ELECTRONIC MEASUREMENT & INSTRUMENTATION (BEC-29)

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UNIT- 2

Lecture-9

Transducers

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Temperature Transducers

- It is a temperature monitoring device.
- It is a device that converts temperature into some other quantity.
- The input is always a thermal quantity.
- It is used for measuring the temperature and heat flow of the devices.

Principle: an electrical device usually used in automated air-temperature control sequences. Its purpose is to make measurement of air temperature and relay the information after translating it into readable form to a power source from the mechanical part of the system.

The temperature transducers are of three types:

- Resistance Temperature Detectors(RTDs)
- Thermistors
- Thermocouples.

- RTDs and thermistors are passive devices whose resistance changes with temperature hence need an electrical supply to give a voltage output.
- Thermocouples are active transducers and are based on the principle of generation of thermoelectricity, when two dissimilar metals are connected together to form a junction called the sensing junction, an emf is generated proportional to the temperature of junction.

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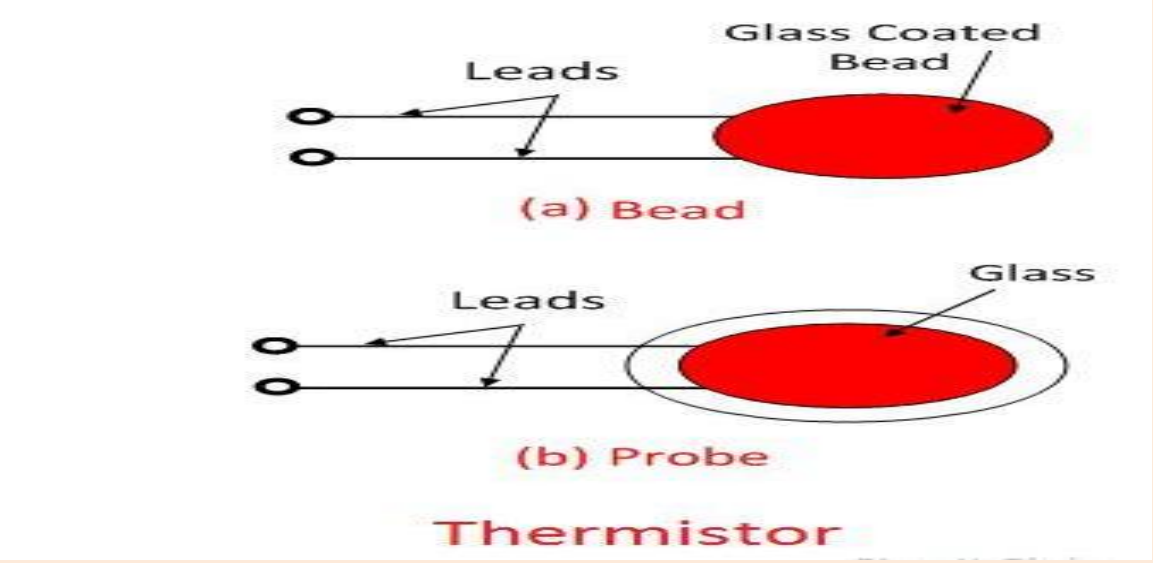
- **Thermistor** – The thermistor is a type of resistor whose resistance varies with the temperature. The resistance is measured by passing the small measured direct current, and this current causes the voltage drop across the resistance.



Negative Temperature Coefficient – Used for sensing the temperature.
Position Temperature Coefficient – Used for controlling the current.

- **Resistance Temperature Detector** – are devices whose resistance changes with temperature hence need an electrical supply to give a voltage input. RTD commonly use platinum, nickel or any resistance wire whose resistance varies with temperature and has a high intrinsic accuracy. Platinum is the most widely used RTD because of its high stability and large operating range. RTDs are connected in Wheatstone Bridge circuit.

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- RTD commonly use platinum, nickel or any resistance wire whose resistance varies with temperature and which has a high intrinsic accuracy. They are available in many configuration and sizes as shielded or open units for both immersion and surface applications.
- The relationship between temperature and resistance of conductors in the temperature range near 0C can be calculated using the equation

  $R_t = R_{ref}(1+ \alpha \Delta t)$

  R_t = resistance of conductor at temperature at t °C

  R_{ref} = resistance of the reference temperature , usually 0 °C

  α = temperature coefficient of resistance.

  Δt = difference between operating and reference temperature
- Almost all metals have positive temperature coefficient (PTC) of resistance, so that their resistance increases with increase in temperature.
- Some materials such as carbon, germanium have a negative temperature coefficient (NTC) of resistance.
- A high value of α is desired in a temperature sensing element, so that sufficient change in resistance occurs for a relatively small change in temperature. This change in resistance can be measured with a Wheatstone's bridge which can be calibrated to indicate the temperature, that caused the resistance change rather than the resistance itself.

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RTDs have the following advantages:

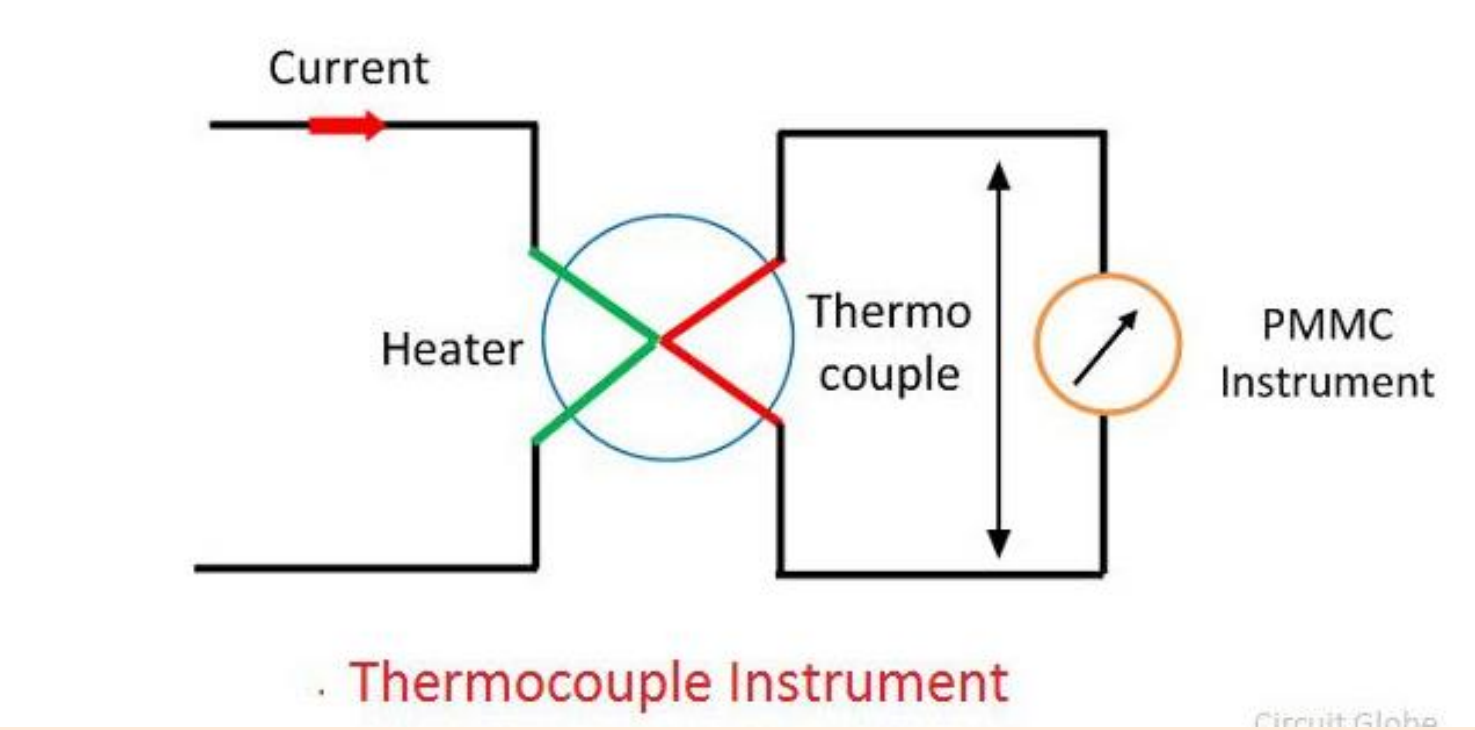
- Platinum RTDs provide high accuracy and stability.
- Linearity over a wide operating range.
- Wide operating range.
- Higher temperature operation.
- Better stability at high temperature.

Disadvantages of RTDs:

- Low sensitivity .
- It can be affected by contact resistance, shock and vibration.
- Requires no point sensing.
- Higher cost than other temperature transducers.

Thermocouples

- The thermocouple converts the temperature into the electrical energy at the point of the contact. It works on the principle that the metals have different temperature coefficient and when these two metals join then the voltage induces, and this voltage is directly proportional to the temperature.



- Temperature measurement with thermocouple is based on the Seebeck effect.
- A current will circulate around a loop made of two dissimilar metal when the two junctions are at different temperatures.

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- When the circuit is opened, a voltage appears that is proportional to the observed Seebeck current.
- There are four voltage sources, their sum is the observed Seebeck voltage. Each junction is a voltage source known as Peltier emf. further, each homogenous conductor has a self induced voltage or Thomson emf.
- Both Thomson and Peltier emfs originate from the fact that, within conductors, the density of charge carriers increases with temperature.
- When two dissimilar conductors are joined, electrons diffuse across the junction from the conductor with higher electron density. When this happens the conductor losing electrons acquire a positive voltage with respect to the other conductor. This voltage is called Peltier emf.
- Type E: Thermocouple units use Chromel alloy as the positive electrode and Constanton alloy as negative electrode.
- Type S: Thermocouple produces least output voltage but can be used over greatest temperature range.
- Type T: uses copper and Constanton.

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- **Advantage of Thermocouple** :
  - It has rugged construction.
  - Using extension leads and compensating cables, long distances transmission for temperature measurement is possible.
  - Bridge circuits are not required for measurement.
  - Comparatively cheaper in cost.
- **Disadvantages of Thermocouple**:
  - Cold junction and other compensation is essential for accurate measurement.
  - Stray voltage pick up are possible.
  - In many applications, signals need to be amplified.

Mechanical Transducers

- The measurement of flow rate and quantity is the oldest of all measurements of process variables in the field of instrumentation. The transducer can be used to measure the flow of any flowing material that is electrically conductive.
- Two saddle coils are arranged opposite to each other and electrodes diametrically opposite are arranged flush with the inside of the lining. If the coils are energized, the moving liquid, cuts the line of force , resulting in the generation of an electromotive force that is picked up by the electrodes.

Mechanical Flow Meter:

- There is a mechanism in the path of the flow which moves continuously at a speed proportional to flow rate. These are generally used for metering liquids with certain modifications. They are designed into two main groups:
    - Displacement type
    - Inferential type
- **The displacement type:** are volumetric in operation, the cyclic displacement of the detecting element, example piston, being proportional to the volume of fluid passing through the meter during each cycle.
- **Inferential type flow meters:** are current type flow meters to measure the velocity of flow, from which the velocity flow is inferred.

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- **Magnetic Flow Meters:** Are the first type of flow meters to be considered for high corrosive applications and applications involving measurement of erosive slurries. These meters work on the principle of Faradays law of electromagnetic induction, which states that whenever a conductor moves through a magnetic field of given strength, a voltage is induced in the conductor proportional to relative velocity between the conductor and magnetic field. In case of flow meters , electrically conductive flowing liquids work as the other conductor. The voltage induced is given by the equation:

  E= C*B*L*V where

  E = induced voltage in volts

  C = dimensional constants

  B = magnetic flux in Wb/sq.m

  L = length of the conductor in m

  V = velocity of conductor in m/s

The equation to convert a velocity measurement to volumetric flow rate is

Q = V*A

Q = volumetric flow rate

V = fluid velocity and A= cross sectional area of the flowmeter

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$$V = \frac{E}{C*B*L} \text{ and } Q = \frac{E*A}{C*B*L}$$

for a given flowmeters A,B,C and L are constants

$$Q = K*E \text{ where } K = \frac{A}{C*B*L}$$

therefore the induced voltage is directly proportional to volumetric flow rate.

- **Construction**

- The Magnetic Flow Meter Construction consists of an electrically insulated or non conducting pipe, such as fiber glass, with a pair of electrodes mounted opposite each other and flush with the inside walls of the pipe, and with the magnetic coil mounted around the pipe so that a magnetic field is generated in a plane mutually perpendicular to the axis of the flow meter body and to the plane of the electrodes.
- If a metal pipe is used, an electrically insulating liner is provided on the inside of the pipe.

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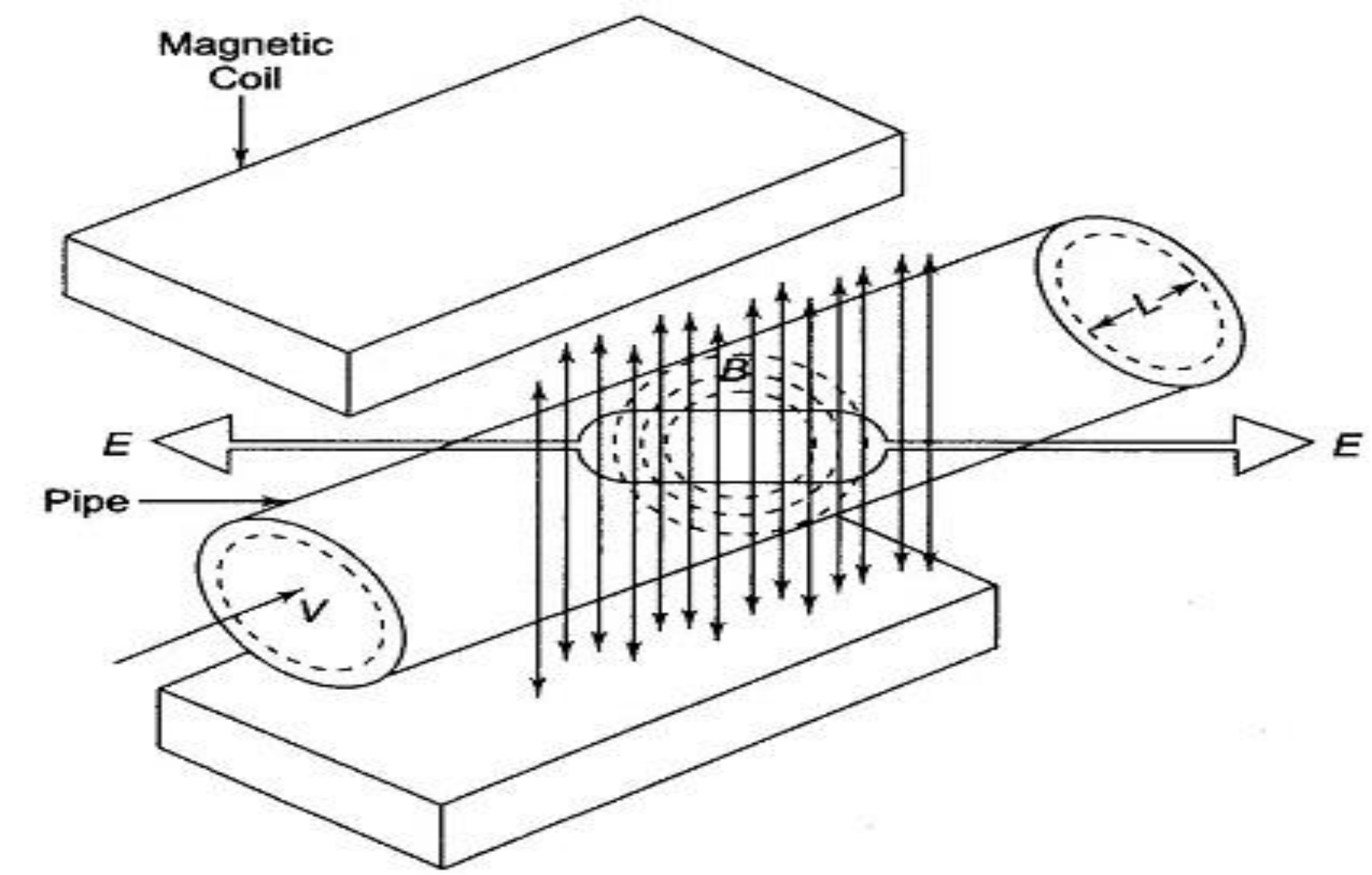

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- The length L is the distance between the electrodes and equals the pipe diameter. As liquid passes through the pipe section, it also passes through the magnetic field set up by the magnet coils, thus inducing a voltage in the liquid, which is detected by a pair of electrodes mounted on the pipe wall. The amplitude of the induced voltage is proportional to the velocity of the flowing liquid.
- The magnetic coils may be excited by either ac or dc voltage. Currently, pulsating dc in which magnetic coils are periodically energized is used.
- Magnetic Flow Meter Construction meters are available in sizes from 2.54 — 2540 mm in diameter, with an accuracy range of ± 0.5 to ± 2%. The measurement taken by these meters are independent of viscosity, density, temperature and pressure. (The range of such meters may be 30:1, but normally a 20:1 range is accepted.)
- A modern design of Magnetic Flow Meter Construction is one which can be inserted into the line through couplings.
- It consists of electrodes mounted on each side of a probe and magnetic coils which are also integral to the probe.
- The probe can be mounted on pipes of diameters 152.4 mm and above can easily be mounted for open channel flow.

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- **Advantages of Magnetic Flowmeter**
  - It can handle slurries and greasy materials.
  - It can handle corrosive fluids.
  - It has very low pressure drop.
  - It is totally obstruction less.
  - It is available in large pipe sizes and capacity as well as in several construction materials.
  - It is capable of handling low flows (with minimum size less than 3.175 mm inside diameter) and very high-volume flow rate (with sizes as large as 3.04 m).
  - It can be used as bidirectional meter.
- **Disadvantage of Magnetic Flowmeter**
  - It is relatively expensive.
  - It works only with fluids which are adequate electrical conductors.
  - It is relatively heavy, especially in larger sizes.
  - It must be full at all times.
  - It must be explosion proof when installed in hazardous electrical areas.

Assignment Questions

- List the various types of temperature transducers and describe the application of each.
- Differentiate between thermocouple and thermistor.
- Explain the working principle of Resistive temperature detector.
- Explain the working principle of a magnetic flow meter.
- State the applications of magnetic flowmeter.

Conceptual Questions

- Mechanical transducers sense _____
  a) electrical changes
  b) physical changes
  c) chemical changes
  d) biological changes
- Mechanical transducers generate _____
  a) electrical signals
  b) chemical signals
  c) physical signals
  d) biological signals
- Mechanical transducers cause _____
  a) power loss
  b) hysteresis loss
  c) eddy current loss
  d) frictional loss

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- Monnit temperature sensor is used for what?
  a) Accurate results
  b) To measure the temperature at high degree
  c) Temperature sensor
  d) Pressure sensor
- _____ measures temperature by correlating the resistance of the RTD with temperature.
  a) Thermistor
  b) Resistance Thermometer
  c) Thermo couple
  d) Semiconductor based sensor
- _____ consists of two different metals connected at two points.
  a) Thermistor
  b) Resistance Thermometer
  c) Thermocouple
  d) Semiconductor based sensor

THANK YOU