

MEASUREMENT OF POWER, FLOW AND TEMPERATURE

Force, Torque, Power - Mechanical, Pneumatic, Hydraulic and Electrical Type, Flow Measurement, Venturimeter, Orifice meter, Rotameter, Pitot tube - Temperature, bimetallic strip, thermocouples, electrical resistance Thermometer - Reliability and Calibration - Readability and Reliability.

Force Measurement :-

Force is Nothing but Product of Mass and acceleration.

$$F = ma$$

The Force is a Vector Quantity.

Unit of force is Newton (N)

Generally Force can be measured by two methods.

1. Direct force Measurement.

2. Indirect force Measurement.

Direct Force Measurement :-

- (i) Analytical Balance Method.
- (ii) Platform Balance
- (iii) Chemical Arms Balance Method.
- (iv) Pendulum scale.

Indirect force Measurement :-

- (i) Accelerometers
- (ii) Electromagnetic Balance Method.
- (iii) Load cells.
 - (a) Capacitive load cells.
 - (b) Magnetoelastic load cells.
 - (c) Strain Gauge load cells.
 - (d) Hydraulic load cells.
 - (e) Pneumatic load cells.
 - (f) S'head Type load cells.

Elastic Loaded Members :-

Elastic loaded members are also used to measure the force. The deflection can be measured either directly or indirectly by using secondary transducers.

Direct measurement of elastic load members are

- (i) Coil springs
- (ii) Proving rings
- (iii) Load cells.
- (iv) Electronic weighing system.

Measurement of Pressure :-

Fluid Pressure sensors :-

The fluid pressure sensors are used to measure the pressure within the fluid to various forces acting on the fluid during flow.

The various types of pressure sensors are discussed.

The pressure in a fluid is measured by the following device.

- 1) Mano Meters.
- 2) Mechanical Gauges.

Mano Meters :-

Mano meters are defined as the devices used for measuring the pressure at a point in a fluid by balancing the column of fluid by the same or another column of fluid.

Manometers are classified as.

Simple Manometers :-

Used to measure pressure at a point in a fluid flowing through pipe (or) contained in vessel.

Differential Manometers :-

Used to measure the pressure difference between any two points in a fluid flowing through pipe (or) contained in a vessel.

Mechanical Gauges :-

Mechanical Gauges are devices used for measuring the pressure by balancing the fluid column by the spring or dead weight.

- (a) Diaphragm Pressure gauge
- (b) Bourdon tube Pressure gauge.
- (c) Dead-weight Pressure gauge.
- (d) Bellows Pressure gauge.

Pressure Measurement Methods

- 1). Elastic Pressure Transducers ;
Bourdon tube , Pressure Gauge
(C - type , Helical type , spiral type)
Diaphragm Pressure Transducers , Bellows.

2. Manometer Method.

3. Electric Pressure Transducers:

Strain gauge type, Potentiometer type (resistance type), Capacitance type etc..

SIMPLE MANOMETERS :-

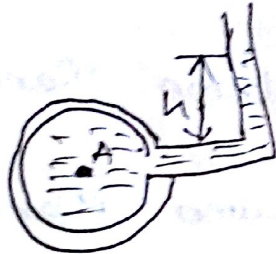
A simple manometer consists of a glass tube having one of its ends connected to a point where pressure is to be measured and other end remains open to atmosphere.

Common type of simple manometers are .

- (i) Piezometer.
- (ii) U-Tube Manometer
- (iii) Single Column Manometer.

Piezometer :-

It is the simplest form of Manometer used for measuring gauge pressure.



Piezometer

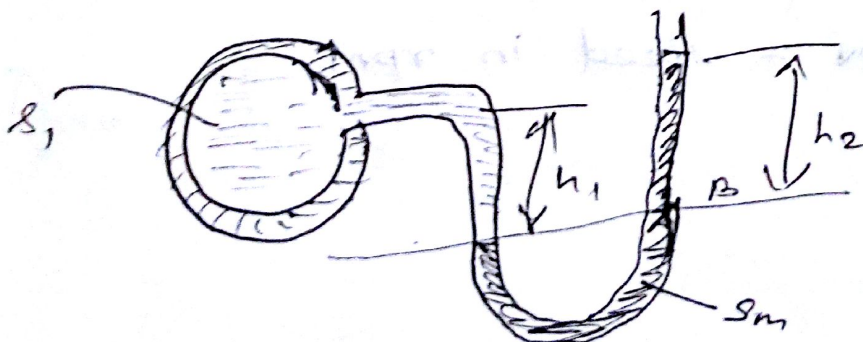
$$P_A = \rho \times g \times h$$

ρ = Density of liquid in kg/m^3 .

g = Acceleration due to gravity.

Simple U tube Manometer :-

U tube Manometer consists of a glass tube bent in U-shape. One end is connected to the pipe and other end is open to atmosphere.



Single Column Manometer :-

Single Column Manometer is Modified form of U tube Manometer having a very large reservoir. There are two types of single column manometer

(a) Vertical single Column Manometer.

(b) Inclined single Column Manometer.

Torque Measurement :-

Torque is nothing but twisting Moment. Torque may be defined as the force applied on the body on which it acts about an axis, causing the tendency of body to rotate.

$$\text{Power, } P = \frac{2\pi NT}{60}$$

Let T = Torque in (N-m)

N = speed in rpm.

Dynamometers :-

Hydraulic Dynamometer :-

The Water brake is of hydraulic nature and it is the simplest example for hydraulic dynamometer.

Generally the water brake is used for large amount of heat is dissipated to the water in water brake system.

Other types of Dynamometers are .

Eddy current Dynamometer .

Strain Gauge type .

Slip ring type .

These are the types of

Dynamometers.

Torque Measurement Using Torsion Bar :-

Bar :-

It is classified into following types:

- (i) Torsion bar
- (ii) Magnetostrictive
- (iii) Laser optic method.
- (iv) Proximity sensor method.
- (v) Stroboscope method.
- (vi) SAW method.

Flow Measurement :-

The fluid flow can be measured by flow meters. The flow meters

(a) Obstruction meters are generally mechanical type,

- (a) Orifice meter.
- (b) Venturimeter.
- (c) Variable area meter
- (d) Flow Nozzle.

Types of Fluid Flow

The fluid flow can be divided into three categories.

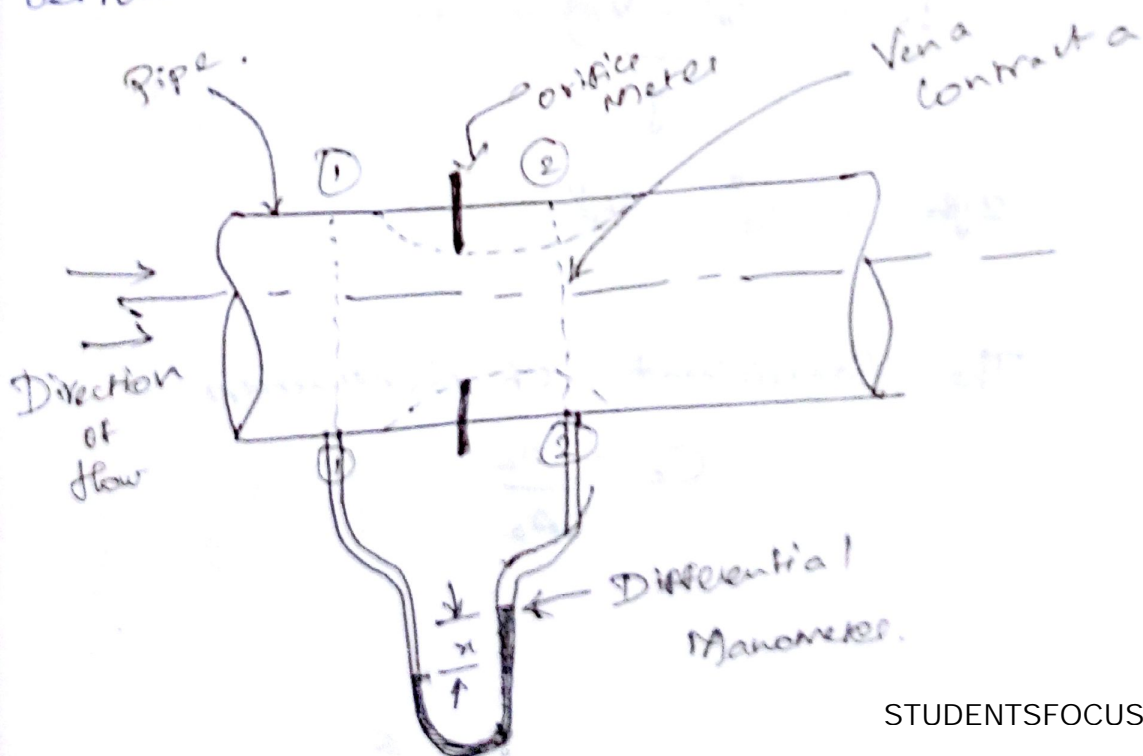
These are

1. Laminar flow.
2. Transient flow.
3. Turbulent flow.

ORIFICE METER :-

An orifice meter is a simple device used for measuring discharge of fluid through a pipe.

It works on the basis of Bernoulli's equation like Venturi meter.



P_1 , V_1 , and A_1 are Pressure, Velocity and Area at the section 1

Similarly P_2 , V_2 , A_2 are section 2

Applying Bernoulli's equation

$$\frac{P_1}{\rho} + \frac{V_1^2}{2g} + z_1 = \frac{P_2}{\rho} + \frac{V_2^2}{2g} + z_2$$

$$\left(\frac{P_1}{\rho} + z_1 \right) - \left(\frac{P_2}{\rho} + z_2 \right) = \frac{V_2^2}{2g} - \frac{V_1^2}{2g}$$

$$\text{But } \left(\frac{P_1}{\rho} + z_1 \right) - \left(\frac{P_2}{\rho} + z_2 \right) = h$$

Difference head

$$h = \frac{V_2^2 - V_1^2}{2g}$$

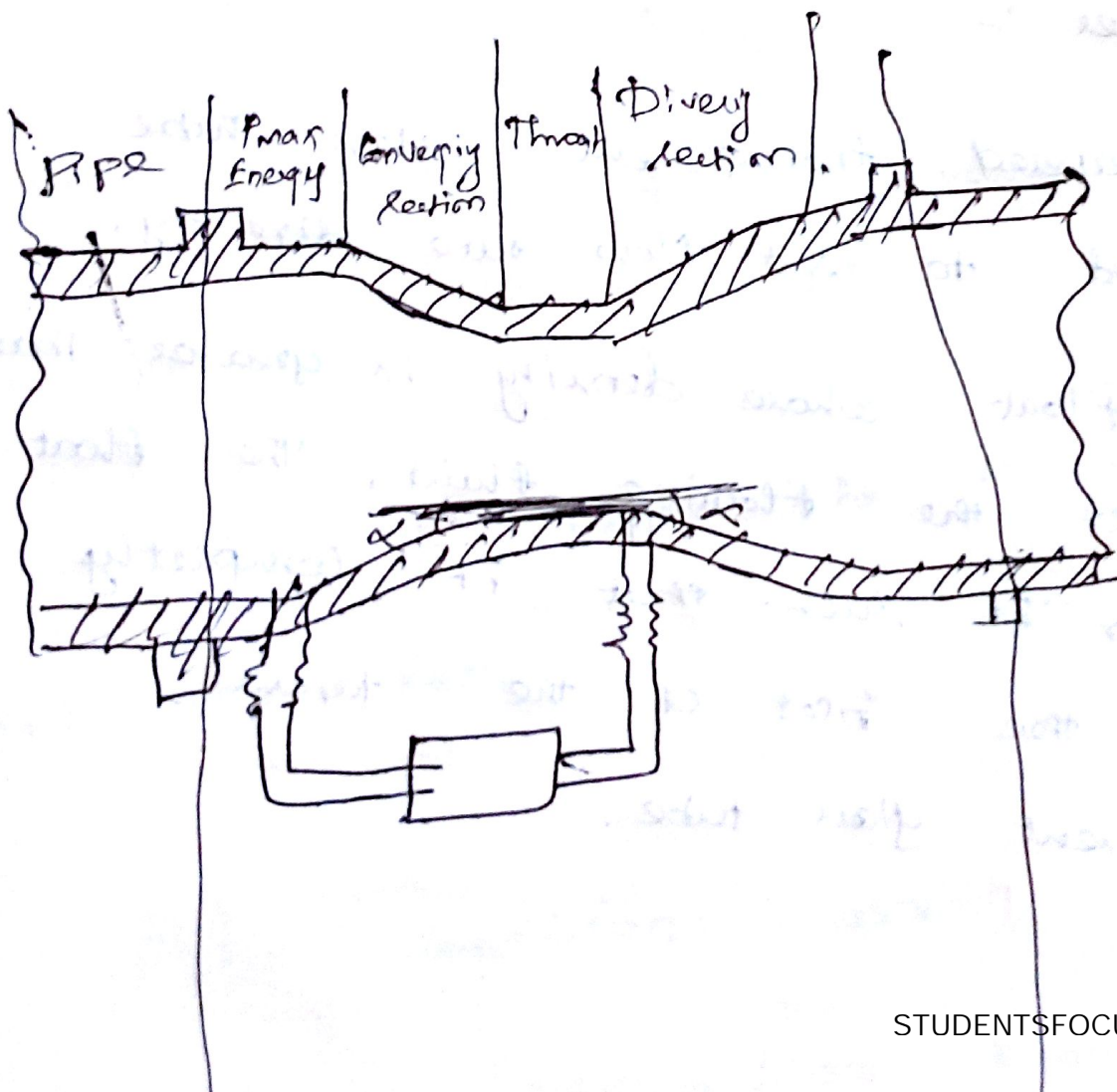
$$2gh = V_2^2 - V_1^2$$

The Coefficient of Contraction

$$C_c = \frac{A_2}{A_0}$$

Venturimeter :-

When a Venturimeter is placed in a pipe carrying the fluid whose flow rate is to be measured, a pressure drop occurs between the entrance and throat of the Venturimeter. This pressure drop is measured using a differential pressure sensor and when calibrated this pressure drop becomes a measure of flow rate.



It is used where high pressure recovery is required.

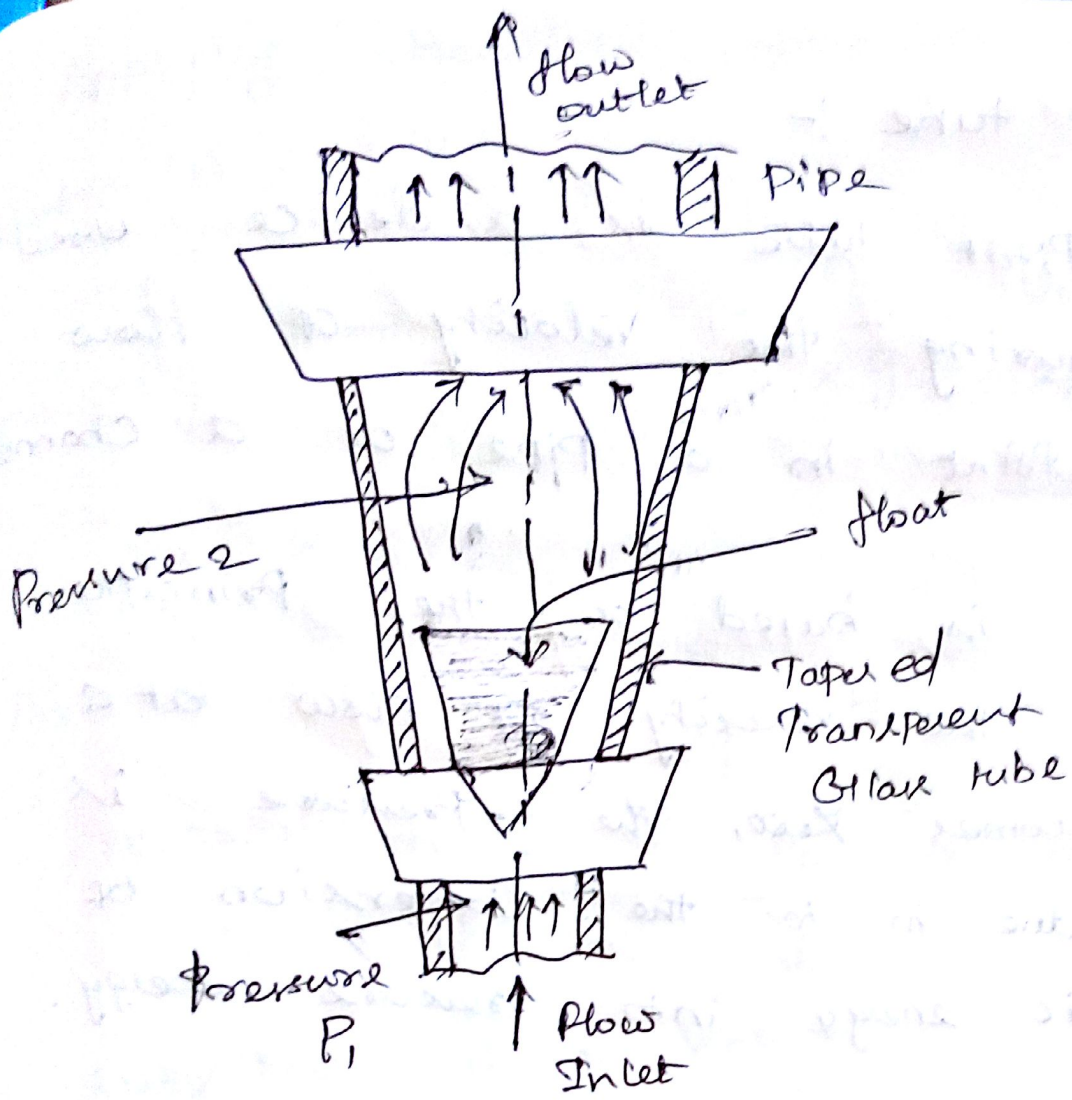
Can be used for measuring flow rate of water, wastes, gases, suspended solids, slurries and dirty liquids.

Can be used to measure high flow rates in pipes having diameters in a few meters.

Rotameter :-

A tapered transparent glass tube graduated to read flow rate directly.

A float whose density is greater than that of the flowing fluid. The float diameter is such that it completely blocks the inlet of the tapered transparent glass tube.



Can be used to measure flow rates of Corrosive fluids.

Particularly Useful to measure low flow rate.

Flow conditions are visible.

Flow rate is a linear function.

Pitot tube is

Pitot tube is a device used for measuring the velocity of flow at any point in a pipe or a channel.

It is based on the principle that if the velocity of flow at a point becomes zero, the pressure is increased due to the conversion of the kinetic energy into pressure energy.

P_1 : Intensity of Pressure at Point 1

V_1 : Velocity at 1

P_2 : Intensity of Pressure at 2

V_2 : Velocity at Point 2.

H : depth of tube in the liquid.

h : rise of liquid in the tube

Applying Bernoulli's equation at

point (1) and (2)

$$\frac{P_1}{\rho g} + \frac{V_1^2}{2g} + z_1 = \frac{P_2}{\rho g} + \frac{V_2^2}{2g} + z_2$$

↳ (i)

$$\text{But } z_1 = z_2$$

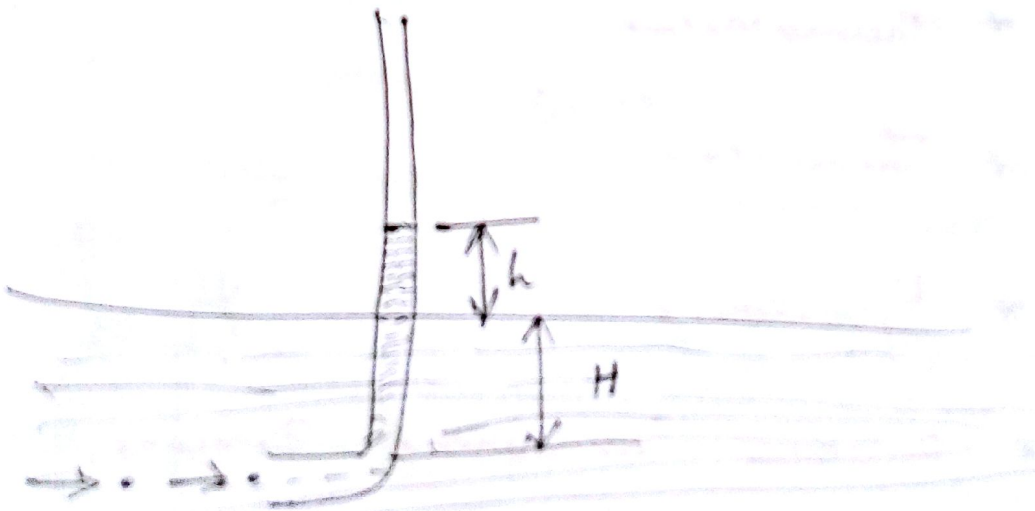
$$\text{Pressure at (1)} = \frac{P_1}{\rho g} = H$$

$$\text{Pressure at (2)} = \frac{P_2}{\rho g} = (h + H)$$

Substituting these values.

$$H + \frac{V_1^2}{2g} = (h + H)$$

$$h = \frac{V_1^2}{2g} \quad \text{or} \quad V_1 = \sqrt{2gh}$$



Pitot tube.

Temperature :-

It is a Numerical Measure of hot and cold bodies.

Its measurement is done by detection of heat transfer. Temperature is one of the most frequently used parameters for measurement and controlling of industrial processes.

Examples : Metallurgical Processes.

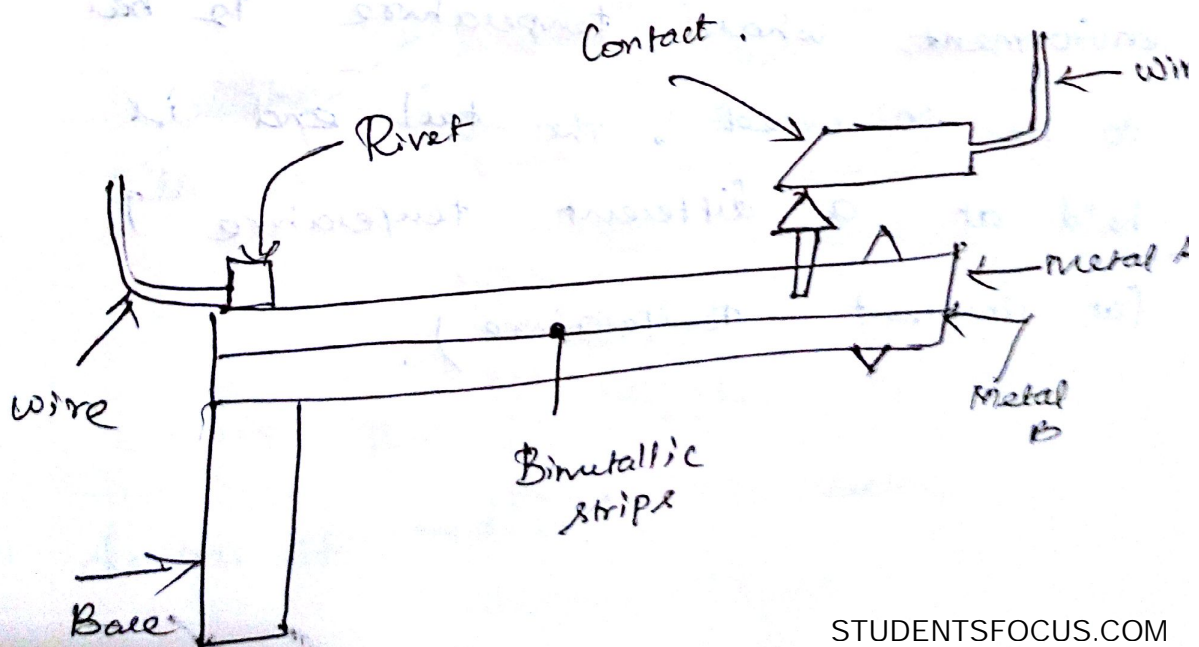
Temperature Measurement devices :-

- * Bimetallic Strips.
- * Thermocouples.
- * Thermometers.
- * Thermistors.
- * Pyrometers.
- * Resistance Temperature Detectors.

Bimetallic Strip Thermometer :-

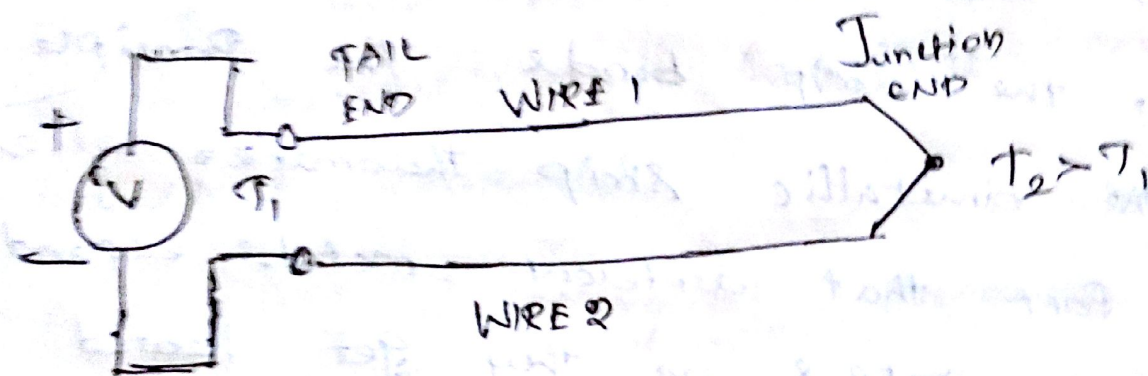
It is a strip made of two different metals, one on each side.

In a bimetallic strip, the two metals have two different coefficients of expansion and when the temperature changes, the strip bends. The principle behind the bimetallic strip thermometer relies on the fact that different metals expand at different rates as they get heated up. By bonding two different metals together, we can make a simple electric controller that can withstand fairly high temperatures. This type of controller is often found in ovens.



Thermocouple :-

A thermocouple is a device made of two different wires joined at one end, called Junction end. The two wires are called thermoelements.



The two thermocouples are distinguished as positive and negative ones. The one end of the thermocouple is called tail end or reference end.

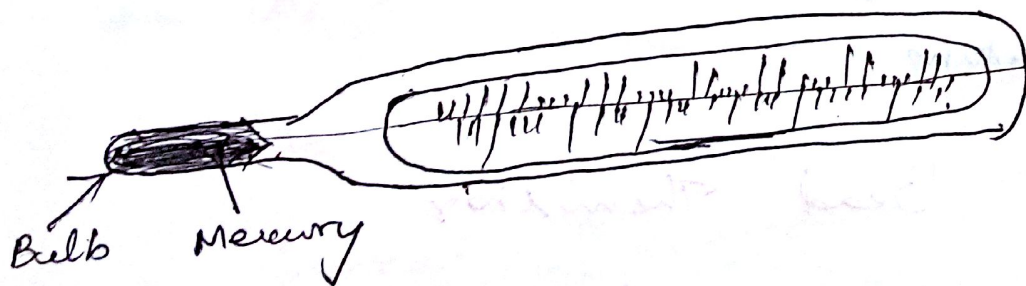
The Junction end is placed in the environment whose temperature T_2 has to be measured. The tail end is held at a different temperature T_1 (at ambient temperature).

Thermometer :-

Thermometer was invented by Daniel Gabriel Fahrenheit, one of the most common device for measuring the temperature in the glass thermometer.

It consists of glass tube filled with mercury or some other liquid, which acts as the working fluid.

When the liquid mercury is heated, it expands inside a narrow tube that has been calibrated to show the temperature. Temperature can be recorded in Celsius.



Thermometer.

This is similar to the design of medical thermometer.

Thermistors :-

Thermistors are made up of solid semiconductor materials having high coefficient of resistivity.

Semiconductors used to measure the temperature are called thermistors.

When a thermistor is employed for temperature measurement, its resistance decreases with increase in temperature.

The valence electrons, which are mutually shared by the metal atoms, move continuously and freely through the metal during their movement from atom to atom.

Bead Thermistor

Wafer Thermistor

Disc Thermistor

Rod Thermistor

Probe Thermistor.

PYROMETERS :-

If the temperature of a very hot body has to be measured, then contact type temperature measuring devices will not be suitable, since they will be damaged.

When they come in contact with the very hot body.

So, Non contact type temperature measuring devices are needed and they are called Pyrometers.

Types of Pyrometers :-

* Optical Pyrometers.

* Total Radiation Pyrometer

* Infrared Pyrometer.

Pyrometer derived from the Greek word Pyro mean fire and Metro mean measuring.

Readability :-

It is a measure of an instrument's ability to display incremental changes in its output value. This is known as Readability.

Reliability :-

Reliability of an item is the probability that it will perform a required function under a specified condition for a stated period of time. It is known as Reliability.