B.E.

Sixth Semester Examination, Dec., 2008

Measurements and Instrumentation (ME-310-E)

Note : Attempt any ***FIVE*** questions.

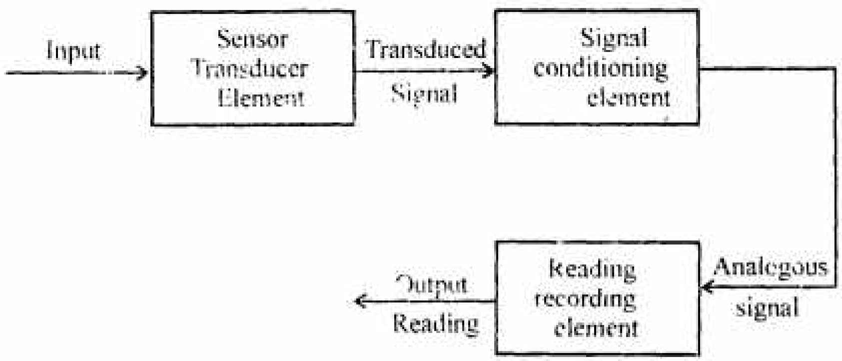
Q. 1. Explain generalized measurement system with the help of bourdon tube pressure gauge with LVDT.

Ans. A generalised measuring instrument should have various essential features. There are three categories of elements present in the generalized measuring instrument. These are

(i) Initial sensing element

(ii) Signal conditioning element

(iii) Reading recording elements.



(i) Initial Sensing Element : It is also called sensor transducer element or simply transducer element. It is the first element which detects or sense the measurand. It is the part which first receive energy from the measured medium and convert this input into a more practically convenient form of output.

(ii) Signal Conditioning Element : Input signal sensed are not of our important because of many reasons. They need to be converted in significant amount, that is of our use.

This is done by signal conditioning element. There are three categories in it :

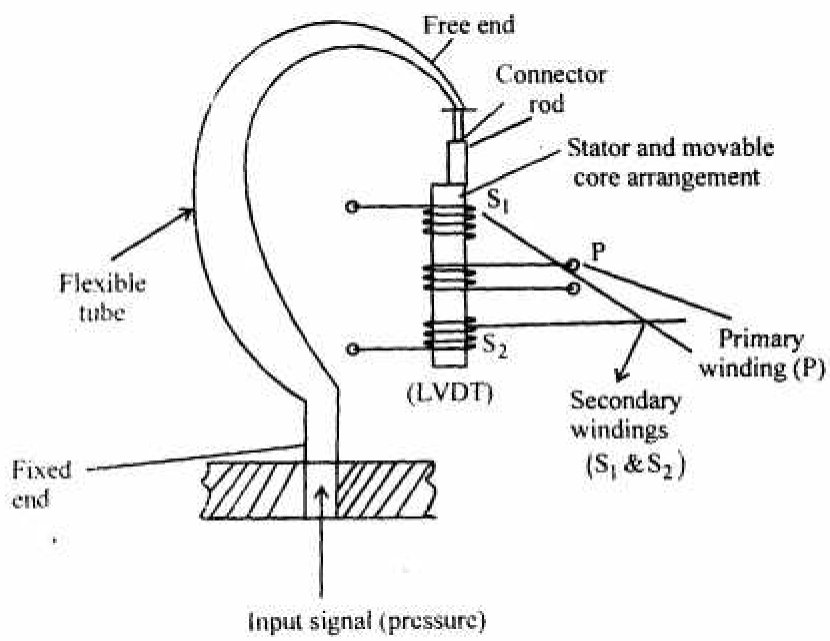
(a) Variable Transformation : In it the transduced signals are further transformed into the form, which is more convenient.

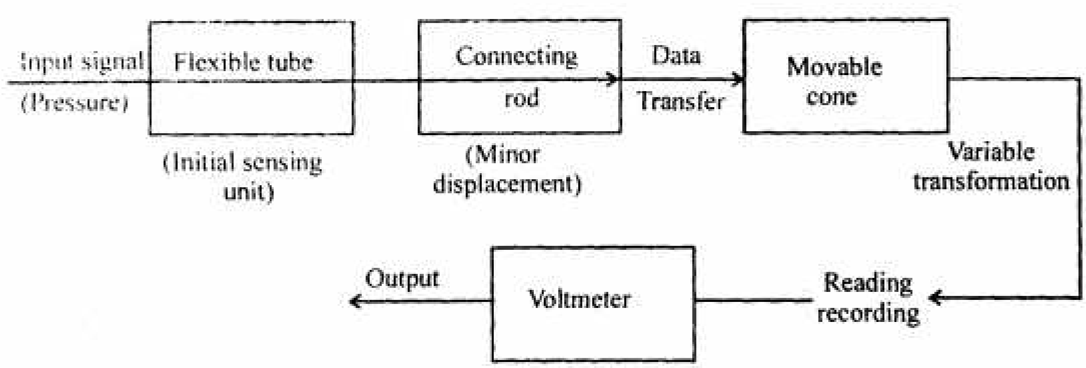
(b) Variable Manipulation : In variable manipulation the transformed signals are manipulated, either we increase their strength or amplitude or we decrease.

(c) Data Transmission : In signal transmission or data transmission we doesn't change the form of signal but only transmit it from one part to other.

(iii) Reading and Recording Element : This is used to represent the data finally obtained for comparing with standard.

In the example of bourdan tube with LVDT there are two integrated transducers which are used to perform measurement.





Q. 2. Define and hence derive the equations for response of a second order system subjected to step input.

Ans. The behaviour of a second order system is given by the following differential equation obtained by putting n = 2 in the general equation,

$$A_2 \frac{d^2 I_0}{dt^2} + A_1 \frac{dI_0}{dt} + A_0 I_0 = B_0 I_i$$

Deviding the above equation by A_0 we get

$$\frac{A_2}{A_0} \frac{d^2 I_0}{dt^2} + \frac{A_1}{A_0} \frac{dI_0}{dt} + I_0 = \frac{B_0}{A_0} I_i$$

Let, $W_n = \sqrt{\frac{A_0}{A_2}}$ = Undamped natural frequency rad/s.

$\gamma = \frac{A_1}{2\sqrt{A_0 A_2}}$ = Damping ratio, dimensionless.

$S = \frac{B_0}{A_0}$ = Static sensitivity or steady state gain.

Then by substituting the values, we get

$$\frac{1}{W_n^2} \cdot \frac{d^2 I_0}{dt^2} + \frac{2r}{W_n} \cdot \frac{dI_0}{dt} + I_0 = SI_0$$

Or, in terms of D-operator

$$\left[\frac{D^2}{W_n^2} + \frac{2\gamma}{W_n} D + 1\right] I_0 = SI_i$$

Or.

$$\frac{I_0}{I_i} = \frac{S}{\frac{1}{W_n^2} D^2 + \frac{2r}{W_n} D + 1}$$

Steady state response is given by

$$(1 + CD) I_{0,s} = I_i$$

Or

$$I_{0,s} = (1 + CD)^{-1} I_i$$

$$= \left[(1 - CD) + \text{Terms in } D^2 \text{ \& higher}\right] I_i$$

For step input, since the input is a step of constant magnitude, it's differential equals zero and subsequently, we get

$$I_{0,s} = (1 - CD) I_i = I_i$$

Total response = Transient response + steady state response

$$I_0 = Ae^{-t/\tau} + SI_i$$

The constant A is evaluated from the initial condition as follow

$$t = 0,\ I_0 = 0$$

$$0 = A + SI_i \text{ or } A = -SI_i$$

$$I_0 = \underbrace{-I_i e^{-t/\tau}}_{\text{Transient}} + \underbrace{I_i}_{\text{Steady state}}$$

$$I_0 = I_i\left(1 - e^{-t/\tau}\right)$$

$$\frac{I_0}{I_i} = \left(1 - e^{-t/\tau}\right)$$ **Ans.**

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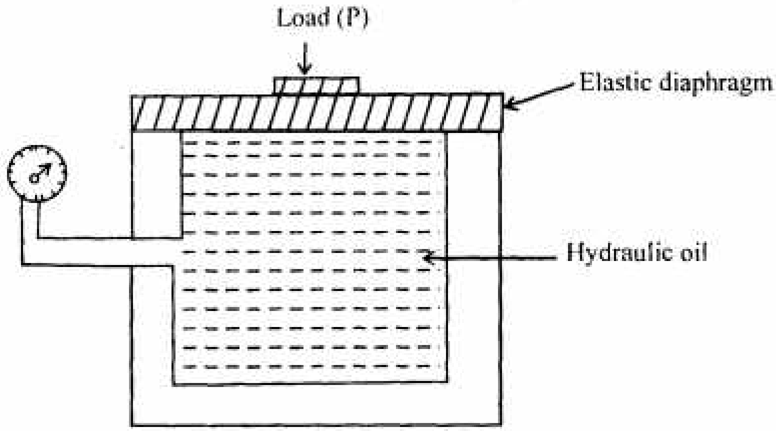
Q. 3. Define load cell. Explain how Hydraulic and Pneumatic load cells are used for the measurement of Force.

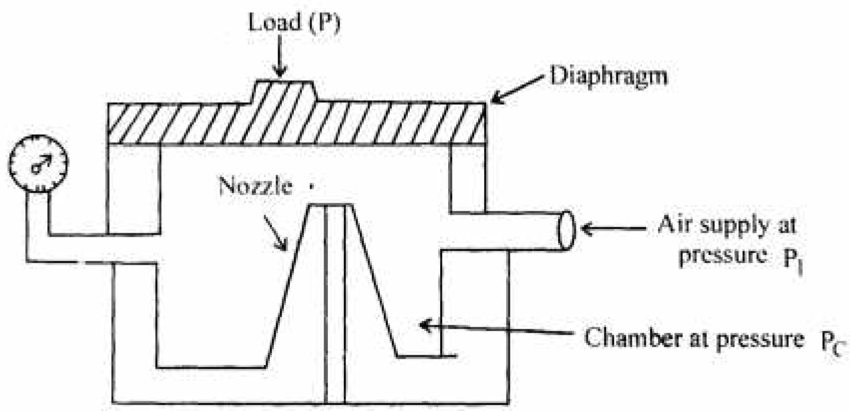
Ans. Load cell is the arrangement for the measurement of force by absorbing it in the fluid.

Hydraulic Load Cell : It can be used to measure force of very high magnitude (of the order of millions of newtons). It consists of a closed container filled with oil and covered with diaphragm as shown. A pressure measuring device such as Bourdon tube pressure gauge is connected to the container. When load (P) acts on the diaphragm, it gets deflected and transmits force to the oil as a result of which pressure develops in the oil. The magnitude of pressure developed is indicated by the pressure gauge which can be converted into force. The pressure gauge can be directly calibrated in units of force.



Hydraulic Load Cell

Pneumatic Load Cell : It is used to measure force upto 20,000N. It consists of a chamber with a nozzle as shown in figure and covered with elastic diaphragm. Pressurized air is supplied through a pipe to the chamber. The pressure in the chamber is detected by the pressure gauge.



Pneumatic Load Cell

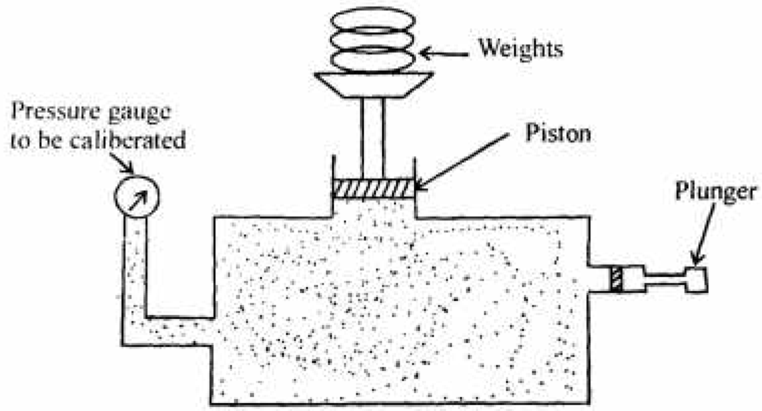
As load P acts on the diaphragm, it deflects and the gap between diaphragm and nozzle decreases while pressure P_C in the chamber increases. Rise in pressure P_C applies outward force on the diaphragm opposite the force P. For any force P, the diaphragm attains equilibrium under the impact of two equal and opposite forces.

Q. 4. What is calibration? How pressure measuring instruments are calibrated? Explain the method of calibration using dead weight piston tester.

Ans. Calibration is the process of defining the system response to known, controlled signal inputs.

In this process, magnitude of the output of measuring instrument is related to the magnitude of the input deriving the instrument.

The calibration of moderate pressure measuring instruments is done with dead weight tester or manometer.



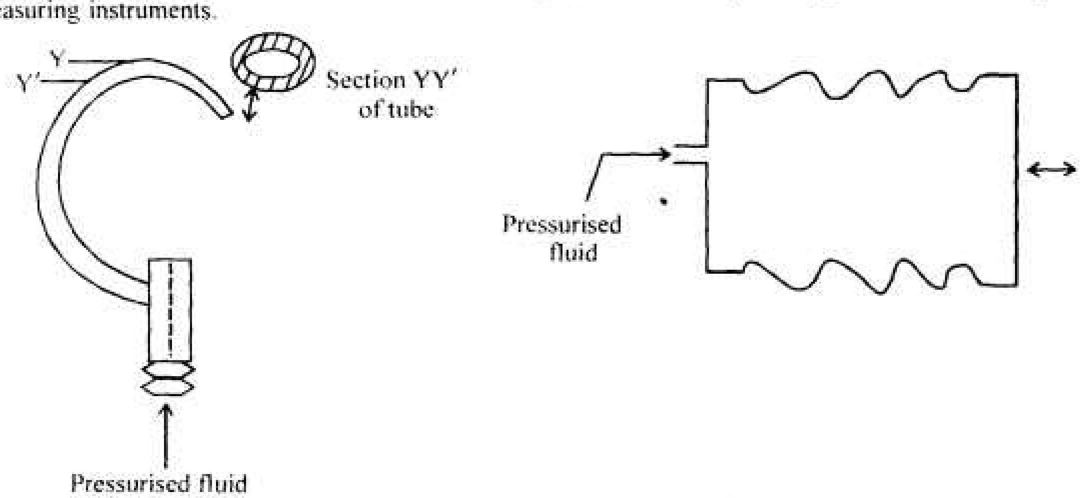
(Dead weight tester)

The plunger is pushed into sufficient build up pressure in tester, till the weights just seem to be lifted upwards (floating condition). At this point, fluid gauge pressure is equal to the pressure exerted by dead weights (i.e., weight/piston area).

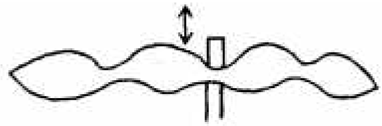
Thus, the gauge can be calibrated for different leads or weights.

For calibrating very low pressure measuring devices, Mc. leod gauge can be used.

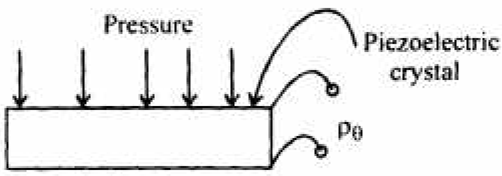
Different types of elastic elements have been employed successfully to design and manufacture pressure measuring instruments.



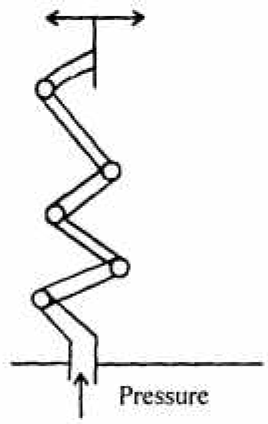
(a) Bourden Tube *(b) Bellows*



(c) Capsule



(d) Piezoelectric Type Pressure Transducer



(e) Expandable Helical tube

Q. 5. Obtain the best linear relationship in accordance with a least square analysis for the following data. Calculate its standard deviation from the result.

X	**0.9**	**2.3**	**3.3**	**4.5**	**5.7**	**6.7**
Y	**1.1**	**1.6**	**2.6**	**3.2**	**4.0**	**5.0**

Ans. Let,

X	0.9	2.3	3.3	4.5	5.7	6.7
Y	1.1	1.6	2.6	3.2	4.0	5.0

x	y	x^2	xy	Y' = mx + C	Y–Y'
0.9	1.1	0.81	0.99		
2.3	1.6	5.29	3.68		
3.3	2.6	10.89	8.58		
4.5	3.2	20.25	14.40		
5.7	4.0	32.49	22.80		
6.7	5.0	44.89	33.50		
$\Sigma x = 23.4$	$\Sigma Y = 17.5$	$\Sigma x^2 = 114.62$	$\Sigma xy = 83.95$		

By least sequence method,

$$\Sigma y = m\Sigma x + nC \quad \text{...(i)}$$

$$\Sigma xy = m\Sigma x^2 + Czx \quad \text{...(ii)}$$

$$17.5 = m \times (23.4) + (6)C \quad \text{...(iii)}$$

$$84 = m \times (114.6) + C(23.4) \quad \text{...(iv)}$$

Equation (i) × (23.4) − (ii) × 6

$$409.5 = m(547.6) + (23.4 \times 6)C$$

$$504.0 = m(687.6) + (23.4 \times 6)C$$

$$(-1) \quad (-1) \quad (-1)$$

$$m = \frac{94.5}{140} = 0.68$$

& on solving

$$C = \frac{17.5 - (23.4) \times (0.68)}{6}$$

$$C = 0.28$$

The equation is,

$$\boxed{y' = (0.68)x + 0.28}$$

Standard deviation is the square root of variance,

$$\sigma = \sqrt{\frac{\sum_{i=1}^{N} (X_i - \overline{X})^2}{N}}$$

Here,

$$\overline{X} = \frac{\Sigma x}{n} = \frac{23.4}{6} = 3.9$$

$$\sigma = \sqrt{\frac{(0.9-3.9)^2 + (2.3-3.9)^2 + (3.3-3.9)^2 + (4.5-3.9)^2 + (5.2-3.9)^2 + (6.7-3.9)^2}{6}}$$

$$\sigma = \sqrt{\frac{9 + 2.56 + 0.36 + 0.36 + 3.24 + 7.84}{6}}$$

$$\sigma = \sqrt{\frac{33.36}{6}} = \sqrt{5.56}$$

$$\sigma = 2.35$$ **Ans.**

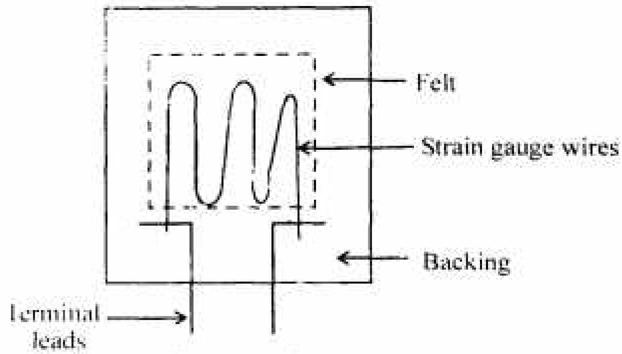
Q. 6. What do you mean by a metallic resistance strain gauge? Describe their types, theory of operation and different material and their properties used for the construction of these types of gauges.

Ans. Metallic resistance strain gauge are based on measurement of change in resistance.

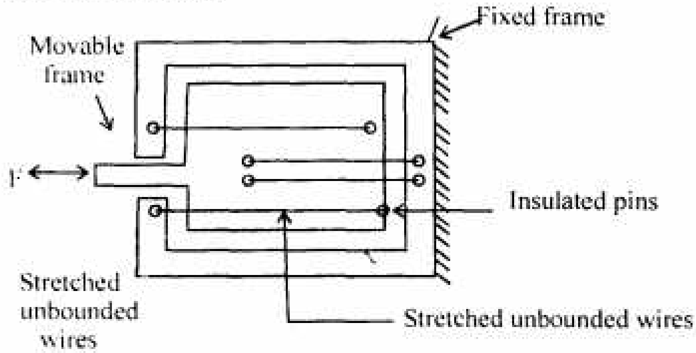
Types of Resistance Strain Gauges :

1. Wire Wound Gauges : Based on method of fabrication, wire wound gauges are can be classified as follows :

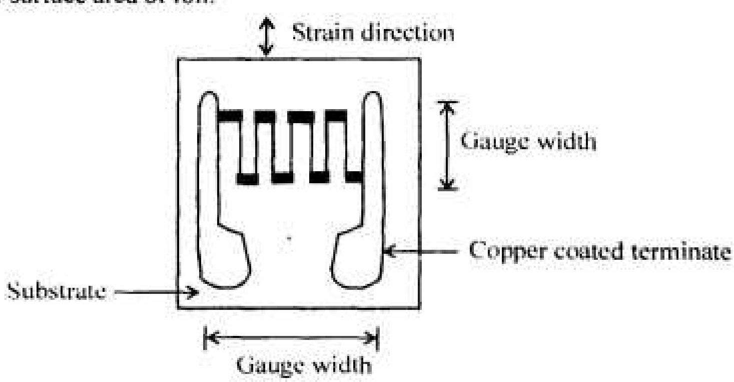
(i) Bonded Strain Gauges : Bounded strain gauges are bonded directly to the surface of specimen being examined with thin layer of adhesive cement. Depending on the requirement, bounded strain gauges can have various structures through basically they consist of grid of fine resistance wire of $25\mu m$ diameter or even less.



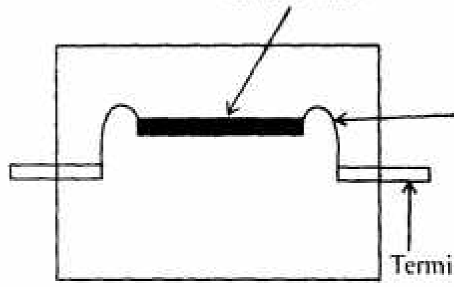
(ii) Unbonded Metal Wire Strain Gauges : These gauges does not have backing material, so strain is transferred to the resistance wire directly.



2. Foil Strain Gauge : It is an extension of wire strain gauge but instead of wires, it makes use of thin sheets or foils as sensing elements. Using the process of photoetching or masked vaccum deposition, the foil can be spread in suitable form on the backing (substrate). The foil with thickness less than $5\mu m$ is made from platinum tungsten alloy. It has higher neat dissipation capability, thermal stability larger available bonding area on account of larger surface area of foil.



3. Semiconductor Stain Gauge : Doped silicon and germanium have a unique property called piezo resistivity that is when these materials are stressed, they undergo a change in their resistivity.



Theory of Operation : When axial load is applied on metallic bar in the outward direction, it leads to increase in length of the bar. But it is also accompanied by decrease in area of cross-section perpendicular to the load.

Poisson's Ratio $= v = \dfrac{\Delta D / D}{\Delta l / l}$

Consider a conductor of length l, cross-sectional area A and resistivity P.

$$R = \frac{Pl}{A}$$

$$\log_e R = \log_e P + \log_e l - \log_e A$$

$$\frac{dR}{R} = \frac{dP}{P} + \frac{dL}{L} - \frac{dA}{A}$$

$$\frac{dR}{R} = \frac{dP}{P} + \frac{dL}{L} - 2\frac{dD}{D}$$

$$G_f = \frac{dR/R}{dL/L} = \frac{dP/P}{dL/L} + 1 + 2V$$

Different material used for strain gauges :

Constantan, Nichrome, Karma etc.

Properties :

(i) Gauge factor is 2.

(ii) Poisson's ratio is approximately 0.5.

(iii) Piezoresistance effect is nearly zero.

Q. 7. What is radiation pyrometer? Explain different principles used for radiation measuring temperature devices. Discuss infrared pyrometers in detail.

Ans. Radiation Pyrometers : The device used to measure temperature using radiation method are called radiation pyrometers.

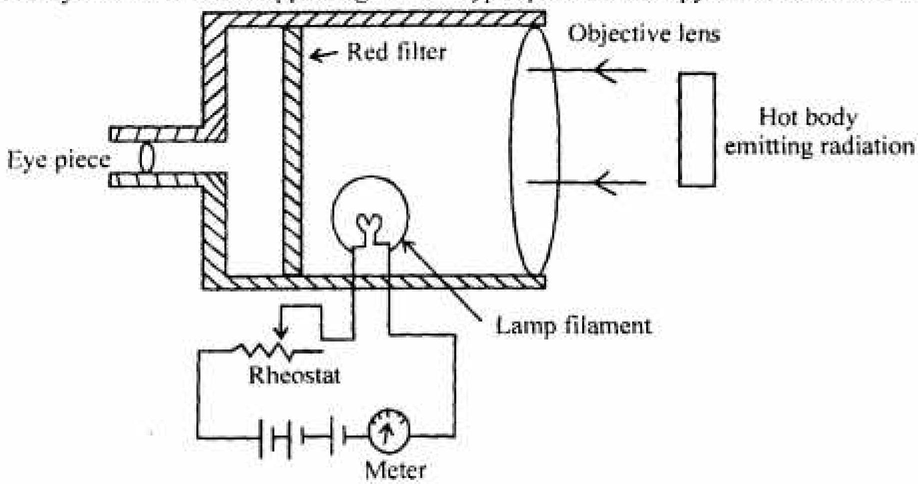
Different principles used for radiation measuring temperature devices :

(a) Stefan Boltzmann Law : It states that the total energy emitted by a unit area of a perfect radiator per second is proportional to the fourth power of its absolute temperature.

$$Q = \sigma\left(T_A^4 - T_B^4\right)$$

(b) Plank's Law : It states that energy levels in the radiation emitted by a not body are distributed in different wavelengths. As the temperature of the hot body rises, the emissive power shifts towards shorter wavelengths. The radiations from a hot body at high temperatures fall within visible region of electromagnetic spectrum.

Infrared Pyrometer : The disappearing filament type optical infrared pyrometer is shown in



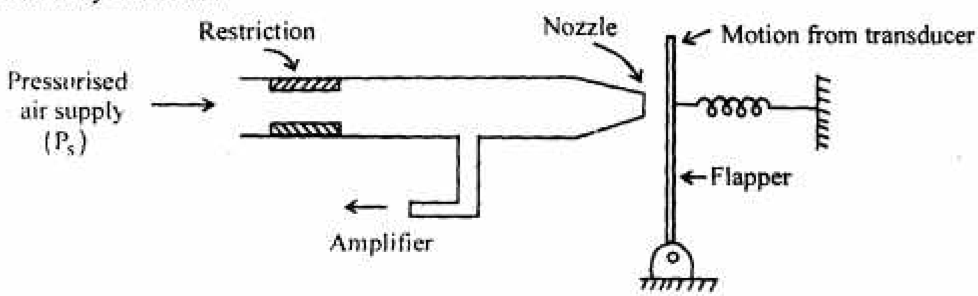
Using the rheostat, current can be varied in the tungsten temperature, so as to very the brightness of light. The image of radiating source, produced by the objective lens system, is made to superimpose on filament of electric lamp. The electric current through the filament is varied while being viewed through a filter and eye-piece. If the filament temperature is higher than the hot body, it becomes two bright as compared to superimposed image of hot body.

Q. 8. Write short notes on the following :

(i) Pneumatic Type of Amplifying elements.

(ii) Data Acquisition System.

Ans. (i) Pneumatic Type of Amplifying Elements : Pneumatic transmission elements can be easily adopted for transmission of signals and can be designed according to the requirement. The advantage of pneumatic transmission is that its is less expensive as compared to the hydraulic system because air is used as working fluid instead of hydraulic oil.



Pneumatic Transmission Unit (Flapper-Nozzle Mechanism)

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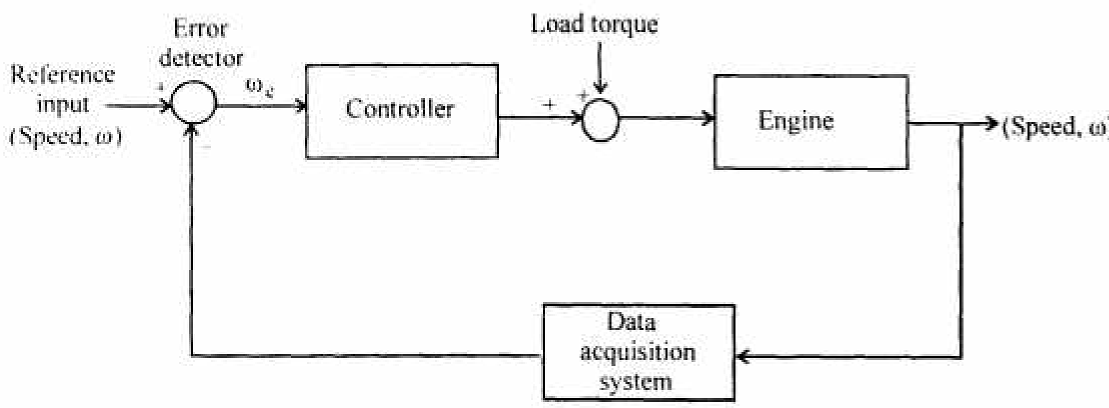
The above figure shows a basic preumatic transmission unit. It comprise of flapper-nozzle arrangement as shown in the figure with flapper being positioned close to the mouth of nozzle. The linear displacement from the transducer, moves the free end of the flapper towards the nozzle, while the spring brings it back to the original position (vertical position). Pressurised air is forced through the restriction when the flapper is away from the nozzle mouth, the air passes through the nozzle so that a low pressure through the amplifier. But when the flapper touches the nozzle mouth, maximum available air pressure (P_s) is passed through the amplifier. Hence, the air pressure in the amplifier is directly proportional to displacement of the flapper towards the nozzle.

(ii) Data Acquisition System : These are automatic control system with components to condition and interpret the data and take decision accordingly. They have the capability to store data as benchmark and they take comparative action accordingly to the previous instances. They can take corrective actions by matching the previous instances occured in the past and they store this instance in the memory.



Schematic View of Data Acquisition System