the meter's indicator.
   - Simple and high accuracy.

2. **STATIC PRESSURE TYPE LEVEL SENSOR**
   - Hydrostatic pressure is measured directly through pressure transducer.
   - Easy installation and high accuracy.
   - Connection to D/P transducer is easily expose to leakage and formation of impurities.

Float Type Level Sensor



Static Pressure Type Level Sensor

$$P_H = P_L + \rho g h$$

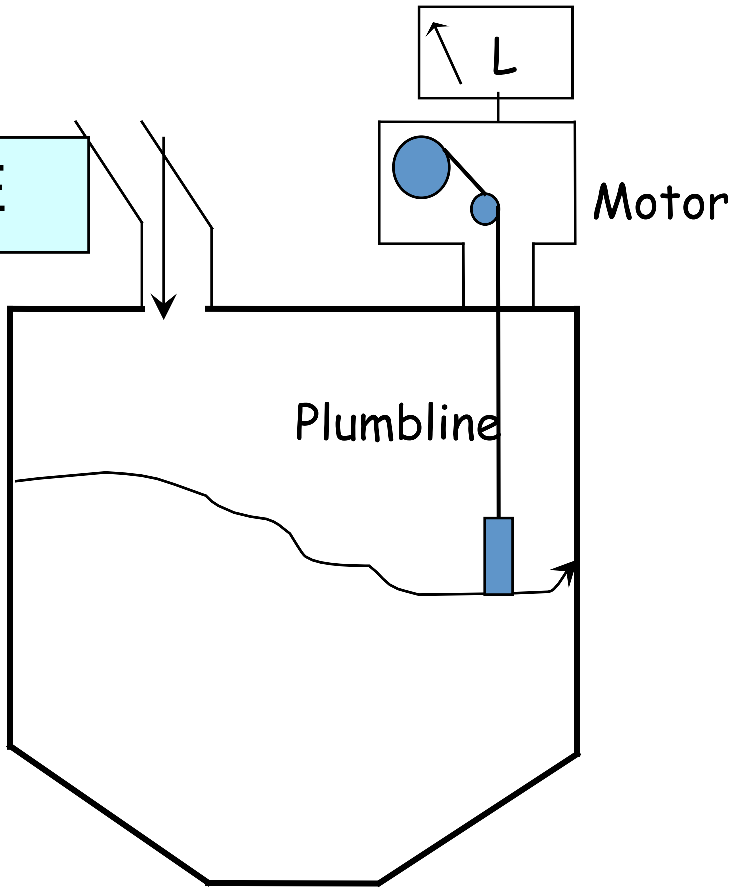
$$P_H - P_L = \rho g h$$

Examples of Inferential Measurement

3. PLUMBLINE SYSTEM

- Weighing element is moved downward using cable.
- When it reaches the product, the cable will ease, unstretch and the level is measured according to how long the cable is being released. Suitable for deep type silo.
- High accuracy.
- Requires frequent maintenance.

PLUMBLINE

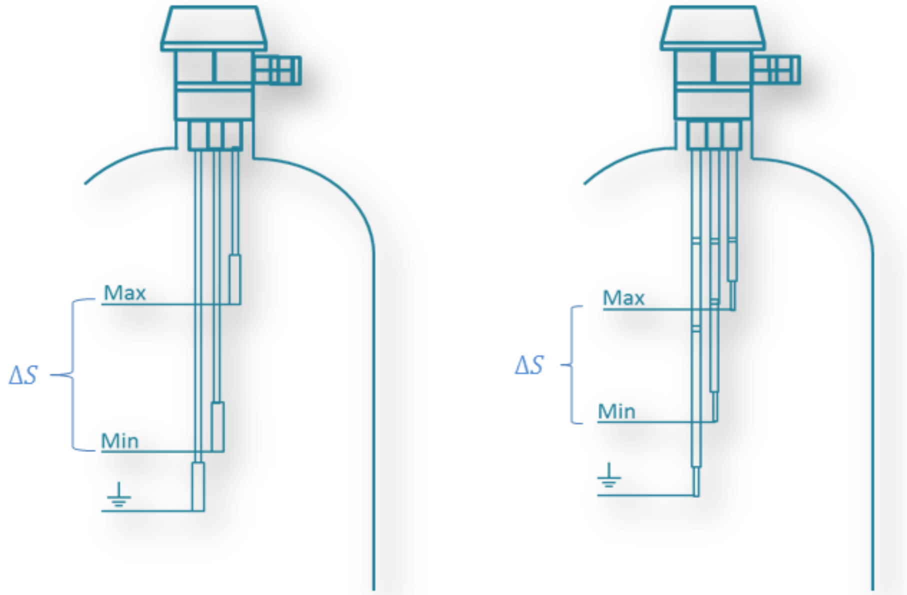


Examples of Screen Measurement

4. CONDUCTIVE TYPE LEVEL SENSOR

- Conductivities changes at electrode are used to measure the level.
- The tank's metal body is used as one of the electrode.
- Suitable for conductive type fluid.
- Cheap and easy to use.
- Probe should be inspected to avoid *contamination*.

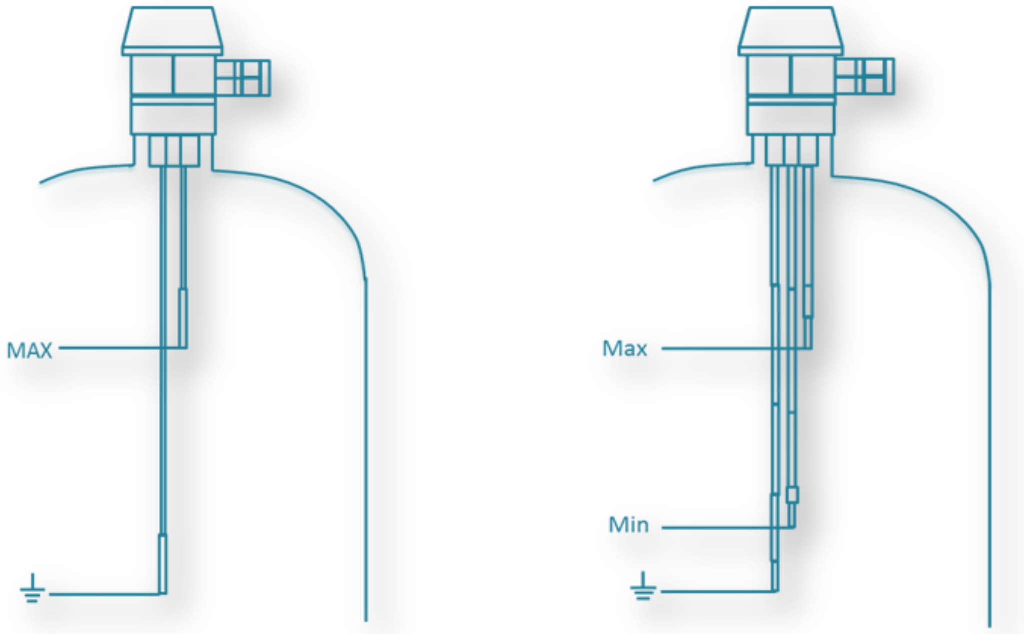
Level Limit Detection(Standard Application)



Two-point control (ΔS) e.g. pump control

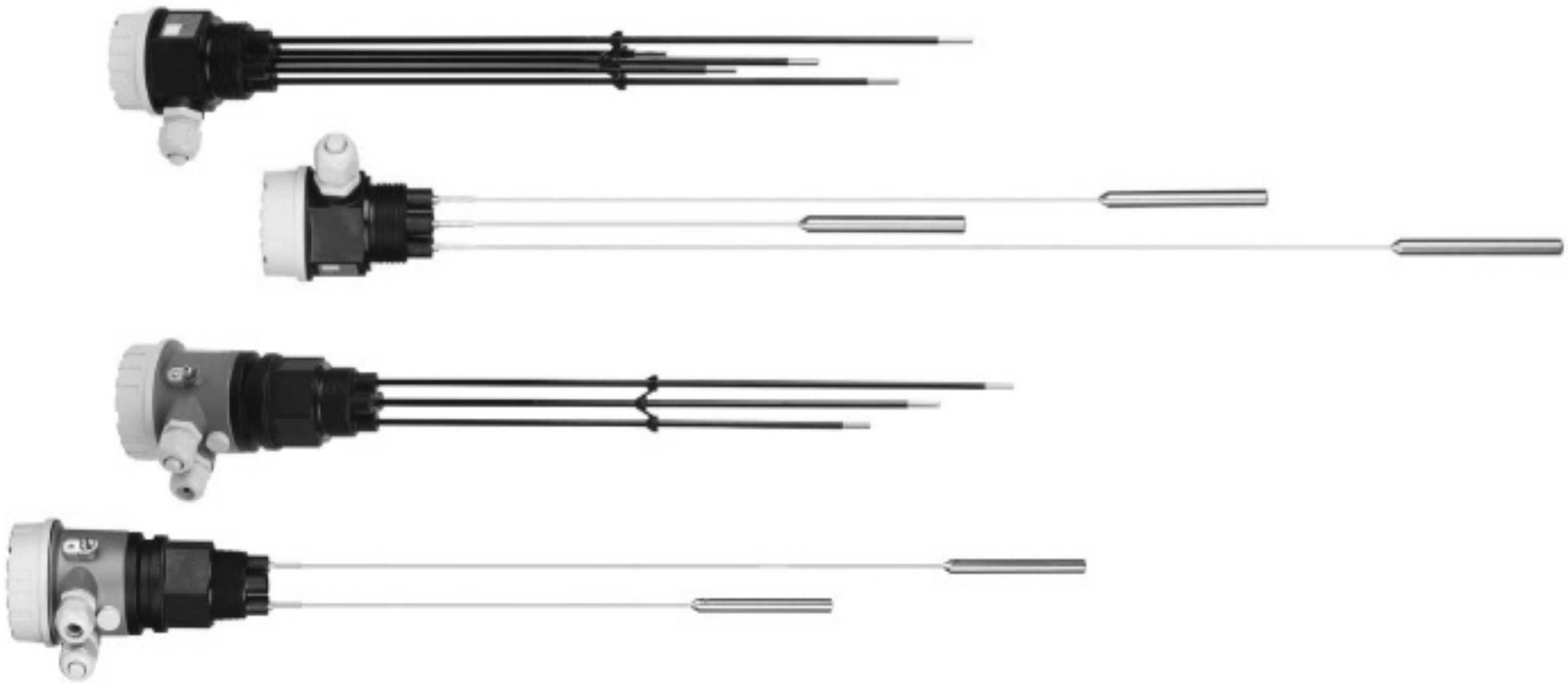
Conductive Type Level Sensor

Level Limit detection (Standard Application)



Level Limit detection (Max), maximum and minimum detection for compact-instrument devices only possible with ΔS

Conductive Type Level Sensor

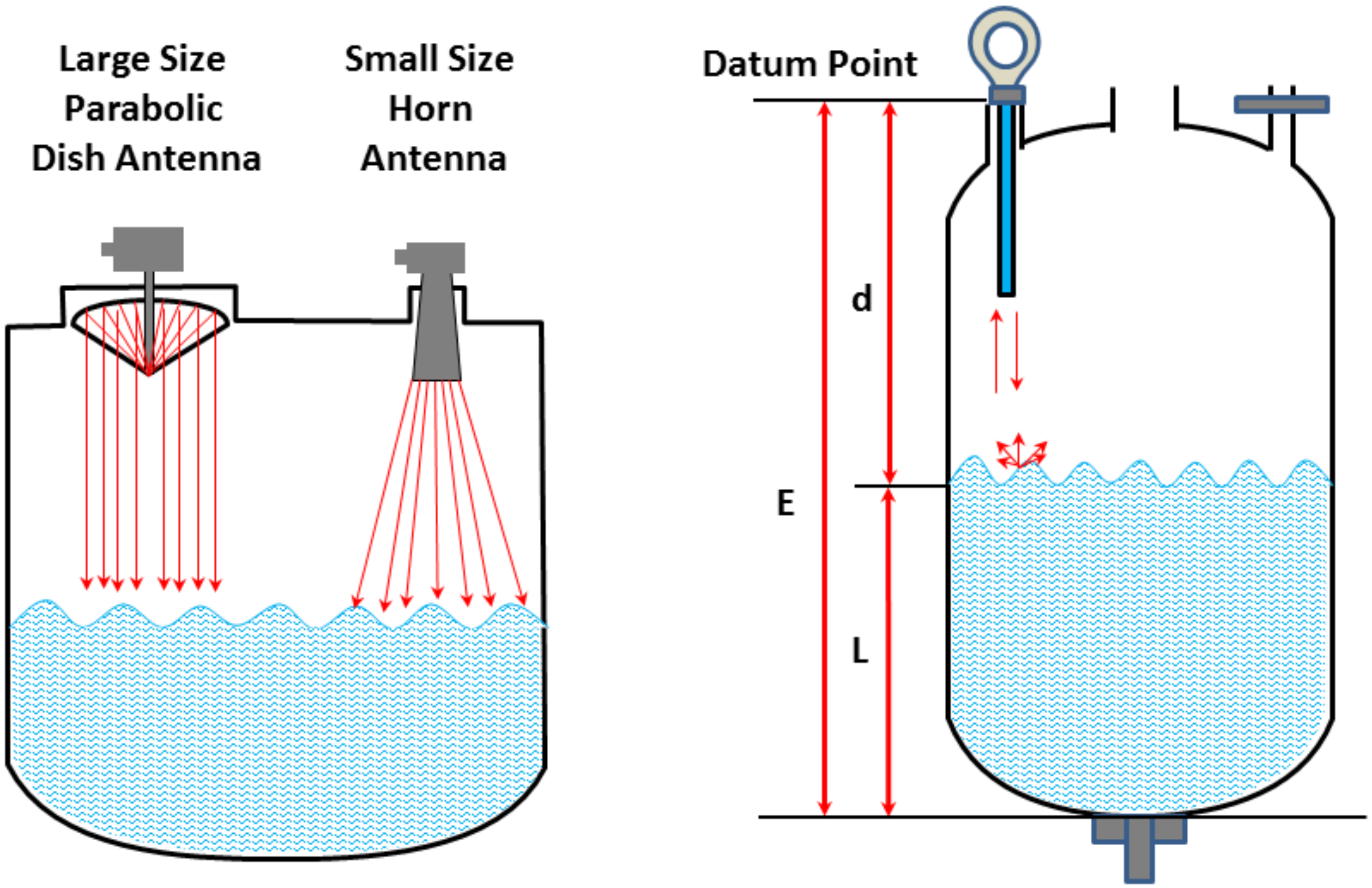


Conductive Type Level Sensor

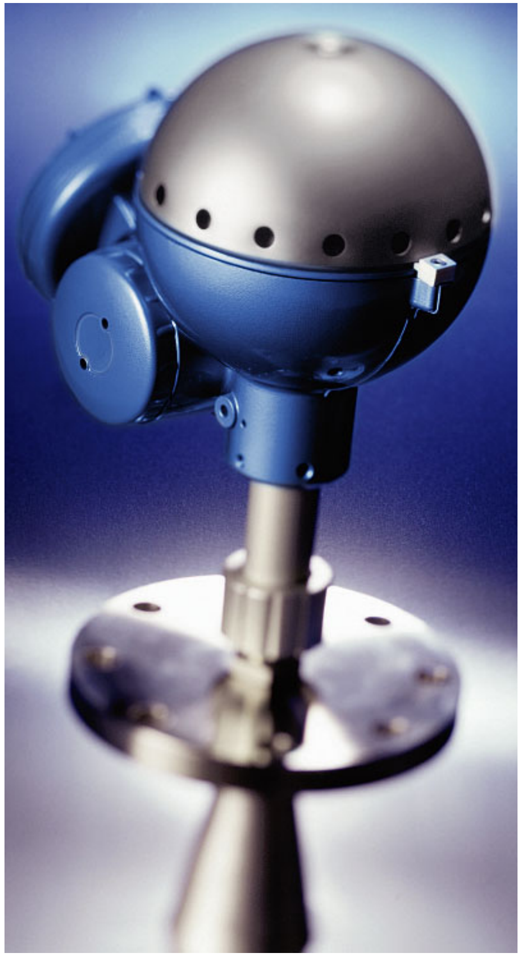
Examples for Inferential Measurement

5. RADIATION TYPE LEVEL SENSOR

- Used for dangerous, corrosive and high temperature/ pressure process.
- Based on the optic, ultrasonic, microwave or gamma radiation principle.
- This method is based on the concept where signal transmitted from the transmitter will be absorbed by the sensor (higher level value means more signals being absorbed).
- For gamma radiation system, radioactive isotope (e.g. Cesium 137) are located opposite to detector where it will give the level reading.



Level Sensor: Radiation Type



Level Sensor: Radiation Type

APPLICATION OF PNEUMATIC AND ELECTRICAL SIGNAL IN PROCESS INDUSTRY

STANDARD SIGNALS

- **It is divided into 2 categories, pneumatic and electric signal, according to 1973 IEC Recommendation :**

Pneumatic signal	***20 to 100 kPa or***
	3 to 15 psi
Electrical signal	***4 to 20 mA or***
	1 to 5 V DC

- **The advantage of using standard signal is to simplify any changes at the display system and making the overall system relatively easy form.**
- **Comparisons between pneumatic signal and electric signal are given in Table 4.1.**

Type of Signal	Advantages	Disadvantages
Pneumatic signal	▪Explosion proof ▪Simple construction ▪Simple installation	▪ Bigger 'transmission lag' ▪Cannot be connected to computer system
Electrical signal	▪Fast respond ▪Doesn't have problem with 'transmission lag' ▪Long distance transformation	▪ Need explosion protection ▪Need a E/P converter as a pneumatic final control element

Table 4.1: Comparison Between Pneumatic and Electrical Signals

FLOW SENSOR

- The important factor is to determine the flow rate of a fluid or the total flow of fluid that flows through a point at a certain time.
- A very important sensor in process industry.
- Consists of many types:
  i. Differential pressure flow meter.
  ii. Turbine flow meter.
  iii. Magnetic flow meter.

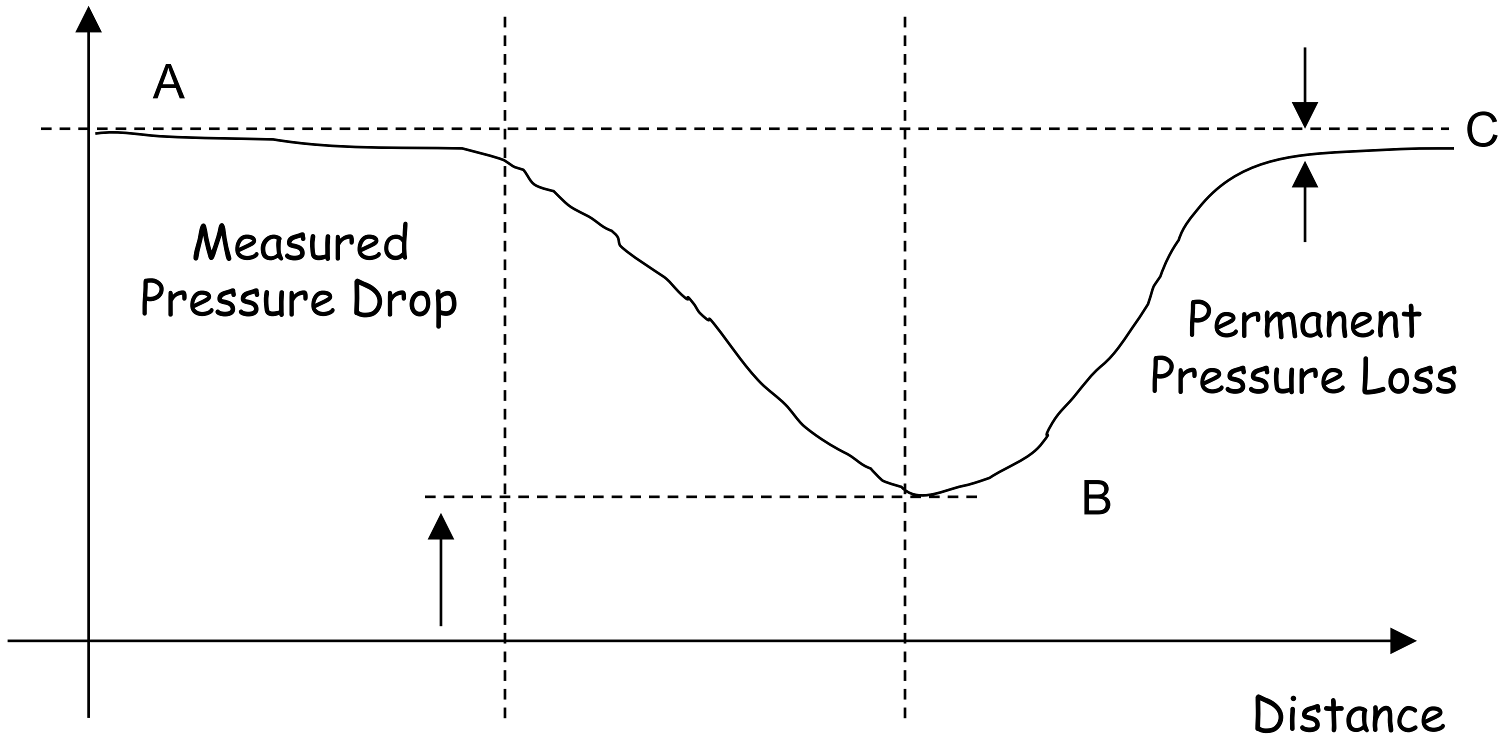
1. DIFFERENTIAL PRESSURE FLOW METER

- The basic principle used is to measure the pressure change of fluid flow through an obstruction by using a differential pressure transducer.
- The flow rate of fluid after the obstruction will increase but the pressure will reduce. The relation between both factors are:

$$q = K\sqrt{\Delta P}$$

where,	q	: flow rate
	K	: constant
	ΔP	: pressure change

- **This meter is popular because there are no moving parts. Therefore this meter is reliable and easy to maintain.**
- **The disadvantage of this meter is the obstruction used will cause constant pressure loss and a pump has to be used to increase the pressure. Therefore the pattern of pressure change in the pipe needs to be known.**
- **The sensed pressure difference has to be sent to the differential pressure transmitter or "D/P cell" to change the pressure to proportionate output current signal which is (4-20 mA).**
- **Square-root extractor is used for linearization.**



A : maximum pressure
B : minimum pressure (vena contracta point)
C : pressure C ≠ pressure A

ADVANTAGES AND DISADVANTAGES

Advantages

- Simple and easy to fabricate.
- No moving parts.
- Suitable for most gases and liquids.
- Price does not increase with diameter increase.

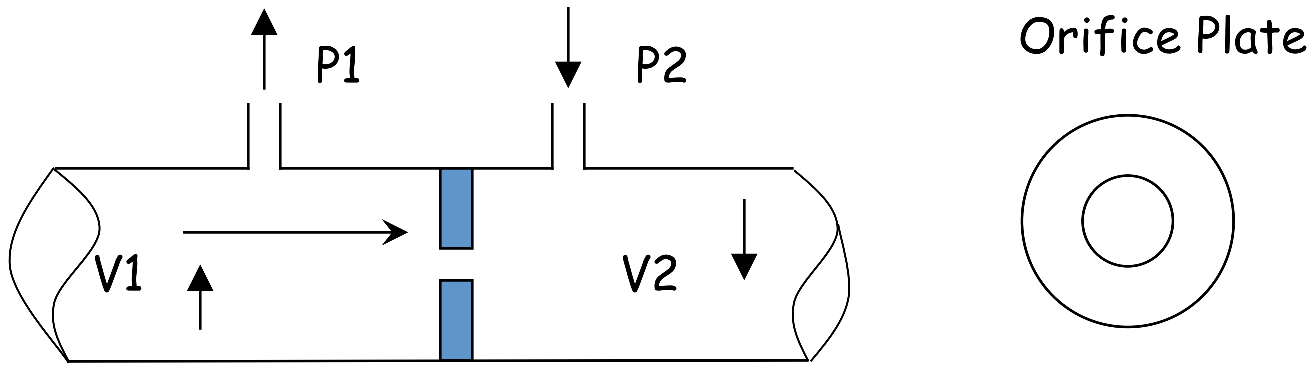
Disadvantages

- Fluctuation of value and and pressure effects the accuracy of measurement.
- High pressure loss.
- Worn off obstruction will effect the reading.
- The usage limit if this meter depends on the viscosity of fluid where it is not suitable for slurries and corrosive fluids.

EXAMPLES OF DIFFERENTIAL METER

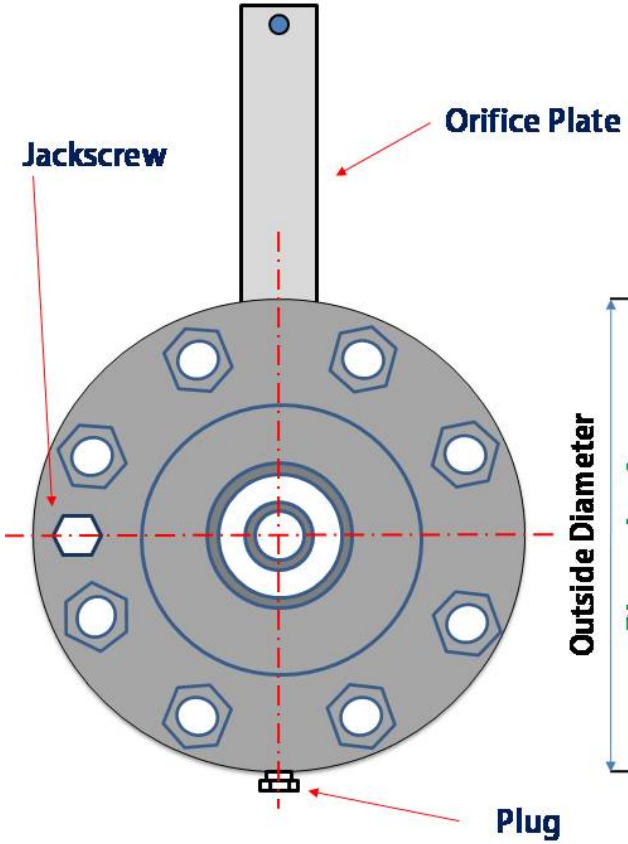
i. ORIFICE METER

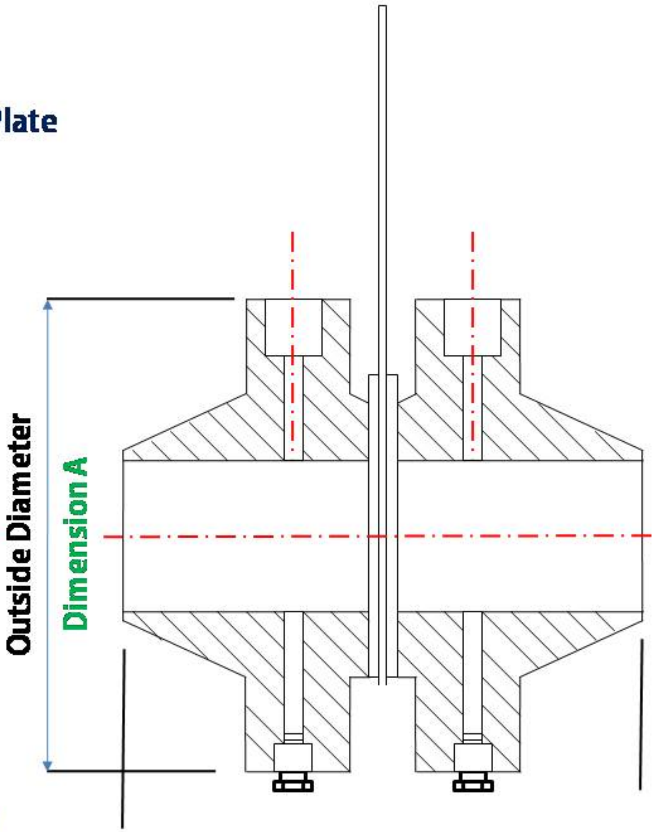
- **Uses orifice plate, metal discs with a hole in the middle which is inserted into the pipe.**
- **Orifice meter is widely used because it is easy to use, cheap and can be obtained in a wide range of diameters.**



Restriction Orifice Plate

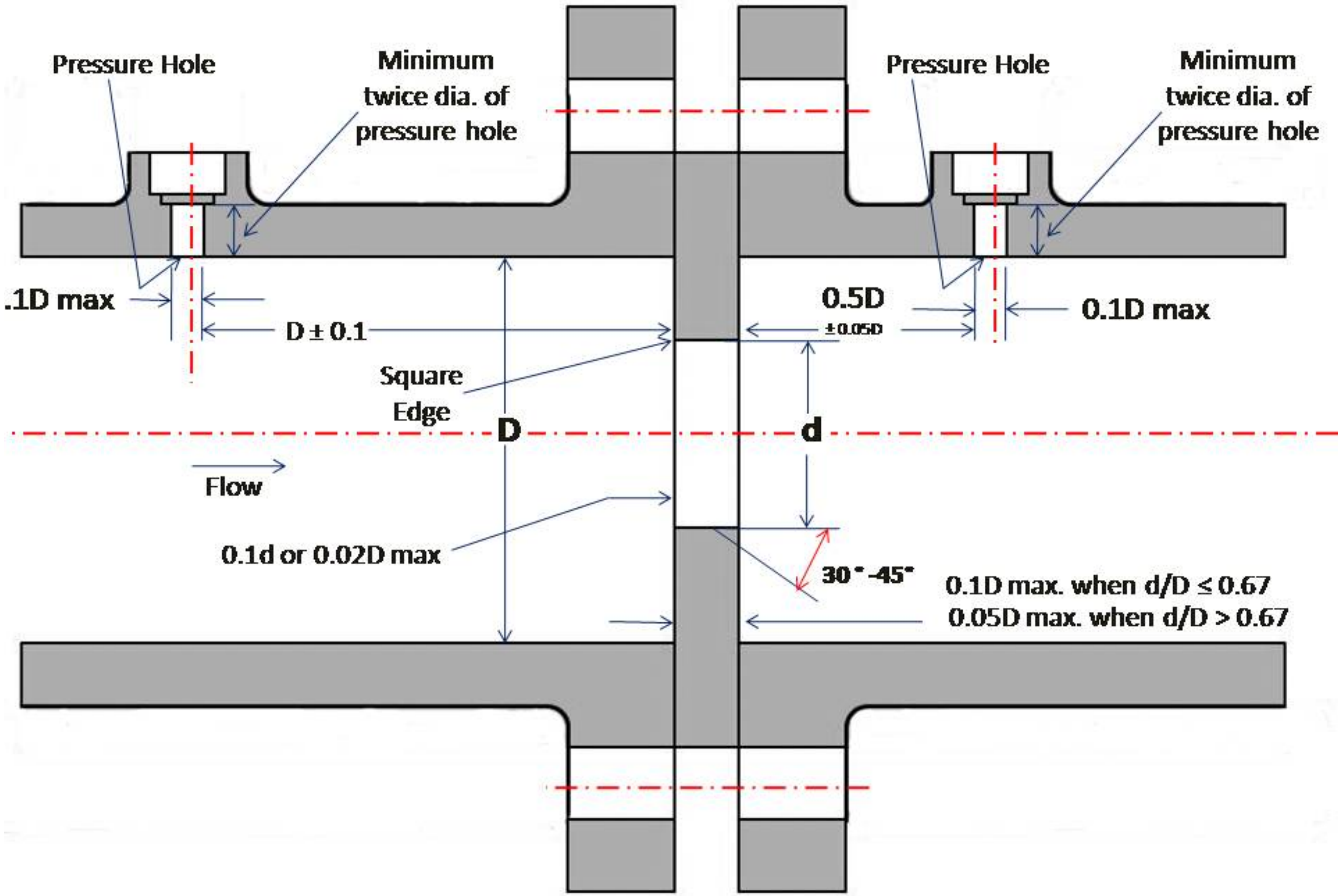
Orifice Carrier and Integral Plate
shown with optional isolation valves






Orifice Flange Assembly

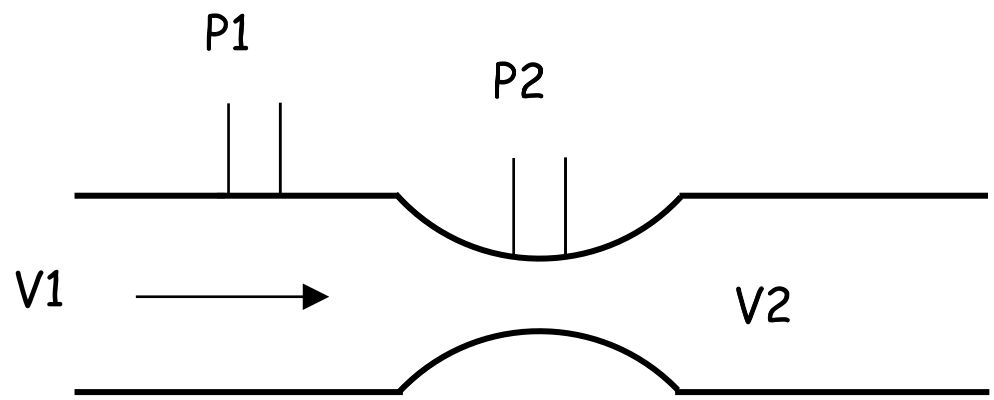
Orifice Meter



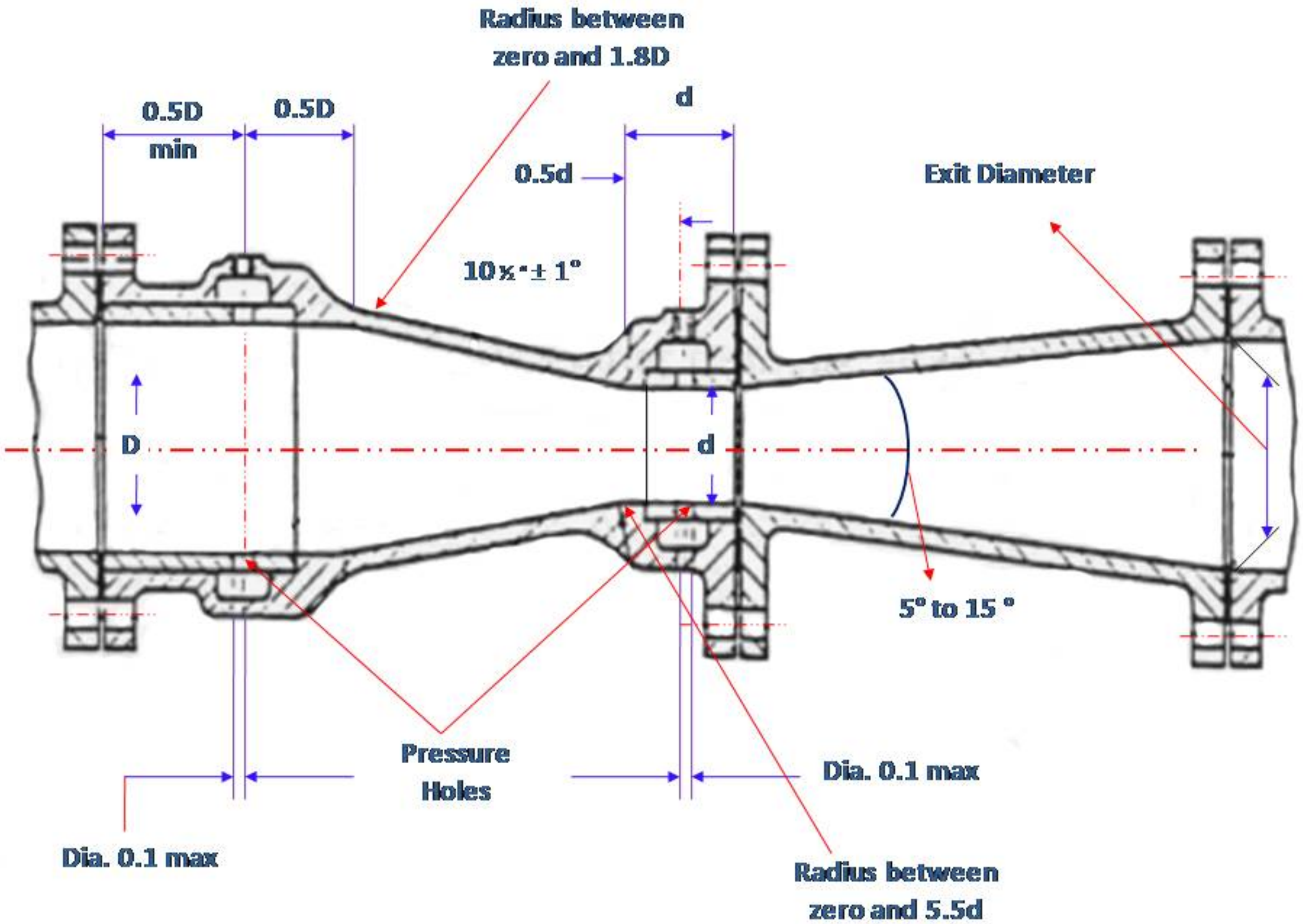
Orifice plate with D and ± D tapping

ii. VENTURI METER

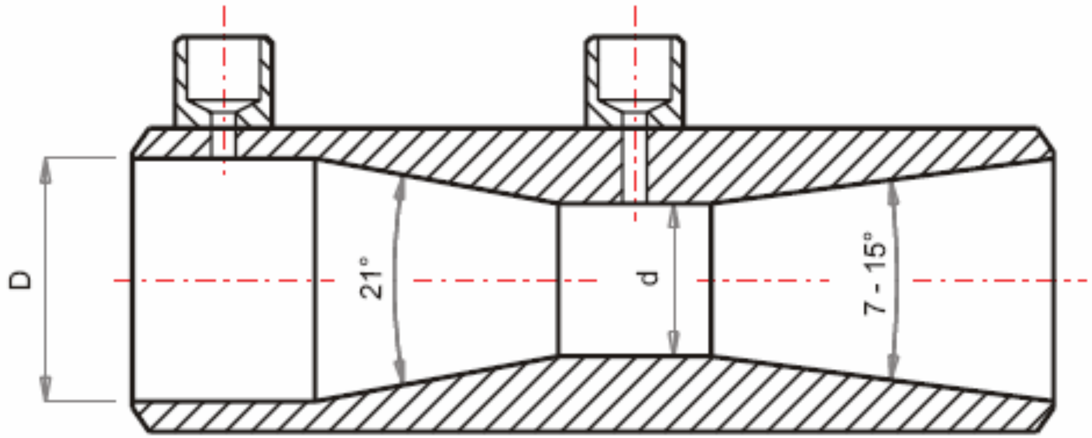
- Venturi is a tube that has a certain shape.
- It has a higher accuracy and a lower pressure drop compared to orifice meter.
- More expensive.



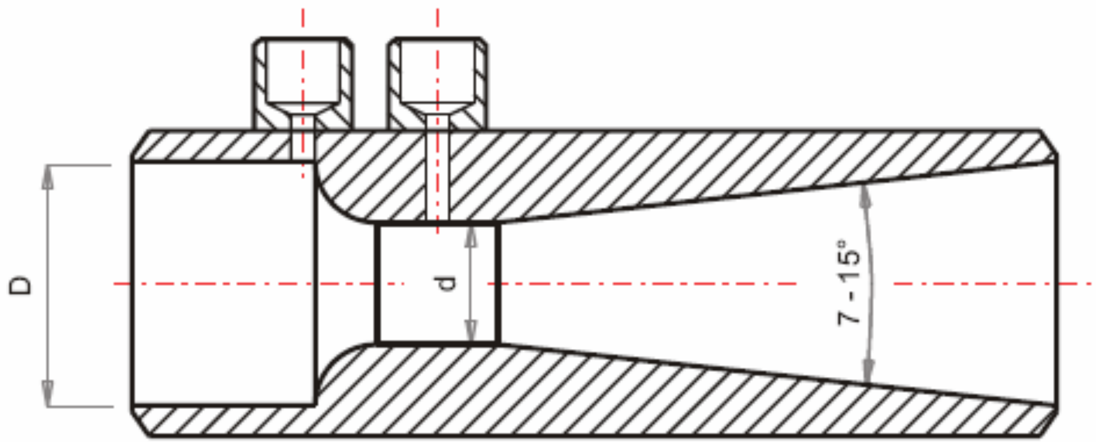
Venturi Meter



CLASSICAL VENTURI (MACHINED)



VENTURI NOZZLE (MACHINED)



2. TURBINE FLOW METER

- Consists of a rotor which is axially mounted in a pipe.
- A permanent magnet is connected to the body of the rotor (connected to one of the propeller blades).
- The speed of rotor is proportionate to the flow rate of fluid through the pipe.

Operation Principles

- When fluid flow through a pipe, it will pass through a set of vanes and it will cause the rotary blade to rotate.
- Turbulent vanes are mounted at both end of the pipe and it is use to reduce the swirling factor.
- A small magnet is fix onto one of the rotary blade and this will induce electric current at the pick-up coil and form magnetic field. Therefore, every time the blade rotate, it will disturb the magnetic field formed at the pick-up coil and produces electrical pulse at the coil.

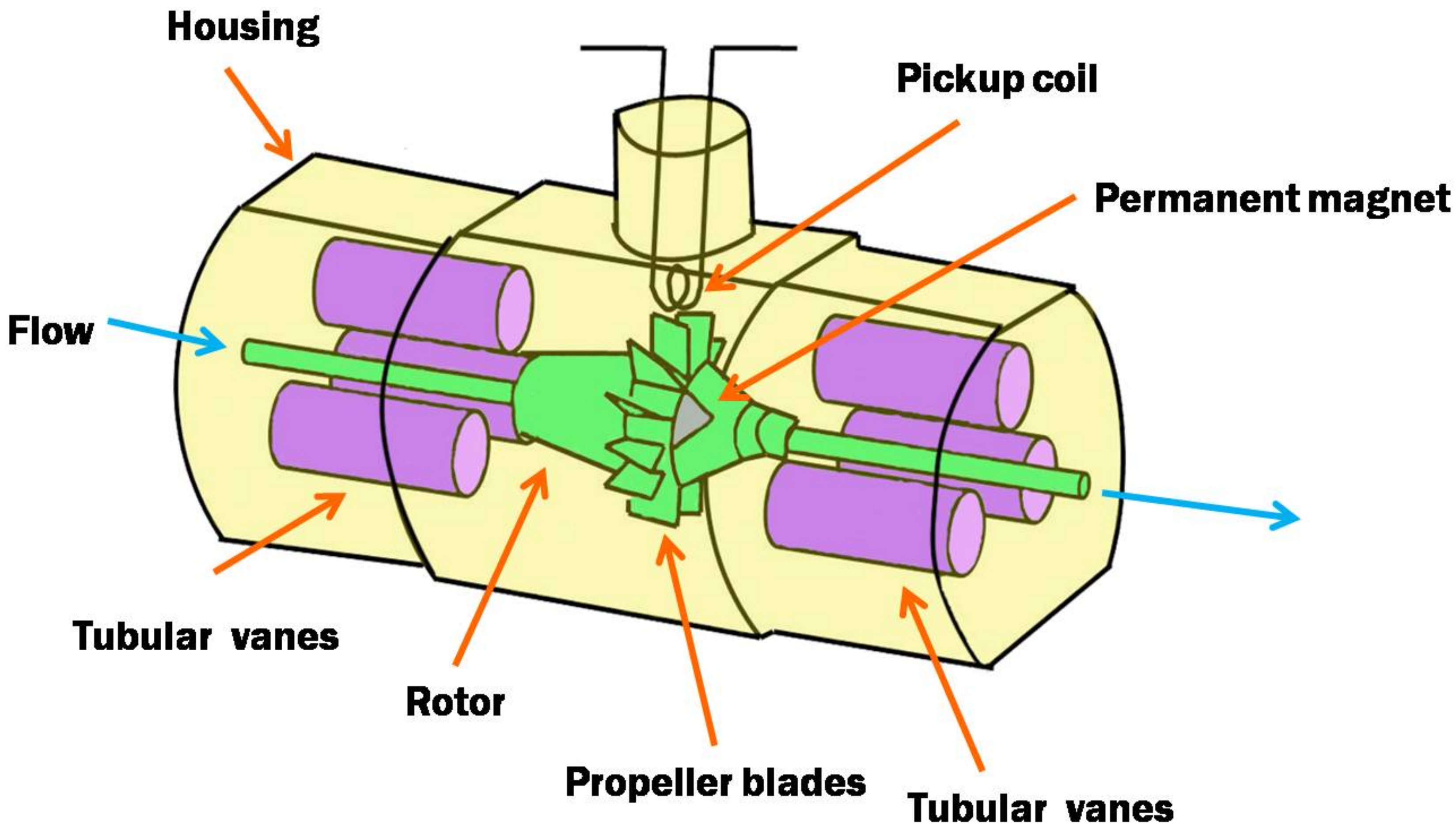
- This electrical pulse frequency will show the actual flowrate. By counting the number of electrical pulse in a certain period of time, the actual fluid flowrate can be calculated.
- Flow rate were measured using this equation:

$$q = \frac{K \cdot N}{\Delta t}$$

where, K : volume per pulse

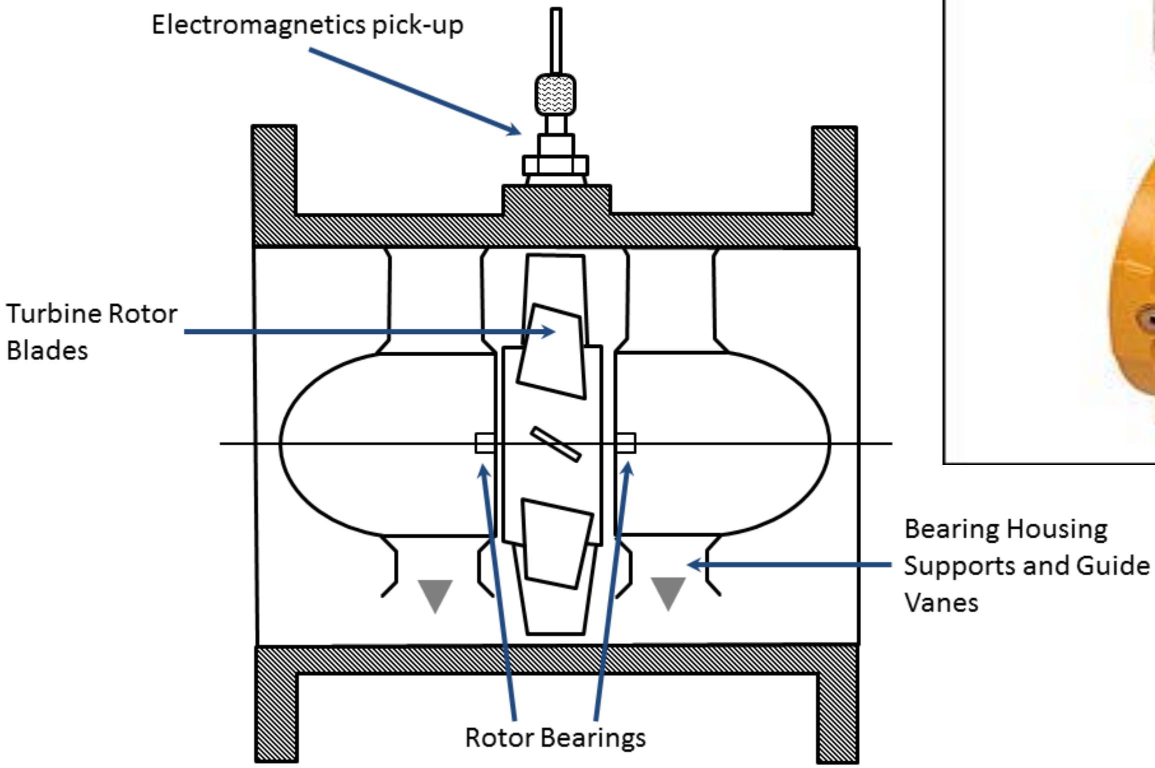
N : total number of pulse

Δt : time



Turbine Flow Sensor

Turbine Meter



ADVANTAGES AND DISADVANTAGES

ADVANTAGES

- **Output pulse is suitable with digital control system.**
- **High accuracy.**
- **Wide range of temperature,which is at the lowest of -200ºC to the highest of 350ºC.**
- **Can be used with non-conductive fluid.**

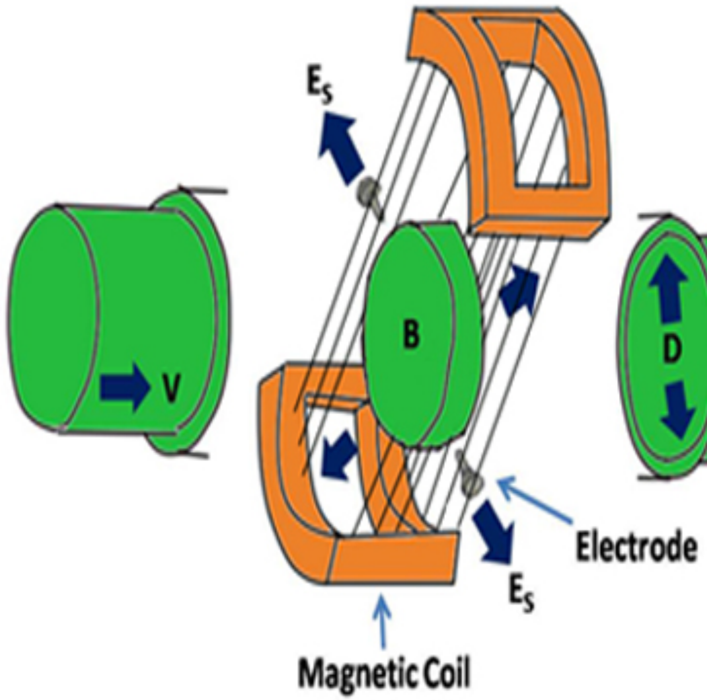
DISADVANTAGES

- **Fluid density must be known prior to install this type of meter.**
- **Not suitable for slurry fluid.**
- **The pipe system cannot be exposed to any *vibration*.**

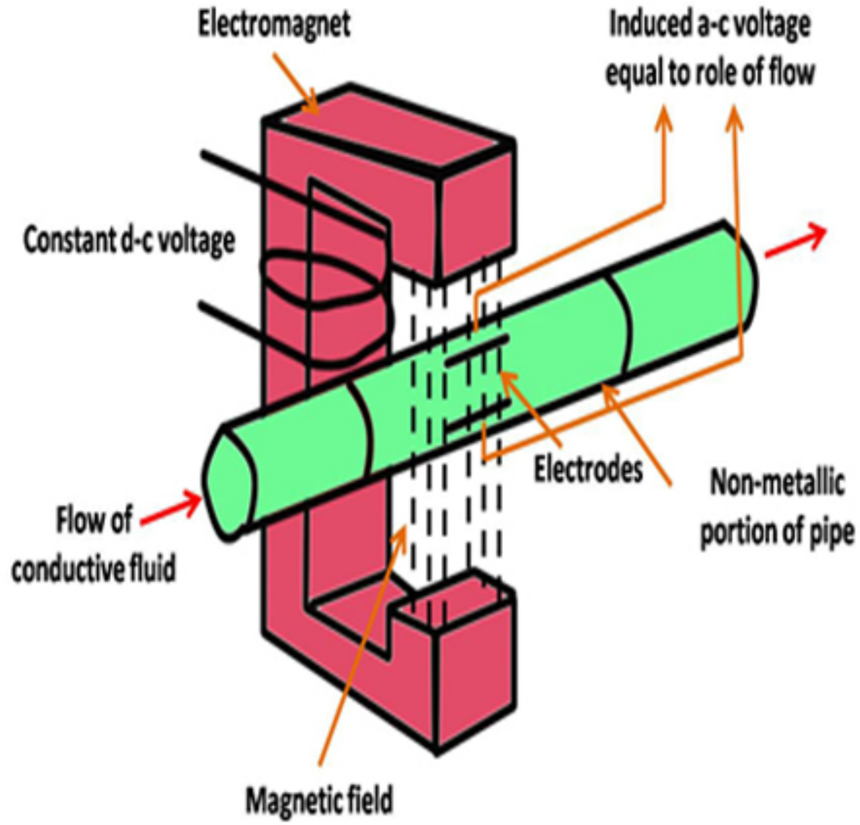
3. MAGNETIC FLOW METER

- **The operation is based on Faraday's Law where the voltage (*emf*) induced when the conductor moves through the magnetic field and the *emf* is proportionate to the conductor's velocity.**
- **The magnetic field remain constant through the DC current flowing through the electromagnetic coil.**
- **The fluid has to be conductive and flows through the non-metal part of the piping system.**
- **Two electrodes installed at the pipe are used to detect induced voltage.**

Magnetic Flow Sensor



The Magmeter and Its Component



Deria Aliran Magnetik

ADVANTAGES AND DISADVANTAGES

ADVANTAGES

- **No obstacle in flow, therefore no pressure drops.**
- **There is no mechanical movement,therefore there is no leak or wear off problems.**
- **Fluid flow measurement is independent of temperature, pressure factor and density of the fluid.**
- **Good linearity even at a small range.**

DISADVANTAGES

- **Can only be used with conductive type fluid.**
- **Any slurry in the flow will cause error in reading.**