

UNIT-II:**Thermal Sensors****1. THERMAL SENSORS – INTRODUCTION****Definition**

Thermal sensors are devices used to measure temperature or heat-related parameters by converting thermal energy into electrical signals.

Functions

- Temperature measurement
- Heat flow measurement
- Thermal monitoring
- Process control

Applications

- Industrial furnaces
- Power plants
- Medical instruments
- Refrigeration systems
- Aerospace systems

2. GAS THERMOMETRIC SENSORS**Principle**

Based on the relationship between temperature, pressure, and volume of a gas.

Ideal Gas Equation

$$PV = nRT$$

atm

 P

L

 V

mol

 n

K

 T

P is pressure; V is volume; n is amount of gas; T is temperature.

Where:

- P = Pressure
- V = Volume
- T = Temperature
- n = Number of moles
- R = Gas constant

Working

Temperature changes cause pressure or volume changes in the gas.

Advantages

- High accuracy
- Wide temperature range

Applications

- Calibration laboratories
- Scientific research

3. THERMAL EXPANSION TYPE THERMOMETRIC SENSORS

Principle

Materials expand when temperature increases.

Types

1. Liquid-in-Glass Thermometer
2. Bimetallic Thermometer
3. Filled-System Thermometer

Advantages

- Simple construction
- Low cost

Disadvantages

- Slow response
- Mechanical wear

Applications

- Domestic thermometers
- Industrial temperature measurement

4. ACOUSTIC TEMPERATURE SENSOR

Principle

Speed of sound in a medium varies with temperature.

Working

Temperature changes alter sound velocity.

Features

- Non-contact measurement
- Suitable for harsh environments

Applications

- High-temperature furnaces
- Gas temperature monitoring

ND REFRACTIVE INDEX THERMAL SENSORS

Principle

Temperature changes affect dielectric constant and refractive index.

Working

Temperature variation changes:

- Electrical permittivity
- Optical refractive index

Advantages

- High sensitivity
- Non-contact measurement

Applications

- Optical fiber sensors
- Semiconductor industries

6. HELIUM LOW TEMPERATURE THERMOMETER

Principle

Based on pressure changes of helium gas at very low temperatures.

Temperature Range

Approximately 1 K to 20 K

Advantages

- Extremely accurate at cryogenic temperatures

Applications

- Superconductivity studies
- Cryogenic engineering
- Space research

7. NUCLEAR THERMOMETER

Principle

Uses temperature dependence of nuclear properties.

Working

Measures nuclear magnetic behavior affected by temperature.

Features

- Operates at extremely low temperatures
- High precision

Applications

- Nuclear research
- Cryogenic laboratories

8. MAGNETIC THERMOMETER

Principle

Magnetic susceptibility changes with temperature.

Working

Temperature affects magnetic properties of paramagnetic materials.

Advantages

- Accurate at low temperatures

Applications

- Cryogenic systems
- Scientific laboratories

9. RESISTANCE CHANGE TYPE THERMOMETRIC SENSORS

Principle

Electrical resistance changes with temperature.

Types

Resistance Temperature Detector (RTD)

Uses pure metals such as platinum.

Thermistor

Uses semiconductor materials.

Equation

$$R_t = R_0(1 + \alpha T)$$

Where:

- R_t = Resistance at temperature T
- R_0 = Initial resistance
- α = Temperature coefficient

Applications

- Industrial process control
- Laboratory instruments

10. THERMO EMF SENSORS (THERMOCOUPLES)

Principle

Based on Seebeck Effect.

Working

When two dissimilar metals are joined and their junctions are at different temperatures, an emf is generated.

Advantages

- Wide temperature range
- Rugged construction

Applications

- Furnaces
- Boilers
- Industrial plants

11. JUNCTION SEMICONDUCTOR TYPE TEMPERATURE SENSORS

Principle

Semiconductor junction voltage changes with temperature.

Examples

- Diode temperature sensor
- Transistor temperature sensor
- IC temperature sensor

Advantages

- High sensitivity
- Small size

Applications

- Electronic circuits
- Computers
- Consumer electronics

12. THERMAL RADIATION SENSORS

Principle

All objects emit thermal radiation depending on temperature.

Working

Radiation intensity is measured to determine temperature.

Types

- Infrared Thermometer
- Optical Pyrometer

Advantages

- Non-contact measurement
- Fast response

Applications

- Molten metal measurement
- Remote temperature sensing

13. QUARTZ CRYSTAL THERMOELECTRIC SENSORS

Principle

Temperature changes alter quartz crystal resonance frequency.

Working

Temperature variation causes frequency shift.

Advantages

- High stability
- High precision

Applications

- Scientific instruments
- Precision temperature measurement

14. NQR THERMOMETRY

(Nuclear Quadrupole Resonance Thermometry)

Principle

Nuclear quadrupole resonance frequency changes with temperature.

Features

- Very high accuracy
- Suitable for low temperatures

Applications

- Research laboratories
- Nuclear physics studies

15. SPECTROSCOPIC THERMOMETRY

Principle

Based on temperature dependence of spectral lines.

Working

Temperature is determined by analyzing emitted or absorbed light spectra.

Advantages

- Non-contact
- Suitable for extreme temperatures

Applications

- Plasma studies
- Combustion analysis
- Astronomy

16. NOISE THERMOMETRY

Principle

Based on thermal noise generated by electrical resistors.

Working

Temperature is proportional to electrical noise power.

Advantages

- High accuracy
- Wide temperature range

Applications

- Precision laboratories
- Cryogenic measurements

17. HEAT FLUX SENSORS

Definition

Sensors used to measure heat transfer rate through a surface.

Principle

Heat flow generates a temperature difference across the sensor.

Working

Heat flux is proportional to the generated temperature gradient.

Advantages

- Direct heat measurement
- Good accuracy

Applications

- Thermal insulation testing
- Energy auditing
- Aerospace engineering

IMPORTANT EXAM POINTS

Definitions

- Thermal Sensor → Measures temperature.
- Thermocouple → Uses Seebeck Effect.
- RTD → Resistance changes with temperature.
- Thermistor → Semiconductor temperature sensor.
- Acoustic Sensor → Based on speed of sound.
- Magnetic Thermometer → Based on magnetic susceptibility.
- Heat Flux Sensor → Measures heat transfer rate.

Important Principles

1. Gas Thermometer → Ideal Gas Law
2. Thermocouple → Seebeck Effect

3. RTD → Resistance Change
4. Thermal Radiation Sensor → Infrared Radiation
5. Magnetic Thermometer → Magnetic Susceptibility
6. Noise Thermometer → Thermal Noise
7. Quartz Crystal Sensor → Frequency Change