Resistance temp detector (RTD)

RTD's work on the principle that the electric resistance of a metal changes due to change in its temp. on heating up metals, their resistance increases and follow a linear relationship.

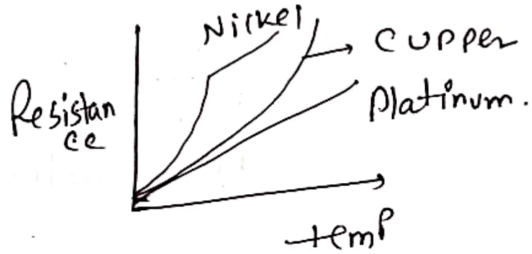


fig: Behaviour curve of RTD materials.

The co-relation of RTD's is →

$$R(T) = R_0\left[1 + A(T-T_0) + B(T-T_0)^2\right]$$

$R(T)$ = the resistance at temp, T

R_0 = " " " a refrence temp, T_0

A, B = temp co-efficients of resistance depending on material.

Over a limited temp interval (around 50°c for platinum), a linear approximation to the resistance variation may be quite acceptable.

$$R(T) = R_0\left[1 + A(T-T_0)\right]$$

But for the high accuracy, a high order polynomial fit is required.

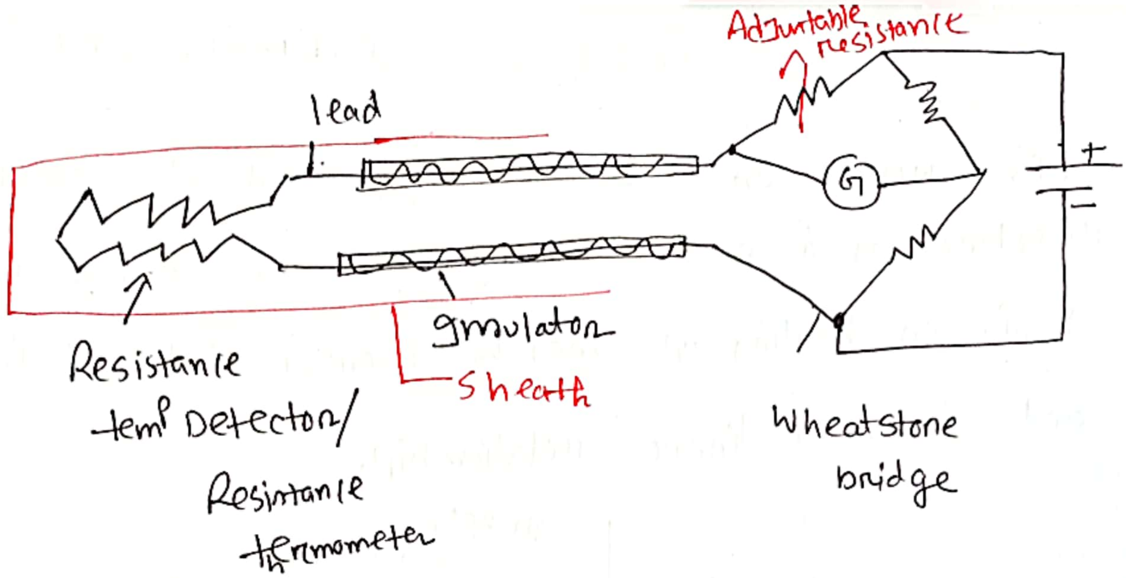


fig: Construction of RTD

Here RTD has a resistor element Connected to Wheatstone bridge. This element and Connection lead are insulated and Protected by a Sheath. A small amount of current is Continuously passing through the coil.

An RTD works by using a basic Principle as the temp of a metal increase so does the resistance to the metal is also increase. When the resistance of one arm in Wheatstone bridge is increase, this bridge get unbalanced. So, there is a deflection shown in wheat Stone bridge Galvanometer. By Adjusting this increase resistance using an Adjustable resistance (which is another arm of wheatstone bridge) the bridge is in balanced Conditions. This increase resistance is measured ~~by~~ ~~using~~ in ohm's and this value is converted into temp based on the characteristics of the element.

Applications:-

1) food Processing industry

2) Textile industry

3) Petrochemical "

4) plastic industry

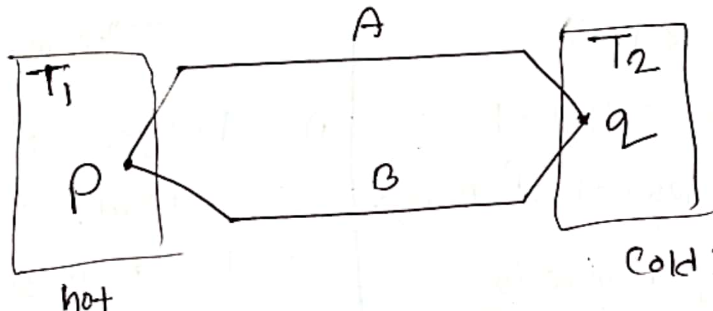
5) Air conditioning & Refrigeration Servicing.

Thermocouple

It is a sensor use to measure the temp.

It works on the principle of See-back effect.

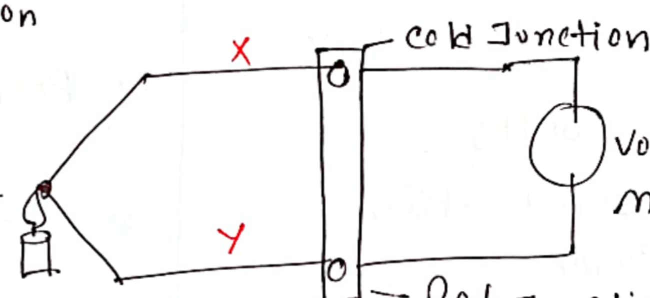
See Back effect → It is a phenomenon in which a temp difference between two dissimilar metal/ electrical conductors produce a voltage / EMF difference between the two substances.



a) Chromel vs Alumel

b) Iron vs Constantan [or Cu+Ni Alloy]

c) Cu vs Constantan. [or Cu+Ni Alloy]



* In thermocouple, two dissimilar metals are used.

Because different metals develop different voltages. By measuring the voltage difference at the other end / cold end the temp is figure out.

প্রতিটি conductor এর heat absorb করে heat transfer করার ক্ষমতা same না; like → conductor X দ্রুত তাপেতে e⁻ move করে আর conductor Y ধীরে ধীরে electron(e) মুক্ত করে, ফলে Reference Junction এর একপাশে বেশি e জমা হয় অন্য পাশে কম e জমা হয়, ফলে এক প্রান্ত (−) অন্য প্রান্ত (+) হিসাবে থাকে

voltage difference তৈরি করে, এই difference কে multimeter / voltmeter এ দেখা যায়।

$$E = C(T_1 - T_2) + K(T_1^2 - T_2^2)$$

C, K = Constant of thermocouple material.

T_1 = hot Junction Temp

T_2 = Cold " "

Application →

1) Medical equipment
2) Packaging "
3) Food Processing ".
4) plastic injection molding machinary.

RTD	Thermocouple
1) RTD is more suited to measure the lower temp range. The measuring range is between $-200°C$ to $500°C$.	1) larger Range of temp. The range is $-180°C$ to $2320°C$.
2) Good Stability.	2) Poor Stability.
3) More Accurate than thermocouple.	3) Poor accuracy.
4) very Good Sensitivity and can register small changes in temp	4) Poor sensitivity, a small changes in temp is not recognised by it.
5) RTD has a good response time.	5) The reaction time of a thermocouple is faster than that an RTD.
6) The o/p is linear	6) Non-linear.
7) more expensive than thermocouple	7) Cheaper than RTD
8) o/p is change in Resistance	8) o/p is change in voltage.

Piezo-electric Sensor/transducer

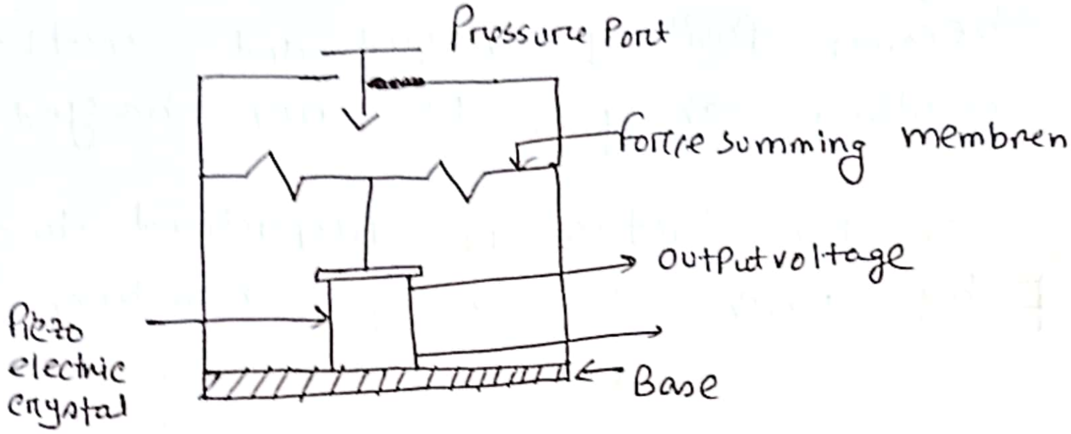
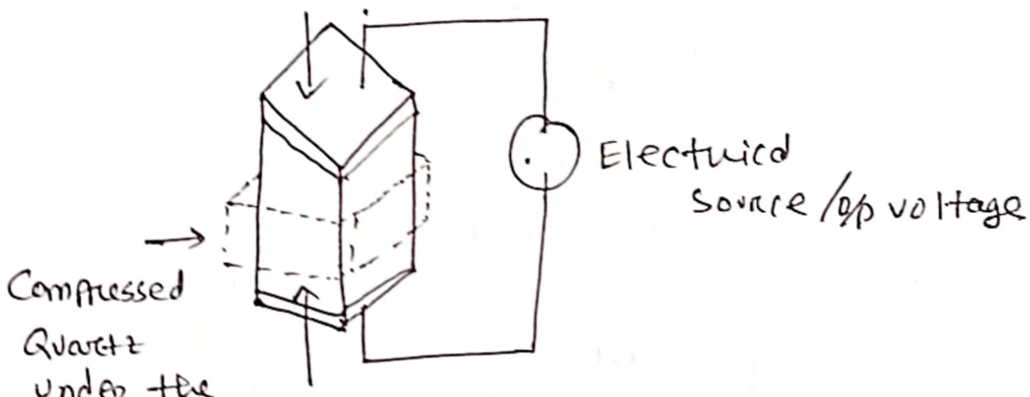
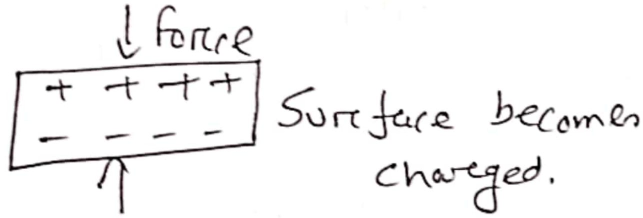


fig: Piezo-electric crystal working principle.

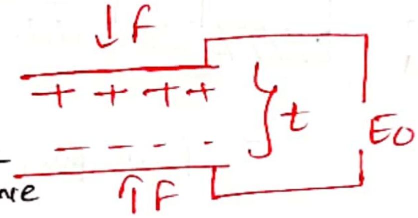


application of external force/pressure.



This sensor basically used for the measurement of Pressure, acceleration and dynamic force such as oscillation, impact or high speed Compression or tension. It Contains piezoelectric Ionic crystal materials. such as Quartz. When force or pressure is applied these materials gets strected or Compressed.

During this process, the charge over the material changes and redistributed. One face of the material becomes positively charged and another one is negatively charged. The net charged "Q" on the surface is proportional to the amount of force "F" by which the charge has been displaced.



charge — Piezoelectric Capacitance

$$\underbrace{Q}_{\text{charge}} = \underbrace{C_p}_{\text{Piezoelectric Capacitance}} V$$

$$= C_p E_0$$

$$\therefore E_0 = \frac{Q}{C_p}$$

Now,

$$Q \propto F$$

$$\text{or, } Q = K_p \times F$$

K_p = charge sensitivity of piezoelectric crystal.

$$\therefore E_0 = \frac{K_p F}{C_p}$$

Again,

$$C_p = \frac{\varepsilon_0 \varepsilon_r A}{t}$$ → this C_p is for parallel plate capacitance.

C_p → Capacitance

t → tickness/distance.

$$= \frac{K_p \times F}{\frac{\varepsilon_0 \varepsilon_r A}{t}}$$

$$= \left(\frac{K_p}{\varepsilon_0 \varepsilon_r}\right) \times t \times \frac{F}{A}$$

$g = \frac{K_p}{\varepsilon_0 \varepsilon_r}$ (voltage sensitivity)

$$E_0 = g \times t \times P$$

$$\therefore \boxed{E_0 \propto P}$$

means, applied force is proportional to o/p voltage.

Applications →

1) medical devices.
2) Fire alarm.
3) microwave ovens
4) Exercise equipment.

Strain gauge

Stress, $\sigma = \frac{F}{A}$

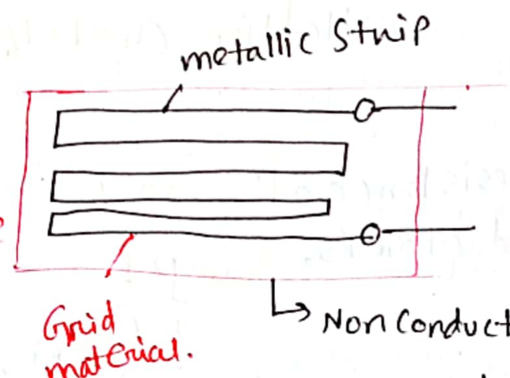
Strain, = Deformation per unit Area.

= the ratio of change in dimension to the original dimension when a force is applied to the body.

$= \frac{\Delta l}{l}$

N.B = Strain gauge are designed to measure the strain in order to determine the associated stress.

যখন কোনো বস্তুর উপর force Apply করা হয় তা Direct measure করা হয় যায় না, এখন force apply করার ফলে যে বিকৃতি সৃষ্টি হয় এগুলো measure করে finally force measure করা হয়, এটাই strain guage এর Basic.



↳ Non Conducting material. } Provide support to metallic strip

Here, metallic strip are placed on Non-Conducting material.

When force, pressure, tension, compression applied to an object, the resistance of metallic strip is changed and this changed resistance measure by using wheatstone bridge.

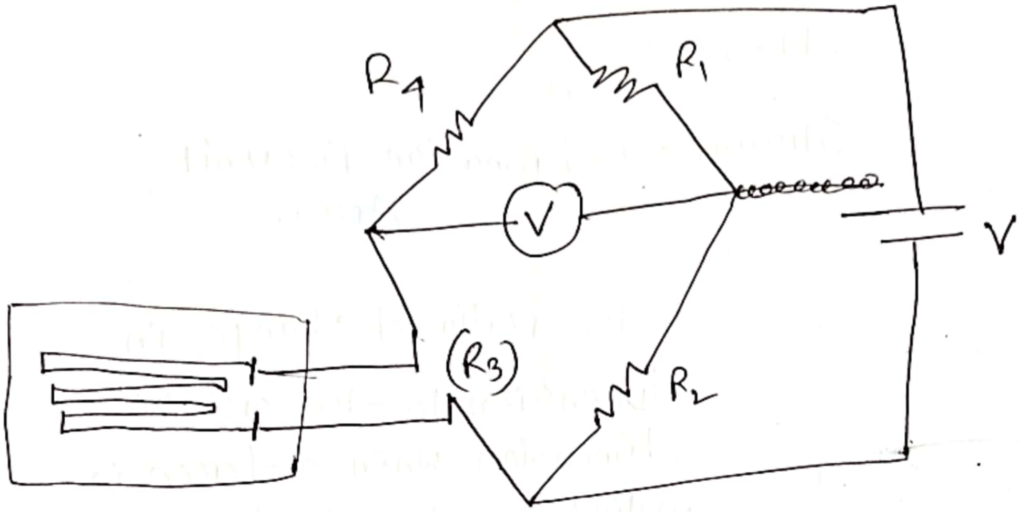


Fig → Bridge arrangement of Strain gauge.

এখানে, R_1, R_2 এর মান Same
R_3, R_4 এর মান Same (initially)

But Stress এর ফলে R_3 এর মান change হয়ে যাবে, তখন Voltmeter এ কাঁটার Deflection দেখা যাবে।

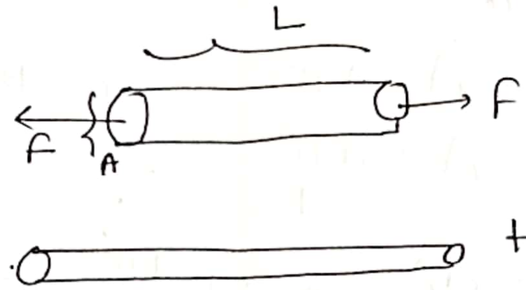
We Know, the resistance of any metal Conductor is, $R = \rho \frac{L}{A}$

ρ → Resistivity (Ω-m)

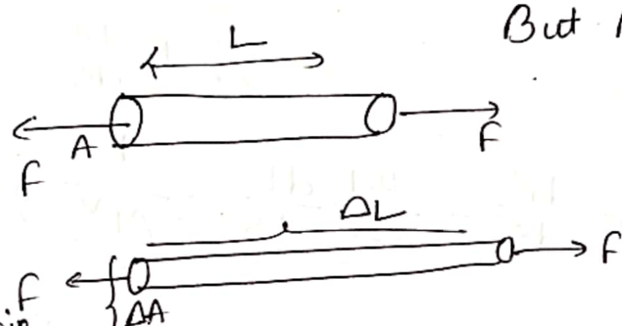
মানে load/force Apply করার ফলে যে বিকৃতি হয় এর কারণে ρ এর মান ও change হয়ে যায়, ফলে R ও change হয়ে যায়।

Gauge factor, $= \frac{\Delta R/R}{\Delta L/L} = \frac{O/P}{I/P} = G_f$

মানে Strain এর ফলে R কতটুকু পরিবর্তন হচ্ছে তাকে বের করা।



Here,
L is ↑
But A is ↓



Poisson Ration $= -\dfrac{\text{Laterial strain}}{\text{Axial strain}}$

Axial Strain $= \dfrac{\Delta L}{L}$

Laterial Strain $= \dfrac{\Delta A}{A}$

Now,

$$R = \frac{\rho L}{A}$$

Differentiate R w.r.to S (Stress) → কারণ stress এ দিলে ρ, L, A সবগুলো Change হচ্ছে সেই জন্য,

Apply Partial differentiate →

$$\frac{dR}{dS} = \frac{d}{dS}\left(\frac{\rho L}{A}\right)$$

$$\frac{d}{dS} A^{-1} = (-1) A^{-1-1} = (-1) A^{-2} = -\frac{1}{A^2}$$

$$\frac{dR}{dS} = \rho/A \frac{dL}{dS} - \frac{\rho L}{A^2}\frac{dA}{dS} + \frac{L}{A}\frac{d\rho}{dS}$$

Divide R,

$$\frac{1}{R}\frac{dR}{dS} = \frac{\rho}{AR}\frac{dL}{dS} - \frac{\rho L}{A^2 R}\frac{dA}{dS} + \frac{L}{AR}\frac{d\rho}{dS}$$

$$= \frac{\rho}{A\frac{\rho L}{A}}\frac{dL}{dS} - \frac{\rho L}{A^2\frac{\rho L}{A}}\frac{dA}{dS} + \frac{L}{A\frac{\rho L}{A}}\frac{d\rho}{dS}$$

$$= \frac{1}{L}\frac{dL}{dS} - \frac{1}{A}\frac{dA}{dS} + \frac{1}{\rho}\frac{d\rho}{dS}$$

Here,

$$A = \pi r^2 \qquad r = \frac{D}{2}$$

$$A = \frac{\pi D^2}{4}$$

$$\therefore \frac{dA}{ds} = \frac{\pi}{4}\, 2D \frac{dD}{ds}$$

$$= \frac{\pi}{2} D \frac{dD}{ds}$$

Now,

$$\frac{1}{R}\frac{dR}{ds} = \frac{1}{L}\frac{dL}{ds} - \frac{1}{\frac{\pi D^2}{4}}\, \frac{\pi}{2} D \frac{dD}{ds} + \frac{1}{\rho}\frac{d\rho}{ds}$$

$$= \frac{1}{L}\frac{dL}{ds} - \frac{2}{D}\frac{dD}{ds} + \frac{1}{\rho}\frac{d\rho}{ds}$$

$$\therefore \frac{1}{R}\frac{dR}{ds} = \frac{1}{L}\frac{dL}{ds} + \frac{2\gamma}{L}\frac{dL}{ds} + \frac{1}{\rho}\frac{d\rho}{ds}$$

from Poission Ration

$$\gamma = -\frac{dD/D}{dL/L}$$

$$\frac{1}{R}\frac{\Delta R}{\Delta s} = \frac{1}{L}\frac{\Delta L}{\Delta s} + \frac{2\gamma}{L}\frac{\Delta L}{\Delta s} + \frac{1}{\rho}\frac{\Delta \rho}{\Delta s}$$

$$\gamma = -\frac{\frac{\Delta D}{D}}{\frac{\Delta L}{L}}$$

Divide by Δs →

$$\frac{\Delta R}{R} = \frac{\Delta L}{L} + 2\gamma\frac{\Delta L}{L} + \frac{\Delta \rho}{\rho}$$

$$\therefore \frac{dD}{D} = -\gamma \frac{dL}{L}$$

Again Divide, $\Delta L/L$ →

$$\frac{\frac{\Delta R}{R}}{\frac{\Delta L}{L}} = \frac{\Delta L/L}{\frac{\Delta L}{L}} + \frac{2\gamma \frac{\Delta L}{L}}{\frac{\Delta L}{L}} + \frac{\frac{\Delta \rho}{\rho}}{\frac{\Delta L}{L}}$$

form Gauge factor,

$$G_f = \frac{\Delta R/R}{\frac{\Delta L}{L}} = \frac{dR/R}{\frac{dL}{L}}$$

$$G_f = 1 + 2\gamma + \frac{\Delta \rho}{\rho} \Big/ \frac{\Delta L}{L}$$

strain (ϵ)

force / $G_f = 1 + 2\gamma + \frac{\Delta \rho}{\rho\,\epsilon}$

$$\therefore \frac{\Delta R}{R} = G_f \frac{\Delta L}{L}$$

$$\boxed{G_f = 1 + 2\gamma}$$

এটা পরিবর্তন হলেও ছোট।
তাই omit করা যায়।