Experimental Engineering Report

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1 Short Notes

1.1 Thermocouple

It is a temperature measurement device based on electrical method. Working principle of a thermocouple is based on **Seebeck effect** - When two or more dissimilar metals are joined together at a junction. An EMF which is function of temperature is generated across the two free ends.

$$E_{emf} = -S\nabla T$$

S is known as Seebeck coefficient or thermopower.

Peltier effect - If the junction draws current from a source, then its EMF is altered. and **Thompson effect** - If a temperature gradient exists between the two free ends, the EMF of thermocouple junction gets altered.
The working procedure involves measuring the voltage across the junction for a calibrated thermocouple, this way we can accurately measure the temperature. There must exists at least two junctions for proper functioning of a thermocouple. If we know temperature at one junction, the temperature at other can be calculated easily. It is called as reference temperature.

Advantages of thermocouple
1. Can measure large range of temperatures, from 0℃ to 3000℃.
2. Cheaper to manufacture and set-up
3. Faster response time (electrical method)

Disadvantages of thermocouple
1. Accuracy is 1℃. Whereas for RTD accuracy is 0.1℃.
2. Linearity is not present in temperature measurement (S shaped plots)
3. Prone to corrosion and oxidation errors

1.2 Pyrometer

It is a device which measures the temperature of surface of item by measuring the intensity of radiation it emits. Its working principle is based on **stefan-boltzmann law**-Intensity of light emitted by black body is proportional to T^4.

The device consists of two systems -
1. Optical system - Captures radiation emitted by item through lenses, and calculates intensity.
2. Detection system - Measures surface temperature of the item using measured intensity.

Multiple types of pyrometers are available like - infrared pyrometer etc.

Advantages of pyrometer
1. Can measure temperature from a distance without any contact
2. Fast response time
3. Fairly good accuracy

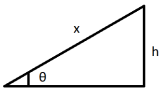
Disadvantages of pyrometer
1. Expensive
2. Accuracy can be adversely affected through environmental factors like - smoke and dust particles or other thermal radiations.

2 Explain the following

2.1 Use of inclined U-tube manometer

A manometer is a device used for measuring unknown pressure (say p1), against a reference pressure (say p2) usually considered as atmospheric pressure. Different types of manometers in use are - u-tube manometer, inclined u-tube manometer, manometer in series etc.

The Inclined tube manometer consists of a section of u-tube placed a an angle < 90 to the ground. It helps improve accuracy of the readings. For the cases where (p1 - p2) ie, the pressure difference is very small, taking the correct reading is not possible. One way to correct this flaw is that - we can take manometer fluid such that the ratio ($\rho m/\rho w$) is close to 1. But usually it's not possible to find such a liquid which also gives a well defined meniscus at the junction.

As pressure reading is proportional to vertical height. Using inclined tube at angle θ, we will get reading as Δx (The distance along inclined tube). such that the height difference $\Delta h = \Delta x \cdot sin\theta$. Now as $sin\theta <= 1$, We require more Δx for the same height, 

and hence we have higher precision readings.
Note:- We have to keep θ larger than 5 degrees to obtain correct readings.

2.2 Why mercury is used in U-tube manometer?

Manometers are device used to measure unknown pressure by measuring difference in height of manometer fluid in the two sections. Mercury is the best choice for manometer fluid because of the following characteristics.
Mercury has higher density ($13.6 g.cm^{-3}$) than most liquids and is able to measure larger pressure for smaller u-tube size. This is due to the relation :-

$$\text{p1 - p2} = \rho\text{gh.}$$
$$\text{or, h} = (\text{p1 - p2}) \,/\, \rho\text{g.}$$

We can see that h is inversly proportional to density of liquid hence mercury is used as it has high density.
Also as density of mercury is 13.6 times density of water - the same pressure difference would require 13.6 times the height of mercury to measure if we use water.
Mercury has low vapor pressure so does not evaporate easily and has a quick response to changes in pressure
Mercury has low freezing point and is a very stable liquid
Mercury has a clearly visible meniscus as it is a shiny liquid

3 Explain the following

3.1 Use of IR sensor with one application

Infrared waves are a band in Electro-Magnetic Spectrum, lying between visible and microwaves bands. Having wavelength from 1 μm to 1000 μm. These have property to cause vibrations in molecules and generate heat, hence these are also called 'heat waves'.
IR Sensors are a type of electronic device which can be used to detect radiations in Infrared regions. A set-up of IR emitter and sensor can be used to detect movement and heat-mapping.
IR emitters are IR LED's (Light Emitting diodes) made of specific semiconductors (eg- Indium Gallium Arsenide). On excitation they generate radiations in IR spectrum.
IR Sensors are photodiodes which are sensitive to the Infrared band.
The working principle of an IR sensor is - when a radiation of specific frequency in IR spectrum falls on the photodiode, in the p-n junction, photo-current is generated through generation of electron-hole pairs. This phenomenon is called 'inner-photoelectric effect'. Thus resistance and voltage across photodiodes changes in proportion to the intensity of the radiations.
The emitter will generate radiation in line of sight of IR sensor, which will in turn generate a potential difference.

There are **Two types** of IR sensors:
1. Active - Both emitter and sensor in the same device (Useful when feedback is required). eg, break beam sensor
2. Passive - sensor is a seperate device. eg, pyroelectric sensor, thermocouple-thermophile

Further passive sensors can be classified on basis of their functioning -
(1) Thermal sensor - thermal radiation heat-up and cause vibrations , this is slow and less accurate.
(2) Quantum sensor - Based on photoelectric effect - Fast and accurate response

Advantages of IR sensor
1. Uses less power
2. No contact measurement
3. Sensors are not affected by corrosion
4. Accurate sensor

Disadvantages of IR sensor
1. Based on line-of-sight method
2. Limited range
3. Less data can be transmitted

3.1.1 Application of IR Sensor

Burglar Alarm Sensor
This device uses a pair of IR emitter and sensor together. A Infrared ray of an adequate intensity is projected onto the IR Sensor. This keeps the circuit closed.
If a obstacle (Supposedly a burglar) comes in between path of the ray, the circuit will break and alarm will start to notify the appearance of an obstacle.

3.1.2 Other applications

Thermal imaging - ie thermal infrared detectors - for heat-mapping and night vision
Television remote - Simple sensor to detect IR waves