



R. C. Patel College of Engineering & Polytechnic, Shirpur



Department of Electrical Engineering

Name of Subject: - **Electrical & Electronic Measurement (EEM)**

Course Code: - **313334**

Scheme:- **EE-3K**

Semester:- **Third**

Unit No. 05- Flow, Level and Temperature Measurement

CO5 - Use appropriate transducer for maintaining required flow, level and temperature in given application.

Unit	Title	COs	Learning hours	R Level	U Level	A Level	Total Marks
5	Flow, Level and Temperature Measurement	CO5	10	2	6	8	16

THEORY SYLLABUS CONTENT

Fundamentals of Measurement

5.1 Flow measurement -Flow and its units, classification of flow transducers -Variable head flow meter, Variable area flow meter.

5.2 Methods of measurement of electrical flow meter: a) Electromagnetic Flow meter. b) Ultrasonic flow meter.

5.3 Level measurement-Level and its units classification of level measurement transducer-Resistive, Inductive and Capacitive.

5.4 Method level measurement: Capacitive, Ultrasonic and Radiation.

5.5 Temperature Measurement-Temperature and its Units, classification -Thermistors, Resistance Temperature Detector (RTD) and Thermocouple.

5.6 Methods of temperature measurement- RTD and thermocouple.

Subject Incharge

Mr. N. S. Borse

Unit - 5

Flow, Level and Temperature Measurement.

Flow :- It is defined as fluid in motion.

Flow may be of gas or liquids.

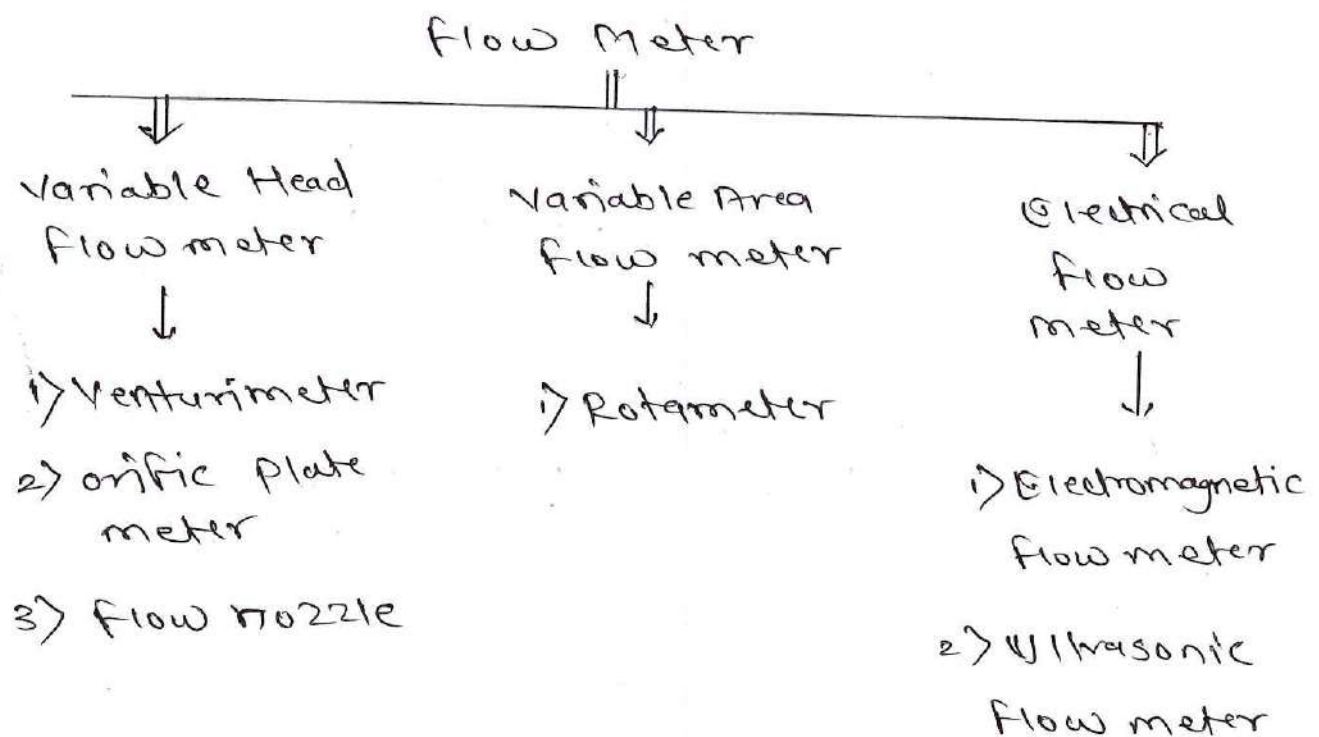
OR

Flow is the movement of fluid from one point to another with respect to time.

unit: cubic meter per second (m^3/s)

Pound Per Second (lb/s)

* classification of flow measuring transducers:

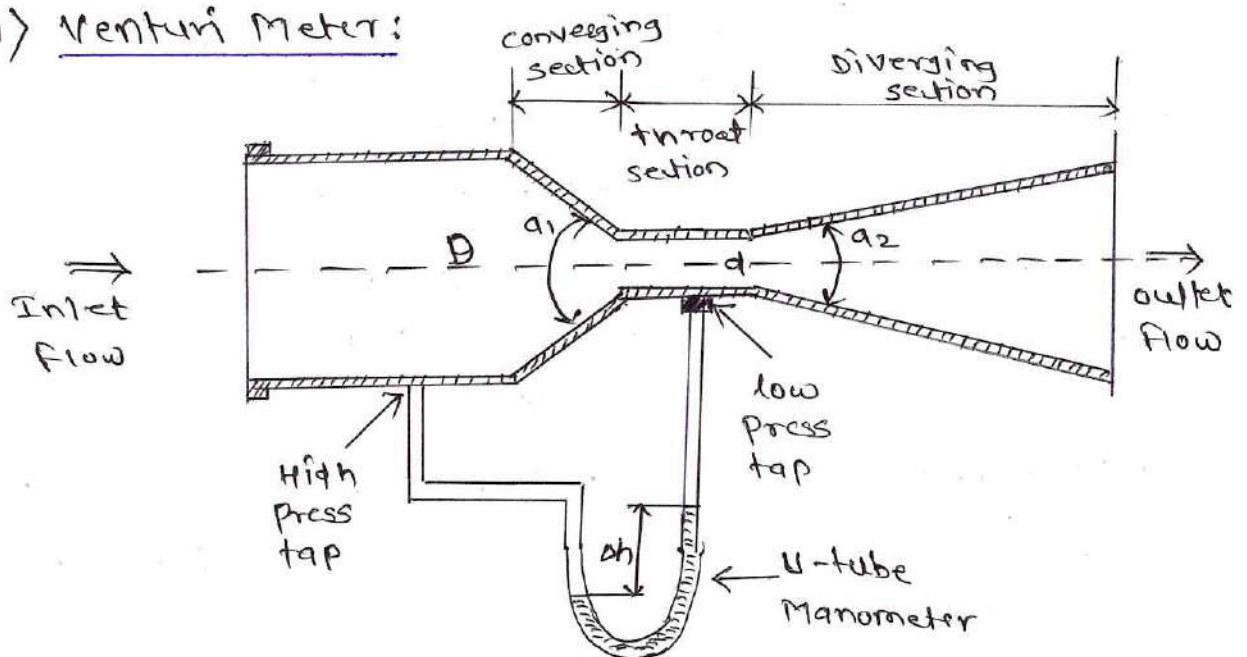


A] Variable head flow meter:

Principle: when obstacle is placed in the path of flow, it produces a differential pressure across the restriction which is proportional to the flow rate.

The relationship between actual flow rate and differential pressure is not linear. i.e. Flow rate is proportional to the square root of the differential pressure.

1) Venturi Meter:



D = diameter at inlet

d = diameter at throat

α_1 = inclined angle ($19^\circ - 23^\circ$)

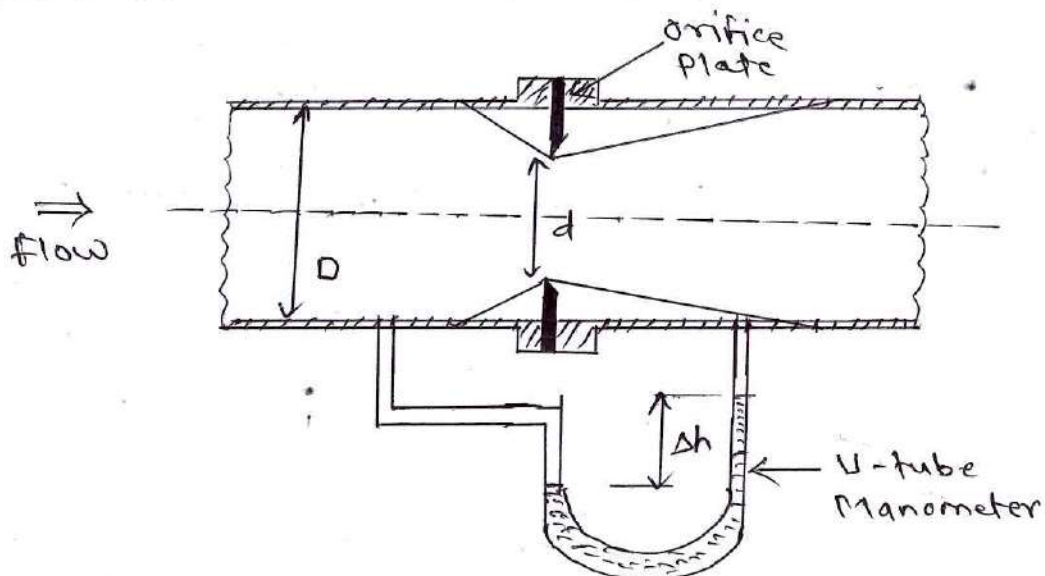
α_2 = inclined angle ($5^\circ - 15^\circ$)

- Venturimeter consist of three sections that is converging, throat & diverging section.

- The flow is enter thro inlet with diameter D , the inclined angle of converging section is α , which may between 19° to 23° .
 - The flow is then passed through the throat section having diameter ' d '.
 - Two press (one at inlet & second at throat section) are provided to measure the press. diffⁿ by using U-tube manometer.
 - Flow rate is proportional to the square root of the differential pressure
- $$\text{Flow rate} \propto \sqrt{P_1 - P_2}$$
- The venturi tube made up of cast iron or steel.

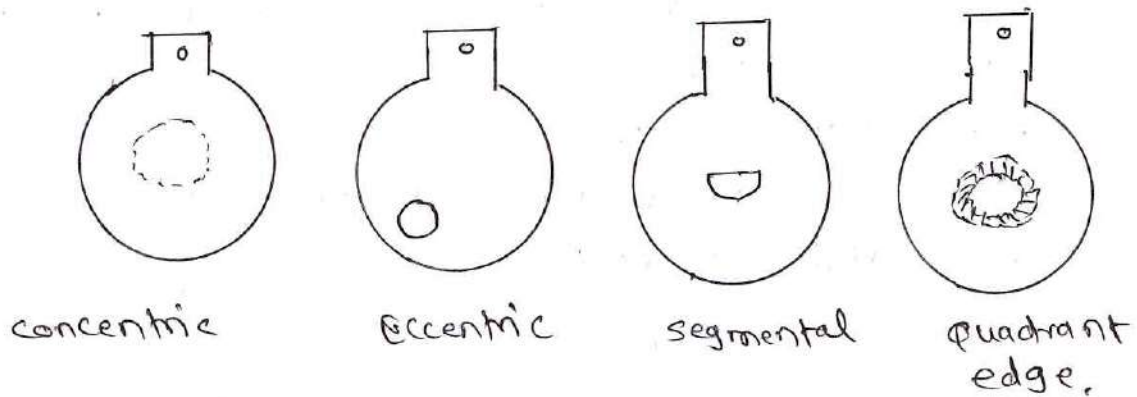
2) orifice plate Meter:-

- It is variable area flow meter in which the differential pressure is developed by using orifice plate by inserting it in the path of the fluid flow.



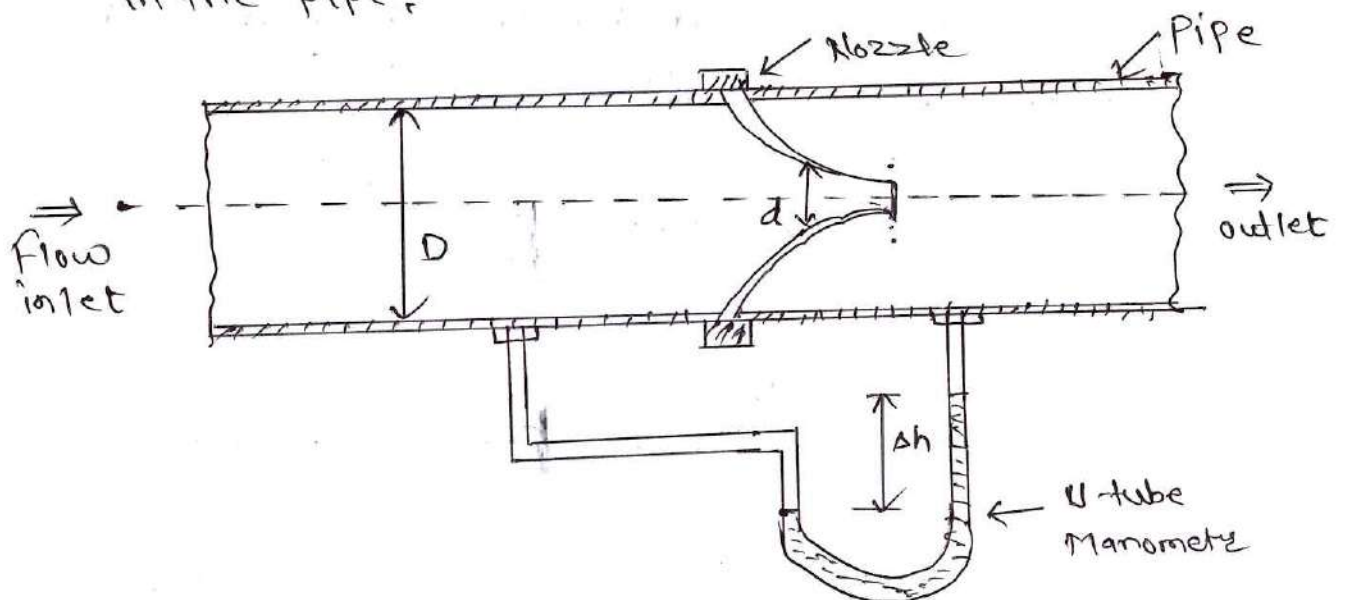
- It consist of circular shape plate with a hole in it. This plate is inserted into pipe in the path of fluid & differential press is developed across the plate.

- The orifice plate made up of stainless steel, phosphor bronze or monel.
- depending on the location & shape of hole on plate, orifice plate has 4 types.



3) Flow Nozzle:

- A flow nozzle operates on the principle that of variable head type flow meter. different pressure is developed by inserting flow nozzle in the pipe.



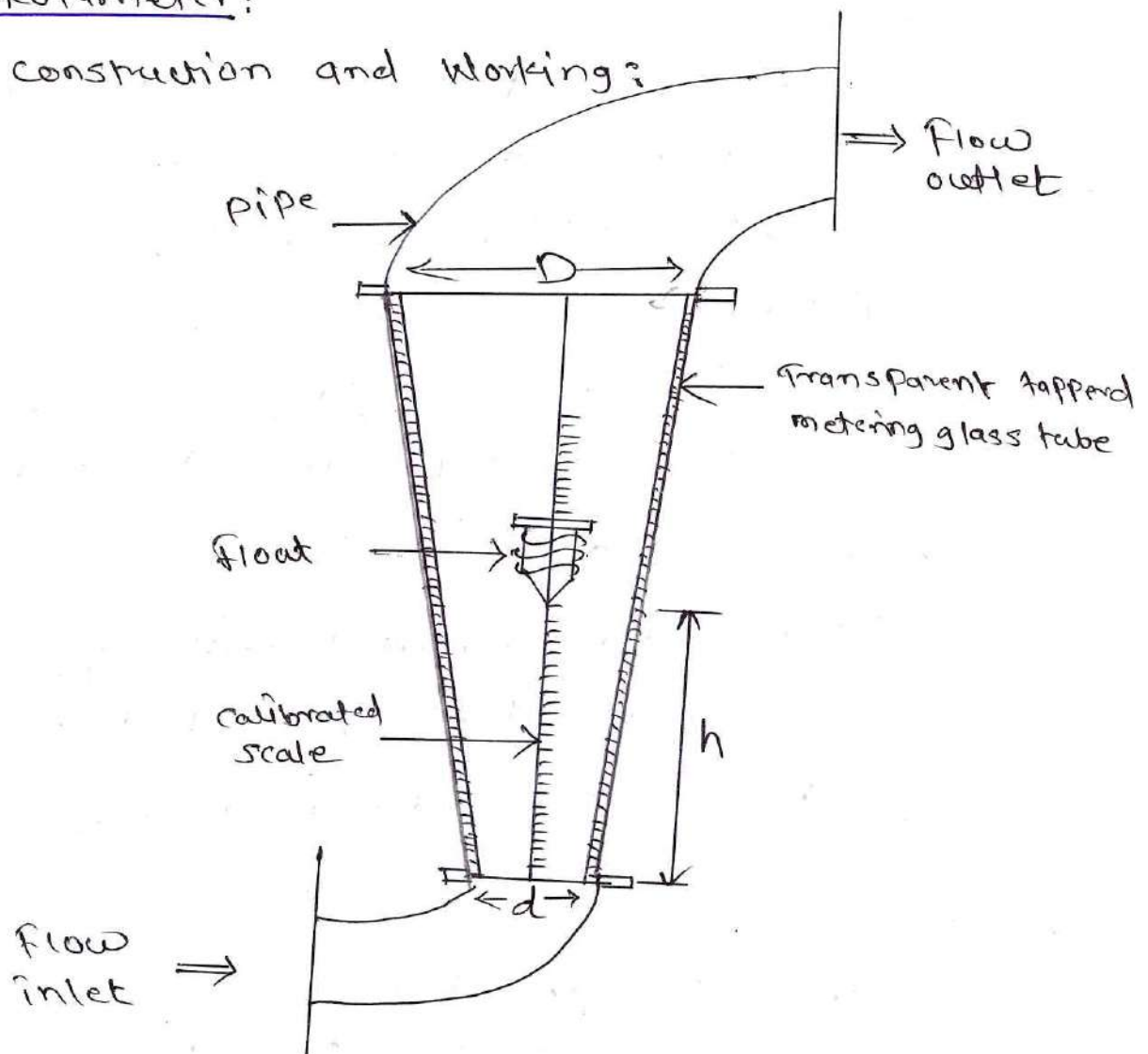
Stainless steel is the material used for manufacturing of flow nozzle

B) Variable Area Flow meter:

In variable area flow meter, the pressure difference is kept constant by changing the restriction area. Rotameter is variable area flow meter.

* Rotameter:

Construction and Working:



- Rotameter consist of tapered transparent glass tube with small diameter at bottom and top is bigger (D), which is mounted vertically. The fluid ~~whose~~ whose flow is measured is entered to the tube from bottom side.

- Inside the tube, there is float with grooves on the body, which has higher density than fluid. The fluid moves the float upwards.
- When the float achieves some level in the tube, it directly indicates the flow rate.

Advantages:-

- 1) It gives direct visual indication on scale.
- 2) Cost of rotameter is low.
- 3) It has good range ability.
- 4) It has low pressure drop.
- 5) Useful for some slurry services.
- 6) Scale is directly calibrated into flow rate.

Disadvantages:-

- 1) It must be mounted vertically.
- 2) It is not suitable for pulsating flow.
- 3) Accuracy of rotameter is fair.

Applications:-

- 1) Used in laboratories.
- 2) Used in testing & production lines.

* Comparison

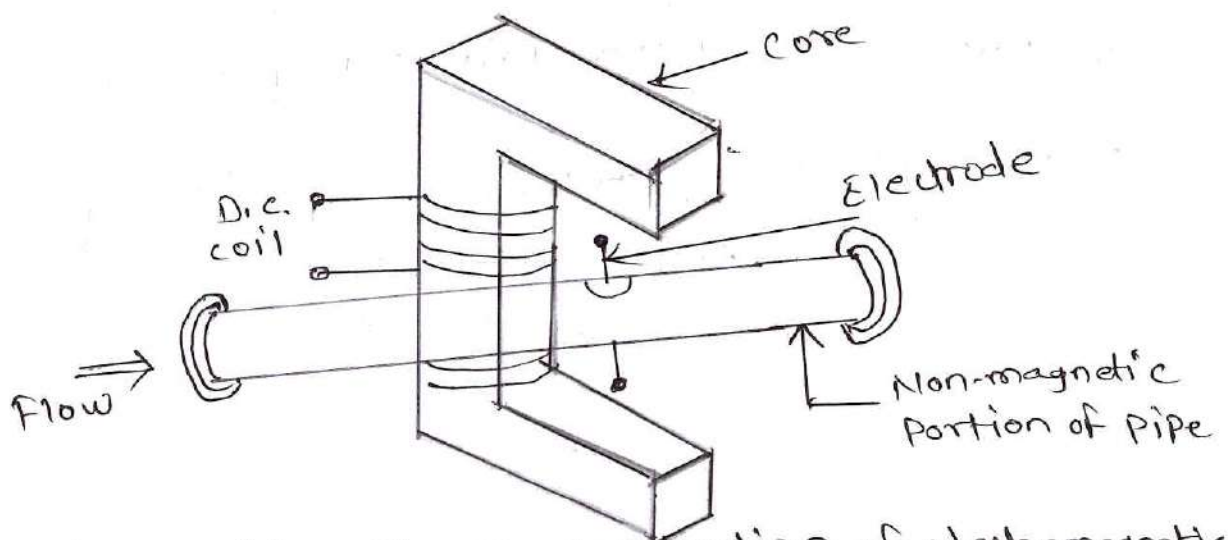
Parameter	Variable Head	Variable Area
1) Operating Principle	Differential press across restriction is proportional to flow rate.	press difference is constant by changing restriction area.
2) Application	used for slurry, dirty fluids.	used in laboratories.
3) Disadvantages	High cost	mounted vertically
4) Types	venturimeter	Rotameter
5) pressure drop	High	low

c] Electrical flow meter:

1) Electromagnetic flow meter:

operating principle - flow meter work on the principle of electromagnetic principle which state that, when moving conductor moves in a magnetic field, an EMF is induced in the conductor which is proportional to the velocity of moving conductor.

Construction & Working :-



- Above fig. Shows construction of electromagnetic flow meter.
- It consist of non-metallic & non-conducting portion of pipe.
- A pair of electrode are mounted opposite to each other.
- A pipe is placed within a electromagnet which produced magnetic field generated by current flowing through coil which is connected with D.C. supply.

- according to faradays law of electromagnetic induction, emf is induced in the electrode having direction given by flemings right hand rule.
- The magnitude of induced emf is given by

$$\text{emf} = B \cdot l \cdot v.$$

where B = flux density
 l = length of conductor
 v = velocity of fluid

- From above eqⁿ, B & L are constant, the magnitude of induced emf is proportional to the velocity of the fluid (conductor).

- Advantages:
- 1) linear relation betⁿ flow to o/p v/tg
 - 2) o/p is independant on press & temp
 - 3) Good transient response.
 - 4) It can handle slurries & greasy material
 - 5) It is available in large pipe size.
 - 6) It can be used as bidirectional flow.

- Disadvantages:
- 1) It has high cost.
 - 2) used only for conducting material

- Applications:
- 1) usefull for any electrically conducting fuel.
 - 2) used for measuring the fluid like corrosive acid.

2) Ultrasonic Flow Meter:

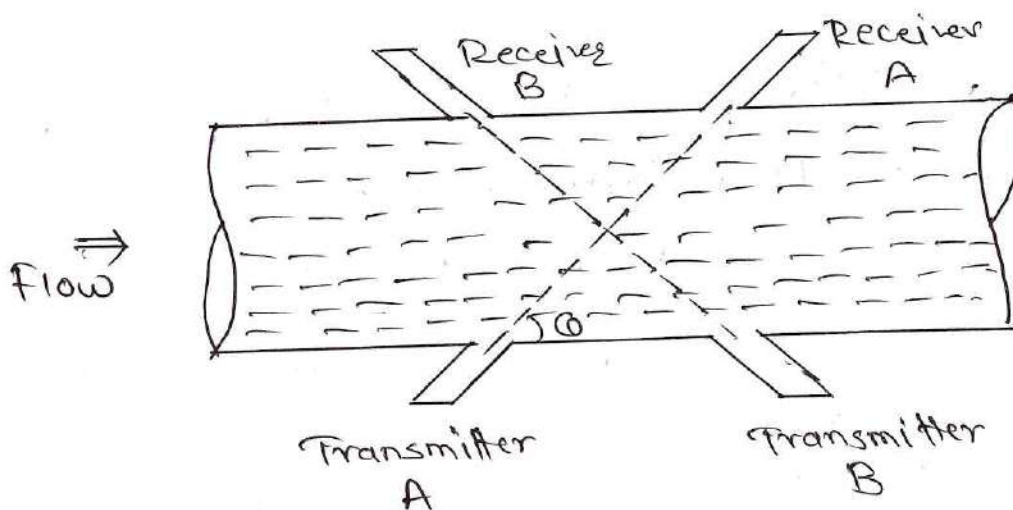
Ultrasonic flow meters are of two types according to the working principle.

- a) Time difference type
- b) Doppler flow meter.

a) Time difference type:

Operating principle: The operating principle is based on an apparent change in the velocity of propagation of ultrasonic wave pulses in a fluid with a change in velocity of fluid flow.

Construction & Working:-



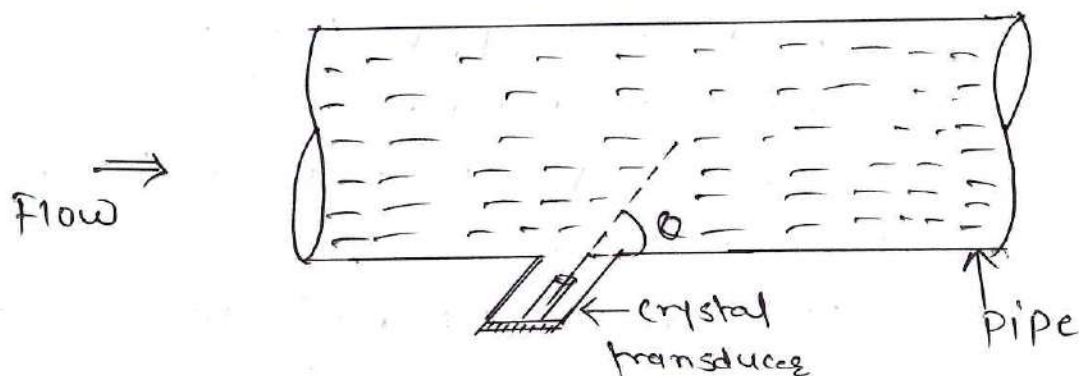
- Fig. shows time difference type ultrasonic flow meter. It consists of two transmitters and two receivers.
- Transmitter transmits waves in the direction of receiver, one is in the direction with flow and the other is in the opposite direction to the flow direction.

- The velocity of wave increased or decreased depend on fluid velocity and direction of fluid.
- The detector measures the transit time.
- By measuring the difference in frequency and value of θ and L , the velocity of fluid can be counted.

b) Doppler Flow Meter:

operating principle:- operating principle of this flow meter is based on doppler principle.

construction & working:



- Fig. shows doppler type flow meter which consist crystal transducer mounted outside the pipe.
- This transducer emit an ultrasonic wave & the wave is projected at an angle through the pipe wall into the liquid.

- Some parts of ultrasonic wave are reflected by liquid particles & bubbles and it is returned towards the transducer.
i.e. water particles or bubbles act as reflectors for the ultrasonic wave.
- The frequency of reflected wave is depend on particle velocity, it is given by doppler principle.
- The Velocity of flowing fluid is given by,

$$V = \frac{\Delta F \cdot C_t}{2 F_0 \cos \theta}$$

V = velocity of fluid
 ΔF = diffⁿ betⁿ trans-
 mitted & receive freq
 C_t = velo. of ultra wave
 F_0 = freq of transmission
 θ = angle betⁿ trans-
 mitted wave & pipe.

- Advantages:
- 1) Good accuracy, fast response
 - 2) No moving part
 - 3) Suitable for both gas & liquid
 - 4) No pressure loss
 - 5) Not affected by fluid viscosity, press & temp variation.

- Disadvantages:
- 1) cost is high
 - 2) Complicated circuit.

- Applications:
- 1) Mostly used for liquid without any pressure loss
 - 2) Mainly used for liquid flow.

Level:- It is defined as regulation of the linear vertical distance between the surface of a liquid with some reference point.

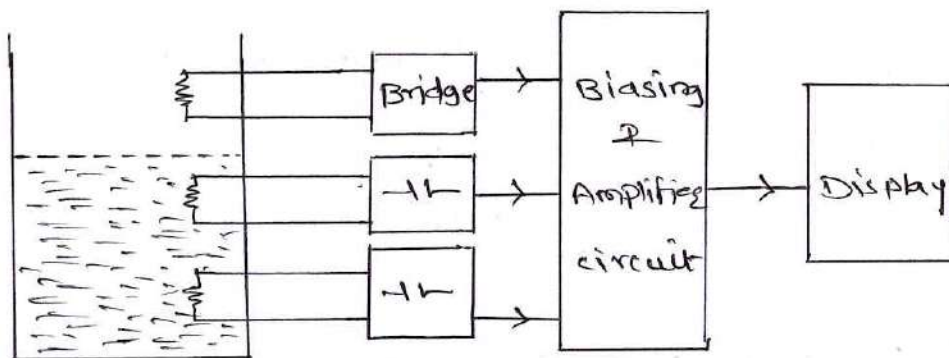
Level commonly refers to the height of a liquid surface in a tank.

Unit - level is a measure of length (height) having unit - meter, centimeter, mm inch or foot.

* classification of level measurement transducers:

- 1) Resistive transducers
- 2) Inductive transducers
- 3) Capacitive transducers

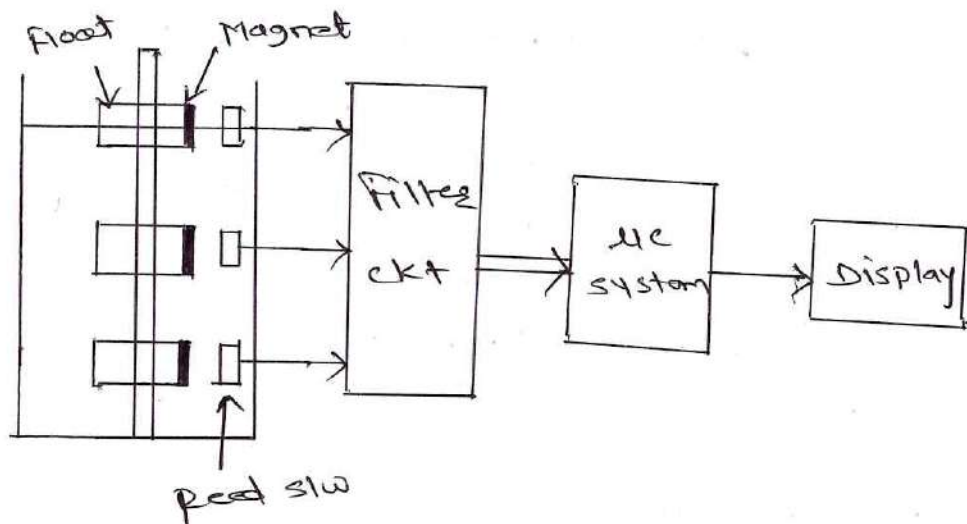
1) Resistive transducers:



- Resistive electrodes are located at known height interval. resistance element changes value when dipped in liquid.
- This change in resistance is sensed & digital output is generated.
- This digital signal representing liquid level is given to MC based system for processing and o/p is displayed on display device.

2) Inductive transducer:

- In this type of level measurement, a permanent magnet is fixed on a float.
- as the float moves up & down, depending upon level of liquid, the reed switches placed at known level close due to magnet.



- This sw position is sensed and given to mc based system on digital input
- mc process the i/p & o/p is given to display for showing the liquid level.

3) capacitive transducer:

Working principle:- The capacitive level detector operates on the equation of parallel plate capacitance.

$$C = \frac{\epsilon A}{d}$$

where C = capacitance in Farad

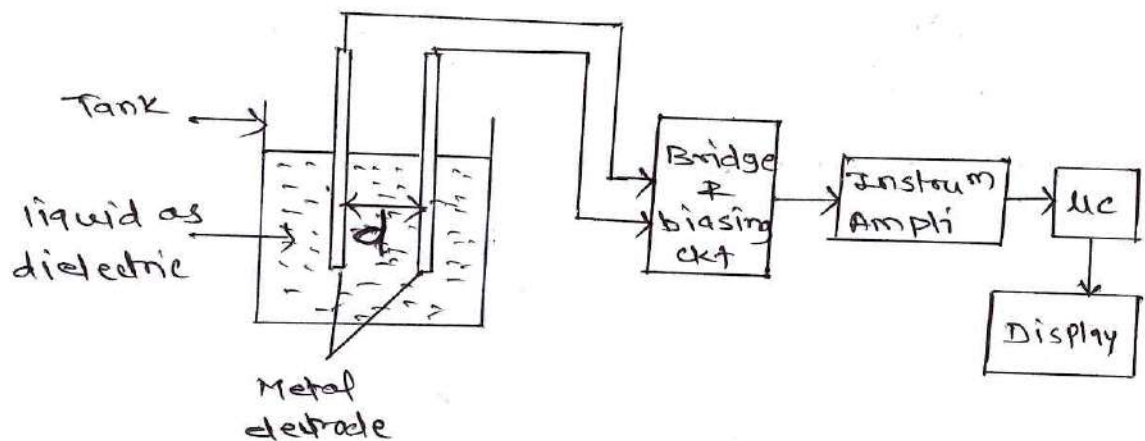
ϵ = dielectric const.

d = dist betⁿ plates

A = area of plate

If A & d are constant, then C \propto dielectric const (ϵ)

Construction & Working:



- Fig. shows construction of capacitive type level measurement gauge, it consists of two electrodes connected in parallel to each other, act as plate capacitor.
- This system is used for non-conducting liquid, which act as dielectric material.
- When liquid level in the tank increases, then capacitance also increases and as liquid level decreases, capacitance decreases.

Advantages: 1) Suitable for small system.

2) High sensitivity

3) Continuous measurement & control

4) It is good for slurry material.

Disadvantages: 1) It is affected by dirt & other material

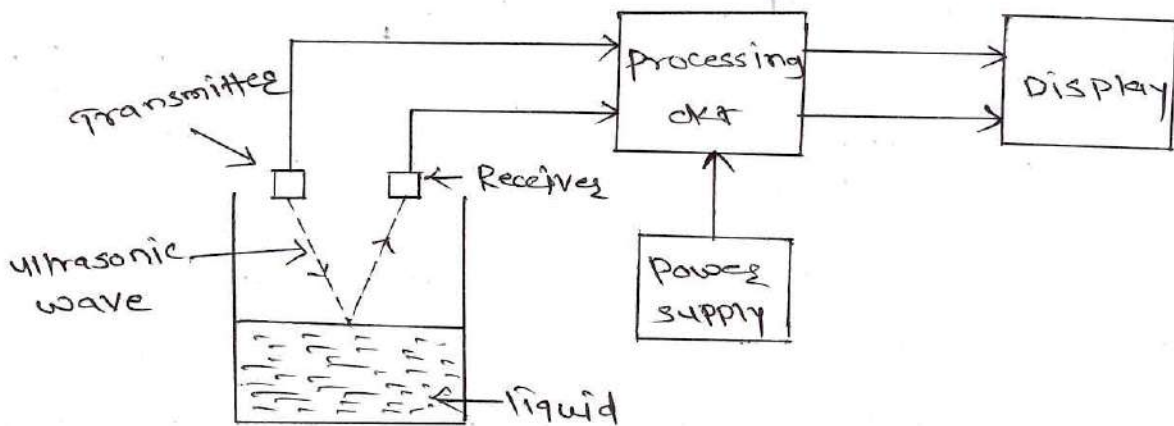
2) Suitable for fluid having high dielectric quantity

3) It is affected by change in temp.

* Ultrasonic type level Measurement:

Working principle: It operates by generating an ultrasonic wave or pulse & measuring time takes for it return.

Construction & Working:



- Fig. shows construction of ultrasonic liquid level gauge.
- It consist of set of transmitter & receiver which is mounted at top of tank containing liquid whose level is to be measured.
- Transmitter & receiver is connected to the processing ckt which is use to calculate time takes by wave travels from transmitter to receiver.
- The time takes by wave is measured of the distance travel by the wave.
- The time is directly proportional to distance.

$$T \propto \frac{1}{\text{level}}$$

- Advantages:
- 1) No moving parts
 - 2) o/p is not affected by density of liquid
 - 3) Non-contact type level measurement
 - 4) reading is unaffected by dielectric property.

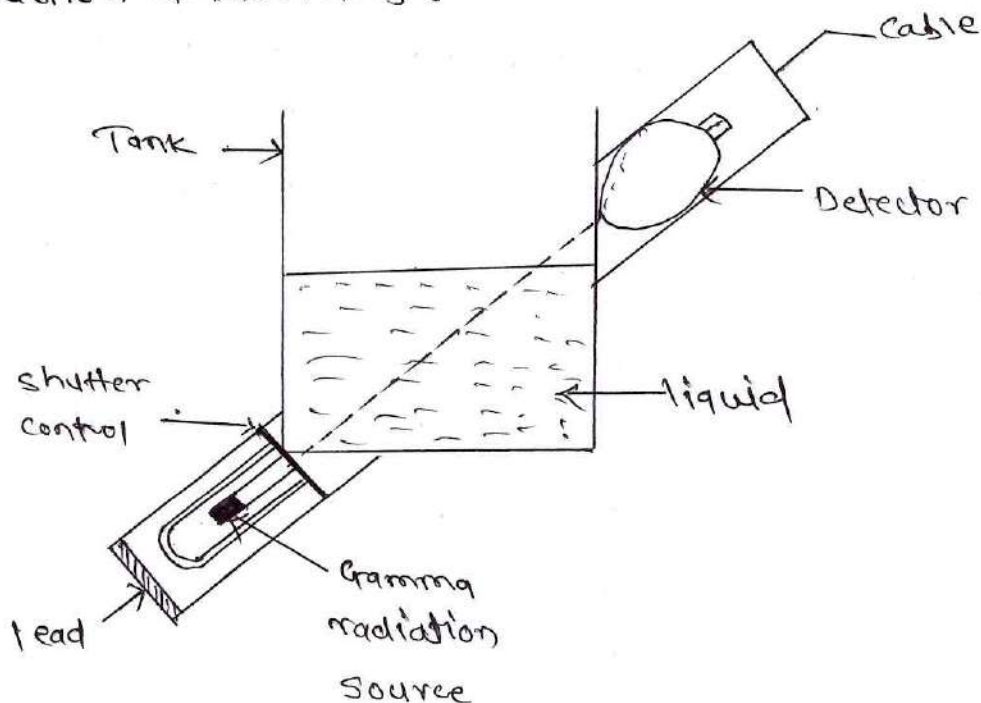
Disadvantages :

- 1) Accuracy is affected by dirt, irregular surface.
- 2) Temp is constant during measurement.
- 3) Instrument is expensive.

* Radiation type Level Measurement:

Operating principle: The working principle of gamma ray liquid level gauge is that the absorption of gamma rays varies with thickness of absorbing material (i.e. height of liq. column) between source & detector.

constitutions & working :



- Fig. shows constitution of gamma ray liquid level gauge, it consists of gamma radiation source, which radiates gamma rays.
- The amount of radiation is controlled by shutter.

- The gamma rays pass through liquid towards the detector.
- As gamma rays pass through liquid, liquid area absorbs the gamma rays, higher the height of liquid higher the absorption of gamma rays and lower is the ~~detected~~ detector output.
- The o/p is measured by using expression

$$I = I_0 e^{-\mu \rho x}$$

where I = intensity of radiation on detector
 I_0 = intensity of radiation on detector when absorbing material absent
 μ = absorption constant
 ρ = mass density of test material
 x = thickness of absorbing material (i.e. height of liquid)

- From above eqⁿ, the intensity of radiation falling on detector is depends on height of liquid.

- Advantages:
- 1) continuous measurement is possible.
 - 2) Non-contact device
 - 3) suitable for large reservoirs.
 - 4) Independent on temp, press, corrosion

Disadvantages:

- 1) It is risky to use due to radiation effect
- 2) It is required to limit the radiation field intensity.

Application: 1) To record level of liq & solid substance.

* Temperature: It is defined as, the degree of hotness or coldness of a body.

- It is thermal state of a body or substance which determine whether it will give ~~to~~ heat or receive heat from surrounding.
- Heat always flow from high temp body to low temp body if these bodies are kept near to each other.

unit: kelvin, celsius, Fahrenheit

$$K = ^\circ C + 273.15$$

$$^\circ C = \frac{5}{9} (^\circ F - 32)$$

$$^\circ F = \frac{9}{5} ^\circ C + 32$$

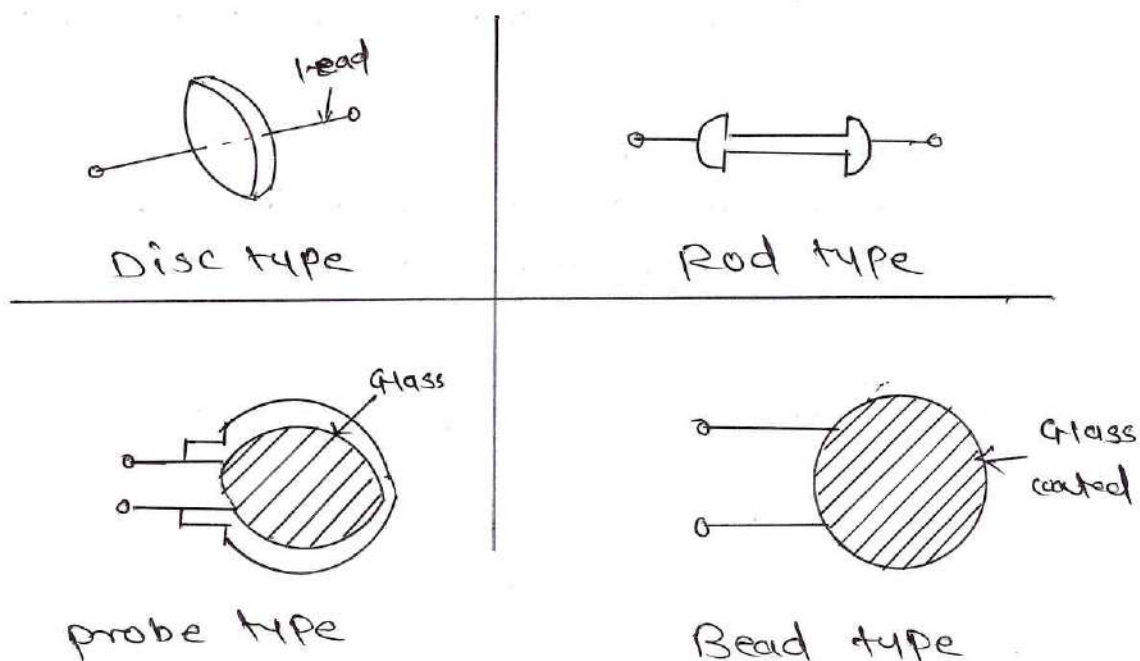
* Thermistors:

- Thermistor is nothing but thermal resistor which is temp dependent resistance whose resistance varies with temp varies.



- The resistance of thermometer ranges from 0.5Ω to $0.75 M \Omega$
- Thermistor work on the principle of temp coefficient of resi. i.e. change in temp produces change in resistance.
- Based on operating principle, thermistor are classified as
 - i) PTC (Positive temp coeff) - $T \propto R$
 - ii) NTC (Negative temp coeff) - $T \propto 1/R$

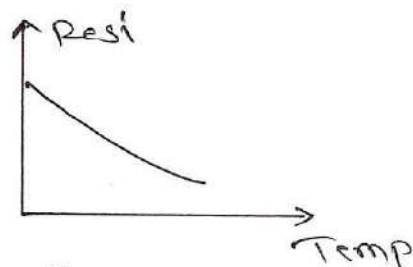
- Thermistor are available in various shape such as -



- It is a temp dependent resistance in which value of resistance is increased or decreased according to temp change.

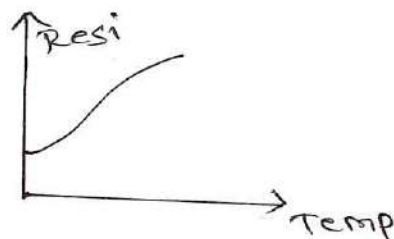
- In NTC, if temp is increases then resi. decreases and vice versa.

i.e. $R \propto \frac{1}{T}$



- In PTC, if temp is increases then resi increases and vice versa.

i.e. $R \propto T$



- operating range -150°C to 300°C

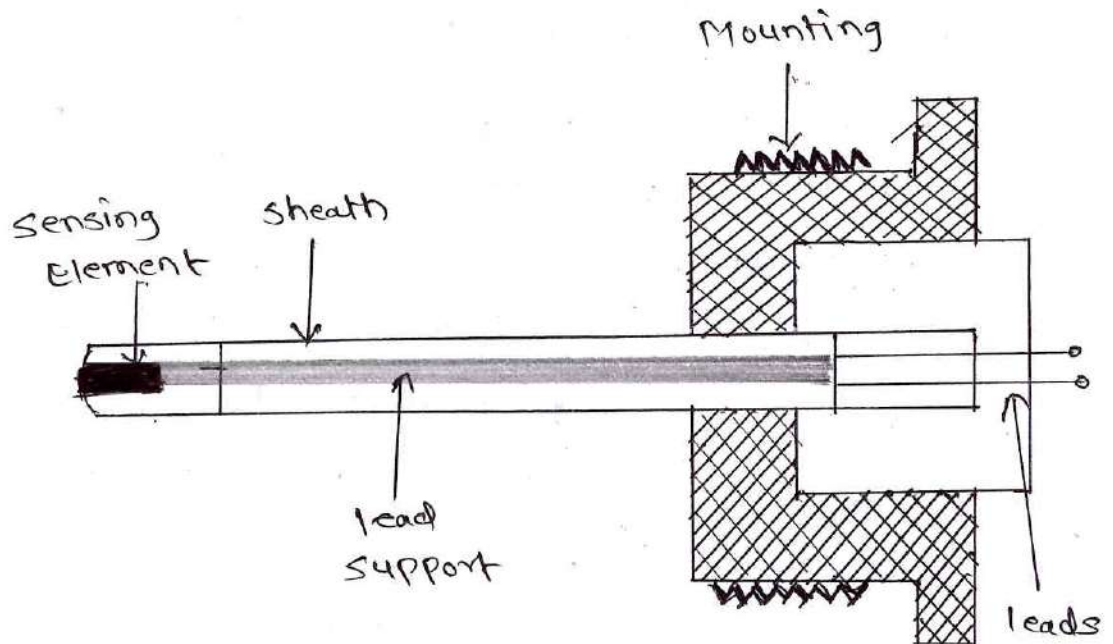
- Advantages :-
- 1) small size, low cost, High sensitivity
 - 2) Available in various shape & size
 - 3) fast response.

- Disadvantages :-
- 1) Relⁿ betⁿ resi & temp is non-linear
 - 2) Not available for wide temp range
 - 3) unstable at high temp.

* Resistance Temperature Detector (RTD) :-

operating principle: A pure metallic element or wire with large positive temp coefficient (PTC) changes its resistance with change in temperature, the element is used as resistance thermometer.

Construction & Working:



- Fig. shows construction of platinum resist thermometer.
- In which platinum is a sensing element.
- It is long spring like shape, enclosed in a metal sheet, it is inserted in a medium whose temp is to be measured.
- leads are provided and draw out for connectivity to the bridge ckt to measure the resistance.
- mounting threads are provided for perfect installation of the thermometer.



- above fig. shows, resistance thermometer (R_T) connected in bridge ckt. Resi thermometer act as a one arm of wheastone bridge.
- The bridge consist of sensing element. resi (R_T) and R_1, R_2, R_3 are the other resi. connected to the bridge.
- R_1, R_2, R_3 are the fixed resistance and R_T depends on temp of material.
- At balance condition, ratio of resistance is given by

$$\frac{R_2}{R_3} = \frac{R_1}{R_T}$$
- when some temp apply to R_T then the value of R_T changes and bridge become unbalance and galvanometer shows some deflection & gives output.
- If there is no change in R_T , bridge becomes balance and output voltage is zero.

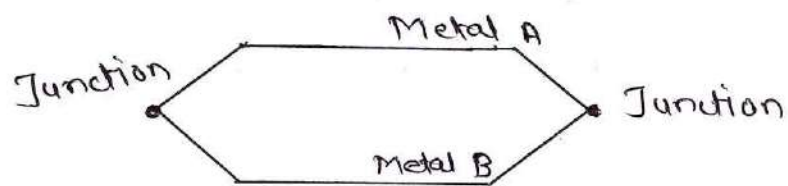
Advantages:

- 1) linear over wide operating range
- 2) wide range of temp
- 3) Good stability at high temp
- 4) long life
- 5) stable under various env. condition.

* Thermocouple:

- When two different metals are joined together, there is a continuous small vltg generated at the junction. This voltage is generated by seebeck effect or thermo electric effect.
- The magnitude of voltage depends on temp of junction and nature of metals used.

Construction:



- When two dissimilar metal are connected to each other, to form two junctions and this junctions are maintain at diffⁿ temp.
- When the temp diffⁿ is created, c/n flows through a metal and e.m.f. is generated which is proportional to diffⁿ in a temp.
- Thermocouple is the self generating transducer, i.e. Active transducer.
- It is one of the most commonly used device to measure high temp.

Advantages: 1) Small size, cheaper than RTD, High temp range (1400°C), Speed of response is good.

Disadvantages: 1) Accuracy is less than RTD
2) Need periodical checking
3) lead compensation is required.

* Types of Thermocouple; They are classify based on type of metals used in thermocouple.

TYPE	Material used		Temp range in $^{\circ}\text{C}$	Sensitivity in $\mu\text{V}/^{\circ}\text{C}$
	Ave wire	-ve wire		
TYPE K	Iron	Constantan-57-chromium 43-Nickel	-200 to 850	45-50
TYPE T	Copper	57-chromium 43-Nickel	-200 to 350	15 to 60
TYPE R	Platinum-87 Rhodium-13	Platinum	0 to 1600	5 to 12
TYPE S	Platinum-90 Rhodium-10	Platinum	450 to 1500	5 to 12

* Compare RTD & Thermistor

Parameter	RTD	Thermistor
1) operating principle	resist. of wire varies with temp	resist of metal oxide varies with temp
2) Material used	platinum, copper, tungsten	Magnise, copper, cobalt & iron oxide
3) cost	High cost	low cost
4) size	large size	small size
5) operating range	$-270^{\circ}\text{C} - 2800^{\circ}\text{C}$	$-150^{\circ}\text{C} - 300^{\circ}\text{C}$
6) characteristics	linear	Non-linear
7) Temp coefficient	+ve temp coeff.	+ve & -ve temp coeff.

Question Bank

unit 5 - flow, level & Temp Measurement.

- 1) classify the flow transducer
W-25
- 2) state the methods used for level measurement
W-25
- 3) Explain in brief, level measurement with capacitive transducer
W-25, S-26, W-24
- 4) Elaborate the working of electromagnetic flow meter. state it's application
W-25
- 5) Explain with neat sketch, measurement of temperature with thermocouple.
W-25
- 6) Give the classification of level measurement method.
S-25, S-26
- 7) predict the applications of Thermistor & RTD
S-25
- 8) Name the material used for J, K, R, S type thermocouple
S-25
- 9) compare ultrasonic type and radar type level measurement transducer.
S-25
- 10) Draw neat sketch of Rota meter and explain it's working principle.
S-25
- 11) Define temperature with it's unit.
W-24, S-26

12) Explain the concept of variable area flow meter

W-24

13) Describe with neat diagram resistance temperature detector. (RTD)

W-24, S-26

14) State different methods of measurement of flow meter and explain electromagnetic flow meter.

W-24, S-26

15) Explain working of ultrasonic ~~level~~ flow meter and radiation level measurement method.

W-24.