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CHAPTER 2

THERMOELECTRIC COOLING

Discovery, Performance of Thermoelectric Couples, Refrigerating System Analogies, Advantages, Applications, Design

IN 1821 Seebeck observed that, if a closed circuit was made of two dissimilar metals, an electrical current flowed in the circuit when the two junctions were maintained at different temperatures. His investigations were very extensive, covering a wide range of elements and compounds. This resulted in publication of a series in which the materials he had investigated were arranged in a logical sequence, in the order of the magnitude of their effect. However, he failed to realize the significance of his discovery. In 1834 Peltier observed the inverse effect, namely, that if an electrical current flowed across the junction between two dissimilar materials, heat was either absorbed or evolved. Peltier did not realize the significance of his discovery either, and moreover failed to recognize the connection between his discovery and that of Seebeck. It is alleged that Lens ended all conjecture surrounding these discoveries by freezing a small quantity of water placed in the vicinity of the junction between a bismuth and antimony rod through which a direct current was passed. These were two of the materials in which Seebeck had observed his effect to be most pronounced. A third effect was pointed out by Thomson (Lord Kelvin) in 1851. It related the heat absorbed or evolved in a single conductor to the temperature gradient along it and the current flowing through it. This is an effect which takes place in addition to the Joule (I^2R) heating. However, in thermoelectric cooling materials, Kelvin's is a second order effect, compared with those of Peltier and Seebeck, and will not be further considered.

For many years, the practical application of these thermoelectric effects was almost exclusively restricted to thermocouples for the measurement of temperature, because metals exhibit a comparatively small Seebeck effect. However, the Seebeck effect in semiconductors can be considerably greater. The advent of the transistor and other semiconductor devices has stimulated research pertaining to the properties of semiconductors in general, and from this has come materials in which the thermoelectric effects are of sufficient magnitude so that the fabrication of useful devices has become a reality.

THERMOELECTRIC EFFECTS

Seebeck Effect (Fig. 1). For a small temperature difference between the two junctions of materials A and B, the open circuit voltage developed is proportional to the temperature difference and is given by:

$$\Delta E = \alpha_{AB} \Delta T \qquad (1)$$

where

ΔE = open circuit voltage developed.
α_{AB} = relative Seebeck coefficient (the difference between the absolute Seebeck coefficients for materials *A* and *B*).
ΔT = temperature difference between junctions of materials *A* and *B*.

The general responsibility for this chapter is assigned to TC 1.13, Thermoelectricity.

In practice, the absolute Seebeck coefficient, α, of a material is determined with respect to a material such as lead, in which the Seebeck coefficient is negligible.

In metals, α does not exceed 0.00005 volt per C deg; in semiconductors currently (1964) available for thermoelectric applications, α is typically 0.0002 to 0.00025 volt per C deg.

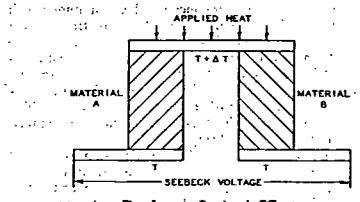

Fig. 1 .... Seebeck Effect

The Generation of an EMF by a Temperature Difference Between the Junctions in a Circuit Composed of Two Dissimilar Electrically Conducting Materials.

Peltier Effect (Fig. 2). The same circuit can be considered as being made up of materials A and B, into which a battery is introduced to provide a direct current, *I*. At the junction between the two dissimilar materials, the heat evolved or absorbed in unit time is proportional to the current flowing and is given by:

$$Q = \pi_{AB} I \qquad (2)$$

where

Q = heat evolved or absorbed in unit time, watts.
π_{AB} = relative Peltier coefficient for materials *A* and *B*.
I = direct current flowing, amperes.

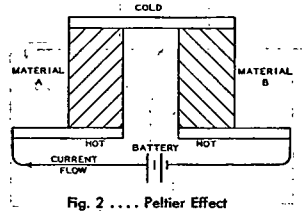

Fig. 2 .... Peltier Effect

The Absorption and Evolution of Heat at the Junctions Between Two Dissimilar Materials Produced by the Passage of an Electric Current Through the Junctions.