Thomson Effect and its Prediction

Let us consider a Thermo-couple ~~made~~ made of two dissimilar metals A and B (Say Cu & Fe) with its hot and cold junctions maintained at absolute temperatures T_2 and T_1 by a Source and a Sink of very large Thermal capacities respectively (fig-6)

Let π_1 and π_2 be The Peltier emf's at T_1 and T_2 K (Kelvin) respectively, directed from The metal A to The metal B Through The junctions. Since $T_2 > T_1$; $\pi_2 > \pi_1$:

Thus a resultant e.m.f. of $\pi_2 - \pi_1$ acts in The Thermo-couple due to peltier e.m.f. If we assume that the peltier e.m.f. is The only source of e.m.f. in The Thermo-couple, Then The Thermo-electric e.m.f. developed in The Thermo-couple is

$$e = \pi_2 - \pi_1 . \quad \text{—— (1)}$$

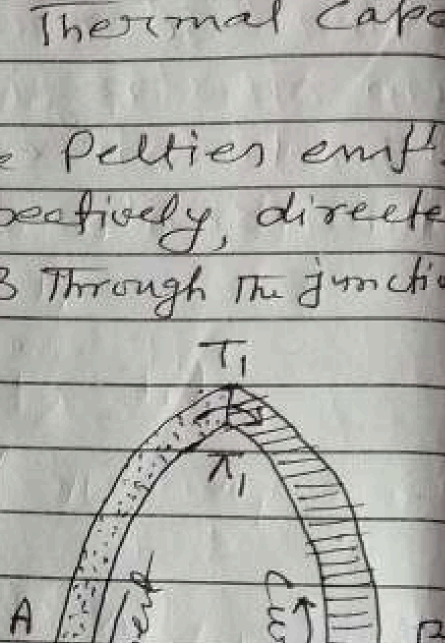

fig-6

This e.m.f gives rise to electric Current flowing round The Circuit in the anti-clockwise direction as shown in fig (6), which due to Peltier effect, causes absorption of heat at The hot junction and evolution of heat at The cold junction.

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If q is the charge flowing in the Thermo-couple in time t, Then during this time heat absorbed at the hot junction $Q = \pi_2 q$ and heat evolved at the cold junction is $Q_1 = \pi_1 q$. The absorption of heat at the hot junction is made up by the source maintained at constant temperature T_2; hence Q_2 is the energy absorbed from the source. The heat evolved at the cold junction flows to the sink which maintains the junction at $T_1 K$; hence heat given to the sink at $T_1 K$ is Q_1.

Since above Processes are entirely reversible, for the current from an external source in the opposite direction and doing external work heat may be absorbed from the junction at lower temperature $T_1 K$ and given to that at higher temperature $T_2 K$; and Joule effect can be made negligible by considering a very small flow of current; Therefore, The Thermocouple may be treated as a reversible ~~Carn~~ Carnot's engine operating between the temperatures $T_2 K$ and $T_1 K$ of the hot and cold junctions. Now according to Thermodynamics The net gain of entropy in a

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reversible cycle is zero i.e.

$$\sum \frac{Q}{T} = 0$$

or $\frac{\pi_2 q}{T_2} - \frac{\pi_1 q}{T_1} = 0$

or $\frac{\pi_2}{\pi_1} = \frac{T_2}{T_1}$

or $\frac{\pi_2 - \pi_1}{\pi_1} = \frac{T_2 - T_1}{T_1}$

or $(\pi_2 - \pi_1) = \frac{\pi_1}{T_1}(T_2 - T_1)$

Substituting this value of $\pi_2 - \pi_1$ in equn (1), we get

Thermo-electric emf.

$$e = \frac{\pi_1}{T_1}(T_2 - T_1).$$

The if the temperature T_1 of the cold junction is kept at constant temp. and T_2 is increased, then the resultant thermo-electric e.m.f is directly proportional to the difference in temp. between hot and cold junctions i.e. the graph between e and $T_2 - T_1$ should be a straight line. But in actual experiments, it is seen that the relation between e and $T_2 - T_1$ is not linear; but parabolic.

This led William Thomson to predict that peltier e.m.f. is not the only source of electro-motive force in the circuit and pointed out that there must be some other e.m.f. ~~exists between~~ ~~different parts~~ in the Thermocouple also. He pointed out that ~~there~~ must be ~~some~~ an additional source of e.m.f. exists between different parts of the same metal due to the gradient of temperature throughout the metal. This effect is called <u>Thomson effect</u>