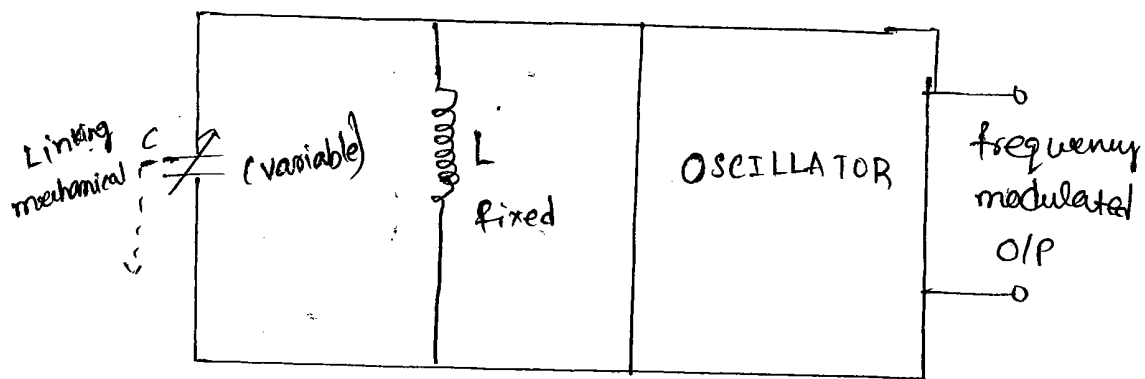


Displacement measurements

Linear or Translational displacement can be measured by a number of transducers such as resistive potentiometers, strain gauges, inductive transducers, LVDT's, etc.

Similarly rotational displacement can be measured by resistive potentiometers, inductive transducers, RVDT's reluctance transducers --- etc.

A scheme for measuring of displacement employing a capacitive transducer is shown in figure.



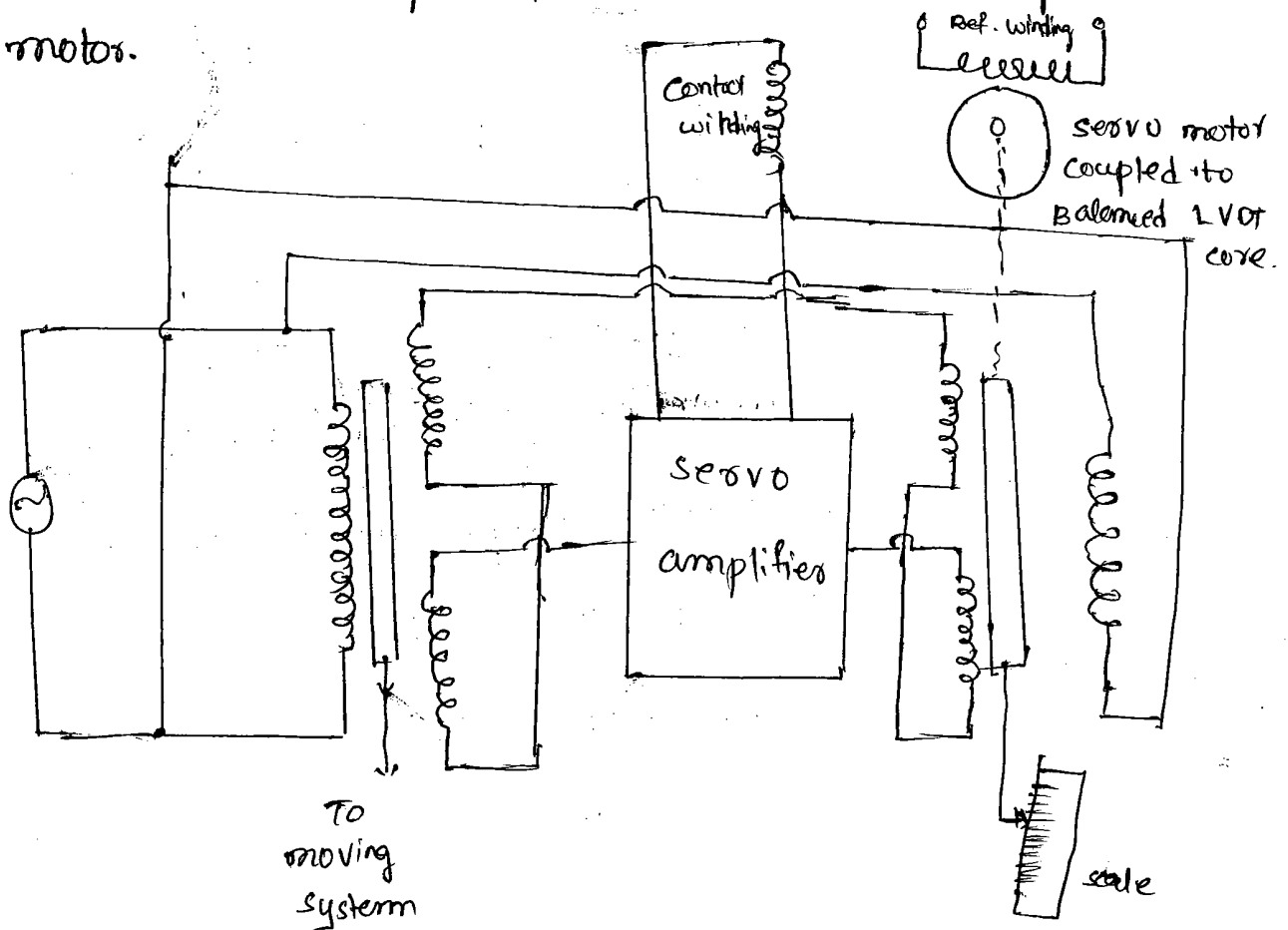
The basic scheme employs the basic elements of an LC oscillator whose frequency is affected by the variation in capacitance of capacitor.

Movable plate of the capacitor is coupled to the moving system. So any movement of

The moving system causes variation in the capacitor capacitance because of variation in separation between plates which in turn causes change in frequency of oscillator. The change frequency is measurement of the magnitude of the displacement under measurement.

Another scheme for measuring displacement employing two LVDT's in a closed loop servo-system.

The resultant of series combination of LVDTs are fed to a servo amplifier. That drives a two phase servo motor.



The servo motor shaft is mechanically coupled to the core of the balancing LVDT. The servo motor continues rotating until the outputs of the two LVDTs are equal as in that case only, no voltage is delivered to the servo amplifier.

The displacement of the balancing LVDT, which is a measure of the displacement under measurement is read on scale.

STRAIN measurement:-

Strain measurement with the help of strain gauge already explained. Resistance of strain gauge gets changed under strained condition and since change in resistance is very small, of the order of 0.2%. For its measurement extremely sensitive & sophisticated instrument is required.

Potentiometer circuit:-

The output voltage appearing across the strain gauge under unstrained condition is-

$$V_{out} = \frac{R_s}{R_s + R_b} V_{in}$$

When gauge is strained

$$\Delta V_{out} = \frac{R_s + \Delta R_s}{R_b + (R_s + \Delta R_s)} V_{in} - \frac{R_s}{R_s + R_b} V_{in}$$

$$= V_{in} \left[\frac{R_s + \Delta R_s}{R_b + (R_s + \Delta R_s)} - \frac{R_s}{R_s + R_b} \right]$$

$$= V_{in} \left[\frac{R_b \Delta R_s}{(R_s + R_b)(R_b + R_s + \Delta R_s)} \right]$$

$$= V_{in} \cdot \frac{R_b}{(R_s + R_b)^2} \cdot \frac{\Delta R_s}{R_s}$$

$$\Delta V_{out} = V_{in} \frac{R_b R_s}{(R_s + R_b)^2} G_f \epsilon$$

hence output voltage under strained condition of gauge is directly proportional to strain (ϵ)

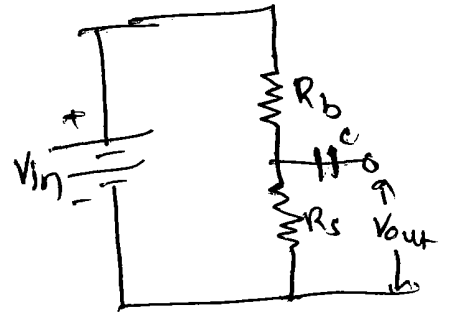
$$\text{Voltage sensitivity} \Rightarrow S_v = \frac{\Delta V_{out}}{\epsilon} = \frac{R_b R_s}{(R_s + R_b)^2} V_{in}$$

When $R_s = R_b$

$$S_{vmax} = \frac{1}{4} G_f V_{in}$$

This circuit can be used for measurement of dynamic strain, where static strain component is negligible.

A capacitor 'c' is therefore connected in series in one of the leads. It acts as t.p.f and does



R_b - Ballast Resistor

R_s → Gauge Resistor

permit dc component of output voltage because of strain to reach output terminals. It permits to pass only ac component of output voltage owing to dynamic strain.

Wheat stone Bridge circuit:

It can be employed for determination of Both dynamic & static strains. In wheat stone bridge, one arm consist of strain guage, where other three arms have standard Resistor of nearly equaly resistance as that of the guage resistance in unstained condition.

The wheatstone bridge can be used for measurement of strain in two-different ways

- Null method
- Deflection method

in Null method, one of 3 resistors are readjusted manually or automatically to balance bridge and required readjustment gives a measure of change in strain guage resistance.

Under, unstained (normal) condition, be R_1 , All other resistance are equal to that of strain gauge resistance R_1 .

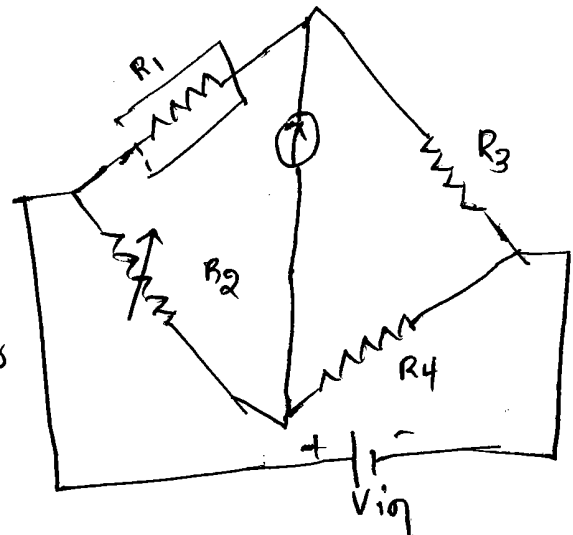
$$\text{Gauge factor } G_f = \frac{\Delta R_1 / R_1}{\epsilon}$$

for balancing the bridge R_2 is changed, let this change be ΔR_2 which will equal to change in resistance of strain gauge i.e., ΔR_1 .

Hence

$$\left. \begin{array}{l} \Delta R_2 \\ = \Delta R_1 \end{array} \right| \epsilon = \frac{\Delta R_2 / R_2}{G_f}$$

This method is used for measuring static strain.



In the deflection or out-of-bound or direct reading

method The output voltage variation.

Initially when the bridge is

balanced the output voltage

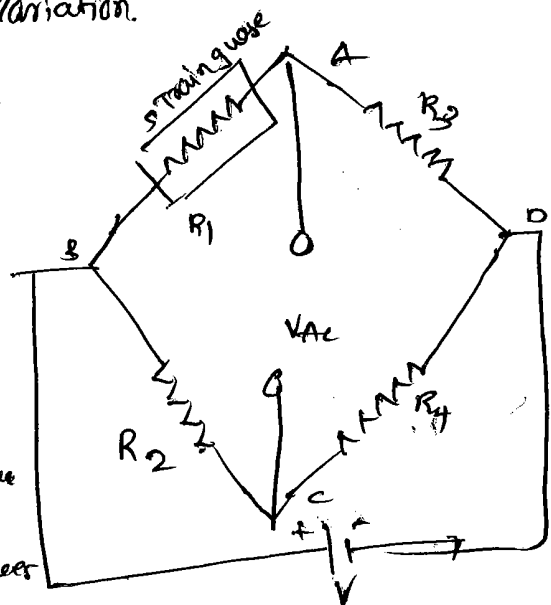
that appears across terminals

A & C i.e. $V_{AC} = 0$ & $R_1 R_4 = R_2 R_3$

Now change in resistance

of the strain gauge unbalances

the bridge & a voltage appears across terminals A & C.



The meter deflection indicates the variation in strain gauge resistance and actually can be utilized for computation of this variation.

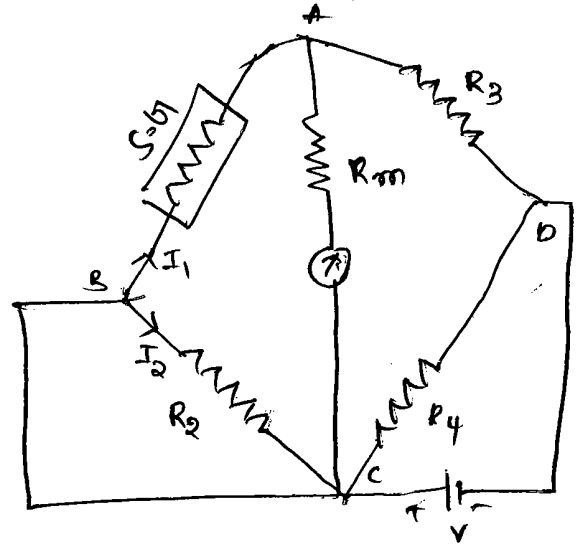
The output can be applied to an oscilloscope, rather than meter. Thus measurement of rapid dynamic phenomenon is possible.

Mathematically,

$$\text{For } I_m = 0$$

$$I_1 = \frac{V}{R_1 + R_3}$$

$$I_2 = \frac{V}{R_2 + R_4}$$



$$V_{AB} = I_1 R_1 = \frac{V R_1}{R_1 + R_3}$$

$$V_{CB} = I_2 R_2 = \frac{V R_2}{R_2 + R_4}$$

$$V_{AC} = V_{AB} + V_{BC} = V_{AB} - V_{CB}$$

$$= \left[\frac{R_1}{R_1 + R_3} - \frac{R_2}{R_2 + R_4} \right] V$$

Under normal conditions $R_1 = R_2 = R_3 = R_4$ & variations in the resistances are such that $+\Delta R_1, -\Delta R_2 = +\Delta R_4 = -\Delta R_3$

$$V_{AC} = \left[\frac{R_1 + \Delta R_1}{(R_1 + \Delta R_1) + (R_3 + \Delta R_3)} - \frac{R_2 + \Delta R_2}{(R_2 + \Delta R_2) + (R_4 + \Delta R_4)} \right] V$$

$$\approx \frac{\Delta R}{R} V$$

$$S = \frac{V_{AC}}{\Delta R} = \frac{V}{R}$$

Gauge sensitivity: Let the resistance of strain gauge increased by ΔR in strained condition

$$\& R_1 = R_2 = R_3 = R_4 = R$$

Then $I_1 = \frac{V}{2R + \Delta R}$, $I_2 = \frac{V}{2R}$

$$V_{AC} = I_2 R - I_1 R = (I_2 - I_1) R$$

$$= R \left[\frac{V}{2R} - \frac{V}{2R + \Delta R} \right]$$

$$= \frac{V}{2} - \frac{V}{2} \left[1 - \frac{\Delta R}{2R} \right]$$

$$V_{AC} \approx \frac{V}{4} \frac{\Delta R}{R} = \frac{V}{4} G \epsilon$$

$$\left[\frac{\Delta R}{R} = G \times \frac{\Delta l}{l} \right]$$

$$S = \frac{V_{AC}}{\epsilon} = \frac{V}{4} G$$

Problem:- A strain gauge has a resistance of 120Ω & gauge factor 2, This strain gauge in series with a Ballast resistance of 120Ω across a 6V supply.

Determine i) voltage sensitivity

ii) change in output voltage

When pressure of 240 MN/m^2 , Modulus of elasticity is 200 GN/m^2

given data: $R_b = 120\Omega$, $R_s = 120\Omega$

$$\text{Stress } p = 240 \text{ MN/m}^2$$

$$\text{Modulus of elasticity } E = 200 \text{ GN/m}^2$$

$$\text{Strain } \epsilon = \frac{p}{E} = \frac{240 \times 10^6}{200 \times 10^9} = 1.2 \times 10^{-3}$$

$$\text{i) Voltage sensitivity, } S_V = \frac{R_b R_s}{(R_b + R_s)^2} \cdot G \cdot V_{in}$$

$$= \frac{120 \times 120}{(120 + 120)^2} \times 2 \times 6 = 3 \text{ volts per meter}$$

$$\text{ii) } \Delta V_{out} = \epsilon \cdot S_V = 1.2 \times 10^{-3} \times 3 = 3.6 \text{ mV.}$$

A strain gauge has two fixed resistors R_3 & R_4 of 150Ω each and a variable resistor R_2 , which is 110Ω at zero strain & 110.75Ω with the strain. The gauge factor is 2.5, determine strain.

Resistances: $R_2 = 150\Omega$, $R_4 = 150\Omega$

Variable resistance $R_3 = 110\Omega$

Resistance of strain gauge $R_1 = \frac{R_2 R_3}{R_4} = \frac{110 \times 150}{150} = 110\Omega$

In strained condition,

Variable Resistance $R_3' = 110.75\Omega$

Resistance of strain gauge $R_1' = \frac{R_2 R_3'}{R_4} = 110.75\Omega$

change in resistance of strain gauge

$$\Delta R_1 = R_1' - R_1 = 0.75\Omega$$

$$\text{strain } \epsilon = \frac{\Delta R_1 / R_1}{G} = \frac{0.75 / 110}{2.54} = 2.684 \times 10^{-3}$$

A resistance strain gauge having a resistance of 120Ω and gauge factor 2 is placed in an equal arm resistance bridge with a supply voltage of 8V. Determine the sensitivity of the detector having a resistance of 80Ω .

Resistance of bridge $R_1 = R_2 = R_3 = R_4 = 120\Omega$

Resistance of detector $R_m = 80\Omega$

Thevenin source voltage $V_{Ac} = \frac{V}{4} G \epsilon$

voltage across detector $V_{AcL} = \frac{V_{Ac}}{1 + \frac{R_e}{R_m}}$

Detector current $I_m = \frac{V_{AcL}}{R_m} = \frac{V_{Ac}}{R_m + R_e}$

Thevenin's source resistance

$$R_e = R_2 // R_4 + R_1 // R_4 = \frac{R}{2} + \frac{R}{2} = R$$

$$\text{Hence } I_m = \frac{\frac{V}{4} G \epsilon}{R_m + R}$$

$$\text{Sensitivity } S_D = \frac{I_m}{\epsilon} = \frac{V G}{4 (R_m + R)} = \frac{8 \times 2}{4 (80 + 120)} = 0.02 \text{ A / strain}$$

A single strain gauge having a resistance of 500Ω , gauge factor of 2 & a temperature co-efficient of $1 \times 10^{-5} / ^\circ\text{C}$ at room temperature is mounted on the beam & connected in the arm AB of the bridge. For measuring a strain in a cantilever beam. The other three arms DA, BC, CD of the bridge resistance of $100, 100, 500 \Omega$ respectively. The detector connected across terminals A & C of the bridge has a resistance of 100Ω and sensitivity $5 \text{ mm per } \mu\text{A}$. Determine the detector deflection for a gauge sensitivity of 0.02 . Also determine the change in effective strain indicated for an increase of 20°C in room temperature. supply 12 V .

$$\text{Strain gauge Resistance} = R_1 = 500 \Omega$$

$$R_2 = 100 \Omega, R_3 = 500 \Omega, R_4 = 100 \Omega$$

$$\text{Detector Resistance } R_m = 100 \Omega$$

$$\text{Sensitivity } S_D = 5 \text{ mm / } \mu\text{A}$$

strain gauge temp. coefficient $\alpha = 1 \times 10^{-5} / ^\circ\text{C}$

change in resistance due to strain of 0.002

$$\Delta R_1 = R_1 G \epsilon = 2 \times 500 \times 0.002 = 2 \Omega$$

$$\text{Hence } R_1 (\text{gauge}) = \Delta R_1 + R_1 = 500 + 2 = 502 \Omega$$

Thevenin source Resistance

$$R_{th} = \frac{R_2 R_4}{R_2 + R_4} + \frac{[R_1 + \Delta R_1] R_3}{R_1 + \Delta R_1 + R_3} = 300.5 \Omega$$

Thevenin source Voltage

$$V_{AC} = \left[\frac{R_1 + \Delta R_1}{R_1 + \Delta R_1 + R_3} - \frac{R_2}{R_2 + R_4} \right] V$$

$$= 11.976 \text{ mV}$$

$$\text{Detector current } I_m = \frac{V_{AC}}{R_{th} + R_m} = \frac{11.976 \times 10^{-3}}{300.5 + 100} = 29.9 \mu\text{A}$$

$$\text{deflection} = S_D \times I_m = 5 \times 29.9 = 149.5 \text{ mm}$$

change in Resistance Due to change in Temp.

$$\Delta R_1' = \alpha R_1 t = 1 \times 10^{-5} \times 500 \times 20 = 0.1 \Omega$$

The equivalent strain,

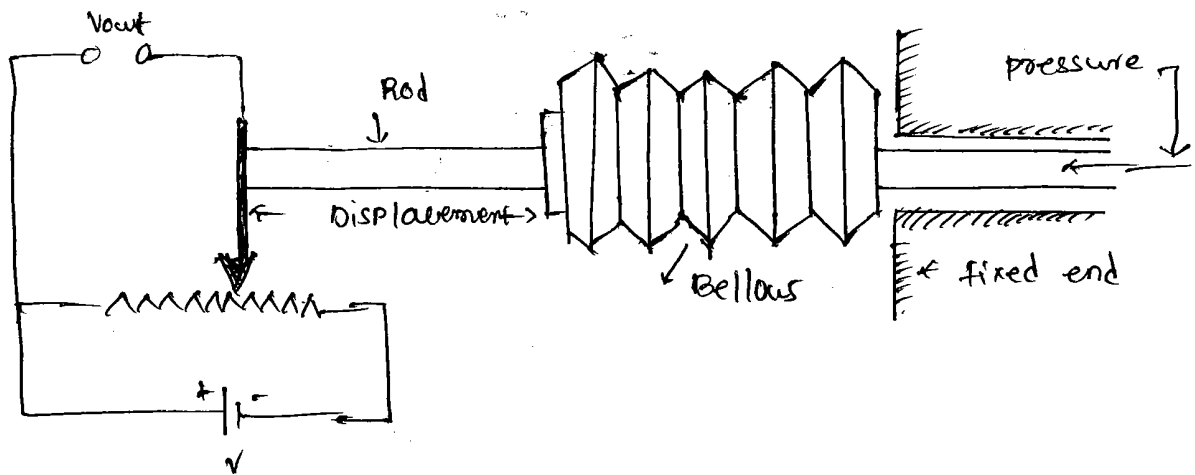
$$\epsilon' = \frac{\Delta R_1'}{G R_1} = \frac{0.1}{2 \times 500} = 1 \times 10^{-4}$$

$> 100 \text{ microstrain}$

pressure measurement.

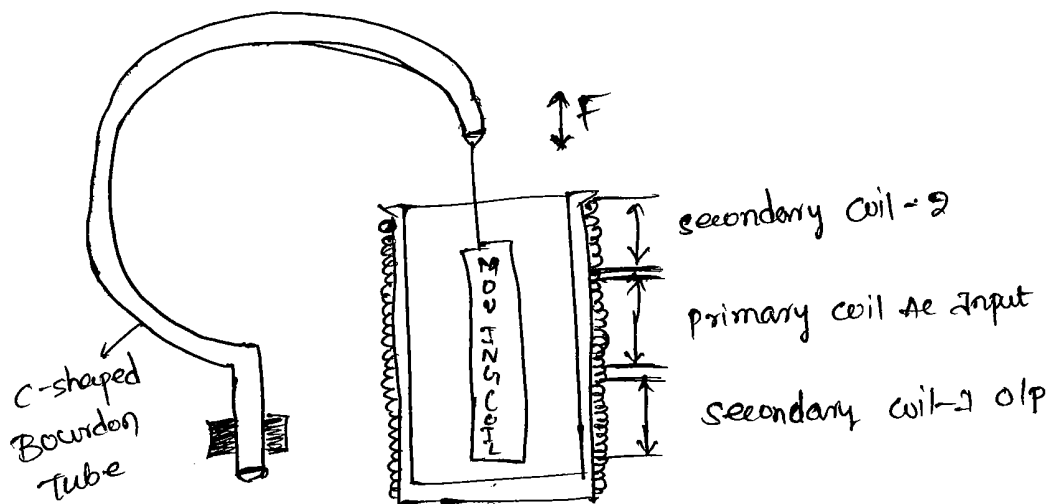
pressure is defined as The force acting per unit area and refers only to The force per unit Area. exerted by The fluids on The wall of The container.

The instruments used in measurement of pressure may be mechanical, electro mechanical, electrical or electric.



This scheme utilizing Bellows as a primary detector and potentiometer as a secondary transducer. one side of Bellows is fixed and pressure is applied inside The Bellows which in turn expands or compresses The Bellows depending upon The nature of pressure. A rod fitted on The other side of The Bellows moves

and transmits the motion to the potentiometer acting as a secondary transducer.



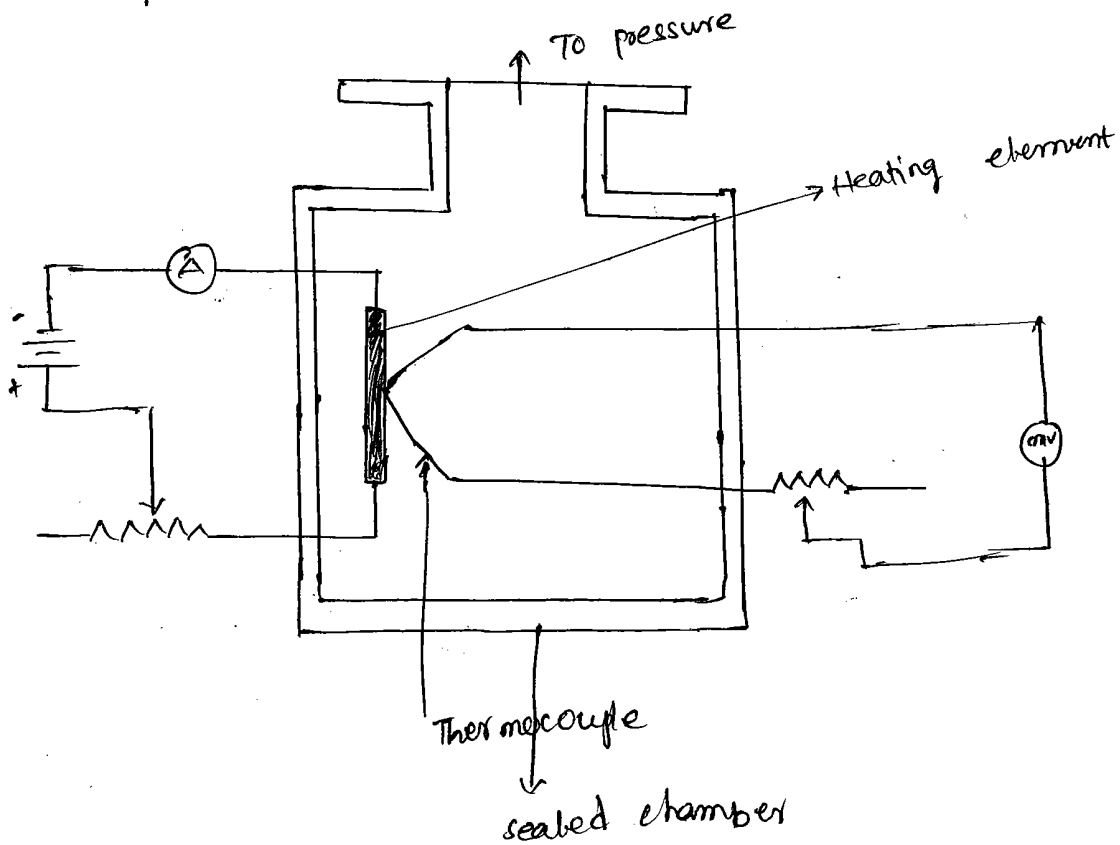
The above arrangement is used for measure of low pressure requiring larger stroke length. In some cases bellows is used with a restraining spring which opposes the axial movement in order to increase the pressure range of bellows.

The above C-shaped tube could be linked to an LVDT for measuring pressure. spiral and helical tubes are usually preferred over C-shaped Bourdon tubes since they give large motion of the settled tip per unit of pressure.

Vacuum measurement²

Thermocouple vacuum gauge.

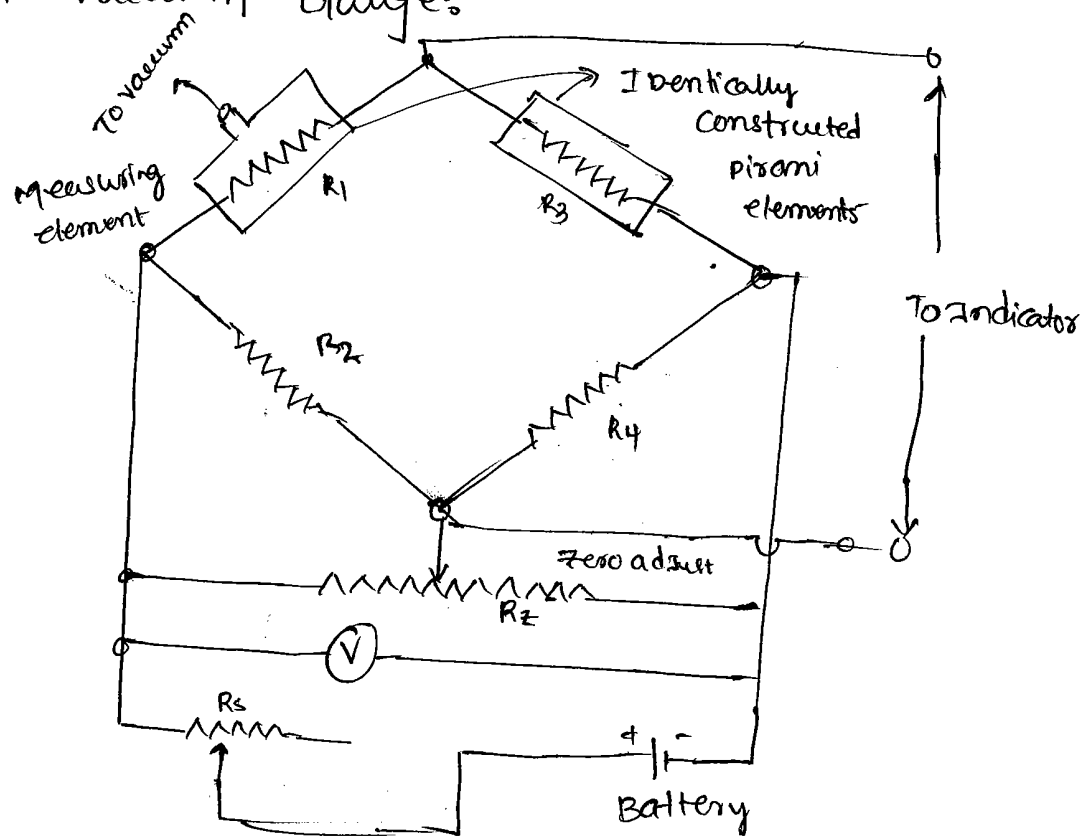
In this type of vacuum gauge heater element is heated upto a temperature from 80°C to 400°C by constant current of known value and the thermocouple is kept in contact with the center of an heater element for measuring its temperature. The heater element and the thermocouple are enclosed in a glass or metal envelope which is sealed into a vacuum system.



When constant current of known value flows through the heater element, it gets heated up and its temperature rises. The temperature which the heater element attains depends upon the amount of heat, which is removed from it by radiation & conduction. Heat removed by convection is so small that it can be ignored.

Any change in pressure causes change in thermal conductivity of gas and with this, the temperature of heater element changes. This change in temperature of heater element is sensed by thermocouple which provides an output voltage.

Pirani Vacuum Gauges



The principle of pirani vacuum gauge is same as that of thermocouple vacuum gauge. Main difference between the two is that in a thermocouple gauge pressure is measured by sensing the variation in temperature of the heater element but in pirani gauge pressure is measured by sensing the variation in temperature of the heater element but in a pirani gauge pressure is measured by sensing the variation in resistance of temperature

The In this type of gauge, the function of heating and temperature measurement is combined in a single element.

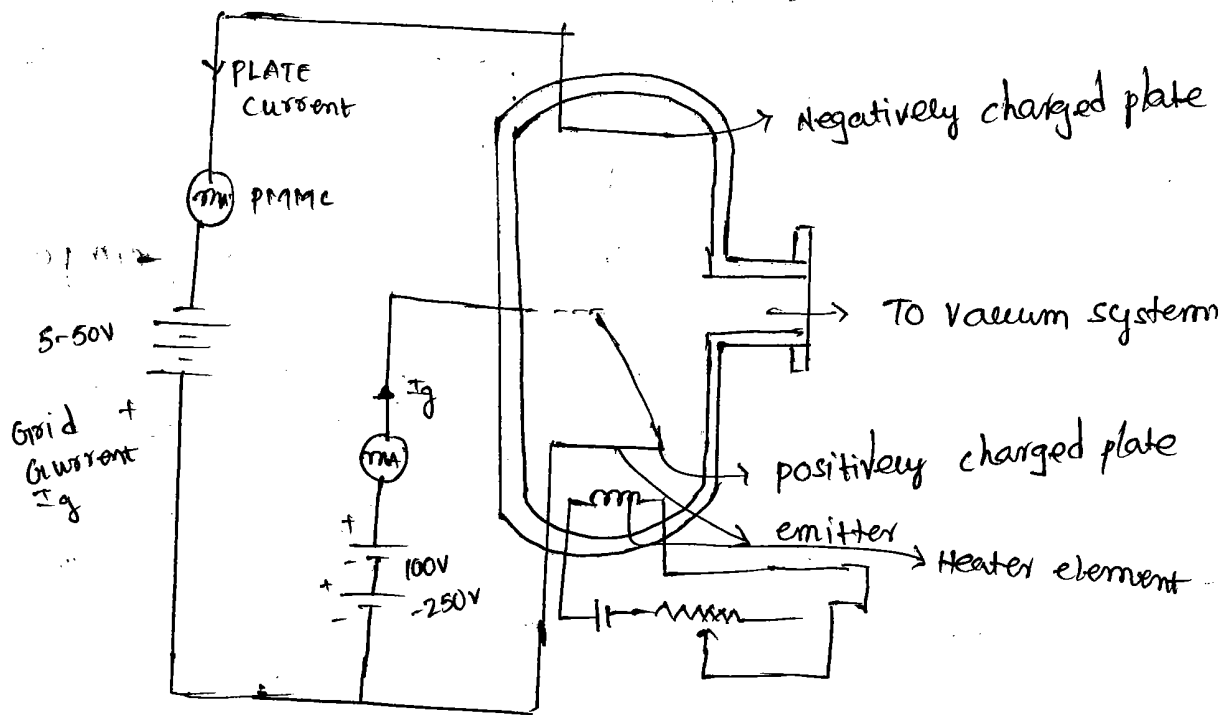
A typical pirani gauge having the resistance element in the form of four coiled tungsten wires connected in parallel and support inside a glass tube which the gas is admitted, again the cold surface is the tube.

Disadvantages: These gauges have to be calibrated individually & checked frequently.

2) These gauges Boon out when exposed to atmosphere pressure during operation.

3) These gauges not easily damaged by organic vapour as elements gets coated with deposit of decomposed vapour which changes its heat.

Ionization Vacuum Gauge:-



Boyle's Law states That, pressure of two gases equal to the ratio of their densities provided the temperature remains constant.

$$\text{i.e } \frac{P_1}{P_2} = \frac{\rho_1}{\rho_2} \text{ \& \; density}$$

The Ionization vacuum gauge is similar to a vacuum triode, in the grid maintained at a

Positive potential with respect to the cathode, The positive ions between grid and plate are collected by negatively charged plate while those in between the grid and cathode are drawn by the cathode.

In Ionization gauge electrons are emitted by the emitter being heated by heater element. These electrons are accelerated towards grid, being positively charged.

It is found that pressure of gas is proportional to the ratio of plate current to the grid current

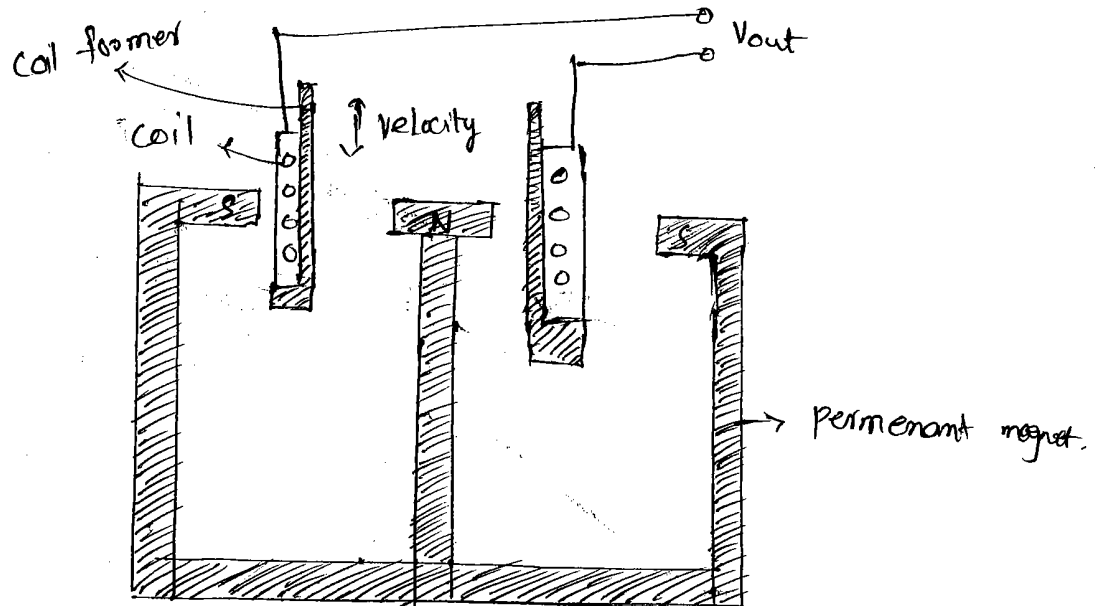
$$\text{i.e., } p = \frac{1}{s} \cdot \frac{I_p}{I_g}$$

Measurement of Linear Velocity:

Linear velocity is measured by converting linear motion into angular motion when distance travelled is long.

In case distance travelled is small, linear velocity measurement is carried out by direct

method. a moving coil magnetic pickup is used which operates on principle Induction.



an emf is induced in the coil when the flux linking with the coil changes and the magnitude of emf induced is proportional to the component of velocity in a direction \perp^{lar} to the direction of magnetic field.

$$\text{Induced e.m.f} = e = Blv \sin\theta \text{ volts.}$$

$B \rightarrow$ flux density (wb/m^2)

$l \rightarrow$ length of moving coil (meters)

$v \rightarrow$ Relative velocity (m/s)

$\theta \rightarrow$ angle of coil movement.

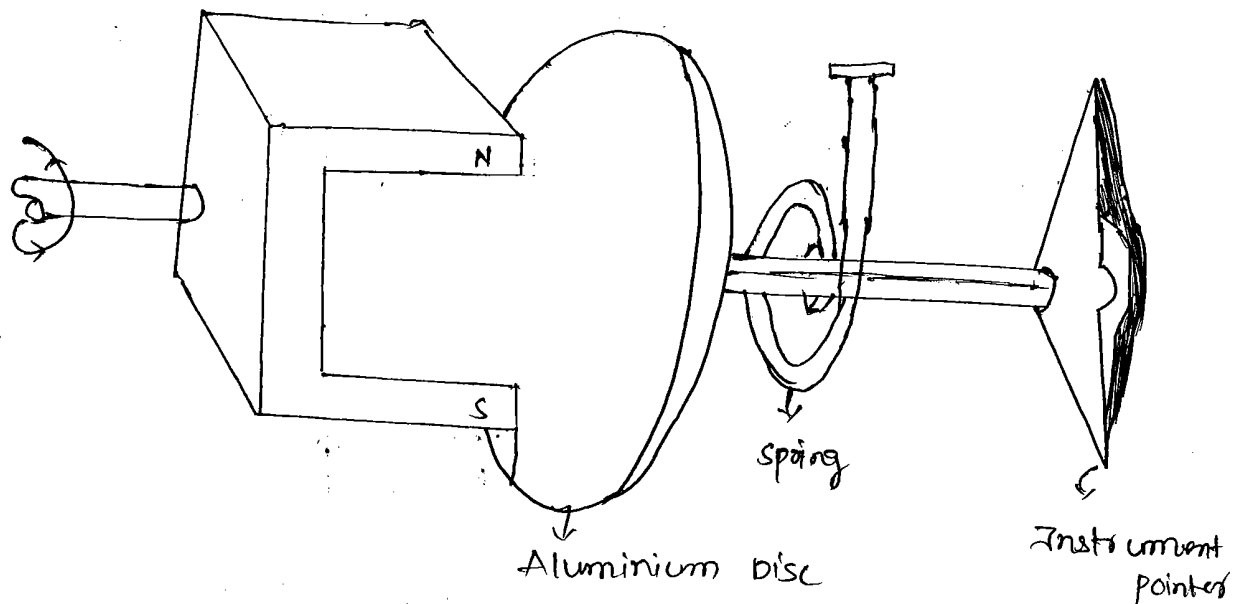
Hence all are constant, output voltage varies linearly with the input velocity.

Polarity of emf in the coil depends upon the direction of movement of coil with respect to the permanent magnet.

A typical pick-up approximately 500Ω resistance has a sensitivity of $6\text{mV}(\text{mm/s})$ and a f.s.d of 4mm with a non-linearity of $\pm 1\%$.

Measurement of Angular velocity ω

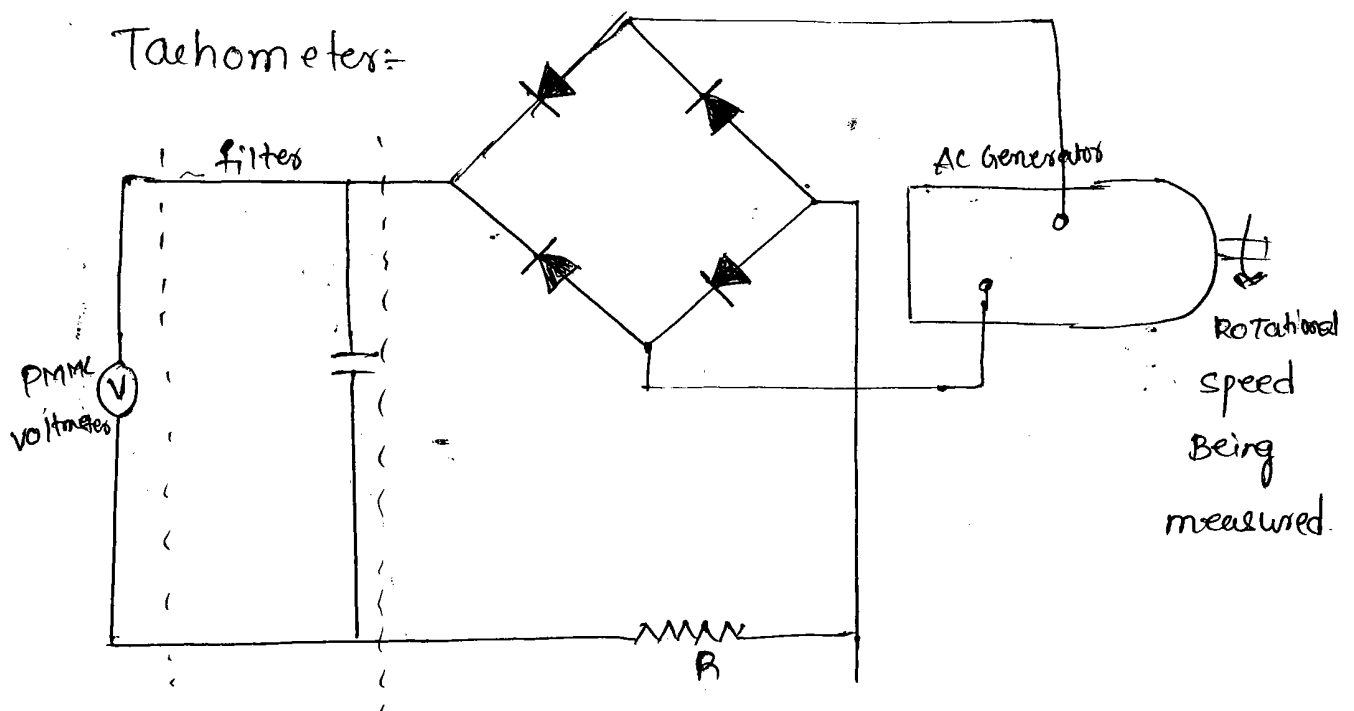
eddy current tachometer:-



It consists of permanent magnet NS coupled mechanically with the test shaft and aluminium disc facing the poles of the permanent magnet.

The disc being mounted on the shaft carrying the instrument pointer. Rotation of permanent magnet induces voltage into the disc which thereby causes circulating eddy currents in the disc.

The interaction of eddy current with the magnetic field of the permanent magnet produces a deflecting torque which turns the disc until this torque is balanced by the restoring torque owing to the spring.



It is an ordinary rotating field type alternator. The magnetic field is produced by permanent magnets or electromagnets mounted on the rotor.

5
which is coupled mechanically to the shaft of the test machine.

The rotation of magnet induces an a.c. voltage in coil, the amplitude and frequency of which are proportional to the rotational speed.

In this method, the output voltage is first rectified and then passed through the filter to smoothen output. Filtered output is measured by a permanent magnet moving coil voltmeter which can be calibrated in terms of rotational speed directly.

Measurement of speed:-

Stroboscopic Method:-

For measurement of speed by means of stroboscopic, a disc known as stroboscopic disc, with the geometrical pattern on it, is rigidly attached to the shaft of the machine, whose speed is to be determined, and illuminated by a series of rapidly flashes, each of being of very short duration in comparison of time interval between successive flashes.

The frequency of the flashes is adjusted such that disc seems to stationary. This will happen when the point adjustment, to that viewed in the preceding flash, has taken up the same position and since all pointers exactly identical. The

In the other words, the disc will seem to be stationary when the disc moves one point pitch during the time interval between the two successive flashes, same effect will be caused if disc moves through $2p, 3p, \dots, np$ between the successive flashes.

If Number of points of the disc = n

Number of flashes per minute = k

The speed of the machine in rpm = N .

Diameter of stroboscopic disc = D

The point pitch $p = \frac{\pi D}{n}$

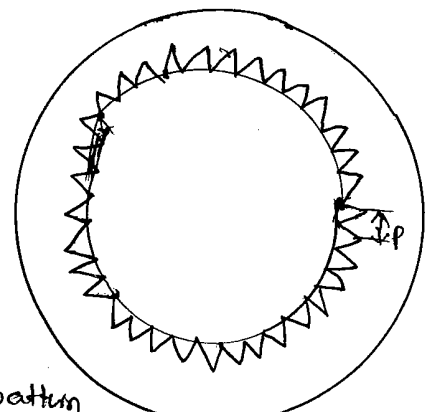
The distance moved by the disc during two

Successive flashes = $\frac{\pi D N}{k} = \text{pitch } p$

$$\frac{\pi D}{n} = \frac{\pi D N}{k}$$

$$\text{or } N = \frac{k}{n}$$

Disc with Geometrical pattern



problems: The frequency of the flashes of a stroboscope is adjusted such that a disc with 20 points mounted on the shaft of the machine seems to be at stand still. If the adjacent frequency of the flashes is 5,000 per minute and approximate speed of machine is 765 rpm is given by other method. Determine the correct speed of the machine in rpm.

Number of points on the disc $n = 20$

Number of flashes per minute $k = 5,000$

prime speed of the machine $N = \frac{k}{n} = \frac{5,000}{20} = 250 \text{ rpm}$

But the apparent speed $N_a = 765 \text{ rpm}$

so the multiplying factor = 3

and the correct speed = $N \times 3 = 250 \times 3 = 750 \text{ rpm}$

Measurement of Vibration:

seismic Transducers:

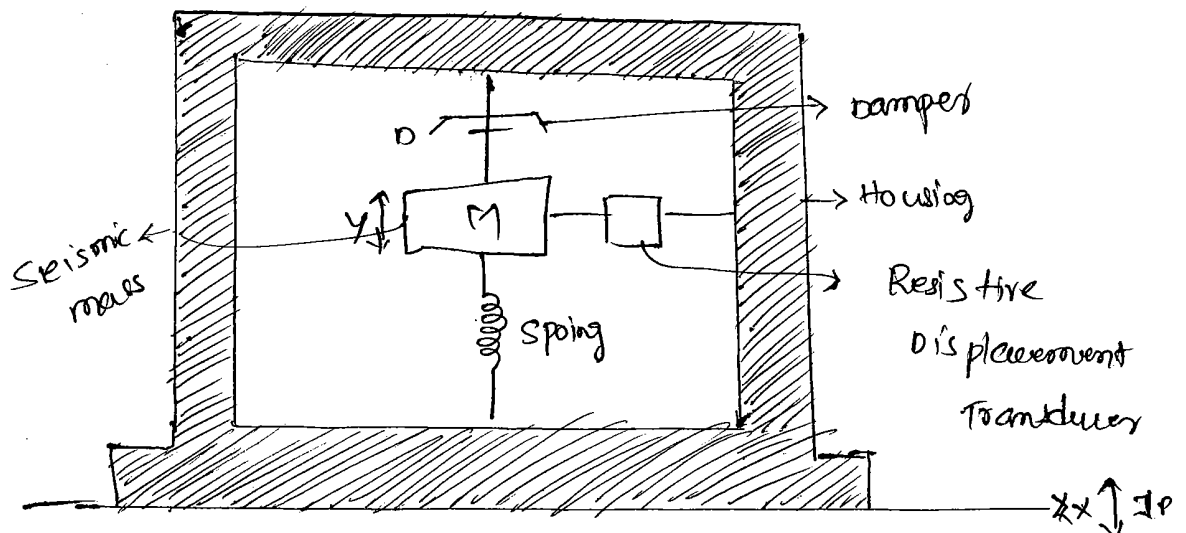
Seismic transducer, also known as seismic accelerometer, is used for measurement of acceleration. In this case the mass is connected through parallel spring and damper arrangement to a housing. Housing frame connected to the surface of vibration.

whose characteristics are to be determined. The mass has a tendency to remain fixed in its optical spatial position so that the vibration motion is registered as relative displacement between mass and housing frame.

The seismic transducer can be used in two different modes namely.

- i) displacement mode
- ii) acceleration mode.

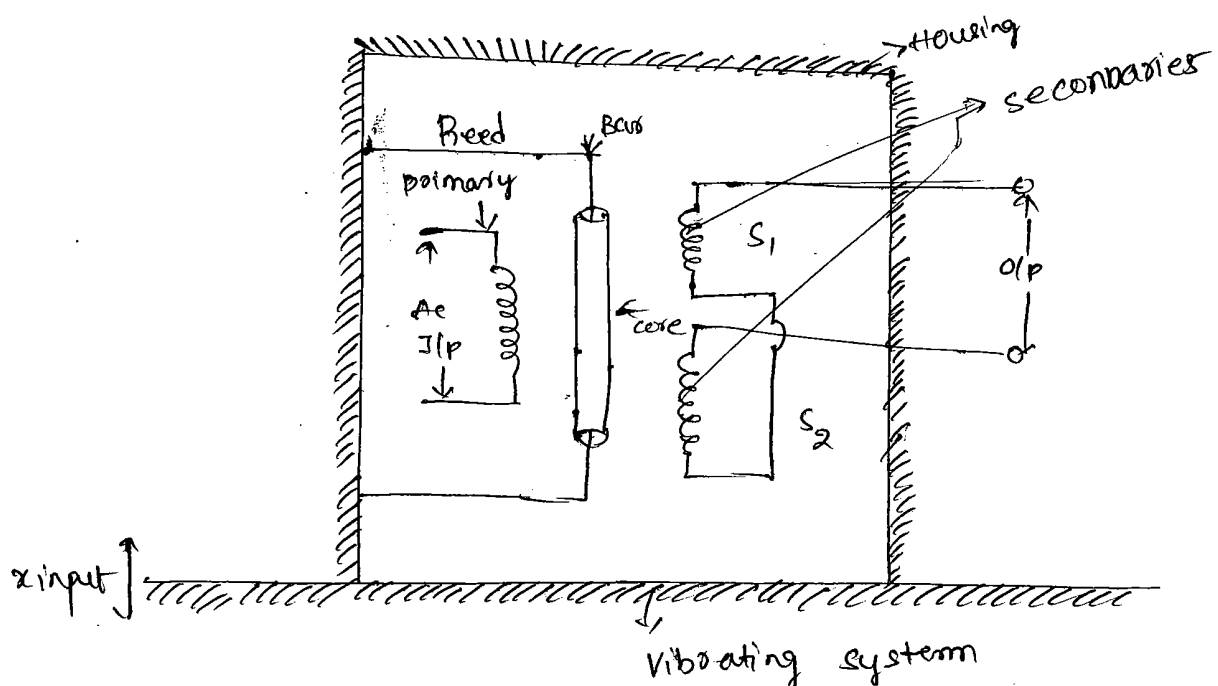
selection of mode depends upon the proper selection of mass, spring and damper combinations. In general, a large mass and a shaft spring are suited for displacement mode measurements where as a relatively small mass and a stiff spring are employed for acceleration mode measurements.



If the acceleration is constant, the mass M will be at rest relative to the frame and thus its absolute acceleration will be the same as the relative acceleration.

If mass m is accelerating, it is only possible due to the action of some force which can come only from the spring deflection is proportional to the force and the force is the measurement of acceleration is reduced to the measurement of force required to accelerate a known mass.

LVDT accelerometer: An LVDT accelerometer using Linear Voltage Differential Transformer. The core of the LVDT acts as the mass and two flexible reeds attached at each end of the rod of core provide the necessary spring action.



The seeds are attached to a housing subjected to vibrations.

In case of vibration measurement as the sensor moves up and down the LVDT secondaries give an a/c o/p voltage, first half one phase and then, alternatively at the opposite phase, the magnitude of this o/p voltage depends upon the amplitudes of the vibrations. Peak-to-peak magnitude of this o/p voltage is measured by peak measuring voltmeter.

The accelerometers using LVDT have the following advantages

1) They have high natural frequency because of smaller mass of the core and therefore they can be used for measurement of vibrations of high frequencies.

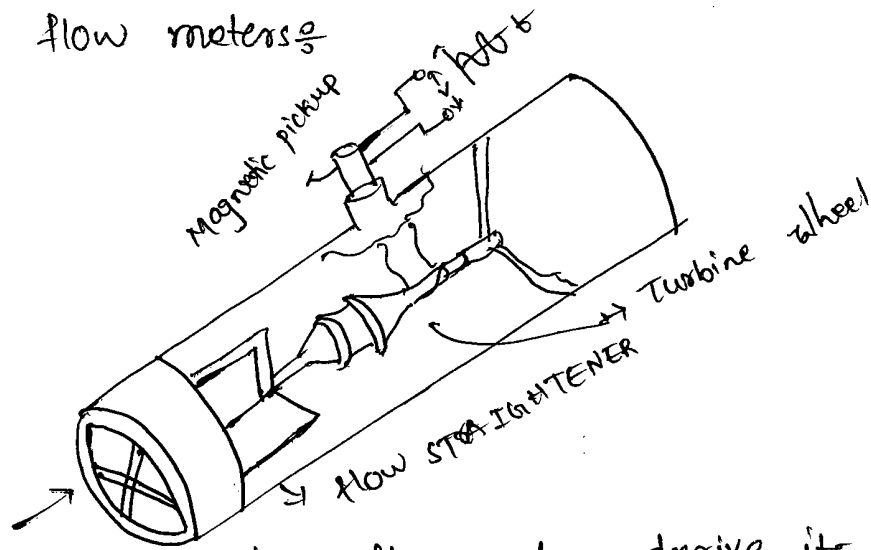
2) They are contactless devices and are, therefore, free from problems arising on account of moving contacts.

3) They offer low resistance to motion that the potentiometers and are capable of much better resolution.

FLOW measurement

The measurement of flow is acquiring ever growing importance because of its increasing field of applications.

Turbine flow meters



The turbine flow meter derives its name from the operating principle employed, and is perhaps the most highly developed non-friction development type of mechanical flow meter. When an axially mounted freely rotating rotor is placed in the path of a fluid stream, the flowing fluid impinging on the rotor blades, imparts a force on the blade surfaces and sets the rotor in the motion with an angular velocity proportional to flow rate of the fluid.

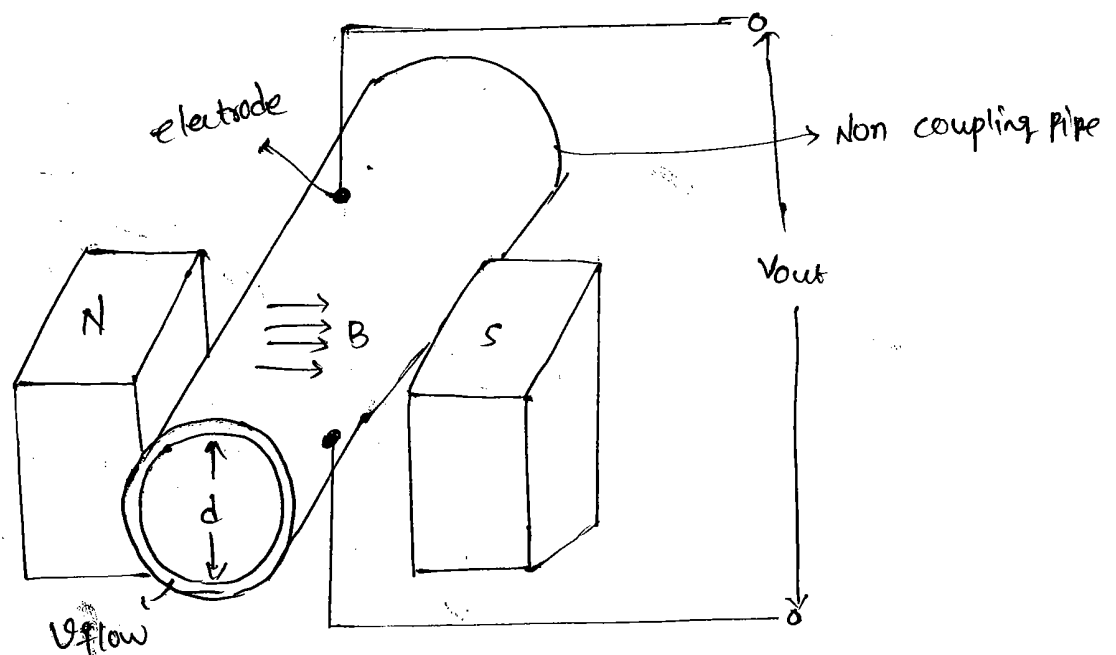
When a steady rotational speed is reached, the rotational speed attained is proportional to the volumetric flow rate of the fluid. The device can be designed to give a linear output by reducing the

Bearing friction and other losses to minimum.

Thus a speed measurement allows a flow rate measurement. The speed can be measured simply and with great accuracy by counting the rate at which turbine blades pass a given point with the help of a magnetic proximity pickup which generates voltage pulses.

Flow rate of fluid can be measured by feeding the pulses generated by the magnetic pickup to an electronic pulse rate meter and total flow can be determined by accumulating the total number of pulses during a time interval.

electromagnetic flow meters:



The operation of electro magnetic flow meters is based on Faraday's law of electro magnetic induction, which states that an emf e volts is induced in a conductor of length l when it moves with a transverse velocity of v m/s across a magnetic field of strength B Wb/m² and the induced emf in the conductor is given by

$$e = B \cdot l \cdot v \text{ volts.}$$

since the voltage induced depends on the rate at which conductor moves through the magnetic field, the magnitude of voltage induced can be used as an indication of the flow rate of liquid.

electro magnetic flow meter consists of a non conducting material with two electrodes mounted opposite each other on the tube wall. The ends of the electrodes are in contact with the fluid flowing in the tube. Surrounding the tube there is a magnet with its field at right angles to the electrodes. The flowing fluid through the pipe should be conductive.

Humidity measurement:

Humidity is the measure of water vapour content in air or some other gas. It may be expressed in various forms such as absolute humidity, relative humidity or dew point temperature.

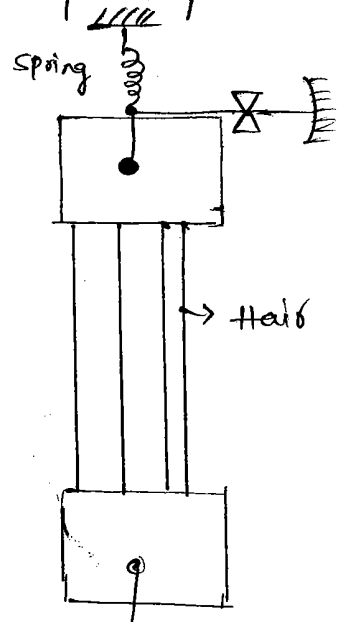
Absolute humidity is the best known amount of water vapour actually present in the air and is usually expressed in ppm.

Relative humidity is the best known and perhaps the most widely used way of expressing the water vapour content of air. Relative humidity is defined as the ratio of the water vapour actually present in the air to maximum amount of water that the air could possibly hold at the same temperature.

Dew point is defined as the saturation temperature of the mixture at the corresponding vapour pressure.

Hair hygrometer:

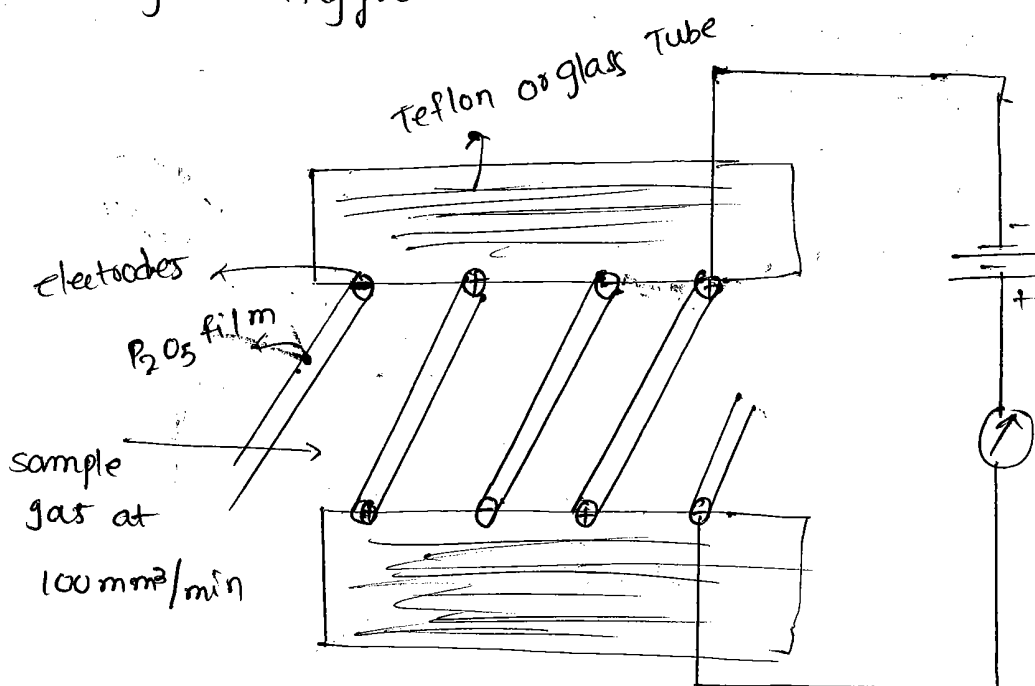
Absorption of water causes increase in length of the hair and amount of moisture that it can absorb depends upon the relative humidity.



Thus The extension of hair is a function of relative humidity. A bunch of hair is used for increased mechanical strength in the construction. The element is maintained at a slight tension by a spring. Excess of stress on the hair element may lead to a permanent set in it. Such an hygrometer is recommended for a range of 25% to 95% relative humidity & in a temperature range of -15°C to 70°C , and is calibrated before use against psychrometer. It is slow in its response and aging effects its calibration and produces considerable drifts.

Animal membrane has a larger elongation in comparison to hair for the same relative humidity. But calibration drift is also large.

Electrolytic Hygrometer



A typical electrolytic hygrometer utilizes a cell coated with a thin film of phosphorous pentoxide (P_2O_5) which absorbs water from the sample gas. The cell has a bifilar winding of Inert electrodes on a hydro-carbon capillary. Direct voltage applied to the electrodes dissociates the water, which is absorbed by the phosphorous pentoxide, into hydrogen & oxygen. Two electrons are required for electrolyzing each water molecule, and so the current in the cell represents the number of molecules dissociated. A

A typical electrolytic hygrometer can cover a range of from 0 to 2,000 ppm with an accuracy of $\pm 5\%$ of the reading, which is more than adequate for most industrial applications.

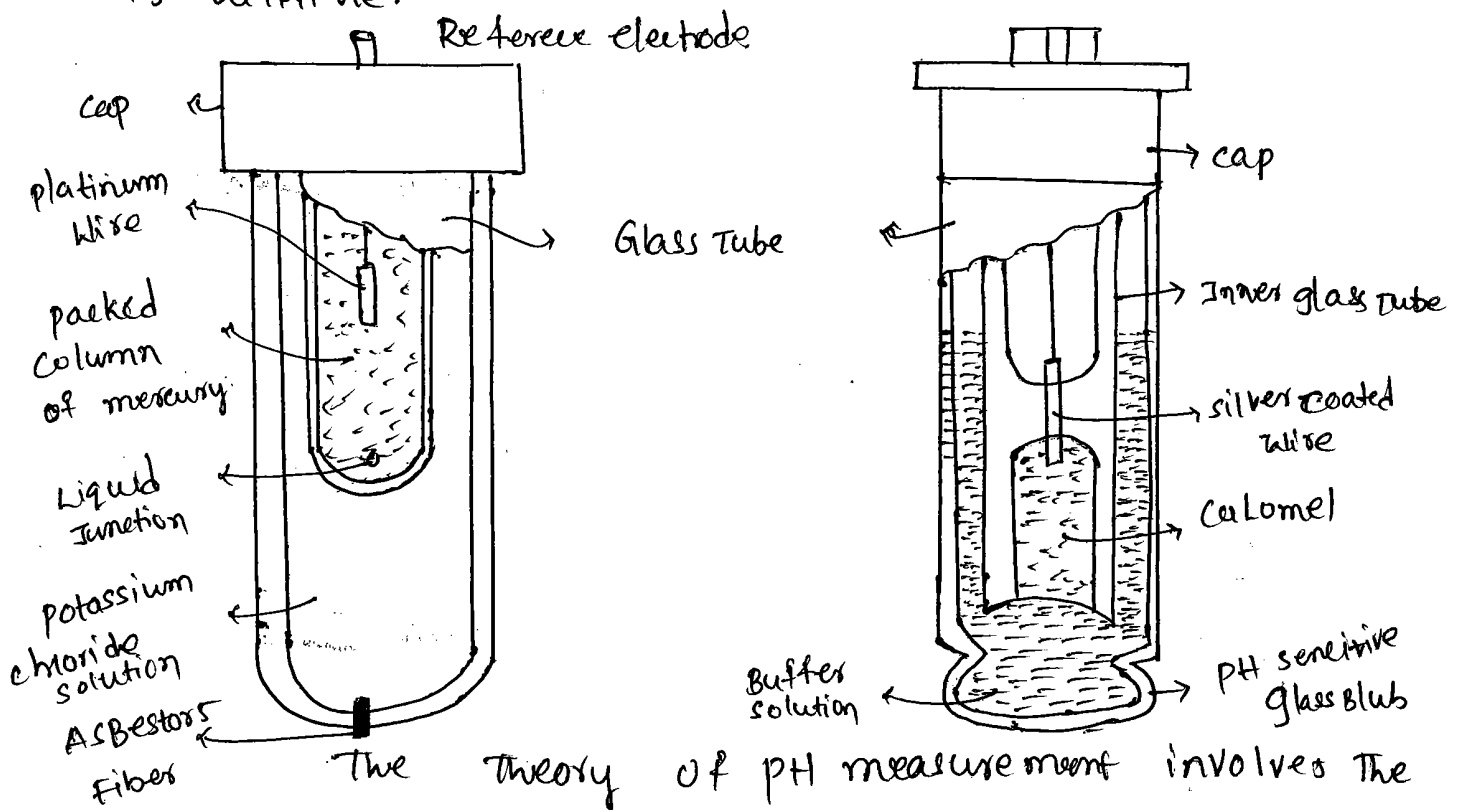
Measurement of pH

Measurements of concentration and strengths of acids and bases are the most common and usually carried out on "chemical" systems because acids and bases are of vital significance in such diverse fields as medicine, biology, food technology

as well as the chemical industry. The scale on which the acidity or alkalinity is measured is the pH scale.

$$pH = -\log_{10} [H^+]$$

In a solution both H^+ and (OH^-) are present. If H^+ ions are more, the solution is acidic and on the other hand if the hydroxyl ions are excess, the solution is alkaline.



The theory of pH measurement involves the breakdown of certain chemical compounds when combined with water. As these compounds breakdown, the electrically charged particles are released. Some of these are positively charged particles - Hydrogen ions (H^+)

Problems on LVDT:

and some are hydroxyl ions (OH^-)

The pH of a solution can be accurately measured by means of an electronic pH meter. pH meters usually cover a range of 0 to 14 pH units. However, it is possible to make measurements beyond these limits in very concentrate solutions.

The pH meter consist of two special electrodes which are immersed into the test solution. One electrode is kept at a constant voltage, while the other is allowed to develop a potential because of the pH of the solution under test. The most common electrode is the calomel electrode and most common pH sensitive or measuring electrode is glass electrode.

sound measurement :-

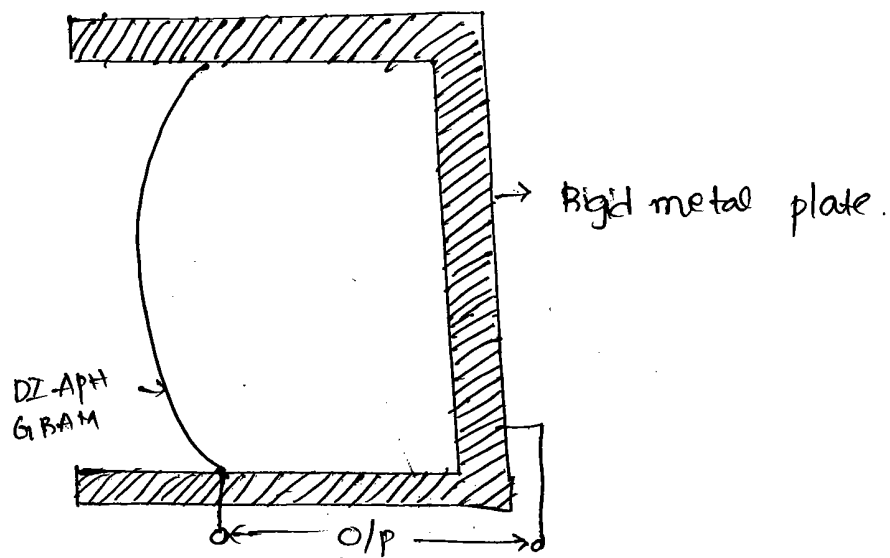
The measurement of airborne and waterborne sound is of increasing interest to engineers. Airborne sound measurements are important in the development of less noisy machinery and equipment, in diagnosis of vibration problems, and in the design and test of sound.

sound is defined in terms of the magnitude of the fluctuating component of pressure in a fluid medium. The sound pressure level is defined as

$$SPL = 20 \log_{10} \frac{p}{2 \times 10^{-4} \text{ lbars}} \text{ decibels (db)}$$

capacitor microphone:-

The operation of a capacitor microphone is based on the fact that the capacitance between two plates varies as the distance between the plates is varied. The capacitor microphone uses a metal diaphragm as one plate and a rigid metal plate as the other capacitor plate.

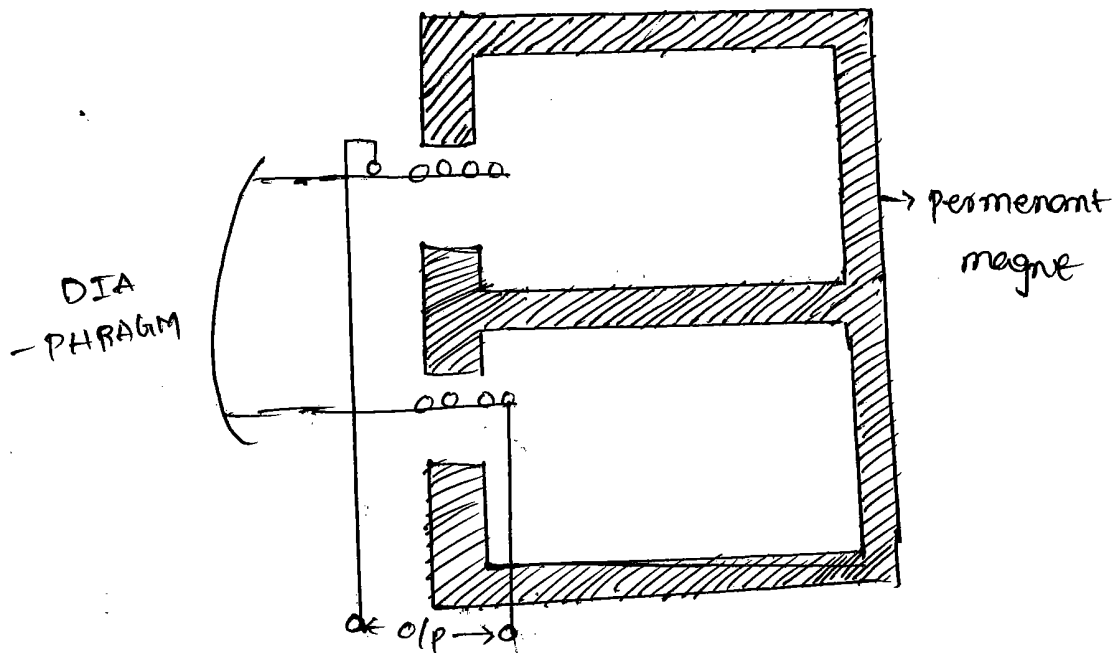


The variations in air pressure in a sound wave striking the diaphragm makes diaphragm in or out and this, in turn causes the variation in capacitance.

The varying voltage produced due to the incident sound exists as an ac component superimposed on the dc level. The ac component is then amplified and delivered to the measuring or recording instrument.

The instrument used for measuring output of the capacitor microphone should be of very high input impedance in order to reduce loading errors. Because a capacitor appears as a high output impedance source.

Dynamic microphones:



The dynamic microphone operates on the principle of electromagnetic transduction. Such a microphone makes use of a metal diaphragm mechanically linked to a moving coil surrounded by a magnet. The diaphragm and the coil are suspended so that they

They can move back and forth. The motion of the coil, which is produced due to variations in the pressure of the incident sound wave in the magnetic field, produces a varying voltage, whose magnitude obviously depends upon pressure intensity of the sound waves across the coil. The signal is amplified and delivered to the measuring or recording device.

The dynamic microphones are self-generating transducers and they have a low output impedance low sensitivity of the order of 80dB, and a frequency response of maximum 20kHz.

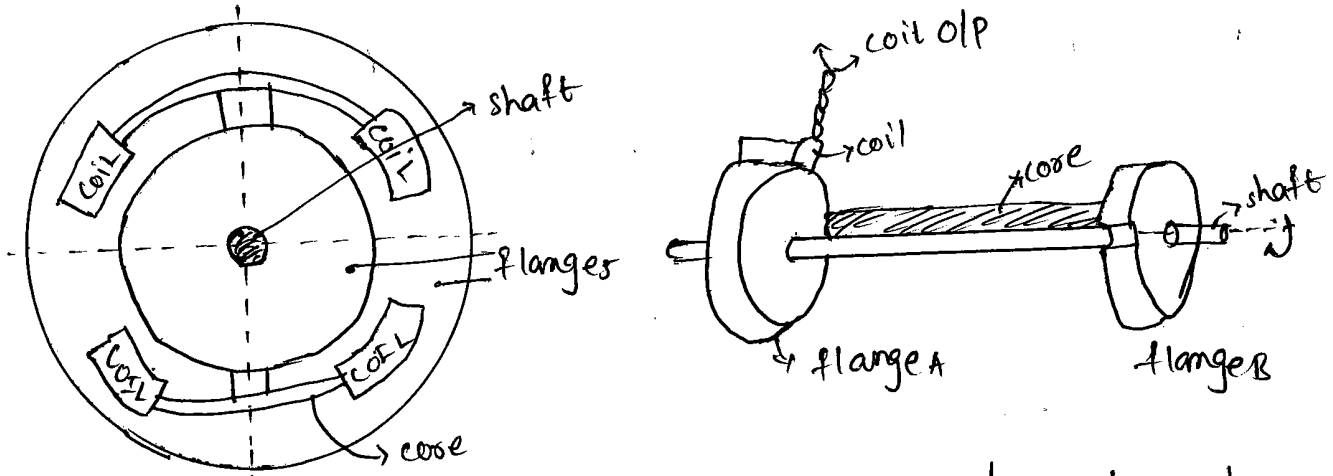
TORQUE MEASUREMENT

The torque is the torsional twisting measurement or couple which tends to twist a rigidly fixed body such as shaft turning about its axis of rotation. The application of a torque creates an angular displacement of the body about its axis of rotation.

By inductive transducers:

The arrangement for measuring torque with the use of an inductive transducer. One flange of shaft carries a coil and the other flange carries the core. The core moves in and out of the coil

due to relative displacement of the two flanges and causes the change in the coil inductance, which can be measured with an bridge.

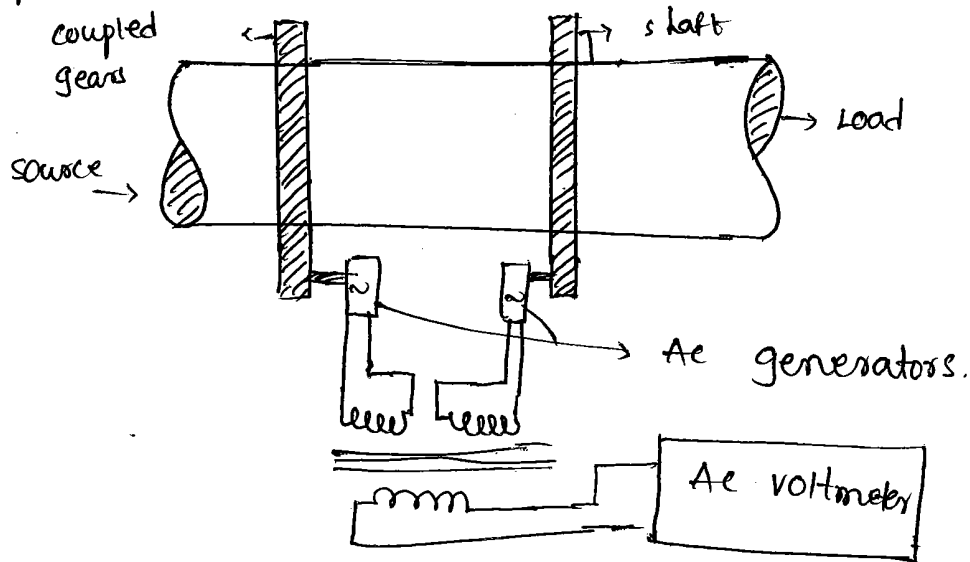


Thus the output of a.c bridge depends upon the coil inductance which can be measured with an a.c bridge, function of the position of the core and so of displacement. The bridge output can be calibrated to read the torque directly because the relative displacement between two flanges depends upon the torque.

Higher sensitivity and better linearity can be achieved by using four inductive transducers connected in the four arms of an a.c bridge. The arrangement is such that if torque applied to the shaft in a given direction moves the cores in such a way that the inductance of two coils increases while that of the other two coils decreases.

electrostatic Torque measurement:

In This method of measuring torque two ac generators coupled to The rotating shaft through Super gears are used.



A change in The originally Balanced phase relationship of The ac generators caused by The shaft Torque results in unbalancing of The transformer primary voltages. Which is a function of torque, is measured, such torque meter operates satisfactorily if The shaft elasticity is large enough to permit large phase difference in generator voltage (10 to 15 degrees)

The accuracy depends upon several electrical factors and is not high unless large deflections are produced or multiple windings are used.