THERMOCOUPLES (Thermo-junctive temperature measuring devices)

Thomas Johan Seeback discovered in 1821 that thermal energy can produce electric current. When two conductors made from dissimilar metals are connected forming two common junctions and the two junctions are exposed to two different temperatures, a net thermal emf is produced, the actual value being dependent on the materials used and the temperature difference between hot and cold junctions. The thermoelectric emf generated, in fact is due to the combination of two effects: Peltier effect and Thomson effect. A typical thermocouple junction is shown in fig. 5. The emf generated can be approximately expressed by therelationship:

$$e_0 = C_1(T_1 - T_2) + C_2(T_1^2 - T_2^2)\,\mu v$$

Where, T_1 and T_2 are hot and cold junction temperatures in K. C_1 and C_2 are constants depending upon the materials. For Copper/ Constantan thermocouple, C_1=62.1 andC_2=0.045.

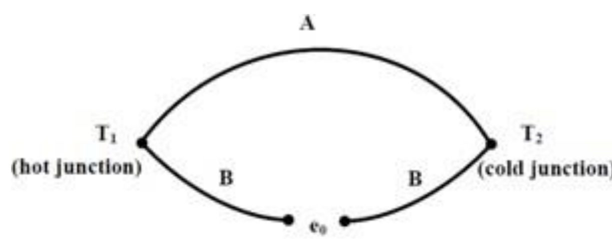


Fig 5.27 Thermocouple

Thermocouples are extensively used for measurement of temperature in industrial situations. The major reasons behind their popularity are:

(i) They are rugged and readings areconsistent

(ii) They can measure over a wide range oftemperature

(iii) Their characteristics are almost linear with an accuracy of about 0.05%. However, the major shortcoming of thermocouples is low sensitivity compared to other temperature measuring devices (e.g. RTD,Thermistor).

ThermocoupleMaterials

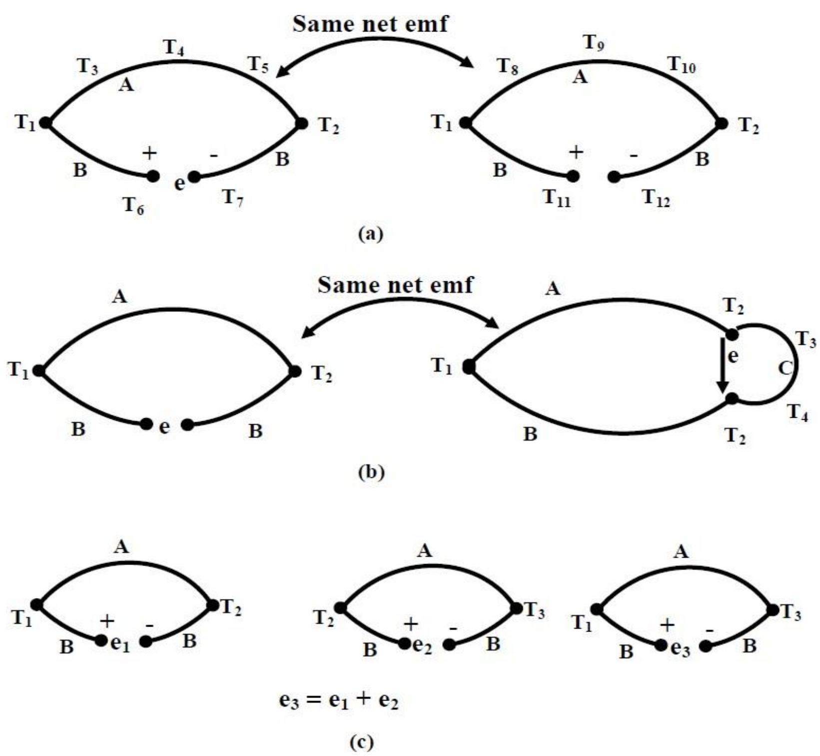
Table-1 Thermocouple materials and Characteristics

Type	Positive lead	Negative lead	Temperature range	Temperature coeff.variation µv/°C	Most linear range and sensitivity in the range
R	Platinum-Rhodium (87% Pt, 13% Rh)	Platinum	0-1500°C	5.25-14.1	1100-1500°C 13.6-14.1 µv/°C
S	Platinum-Rhodium (90% Pt, 10% Rh)	Platinum	0-1500°C	5.4-12.2	1100-1500 °C 13.6-14.1 µv/°C
K	Chromel (90%Ni, 10% Cr)	Alumel ($Ni_{94}Al_2$ Mn_3Si)	-200-1300°C	15.2-42.6	0-1000 °C 38-42.9 µv/°C
E	Chromel	Constantan (57%Cu, 43%Ni)	-200-1000°C	25.1-80.8	300-800 °C 77.9-80.8 µv/°C
T	Copper	Constantan	-200-350°C	15.8-61.8	nonlinear
J	Iron	Constantan	-150-750°C	21.8-64.6	100-500 °C 54.4-55.9

Theoretically, any pair of dissimilar materials can be used as a thermocouple. But in practice, only few materials have found applications for temperature measurement. The choice of materials is influenced by several factors, namely, sensitivity, stability in calibration, inertness in the operating atmosphere and reproducibility (i.e. the thermocouple can be replaced by a similar one without any recalibration). Table-I shows the common types of thermocouples, their types, composition, range, sensitivity etc. The upper range of the thermocouple is normally dependent on the atmosphere where it has beenput.Forexample,theupperrangeofChromel/Alumelthermocouplecanbe increased in oxidizing atmosphere, while the upper range of Iron/ Constantan thermocouple can be increased in reducing atmosphere.

Laws of Thermocouple

The Peltier and Thompson effects explain the basic principles of thermoelectric emf generation. But they are not sufficient for providing a suitable measuring technique at actual measuring situations. For this purpose, we have three laws of thermoelectric circuits that provide us useful practical tips for measurement of temperature. These laws are known as law of homogeneous circuit, law of intermediate metals and law of intermediate temperatures. These laws can be explained usingfigure



The first law can be explained using figure (a). It says that the net thermo-emf generated is dependent on the materials and the temperatures of two junctions only, not on any intermediate temperature.

According to the second law, if a third material is introduced at any point (thus forming two additional junctions) it will not have any effect, if these two additional junctions remain at the same temperatures (figure b). This law makes it possible to insert a measuring device without altering the thermo-emf.

The third law is related to the calibration of the thermocouple. It says, if a thermocouple produces emf e_1, when its junctions are at T_1 and T_2, and e_2 when its junctions are at T and T ; then it will generate emf e +e when the junction temperatures

The third law is particularly important from the point of view of reference junction compensation. The calibration chart of a thermocouple is prepared taking the cold or reference junction temperature as 0^{o}C. But in actual measuring situation, seldom the reference junction temperature is kept at that temperature, it is normally kept at ambient temperature. The third law helps us to compute the actual temperature using the calibration chart.