Stress & Strain

Stress

The stress applied to a material is the force per unit area applied to the material. The maximum stress a material can stand before it breaks is called the breaking stress or ultimate tensile stress.

Tensile means the material is under tension. The forces acting on it are trying to stretch the material. Compression is when the forces acting on an object are trying to squash it.

The equation below is used to calculate the stress.

$$STRESS = \frac{force}{area} = \frac{F}{A}$$

stress = stress measured in Nm^{-2} or pascals (Pa)

F = force in newtons (N)

A = cross-sectional area in m^2

Strain

The ratio of extension to original length is called strain it has no units as it is a ratio of two lengths measured in metres.

$$STRAIN = \frac{extension}{length} = \frac{\Delta L}{L}$$

strain = strain it has no units

DL =extension measured in metres

L = original length measured in metres

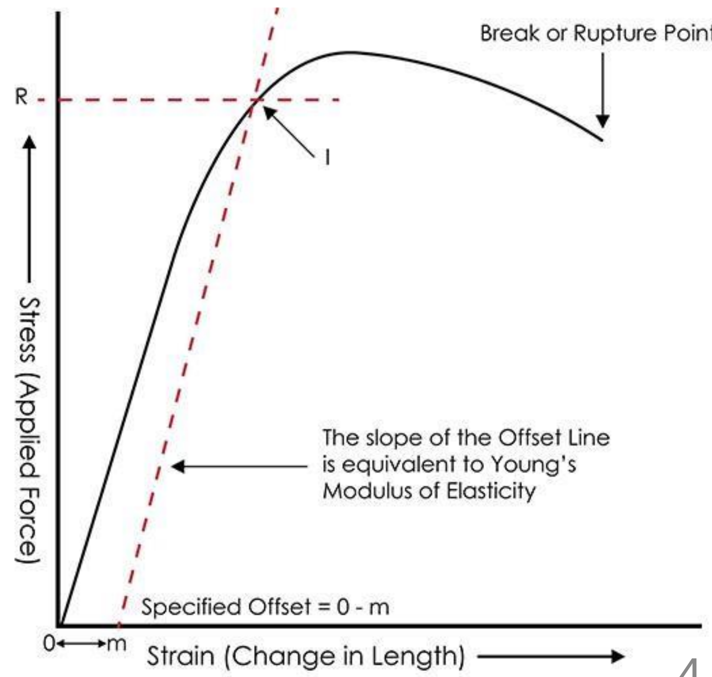
Tensile Test

- A tensile test, also known as a tension test, is one of the most fundamental and common types of mechanical testing.
- A tensile test applies tensile (pulling) force to a material and measures the specimen's response to the stress.
- By doing this, tensile tests determine how strong a material is and how much it can elongate.
- Tensile tests are typically conducted on electromechanical or universal testing instruments, are simple to perform, and are fully standardized.

Hooke's Law

- For most materials, the initial portion of the test will exhibit a linear relationship between the applied force or load and the elongation exhibited by the specimen.
- In this linear region, the line obeys the relationship defined as "Hooke's Law" where the ratio of stress to strain is a constant, $\frac{\sigma}{\epsilon}=E$,

E is the slope of the line in this region where stress (σ) is proportional to strain (ε) and is called the "[Modulus of Elasticity]" or "[Young's Modulus]."



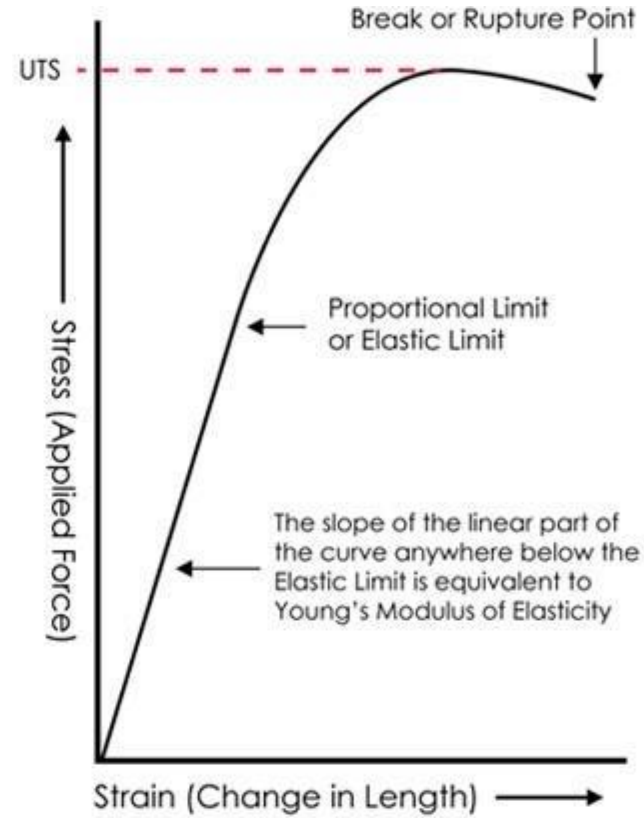
Yield Strength

- A material's "[yield strength]" is defined as the stress applied to the material at which plastic deformation starts to occur.

Modulus of Elasticity

- The modulus of elasticity is a measure of the material's stiffness which only applies in the initial linear region of the curve.
- Within this linear region the tensile load can be removed from the specimen and the material will return to the exact same condition it had been in prior to the load being applied.
- At the point when the curve is no longer linear and deviates from the straight-line relationship, Hooke's Law no longer applies, and some permanent deformation occurs in the specimen.
- This point is called the "elastic or proportional limit."
- From this point on in the tensile test, the material reacts plastically to any further increase in load or stress.
- It will not return to its original, unstressed condition if the load is removed.

- We can learn a lot about a substance from tensile testing.
- By measuring the material while it is being pulled, we can obtain a complete profile of its tensile properties.
- When plotted on a graph, this data results in a stress/strain curve which shows how the material reacted to the forces being applied.
- The point of break or failure is of much interest, but other important properties include the modulus of elasticity, yield strength, and strain.

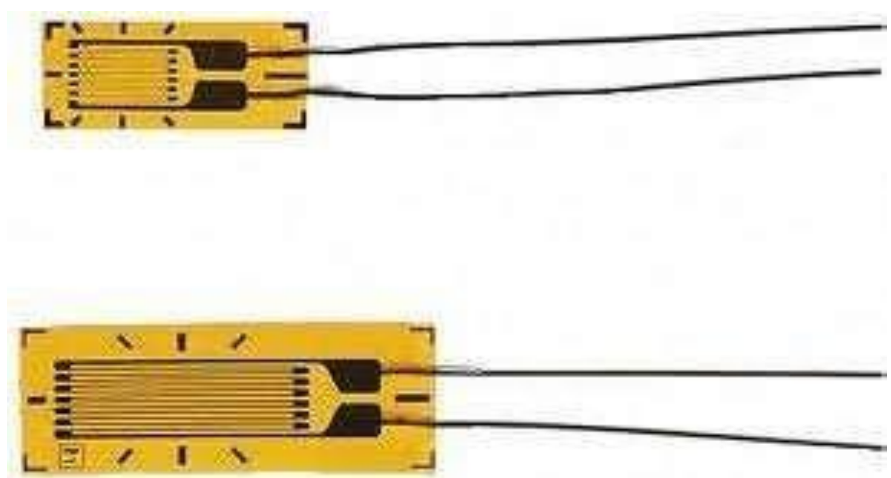


Ultimate Tensile Strength

- One of the most important properties we can determine about a material is its ultimate tensile strength (UTS).
- This is the maximum stress that a specimen sustains during the test.
- The UTS may or may not equate to the specimen's strength at break, depending on whether the material is brittle, ductile, or exhibits properties of both.
- Sometimes a material may be ductile when tested in a lab, but, when placed in service and exposed to extreme cold temperatures, it may transition to brittle behaviour.

STRAIN GAUGE DEFINITION

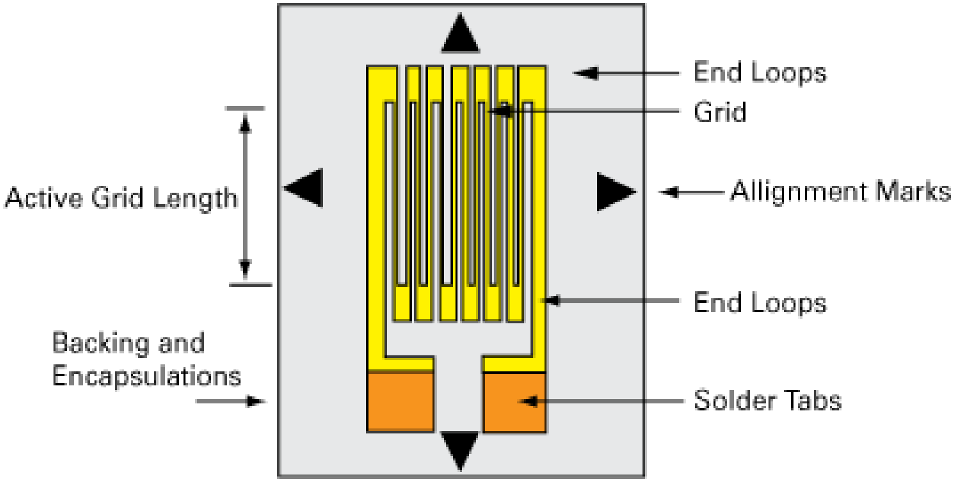
- A strain gauge is an example of passive transducer that converts a mechanical displacement into a change of resistance.
- A strain gauge is a thin, wafer-like device that can be attached to a variety of materials to measure applied strain.



STRUCTURE

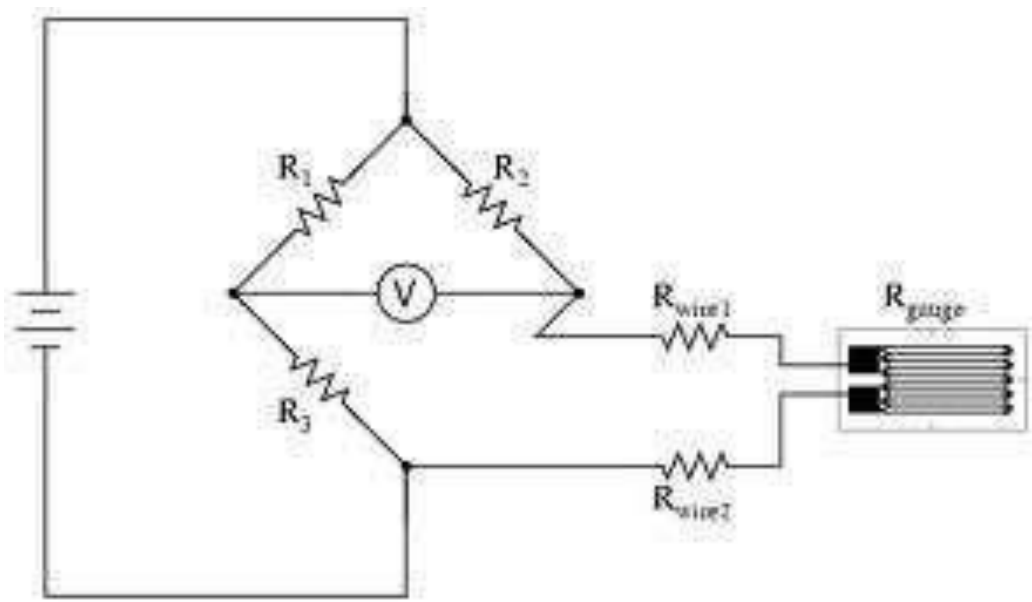
- The majority of strain gauges are foil types, available in a wide choice of shapes and sizes to suit a variety of applications. They consist of a pattern of resistive foil which is mounted on a backing material.

- They operate on the principle that as the foil is subjected to stress, the resistance of the foil changes in a defined way.



WORKING

- The strain gauge is connected into a Wheatstone Bridge circuit. The change in resistance is proportional to applied strain and is measured with Wheatstone bridge.



WORKING

- The sensitivity of a strain gauge is described in terms of a characteristic called the gauge factor, defined as unit change in resistance per unit change in length, or

$$K = \frac{\Delta R/R}{\Delta l/l}$$

- Gauge factor is related to Poisson's ratio μ by,

$$K=1+2\mu$$

TYPES

Based on principle of working :

- Mechanical
- Electrical
- Piezoelectric

Based on mounting :

- Bonded strain gauge
- Unbonded strain gauge

TYPES

Based on construction :

- Foil strain gauge
- Semiconductor strain gauge
- Photoelectric Strain gauge

MECHANICAL STRAIN GAUGE

- It is made up of two separate plastic layers. The bottom layer has a ruled scale on it and the top layer has a red arrow or pointer. One layer is glued to one side of the crack and one layer to the other.
- As the crack opens, the layers slide very slowly past one another and the pointer moves over the scale. The red crosshairs move on the scale as the crack widens.

ELECTRICAL STRAIN GAUGE

- When an electrical wire is stretched within the limits of its elasticity such that it does not break or permanently deform, it will become narrower and longer, changes that increase its electrical resistance end- to-end.

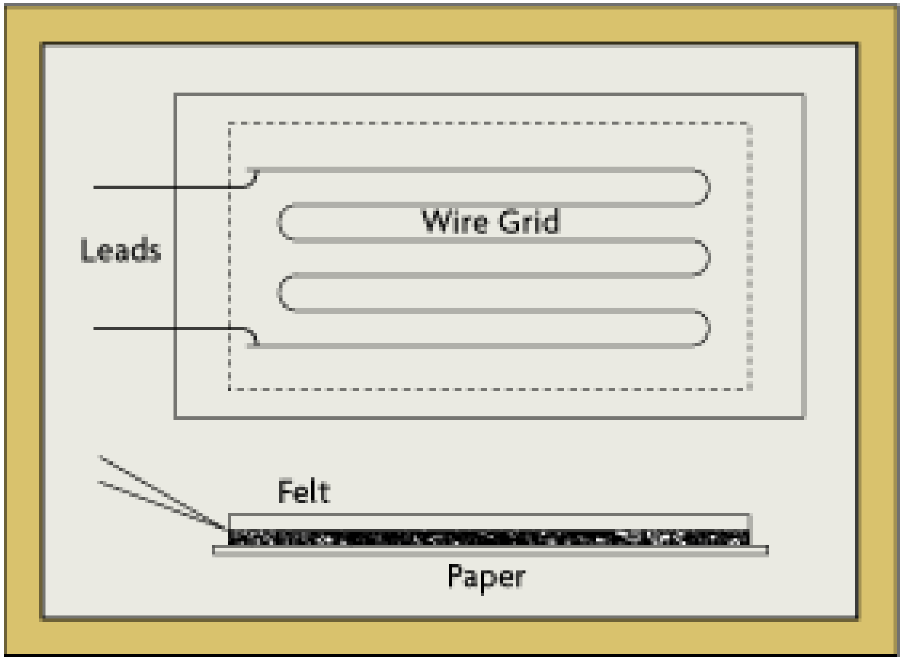
- Strain can be inferred by measuring change in resistance.

PIEZOELECTRIC STRAIN GAUGE

- Piezoelectric generate electric voltage when strain is applied over it.
- Strain can be calculated from voltage. Piezoelectric strain gauges are the most sensitive and reliable devices.

BONDED STRAIN GAUGE

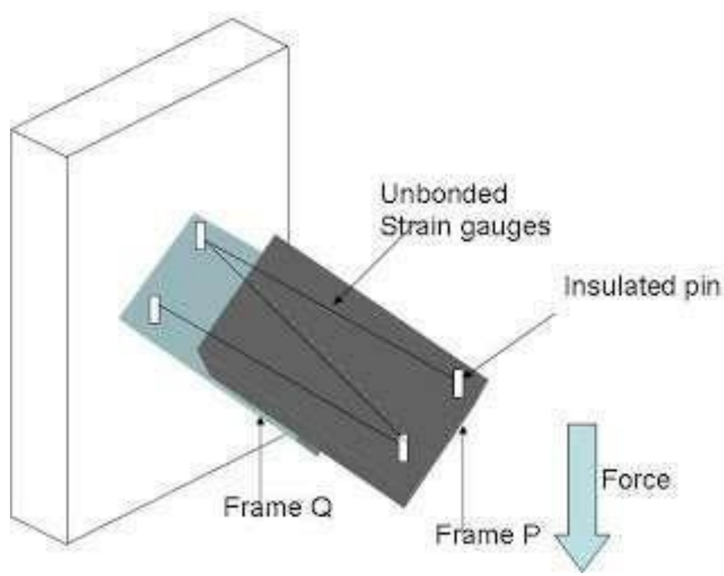
- A bonded strain-gage element, consisting of a metallic wire, etched foil, vacuum-deposited film, or semiconductor bar, is cemented to the strained surface.



UNBONDED STRAIN GAUGE

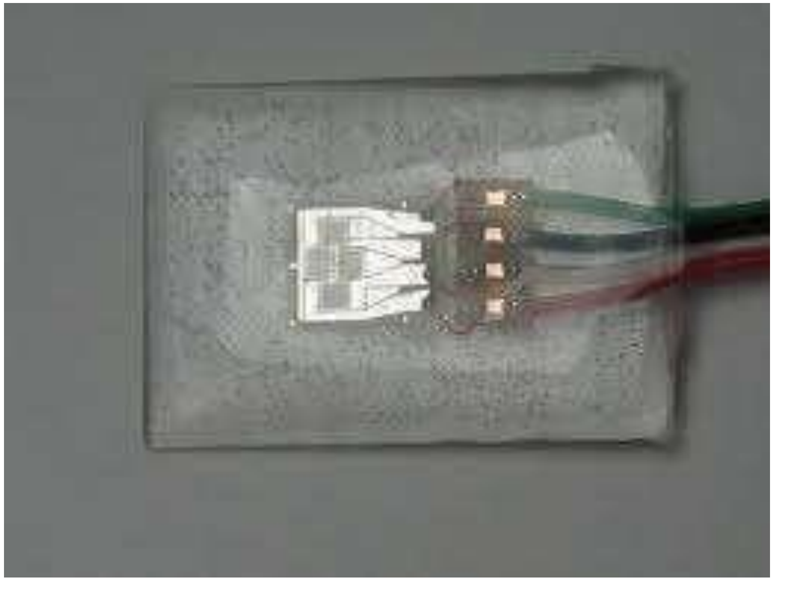
- The unbonded strain gage consists of a wire stretched between two points in an insulating medium such as air.
- One end of the wire is fixed and the other end is attached to a movable element.

Unbonded Strain Gauge



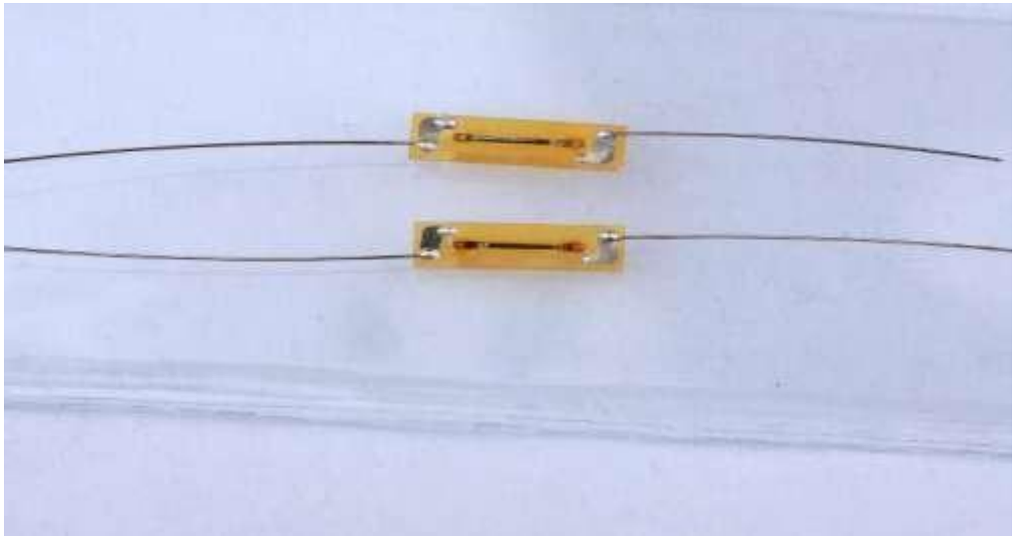
FOIL STRAIN GAUGE

- The foil strain gage has metal foil photo-etched in a grid pattern on the electric insulator of the thin resin and gage leads attached,



SEMICONDUCTOR STRAIN GAUGE

- For measurements of small strain, semiconductor strain gauges, so called piezoresistors, are often preferred over foil gauges. Semiconductor strain gauges depend on the piezoresistive effects of silicon or germanium and measure the change in resistance with stress as opposed to strain.



PHOTOELECTRIC STRAIN GAUGE

- The photoelectric gauge uses a light beam, two fine gratings, and a photocell detector to generate an electrical current that is proportional to strain. The gage length of these devices can be as short as 1/16 inch, but they are costly and delicate.

STRAIN GAUGE

STRAIN GAUGE SELECTION CRITERIA:

- Gauge Length
- Number of Gauges in Gauge Pattern
- Arrangement of Gauges in Gauge Pattern
- Grid Resistance
- temperature sensitivity
- Carrier Material
- Gauge Width
- Availability
- low cost

ADVANTAGES & DISADVANTAGES

Advantages

- There is no moving part.
- It is small and inexpensive.

Disadvantages

- It is non-linear.
- It needs to be calibrated.

APPLICATIONS

- Residual stress
- Vibration measurement
- Torque measurement
- Bending and deflection measurement
- Compression and tension measurement
- Strain measurement

MEASUREMENT OF FORCE

- Force maybe defined as a that produces resistance or obstruction to any moving body, or changes the motion of a body, or tends to produce these effects.

- Force is usually measured by applying it to a calibrated device which resists the force and indicates or records its magnitude.

Methods of measuring force

- The unknown force may be measured by following methods:-

1. Balancing the unknown force against known gravitational force due to standard mass. Scales and balances works based on this principle.
2. Applying unknown force to an elastic member and measuring the deflection on calibrated force scale or the deflection may be measured by using a secondary transducers. i.e. Spring scale, cantilever beam, Providing ring, Strain

gauge load cell.

3. Translating the force to a fluid pressure and then measuring the resultant pressure and then measuring the resultant pressure. Hydraulic and pneumatic load cells works on this principle.
4. Applying force to known mass and then measuring the resulting acceleration.
5. Balancing a force against a magnetic force which is developed by interaction of magnet and current in coil.

Scales and balances

1. Equal arms beam balance scale
2. Even or equal arms balance scales
3. Pendulum scale

EQUAL ARMS BEAM BALANCE SC

- As shown in figure equal arm beam balance scale operates on the principle of moment comparison.
- The moment produced by the unknown mass or force is compared with that produced by a gravitational force due to known standard mass.
- When null balance is obtained the two weights or forces are equal.
- For null balance $w_1 l_1 = w_2 l_2$. If equal arms $l_1 = l_2$.

  $\therefore\ w_1 = w_2$.
- This types of instruments generally used in

  weights

physics and   chemistry labs to measure the unknown

weights

Even or unequal arms balance scale

- The main dis advantage of equal arms balance scale is requires a set of weights at least as heavy as the heaviest load to be measured.
- There are two arms in that system 1st is load arm which is associated with unknown load and other is power arm which is associated with known weights.
- In this scale known weight can be decreased by increasing length of load arm, hence heavier load can be measure with help of small known mass and large arm.
- For null balance ,

$$w_1 * \text{length of power arm} = w_2 * \text{length of load arm}$$

Pendulum scale

- ❖ The pendulum scale is deflection type instrument in which the unknown weight is converted to a torque that is then balanced by the torque of a fixed standard mass arranged as pendulum.
- ❖ When the unknown weight is applied to the load rod, sectors tend to rotate due to tension in loading tubes, and consequently the counter weight W_c
swing out.
- ❖ The motion of the equilibrium are attained when

the moment due to counter weights is becomes same as
moment due to applied
load

- The motion of the equalizer bar is converted into an angular movement of the indicator by a rack and pinion arrangement.
- The deflection of the pointer is calibrated in terms of applied force.

Elastic force meter

- ❖ The elastic elements (spring, rod, cantilever, simply supported beam, ring, bellows, diaphragm etc.) can be used for measurement of force directly or indirectly through displacement of elastic limit.

SPRING SCALE

- As shown in figure spring scale, the unknown weight is suspended from a hook.
- The deflection of spring with respect to weight is read on the scale in terms of the weight.
- The scale is calibrated on the basis of the spring.

$$□ = □.□,$$

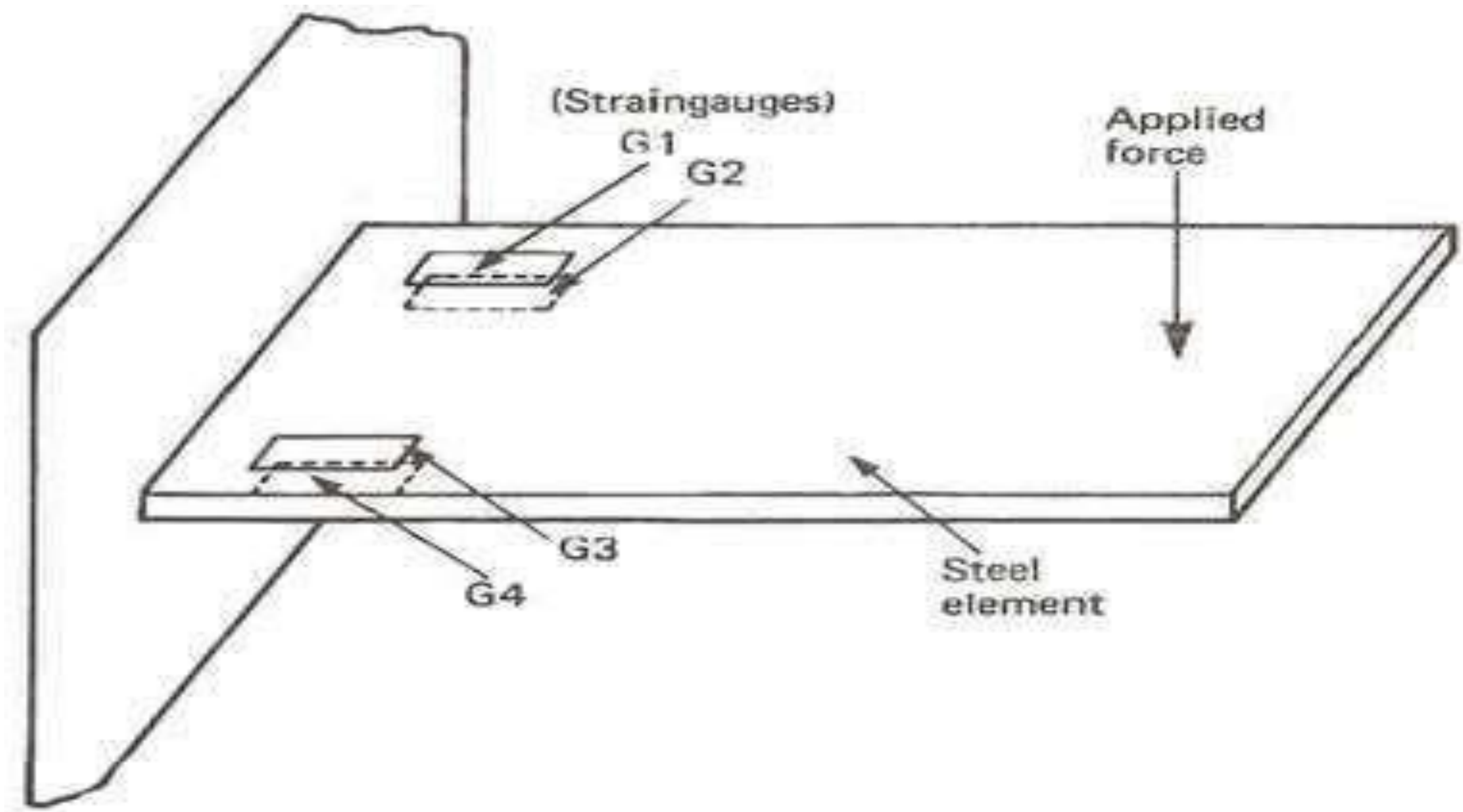
- □h □□□ □ □□□□□□□□□

□deflection, F is load

□□ □□□□□□,

□deflection, F is load

Cantilever beams load cell



- It is the simplest type of load cell of force measurement. It measures force based on principle as ‘bending moment developed in the beam is proportional to applied force’ to the end of beam.
- The deflection at free end is given by

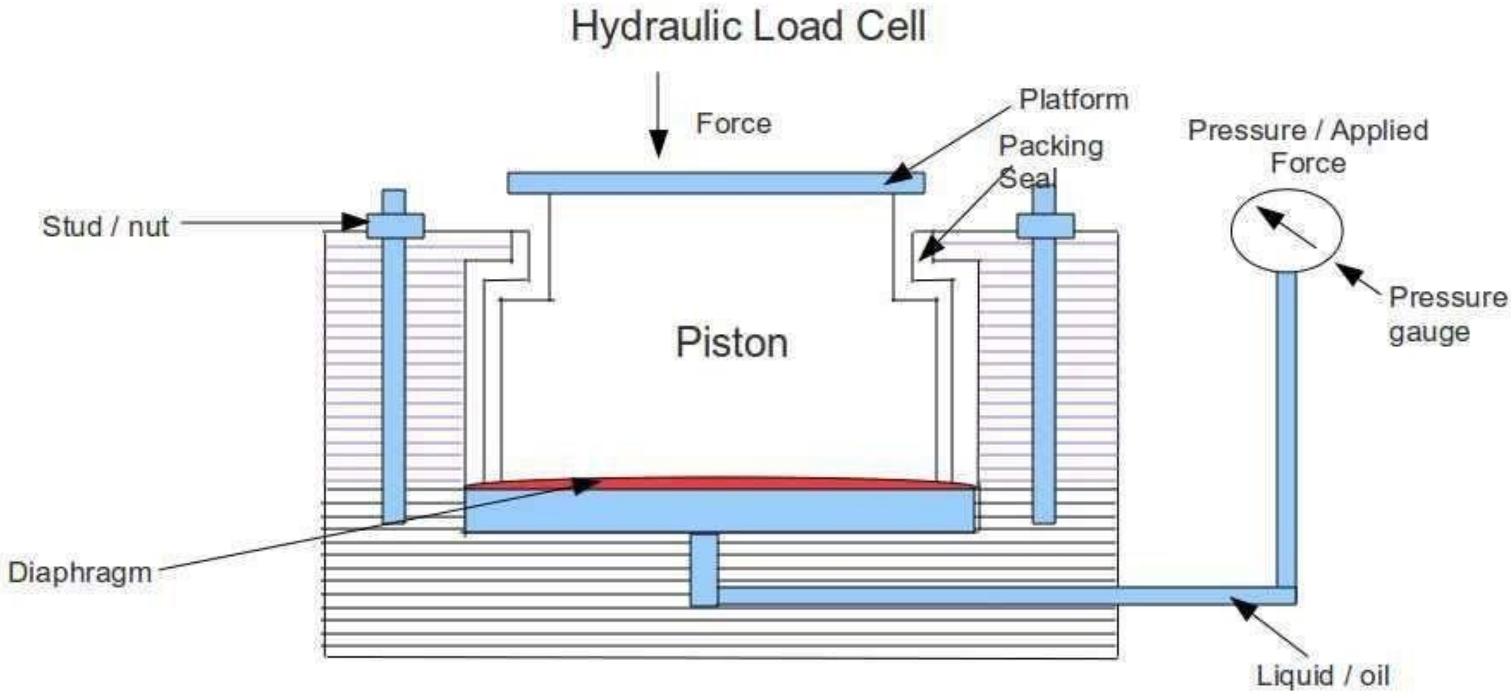
$$\square = \frac{4\square\square^3}{\square\square\square^3}$$

- The strain at fixed end is given by

$$\square = \frac{6\square\square}{\square\square\square^3}$$

Proving ring

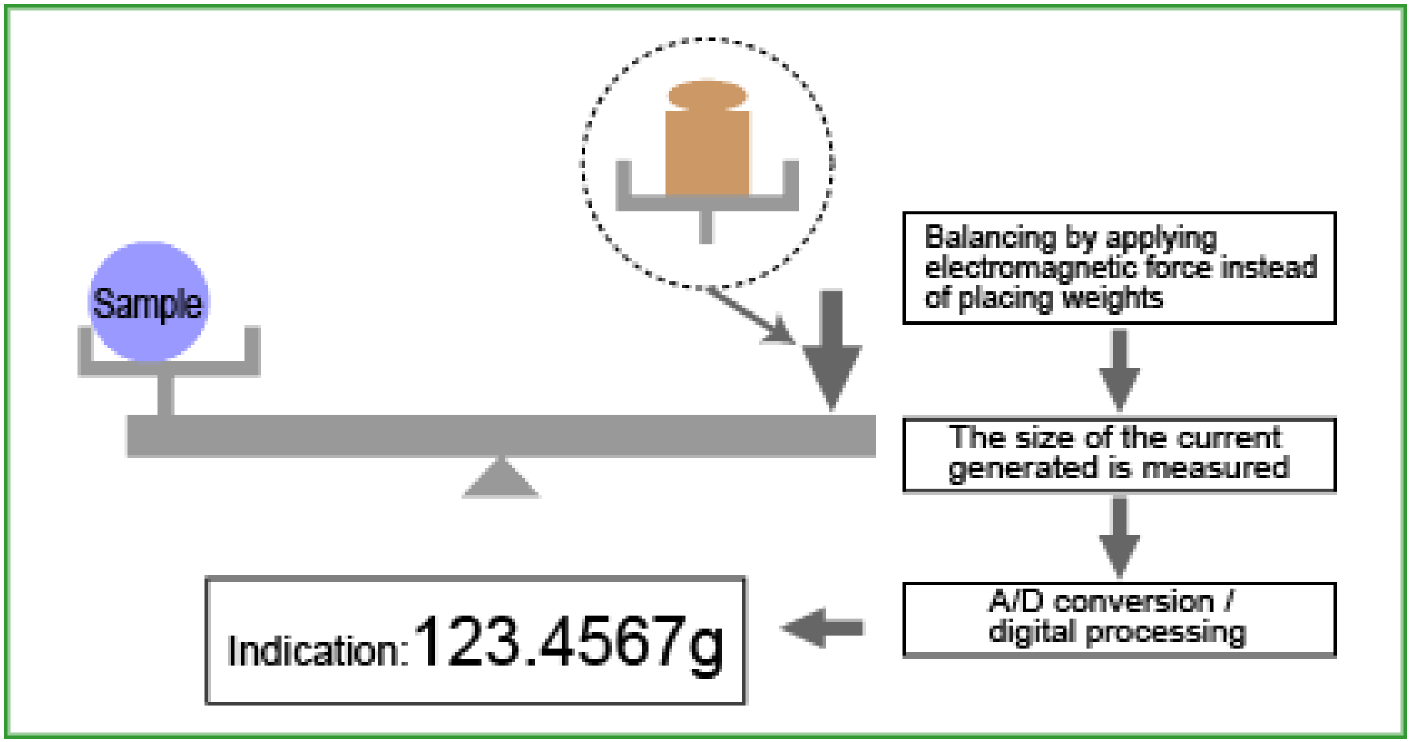
Hydraulic force meter



- The cell uses conventional piston and cylinder arrangement.
- The piston is placed in a thin elastic diaphragm.
- The piston doesn't actually come in contact with the load cell.
- Mechanical stops are placed to prevent over strain of the diaphragm when the loads exceed certain limit. The load cell is completely filled with oil.

- When the load is applied on the piston, the movement of the piston and the diaphragm arrangement in an increase of oil pressure which in turn produces a change in the pressure on a Bourdon tube connected with the load cells.
- Because this sensor has no electrical components, it is ideal for use in hazardous areas.
- Typical hydraulic load cell applications include result tank, bin and hopper weighing.

ELECTROMAGNETIC BALANCE METHOD



ELECTROMAGNETIC BALANCE METHOD

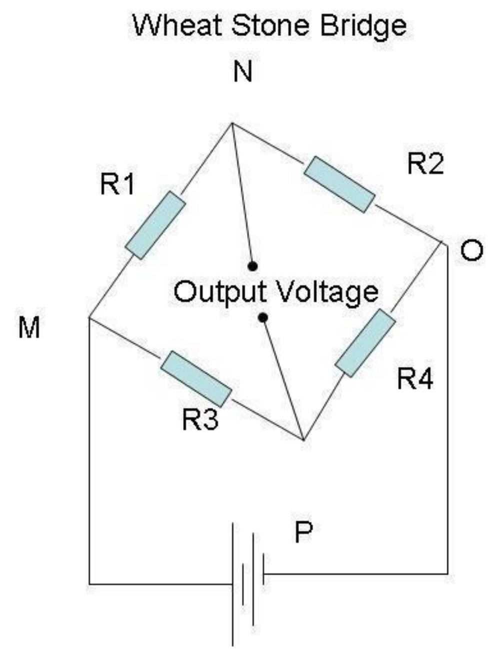
- This is also called the "electromagnetic balance method." With mechanical balances, the sample is placed at one end of the beam and the weight is placed at the other end, and the value of the weight when both are perfectly balanced becomes the mass of the sample.
- With electromagnetic type balances, an electrical force (electromagnetic force) is applied instead of a placed weight to balance the beam.
- The amount of electricity required for balancing the beam changes according to the weight of the sample that is placed.
- The amount of current when the beam is perfectly balanced is detected, and the mass is obtained from that

detected value.

Strain gauge load cell

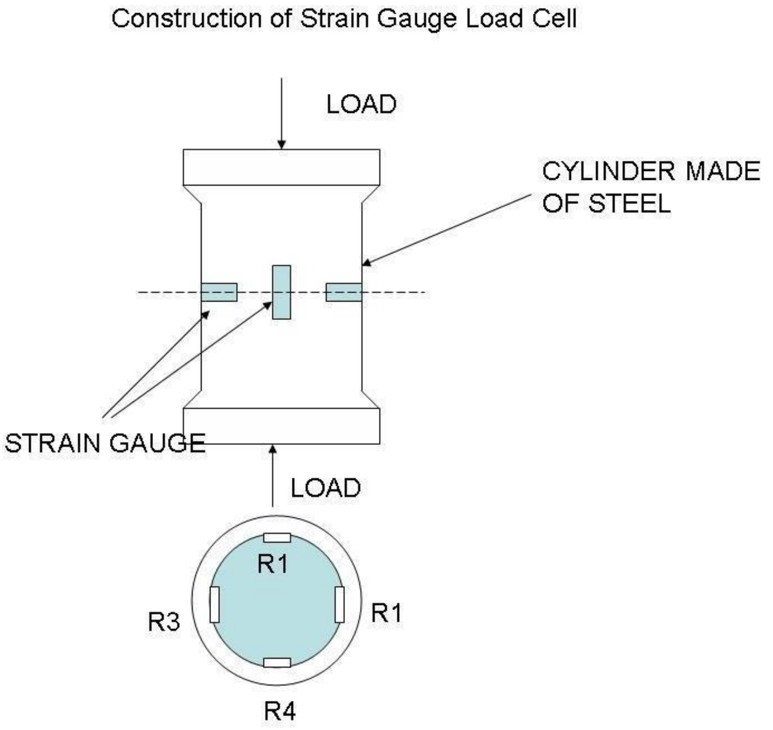
Basic Principle of Strain gauge load cell

- When steel cylinder is subjected to a force, it tends to change in dimension.
- On this cylinder, if the strain gauges are bonded, the strain gauge also is stretched or compressed, causing a change in its length and diameter.
- This change in dimension of the strain gauge causes its resistance to change.
- This change in resistance or output voltage of the strain gauge becomes a measure of applied force.



Construction of strain gauge Load cell

- The main parts of the strain gauge load cell are as follows.
- They are a cylinder made up of steel on which four identical strain gauge are mounted and out of four strain gauges, two of them (R1 and R4) are mounted along the direction of the applied load(vertical gauges).
- The other two strain gauges (R2 and R3 Horizontal gauges) are mounted circumferentially at right angles to gauges R1 and R4.



Case 1
When there is no load (force) on the steel cylinder, all the four gauges will have the same resistance. As the terminals N and P are at the same potential, the wheat stone bridge is balanced and hence the output voltage will be zero.

Case 2
Now the load (force) to be measured (say compression force) is applied on the steel cylinder. Due to this, the vertical gauges R1 and R4 will under go compression and hence there will be a decrease in resistance. At the same time, the horizontal gauges R2 and R3 will under go tension and there will be an increase in resistance. Thus when strained, the resistance of the various gauges change.

Now the terminal N and P will be at different potential and the change in output voltage due to the applied load (force) becomes a measure of the applied load force when calibrated.

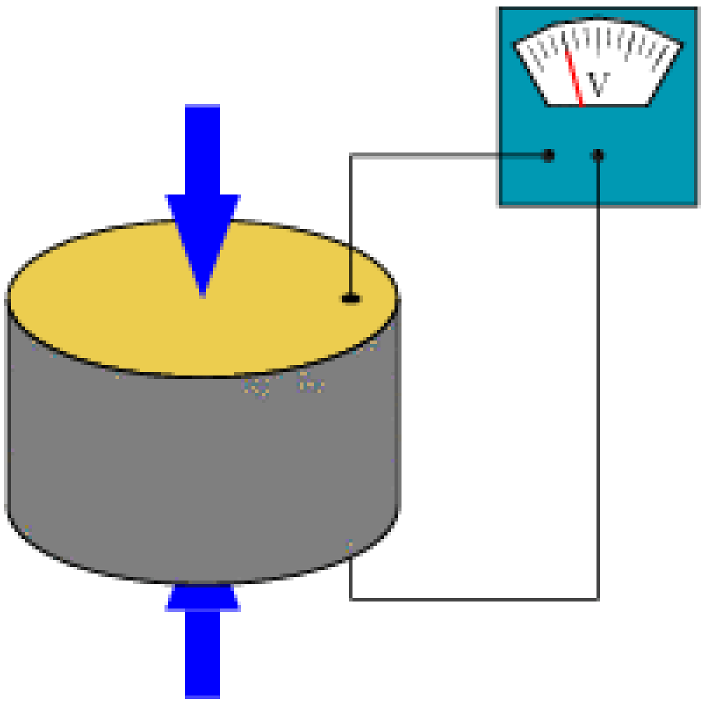
Uses of Strain Gauge Load Cell.

Strain gauge load cells are used when the load is not steady.
Strain gauge load cells are used in vehicle weigh bridges, and tool force dynamometers.

WHAT IS PIEZOELECTRIC EFFECT ?

- **Piezoelectricity** is the electric charge that accumulates in certain solid materials (such as crystals, certain ceramics, and biological matter such as bone, DNA and various proteins) in response to applied mechanical stress. The word *piezoelectricity* means electricity resulting from pressure
- The piezoelectric effect is understood as the linear electromechanical interaction between the mechanical and the electrical state in crystalline materials with no inversion symmetry.

PIEZO SENSOR GENERATES VOLTAGE WHEN DEFORMED !



PRINCIPLE OF OPERATION :

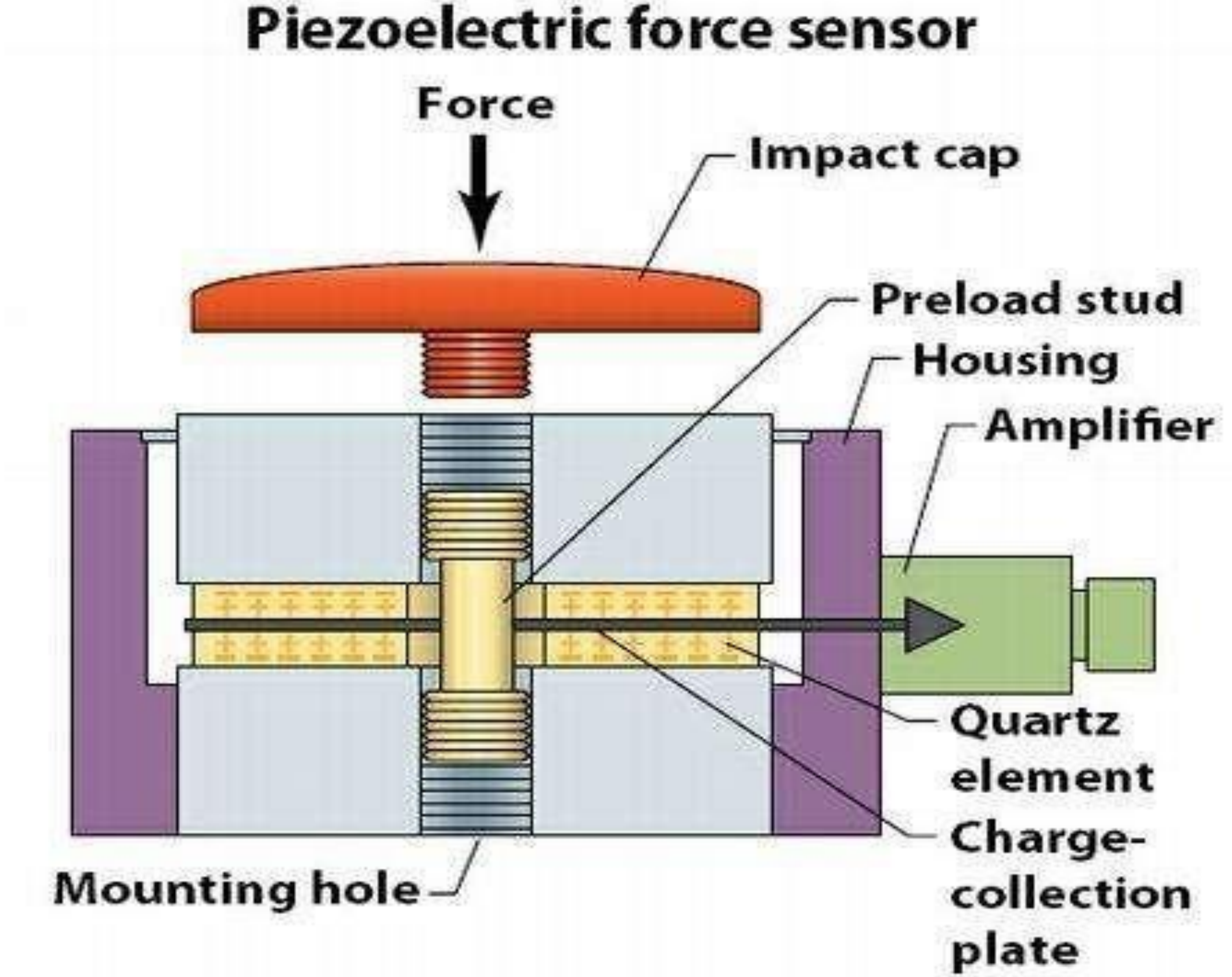
- Force applied to the piezoelectric sensing element produces a separation of charges within the atomic structure of the material, generating an electrostatic output voltage. The polarity of the voltage generated depends on the atomic structure of the material and the direction in which the force is applied.

- In a typical quartz-based force sensor, a charge-collection electrode is sandwiched between two quartz-crystal elements. The quartz elements are oriented to supply the same polarity voltage to the electrode when compressed, while the opposite polarity is applied to the sensor housing.

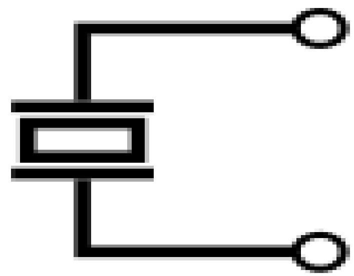
- This assembly resides between two mounting disks held together by an elastic, beryllium-copper stud and then weld-sealed within the enclosure to prevent contamination. The stud preloads the quartz elements to assure all parts are in intimate contact and to provide good linearity and tensile-force measurements.

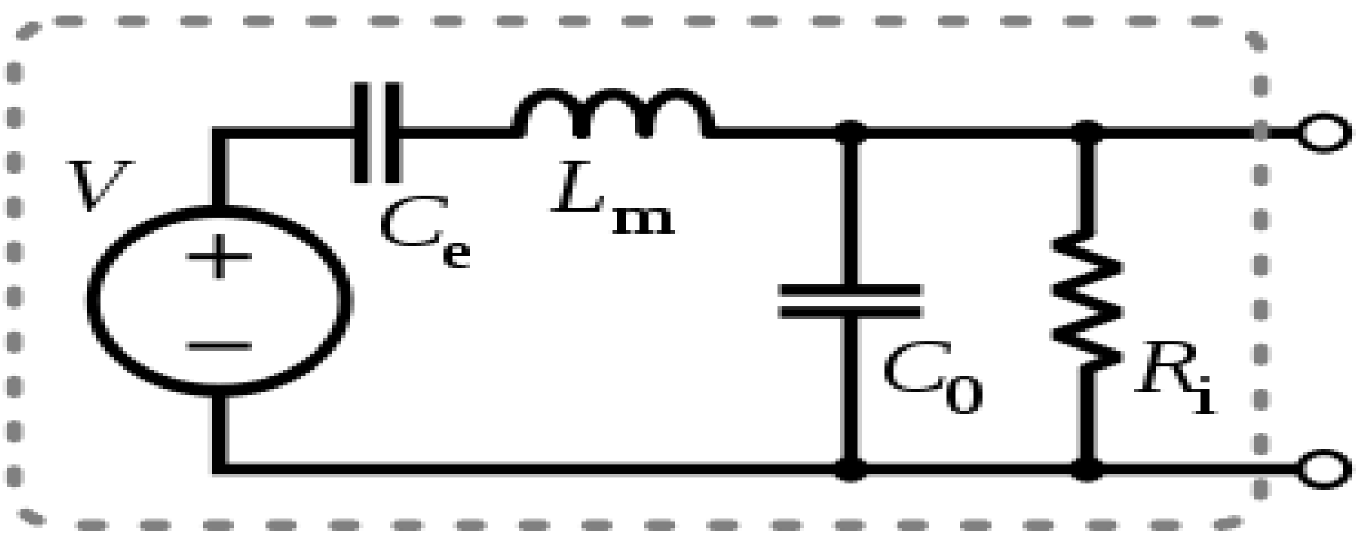
- When a force is applied to the impact cap, the quartz elements generate an output voltage which can be routed directly to a charge amplifier or converted to a low-impedance signal within the sensor

- The use of the direct sensor output demands that any connector, cable, and charge amplifier input must maintain a high insulation resistance on the order of >10≠” Ω.


Piezoelectric force sensor
Force
Impact cap
Preload stud
Housing
Amplifier
Quartz element
Charge-collection plate
Mounting hole

SCHEMATIC SYMBOL AND REPRESENTAION





APPLICATIONS ~

- Piezoelectric sensors have proven to be versatile tools for the measurement of various processes. They are used for quality assurance, process control and for research and development in many industries.
- In the automotive industry, piezoelectric elements are used to monitor combustion when developing internal combustion engines.
- It has been successfully used in various applications, such as in medical, aerospace, nuclear instrumentation, and as a pressure sensor in the touch pads of mobile phones
- Piezoelectric sensors are also seen in nature. The collagen in bone is piezoelectric, and is thought by some to act as a biological force sensor.

- Definition
- Types of Dynamometer
  - Brief Introduction about
    - Prony brake dynamometer
    - Rope brake dynamometer
    - Hydraulic dynamometer
    - Belt transmission dynamometer
    - Epicyclic dynamometer
    - Torsion dynamometer

DEFINITION

- Dynamometer is a device which is used to measure the frictional resistance. By knowing frictional resistance we can determine the torque transmitted and hence the power of the engine.

TYPES OF DYNAMOMETER :-

Absorption dynamometer:

- Prony brake dynamometer
- Rope brake dynamometer
- Hydraulic dynamometer

Transmission dynamometer:

- Belt transmission dynamometer
- Epicyclic dynamometer
- Torsion dynamometer

ABSORPTION DYNAMOMETER

- This dynamometers measure and absorb the power output of the engine to which they are coupled, the power absorbed is usually dissipated as heat by some means.

Examples such dynamometers are:

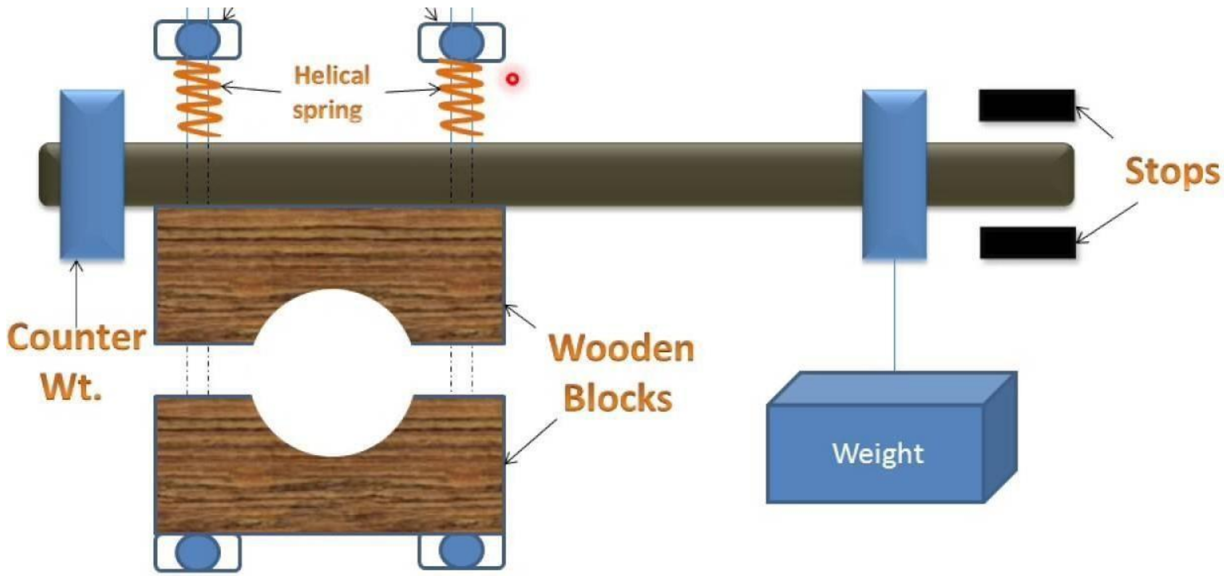
- Prony brake dynamometer
- Rope brake dynamometer
- Hydraulic dynamometer

PRONY BRAKE DYNAMOMETER

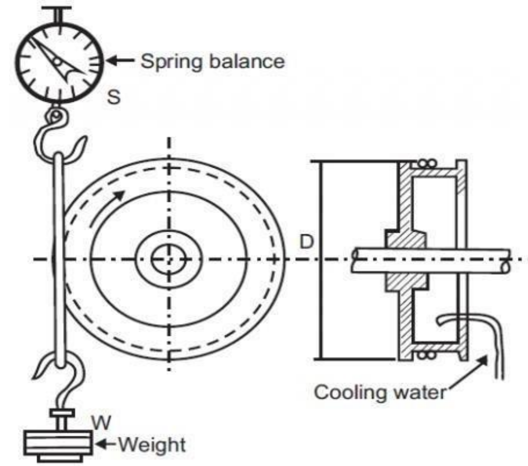
Construction & Working :

- A simplest form of an Absorption type Dynamometer is a Prony Brake Dynamometer .
- It consists of Two wooden blocks around a Pulley fixed to the shaft of an engine , whose power is required to be measured . The blocks are clamped by means of Two Bolts and Nuts . A Helical Spring is provided between the nut and the upper block to adjust the Pressure on the Pulley to Control its Speed
- The upper block has a long lever attached to it and carries a weight W at its outer end . A Counter Weight is placed at the other end of the lever which balances the Brake when Unloaded .
- Two stop are provided to limit the motion of the Lever .

- In Prony Brake Dynamometer , when the Brake is to be put in operation , the long end of the lever is loaded with suitable weights W and the nuts are tightened until the engine shaft runs at a constant speed and the lever is in Horizontal Position.
- Under these conditions , the moment due to the weight W must balance the moment of the Frictional Resistance between the Blocks and Pulleys .



ROPE BRAKE DYNAMOMETER



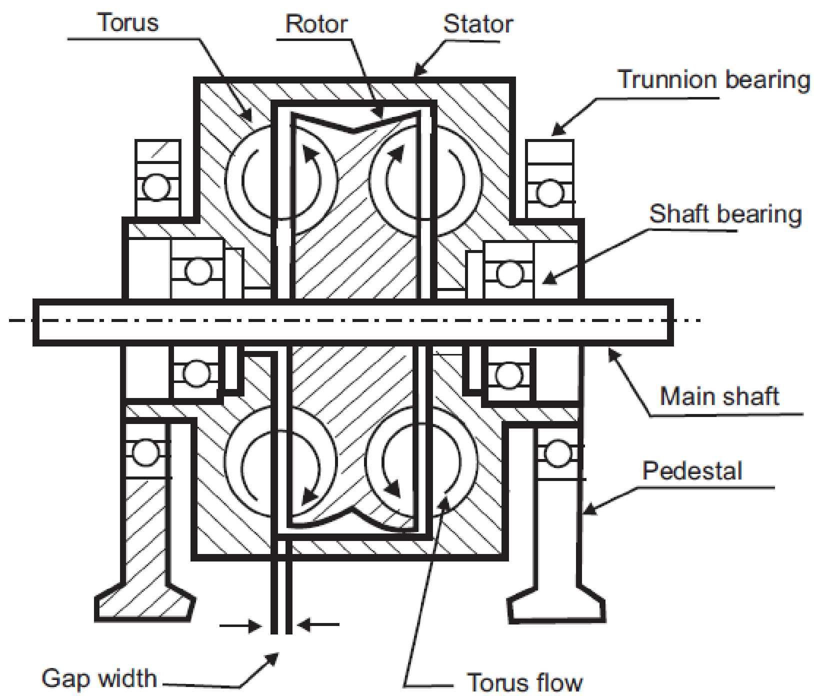
Construction & Working:

- It is another form of Absorption type Dynamometer which is most commonly used for measuring the Brake Power of the Engine . It consists of one , two or more ropes wound around the flywheel or rim of a pulley fixed rigidly to the shaft of an engine . The upper end of the ropes is attached to a spring balance while the lower end of the ropes is kept in position by applying a dead weight.
- In the Operation of Brake , the engine is made to run at a constant speed . The Frictional Torque , due to the Rope , must be equal to the torque being Transmitted by the Engine . .

HYDRAULIC DYNAMOMETER

- It works on the principle of dissipating the power in fluid friction rather than in dry friction.
- It consists of an inner rotating member or impeller coupled to the output shaft of engine, this impeller rotates in a casing filled with fluid.
- The heat developed due to dissipation of power is carried away by a continuous supply of working fluid, usually water.
- The output can be controlled by regulating the sluice gates which can be moved in and out to partial or wholly obstructive flow of water between impeller and the casing.

HYDRAULIC DYNAMOMETER



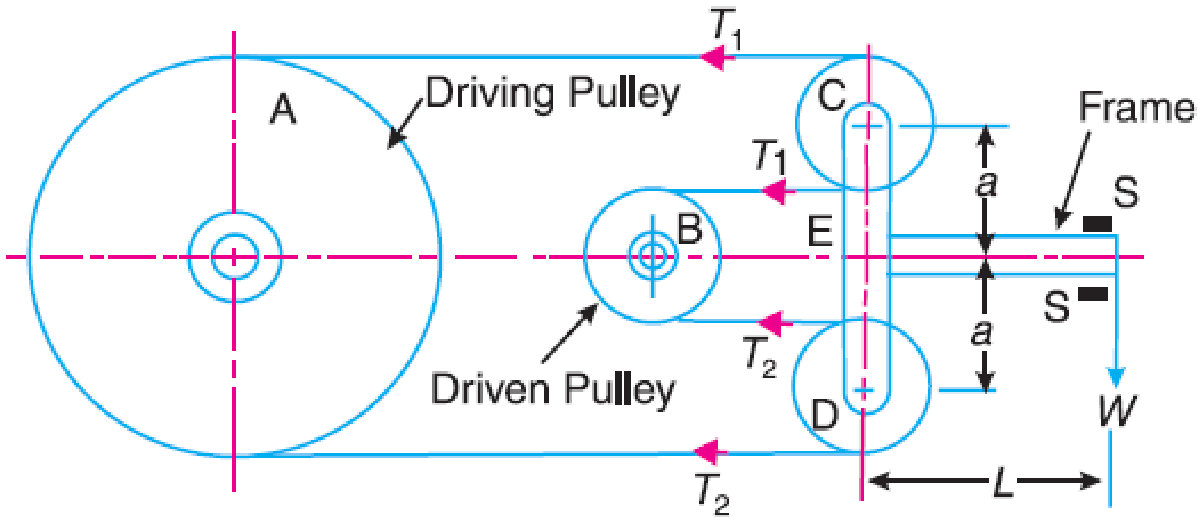
TRANSMISSION DYNAMOMETERS

- Power-measuring dynamometers may be transmission dynamometers or absorption dynamometers. The former utilize devices that measure torque, in terms of the elastic twist of the shaft or of a special torque meter inserted between sections of the shaft. The torque is produced by the useful load that the prime mover, motor, or machine is carrying.

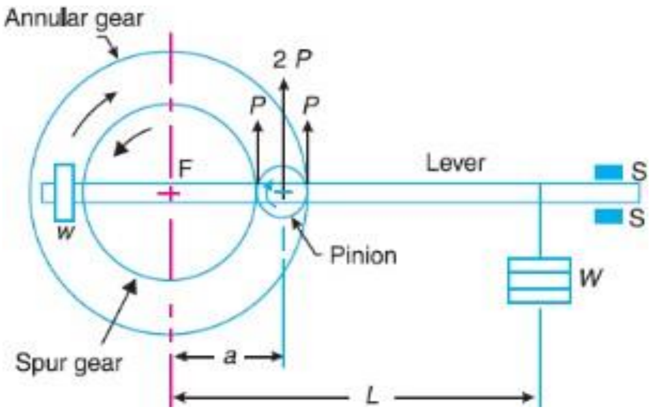
BELT TRANSMISSION DYNAMOMETER

- It consists of endless or continuous belt run over the driving pulley.
- The driving pulley is rigidly fixed to the shaft of an engine whose power is to be transmitted.
- The intermediate pulleys rotates on a pin fixed to a lever having a fulcrum at the midpoint of the two pulley centers.
- A balancing weight is provided in the
- lever to initially keep it in equilibrium.
- The weight of suspended mass at one end of the lever balances the difference in tensions of tight and slack sides of the belt.

BELT TRANSMISSION DYNAMOMETER



EPICYCLIC TRAIN DYNAMOMETER



- Epicyclic train dynamometer which measures power while it is being transmitted from driving to the driven shaft.
- It consist of simple Epicyclic gear train.
- The pinion is free to rotate on a pin fixed to the lever arm.
- The lever is pivoted about common axis of the driving and driven shaft.
- When the dynamometer is in operation, two tangential forces acts at the end of pinion.

TORSION DYNAMOMETER

- When power is transmitted along a shaft, the driving end twists through a small angle relative to the driven end.
- Torque transmitted is directly proportional to the angle of twist.
- Therefore, a torsion dynamometer works on the principle of angle of twist.
- Torsion dynamometers can measures large powers as in case of power transmitted along the angle of twist.

Vibration Measuring Instruments

- The instruments or equipments which are used for measure the displacement, velocity, frequency, phase distortion and acceleration of a vibrating g body are called vibration measuring instruments.
- The displacement, velocity and acceleration is identify by the relative motion of the suspended mass of the instruments with respect to its case which is placed on the vibrating body.
- Vibration measuring devices having mass , spring , dashpot etc. are called seismic instruments .

- The quantity which is measure by the instruments are displayed on the screen in the form of electric signal which can be readily amplified and recorded.

- The output of electric signal of the instrument is proportional to the quantity which is measured. The input is reproduced as output very precisely.

Types of Vibration Measuring Devices

1. Vibrometer

2. Accelerometer

Figure : 1

Vibrometer

- A Vibrometer or seismometer is used for measuring displacement of a vibrating body. Basically it is design under the condition of low natural frequency due to this reason it is also called as low frequency transducer. This is used to measure high frequency ω of a vibrating body.
- Its natural frequency has ranged between 1 Hz to 5 Hz and useful natural frequency range of 10 Hz to 2000 Hz.
- The sensitivity of this instruments is in the range between the 20 to 350 mV/cm/s. The maximum displacement is ranged between the 0.5 peaks to one peaks.

Application & Disadvantages of Vibrometer

Application

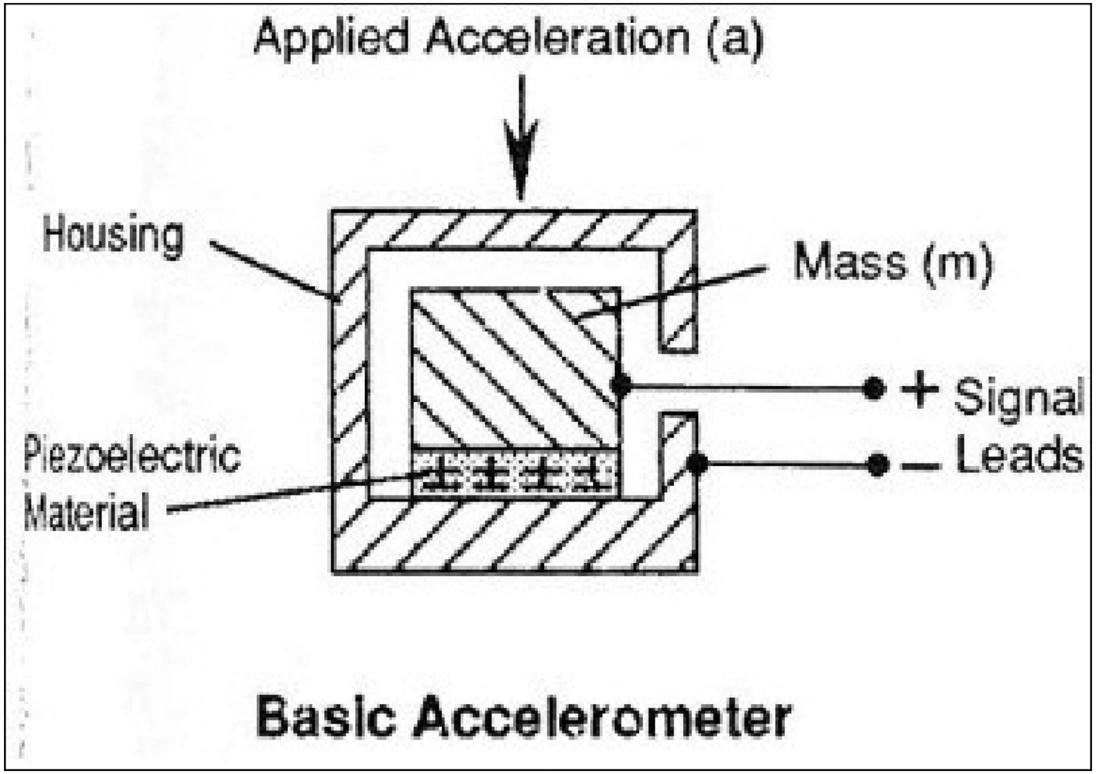
•The instrument is used to record building vibrations. also used for measuring vibration of the huge structure like railway bridge.

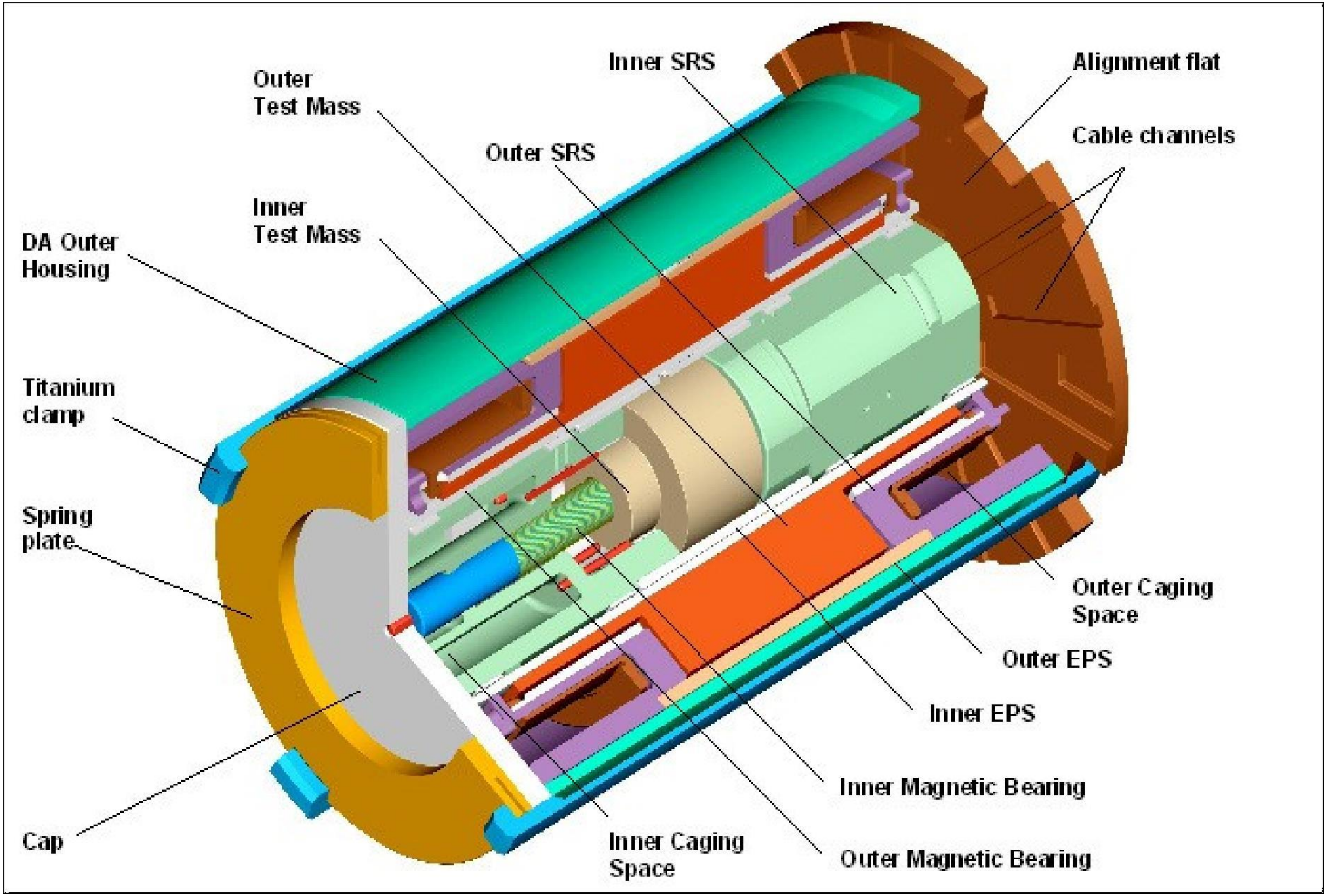
Disadvantage

•It is large in size because of its relative motion of the seismic mass must be of the same arrangement of the magnitude as that of the vibration to be measured.

Accelerometer

- Accelerometer is a instrument used for measuring the acceleration of the vibrating body. The accelerometer is design with the high natural frequency and it is said to be high frequency transducer.




Inner SRS
Alignment flat
Outer
Test Mass
Cable channels
Outer SRS
Inner
Test Mass
DA Outer
Housing
Titanium
clamp
Spring
plate
Outer Caging
Space
Outer EPS
Inner EPS
Inner Magnetic Bearing
Cap
Inner Caging
Space
Outer Magnetic Bearing

Types of Accelerometer

- ***Electromagnetic type of accelerometer*** use damper to extend the useful natural frequency range. it is also using for the prevents phase distortion.
- ***Piezoelectric crystal accelerometer*** having zero damping is operating without distortion. It is used for measuring high frequency.
- ***Seismic mass accelerometer*** is used for low frequency vibration. The supporting springs are four electric strain gauges wires which is connected with the bridge circuit.

INTRODUCTION

- ✓ The accurate measurement of temperature is vital across abroad spectrum of human activities,
  - ❖ Including industrial processes (e.g. making steel) Manufacturing;
  - ❖ Health and safety.
- ✓ In fact, in almost every sector, temperature is one of the key parameters to be measured.
- ✓ Different people will have different perceptions of what is hot and what is cold.

.

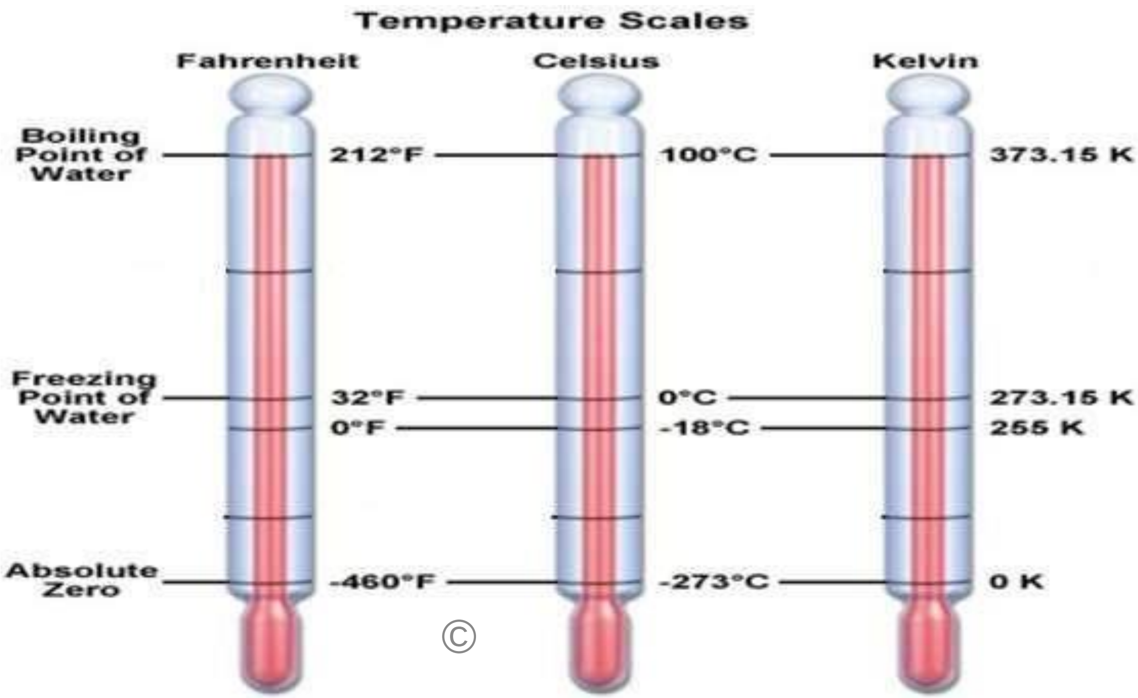
- Temperature ?
  - scalar quantity
  - Degree of hotness or coldness
  - Molecular K.E. ↑ = Temperature ↑
- Heat ?
  - Form of energy.
  - Measured in calories or BTU'S[British Thermal Units].

Scale

❖ Temperature - measure of the thermal energy.

❖ Measured in degrees [°]using scales.

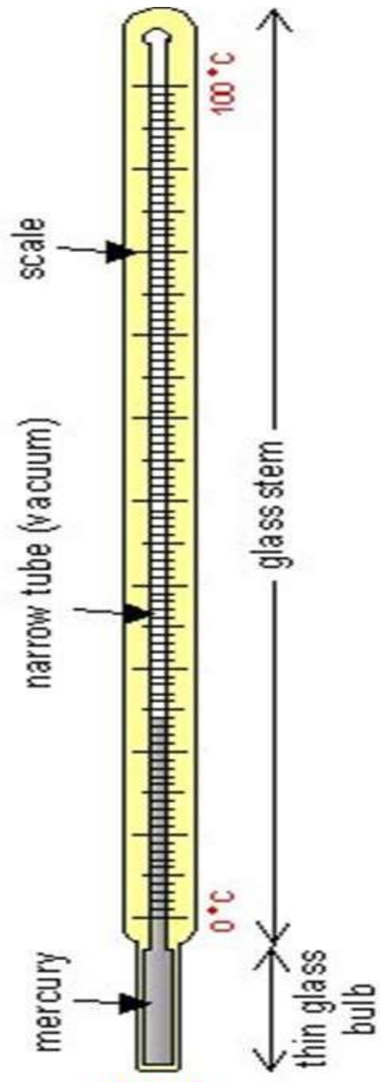
1. Fahrenheit.[°F]
2. Celsius or centigrade. [°C]
3. Kelvin .[°K]



1. quid – in – Glass Thermometer

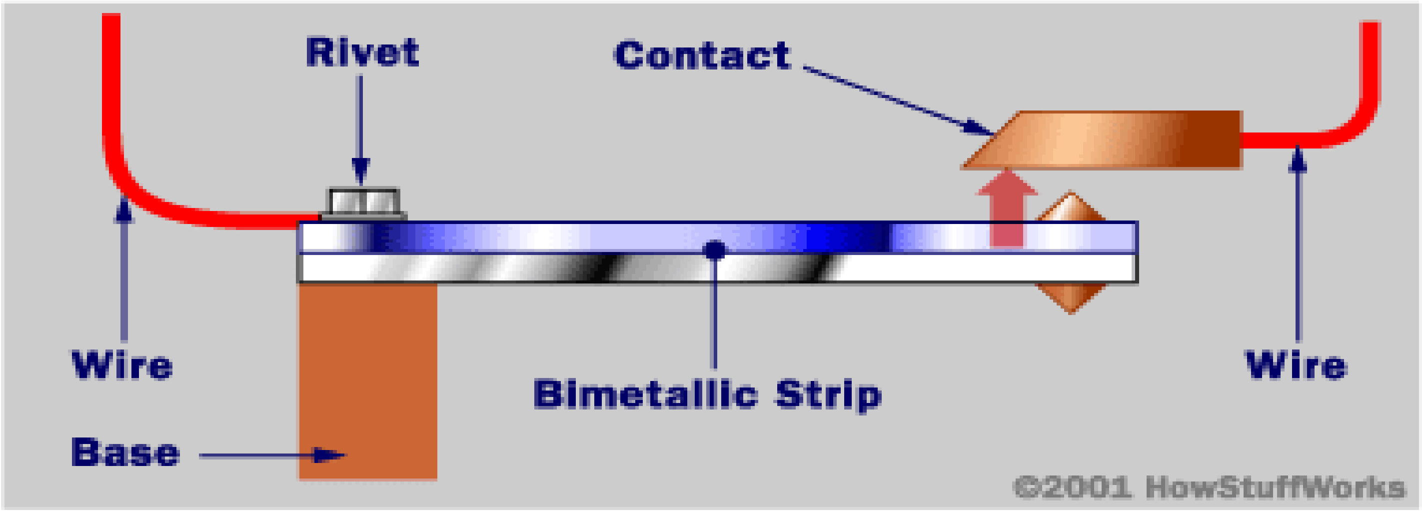
- The volume of mercury changes slightly with temperature.

- The space above the mercury may be filled with nitrogen or it may be at less than atmospheric pressure, a partial vacuum



2. etallic Thermometer

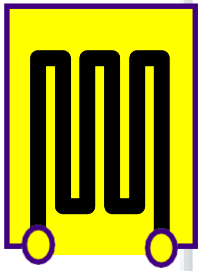
✓ Temperature Indicators (TI) or Temperature Gauges (TG)



Principles :

- ❑ Expansion/Contraction - change in temperature.
- ❑ Different metals -- different co-efficient of temperatures. The rate of volumetric change depends on this co-efficient of temperature.

3. nce Temperature Detector (RTD)



- Resistance thermometer
- PRINCIPLE :

  TEMPATURE ↑↓ = RESISTANCE ↑↓

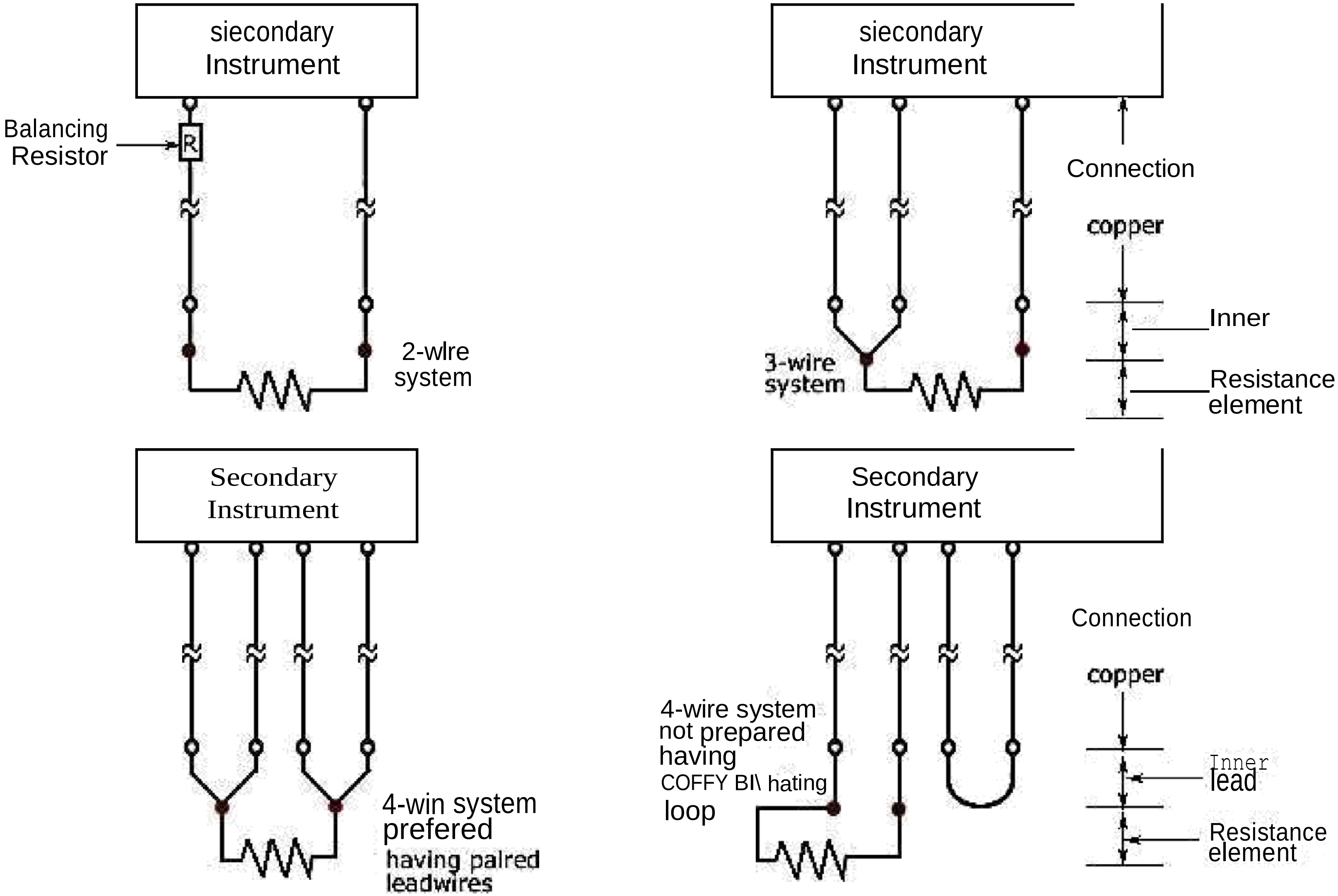
- Positive temperature coefficient

RTD Types

- classified according to the different sensing elements used -

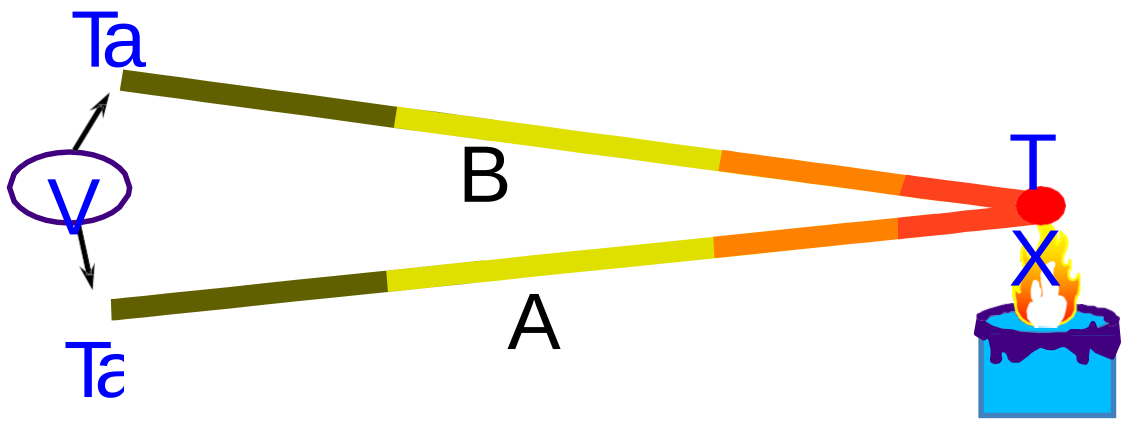
  Platinum
  Nickel
  Copper

Resistance Temperature Detector (RTD) - 2-Wire,3-WIre,4-Wire Systems



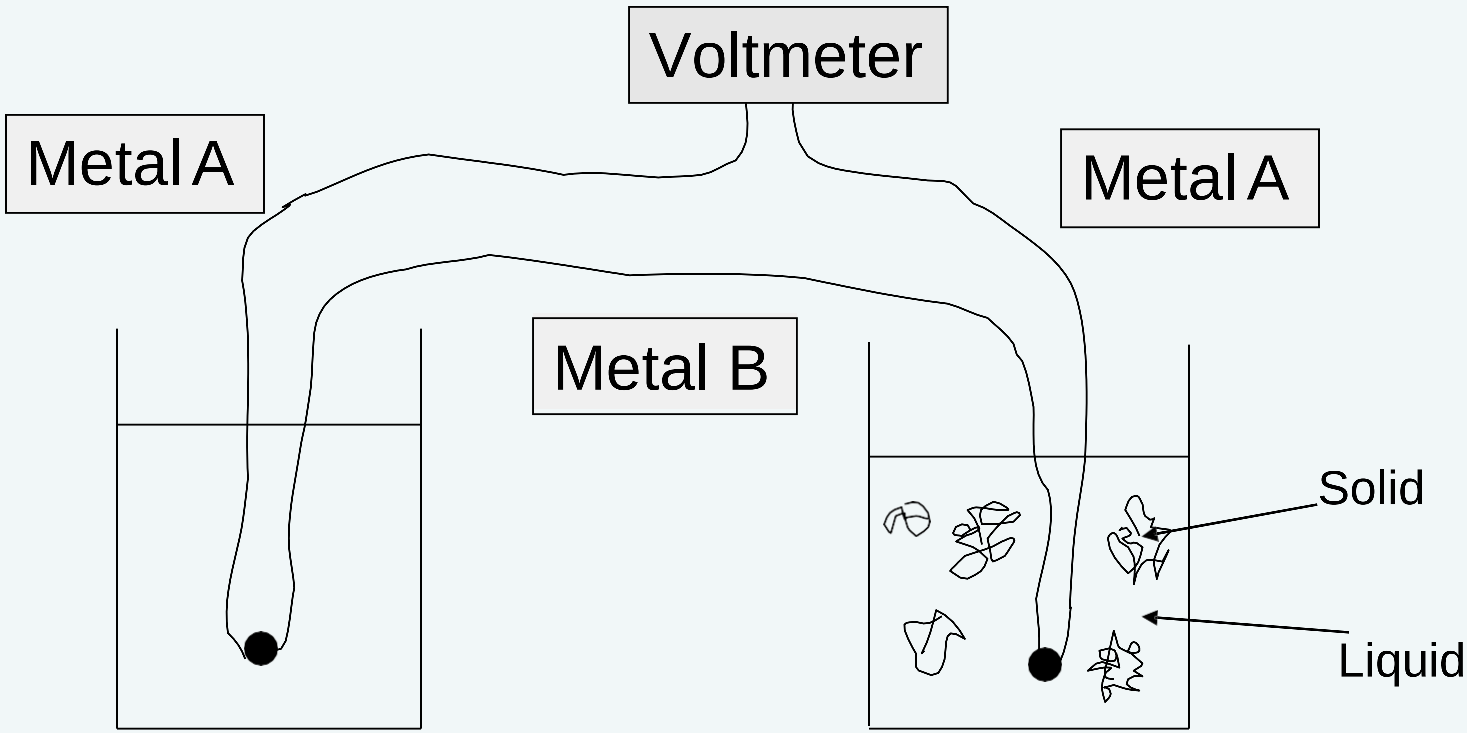
For each arrangement,the secondary instrument measuw s the resistance of the wires drawn with a heavy line

4. S



❑ SEEBECK EFFECT

Typical Thermocouple Configuration



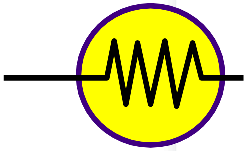
Unknown temperature

Reference temperature (slush bath)

Thermocouple Types

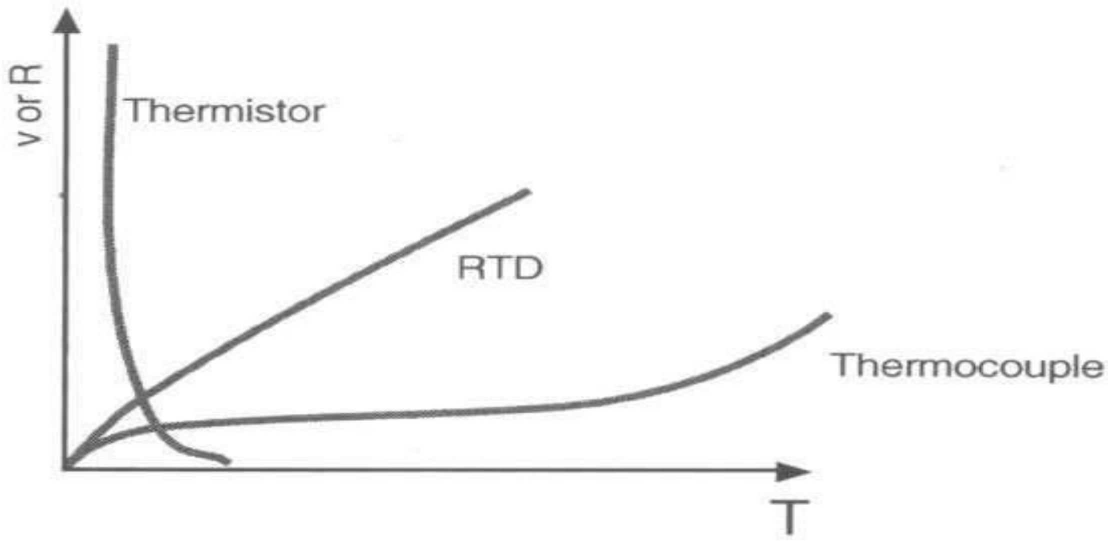
Type	Metals	See beck Coif: uV/C
J	Fe-Con	50
K	Ni-Cr	40
T	Cu-Con	38
S	Pt./Rh-Pt.	10
E	Ni/Cr-Con	59
N	Ni/Cr/Si-Ni/Si	39

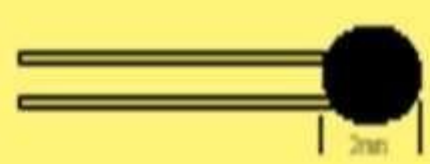
5. rmistors



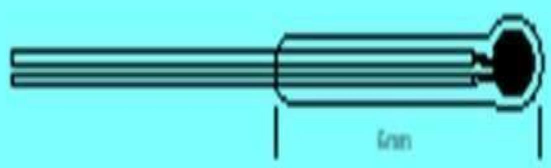
- ❑ Thermally sensitive resistors
- ❑ Highly sensitive and very reproducible resistance vs. temperature.
- ❑ Limited range
- ❑ Typically used over a small temperature range (due to non-linear characteristics)
- ❑ Thermistors do not do well at high temperatures and show instability with time
- ❑ Manufactured from oxides of nickel, magnesium, iron, cobalt,manganese,titatinum and other metals.
- ❑ NTC Thermistor
- ❑ **Steinhart – Equation** : $1/T = a + b\ ln(R)+ln\text{^}3(R)$

Thermistor Non-Linearity





a. Epoxy Coated Thermistor Bead.



b. Glass Coated Thermistor Bead.

More temperature measurement possibilities

- ✓Thyorister
- ✓Thermowell
- ✓Infrared Thermometer
- ✓pyrometer