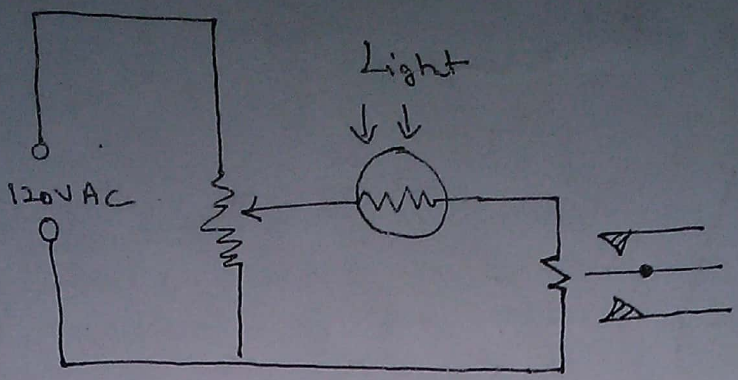
1

UNIT → III

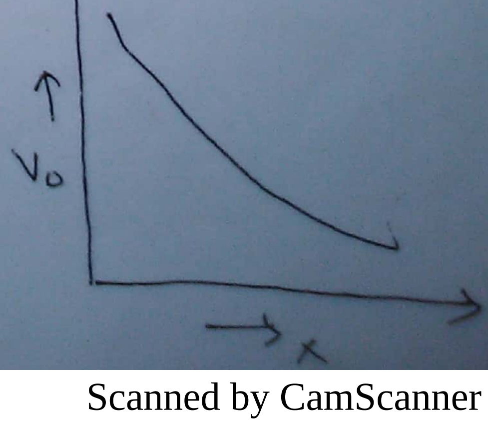


Light Dependent Resistor

1. It works on the principle of photo-conductive effect, In this effect, the electrical resistance of the material varies with the amount of incident. Light.
2. A typical control ckt. utilizing a photo-conductive cell (LDR) is as shown above.
3. The potentiometer is used to make adjustments to compensate for manufacturing tolerances in LDR., sensitivity and relay operating sensitivity
4. When the LDR has the appropriate light shining on it, its resistance is low and the current thr. the relay is consequently high enough to operate the relay. When the Light is interrupted, the resistance increases causing the relay current to decrease enough to de-energise the ~~det~~ relay.

Advantages of LDR:
i) O/p given is in the form of electrical signal.
ii) sensitivity is High.
iii) The curve is smooth.
iv) Resolution is good.

Disadvantages!
(i) Non-Linear characteristics.



Kirti sir

(1) UNIT→III

Low Pr. Gages :- Pr. less than 1 mm of Hg are considered to be low pressures & are expressed by the units torr & micron.

1 torr = 1mm of Hg as std. Condns

1 micron = 10^{-3} torr

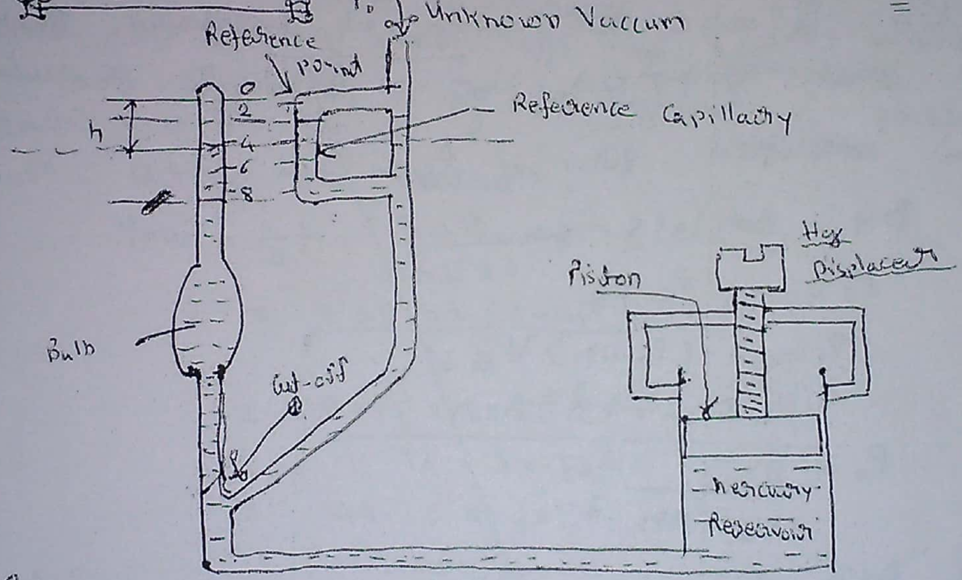
The term vacuum pr. refers to pr. below atmp

Low Vacuum — 760 to 25 torr

Medium Vacuum — 25 torr to 10^{-3} torr

High Vacuum — 10^{-3} torr to 10^{-6} torr

(A) **McLeod Gage** :- Gages for measuring Low Pr. Gage



(A) The unit comprises a system of Glass Tubing as shown in fig.

Working Principle : 1. Piston is withdrawn & the Hg level is lowered down upto the cut-off position, thereby admitting gas at unknown pr. P_0 & known volume into the system

Let V_0 be the vol. of the gas admitted into the bulb & Capillary, The bulb & tube down upto the cut-off point.

2. Piston is pushed in till the Hg level goes up to the ~~reference~~ zero mark in reference capillary, the mercury in the capillary above the bulb will not reach to the same level because of the pr. of the gas untrapped, In this way <u>the unknown pr. is amplified.</u>

Let "a" be the area of capillary then the final volume "V_f" = $A \times h$ & the final amplified pr. $P_f = P_0 + h$

By Boyle's Law

$$P_0 V_0 = P_f V_f$$

$$P_0 V_0 = (P_0 + h) V_f$$

$$P_0 V_0 = (P_0 + h) A \times h$$

$$P_0 = \frac{Ah^2}{V_0 - Ah}$$

If "$A \times h$" $<< V_0$, then

$$P_0 = \frac{Ah^2}{V_0}$$

~~Thus the pr. is~~ The capillary can be directly calibrated in terms of pr. P_0

For greater amplification of the pr. & the reading "h"

$\frac{A}{V_0}$ should be small, which will increase "h" for same "P_0"

For this 1. Size of the bulb should be made large, but it will acquire the excessive quantity of Hg.

2. Size of the capillary should be made small, but if the bore is made below 1mm, the Hg tends to stick in the capillary tube.

Prob: It is reqd. to design a diaphragm pr. gage to measure a max^m pr. of 15 Kgf/cm^2 gauge, what would be the diaphragm thickness if the max^m deflecⁿ is limited to ~1/3rd of thickness. The diaphragm is to be constructed of spring steel 5cm in diameter, Modulus of elasticity = 2×10^6 Kgf/cm^2 & poisson's ratio = 0.3

Solⁿ: Using the relation:

$$y_{max} = \frac{1}{3}t = \frac{3\Delta P}{16 E t^3} r^4 (1-\mu^2)$$

$$t^4 = \frac{9 \Delta P r^4 (1-\mu^2)}{16 E}$$

$$= \frac{9 \times 15 \times 2.5^4 [1-(0.3)^2]}{16 \times 2 \times 10^6}$$

$$= 149.96 \times 10^{-6} \text{ cm}^4$$

$$= 0.1106 \text{ cm}$$

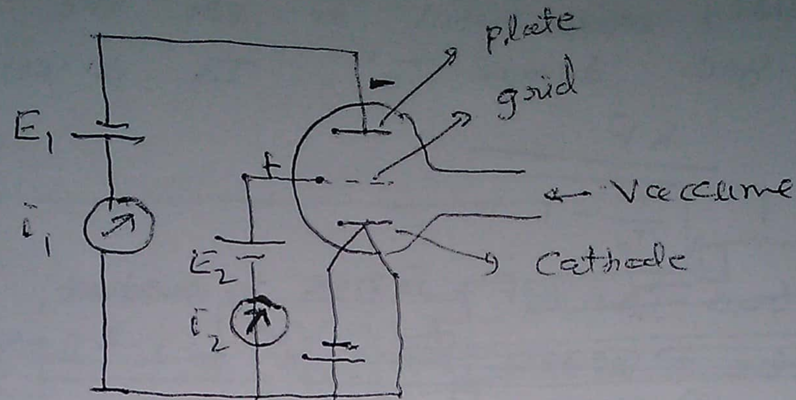
Prob: A Mcleod gauge of $V_0 = 200 \text{cm}^3$ & capillary cross-sectional area $a = 0.1 \text{cm}^2$ indicates 1cm of Hg. Express the pr. in microns.

$$P_0 = \frac{ah^2}{V_0} = \frac{0.1 \times (1 \times 1)}{200}$$

$$= 0.5 \times 10^{-3} \text{ cm of Hg}$$

$$= 5 \times 10^{-3} \text{ mm of Hg}$$

$$= 5 \times 10^{-3} \text{ torr} = 5 \text{ microns}$$ — (Ans)



producing grid current i_2

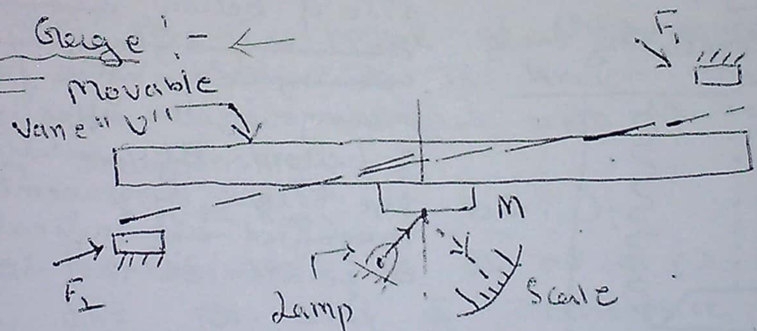
The rate of ion production is proportional to the number of electrons available to ionise the gas and the amount of gas present (which depends on the gas pr). The following approximate relation holds

$$p = \frac{1}{K}\frac{i_1}{i_2}$$

where K is termed as sensitivity of the gage

Knudsen Gage :-

(A)



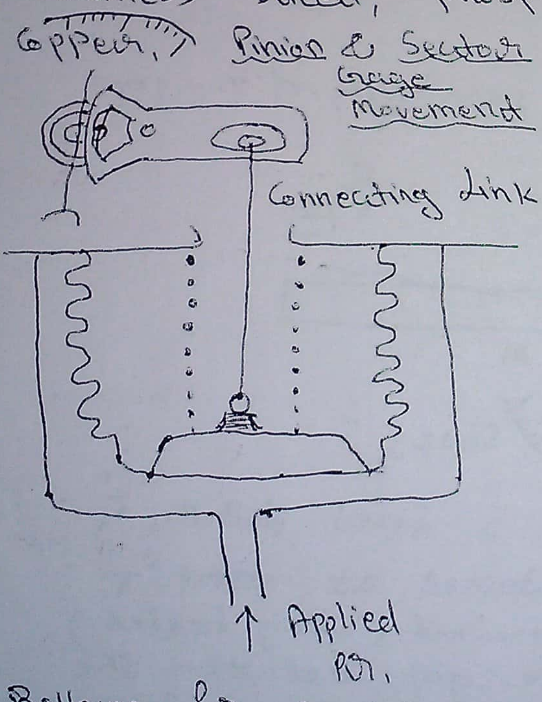
The Gas chamber contains 2 fixed plates "F_1" & "F_2" heated to & maintained at temp. "T". Near these plates there is a restrained (spring loaded) movable vane V such that the gap between the vane & fixed plates is less than the mean free path of the gas. The kinetic theory of gases show that the gas molecules rebound from the heated plates with great momentum than from the cooler movable vane thus giving a net force on the movable vane which can be measured by measuring the angular displacement of vane or mirror M, Analysis's shows that the force is directly proportional to pr. The vane is at gas temp. "T_0". It is seen that

$$P = \frac{kF}{\sqrt{\frac{T}{T_0} - 1}}$$

where P – Gas Pr. F – Force k – Constant,
~~For smaller pr. difference~~, Range: 10^{-8} to 10^{-2} Torr.

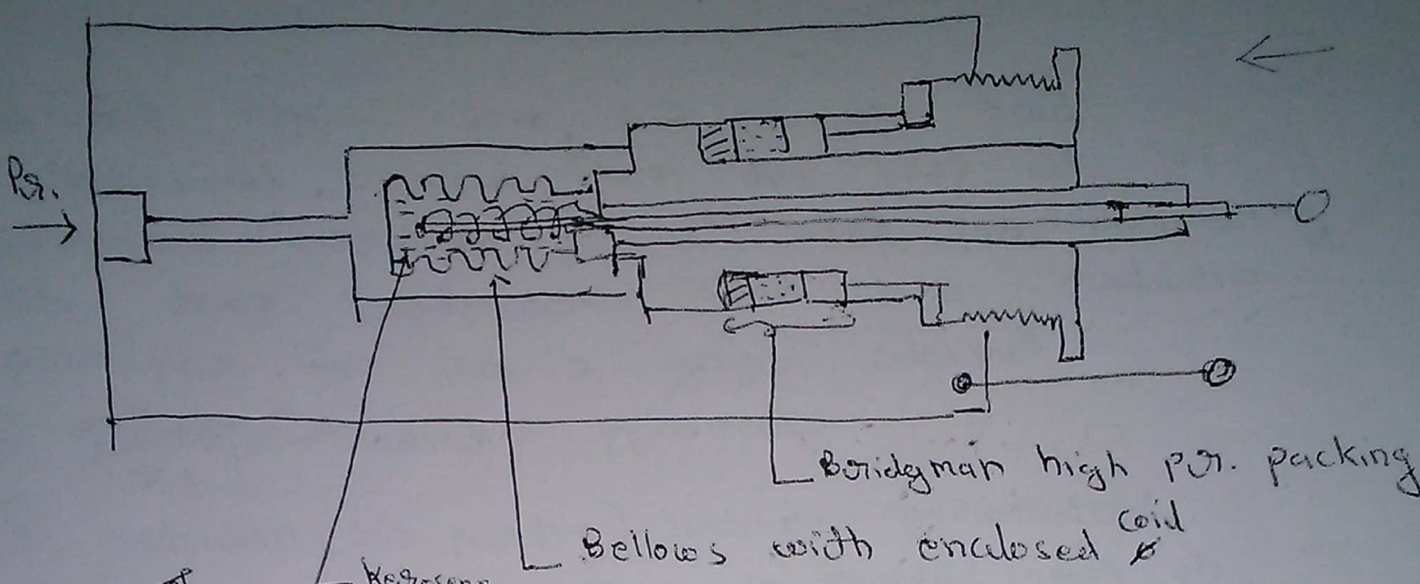
(A) Bellow Gauges :- (High pr)

The Bellows is a longitudinally expansible & collapsible member consisting of several convolutions & folds, Common material for Bellow are Tombac (?), Brass, stainless steel, phosphor bronze & beryllium copper,



Pressure is applied to one side of bellow ~~and the resulting deflection in causing~~ causing a proportional change in the effective length of bellow By suitable linkages the Bellow displacement is magnified and indicated by a pointer on the scale

Bellows Pr. gauge



Bridgman Gauge: For measurement of prs. above 70,000 MPa, electrical gauges based upon the principle of change of resistance with change of pr. are used. It is known that resistance of fine wires changes with pr. according to a linear relationship:

$$R \simeq R_0 (1 + b\Delta P)$$

where R = Resistance in Ω at a pr. of 1 atm,
b is the pr. coeff of resistance & ΔP is the gauge pr.

A typical gauge employs fine wire of Manganin or Gold chrome. Manganin has a pr coeff. of resistance of $25 \times 10^{-12} Pa^{-1}$ & the total resistance of wire is 100 Ω. The wire is wound in the form of a coil enclosed in a pr. container filled with kerosene oil. One end of the coil is grounded to the cell body & the other end is brought thr. a suitable insulator. The coil is enclosed in a flexible kerosene filled bellows which transmits the pr. under measurement to the coil. The change in resistance with change in pr. is measured with Wheatstone Bridge.

[Pyre] For temps. above 650°C, the heat radiations emitted from the body are of sufficient intensity to be used for measuring the temp. Instruments that employ radiation principles fall into 2 ~~general~~ classes

(a) ~~Selective~~ Total radiation pyrometer

(b) Selective (or partial) radiation pyrometers.

It ~~receives~~. receives a controlled sample of the total radiation of a hot body & focusses it on to a temp. sensitive transducer. The term 'total radiation' includes both visible (light) & invisible (infrared) radiations. The infrared radiations are associated with relatively large wave-lengths. They require special optical materials for focussing. Ordinary glass is un-satisfactory, as it absorbs infrared radiations.

It consists of blackened tube "T" open at one end to receive the radiations from the object whose temp. is to be measured. The other end of the tube has a sighting aperture in which an adjustable eye-piece is usually fitted. The thermal radiations ~~impinge~~ attack on the concave mirror whose position can be adjusted suitably by a rack-&-pinion arrangement so as to get proper focussing of the thermal radiations on the detector disc "S". The detector ~~disc~~ disc is usually of blackened platinum sheet / foil & is connected to a thermocouple junctions or to a resistance thermometer bridge ckt. Leads ~~from~~ from the detector are come out of the casing to a meter for measuring the thermoelectric emf or the variation of electric resistance of the platinum foil.

The theory indicates that the rate ~~of~~ of radiation from a body A (the source) to a Body B (the pyrometer), i.e. $E_{A/B}$ is given by the Stefan - Boltzmann law as

~~$E_{A/B} = C \epsilon \sigma [T$~~

$$E_{A/B} = C \epsilon \sigma [T_A^4 - T_B^4]$$

$E_{A/B}$ - The energy received by the pyrometer in $W m^{-2}$

C — Geometrical factor to adjust the relative shapes of the 2 bodies — eg [$W m^{-2}$]

ϵ - Emissivity of the detector disc which varies from 0.05 to 1.0 for the theoretical black body

σ - Stefan - Boltzmann constant - 56.7×10^{-12} $kW\text{-}m^{-2}\text{-}K^{-4}$

T_A, T_B - Steady State Absolute Temperatures.

Selective Radiation Pyrometer ; The principle of this instrument is based on Planck's law which states that the energy levels in the radiation from a hot body are disturbed in the different wavelengths. As the temp. increases, the emissive power shifts to shorter wavelengths. The Planck's distribution eqn is ;

$$W = \frac{C_1 \lambda^{-5}}{e^{C_2/\lambda T} - 1}$$

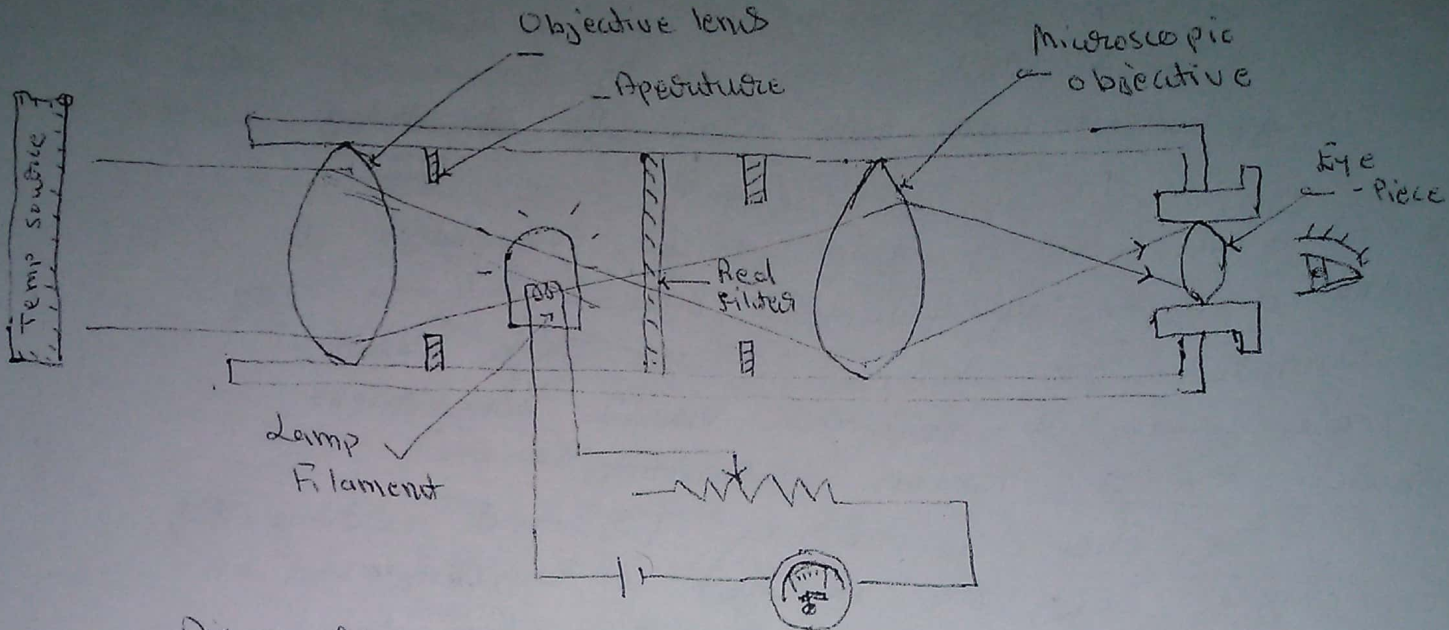
where C_1 - 3.74×10^{-12} $W\text{-}cm^2$

C_2 - 1.4385 cm-°C

λ – Wavelength in cm
T – Absolute Temp in K
W – energy level associated with wavelength at temp "T" in W/cm^3

The classical form of this optical pyrometer is the disappearing filament optical —//—. It is limited to temps. greater than about 700°C since it requires visual brightness match by a human operator.

In the disappearing filament instruments, an image of the target is superimposed on the heated filament. The tungsten lamp, which is very stable, is previously calibrated so that when the current thr. the filament is known the brightness temp. of the —//— is also known. A red filter that passes only a narrow band of wavelengths around 0.65 μm is placed betn the observer eye & the tungsten lamp & the target image. The observer controls the lamp current until the filament disappears in the superimposed target image. The accuracy of such pyrometers is usually ± 5°C in the range of 850°C – 1200°C.



Disappearing filament type of optical pyrometer

(a) Filament too dark

(b) Filament too bright

(c) Equal Brightness

Appearance of filament images when filament temps. are (a) Too high (b) Too low (c) Correctly matched.

$$V_o = \frac{1}{4}\frac{dR}{R}V_s$$
$$= \frac{1}{4} FE V_s$$
} Quarter Bridge.

$$V_o = \frac{1}{2} FE V_s$$ } Half Bridge.

$$V_o = FE V_s$$ } Full Bridge.

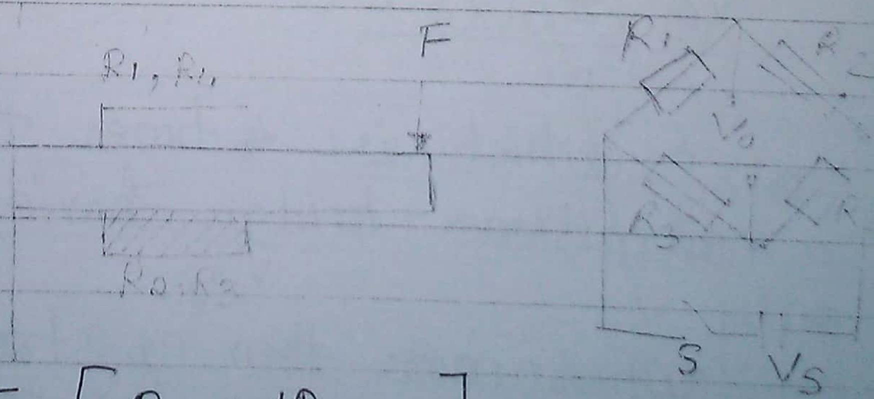
Note :-

Full Bridge :- When load is applied to the Beam, the resistances R_1 & R_4 increase due to tensile load. while the resistances R_3 & R_2 decrease due to equal compressive strain.

When Strain, the resistances of the various gauges are

$R_1 = R_4 = R + dR$ (Tensile)

$R_2 = R_3 = R - dR$ (Compresive)



$$V_{ab} = \left[\frac{R_1 + dR}{R_1 + dR + R_2}\right] V_s$$
$$= \left[\frac{R + dR}{\quad}\right.$$

$$V_{ab} = \frac{R_1}{R_1 + R_2} V_s$$

$$= \frac{R + dR}{R + dR + R - dR} V_s$$

$$V_{ab} = \frac{R + dR}{2R} V_s$$

$$V_{ad} = \frac{V_s}{2}$$

$$V_o = V_{ab} - V_{ad}$$

$$= \frac{R + dR V_s}{2R} - \frac{V_s}{2}$$

$$V_o = \frac{V_s}{2}\left(\frac{R + dR}{R} - 1\right)$$

$$= \frac{V_s}{2}\left(\frac{R + dR - R}{R}\right)$$

$$V_o = \frac{V_s}{2}\left(\frac{dR}{R}\right)$$

$$V_o = V_s F \epsilon \text{ (strain)}$$

Which is 4 times the output of a Wheatstone bridge having one gauge only.

When more then 1 strain gauge are active, the Bridge output & thereby

1kgf = 10N

the system senstivity increases.

Problem

A Wheatstone Bridge having one active gauge is supplied at 5V, and initially balanced. The gauge factor is 1.4. If it is attached carbon-steel bar of diameter 2cm, what will be the output voltage of the Bridge when a load of 850 kgf is applied in tension. Assume $E_{c.s} = 2.1 \times 10^6$ kg/fcm²

Soln Data:- $V_s = 5V$

$F = 1.4$

$d = 2cm = 0.02m$

Load = 850 kgf

$= 850 \times 10$ N

$= 8500$ N

$E_{c.s} = 2.1 \times 10^6$ kgf/cm²

$= \frac{2.1 \times 10^6 \times 10}{10^{-4}}$

$= 2.1 \times 10^6 \times 10^4 \times 10$

$E_{c.s} = 2.1 \times 10^{11}$ N/m²

$V_o = ?$

Soln Governing eqn for the above situation is

$$V_o = \frac{1}{4} \frac{dR}{R} V_s$$

$$= \frac{1}{4} F \epsilon V_s$$

quarter bridge ckt

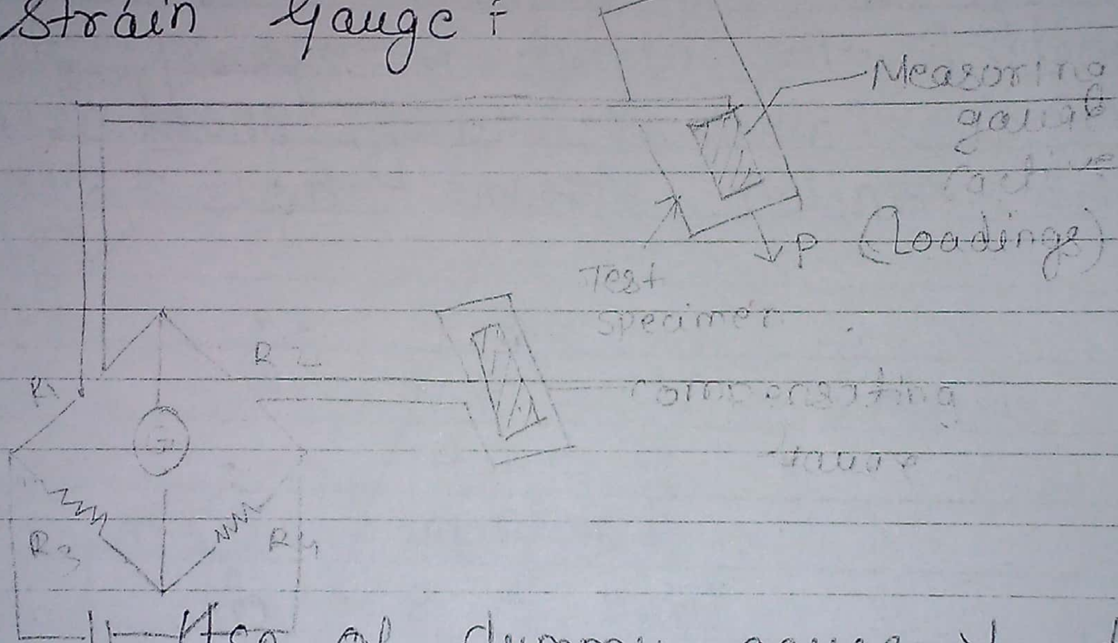
$$V_0 = \frac{1}{4} V_S F \epsilon$$

$$= \frac{1}{4} \times 6 \times 2 \times 0.002$$

$$= 6 \times 10^{-3} V$$

$$V_0 = 6 mV$$

Temperature Compensation For Strain Gauge :



Use of dummy gauge for temp compensation :

The ambient temp affect the change in resistence of strain gauge. It is compensated by the following arrangement.

The active gauge is mounted on the test specimen & constitutes R_1 of the bridge ckt. The gauge for temp compensation (dummy gauge) is connected to the link R_2

It is identical to the active strain gauge.

It is bonded to a separate ustrained component identical to that of the rotate member the dummy gauge remains unstrained throughout the test run & suffers change in resistance due to temperature only.

Now the situation is like.

Strain in active gauge
$= E_d + E_t$

& strain in dummy gauge.
$\rightarrow E_t$

where $d \rightarrow$ refers direct stress &
$t \rightarrow$ temp strain.

& now, the eqn of O/P voltage is given as

$$dV_o = \frac{V_s}{4}\left[\frac{dR_1}{R_1} - \frac{dR_2}{R_2}\right]$$

∴ (refer the derivation of half, quarter, full bridge ckt)

$$dV_o = \frac{V_s}{4}\left[\frac{dR_d + dR_t}{R_1} - \frac{dR_t}{R_2}\right]$$

$\therefore R_1 = R_2 = R$

$$dV_o = \frac{V_s}{4}\left[\frac{dR_d + dR_t - dR_t}{R}\right]$$

$$dV_o = \frac{V_s}{4}\left[\frac{dR_d}{R}\right]$$

* Elastic Force Devices :-

These are important for measurement of both static & dynamic forces. In such devices the force applied to the elastic member results in a displacement / strain in the elastic member, which is sensed by mechanical or electromechanical means. The elastic member may be in the form of rings, diphrams, strips or cylinders.

* VIBRATING REED TACHOMETER

1. VRT is working on the fact that speed & vibration in a body are inter-related, the instrument consist of a set of vertical reeds, each having its own freq. of vibration.
2. The Reeds are lined up in order to their natural frequency & are fasten to a base plate at one end, with the other end free to vibrate
3. When the tachometer is placed in a mechanical contact with the frame of a rotating m/c a reed tuned to resonance with the m/c vibration response most frequently.

4. The indicated reed vibration frequency can be calibrated to indicate the speed of the rotating m/c.

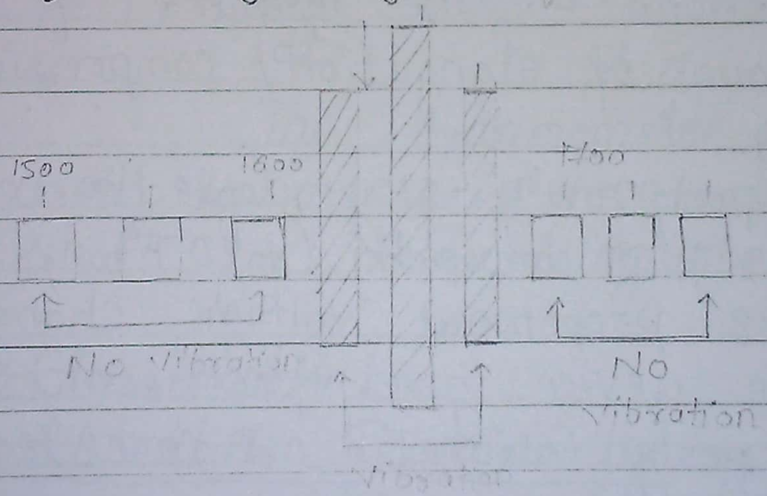
These tachometers ~~may~~ need only a firm contact with the m/c & there is no shaft connection.

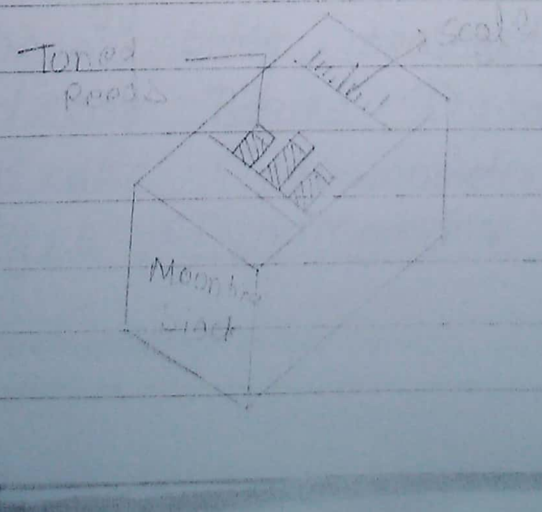
These aspects suggest their ~~views~~ use when shafts are inaccessible or are sealed, such as those of a hermatically sealed refrigerating compressor.

Range — 600 to 10,000 rpm

Accuracy — ± 0.5 %

It is well explained with the following fig.





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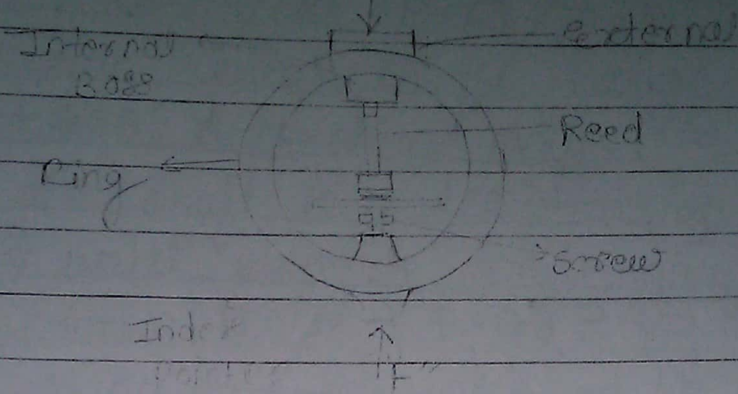
PROVING RING FOR Force Measurement

1. It is a ring of known physical dimensions & mechanical properties. When an external compressive / tensile load is applied to the external element, the ring changes in its diameter, the change being propotional to the applied force.
2. The amount of ring deflection (being an elastic membrane) is measured by means of a micrometer screw & a vibrating reed, which are attached to the internal element.
3. The difference in the micrometer reading taken before & after the application of load is the measure of the amount of elongation / compression of the ring.
4. The proving ring deflection can also be pick up by (LVDT), resulting in a propotional voltage change
5. The device gives precise results & properly Calibrated & corrected for temperature variation.



PROVING RING / STRESS RING.

Power Measurement (Dynamometers)

$$T \times \omega = \frac{2\pi N T}{60} \quad \text{If } N \text{ is in rpm.}$$

$$F = m \times a$$
$$W = F \times d$$
$$P = \frac{dW}{dt}$$

The dynamometer is a device used to measure the torque of a rotating shaft for determining the shaft Power.

Classification:-

Absorbtion Dynamometer:- In this the energy is converted into heat by friction when being measured, this type includes Prony Brake Dynamometer, Hydraulic Brake Dynamometer & Eddy current type Dynamometer.

$$T = (W-S) \times R_{eff}$$
$$= (40-5) \times 0.51$$
$$T = 17.85\ Nm$$

$$P = \frac{2\pi N T}{60} = \frac{2\pi \times 3000 \times 17.85}{60}$$

$$\boxed{P = 560.77\ Watt}$$

* TORSION DYNAMOMETER / TORSION METER

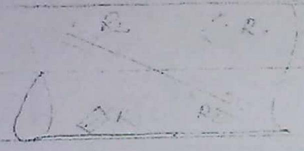


fig (i)
Resistances mounting on the shaft

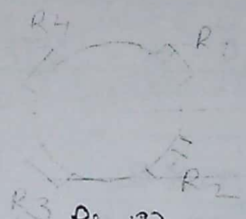
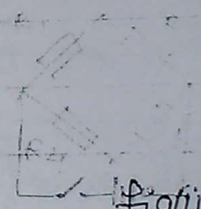


fig (ii)
Arrangement of resistances on the periphery of the shaft



fig(iii)
Arrangement for wheat stone Bridg

i. During torsion of a cylinder the principle strains (tensile or compressive) exist at 45° to the axis, these can be measure by bonded resistance gauges.

ii) ~~But~~ Four Strain gauges are mounted on a 45° helix with the axis of rotation as shown above.

The system is temp compensated & also insensitive to Bending and thrust, Also coal effects.

Any change in the gauge ckt is due to torsion deflection only.

3. When the shaft is under torsion gauges ① & ③ will elongate while gauges 2 & 4 will contract.

This principle strains (E) can be measured & the shaft torque can be calculated.

4. For taking signals from the rotating shaft slip rings & brushes are used.

Note :- For a rotating shaft subjected to torque within elastic limit, the governing eqn is

$$\frac{T}{I_P} = \frac{f_s}{r} = \frac{G\theta}{L}$$

where,

T — Torque

I_p — Polar moment of inertia of shaft

f_s — Shear stress induced.

r — radius

G — modulus of rigidity of shaft material.

θ — Angular twist in radians

L — length of the shaft.

Er. Amol R. Malode

UNIT-V

Measurement of tempt. level, flow.

Unit - III

* Temperature measurement *

* Classification of tempt. measurement instruments:

I) Electrical method

a) Thermistor (electrical resistance)

b) Thermocouple.

II.) Non-Electrical method

a) Pressure thermometer.

b) liquid in glass thermometer.

c) Bimetallic thermometer.

III.) Radiations.

a) Radiation pyrometer.

b) optical pyrometer.

1) Thermistor

Thermistor is thermally sensitive variable resistor available in two types:

i) Negative tempt. coefficient thermistor:

- In this type of thermistor, as temperature increases, it's resistance decreases. & as tempt. ↓, Resistance ↑
- It is made of semiconducting materials.
- These are manufactured by from the oxides of copper, manganese, nickel, cobalt & Lithium.
- these oxides are blended in a suitable proportion and pressed into the desired shape by using binder and lastly sintered.
- Thermistors may be shaped in the forms of bead, washers, rods, disk.

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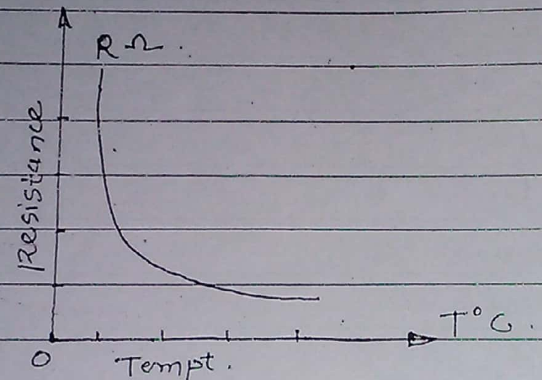
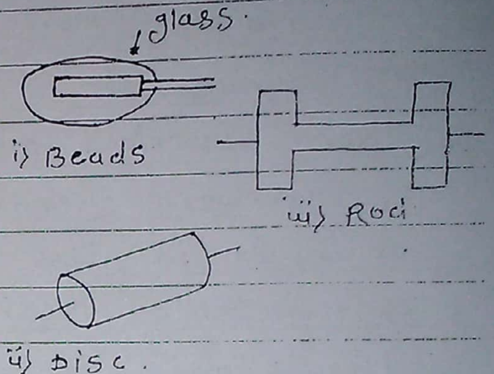
• Disk & rod type are used more as time delay element; temp compensators & for voltage & power control in electrical ckt.

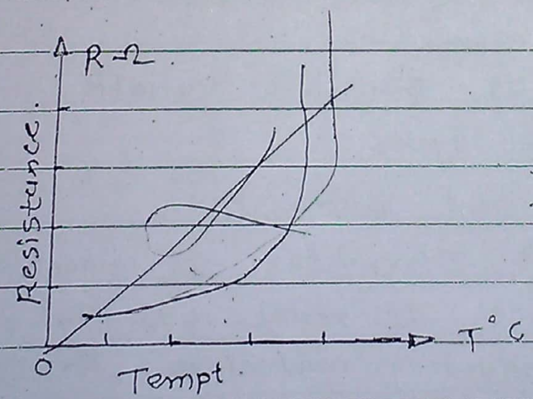
• The electrical behaviour of thermistors are controlled by varying the type of oxide used and physical size and shape of thermistors.

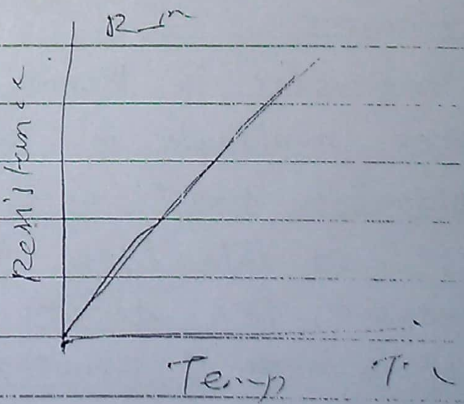




ii) Positive tempt. coefficient thermistor:

In this type of thermistor, As the tempt. increases, it's resistance increases.





Advantages:

i) The operating range is -100°c to 300°c. which is fairly good.

ii) It is small and compact having high sensitivity.

iii) It is more stable. & cost low

Disadvantages:

i) it has non-linear characteristics.

ii) It requires external energy source.

iii) Not suitable for wide range

The most commonly or the generally used method for the temp measurement are the thermo-electric sensor is called as thermocouple.

* Thermocouple: (Thermo-electric sensor)

Working principle.

thermocouple works on seebeck effect,

Seebeck effect :-

It states that when two dissimilar metal wires are joined together so as to form two junctions, if one junction is kept at reference tempt, and it's another junction is heated then it gives e.m.f. between two terminals of metal wires and the magnitude of emf measured is directly proportional to change in tempt.

Thermoelectric effect arises in two ways:

1) peltier effect :-

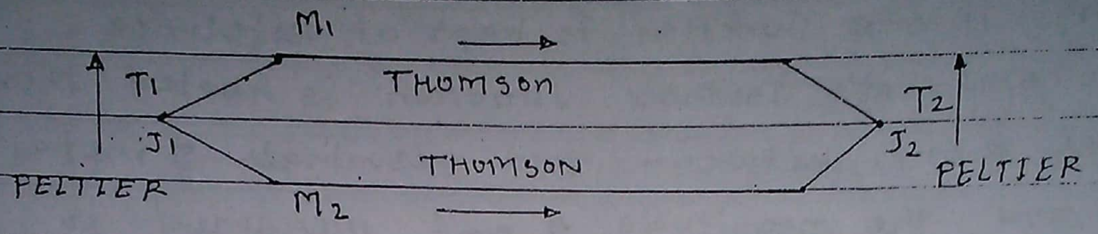
When the thermo electric current is allowed to flow through the circuit, the tempt T_1 & T_2 at junctions J_1 & J_2 are slightly altered. Thus, there is a generation of heat at cold junction and is absorbed from hot junction, thereby heating the cold junction slightly and cooling the hot junction slightly. This effect is known as peltier effect.

peltier effect can be stated as "a potential difference always exists between two dissimilar metals in contact with each other".

2) Thomson effect :-

The junction emf may be slightly altered if a tempt. gradient exists along either or both the materials. This is known as Thomson effect.

Thus, a potential gradient exists even in a single conductor having a tempt. gradient.



Construction & Working :→

If junctions A & B are maintained at same tempt, no current will flow around the circuit since the emf in the circuit will be equal & opposite. If, however, A is heated to a higher tempt than B, then current will flow since the emf at one junction will be greater than the opposing emf at the other junction.

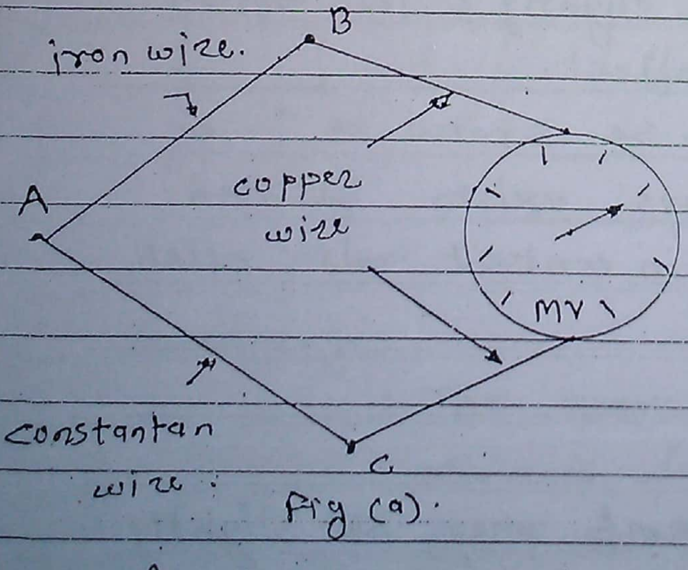


Fig (a).

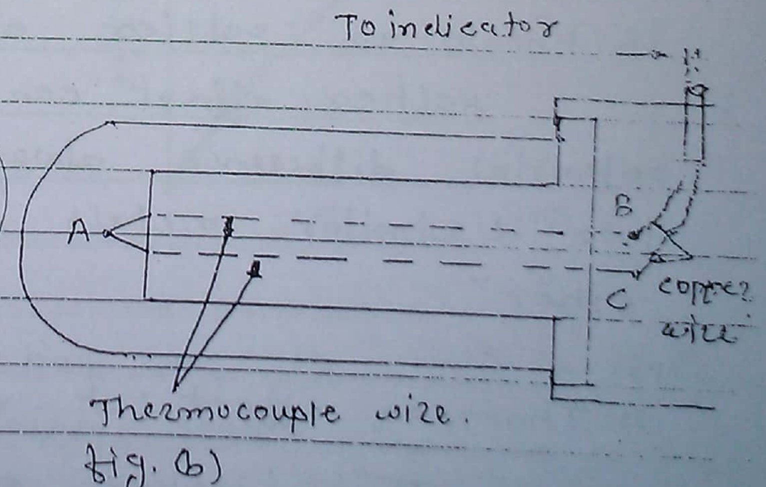


fig. (b)

fig (a) shows a thermocouple consisting of two wires, one iron, one constantan (i.e. copper nickel alloy), with millivoltmeter coupled to copper wire.

- Fig (b) shows AB & AC as thermocouple wires, if junctions B & C are maintained at same tempt, the introduction of third wire BC will not affect the emf generated.
- 'A' will be hot junction and B with C form cold junction.
- Thermocouple wires AB & AC shown as iron & constantan resp. can be made of various metals and alloys depending on operating tempt.
- The wire BC is generally long compared to thermocouple wire and is made of copper.

Thermocouple characteristics:

When the tempt at reference & hot junction is same, then the reading shown by millivoltmeter is zero. When the tempt. of sensing junction increases, due to tempt. difference it circulates current through dissimilar metals creating potential drop across it. This is measured by millivoltmeter. Therefore, the reading shown by voltmeter is directly proportional to change in tempt.

Advantages:

i) Design is very simple.

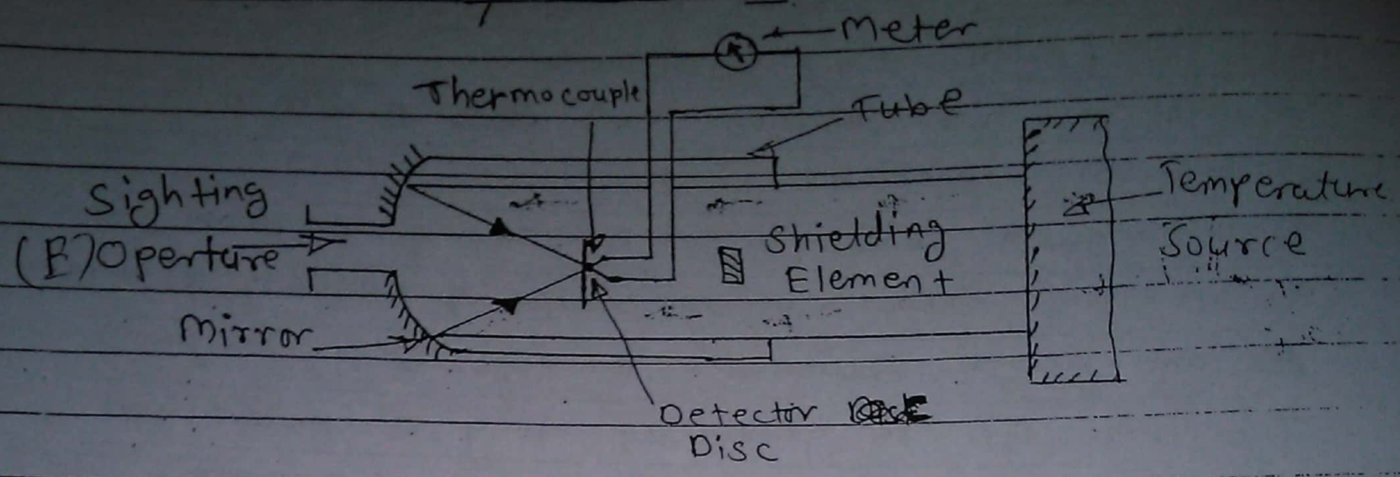
ii) It does not require external excitation source.

Disadvantages:

i) Lower accuracy.

ii) It has a non-linear characteristic at higher tempt.

* Radiation Pyrometer OR Total Radiation Pyrometer



Principle:→

The radiation pyrometers are intended to measure the total energy of radiation from a heated body. It operates according to Stefan - Boltzman law.

Construction & Working:→

- The pyrometer consists of a blackened tube 'T' open at one end to receives radiations from the object whose tempt. is to be measured.
- The other end (E) of a tube has a hole in which adjustable eyepiece is fitted.
- The thermal radiation impinge on the concave mirror whose position can be adjusted by Rack & Pinion arrangement so as to get proper focussing of the thermal radiation on detector disc 'S'. (Say hot junction of thermocouple)
- The emf developed by the thermocouple circuit is measured by a suitable milli-voltmeter, which can be calibrated to give tempt. of the radiating body.

~~Advantages~~

~~i) It has fast~~

The rate of radiation from body A (source) to body B (Pyrometer). $E_{A/B}$ is given by the Stefan Boltzman's law

$$E_{A/B} = C \epsilon \sigma [T_A^4 - T_B^4]$$

where,

$E_{A/B}$ = Energy received by Pyrometer.

σ = Stefan Boltzman's constant
= 56.7×10^{-12} kW/m²K⁴.

C = Geometrical factor to adjust the relative shapes of two bodies.

ϵ = Emissivity of detector disc.

T_A = Absolute tempt of source.

T_B = Abs. tempt. of pyrometer detector disc.

Advantages:

i) It has fast speed of response.

ii) It can measure the tempt. of moving objects like molten metal.

iii) It is less affected by corrosive atmosphere.

Application:

i) It measures tempt. of moving objects.

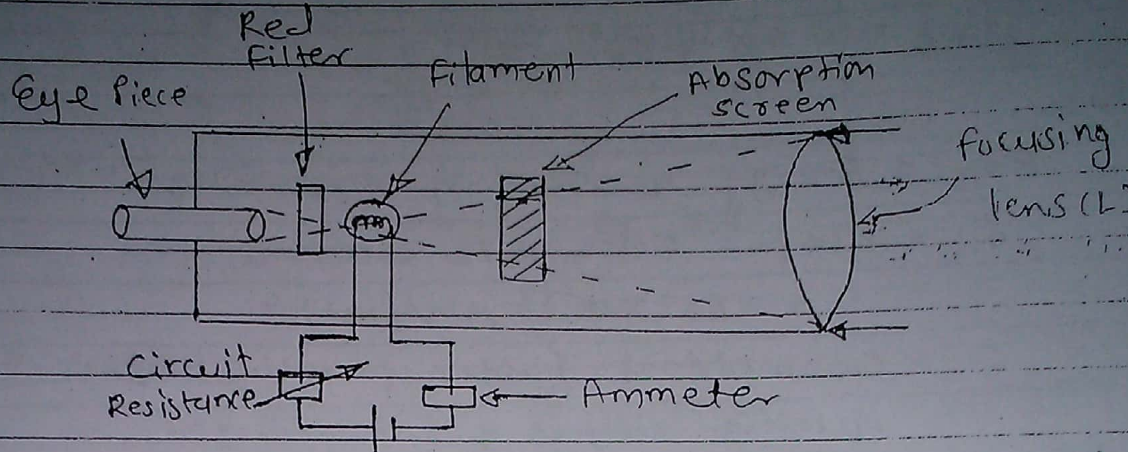
ii) It is used to measure average tempt. of large surface.

Dis-advantage.

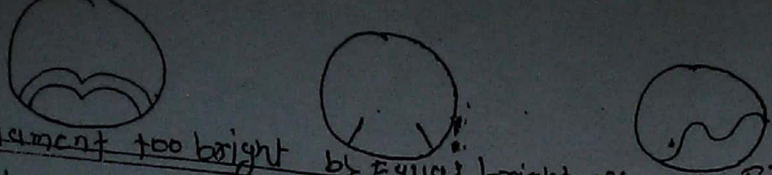
(1) Error may be introduced by smoke or gases between the observer & the source

(2) Uncertainity as to the amount of departure from black body Conditions.

* optical Pyrometer
or Disappearing filament Pyrometer.
or selective radiation pyrometer.



- When radiation from heated body at high tempt. falls within the visible region of electromagnetic spectrum.
- An image of radiating source is produced by lens and made coincide with filament of lamp.
- In optical pyrometer wavelength of radiation accepted is restricted by colour filter and it's brightness is compared with standard lamp.
- The current through the lamp filament is made variable so that lamp intensity can be adjusted. The filament is viewed through the eyepiece and filter. The current through the filament is so adjusted that filament and image are of equal brightness. When brightness of source and image produced is same, we can say both tempt. are same.
- However if the tempt. of filament is higher than that required for equal brightness,



a) Filament too bright b) Equal brightness c) Filament too dark.

filament become too bright in fig (a). & if the tempt of filament is lower, it becomes too dark as shown in fig (c)

- The intensity of light of any wavelength depends on tempt. of radiating body and tempt of filament depends upon the current flow through the lamp.
- The optical pyrometer can be ~~easily~~ directly calibrated in terms of filament current.
- But filament current depends on resistance of the filament, therefore, modern type of pyrometers are calibrated in terms of resistance of filament.

Advantages:

i) optical pyrometer is portable.
ii) It can be used to detect the tempt. of moving object.
iii) It is also used to detect the tempt at distant places.

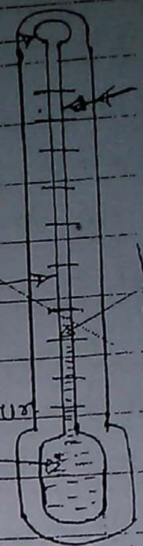
Disadvantages:

i) Device is very costly.
ii) More chances of human error while adjusting the image.
iii) It measure the tempt. of only hot surfaces.

Application:

(i) Optical pyrometer can be used for accurate measurement of furnance
(ii) It can be used to measured molten metal & other heated material.

* Liquid in Glass thermometer:



It is one of the most common devices used for the temperature measurement.

Construction :→

- The device consists of glass envelope, a responsive liquid and a calibrated tempt. indicating scale.
- The envelope consists of a thick-walled glass tube with a capillary bore and a cylindrical bulb filled with liquid.
- The capillary tube and cylinder are fused together as a single unit and the capillary tube is sealed.
- The fluid generally used in bulb is the mercury.
- The top of the capillary tube is also bulb shaped to provide safety feature in case tempt. range of instrument is exceeded.

Working :→

As the tempt. rises, the fluid in the bulb expands and rise up the stem.

As the area of stem is much less than that of bulb, for small expansion of fluid, there is large rise in the stem, which indicates the tempt. of bulb by prior calibration.

Advantages:

i) Simplicity of use & relatively low cost

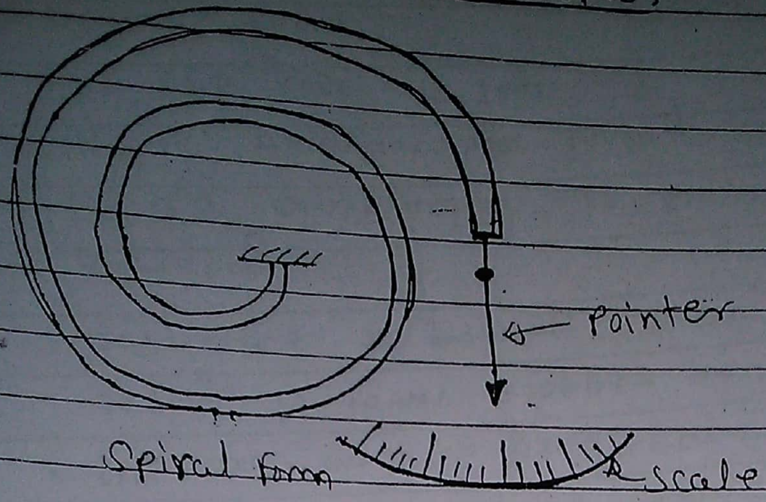
ii) checking for physical damage is easy.

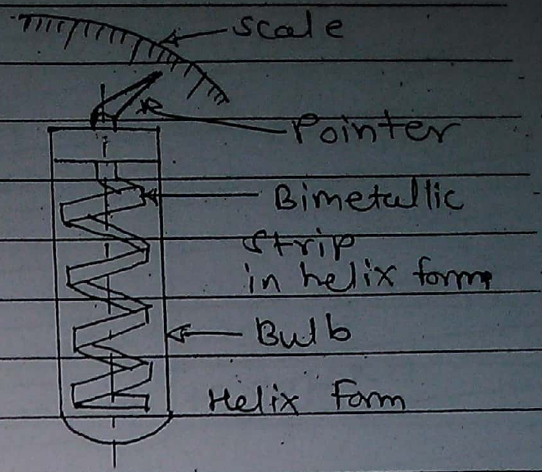
Disadvantages:

i) Time lag in measurement

ii) It can not be adopted for automatic recor

* Bimetallic Thermometer:





- Different two materials having different coefficient of thermal expansion rigidly joint together, one on other form a bimetallic strip.
- When bimetallic strip is fixed at one end heated from free end then it bends in the direction of material having low thermal coefficient of expansion.
- The bending movement of free end is connected to pointer which moves over calibrated scale.
- Always Bimetallic strip is wound in the form of helix or in the spiral form.
- It's one end is fixed permanently to outer casing to form stopper and other end is connected to pointer.

Advantages:

i) It's construction is simple.

ii) No maintenance is required.

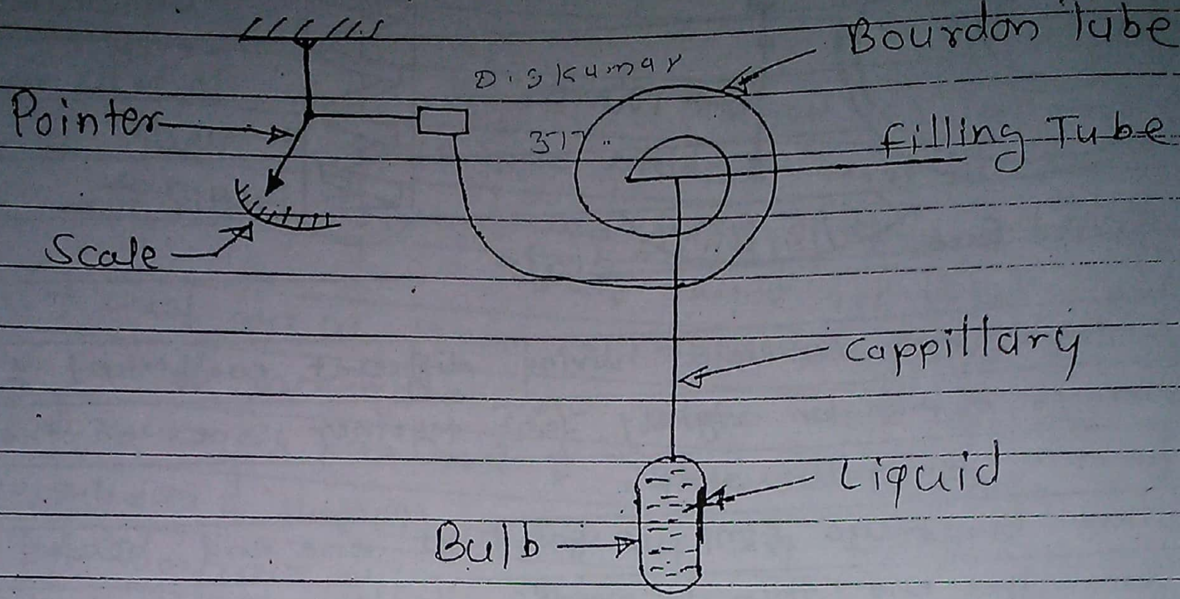
iii) It's cost is low.

Disadvantages:

i) Speed of response is low.

ii) Material is subjected to creep at high tempt.

* Pressure Thermometer:
OR Filled - system thermometer



Construction :-

It is widely used device in industrial tempt. measurement.

The system usually embodies:

i) A tempt. sensitive element (bulb) filled with expanding fluid.

ii) A flexible capillary tube.

iii) A pressure sensitive device such as Bourdon tube.

iv) A device for indicating a signal related to the measured tempt.

The bulb, capillary and gauge is directly calibrated on the basis of pressure change corresponding to the tempt change.

Working :-

As the tempt. rises, there is an increase in volume or pressure of material

filled in bulb. This effect is transmitted to Bourdon tube, through the fine capillary tube.
The Bourdon tube transmits the signal to the pointer through the mechanical linkage and pointer indicates the measurement on the calibrated scale.

* Resistance Thermometer Detector (RTD)
OR Resistance thermometer.
OR Platinum Resistance Thermometer
OR Que: How does resistance change with tempt for resistance Thermometer?
which is the best material for such a thermometer?

Principle :→
RTD works on the principle of positive temperature coefficient of resistance i.e. as tempt. increases, resistance offered by thermometer also increases.
The resistance of wire at t°C is given by

$$R_t = R_o (1 + \alpha_o t).$$

where, R_t - Resistance at t°C.
R_o - Resistance at 0°C.
α_o - Resistance tempt. coefficient.
t - change in tempt.

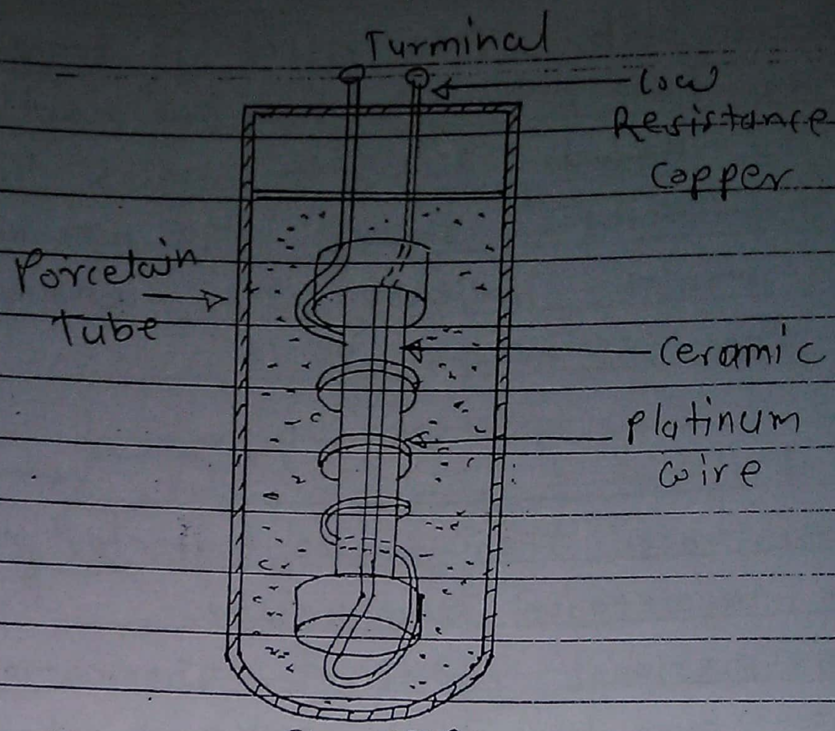


Fig. RTD

Construction & Working :→

- figure shows the modern platinum resistance thermometer.
- It consists of pure, well-annealed platinum wire wound on thin strip of insulating ceramic and placed in porcelain sheath.
- Free ends of platinum wire are attached to long lead of low resistance copper wires.
- To measure the change in resistance, Bridge network is used.
- The resistance thermometer is connected to one of the arm of wheatstone bridge circuit. When resistance thermometer is subjected to tempt. variation, the wheatstone bridge gets unbalanced.
- The galvanometer deflection can be directly calibrated to give temperature.
- The unknown tempt is given by

$$t = \frac{R_t - R_0}{R_{100} - R_0} \times 100$$

where, R_t - Resistance of wire at tempt. 't'
R_0 - Resistance of wire at 0°C.
R_{100} - Resistance of wire at 100°C.

Advantages:

i) It can be used for wide range of tempt from -200°c to 1200°c.
ii) It has linear characteristics.
iii) Installation is easy.
iv) It has high sensitivity.

Disadvantages:

i) Response is low.
ii) Balancing of the bridge takes time.
iii) Possibility of current leakage between resistance element & ground.

* Differentiate between RTD & thermistor.

RTD	Thermistor
i) The industrial thermometer is referred as resistance tempt. detector.	i) They are essentially semiconductors which have behave as resistors with a high negative tempt. coefficient.
ii) change in resistance is directly proportional to change in tempt.	ii) Tempt. is inversely proportional to the resistance.
iii) Leads are taken out of the thermometer for measurement of change in resistance in order to	iii) The change in resistance is measured by using circuitry similar to that of metal

determine the value of tempt.

iv) The operating range of RTD is much greater i.e. from -160° to 600°C.

v) Metal resistance elements are more stable than oxides, they provide better reproducibility with low hysteresis.

conductor.

iv) The operating range of thermistors lies betn -100° to 300°C.

v) Thermistor have the advantage of high sensitivity, availability in very small sizes, fast thermal response, fairly low cost.

* Differentiate betn RTD & Thermocouple.

i) Thermocouple sensing element installed easily.

ii) Thermocouple have better response.

iii) Thermocouple have higher range of tempt. measurement.

iv) Resistance thermometer are more sensitive where as thermocouple has poor sensitivity.

v) change in ambient tempt. affects the accuracy of thermocouple but not in case of resistance thermometer.

vi) Resistance is a function of tempt & therefore RTD measures the tempt. directly. However, thermocouple measures the tempt. difference betn the hot and reference junctions.

=== o ===

ascertain – To find out

is then the difference between the voltages of the two secondary windings.

vii) At the null position of the core, the output voltage of secondary windings S_1 & S_2 are equal and in opposition. therefore, the net output is zero.

viii) Any angular displacement from the null position will result in a differential voltage output.

ix) Clockwise rotation produces an increasing voltage of a secondary winding of one phase while counter-clock-wise rotation produces an increasing voltage of opposite phase.

x) Hence, the amount of angular displacement and it's direction may be ascertained from the magnitude and phase of the output voltage of the transducer.

Sub: Mechanical Measurement & Metrology [redacted]
Topic: - Pressure Measurement

Instrument Used For Pressure Measurement

1) For measuring low pressure below 1 mm of Hg
   -Manometer, Mcleod gauge, Thermal Conductivity gauge
2) For medium and low pressure between 1 mm of Hg to 1000 atm
-Bourdon tube & Diaphragm gauge
3) For low vacuum or ultra high vacuum 760 torr to 10^{-9} torr & beyond
-Pirani gauge or thermal conductivity gauge
4) For very high pressure 10000 atm and above
- Bourdon tube, Diaphragm gauge, Electrical resistance strain gauge.
5) For varying pressure
- Cathode ray Oscilloscope, Dead weight piston gauge

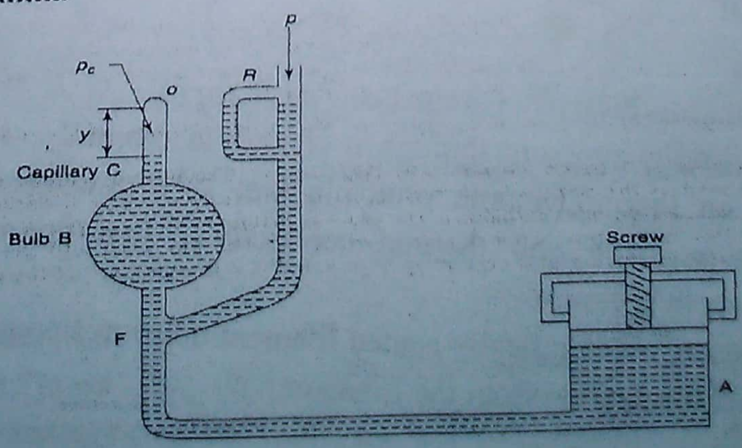
Low pressure Gauges

Pressure less than 1 mm of mercury considered to be low pressure
The pressure measuring devices for the low pressure i.e. vacuum can be classified as

1) Direct measurement
   Where the displacement or deflection caused by the pressure. It is incorporated in manometer spiral bourdon tube, flat and corrugated diaphragm and capsules.
2) Indirect measurement
   Where the low pressure is detected through the measurement of pressure controlled property such as volume thermal conductivity etc. These gauges includes Mcleod gauge, Thermal Conductivity gauge. Radioactive vacuum meter.

Mcleod gauge

- Mcleod gauge is a modified mercury manometer.
- It operates on the principle of compressing a known volume of low pressure gas to a high pressure and measuring the resulting volume change. with simple manometer
- The unknown pressure source is connected to a gauge as shown in fig. And the mercury level is adjusted so that the pressure source fills the bulb B and capillary C.
- Mercury is thus forced out of the reservoir A and reference column R
- When the level reaches to the cut off point F, a known volume of gas is trapped in the bulb and capillary.



- The mercury level is raised till it reaches to the zero reference point O in R.
- Under this condition the volume remaining in the capillary is read directly from the scale and the difference in height y is measure of the pressure p.

- Thus the p then obtained by Boyles law

  if , $p = unknownb\ pressure$

  $A = area\ of\ cross - ection\ of\ capillary$

  $V_c = volume\ of\ gas\ in\ capillary = Ay$

  $P_c pressure\ of\ gas\ in\ the\ capillary\ c\ after\ comression$

  $V_F = volume\ of\ capillary\ and\ bulb\ till\ F$

  $then$

$$p = P_c \frac{V_c}{V_F}$$

$Where$

$$y = P_c - p$$

The pressure being expressed in terms of height of mercury column
Therefore we can get

$$p = \frac{Ay^2}{V_F - Ay}$$

The capillary can be directly calibrated in terms of pressure p

Advantages

- Independent of gas composition

Pirani Gauge or Thermal Conductivity Gauge (10^{-5} *to* 1 *torr*)

- These gauges measures the pressure through a change in thermal conductivity, these operations is based on thermodynamic principle that is at low pressure there is a relationship between pressure and thermal conductivity i e thermal conductivity decreases with decrease in pressure.
- Further the temperature of an electrically heated filament depends upon the magnitude of current and rate of heat dissipation from the filament.

- If the current is kept constant, then there will be heat loss from the filament and hence its temperature will be governed by the surrounding gas medium
- Lower the gas pressure, lower will be the thermal conductivity and consequently higher the filament temperature. These aspect is utilised in thermal conductivity vacuum gauge where an estimate of gas pressure is made by measuring either temperature or resistance variation of the filament.

Pressure of gas is measured by following technique

1. Maintaining constant voltage on the wire and noting change in the current as a function of pressure
2. Maintaining the constant resistance and hence the temperature of the wire and noting the change in energy input as a function of pressure.
3. Maintaining the constant current and observing change in filament resistance as a function of resistance.

- Last technique is recommended as being the most sensitive for making pressure measurement
- Pirani gauge consist of platinum filament enclosed in a chamber, wire forms a part of wheat stone bridge.
- The temperature of the wire depends upon the rate of heat dissipation
- Thus with the change in pressure of the medium the temperature changes hence the resistance of the wire changes which can be measured by using Wheatstone bridge.
- A milli-ammeter carrying a current on account of unbalanced of bridge can be calibrated to read the pressure directly.

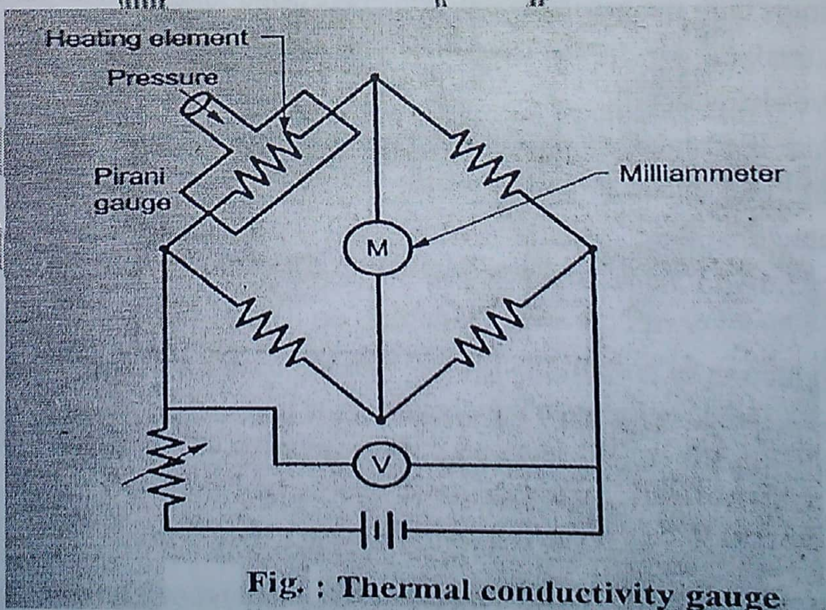


Fig. : Thermal conductivity gauge

Advantages

- Rugged more accurate
- Wide pressure reading range
- Fast response to the pressure changes
- In most of its range gives linear characteristics.

Disadvantages

- It is more expensive
- It needs frequent and individual calibration
- Its require electrical power

Ionisation gauge

- It is also known as triode vacuum tube
- It consists of cathode grid and anode
- Grid is maintained at positive potential at 100-300 Volt
- Anode is maintained at negative potential with respect to cathode, cathode is thus a positive ion collector and anode plate is electron collector.
- When electrons are emitted by heated cathode, the high positive change on grid accelerates the stream of electron away from the cathode.
- Most of the electron passed the grid because of their speed and wide spacing of the grid.
- These electron colloids with the gas molecule, thereby causing ionisation of gas atom.
- Ionisation is the knocking off an electron from one atom and thus producing a free electron and positive charged ion.
- Since the anode plate is maintained at negative potential , the positive ions in the space between the grid and the anode migrate towards the anode plate and a current I_1 is produced in the plate.
- The electron and negative ions are collected by the grid and a current I_2 is produced in the grid circuit.
- The rate of ion production is proportional to the number of electron available to ionise the gas and the amount of gas present.
- Thus the ratio of positive ions i e anode current I_1 to negative ions and electrons i e grid current I_2 is the measure of gas pressure P.
- Therefore following approximate relation holds good

$$P = \frac{1}{S} \times \frac{I_1}{I_2}$$

- where, S is the sensitivity of gauge and it is the function of tube geometry, nature of gas and operating voltage

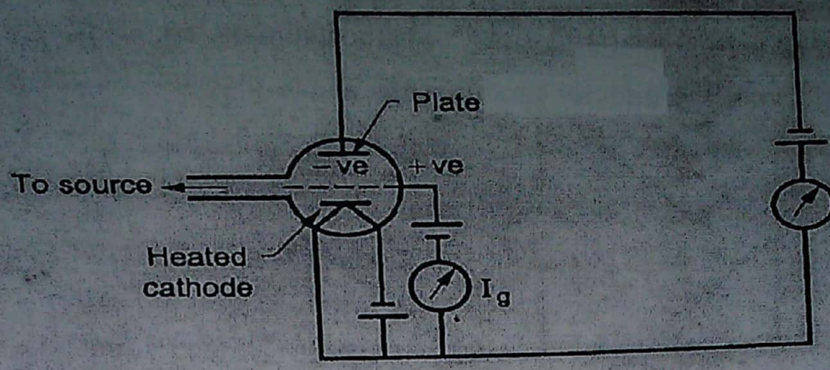


Fig. Ionization gauge

Advantages

- Wide pressure reading range
- Fast response to the pressure changes
- Sensitivity is constant for a given wide range.

Disadvantages

- High cost and complex electrical circuitry.
- Calibration varies with gases
- Decomposition of some gases by the hot filament.
- Contamination of measured gas by gases forced out of the hot filament.

Knudson Pressure gauge

- It is an enclosed chamber in which the gas whose pressure P is to be measured.
- The gauge consists of two heated plates.
- Each of these plates is maintained at absolute temperature T, which must be measured.
- A movable vane is placed between the two heated plates, the movement of vane is restrained by a springs.
- A mirror is attached to the movable vane on which a beam of light falls and this beam of light deflected with the movement of the vane.
- The deflection is measured by scale on which it falls.
- The separation distance between the fixed plate and the movable vane must be less than the mean free path of the surrounding gas.
- The absolute temperature of the gas T_g which is also the temperature of the vane.
- The gas molecule striking the vane from the hot plate has a higher velocity than that of the gas molecule leaving the vane.

- Thus there is the net momentum imparted to the vane giving rise to the net force F, which is measured by observing the angular deflection of the beam on the mirror.
- The force produced on the vane is directly proportional to the pressure for the given value T and T_g according to the following relationship

$$P = \frac{KF}{\sqrt{\frac{T}{T_g} - 1}}$$

Where,
K is constant

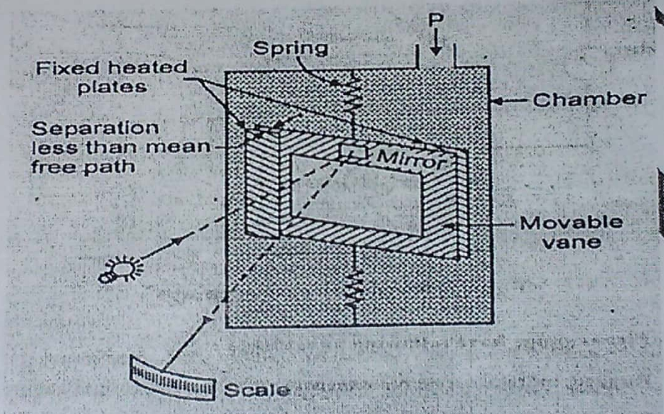


Fig. Knudsen gauge

Advantages

- It gives an absolute pressure P.
- It is independent of gas composition

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* LDR or Light dependent resistor

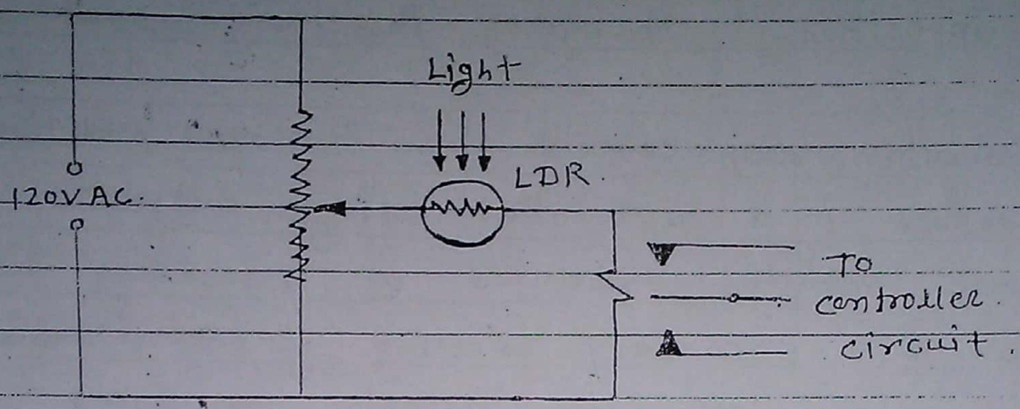

Fig: Light dependent Resistor

i) A Light dependent resistor is shown in figure.

ii) It works on the principle of photo-conductive effect.

In photo-conductive effect, the electrical resistance of the material varies with the amount of incident light.

iii) When the LDR has the appropriate light shining on it, it's resistance is low and the current through the relay is consequently high enough to operate the relay.

iv) When the light is interrupted, the resistance increases causing the relay current to decrease enough to de-energise the relay.

Advantages:

i) sensitivity is high

ii) output given is in the form of electrical signal.

iii) Resolution is good.

Disadvantages: i) Non-linear characteristics.

UNIT - II & III

1) Total Radiation Pyrometer:

* Advantages :→
  i) Can be used to measure the tempt. of an object which may be either stationary or moving, and so adaptable to continuous industrial processing.
  ii) High speed of response.
  iii) Accuracy ±2% of scale.
  iv) Direct contact is not necessary with the object whose tempt. is to be measured.
  v) Relatively independent of the distance betn. the measuring element & the heated body.

* Disadvantages :→
  i) In the situations where the tempt. may be high due to operating conditions, cooling is required to protect the instrument from overheating.
  ii) The presence of dust & dirt on the mirror or lens causes the instrument to read too low.

40

Optical Pyrometer

* Uses :→

The optical pyrometer is widely used for accurate measurement of tempt. of :

- furnaces
- molten metals.
- other heated materials.

* Advantages :→

i) No direct contact is necessary with the object whose tempt is to be measured.

ii) Excellent accuracy within ±5°C for the operating range 700 - 3000°C.

iii) measurement is independent of the distance betn. the target & measuring instrument.

* Disadvantages :→

i) The lower measuring tempt. is limited to 700°C (The eye is insensitive to wavelength characteristics below this tempt.)

ii) owing to the manual null - balance operation of this pyrometer it is not suitable for continuous reading or automatic control applications.