or $$\frac{1}{A}\frac{dA}{ds} = \frac{(2\pi/4)D}{(\pi/4)D^2}\frac{\partial D}{\partial s} = \frac{2}{D}\frac{\partial D}{\partial s}$$

Now, Position's ratio

$$\partial D/D = -\nu \times \partial L/L$$

$$\frac{1}{R}\frac{dR}{ds} = \frac{1}{L}\frac{\partial L}{\partial s} + \nu\frac{2}{L}\frac{\partial L}{\partial s} + \frac{1}{\rho}\frac{\partial \rho}{\partial s}$$

For small variations, the above relationship can be written as :

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

The gauge factor is defined as the ratio of per unit change in resistance to per unit change in length

Gauge factor $$G_f = \frac{\Delta R/R}{\Delta L/L}$$

or $$\frac{\Delta R}{R} = G_f\frac{\Delta L}{L} = G_f \times \in$$

where $$\in = \text{strain} = \frac{\Delta L}{L}$$

The gauge factor can be written as:

$$= 1 + 2\nu + \frac{\Delta\rho/\rho}{\in}$$

$= 1$	$+$	2ν	$+$	$\frac{\Delta\rho/\rho}{\in}$
Resistance change due to change of length		Resistance change due to change in area		Resistance . change due to to piezoresistive effect

$$G_f = \frac{\Delta R/R}{\Delta L/L} = 1 + 2\nu + \frac{\Delta\rho/\rho}{\Delta L/L}$$

The strain is usually expressed in terms of micro strain. 1 micro strain = 1 μm/m.

If the change in the value of resistivity of a material when strained is neglected, the gauge factor is

$$G_f = 1 + 2\nu$$

Eqn. is valid only when Piezoresistive Effect i.e. 'change in resistivity due to strain is almost negligible.

The Poisson's ratio for all metals is between 0 and 0.5, this gives a gauge factor of approximately, 2. The common value for Poisson's ratio for wires is 0.3. This gives a value of 1.6 for wire wound strain gauges.

∴ The change in resistance is only 0.1%.

∴ *Comments:* The above example illustrates that a very heavy stress of 100 MN/m^2 results in resistance change of only 0.1 per cent, which is by all means a very small change. This may present difficulties in measurement. Lower stresses produce still lower changes in resistance which may not he perceptible at all or the methods required to detect these changes may have to be highly accurate. To overcome this difficulty we must use strain gauges which have a high gauge factor which produce large changes in resistance when strained. These changes are easy to detect and. measure with good degree of accuracy.

Types of Strain Gauges :

The following are the major types of strain gauges:

1. Unbonded metal strain gauges
2. Bonded metal wire strain gauges
3. Bonded metal foil strain gauges
4. Vacuum deposited thin metal film strain gauges
5. Sputter deposited thin metal strain gauges
6. Bonded semiconductor strain gauges
7. diffused metal strain gauges.

Strain gauges are broadly used for two major types of applications and they are :

(i) Experimental stress analysis of machines and structures.

And

(ii) construction of force, torque, pressure, flow and acceleration transducers.

Unbonded Metal Strain Gauges

An unbonded metal strain gauge is consists of a wire stretched between two points in an insulating medium such as air. The wires may be made various copper nickel chrome nickel or nickel iron alloys.

Types of Strain Gauges

Bonded wire strain gauge

- In such strain gauge, the wire is spread uniformly and hence they can be used to measure the stress which is spread uniformly over it.
- The material used is same as that used by unbonded metal wire strain gauge.

Bonded metal foil strain gauge

- These type of strain gauges are the extension to the metal wire strain gauges.
- They have large surface area hence they have large heat dissipation capacity. So they are used at the higher operating range of temperature.

Semiconductor strain gauge

- These type of strain gauge have higher sensitivity and higher gauge factor, thus they [illegible] accuracy.
- For P type semiconductor strain gauge G is positive and for N type semiconductor strain gauge [illegible] negative.

Note:

- Gauge factor for metals is nearly 2.
- Poisson ratio of metals lies between 0 to 0.5.
- For metallic and P type strain gauges G is positive that is on tensile stress resistance increases [illegible] where as on the compressive stress resistance decreases (R – δR).
- For N type strain gauges GF is negative that is on tensile stress resistance decreases (R – δR) [illegible] on the compressive stress resistance increases (R + δR).

Signal Conditioning for Strain Gauges

- The signal conditioning of strain gauge involves the use of the Wheatstone Bridge Circuit.
- The Wheatstone Bridge can operate in two modes.

Null Mode (No deflection)	Deflection Mode
More accurate	Accuracy is low
Used for static input only	Used for both static and dynamic input
Less used	More used
Slow in operation	Fast in operation

Temperature Compensation

The resistive type strain gauges are sensitive to temperature. Therefore it becomes necessary to [illegible] variations in the strain gauge resistance which occurs on account of temperature changes.
Temperature compensation may be provided by:

- Use of adjacent arm balancing or compensating gauge.

Use of Dummy gauge

One of the ways in which temperature error can be eliminated by using adjacent arm compensating gauge [illegible] as a dummy gauge in the adjacent arm. This arrangement is shown. Gauge 1 is installed on the test [illegible] gauge is installed on a like piece of material and is not subjected to any strain. The [illegible] temperature. A gauge is called dummy gauge in case it is not subjected to any strain. The gauges installed [illegible] is subjected to strain. Initially when the bridge is balanced

$$\frac{R_1}{R_2} = \frac{R_3}{R_4}$$

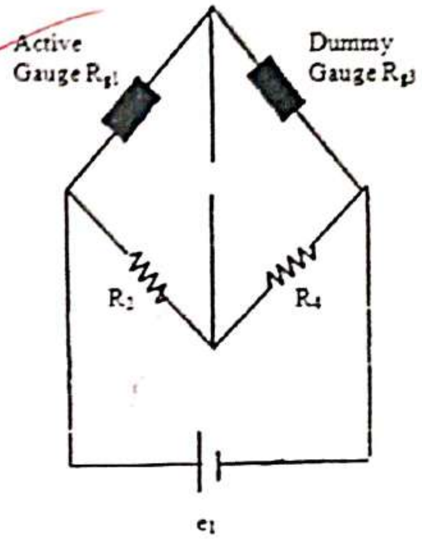
Supposing a change in temperature &curs, the resistance R_1 & R_3 change by an amount ΔR_1 and ΔR_3 respectively.

Hence for balance, $\frac{R_1 + \Delta R_1}{R_3 + \Delta R_3} = \frac{R_2}{R_4}$

Or $\frac{R_4}{R_2}(R_1 + \Delta R_1) = (R_3 + \Delta R_3)$

or $\frac{R_4}{R_2} R_1 + \frac{R_4}{R_2} \Delta R_1 = R_3 + \Delta R_3$

But $\frac{R_4}{R_2} R_1 = R_3 \therefore \frac{R_4}{R_2} \Delta R_1 = \Delta R_3$



Suppose $R_4 = R_2$ this requires that $\Delta R_1 = \Delta R_3$

It means that for the bridge to remain insensitive to variations in temperature the gauges R_1 and R_2 should have their resistances change by equal amount when subjected to variation in temperature. Therefore the active gauge R_1 and the dummy gauge R_3 should be identical.

The use of dummy gauge for temperature compensation is simple and effective and should be employed whenever possible.

Use of two active gauges in adjacent arms

- Certain applications, where equal and opposite strains are known to exist, it is possible to attach two similar gauges in such a way that one gauge experience a positive strain and the other a negative strain. Thus instead of having an arrangement wherein the gauge acts as the active gauge and the other as the dummy gauge, we have now an arrangement wherein both the gauges are active gauges.

  Fig shows the two gauges mounted on a cantilever. The gauge R_o is on top of the cantilever and hence experiences tension or a positive strain. The R_3 is at the bottom surface of the cantilever and hence experiences a compression or a negative strain.

- The bridge arrangement for the two gauges is shown in Fig., There are two active gauges in the 4 arm bridge and hence it is called a Half Bridge.
- The temperature effects are cancelled out by having $R_2 = R_3$ and using two identical gauges in the opposite arms of the bridge.
- When no strain is applied both points b and d are at the same potential, $e_i/2$ and the value of output voltage $e_o = 0$.