INDEX

NAME:__________ STD.:______ SEC.:______ ROLL NO.:______ SUB.:__________

S. No.	Date	Title	Page No.	Teacher's Sign / Remarks
	Name -	Sidharth Sekhar Mallick		
	Deg. -	Lecturer in AE&I Dept.		
	Sub-	Industrial Measurement & Instrumentation - I.		
	Sem. -	4^{th} second year.		

Syllabus

Chapter-1 Measurement of temperature:

1.1 Classify methods of temperature measurements.

1.2 Explain measurement of temperature by non-electrical methods.

A. Liquid expansion type.

B. Solid expansion type.

C. Gas & vapour expansion type.

1.3 Explain measurement of temperature by electrical methods of measurement.

A. Resistance thermometer.

i) State advantage of resistance thermometers are others types.

ii) Describe the methods of measurement of change in the resistance by null balance bridge method.

iii) compensation of lead resistance by 3-wire & 4 wire method.

B. Thermocouples.

i) Explain principle of thermoelectricity (Seebeck, Peltier & thompson effects).

ii) classify thermocouple materials.

iii) Describe the function of thermocouple extension wire.

iv) Describe the methods of measurement of output of the thermocouples ~~and~~ State the types of thermocouples insulating materials & their function.

v) State the advantages & disadvantages of thermocouple types thermometer.

vi) Explain the cold junction compensation of thermocouple

C. Thermistors.

i) Explain the basic principle & characteristics of thermistors

ii) state the method of temperature measurement by thermistor & their uses.

D. Pyrometers.

i) Explain the principle & operation of radiation & optical pyrometer with suitable diagram & sketch.

E. Describe the function & use of temperature switch.

Chapter-2 Measurement of pressure:-

2.1 classify methods of pressure measurement.

2.2 Explain the working principle & use of mechanical methods of measurement of pressure by:

i) manometers (U-tube, well type, Inclined type)

ii) Elastic type pressure gauge (Bourdon tube, Diaphragm, Bellows).

iii) Bell gauge.

2.3 Explain the working principles & use of electrical methods of measurement of pressure by:

i) strain gauge pressure transducer.

ii) Capacitive pressure transducer.

iii) Reluctance pressure transducer
(v) Piezoelectric pressure transducer

2.4 Describe the operation & Explain the working principle of vaccum gauge
i) Thermal conductivity Gauge
ii) Mc lead gauge
iii) Hot filament ionization vaccum gauge

2.5 Explain the working principle of Mechanical & pnumatic pressure transmitter, pressure switch (two wire & four wire type of transmitter) & State their uses.

Chapter-3 Measurement of flow & level.

3.1 classify flow meters and explain the principle of operation with diagram.

3.2 variable head type flow meter: Explain the principle of operation, advantages & dis advantages of
i) Orifice plate, ii) venturi tube, iii) Nozzles, iv) Dall tubes,
v) Elbow taps vi) weirs & flumes.

3.3 Explain variable area flow meter (Rotatmeter), cylinder & piston type & their uses.

3.4 Explain Non-hydraulic meter and state their industrial uses.
i) magnetic flow meter.
ii) Ultrasonic flow meter.

3.5 Describe the construction and explain working principles of thermal flow meter.

3.6 Describe the construction and explain principle of Quantity flow meter.
i) positive displacement type.
ii) Reciprocating piston type.

3.7 Level Measurement
i. classify level Indication
ii) Explain the working of sight glass, float type of indicator & displacement level detector.
(iii) Explain the construction and use of inductive, resistive level gauge.
(iv) Explain the working of capacitive level dector & radiation level detector.
v) State & explain the function of different types of level switches.

Chapter-4 Measurement of force, Torque & shaft power.

4.1 Define force, torque & shaft power.
4.2 Explain basic method of measurement of force.
4.3 State & Explain equal & non-equal arm balance.
4.4 Explain multiple level Systems of force measurement.
4.5 Explain Hydraulic & Pneumatic load cell.
4.6 Explain methods of measurement of torque using strain gauge

and magnetostrictive torque transducer.

1.7 Explain measurement of shaft power using rope break and prony brake.

Chapter-5 Telemetry & Various Converters:-

5.1 Define telemetry.
5.2 General telemetry System.
5.3 Types of telemetry System.
5.4 problems in telemetry System.
5.5 pressure to current converter.
5.6 pressure to voltage converter.

Chapter-6 Aquastic Measurement

6.1 Define Aquastic pressure.
6.2 Explain characteristic of Sound pressure level & power Level
6.3 Explain the function of typical Sound system Such as microphone.

Text books

1. Industrial Instrumentation by S.K Singh of Mc graw Hill education.
2. Electrical Instrumentation & process control by Dr. J. P Navani, E.R. Sonal Sapre. of S. Chand.
3. Mechanical Measurement & control - by R.K. Khedkar

ifier

f

re

e

nt-

l

ued

r

ire

CHAPTER-1

MEASUREMENT OF TEMPERATURE

1.1 → Classify methods of Temperature →

* The temperature of a substance is a measure of the hotness, or coldness of that substance. If two bodies are placed in contact then heat tends to flow from a body at a higher temperature to a body of a lower temperature.

* Temperature Scales

i) The lower fixed point, or ice-point.
ii) The upper fixed point, or steam point.

→ The lower fixed point or ice-point is the temperature of ice, prepared from distilled water melting under a pressure of 760 mm of mercury.

→ The upper fixed point, or steam-point is the temperature of steam from pure distilled water boiling under a pressure of 760mm of mercury.

→ The temperature interval betn the ice-point & steam point is known as the fundamental interval.

* Fahrenheit and Centigrade (Celsius) Scales →

$$\frac{°C}{100} = \frac{°F - 32}{180}$$

* Kelvin and centigrade Celsius →

$$°K = °C + 273.15$$

* Basic fixed points → all corresponding to the normal atmospheric pressure of 760mm of mercury, and are used to standardise thermometers.

i) Boiling point → The boiling point is the temperature at which the substance changes physical state & becomes a gas.

ii) Freezing point :- The freezing point is the temperature at which the substance changes physical state & becomes a solid.

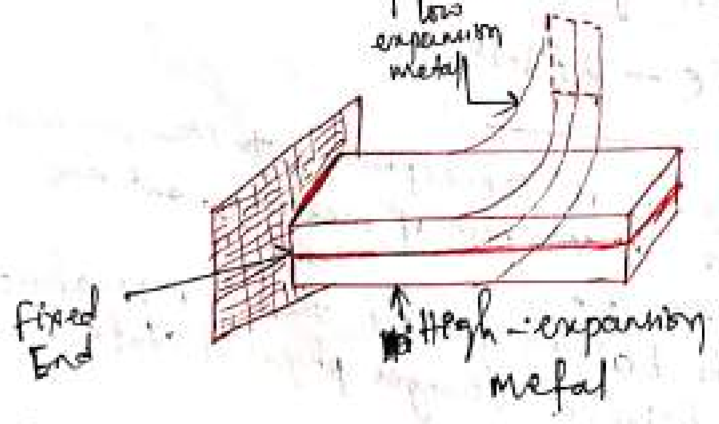
(iii) Triple point :- A particular temperature and pressure at which three different phases of one substance can exist in equilibrium is known as triple point. (03)

* 1) Expansion thermometers
2) Filled system thermometers
3) Electrical temperature instruments
4) pyrometer.

1.2 Explain measurement of temperature by non-electrical methods.

a) Expansion of Solids
→ Bimetalic thermometers

* The expansion of Solids is employed mainly in bimetallic elements by utilizing the differential expansion of bonded strips of two metals
* it consists of two ~~metal~~ strips of metal such as invar and brass welded together, each strip made from a metal having a different co-efficient of thermal expansion.
* whenever the welded strip is heated, the two metals change length in accordance with their individual rates of thermal expansion.
* The two metals expand to different lengths as the temperature rises. This forces the bimetallic strip to bend towards the side with low co-efficient of thermal expansion.



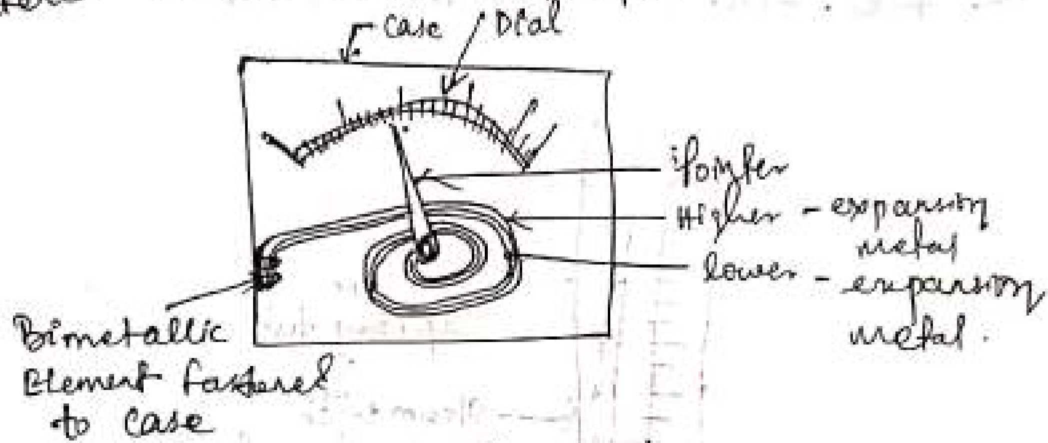
* if one end of the bimetallic strip is fixed so that it cannot move, the distance the other end bends is directly proportional to the square of the length of

the metal strip, as well as to the total change in the temperature, and is inversely proportional to the thickness of the metal.

→ The movement of the bimetallic strip utilized to deflect a pointer over a calibrated scale.

→ A longer strip can be contained in a relatively small space if the strip length if the strip is wound in a spiral, helix or multihelix form.

→ if the bimetallic element is wound in a spiral coil is tightened with increase in tempr.



→ Bimetallic thermometers are inexpensive, relatively rugged, and easy to read. they are also resonably accurate if handled carefully. They are available for the temperature range from −103 to 1004°F (−75 to 540°C)

Advantage

i) their cost is less
ii) they are tough & can't easily be broken.
iii) they are easily installed & maintained.
iv) they have good accuracy relative to cost.
v) they have fairly wide temp'. range.

Disadvantage

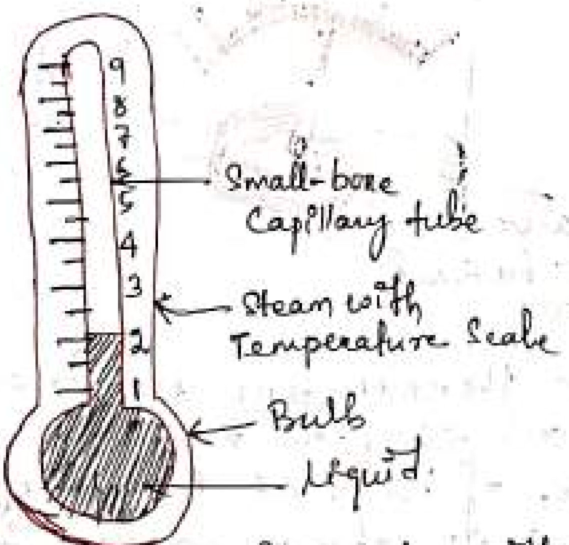
i) They are limited to local mounting.
ii) only indicating type is available.

B) Expansion of liquids

i) Liquid-in-glass thermometers →

→ The liquid-in-glass thermometer is one of the simplest temperature measuring device widely used in both laboratory & industry.

→ Its operation is based on the fact that liquid expands as the temperature rises. In this type of thermometer, the expansion causes the liquid to rise in the tube indicating the temperature.



→ It consists of a small bore glass tube with a thin-wall glass bulb at it's lower end. The liquid that fills the bulb ~~at it's lower en~~ and part of the tube is usually mercury.

→ As heat is transferred through the well and metal stem and into the mercury, the mercury expands, pushing the column of mercury higher in the capillary above which indicates the temperature.

→ The liquid-in-glass thermometer is commonly used for the temperature range of -18.4 to 608°F (-120 to 320°C).

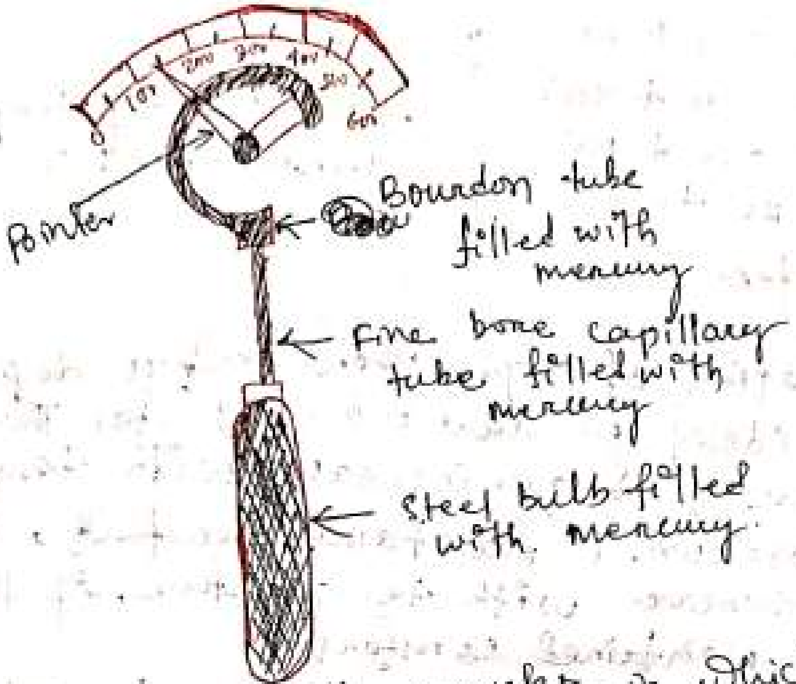
→ Where mercury is used as liquid, it freezes at (-39°C). For measuring very low temperature, alcohol is used as liquid.

→ They are fragile and not easily adapted to automatic recording or transmission of temperature data.

→ The industrial mercury-in-glass thermometer is used in applications such as open tanks containing liquids, cooking kettles, certain molten metal baths, steam lines, pipe lines for fluid flow & air ducts.

(ii) Liquid-in-metal Thermometer

→ The liquid-in-glass thermometers are overcome in liquid-in-metal thermometers. ~~A liquid-in-metal~~.



→ A liquid-in-metal thermometer in which mercury has been used as liquid and the metal is steel. This mercury-in-steel thermometer works on exactly the same principle as the liquid-in-glass thermometer.

→ The glass bulb is replaced by a steel bulb & the glass capillary tube by one of stainless steel. Mercury ~~is used as liquid in~~ is used as liquid in the system. As mercury in the system is not visible, a Bourdon tube is used to measure the change in it's volume.

→ The Bourdon tube, the bulb and the capillary tube are completely filled with mercury, usually at a higher pressure.

→ When the temperature to be measured rises, the mercury in the bulb expands more than the bulb so that some mercury is driven through the capillary tube into the Burdon tube.

→ As the temperature continues to rise, increasing amounts of mercury will be driven in to the Bourdon tube, causing it to bend.

→ One end of the Bourdon tube is fixed, while the motion of the other end is communicated to the pointer which moves on a calibrated temperature scale.

* Mercury → −39 to 650°c
  Xylene → −40 to 400°c
  Alcohol → −46 to 150°c
  Ether → 20° to 90°

} liquid use for temp measurement.

(iii) Gas thermometers

→ The operation of gas thermometers depend upon the ideal gas law which states that the volume of a gas increases with temperature if the pressure is maintained constant, & the pressure increases with temperature, if the volume is maintained constant.

→ If a certain volume of inert gas is enclosed in a bulb, capillary & Bourdon tube and most of the gas in the bulb, then the pressure indicated by the Burdon tube may be calibrated in terms of the temperature of the bulb.

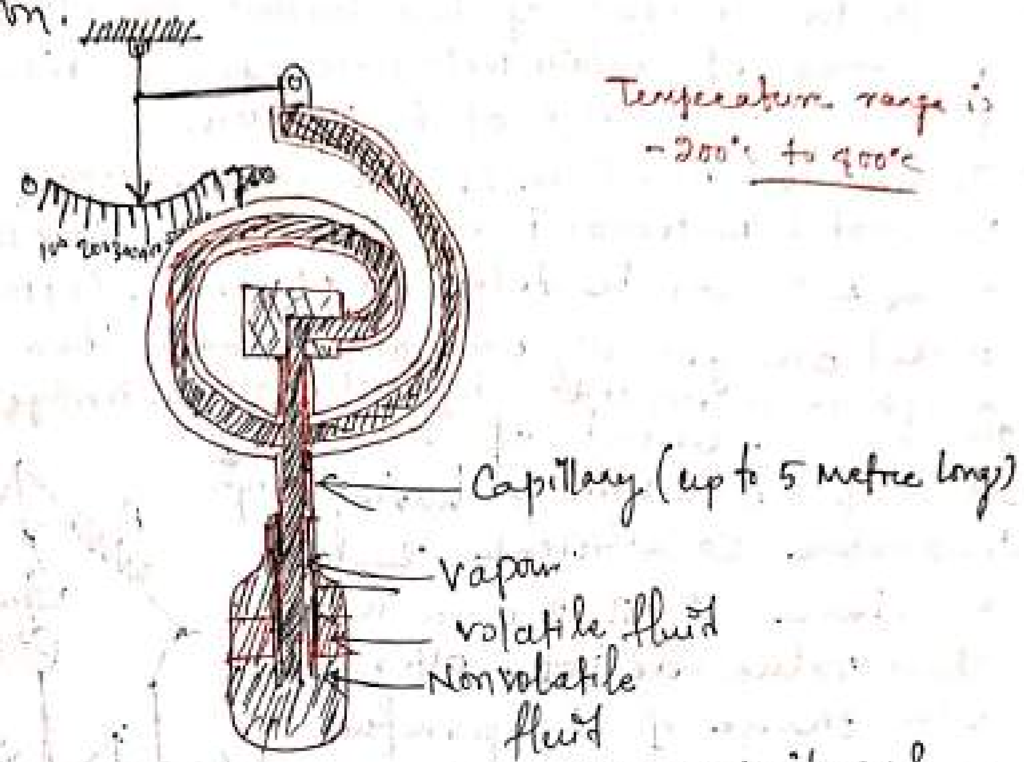
→ Nitrogen is the favorite fill for a gas-filled thermometer because it is almost inert & inexpensive. It does react somewhat with the steel bulb material at temperature exceeding 427°C.

→ Extremely low temperature use gas helium should be used.

(iv) Vapor - pressure thermometers

→ The vapour- pressure thermometer is also a filled system thermometer. In this system the bulb is the partially filled with liquid, while the capillary & Burdon tubes are filled with vapour.

→ In this system some of the liquid vaporizes during operation.



Temperature range is -200°c to 400°c

→ The liquid in a vapour pressure system boils and vaporizes during operation which creates a gas or vaper inside the capillary & Bourdon tube.

→ The liquid inside the bulb continues to boil until the pressure in the system equals the vapour pressure of the boiling liquid. At this point the liquid stops boiling unless its temperature increases.

→ when the temperature of the substance surrounding the bulb drops, the liquid and vapour inside the bulb also cool. This causes some of the vapour to condense.

→ The vapour condense, the pressure inside the system decrease. this action continues until the pressure drops to the vaper pressure of the boiling liquid.

→ Due to this change in pressure, the Bourdon tube uncoils as pressure increases and coils tightly as it decreases. This movement of Bourdon tube may be connected to a pointer or to a pen in a strip chart recorder to indicate temp.

(1.3) Explain measurement of temperature by electrical methods of measurement.

A. Resistance thermometer / Resistance temperature Detector (RTD):

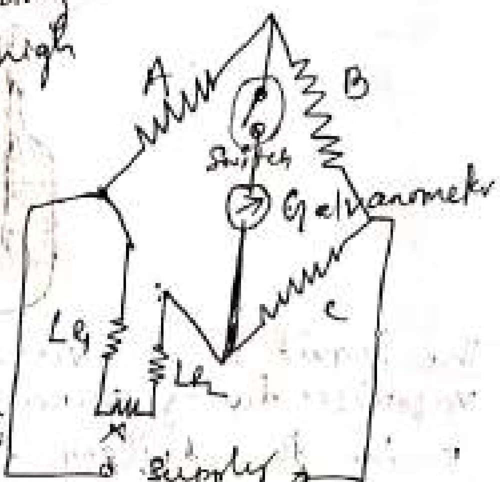
→ The resistance of certain metals changes with temperature change. Resistance thermometer utilizes this characteristics.

→ With the increase of temperature the electrical resistance of certain metals increases in direct proportion to the rise of temperature.

→ The electrical resistance of a wire of known and calibrated material is measured, the temperature of the wire can be determined. Platinum, copper & nickel are generally used in resistance thermometers.

* Change in resistance by null balance bridge method.

→ The bridge consists of a sensing element resistance X having high temperature co-efficient & Resistance A, B & C whose ohmic values do not alter with change of temperature.



→ LR_1 & LR_2 are the lead wire resistance of the sensing element.

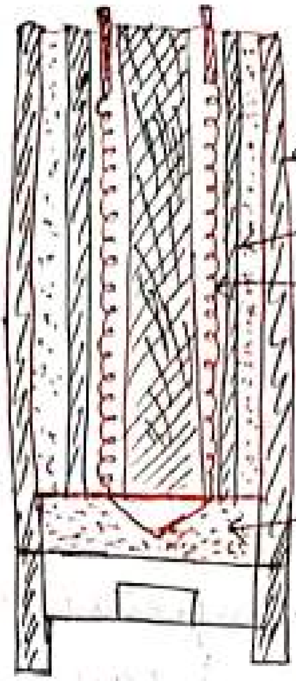
→ The principle of wheat stone bridge states that in balanced condition (when no current flows through galvanometer):

$$\frac{A}{B} = \frac{(X + LR_1 + LR_2)}{C}$$

→ Now when resistance X changes the wheat-stone bridge becomes unbalanced & thus galvanometer will give deflection which can be calibrate to give the suitable temperature scale.

→ Resistance wire are generally long spring like enclosed in a metal sheath.

→ $R_T = R_0(1 + \alpha \Delta T)$ R_0 = Resistance at temperature (0°C)
ΔT = Change in tempr
R_T = Resistance at tempr (T°C)



→ The resistance element is surrounded by a porcelain insulator which prevents short circuit betn wire & the metal sheath.

→ Two leads are attached to each side of the platinum wire when this instrument is placed in a liquid or a gas medium whose temperature is to be measured, the sheath quickly reaches the temperature of the medium.

→ This change in temperature causes the platinum wire inside the sheath to heat or cool, resulting in a proportional change in the wire's resistance.

→ platinum is also available as a deposited film sensor and nickel and Balco are available in foil type sensor.

Advantages

→ They possess high accuracy of measurement.
→ They have a wide temperature range from -200 to 650°c.
→ They are small in size.
→ They are fast in response.
→ They have good reproducibility.
→ They have shown accurate performance.
→ Temperature compensation not required.

Disadvantages

→ Their cost is high
→ They need a bridge circuit, power supply.
→ They produce mechanical abuse of vibration
→ They have larger bulb size than thermocouples.

(iii) Compensation of Lead resistance by 3-wire & 4-wire method.

→ As RTD is a resistor, the ohm meter or the resistance measuring devices are connected parallel to the lead wires of the RTD.

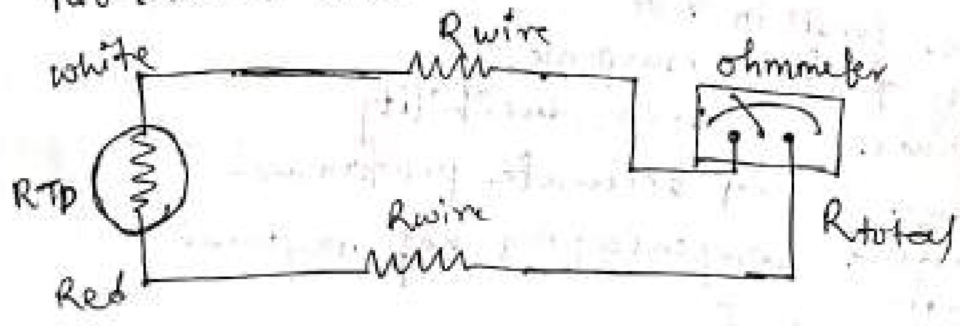
→ The lead wire resistance adds to the RTD resistance as the wires got resistance and this combined resistance will be shown as the RTD resistance incorrectly. So that lead compensation techniques are used in RTD connections.

→ it is compulsory to use compensation technique in the industrial sector, because of the wide range of temperature measurement is needed.

→ The non linearity of RTD becomes a significant problem as range got wider, so we must a way to use low-resistance RTDs & deal with the (lesser) problem of wire resistance.

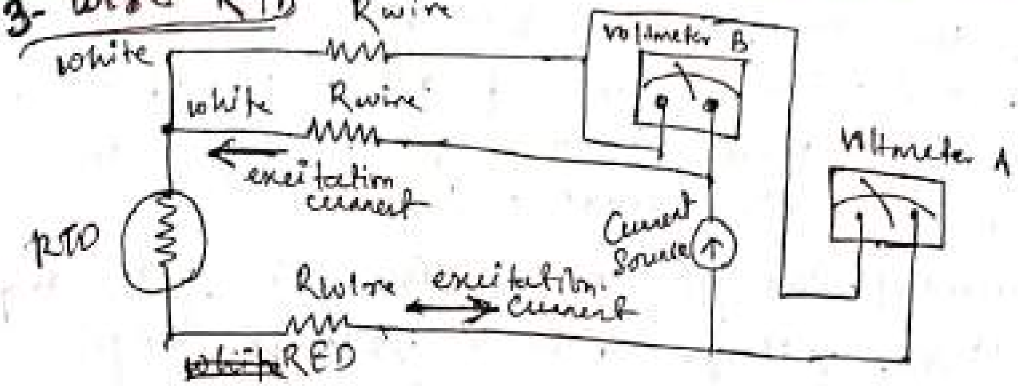
* There are three connection circuits for RTD wire circuit.
  * Two-wire circuit
  * Three-wire circuit
  * four-wire circuit

→ Two-wire circuit



A two-wire RTD connection which shows the wire resistance as R wire. The resistance of the lead wire will be added to the total resistance R total.

3- wire RTD



→ A voltmeter A measures the voltage dropped across the RTD plus the voltage dropped across the bottom current - carrying wire.

→ voltmeter B measures just the voltage dropped across the top current - carrying wire. The both current-carrying wire should have the same resistance so that substracting the voltage across A from the voltage across voltmeter B give the

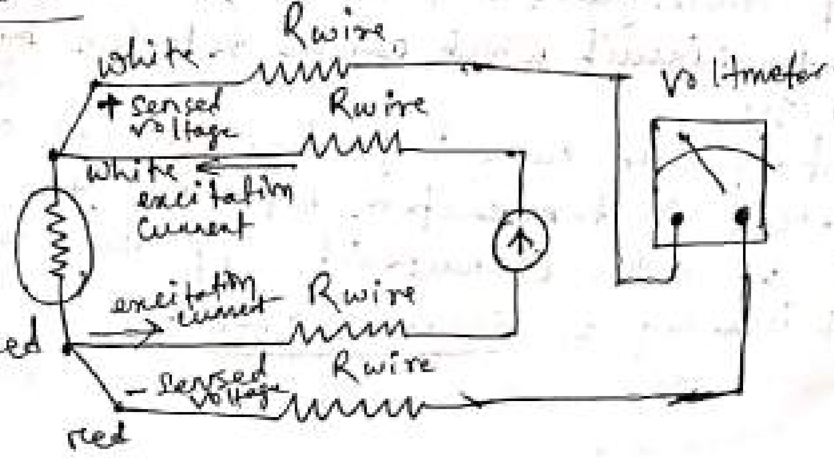
$V_{RTD} = V_{meter}(A) - V_{meter}(B)$

If the resistance of the two current carrying wires is precisely same then the calculated voltage will be same as the actual RTD voltage.

Disadvantages of three-wire RTD:

* Susceptibility to self heating error
* Susceptibility to signal noise.
* Need for lead resistance compensation.
* Need for power supply.

4-wire RTD



→ Here in the four wire RTD circuit, the current and voltage circuit are separated current is supplied to through a separate circuit from the current source.

→ This current carrying excitation wire will drop ~~drop~~ some voltage. Which voltage drop will not read in the voltmeter.

→ The two sense wire connects betn voltmeter & the RTD, it posses resistance & drops voltage in the sensing wire.

→ Only a little current is drawn through the sensing wire which makes the voltage drop ~~as~~ negligible.

→ The resistance of the current carrying wires are of no effect because the voltmeter never senses their voltage drops, and the resistance of the voltmeter's sensing wires are of no effect because they carry practically zero current.

B. <u>Thermocouple :</u>

→ The working principle of a thermocouple depends on the thermo-electric effect. If two dissimilar metal are joined together so as to form a closed circuit, there will be two junction where they meet each other.

→ If one of these junctions is heated, then a current flows in the circuit which can be detected by a galvanometer.

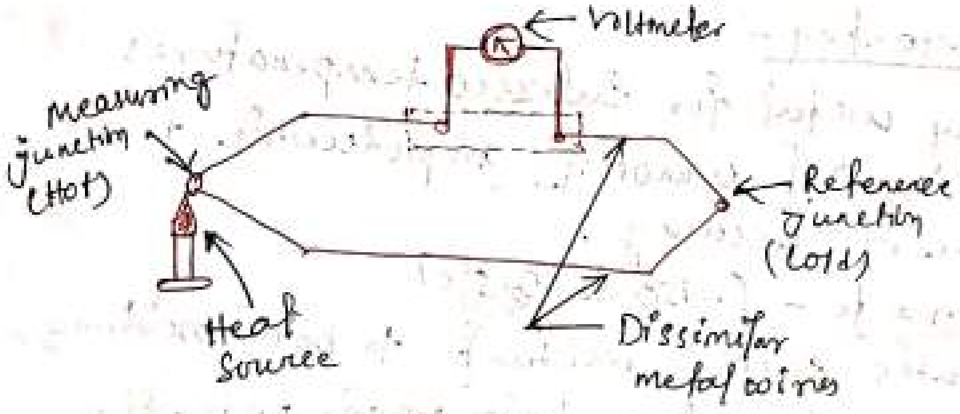
→ The amount of the current produced depends on the difference in temperature betn the two junction & on the characteristics of the two metal. It is known as <u>Seebeck effect</u>.

Peltier effect

* Peltier effect:- this governs the emf resulting soley from contact of two different metals & magnitude varying with temperature of this contact.

Thomson effect

→ This is the emf. resulting from the temperature gradient along the single wire & is less predominant. The materials are so selected that emf due to Thomson effects are negligible & thus the instruments the instruments measures the peltier emf only & in this case of the temperature of one junction kept is kept constant or it's emf generation is compensated for the effective emf.



→ The thermocouple made from two different kinds of metals. The wire are joined at the ends which from two junctions, as measuring junction and a reference junction.

→ Heating the measuring junction produces a voltage greater than the voltages across the reference junction. the difference betn two voltages is measured and voltmeter reading is converted to it's corresponding temperatures.

→ materials are copper - constantan, iron - constantan, chromel - alumel, platinum rhodium & chromel - constantan.

(ii) Thermocouple materials

→ Two metal conductor combination for thermocouples should possess the following

i) Resonably linear tempr emf relationship
ii) Sufficient thermo e.m.f per degree of temperature change to facilitate detection & measurement

(iii) Should be physically able to withstand sustained high temperatures, rapid temperature change & the effects of corrosive atmosphere.

iv) The thermocouple should follow when temperature rise or falls.

→ Thermocouple lead wire sizes vary from gauge 14 to 28. In many instances the size is determined by the strength required to withstand the tension force of pulling wire through the protecting conduit.

→ when thermocouple is used in conjunction with millivoltmeter read out devices.

a) Copper - constantan -

→ it is very useful for subzero temperatures stands well against corrosion, reproducible to a high degree of accuracy.

→ Preferable range - (-150 to 315°C).

→ it is stable couple resistant to both oxidising and reducing atmosphere but needs protection from acidic vapour.

b) Iron - constantan

→ it is useful in low oxygen atmospheres, used for temperatures above 540°C.

→ Oxidation is appreciable and higher size of wire is suggested. if enamelled iron wire is used the couples are stable in emf.

→ Iron wire undergoes crystalline change if kept at high temperature for long time.

c) Chromel Alumel

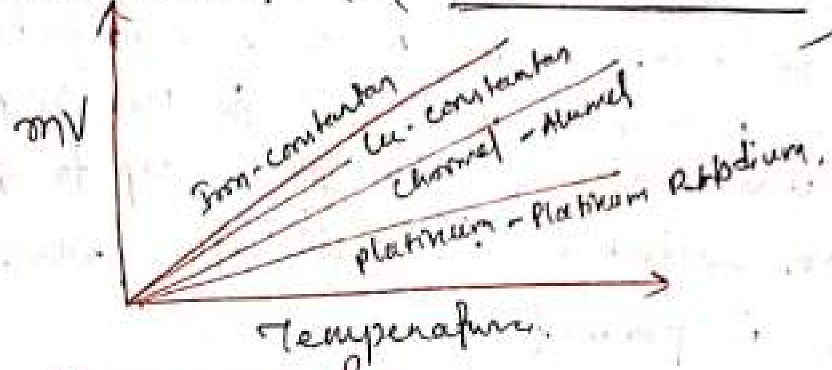
→ Suitable in oxiding atmosphere, more service life than iron constantan at higher temperature

→ Susceptible to inaccuracies in atmosphere free from free oxygen. Suitable upto 1150°C.

→ Both wires are prone to damage by sulphurous gases.

(d) Platinum-Rodium platinum →
Suitable for higher temperature range, affected by reducing gases and shall be protected with Sillimanite tubes when use above 548°C.

* Tungsten - rhenium → (−185° to 2100°C)



* Types of thermocouple

i) Iron-constantan (J-type)

→ The iron-constantan "J" curve thermocouple with a positive iron wire and a negative constantan wire is recommended for reducing atmospheres.

→ The operating range for this alloy combination is 870°C for the largest wire sizes.

→ J (Iron-constantan) (+) white & Red (−)

(ii) Chromel-constantan (E)

→ The chromel constantan thermocouple may be used for the temperatures up to 870°C in a vacuum or inert, mildly oxidizing or reducing atmosphere.

→ As ~~and~~ Sub-zero temperatures, the thermocouple is not subject to corrosion. This thermocouple has the highest emf output of any standard metalic thermocouple.

→ E (chromel-constantan) (+) purple & (−) Red.

→ tempr range : −252 to 870°C.

(iii) Chromel-Alumel (K)

→ The chromel-Alumel (K) curve thermocouple with a positive chromel wire and a negative alumel wire is recommended for use in clean oxidizing atmosphere.

→ The operating range for this alloy is 1260°C.

(→) K chromel – constantan
(+) Yellow, (−) Red.
Range (−252 to 1260°C)

iv) Copper – constantan (T-type)

→ The copper–constantan 'T' wire thermocouple with a positive copper wire & a negative constantan wire is recommended for use in mildly oxiding and reducing atmosphere up to 400°C.

→ They are suitable for application where moisture is present.

→ T (Chromel – constantan)
(+) Blue & Red (−)
Range (−350 to 380°C).

v) platinum Rhodium Alloys (S, R & B)

→ Three types of 'noble-metal' thermocouple are in common use they are (a) a positive wire of 90% platinum & 10% rhodium used with a negative wire of pure platinum, (b) a positive wire of 87% platinum & 13% rhodium used with a negative wire of pure platinum &
(c) a positive wire of 70% platinum & 30% rhodium used with a negative wire of 94% platinum & 6% rhodium.

→ They have a high resistance to oxidation & corrosion temperature as high as 1800°C.

(iii) Describe the function of thermocouple extension wires

→ It is extremely uneconomical to extend the thermocouple elements to the instruments specially for noble-metal thermocouples, therefore, lead wires of cheap materials (possessing the similar thermo-electric characteristics as the thermocouple elements must be used.

There are also ~~known~~ known as compensating leads.

→ Extension wires must be placed in conduits and conduit grounded to prevent leakage from power installations or lighting circuits. it is very important that +ve extension wire be connected to the +ve thermocouple wire and -ve to the -ve and not vice-versa.

→ The wire must be kept at least a 0.3 metre away from any a.c line, otherwise induced alternating current may affect the pyrometer reading.

Thermocouple	Extension wires	Range
① Platinum Rohdium Platinum	copper, copper Nickel alloy	20-220°c
② Chromel Alumel	Chromel Alumel	-15°-100°c
	copper constantan	20-220°c
③	Iron, copper, Nickel alloy	-15 — 220°c
③ Iron constantan	Iron constantan	-15 — 220°c
④ copper constantan	copper -constant	-15 - 100°c

iv) Describe the methods of measurement of output of thermocouples state the types of thermocouple insulation materials & their function.

→ In order to protect the thermocouple wire against the corrosion & erosion effect of working medium & Strength to withstand high pressures, the thermocouple are entirely covered by a sheath made of a material which can withstand the highest temperature as well as atmosphere to which the thermometer is to be subjected.

→ The Sheath is made up of two portions, ~~remaining of low temperature may be made of iron~~, one of which is in the hot medium (Material for it being as specified below) & other portion remaining of low temperature may be made of iron.

(5) The Sheath is securely attached to it's head which contains the connector for attaching the leads & the thermocouple ends.

~~1 wrough iron~~

metal tube

Sr. No.	material composition	temp. limit °c
1.	wrought iron	700°c
2.	Stainless Steel	1000°c
3.	Nickel	1150°c
4.	Inconel	1260°c

Ceramic protecting tubes

1.	Sillimanic	1650°c
2.	Fused Silica	1300°c
3.	fire brick	1450°c
4.	SiC	1650°c
5.	Silica	1600°c
7.	Mullite	1660°c
8.	Vycor	1000°c

v) Thermocouple Advantage & Disadvantage

Advantage

i) They have rugged construction
ii) They are inexpensive.
iii) They are simpler to use than resistance thermometers.
iv) there is no need of a bridge circuit.
v) They have extremely wide temperature ranges from $-270°$ to $2800°c$.
vi) they have wide variety of designs to both standard & special application,
vii) Their electrical output is adaptable to a variety of readout and/or control devices.
viii) They have high response speed. compared to filled systems thermometers.

ix) they possess good accuracy.
x) calibration checking is easily made
xi) They possess long transmission distance.
xii) They have good reproducibility.

Disadvantages

i) They have limited use in temperature span of less than about 33°c because of the relatively small change in junction voltages with the temperature.
ii) Extension leads must be housed in metal conduit, as low junction voltage can cause the device to pickup stray electrical signals.
iii) they need to hold reference junction temperature constant or compensation for any deviation.
iv) their temperature - voltage relationship is non-linear.
v) they hold chances of stray voltage pickups.
vi) Temperature span are not as narrow as filled system or resistance thermometers.
vii) They require much of an amplifier for many application.
viii) they need expensive accessories for control application.

(VI) Explain the cold junction compensation of thermocouple.

→ for correct temperature indication, refrence junction shall be kept at constant temperature, but in practice it is seldom possible to maintain a constant temperature.
→ one method is to use a temperature - sensitive compensating resistor in the measurement circuit. This resistor is located close to the reference junction, so that both are equally affected by changes in ambient temperature.
→ when emf output of the thermocouple drops, because of rise of reference junction temperature, the resistance of the compensating resistance rises.
→ The circuit is arranged such that the increase value of the resistor compensates for decreased thermocouple output

C. Thermistor

→ A thermistor is a non-metallic resistor (Semiconductor of ceramic material) having a negative temperature co-efficient of resistance and this co-efficient at room temperature is about ten times higher than that of copper or platinum.

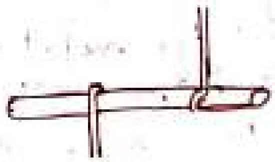
→ These are much more sensitive than conventional elements of metal wire.

→ Thermistors are made by mixtures of metallic oxides such as manganese, nickel, co-balt, copper, iron & uranium.

→ these are suitable for use only up to about 300°c.

Thermistor IC - MCP9700A

Disc type with lead



Rod type.

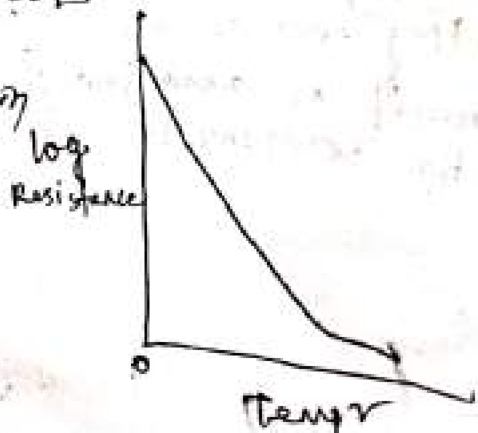
washer type

Bead type.

→ To measure temperature with a thermistor, it is placed in the environment whose temperature is to be measured. As the temperature of the substance or environment increases, the resistance of the thermistor decreases.

Characteristics of thermistors

→ the curve which represents the relationship of resistance - Temperature is usually plotted in terms of the logarithm of resistance & temperature.



(i) Resistance characteristics

$$R = a e^{b/T}$$

where a & b are constants

R = resistance of thermistor at absolute temperature T.

$$\frac{R_0(T_1)}{R_0(T_2)} = e^{\beta\left(\frac{1}{T_1} - \frac{1}{T_2}\right)}$$

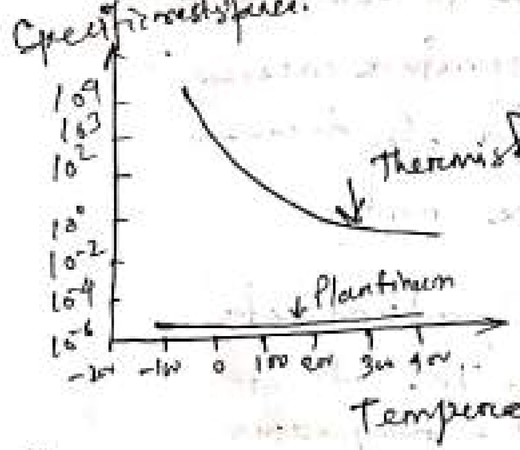
$R_0(T_1)$ & $R_0(T_2)$ = resistance of thermistor in ohms at absolute temperature T_1 & T_2

T_1 & T_2 = absolute temperatures in °K

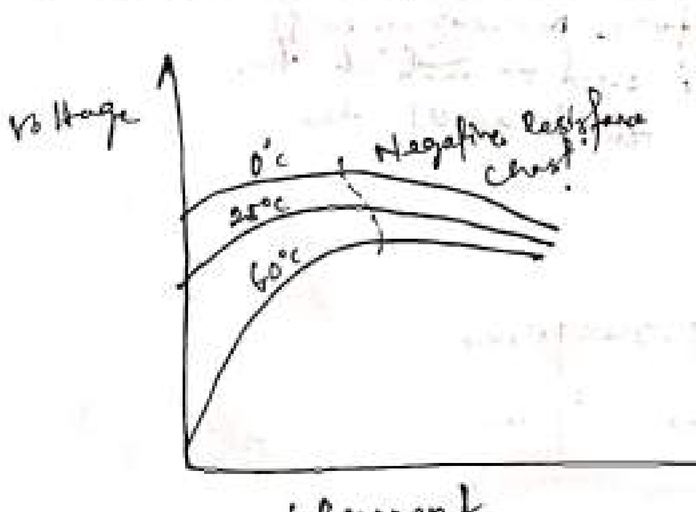
$e = 2.718$

β is constant over small ranges of T and it depends on the material used to make thermistor.

→ electrical power being dissipated within a thermistor will heat it above it's ambient temperature &, thereby reduce it's resistance.



(ii) voltage current characteristics

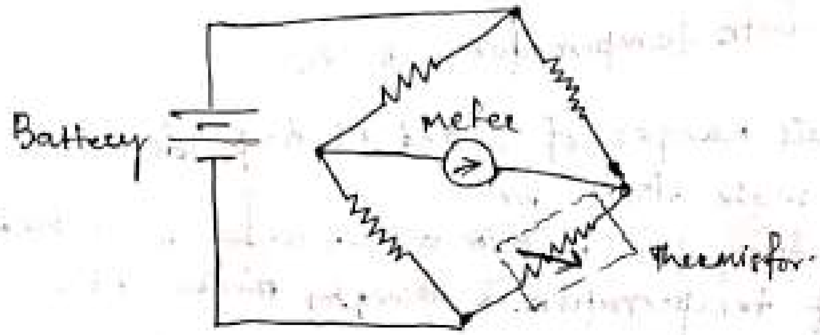


→ The voltage applied to a thermistor is small enough not to cause any rise in heat, it follows ohm's law.

→ if voltage is gradually increased, the current will increase & the heat generated in the thermistor will finally being to raise temperature above that surrounding.

Q. State the methods of temperature measurement by thermistor & their uses

→ There are two main types of thermistor : positive temperature co-efficient (PTC) & negative temperature co-efficient (NTC) & the characteristic of a thermistor is non-linear & cannot be characterized by a single co-efficient



→ At balanced conditions, when there is no change in temperature the galvanometer indicates zero. As the temperature increases or decreases the resistance of the thermistor also decreases or increases due to which the wheatstone bridge circuit becomes unbalanced.

→ The electric current flows through the galvanometer which indicates on the calibrated scale. The deflection of the galvanometer can be calibrated as a temperature scale.

→ for very accurate temperature measurement a differential bridge circuit is used in which two thermistors are connected as two legs of the wheatstone bridge.

Advantages
i) They have small sizes & fast response.
ii) they are suitable for narrow spans.
iii) their cost is low
exhibits a greater sensitivity

Disadvantage

i) Temperature versus resistance curve is very non-linear.
ii) they are unsuitable for wide temperature spans.
iii) Stability is doubtful at higher temperature over 316°c.
iv) they are limited for process applications.

D. Pyrometer

→ All the temperature-measuring methods discussed are physical contact of thermometer with the body whose temperature is to be measured.

→ At high temperature above 1400°c the thermometer may melt due to direct physical contact.

→ Pyrometer is a technique for measuring temperature without physical contact. it depends upon the relationship betn the temperature of a hot body & the electromagnetic radiation emitted by the body.

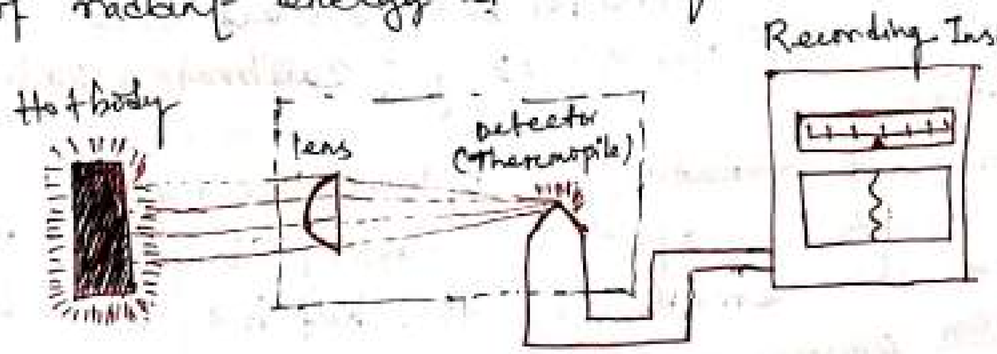
→ A body is heated, it emits thermal energy. known as heat radiations. A black matt surface (or a black body) is a very good absorber of heat radiation & also a very good emitter of such radiation when heated.

There are two types of pyrometer

1. Radiation Pyrometer
2. Optical Pyrometer

Radiation Pyrometer

→ Operation of radiation pyrometer is based upon the measurement of radiant energy emitted by the hot body.



→ The above diagram of a radiation pyrometer, It consists of a lens to focus radiated energy from the body, whose temperature is required on to a detector or receiving element.

→ this element receiving element may have a variety of forms such as resistance thermometer, or a thermocouple or thermopile.

→ A thermopile consist of several thermocouples connected in series. A temperature indicator, recorder or controller is attached with the receiving element to indicate the temperature.

→ When the total energy radiated by a hot body whose temperature is to be measured, enters the pyrometer, it is focussed by the lens on to the detector.

→ The detector is a thermopile whose measuring junction are attached to a blackened disk. the disk absorbs energy when the pyrometer is focussed on a hot body and it's temperature rise.

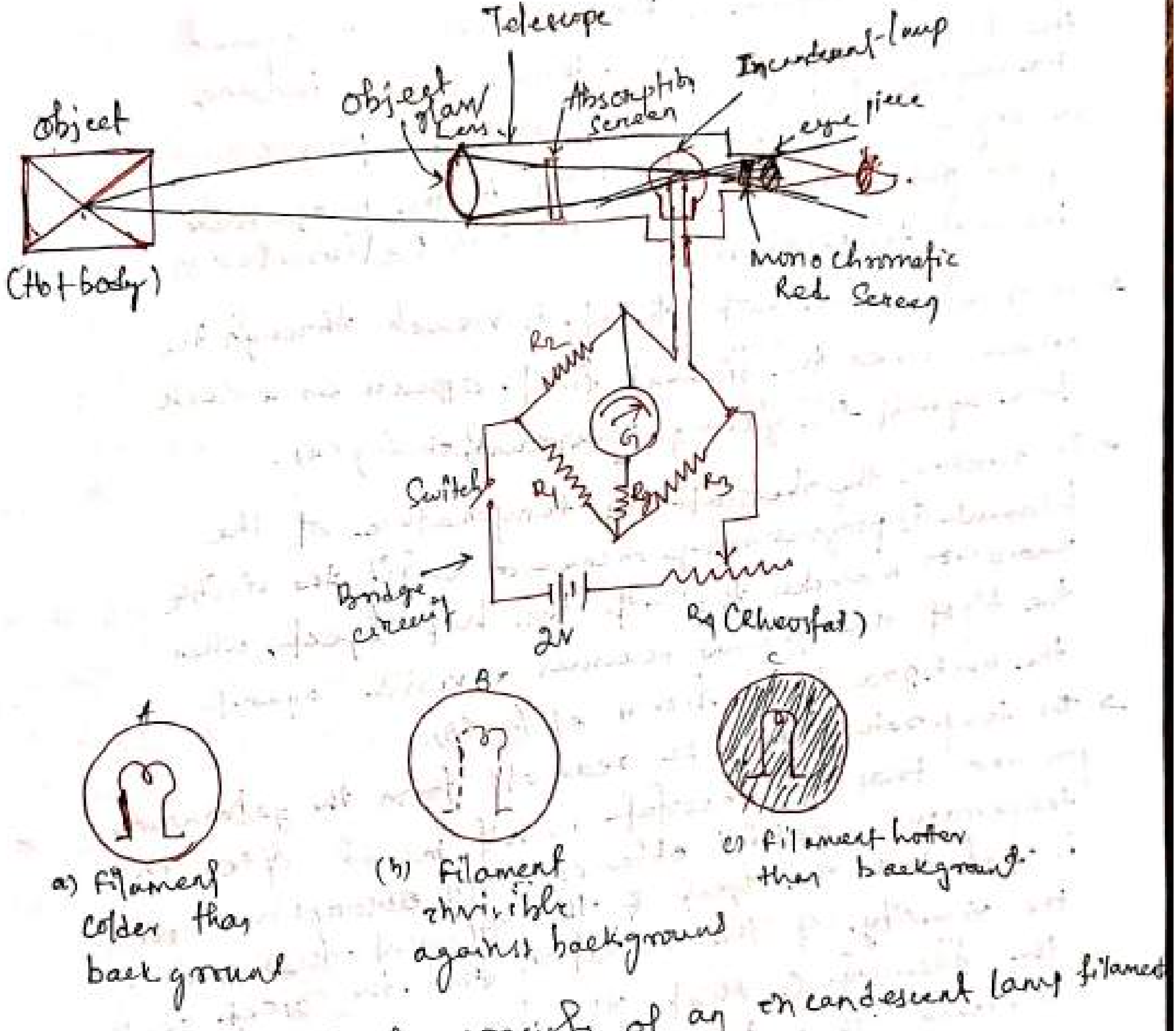
→ the reference junction of the ~~thermopile~~ thermopile is attached to the pyrometer case. The difference in temperature betn the measuring junction attached to the disk & the reference junction attached to the case generates a voltage that is directly related to the temperature of the blackened disk.

Optical Pyrometer

→ optical Pyrometer provide an accurate method of measuring temperatures betn 600 and 3000°c & are very useful for checking & calibrating radiation Pyrometer.

→ the method of operation of optical pyrometer is based on the comparison of the intensity (brightness) of the visual radiation emitted by the hot body with the radiation emitted by the ~~hot body~~ source of known intensity.

→ the brightness (or intensity) of radiation emitted by the hot body whose temperature is to be measured is matched with the brightness of a calibrated reference (lamp) whose temperature is known. for the temperature range from 700 to 3000°C.



→ An optical pyrometer consists of an incandescent lamp filament which is used as the reference source of radiation. this is arranged in the field of vision of a telescope through which both it (the filament) & the hot body are viewed simultaneously.

→ the filament is heated by a 2 volt battery in series with a rheostat by which the temperature of the filament is adjusted. this filament is connected in one arm of a wheat-stone bridge

Circuit across which is connected a moving coil galvanometer.

→ the electrical resistance of the lamp filament varies in accordance with it's temperature, while the resistance in other arms of the bridge are of a material, the ohmic value of which doesn't alter with change of temperature.

→ As the temperature of the filament is increased the bridge is progressively thrown out of balance. ~~The degree of is increased the bridge is progressively~~ the degree of unbalance is shown by the magnitude of the galvanometer deflection which calibrated in terms of temperature.

→ In operation, the hot object is viewed through the telescope when the filament first appears as a dark line against the glowing background, in fig (a).

→ On rotating the rheostat the temperature of the filament is progressively increased until the visible radiation matches that of the hot object, when the tip of the filament becomes invisible against the background. as shown at fig (3).

→ the temperature may be read off from the galvanometer provided that the rheostat is not moved after the temperature match is obtained. → An absorption screen is used both the object & the filament that reduces the intensity of the radiation from the object readings the filament so that the filament may be matched to a hot mass which is considerably higher temperature.

→ A monochromatic red screen is fitted to the eye piece so that it may be brought in to the field of vision at will.

E. Describe the function & use of temperature switch

→ Temperature switches are the mechanisms used to measure temperature. the working of a temperature switch is based upon the temperature variation taking place in an enclosed space, or in an open area adjoining the temperature switch. & a pressure switch is almost same since both the devices get triggered by the variation in pressure.

→ In many of the temperature switch designs, the temperature sensing element is positioned in such a way that the rise or drop in temperature results in the increase and decrease of internal pressure of liquid or gas such as in liquid filled temperature switches.

→ this variation in pressure can then be used to actuate a switching mechanism.

→ Use of temperature switch

→ oil exploration.
→ Radiator overheating.
→ Battery chargers
→ Hot Air Ballons

Question

1. what is the principle of thermometer? which liquid is commonly used in the thermometer? what advantages does liquid has over other thermometer liquids?
2. what is a thermocouple? Name any two types of thermocouple
3. Describe with the help of a diagram, the construction & working of a thermocouple type of pyrometer?

CHAPTER-2

MEASUREMENT OF PRESSURE :-

2.1 Classify methods of pressure measurement

Pressure

→ Pressure is defind as the amount of force applied to a surface or distributed over it & is measured as force per unit of area.

→ The force used to calculate the pressure must act at a right angle to the surface.

→ If force acts at a slant, then only that part of it which acts at right angles is used to calculate the pressure.

→ The part of the force which acts parallel to the surface doesnot contribute to pressure.

Unit of pressure

→ pressure expressed in terms of pounds per square inch (psi).

→ the atmospheric pressure is approximately 14.696 psi (or 1 Kg/cm²)

a) High pressure

1 newton per square metre (1 N/m²) = one pascal (1 Pa)

1 atmospheric pressure (1 atm) = 14.696 psi = 101.325 k Pa.

b) low pressure

1 milibar = 100 dyne/cm² = 14.5×10^{-3} psi

1 micron = 10^{-6} mHg = 19.34×10^{-6} psi

1 torr = 1 mmHg = 1000 microns = 19.34×10^{-3} psi

Different types of pressure

a) Gauge pressure :- most liquid pressure gauge use atmospheric pressure (14.7 psi) as a zero point. i.e they indicate a pressure of zero psi at the surface of a liquid even though the pressure is actually 14.7 psi.

→ A gauge that indicates zero at atmospheric pressure measures the difference betn actual & atmospheric pressure. This difference is called gauge pressure.

b) Absolute pressure

→ Absolute pressure is actual total pressure (including atmospheric pressure) acting on a surface. It is act as psia.

c) Vaccum or Differential pressure

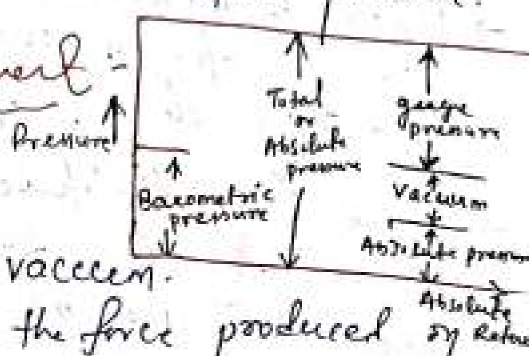
→ Gauges that indicate gauge pressure may be designed to indicate pressure below zero. Such a gauge is called a vaccume gauge. Gauges that indicates absolute pressure canot indicate pressure below zero. because zero is a perfect vaccum.

d) Static pressure and velocity pressure

when the fluid is in equilibrium, the pressure at the particular point is identical in all direction and independents of orientation. This called static pressure.

velocity pressure = Total pressure − static pressure.

★ Methods of pressure measurement :-



i) Manometer method.
ii) Elastic pressure transducer
iii) pressure measurement by measuring vaccum.
iv) pressure measurement by balancing the force produced by a known area by a measured force.
v) Electrical pressure transducer

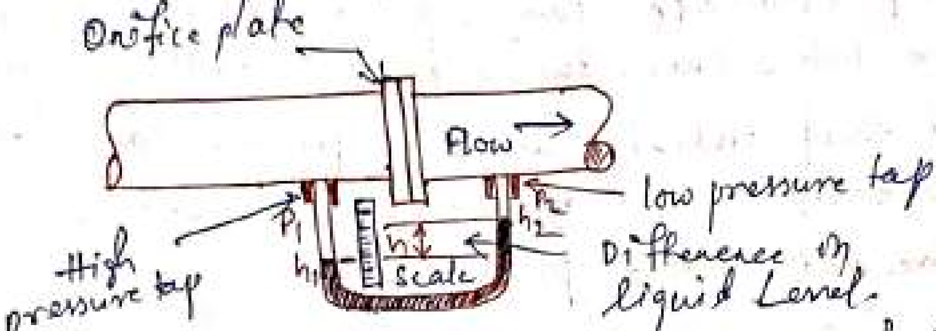
2.2 Explain the working principle & use of mechanical methods of measurement by :-

i) Manometer

→ The manometer is the simplest measuring instrument used for gauge pressure (low-range pressure) measurements, by balancing the pressure against the weight of a column of liquid. The action of all manometers depends on the effect of pressure exerted by a fluid at a depth.

a) U-Tube Manometer

→ The U-tube is the simplest form of the manometer and is used for experimental work in laboratories. By suitable choice of liquids a wide range of pressure can be recorded.



→ Construction:- It consists of a transparent (glass) tube constructed in the form of an elongated U and is partially filled with a liquid; most commonly water or mercury.

→ water & mercury are used because their specific weights for various temperatures are known exactly and they do not stick to the tube.

→ One end of the tube is connected to one pressure tap and the other end is connected to the other pressure tap, or it may be left open to the atmosphere.

→ Working:-

when there is a pressure difference betn the two ends of the tube, the liquid level goes down on one side of the tube & up on the other side. the difference in liquid levels from one side to the other indicates the difference in pressure.

Scanned with CamScanner

$$(P_1 - P_2) = (\rho - \rho_1)(h_1 - h_2) g$$

$$\boxed{P = (\rho - \rho_1) g h}$$

ρ = density of fluid in U-tube

ρ_1 = Density of fluid whose pressure is being measured.

h = $(h_1 - h_2)$, difference in fluid levels

g = acceleration due to gravity.

→ When a manometer is used to measure low pressure then water is used as the liquid & when it is used to measure high pressure then mercury is used as the liquid.

→ Mercury is almost 14 times a heavy as water. Therefore the difference in levels in a mercury-filled manometer is about 1/14 of what it would be if water were in the tube.

Limitation

In the U-tube manometer, the application of pressure causes the liquid in one leg to go down while that in the other leg goes up, so there is no fixed reference.

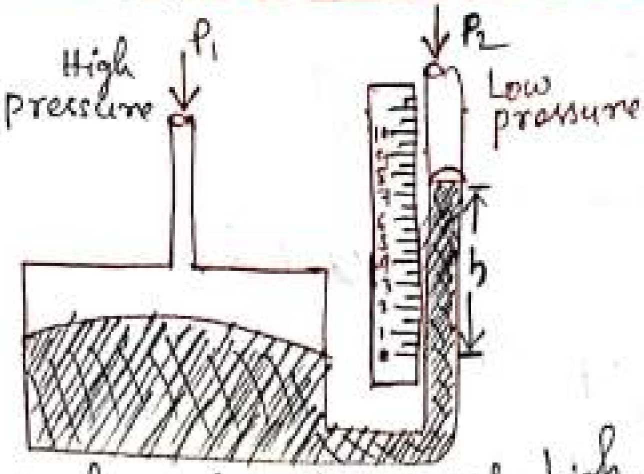
Seen
dy
Mmotiv

b) Well-type manometer :-

* The well-type manometer is widely used because of convenience the reading of only a single is required in it. It is consist of a very large-diameter vessel (well) connected on one side to a very small sized tube.

* Thus the zero level moves very little when pressure is applied. Even this small error is compensated by suitable distorting the length of scale.

→ This arrangement is sensitive to non-uniformly of the tube cross-sectional area and is thus considered some what less accurate.

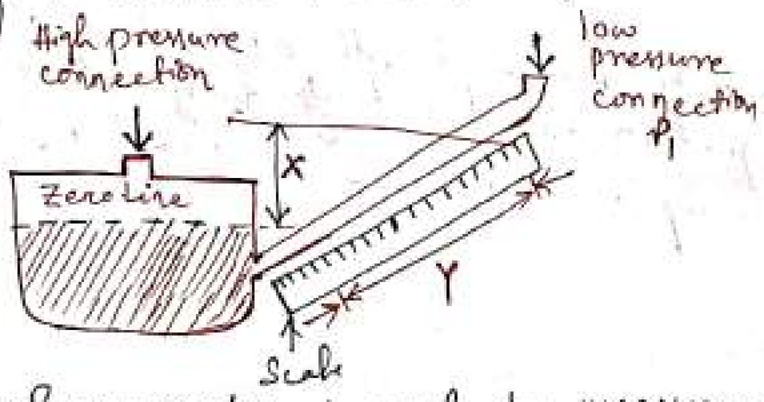


→ In a single-leg instrument, high accuracy is achieved by setting the zero level of the well at the zero level of the scale before each reading is taken.

c) Inclined Manometer

→ The inclined tube manometer or slant manometer is an enlarged leg manometer with it's measuring leg inclined to the vertical axis by some angle.

→ The angle of inclination is of the order of 10°. The inclination is done to expand the scale and there by to increase the sensitivity.



→ The inclined manometer is used to measure very small pressure difference (in hundredth of an inch of water). The manometer is tipped so that the liquid moves a larger distance through the tube as it rises.

→ The distance y that the liquid moves through the tube is greater than the distance x that the liquid rises.

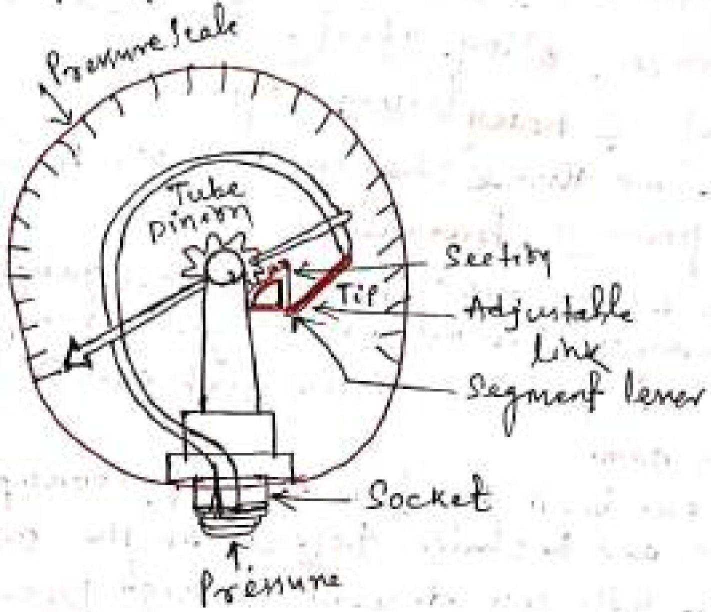
(ii) Elastic pressure Transducer

a) The C-type Bourdon Tube pressure Gauge

→ The bourdon tube is the most ~~frequently~~ frequently used pressure gauge because of it's simplicity and rugged construction. it covers range from 0-15 psig to 0-100,00 psig, as well as vacua from 0 to 30 inches of mercury.

Construction and working:

→ A C-type Bourdon tube consists of a long thin-walled cylinder of non-circular cross-section, sealed at one end, made from materials such as phosphor bronze, steel and beryllium copper, and attached by a light line work to the mechanism which operates the pointer.



→ The other end of the tube is fixed and is open for the application of the pressure which is to be measured. the tube is soldered or welded to a socket at the base through which pressure connection is made.

→ As the fluid under pressure enters the Bourdon tube, it's tries to change the section of the tube from oval to circular and this tends to straighten out the tube.

→ The resulting movement of the free end of the tube causes the pointer to move over the scale. The tip of the bourdon tube is connected to a segmental lever through an adjustable length link.

Scanned with CamScanner

→ The lever length also may be adjustable. The segmental lever end on the segment side is provided with a rack which meshes to a suitable pinion mounted on a spindle.

→ The segmental lever is suitably pivoted and the spindle holds the pointer. A hair spring is sometimes used to fasten the spindle to the frame of the instrument to provide the necessary tension for proper meshing of the gear teeth, there by freeing the system from backlash.

→ Bourdon tubes are made of a number of materials depending upon the fluid & pressure such as phosphor bronze, alloy steel, stainless steel, monel metal & beryllium copper.

→ also we made in three shapes C-type, Helical & Spiral

(b) Diaphragm pressure Transducer

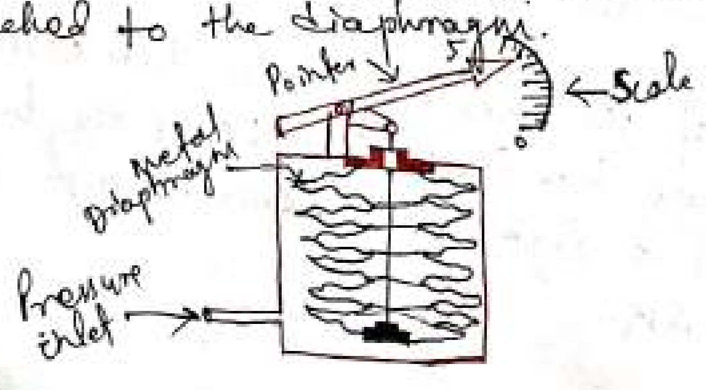
→ Diaphragm are widely used for pressure (gauge pressure) and draft measuring; particularly in very low ranges. They can detect a pressure differential even in the charge of 0 to 4am.

→ The diaphragms can be in the form of flat, corrugated or dished plates and the choice depends on the strength and amount of deflection desired. In high precision instruments the diaphragms are generally used in a pair, back - to - back to form an elastic capsule.

→ Diaphragm elements can be made to cause change in electrical circuits then converting pressure movements to electrical signals.

1) Metallic Diaphragm Gauge:-

→ It consists of a thin flexible diaphragm made of the materials such as brass or bronze. A pointer is attached to the diaphragm.

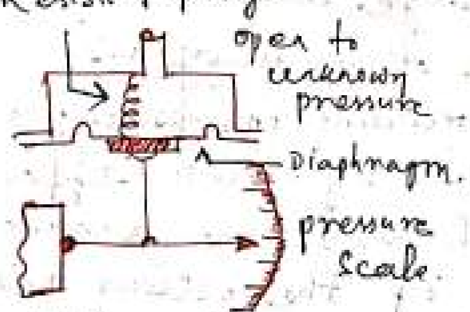


→ The force of pressure against the effective area of the diaphragm causes a deflection of the diaphragm. In some case the diaphragm of the diaphragm is opposed by the spring qualities of the diaphragm itself and in other cases a spring is added to the limit the deflection.

→ The motion of the diaphragm operates an indicating or a recording type of instrument. it is used for installation in moving equipments such as aircrafts.

(2) Slack Diaphragm Gauge :-

→ it is more difficult to measure pressure below the atmospheric pressure because the changes are small. the full range from the atmospheric pressure to a perfect vacuum is only 14.7 psi(kg/cm2)



→ pressure in this range can be measured with a slight modification of the diaphragm. A diaphragm with a large area produces a large change in force from a small change in pressure.

→ Making the diaphragm slack rather than tight allows it to move a large distance in response to a small pressure change.

→ A slack diaphragm can be made of rubber or other flexible materials.

Advantage

→ Their cost is moderate.
→ they possess high over-range characteristics.
→ they are adaptable to absolute and differential pressure measurement
→ They have good linearity.
→ They are available in several materials for good corrosion resistance.

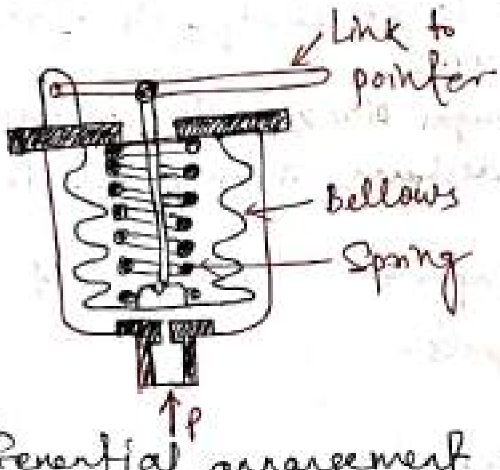
→ They are Small in Size.
→ they are adaptable to Slurry Services.

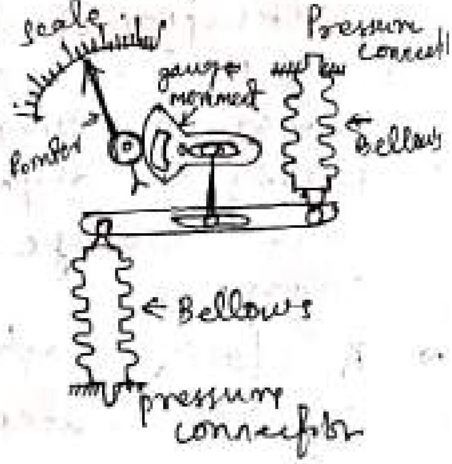
Disadvantages

→ They lack good vibrating & shock resistance
→ they are difficult to repair.
→ They are limited to relatively low pressures.

C. Bellows

→ The bellows-type gauges are used for the measurement of absolute pressure (normal as well as low pressure). It is some what more sensitive than Bourdon-tube gauge.
→ it is generally used for the range down to 155.Hg (3psi) it may be used for even lower pressures up to 40 mm Hg by making the bellows large enough.
→ The bellows are made of an alloy which is ductile, has high strength and retains it's properties over long use i.e has very little hysteresis effect.
→ they are used in two forms. In one arrangement, pressure is applied to one side of the bellows and the resulting deflection is counter-balanced by a spring.





→ In another differential arrangement the differential pressure is also indicated. In this device one pressure is also indicated. In this device, one pressure is applied to the inside of one sealed bellow while the another pressure is applied to the inside of another sealed bellow.

→ Spring - opposed bellow elements are very sensitive & are quite useful in working signalling and tripping devices because of the considerable amount of movement for a given change in pressure.

→ For larger static pressures (up to 2000psig) & large differential pressure upto psi 50 psi).

Advantage

→ its cost is moderate.
→ it is able to deliver high force.
→ it is adaptable for absolute & differential pressure.
→ it is good in the low - to moderate pressure range.

Disadvantage

→ it is unsuitable for high pressures.
→ the availability of metals and work - hardening of some of them is limited.

(iii) Bell type of pressure Gauge

→ In the bell type of pressure gauge, the force produced by the difference of pressure on the inside and outside of a bell is balanced against a weight or against the force produced by the compression of the spring.

* There are two types of bell gauges:

a) Thick wall Bell gauge :-

→ It consists of a bell suspended with the open end downwards in a sealed chamber, usually made of cast iron, containing a liquid such as oil or mercury.

→ The liquid covers the open end of the bell and acts as a seal, forming two chambers. In this type of instrument gravity provides the controlling force.

→ The higher pressure is led in to the inside and the lower pressure acts on the outside of the bell.. the resulting forces causes the bell to rise until equilibrium is reached betn the upward force and the apparent weight of the bell.

Scanned with CamScanner

→ As the bell rises, a small portion of it is immersed in the sealing liquid so that the upward thrust on it due to buoyancy is reduced.

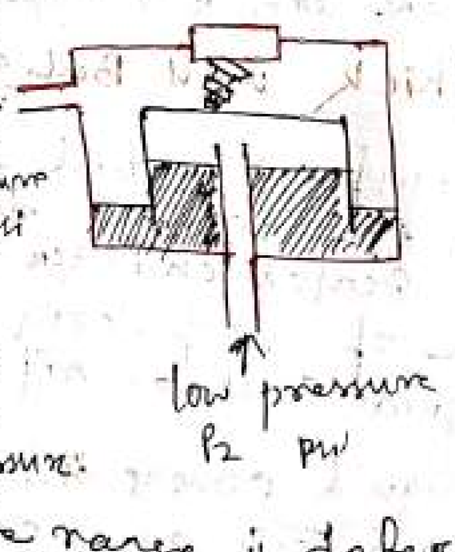
→ its apparent weight will therefore increase. Now, since the pressure within the bell is greater than that outside it will cause the level of the liquid on the outside of the bell to be ~~great~~ greater than the level on the inside, as well as causing the bell to rise.

→ Now, travel of the bell is proportional to the differential pressure to be measured. The thickness and density of the material of which the bell is made its cross-sectional area and the density of the sealing liquid are determined by the range of pressure for which the instrument is meant to be used.

b) Thin wall Bell Gauge

→ In this type of instrument, the bell is made of thin material and the controlling force is obtained by means of a spring.

→ the high pressure is usually applied to the outside of the bell & the low pressure to the inside.



→ The difference betn the force due to the pressure acting on the outside causes the change in length of the spring, which in turn changes the position of the bell. the travel of the bell is proportional to the differential pressure.

→ In this type of instrument the range is determined by the modulus of elasticity of the spring and the density of the sealing liquid

23. Explain the working principles & use of electrical method of measurement of pressure by:-

→ In general a transducer is a device which convert one form of energy into another form of energy. However in the field of electrical instrumentation, a transducer is defined as a device which convert a physical quantity, a physical condition, or mechanical output into an electrical signal.

→ Most of the methods of converting mechanical output into an electrical signal work equally well for the bellows, the diaphragm and the Bourdon tube.

→ Mechanical motion is first converted into a change in electrical resistance & then the change in resistance is converted into a change in electrical current or voltage.

i) pressure sensing element such as a bellow, a diaphragm, or a Bourdon tube.

ii) primary conversion element e.g. resistance or a voltage.

iii) secondary conversion element.

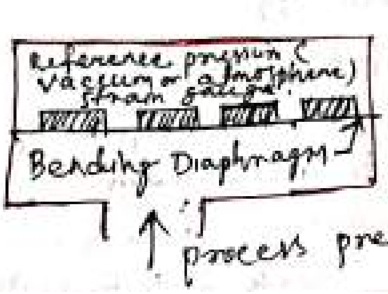
a) Strain gauge pressure transducer

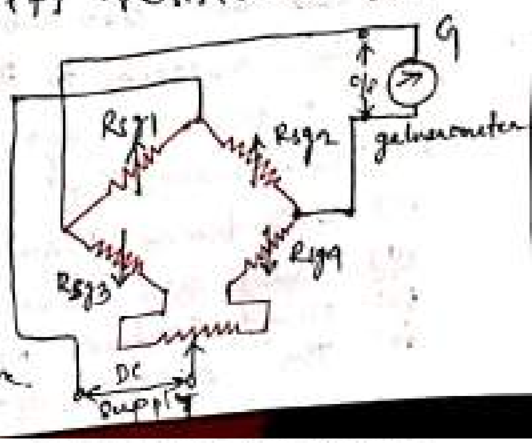
→ Strain gauge is a passive type resistance pressure transducer whose electrical resistance changes when it is stretched or compressed. It can be attached to a pressure sensing diaphragm.

* Basic principle

→ The strain gauge is a fine wire which changes its resistance when mechanically strained, due to physical effects. A strain gauge may be attached to the diaphragm so that when the process pressure applied on it.
diaphragm flexes due to the process pressure applied on it.

→ The strain gauge stretches or compresses. This deformation of the strain gauge causes the variation in its length and cross-sectional area due to which its resistance also changes.





→ The resistance change of a strain gauge is usually converted in to voltage by connecting one, two or four similar gauges as of a wheatstone bridge (known as strain gauge bridge) and applying excitation to the bridge. The bridge output voltage is then a measure of the pressure sensed by the strain gauges.

Construction & working

→ A bridge circuit with four strain gauges R_{sg1}, R_{sg2}, R_{sg3}, R_{sg4}. Two strain gauges R_{sg1} & R_{sg4} are mounted so that increasing pressure increases their resistance.

→ strain gauges R_{sg2} & R_{sg3}, are mounted so that increasing pressure decreases their resistance. A change in temperature affects all the four strain gauges in the same way, resulting in no change in the pressure indication.

→ At balance, when there is no pressure, no current flows through the galvanometer G, and hence there will be no deflection in the galvanometer.

→ the pressure is applied the strain gauge stretches or compresses accordingly and the bridge circuit is unbalanced due to the change in resistance of the strain gauge.

→ A current flows in the galvanometer, which is measured by the deflection of the galvanometer. these changes affect the output of the bridge circuit which indicates a change in measured pressure. this change in output voltage may be calibrated for the pressure change.

Advantages

i) they are small & easy to install.
ii) They have good accuracy.
iii) they are available for wide range of measurements (from vaccum to 200,000 psig)
(iv) they possess good stability.
v) They have high output signal strength.
vi) they have high overrange capacity.
vii) They are simple to maintain.
viii) they contain no moving parts.
ix) They possess good shock & vibration characteristics

x) They are readily adaptable to electronic systems.
xi) They posses fast speed of response.

Disadvantages

i) Their cost is moderate to high (could be offset by reduced installations cost).
ii) Electrical read out is necessary in these transducers.
iii) They require constant voltage supply.

B) Capacitive pressure Transducers

* **Basic principle**

The principle of operation of capacitive pressure transducer is based upon the familiar capacitance equation of the parallel plate capacitor.

$$C = \frac{\epsilon_0 \epsilon_r A}{d}$$

C = the capacitance of a capacitor in farad.
A = area of each plate in m^2.
d = distance betn the two plates in m
$\epsilon_0 = 8.854 \times 10^{-12}$ Farad/m
ϵ_r = dielectric constant (Relative permittivity)

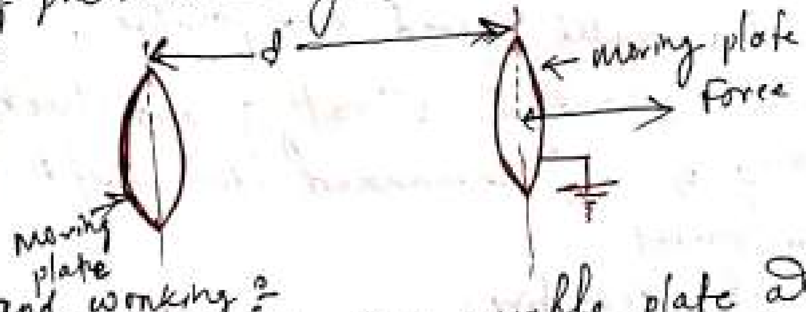
Thus, capacitance of a capacitor varies

i) the area A of the plate is changed.
ii) the distance d betn the two plates is changed
iii) The dielectric constant ϵ_r is changed.

→ The capacitance of a parallel plate capacitor is inversely proportional to the spacing betn the plates. this:

$$C \propto \frac{1}{d}$$

→ This is used in the capacitive pressure transducer for detecting pressure changes.

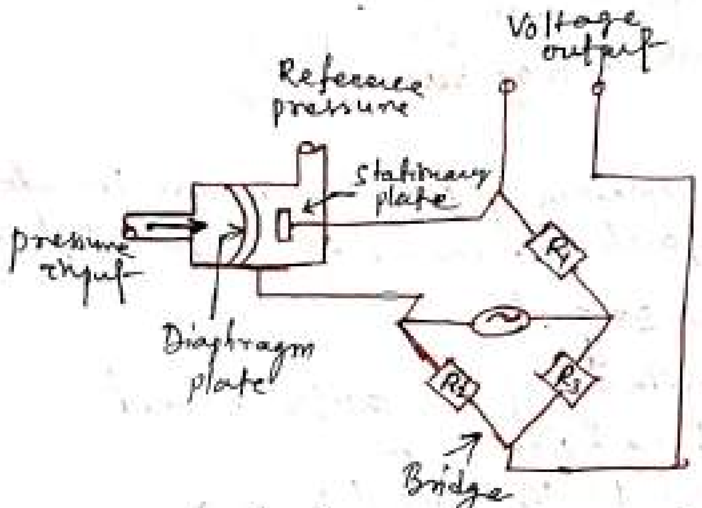


* **construction and working:**

→ It consists of a fixed plate & a movable plate which is free to move as the pressure applied changes. According to the change in pressure the movable plate also changes it's position. due to which the distance d is changed.

→ with an increase in pressure (as $C \propto 1/d$). with an increase in pressure, the distance d becomes less, due to which the capacitance c is increased (as $C \propto 1/d$).

→ with a decrease in pressure, the distance d increases & thus capacitance C is decreased. this change in capacitance can be calibrated to measure the change in pressure.



→ In place of a movable plate a diaphragm may be used which expands and contracts due to change in pressure. The diaphragm plate acts as a movable plate of a capacitor.

→ A fixed plate is placed near the diaphragm. These plates from a parallel plate capacitor which is connected as one of the arms of a bridge.

→ Any change in pressure cause a change in distance betn the diaphragm and fixed plate, which unbalances the bridges. The voltage output of the bridge corresponds to the pressure applied to the diaphragm plate.

Advantages

i) it gives rapid response to change in pressure. Response time as short as ten milli second are possible.

ii) it can withstand a lot of vibration and shock, as in a hard landing by an unmanned Spacecraft on the Surface of a planet.

(iii) It is extremely Sensitive

iv) It has good frequency response

Disadvantages

i) The metallic parts of the capacitor must be insulated from each other.

ii) The performance of a capacitive transducer is severely affected by dirt & other contaminants.

iii) The sensitivity of a capacitance transducer is adversely affected by change in temp.

3c) Reluctance pressure Transducer

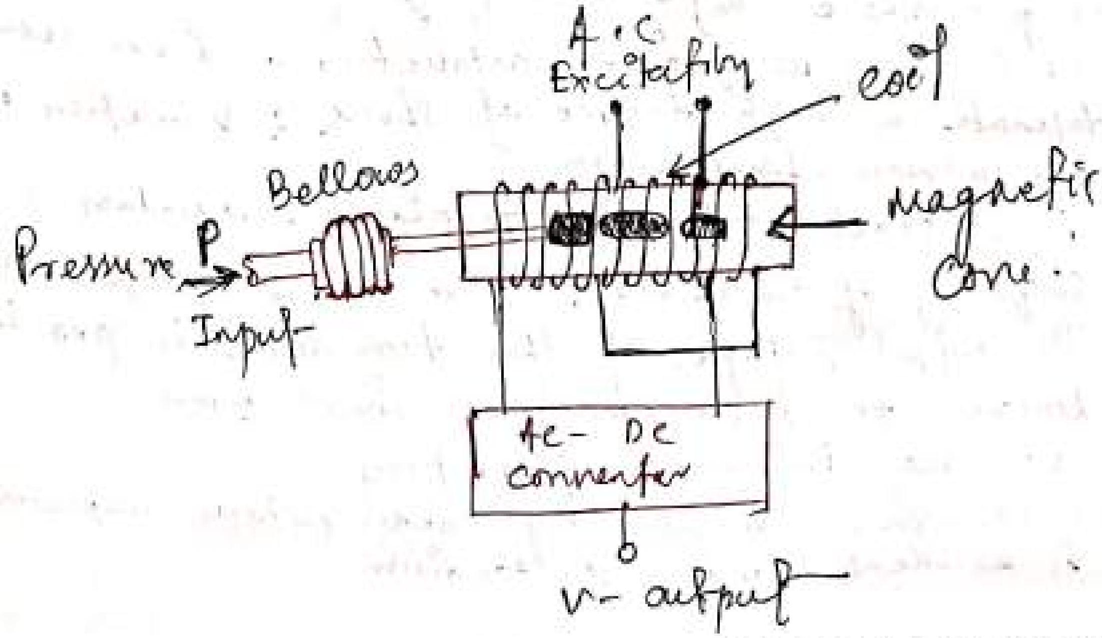
→ Reluctance in a magnetic circuit is equivalent to resistance in an electrical circuit. The spacing (or coupling) betn two magnetic devices (or coils) changes, the reluctance betn them also changes.

→ Thus a pressure sensor can be used to changed the spacing betn two coils by moving one parts of the magnetic circuit.

→ This motion changes the reluctance betn the coils, which in turn changes the voltage induced by one coil in the other. The change in the induced voltage can the be interpreted as a change in pressure.

d) Linear Variable Differential Transformer (LVDT)

→ It is the most widely used inductive transducer to translate linear motion in to an electrical signal.



Construction and working

→ It consists of a primary winding (or coil) and two secondary windings (or coils). The windings are arranged concentrically next to each other.

→ They are wound over a hollow bobbin which is usually of a non-magnetic & insulating material. A ferromagnetic core (armature) is attached to the transducer sensing shaft (such as bellows).

→ The core is ~~generally~~ generally of a high permeability ferromagnetic alloy & has the shape of a rod or cylinder.

→ A.C excitation is applied across the primary and the movable core varies the coupling betn it and the two secondary windings. When the core in the centre position

→ The coupling to one secondary and hence it's output voltage increases while the coupling and the output voltage of the other secondary decreases.

→ Any change in pressure makes the bellows expand or contracts. This motion moves the magnetic core inside the hollow portion of the bobbin. It causes the voltage of one secondary winding to increase, while ~~simultaneously~~ simultaneous reducing the voltage in the other secondary winding.

→ The difference of two voltages appears across the output terminals of the transducer and gives a measure of the physical position of the core and hence the pressure.

Advantage

i) It possesses a high sensitivity.

ii) It is very rugged in construction and can usually tolerate a high degree of shock & vibration without any adverse effects.....

(iii) It is stable and easy to align & maintain due to simplicity of construction, small size & light body.

iv) The output voltage of this transducer is practically linear for displacements of about 5mm.

v) It has infinite resolution.

vi) It shows a low hysteresis, hence repeatability is excellent under all conditions.

Dis advantages

→ Relative large core are required for appreciable amount of differential output.

→ they are sensitive to stray magnetic fields but shielding possible

→ Temperature affects the performance of the transducer

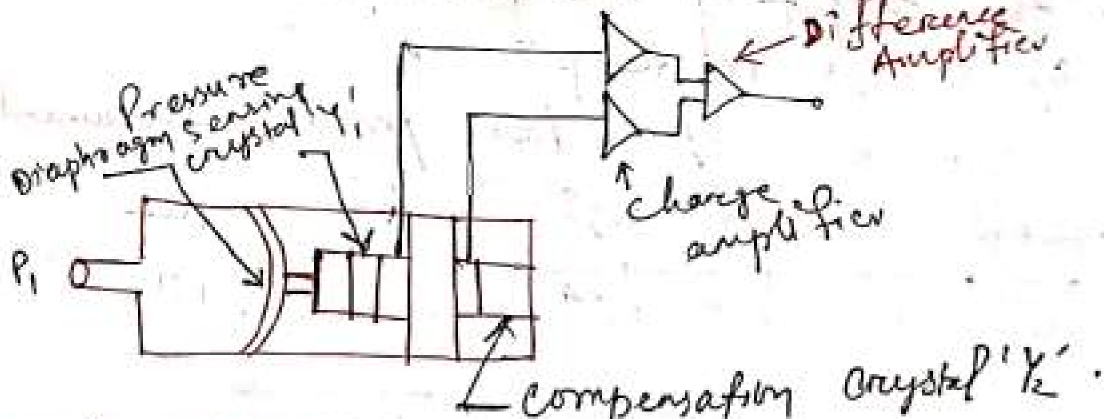
(D) Piezoelectric pressure transducer

→ these devices utilize the piezoelectric characteristics of certain crystalline and ceramic materials (such as quartz) to generate an electrical signal.

Basic principle

→ Such transducer depend upon the principle that when pressure is applied on piezo electric crystals (such as quartz) an electrical charge is generated.

→ there are about 40 crystal-line materials that, when subjected to a squeeze, generate an electrical charge. Some of the piezoelectric materials are barium titanate sintered powder, crystal of quartz, tourmaline, & Rochelle



Construction and working

→ it consists of a diaphragm by which pressure is transmitted to the piezoelectric crystal Y_1. this crystal generates an electrical signal which is amplified by a charge amplifier.

→ A second piezoelectric crystal Y_2 is included to compensate for any acceleration of the device during use. This compensation is needed because rapid acceleration of the transducer creates additional pressure on the piezoelectric crystal. Vibration is ... of high, rapidly changing acceleration.

→ Signals from the compensating crystal, are amplified by a Second charge amplifier. A different amplifier is used which substracts pressure along all effects of acceleration are removed.

→ Piezoelectric pressure transducer are used to measure very high pressures that change very rapidly.

→ Ranges up to 0-50,000 psi

Advantages

→ The transducer needs no external power and is therefore self-generating (active type)

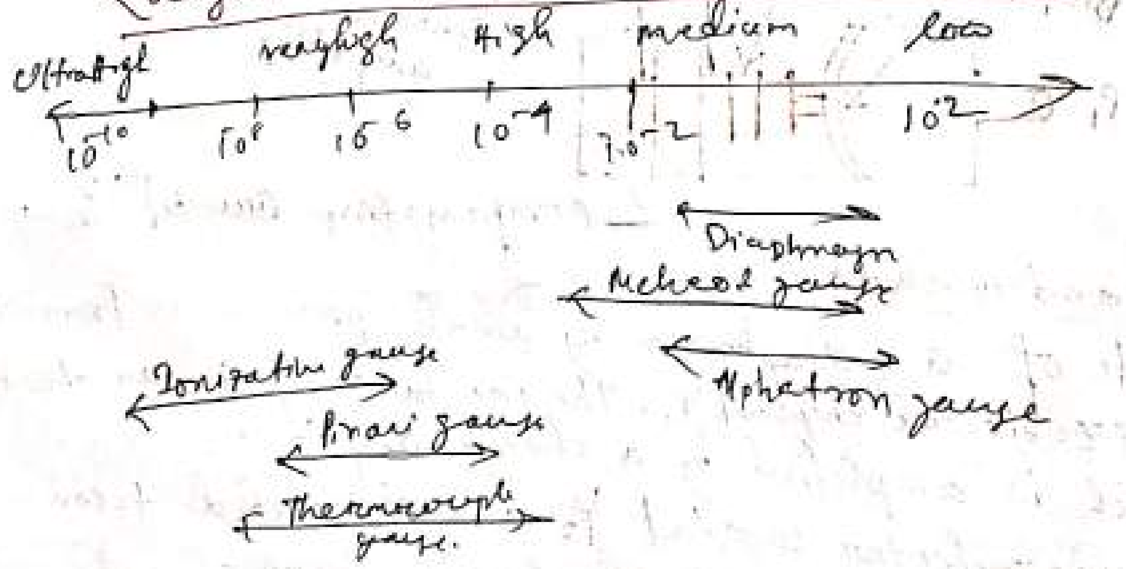
→ It has a very good high-frequency response.

Disadvantages

→ this type of transducer cannot measure static pressures.

→ the output of the transducer is affected by changes in temp.

Ranges of low pressure Instrument



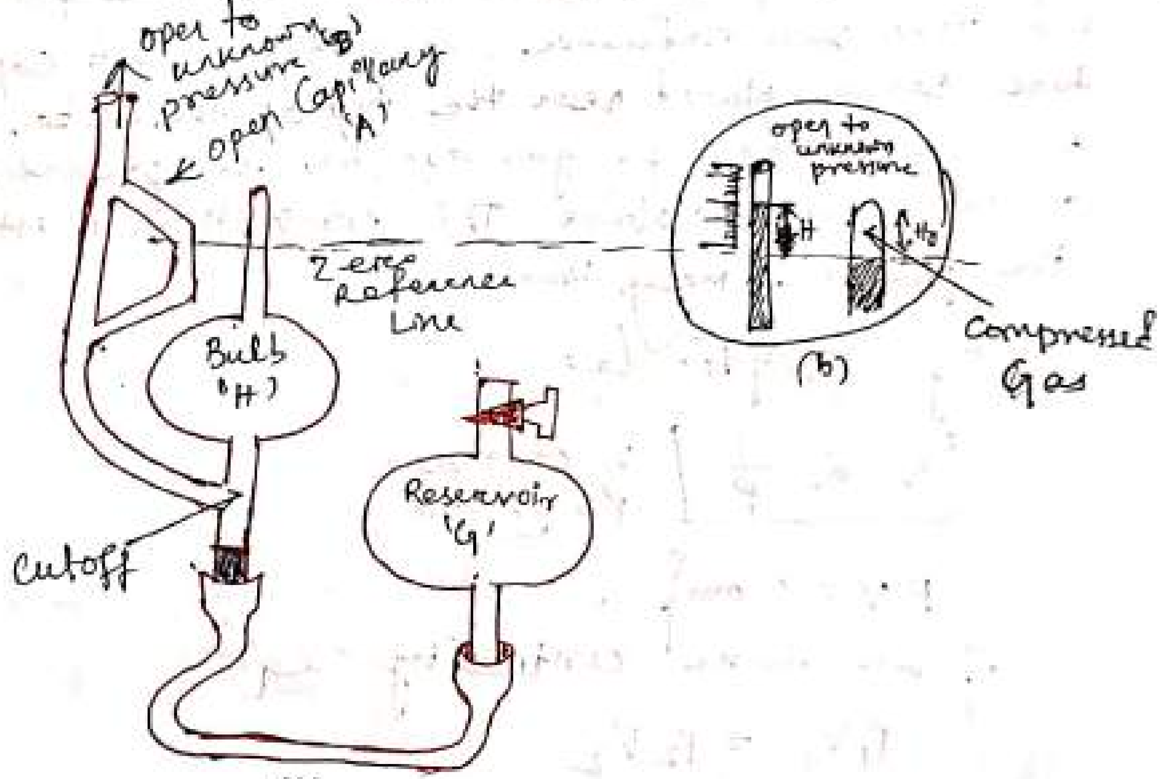
2.4 Describe the operation & Explain the working principle of vaccum gauge.

→ capsule is use for vaccum pressure measurement.

→ It is possible to obtain pressure from 1000mbar down to 10mbar.

Q) Mcleod Gauge

→ The mcleod gauge is used for measuring very low pressures down to one hundred - thousand of an inch of mercury (or 10m bar down to 10^{-3} m bar). The Mcleod gauge amplifies pressures by compressing a gas in to a small volume. The pressure of the compressed gas is then measured with a mercury manometer.



Construction & working

→ A Mcleod gauge is connected to the unknown gas whose pressure measurement is required. The gas enters the gauge through B and fills the tubes down to the level of the mercury reservoir.

→ The pressure is equal throughout the tubes and the bulb mercury is pumped up from the reservoir G. As the mercury rise above the cut-off, it traps gas inside the bulb.

Scanned with CamScanner

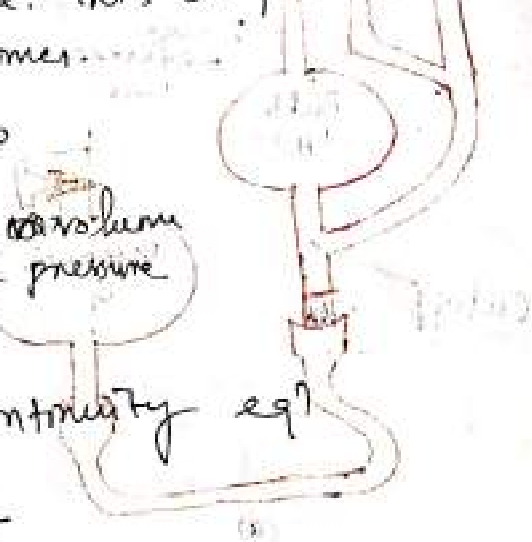
→ The mercury is then pumped higher in the gauge until all the gas in the bulb is compressed in to the closed capillary tube.

→ The operator allows the mercury to rise until its reaches a zero reference line on the closed capillary tube. the mercury rises faster in the open capillary tube 4.

→ The compression of gas in the closed capillary tube makes the pressure of the trapped gas higher than the measured pressure.

→ ~~The compression of gas in the~~ This pressure difference cause a difference in the mercury levels in the two tubes. The difference in height is used to calculate the pressure.

→ the volume of the bulb can be made quite large and the zero reference line on the closed capillary tube can be placed near the top of the tube. Thus a large volume of gas can be compressed in to a very small volume. This compression multiplies the pressure many times.



By Boyle's law

$$V \propto \frac{1}{P}$$

V = volume
P = pressure

$PV = $ const.

If we take continuity eq^n

$P_1 V_1 = P_2 V_2$

$PV = P_c V_c$

$V_c = a_c \times h_o$

$P_c = h_o \rho_m + P$

$\Rightarrow PV = (h_o \rho_m + P)\, a_c \times h_o$

$= P a_c h_o + a_c h_o^2 \rho_m$

$\Rightarrow P[V - a_c h_o] = a_c h_o^2 \rho_m$

$$P = \frac{a_c h^2 \rho_m}{V - a_c h}$$

P = measured pressure
V = volume of air is known
V_c = capilary air volume
a_c = area of capilary
h_o = hight of capilary (or) equal mercury height.
ρ_m = Density of mercury.

→ The McLeod gauge is a very accurate pressure-measuring device and often serves as a standard for calibrating other low pressure gauge

(B) Thermal-Conductivity Gauge

→ thermal conductivity gauge measure pressure by measuring the changes in the ability of a gas to conduct heat. The ability of a material to carry heat by conduction is called "thermal conductivity".

→ the conductivity of a gas does not change when the pressure changes until the pressure drops below about one torr. As the pressure continues to drop, the conductivity of gas decreases and the gas loses it's ability to conduct heat.

~~→ the relationship betn changes in conductivity~~

→ At low pressure the conductivity of a gas has a direct relationship to it's pressure. working range of pressure 10^{-4} torr upto about 10^{-2} torr.

Basic operating principles

→ A pressure gauge based on changes in thermal conductivity is made by enclosing a wire filament in a chamber connected to the pressure source.

→ When voltage is applied to the filament electricity flows making it hot. The rising temperature increases the resistance of the filament. The filament then reaches an 'equilibrium temperature' the temperature at which heat is produced in the filament as fast as it is removed.

→ Heat is removed by both radiation & conduction. convection is so ~~bigest~~ slight that it can be ignored.

→ the voltage applied to the filament is held constant and any change in pressure cause a change in conductivity of the gas surrounding the filament.

→ the change in conductivity changes the equilibrium temperature of the filament, which in turn causes the change in the resistance therefore, the change in resistance is used to indicate the pressure change.

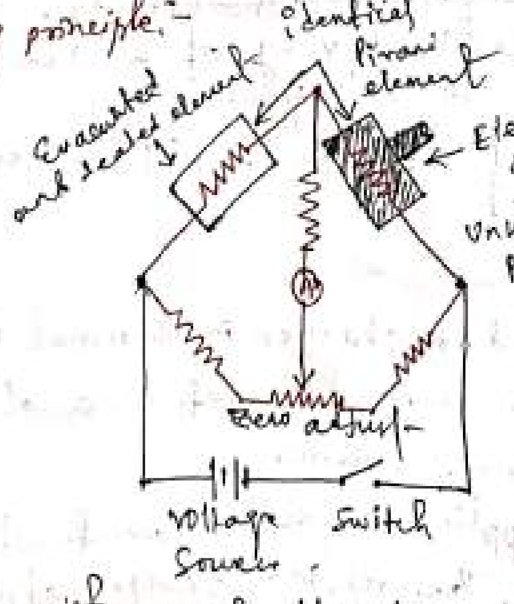
→ An increase in conductivity due to an increase in pressure increase the flow of heat away from the filament decreasing the temperature of the filament. A decrease in conductivity (due to decrease in pressure) increases the filament tempr.

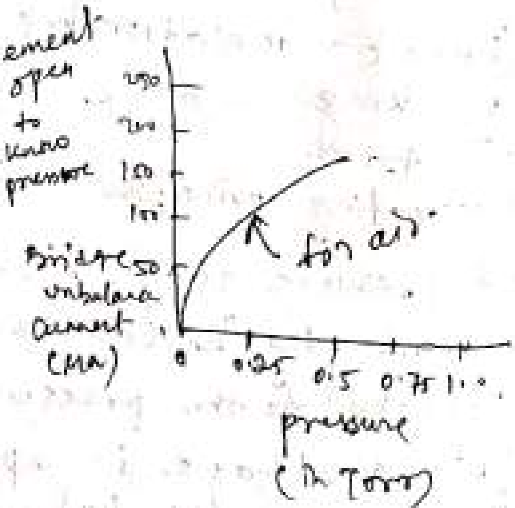
Two types →

a) Pirani Gauge

→ it consists of two wire filaments. one filament serves as a reference and is sealed in an evacuated glass. while the other filament is kept in a container connected to the source of pressure. These two filament are connected in a bridge circuit.

operating principle:-





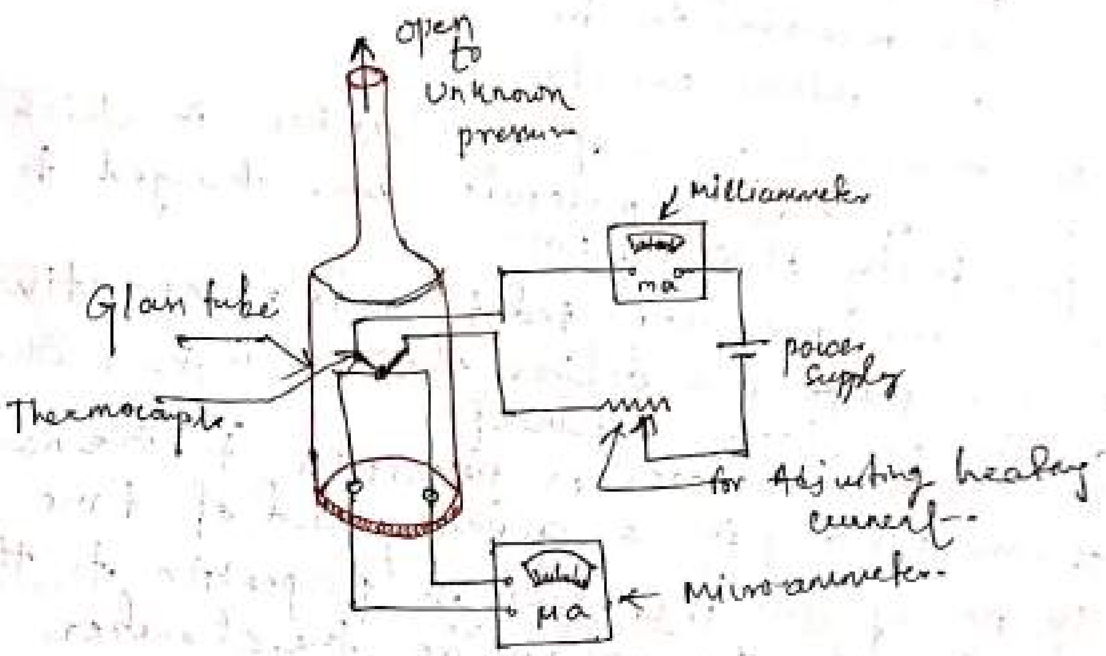
→ If the resistance of the two pirani elements are equal no currents flows through the ammeter. But if the resistance of one pirani element changes current will flow through the ammeter.

→ This current flow indicates a change in pressure of the gas being measured. A curve between the bridge unbalance current (μa) & the pressure (torr). Pirani gauges are used for the pressure range about 10^{-3} to 1 torr.

→ Because gases differ in heat conductivity, the gauge must be calibrated for the gas being measured.

(b) Thermocouple Gauge

→ The thermocouple gauge works on the same basic principle as the pirani gauge. The only difference is that the filament temperature is measured by a thermocouple.



→ It requires careful calibration, but once calibrated it is as accurate as the pirani gauge. A curve betn thermocouple current (μa) & pressure (torr). Thermocouple gauge are used for the pressure range from about 10^{-4} to 1 torr.

Disadvantage

→ Both the pirani gauge & thermocouple gauge are easily damaged by organic vapours. The filaments can become coated with a deposit of decomposed vapours. which alters the way the filament transfers heat.

(c) Ionization Gauges

→ An ionization gauge measures the density of a gas. The operating principle of the ionization gauge follows Boyle's law, i.e at constant temperature the ratio of pressure of two gases is equal to the ratio of their two densities.

$$\frac{P}{P_1} = \frac{\rho}{\rho_1}$$

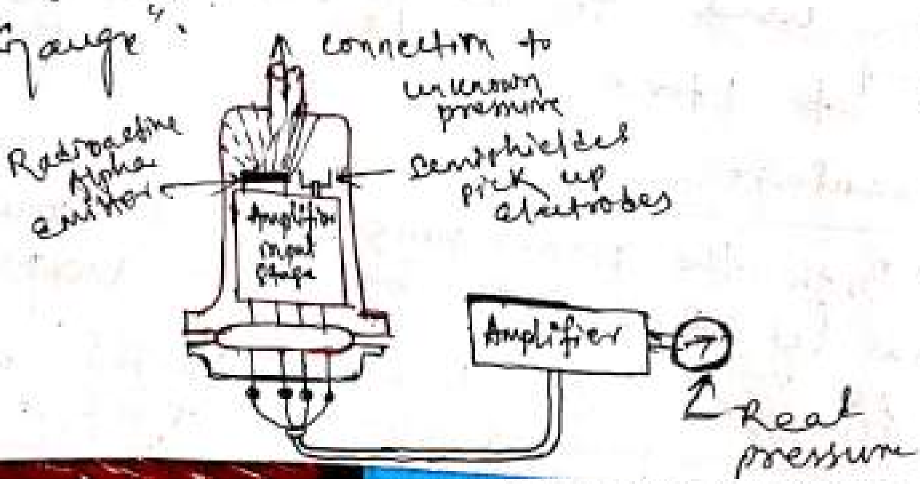
P = measured pressure
P_1 = initial pressure
ρ = measured density
ρ_1 = initial density

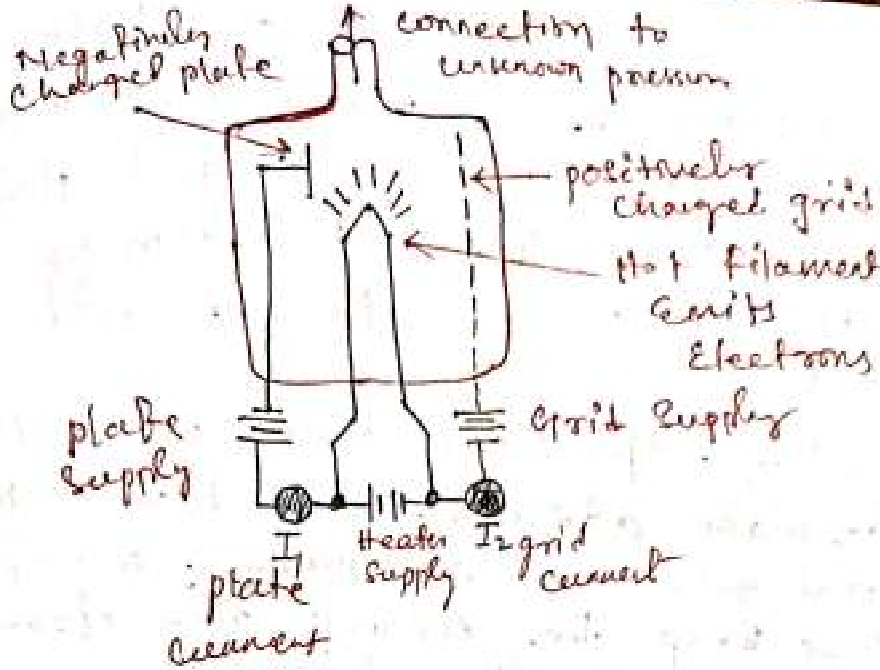
→ This instrument consists of a chamber in which some of the gas molecules are charged to positively charged ions.

→ These ions are attracted towards a negatively charged plate and deliver their charge, which creates an electric current.

→ The current increases in proportion to the number of ions arriving in a given period of time. The no. of ions increases in proportion to the density of the gas inside the chamber.

→ Thus the pressure is measured proportional to the relative density. There are two methods used to produce gas ions. In the first method, a stream of alpha (α) particles are produced from a radioactive source. An ionization gauge using alpha radiation is known as "Alphatron Gauge".





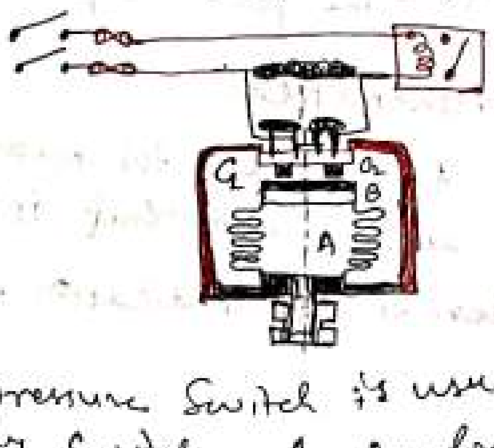
$$\rho = \frac{1}{S}\frac{I_1}{I_2}$$

S = Sensitivity

→ In the second method, a stream of electrons, produced from a red hot filament are attracted towards a positively charged grid of wire. Any positively charged ions produced due to collision of electrons with gas molecules are attracted towards the negatively charged plate. A hot filament ionization gauge which works on this principle.

2.5 Pressure Switch

→ A pressure switch turns an electric circuit 'ON' or 'OFF' at a preset pressure. This pressure is called the set point of the switch. A pressure switch is used in some form of control e.g. to operate a solenoid valve at a given pressure or ~~start~~ start up a pump.



→ The pressure switch is usually a micro switch or a mercury switch. A Burdon tube, a diaphragm or a bellows can be used to actuate the switch. Simplest form of a pressure switch used to actuate
on no...

Scanned with CamScanner

→ The pressure is fed to the inside of a bellows which carries a contact plate B. when the pressure reaches a sufficient (or preset) value the contact plate touches contact point C_1 & C_2 thus closing an electrical circuit to an alarm or motor control gear.

→ The flexibility of the bellows ensure that the plate makes adequate contact with both points and gives a slight rubbing or wiping action that keeps the contact area clean.

uses of pressure switches

→ One of the most important use of the pressure switch is in limiting pressure e.g. in steam power plant. The pressure of the steam entering a turbine must not exceed an upper limit. The pressure switch is used to operate a safety valve which vents steam when the pressure exceeds the upper limit.

→ An another important use of the pressure switch is in the computer panel. In the computer panel, blowers are used for cooling purposes. whenever the blower fails due to any reason, a pressure switch is actuated which cuts off the power supply of the panel.

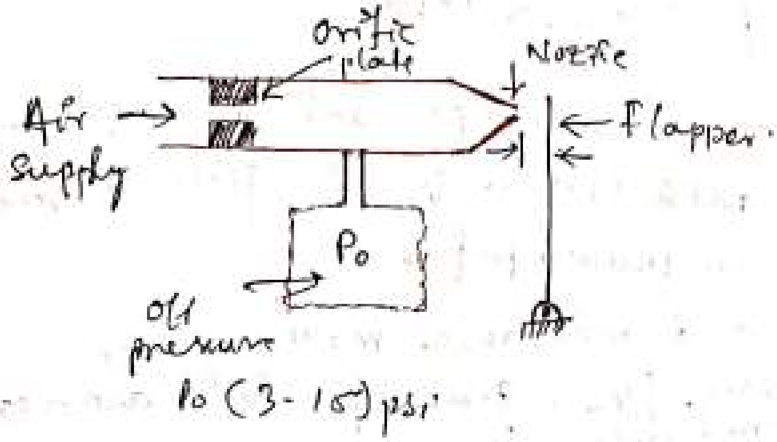
* Pneumatic pressure Transmitters

→ A pneumatic transmitter translates the measured value (from sensors) in to an air pressure that is transmitted to various receiver devices for indication, recording alarm & control.

Flapper nozzle

→ A pneumatic control system operates with air. the signal is transmitted in the form of variable air pressure (often in the range of 0.2 to 0.1 bar)

(3-15) psi that initials the control action.



→ Constant air pressure is supplied to one end of the pipeline. There is an orifice at this end. At the other end of the pipe, there is a nozzle and a flapper. The gap betn the flapper & the nozzle is set by the input signal.

→ As the flapper moves closer to the nozzle there will be less air flow through the nozzle & the air pressure inside the pipe will increase. On the other hand, if the flapper moves further away from the nozzle the air pressure decreases.

→ At the extreme of the nozzle is open (flapper is far off) the o/p pressure is equal to atmospheric pressure.
If the nozzle is blocked the output pressure will be equal to the supply pressure.

Chapter-3

3 Measurement of Flow & Level

3.1 → measurement of flow rate and quantity is the oldest of all measurements of process variables in the field of instrumentation.

→ Many accurate and reliable methods are available for measuring flow, some of which are applicable only to liquids, some only to vapours and gases & some others to both. Fluids to be measured may be clear or opaque, clean or dirty, wet or dry, erosive or corrosive.

3.1 classify flow meter and explain the principle of operation with diagram?

i) Inferential type flowmeter
- a) variable head or differential meters
- b) variable area meters
- c) magnetic meters
- d) Turbine meters
- e) Target meters
- f) Thermal flowmeters
- g) Vortex flowmeters
- h) Ultrasonic flowmeters

~~ii) a) positive displacement meters~~

ii) Quantity flowmeters
- a) positive displacement meters
- b) metering pumps

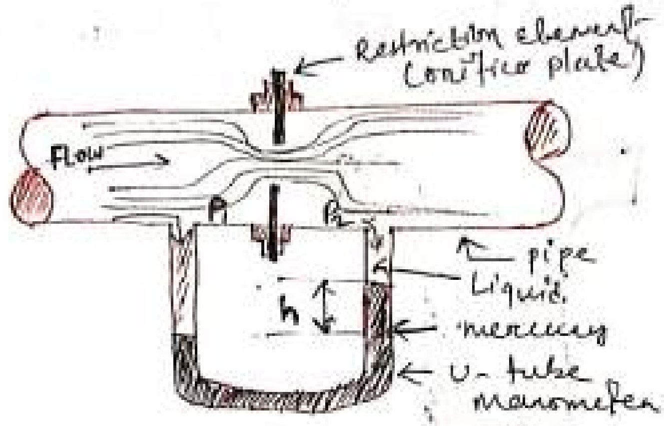
(iii) Mass flowmeter.

3.2 Variable head type Flowmeter:

→ This is one of the oldest and most widely used methods of industrial flow measurement. It measures volume rather than mass flow rates, but mass rate can be calculated or computed easily by knowing or sensing temperature & pressures.

Basic operation

→ Variable head flowmeters operate on the principle that a restriction (or obstruction) in the line (or pipe) of a flowing fluid, introduced by the orifice plate or venturi tube or elbow, produces a differential pressure across the restriction element which is proportional to the flow rate



→ The proportionality is not a linear one but has a square root relationship in that the flow rate is proportional to the square root of the differential pressure.

→ This relationship was derived from Bernoulli's theorem which states that in a flowing stream, the sum of the pressure head.

→ The velocity head and elevation head at one point is equal to their sum at another point removed in the direction of flow from the first point plus the loss due to friction betn the two points.

→ Velocity head is defined as the vertical distance through which a liquid would fall to attain a given velocity.

→ Pressure head is the vertical distance through which a column of the flowing liquid would rise in an open-end tube as a result of the static pressure.

$$V = K\sqrt{\frac{2gh}{\rho}}$$

$$Q = KA\sqrt{\frac{2gh}{\rho}}$$

$$W = KA\sqrt{\frac{2gh}{\rho}}$$

V = velocity of flowing fluid.
Q = Volume flow rate.
W = mass flowrate.
A = cross-sectional area of pipe through which fluid is flowing.
h = differential head (pressure) across the restriction element.
g = acceleration due to gravity.
ρ = density of the flowing liquid.

Reynolds Number

→ Reynolds number is a very important reference number in the accurate determination of flow. It is used to determine the point at which the flow goes from the viscous to the turbulent stage.

→ As the flow changes from viscous to turbulent and vice versa, there is a very marked change in the value of the flow co-efficient, but there is very little change with further increase in speed.

→ If very high degrees of accuracies are desired when head meters are employed

$$R_D = \frac{VD\rho}{\mu}$$

R_D = Reynolds number
V = average velocity
D = inside pipe diameter
ρ = density of flowing fluid.
μ = absolute viscosity.

Advantages

→ It cost is relatively low especially for large lines.

iii) it offers the widest application coverage of any type of meter.

(iii) it is accurate (± 1/4 % to ± 2%) & reliable.

iv) it can be easily removed without shutting down the process

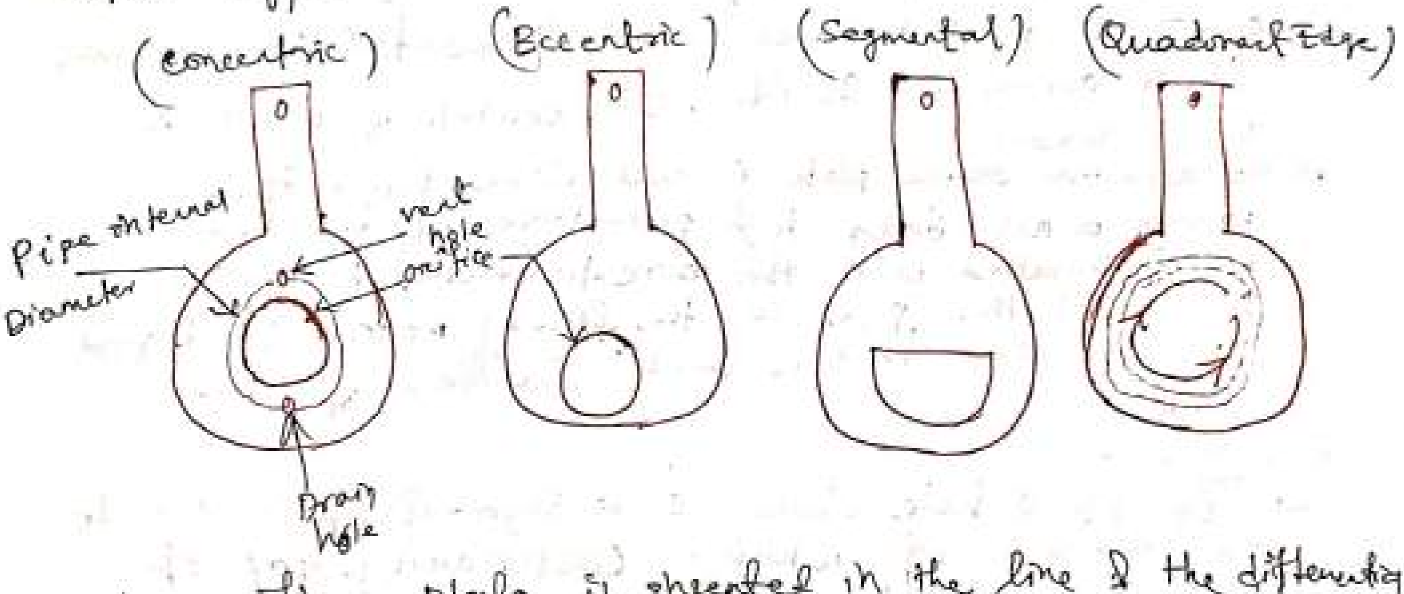
v) it is adaptable to any pipe size & flow rate.

Disadvantages

→ There is relatively high permanent pressure loss in it.
→ it is difficult to use for slurry services.
→ it exhibits square root relationship betn head & flow rate.
→ it is difficult to measure pulsating flow with this type of meter.

i) Orifice plates

→ orifice are the simplest and cheapest form of primary elements and are used more frequently than all other types.



→ An orifice plate is inserted in the line & the differential pressure across it is measured. There are types of orifice plates which are

a) concentric orifice plate.
b) Eccentric "
c) Segmental "
d) Quadrant edge "

i) Concentric orifice plate

→ it is most widely used. it is usually made of stainless steel and it's thickness varies from 3.175 to 12.7 mm ($\frac{1}{8}$ to $\frac{1}{2}$) in. depending on pipe line size and flow velocity.

→ it has a circular hole in the middle & it mounted in the pipeline with the hole concentric to the pipe. it is also made from other materials such as nickel, monel, phosphor bronze etc.

→ to withstand the corrosive effects of the fluid. The plate thickness at the orifice edge should not exceed.

ii) Eccentric orifice plate

→ it is similar to the concentric plate except for the offset hole which is bored tangential to a circle, concentric with the pipe and of a diameter equal to 98% of that of the pipe.

→ Location of the bore prevents damming of solid material or foreign particles and makes it useful for measuring fluids containing solids, oil containing water & wet stream.

→ The eccentric orifice plate is used where liquid fluid contain a relatively high percentage of dissolved gases and is installed with the bore tangential to the upper surface of the pipe when the flowing material is liquid & tangential to the lower surface of the pipe.

(iii) Segmental

→ It has a hole which is a segment of a circle the diameter of which is customarily 98% of the pipe diameter.

→ It is installed with the dam horizontal & with the curved section of the opening coincident with the lower surface of the pipe.

iv) Quadrant Edge

→ This types of orifice plates is used for flows such as heavy crudes, syrups & slurries & viscous flows. It is constructed in such a way that the edge is rounded to form a quarter-circle.

→ The plate has a concentric opening with a rounded to upstream edge rather than the sharp, square edge normally used.

→ it may be used when the line reynolds number range from 100,00 or above down to 3,000 to 5,000.

Advantages

→ its cost is low

→ They can be used in a wide range of pipe sizes.

→ They can be used with differential pressure devices.

→ They are well-known and have predictable characteristics.

→ They are available in many materials.

Disadvantages

→ They cause relatively high permanent pressure loss.

→ They tend to clog, thus reducing use in slurry services.

→ They have square root characteristics.

→ Their accuracy is dependent on care during installation.

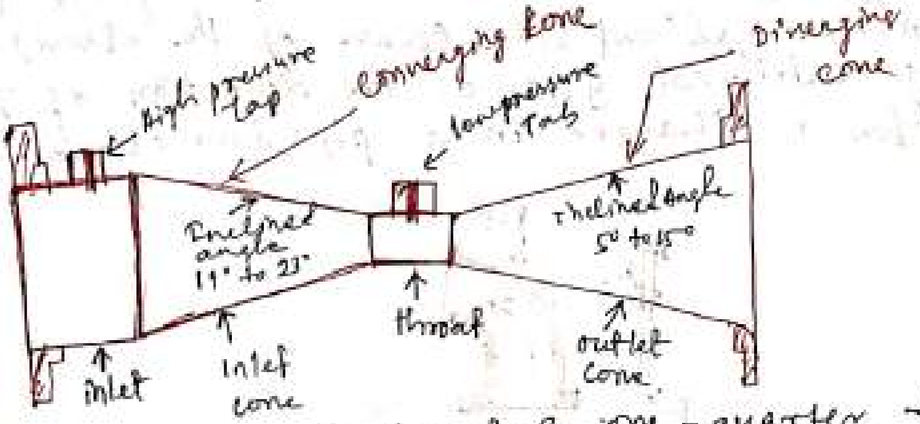
→ They have changing characteristic because of erosion, corrosion & scaling.

b) Venturi tube

→ A venturi tube is used where permanent pressure loss is of prime importance, and where maximum accuracy is desired in the measurement of high viscous fluids.

→ it consists of a straight inlet section of the same diameter as the pipe in which the high pressure tap location of the decreased pressure in an area where flow velocity is neither increasing nor decreasing.

→ A diverging recovery cone in which velocity decreases & the decrease : velocity head is recovered as pressure head.



→ The pressure taps are located one-quarter to one-half pipe diameter up stream of the inlet cone and at the middle of the throat section.

→ The venturi tube can be used to handle a fluid which is handled by an orifice plate and fluids that contain some solids, it contains no sharp corner & don't projectile on to the fluid stream. it can be also used to handle slurries and dirty liquids that build up around other primary elements, if the pressure taps are protected from plugging.

→ these are usually made of cast iron or steel. venturi co-efficient less affected by a decreasing Reynolds number

Advantages

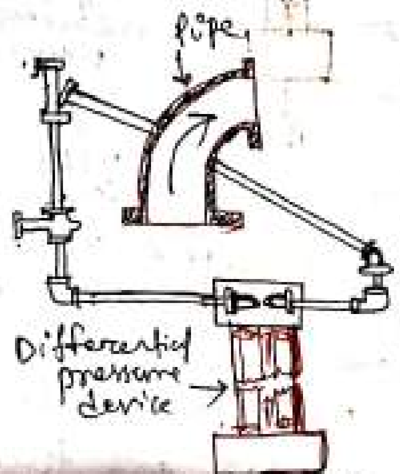
→ it causes low permanent pressure loss
→ it is widely used for high flow rates
→ it is available in very large pipe sizes.
→ it has well-known characteristics.
→ it is more accurate over wide flow ranges than orifice plates or nozzles.
→ it can be used at low & high beta ratios.

Disadvantages

→ it cost is high.
→ it is generally not useful below 76.2 mm pipe size
→ it has the limitation of a lower reynolds number of 150,000.

E) Elbow Taps

→ the flow measurement using elbow taps as a primary element, depends on the measurement of the differential pressure betn the two points (the inside and out-side curves of the elbow) developed by centrifugal force as the direction of fluid flow is changed in a pipe line elbow.



Elbow Tap

→ The taps are located at opposite ends of diameter in the plan of the elbow, and the diameter which passes through the taps is of either 45° or 22.5° from the inlet face.

→ Elbow taps are rarely used. if accuracy is poor varying from ±5 to ±10%.

Advantages

i) The elbow taps are easy to add to existing installation when elbow exist.
ii) it's cost is comparatively low.
iii) it allows no additional pressure loss.
iv) with the elbow taps there are no obstruction in the line.
v) it has good repeatability.

Disadvantages

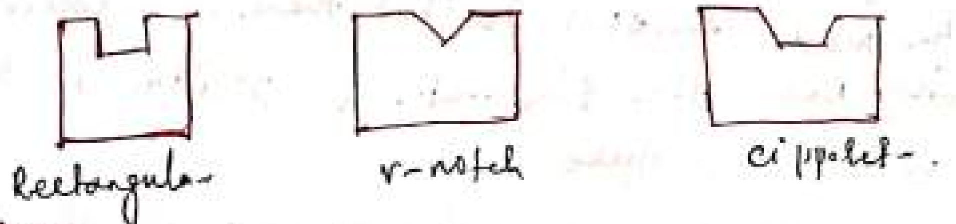
→ it's accuracy is poor.
→ Differential pressure developed is relatively small.

Weirs

→ weirs are used to measure flow rate primarily in open channels such as water works including irrigation, waste and sewage systems, and in pipes and conduits that are generally not completely filled with liquid.

→ it is an obstruction in a flowing stream over which the liquid is made to pass. with the use of weir, flow rates can be measured from a few gallons per minute to millions of gallons per day.

→ there are three types of weirs such as rectangular, v-notch & cippoletti or trapezoidal.



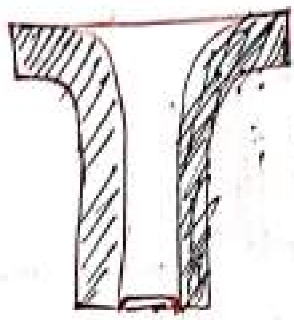
Advantages

i) it's cost is low
ii) it can be constructed on location when being used
iii) it is not easily damaged.

c) Flow Nozzles

→ The flow nozzles are used for flow measurements of high fluid velocities and are more rugged and more resistant to erosion than the types of flow nozzle, the long-radius flow nozzles.

→ A flow nozzle consists of a convergent inlet whose shape is a quarter ellipse, and a cylindrical throat.



→ Differential pressure measurement taps are normally located one pipe diameter upstream and one-half diameter downstream from the inlet faces of the nozzle.

→ For a given diameter and a given differential pressure, it allows measurement of flow rates almost 65% more than that of the orifice plate.

→ Flow nozzle are manufacture commonly from stainless steel, chrome-moly steel. Flow nozzles should use at reynolds number down to 6000.

Advantages

i) It's permanent pressure loss is lower than that for an orifice plate.

ii) it is available in numerous materials

iii) it is useful for fluids containing solids that settle.

iv) it is widely accepted for high-pressure & temperature steam flow.

Disadvantage

→ it's cost is higher than orifice plate

→ it is limited to moderate pipe sizes.

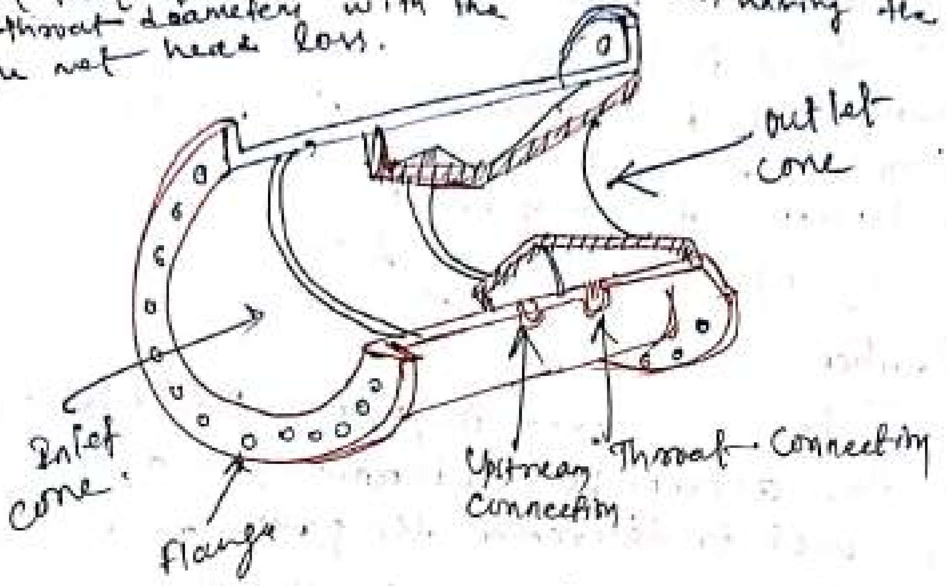
→ it requires more maintenace

~~Dall tubes~~ D) Dall tubes

→ The dall tube is a modified form of venturi tube, a cross-section of

→ It consists of two truncated cones each with a relatively large cone angle. the throat is formed by a circumferential slot located betn the two smaller diameters of the truncated cone.

→ the differential pressure produced by a dall tube is much higher than that of venturi tube or nozzle, having the same upstream & throat diameters with the same net head loss.



→ The dall tube can be used in circumstances where the velocity of flow through the pipe is such that, with a specified head loss, it is not possible to design a venturi tube to generate a sufficiently large differential head to operate a recovery instrument.

Advantage

→ The dall tube has a low head loss.
→ it has a short laying length.
→ Dall table is available in numerous materials of construction.
→ The dall tube has no upper line-size limit.

Disadvantage

→ its pressure difference is sensitive to up-stream disturbances
→ more straight pipe required in the approach pipe length
→ it is not considered for measuring flow of hot feed water

→ The taps are located at opposite ends of diameter in the plan of the elbow, and the diameter which passes through the taps is at either 45° or 22.5° from the inlet face

→ Elbow taps are rarely used. its accuracy is poor varying from ±5 to ±10%

Advantages:

i) The elbow taps are easy to add to existing installation where elbow exist.
ii) it's cost is comparatively low.
iii) it allows no additional pressure loss.
iv) with the elbow taps there are no obstruction in the line.
v) it has good repeatability.

Disadvantages

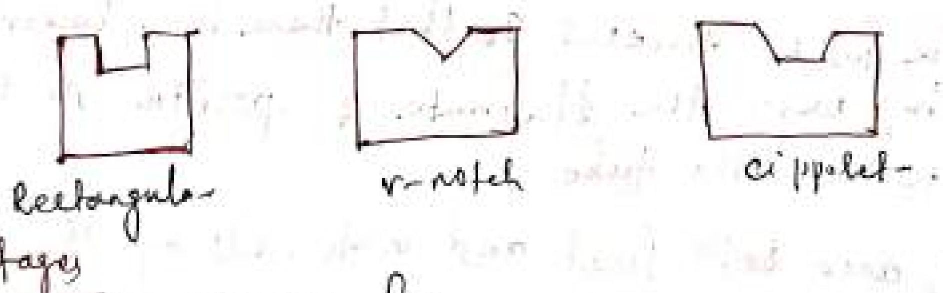
→ it's accuracy is poor.
→ Differential pressure developed is relatively small.

Weirs:

→ weirs are used to measure flow rate primarily in open channels such as water works including irrigation, waste and sewage systems, and in pipes and conduits that are generally not completely filled with liquid.

→ it is an obstruction in a flowing stream over which the liquid is made to pass. with the use of weir, flow rates can be measured from a few gallons per minute to millions of gallons per day.

→ There are three types of weirs such as rectangular v. notch & cippoletti or trapezoidal.



Advantages

i) it's cost is low
ii) it can be constructed on location when being used
iii) it is not easily damaged.

Disadvantages

i) It is applicable only to open-channel measurement
(ii) It's field calibration is required
(iii) It's accuracy is poor (generally not over 2 to 3%)

Flumes

→ The flume (known as parshall flumes) is a special type of venturi flume developed by the colorado agricultural experiment station, and is used essentially for the same purpose as the weirs.

→ It is considered more practical than weirs because it's loss of head is about one-fourth that of a weir.

Advantages

i) It handles greater flow than weir.
ii) It can be constructed on location
(iii) It is easy to construct as all it's sections are plane surface.
iv) It dimension are not easily altered to cause incorrect measurement

Disadvantages

i) It is more expensive than weir.
ii) It requires calibration.

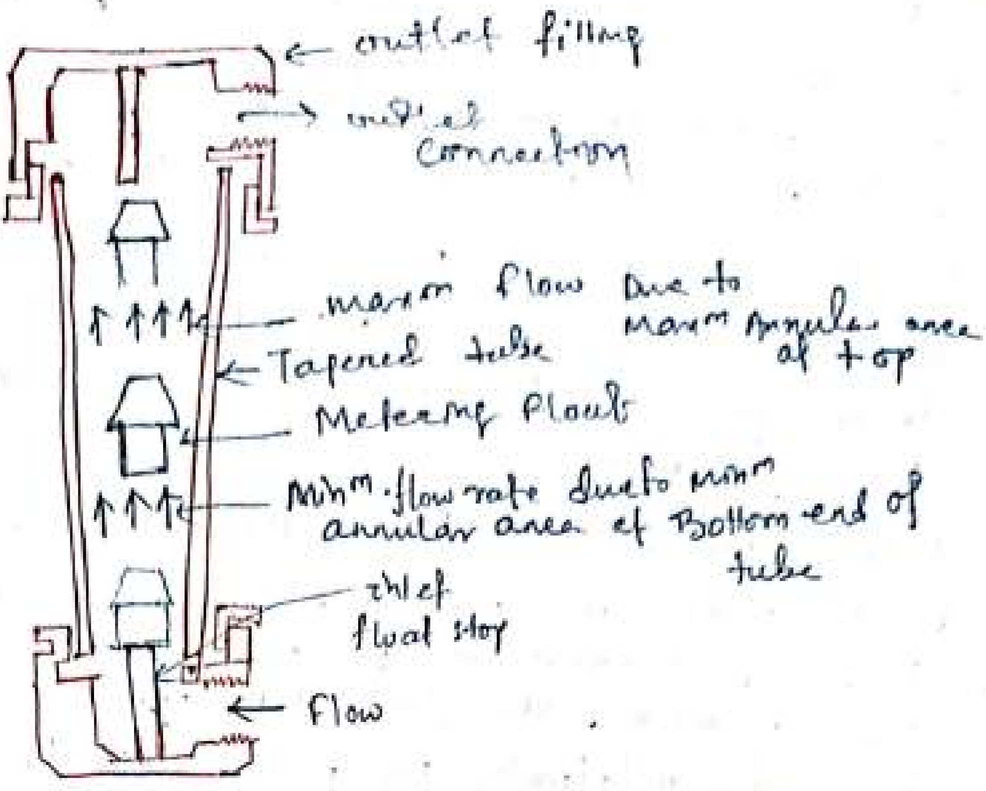
3.3 Variable Area Flowmeters.

Rotameters

→ The rotameter is the most extensively used form of the variable area flowmeter. It consists of a vertical tapered tube

→ The tube made tapered so that there is a linear relationship betn the flow rate & position in the float within the tube.

→ The free area betn float and inside wall of the tube forms an annular orifice. The tube is mounted vertically with the the small end at the bottom.



→ The fluid to be measured enters the tube from the bottom and passes upward around the float, and exit at the top.
when there is no flow through the rotameter, the float rests at the bottom of the metering tube where the maxm diameter of the float is approximately the same as the bore of the tube.

→ When fluid enters the metering tube, the float moves up, and the flow area of the annular orifice increases. The pressure differential across the annular orifice is proportional to the square of it's flow area and to the square of the flow rate.

→ The float is pushed upward until the lifting force produced by the pressure differential across it's upper & lower surface is equal to the weight of the float.

→ If the flow rate rises, the pressure differential and hence the lifting force increases temporarily and the float then rises, widening the annular orifice until the force caused by the differential is again equal to the weight of the float.

Scanned with CamScanner

→ The pressure differential remain constant and area of the annular orifice (i.e. free area betn float and inside wall of tube) to which the float moves, changes in proportion to the flow rate.

→ Any decrease in flow rate causes the float to drop to a lower position. Every float position corresponds to one particular flow rate for a fluid of a given density & viscosity.

→ A calibration scale printed on the tube or near it, provides a direction indication of flow rate.

→ The tube materials of rotameter may be glass or metal. The glass tube are commonly used for relatively low pressure and temperature service of non-hazardous fluids such as water and air.

→ For high pressure the glass is not used because the glass can be broken easily. metal tubes are used. for indication, such as magnetic or electric indication which is the linear motion of the float is converted in to a rotary motion by movement of a point on a scale.

→ The majority of application of rotameters are for low viscosity fluid, corrections must be provided for the changes in fluid density or specific weight.

→ Rotameters can directly measure flows as high as 4000 gpm (920 lt./hr).

Advantages

→ It costs is relatively low.
→ Rotameters have good rangeability.
→ It is good for metering small flows.
→ It is easily equipped with alarm switches or transmitting devices

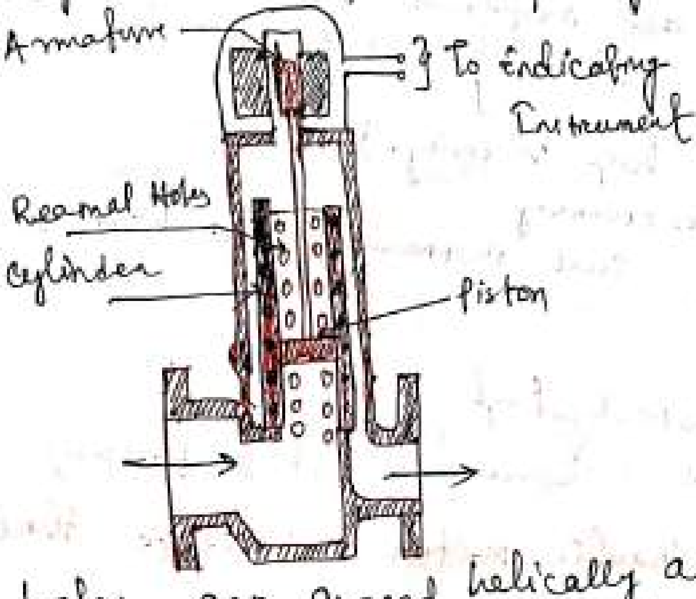
→ it handles wide variety of corrosives.
→ it can be used in some light slurry services.
→ viscosity - immune floats are available in rotameter.
→ it has low pressure drop requirement.

Disadvantages

→ the glass tube type is easily subject to breakage.
→ it must be mounted vertically.
→ it is not good in pulsating services.
→ Rotameter are generally limited to small pipe sizes.
→ Rotameter are limited to low temp.
→ the accuracy about ± 1/2 to ± 10%.

cylinder and piston Type Flowmeters

→ The cylinder and piston type variable area flowmeter is most oftenly used for measuring flow of fuel Oils, tar, chemical liquors, and other such high viscosity fluids.
→ it consists of a cylinder and a piston fitted in to it. A series of reamed holes are provided in the walls of the cylinder to provide passage for fluid flow.



→ These holes are spaced helically around the cylinder in rows, to provide a continuous variation in area for various heights of the piston.
→ By spacing the holes properly in the cylinder, the calibration of the instrument is made linear. As the weight of the piston is constant the pressure differential is constant.

→ The flow reading of the meter is transmitted using a reluctance-type transducer. When fluid enters the cylinder, the piston exerts a constant downward-force & the difference in pressures betn the two sides of the piston places the piston in a particular position.

→ The down stream flow is increased, the pressure on the load side of the piston reduced. The increased differential pressure then forces the piston up.

→ There by increasing the area of the 'opening through which the fluid can flow until the pressure differential is again balanced.

→ The linear movement of the piston in the cylinder is sensed by a linear variable differential transformer (LVDT) which converts this linear motion in to voltage signal which is proportional to the flow rate.

→ These types of meter are used for high viscosity fluids materials which are corrosive or might clog lines, and materials whose flow co-efficients are not well known.

Advantages

i) it is good for high viscosity fluids.
ii) It has good accuracy
iii) The range of such instrument can have wide variations.

Disadvantages

i) it's cost is relatively high
ii) it has limited size range (about 25 to 100 mm).

3.4 Explain Non-hydraulic meter and state their industrial uses.

a) Magnetic Flowmeters :-

→ magnetic flowmeters are traditionally the first type of flowmeters to be considered for high corrosion application & for application involving measurement of erosive slurries.

→ These meters utilize the principle of Faraday's law of Electromagnetic Induction for measurement.

→ It states that whenever a conductor moves through a magnetic field of given field strength, a voltage is induced in the conductor which is proportional to relative velocity betn the conductor & the magnetic field.

→ This concept is used in electric generators. In case of magnetic flowmeters, electrically conductive flowing liquids work as the conductor. The induced voltage is given by the equation

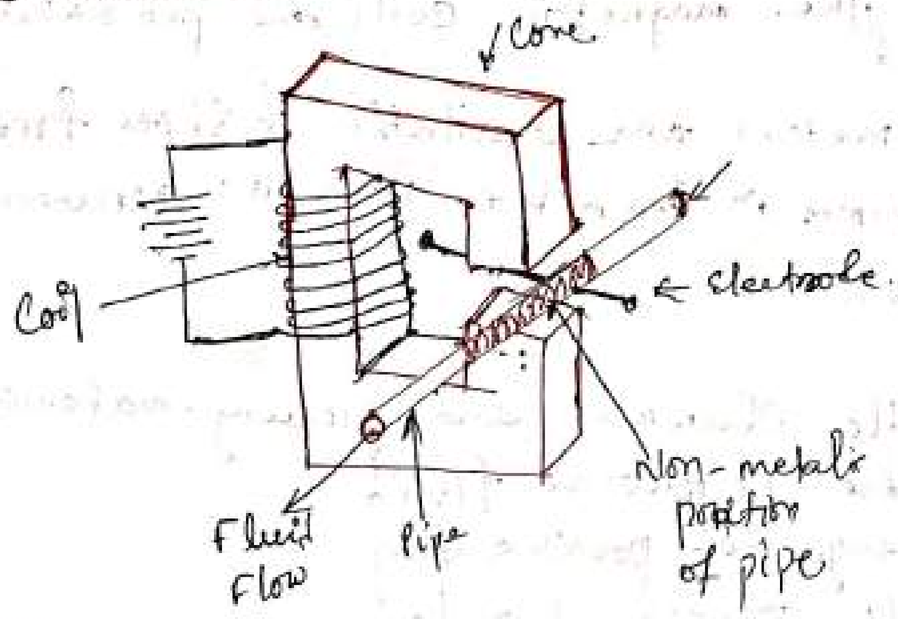
$$E = BVLC$$

$$V = \frac{E}{CBL}$$

E = induced voltage in volts
C = dimensional constant
B = magnetic field in weber/m²
L = Length of conductor (fluid) m
V = velocity of the conductor (fluid) in m/s

The induced voltage is directly proportional and linear with volumetric flow rate.

Construction and working



→ The magnetic flowmeter consists of an electrically insulated or non-conducting pipe such as fiber glass, with a pair of electrodes mounted opposite to each other and flush with the inside walls of it's pipe & with magnetic coil mounted around the pipe so that a magnetic field is generated in a plane ~~of the elect~~ manually perpendicular to the axis of the flowmeter body and to the plane of electrode.

→ principle of a magnetic flowmeter in which the flowing liquid acts as the conductor, the length L of which is the distance betn the electrodes & equal the pipe diameter.

→ The liquid passes through the pipe section, it also passes through the magnetic field set up by the magnet coils, thus inducing the voltage in the liquid which is detected by the pair of electrodes mounted in the pipe wall.

→ The amplitude of the induced voltage is proportional to the velocity of the flowing liquid. The magnetic coils may be energized either by AC or DC voltage, but the recent development is the pulsed DC-type in which the magnetic coils are periodically energized.

→ magnetic meters are available in sizes from 2.54 to 2540mm in diameter, with an accuracy ±1/2 to ±2%.

Advantages

i) it can handle slurries and greasy materials.
ii) it can handle corrosive fluid.
(iii) it has very low pressure drop.
iv) it is totally obstruction less.
v) it is available in several construction materials

Scanned with CamScanner

vi) it is available in large pipe size and capacities.
vii) it can be used as bidirectional meter
viii) measurements are unaffected by viscosity, density, temperature and pressure.

Disadvantage & Limitation:

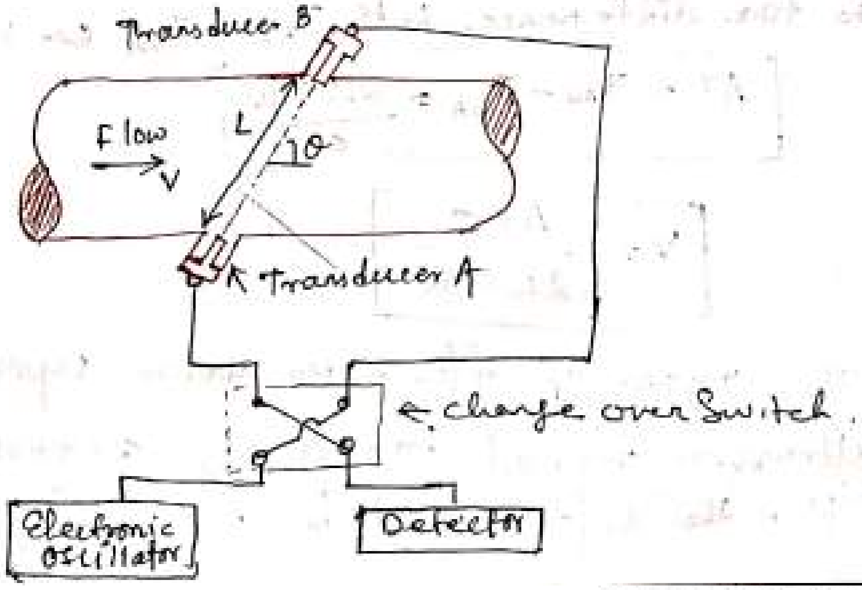
i) It is relatively expensive.
ii) it works only with fluids which are adequate electrical conductors
iii) It is relatively heavy, especially in larger sizes.
iv) It must be full at all times.
v) it must be explosion proof when installed in hazardous electrical areas.

B) Ultrasonic Flowmeters

→ In ultrasonic flowmeter the measurement of flow rate is determined by the variation in parameter of ultrasonic oscillation. There are two types of ultrasonic flowmeters currently use:

i) Time Difference Type

→ These devices measure flow by measuring the time taken for ultrasonic wave to traverse a pipe section, both with and against the flow of ~~liquid~~ liquid within the pipe.
→ it consists of two transducer A & B inserted in to a pipe and working both as transmitter and receiver



→ The ultrasonic waves are transmitted from Transducer A to transducer B and vice versa. An electronic oscillator is connected to supply of Ultrasonic wave alternately to A or B which is working as transmitter through a charge over switch; when the detector is connected simultaneously to B or A which is working as receiver.

→ The detector measures the transit time from upstream to down stream transducer and vice-versa

→ The time T_{AB} for ultrasonic waves to travel from transducer A to transducer B is given by expression.

$$T_{AB} = \frac{L}{C + V\cos\theta}$$

and Time to travel B to A

$$T_{BA} = \frac{L}{C - V\cos\theta}$$

where L = the acoustic path length betn A & B
c = velocity of sound in the fluid.
θ = angle of path with respect to the pipe axis.
V = velocity of fluid in pipe.

The time difference betn T_{AB} & T_{BA} can be calculated

$$\Delta T = T_{AB} - T_{BA} = \frac{2LV\cos\theta}{c}$$

$$V = \frac{\Delta T C}{2L\cos\theta}$$

→ This type of flow meter relies upon an ultrasonic signal traversing across the pipe, the liquid must be relatively