The *e.m.f* and temperature diagram of the thermocouple.

Objectives

After performing this experiment, one should be able to:

• arrange experimental set up for measurement of thermo-emf;

• measure potential difference of the order of a few microvolts;

• plot a graph between the thermo-emf and temperature; and

• determine neutral temperature using the graph.

Introduction:

The principle of conservation of energy is known, which states that energy can neither be created nor destroyed; it can only change from one form to another. For example, in a battery/cell, the chemical energy is converted into electrical energy. In a hydro-power plant, potential energy (of water) is converted into electrical energy by a turbine. In an electric heater, the electrical energy is converted into heat energy. In a steam engine, heat energy is converted into mechanical (kinetic) energy. Can the heat energy be reconverted into electrical energy?

Answer to this question was provided by T.J. Seebeck in 1821. He observed that if wires of two different metals, such as copper and iron, are joined together to form a closed loop and if two junctions are kept at different temperatures, an electric current begins to flow in the loop. This phenomenon is called thermoelectric effect, and generation of current in the loop due to difference in temperatures is called Seebeck effect. The loop comprising the two metals is referred to as a thermocouple. The existence of current implies that there is electromotive force (emf) acting in the circuit. This is known as thermo-electromotive force and the electric current produced in this way is called thermo-electric current. The factors on which the direction of current and the magnitude of thermo-emf depend, are seen to be dependent on the nature of materials used and the difference of temperature between the two junctions, respectively.

The conversion of heat energy into electrical energy by a thermocouple cannot be considered an efficient process because the e.m.f produced is of the order of a few millivolts. So it can however be improved by using better thermocouples, based on alloys. Typical values of thermo-emf per degree rise in temperature for some thermocouples are given below:

Thermocouple	Thermo-emf $\times 10^{-6}$ VK^{-1}
Iron-Copper	13.9
Iron-Constantan (J)	50.2
Cromel-Alumel (K)	39.4
Copper-Constantan (T)	39
Chromel-Constantan (E)	58.5

Thermo-emf generated by some known thermocouple.

On account of their reliability and low cost, thermocouples are suitable as small power supply units in space satellites, ships etc. Thermocouples are extensively used as thermometers, particularly for measuring high temperatures.

Theory:

When thermocouple is set to generate e.m.f, the current first increases gradually as the difference between the temperatures of junctions increases and becomes maximum at a certain temperature of the hot junction and then began to decrease with further rise in the temperature. The temperature of the hot junction for maximum current is called *neutral temperature*. It is independent of the temperature of cold junction. The highest temperature rose above the neutral temperature at which the thermal e.m.f and current becomes zero is called *temperature of inversion.* The temperature of inversion depends upon the temperature of the cold junction and is as much above the neutral temperature as that of the cold junction is below it. Any further increase in the temperature, above the temperature of inversion causes an increase in the current with the direction reversed, i.e., it begins to flow from iron to copper at the hot junction.

As the current depends upon the resistance of the circuit and resistance changes with a change in temperature, it is usual to measure the e.m.f developed in the circuit and not the current. As the e.m.f generated by the thermocouple is of the order of mV thus a very sensitive voltmeter with high impedance is used.

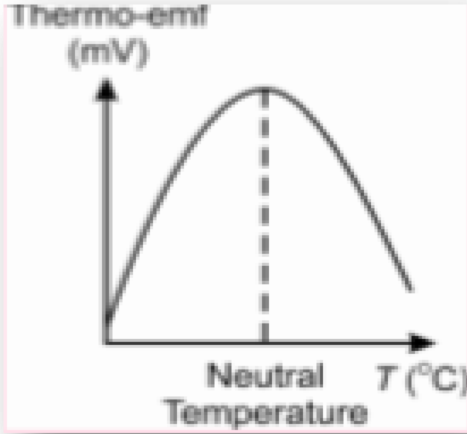

Fig.1: Graph between temperature and thermal emf.

Apparatus:

Thermometers (one up to 360˚C and the other 100˚C), sand bath or electric furnace, ice bath, copper-iron thermocouple and digital multimeter.

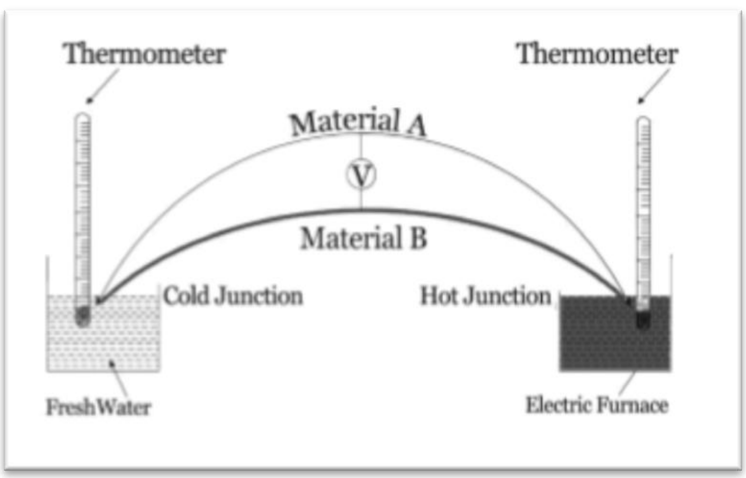

Fig.2: Experimental setup

Procedure:

- Insert one end of the thermocouple in the electric furnace or sand bath and the other end in the ice bath.
- Connect the circuit as shown in the above figure.
- Switch on the multimeter and select the range DC mV.

- Start heating at slow rate, wait for few minutes, and record the temperature and thermal e.m.f for every 10˚ or 20˚ rise in the temperature of hot junction up to 340˚C. Also take the readings of temperature and e.m.f when furnace or sand bath is cooling.
- Plot a graph between e.m.f and temperature to get a curve as shown in the above fig.1. also draw a separate graph for cooling. Find out maximum e.m.f and neutral temperature from the curve.