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POWER GENERATION FROM INDUSTRIAL WASTE HEAT

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Abstract *- Most of the industries, power plants for instance, take in some fuel to generate power which is required for various purposes but during this process there is a considerable amount of heat ejected that is the residue of the*
This paper gives an account of a method which can help us generating electricity from the waste heat that is being ejected out by the industries, a better way this waste heat can be put into use hence conserving energy up to an appreciable extent helping us handle the energy crisis and lead to a greener planet.

Keywords *– Power plant, thermoelectric effect, waste heat, seebeck effect, thermocouple, voltage, and chimney.*

I. INTRODUCTION

The theory behind this design is the thermoelectric effect,According to which there will be a potential difference or voltage or emf that will be generated between any the given points on a conductor given that there is a considerable difference in the temperature of the conductor at those two given points. In practicality it is the difference in the temperature that results in difference in the rate of electron transfer between a hot and a cold side that results in the generation of electric potential difference.

Approximately 90% of world's electricity is generated by heat energy, typically operating at 30 – 40 % efficiency, losing roughly 15 terawatts of power in the form of heat to the environment. Thermoelectric devices could convert some of this waste heat in to useful electricity.[1] As of 2010, thermoelectric generators serve application niches where efficiency and cost are less important than reliability, light weight, and small size.[2]

Cogeneration power plants use the heat produced during electricity generation for alternative purposes. Thermo electrics may find applications in such systems or in solar thermal energy generation.[3]

The fundamental principle behind this is seebeck effect. According to Seebeck effect when there is a temperature difference between the two junctions of two dissimilar metals there will be a small current flowing in the circuit. The emf or the voltage produced resulting in the current flow in the circuit is called seebeck voltage and can be denoted by V_s . If T is the temperature the relation can be expressed as $V_s \propto \Delta T$ where, ΔT corresponds to temperature gradient. The proportionality constant to make this a equation is the seebeck coefficient and varies from metal to metal since the equation deals with the combination of the metals the relative seebeck coefficient should be considered. If S_a corresponds to the seebeck coefficient of metal a, and if S_b correspond to the seebeck coefficient of metal b, then the relative coefficient of the combination

$$S_{ab} = S_a - S_b \qquad (1)$$

and the overall equation will be

$$Vs = Sab \times \Delta T \qquad (2)$$

The seebeck coefficients of few metals[4] are tabulated under in TABLE : 1

TABLE 1 : SEEBECK COEFFICIENTS

METALS	SEEBECK COEFFICIENT (μV/ K)
ANTIMONY	47
NICHROME	25
MOLYBDENUM	10
CADMIUM	7.5
TUNGSTEN	7.5
GOLD	6.5
SILVER	6.5
COPPER	6.5
RHODIUM	6.0

LEAD	4.0
ALUMINIUM	3.5
CARBON	3.0
PLATINUM	0

The emf generated in the thermoelectric effect is due to the temperature gradient along the wire. The emf is not generated at the junction between two dissimilar wires.
A thermocouple is nothing but two metal conductors which are thermoelectrically active whose ends are soldered together there are three basic types of the thermocouples namely base metal, noble metal, and refractory metal thermocouples. Several thermocouples connected in series is called a thermopile. And the potential difference in a thermopile is nothing but the sum of all the emf of the constituent thermocouples hence resulting in greater emf.

II EXPERIMENTAL PROCEDURE

This concept aims in generation of electricity from waste heat that is being ejected in huge amounts from various industries to make things more generic this paper explains the concept in a power plant, where there is a cooling tower from which water in its vapour state is ejected out from the chimney where the working fluid is still in its vapour state now the energy this fluid contains is more or less equal to the energy that is used to bring this fluid from a liquid state to a vapour state which takes a considerable amount of fuel.

This heat that is being ejected through the chimney can be used in a smarter way instead. In order to do so first things first, the potential heat is supposed to be calculated and this can be done as follows, Estimates say that 80,000 cubic meters of water is ejected through the cooling tower per hour on an average, Density of water is equal to 0.001 kg/m^3 that converts to 80,000,000 kg of water per hour.
Now the heat required to heat water from room temperature to the exit temperature will be equal to the heat that is ejected. This much energy is being wasted now the exit temperature will be around 70^0 C and the ambient temperature will be around 35^0 C so there is a temperature difference of 35 degrees now the best operating material in this temperature range will definitely be a E type thermocouple which can be clearly observed from the thermocouple literature mentioned in the FIG 1.
The reason for selection of the type E thermocouple is it has higher output voltage is comparison with other types of thermocouples. After building the thermopile all the odd ends or odd junctions are set in contact with the hot gas ie. Inwards the cooling tower and all the even ends or the even junctions are brought in contact with the ambient atmosphere. Now due to the temperature difference or the temperature gradient between the two bodies according to the seebeck effect there is a emf generated henceforth resulting in the flow of the electric current across the ends.

The output voltages measured at the ends of the different types of thermopiles after creating similar environment are tabulated in TABLE : 2

TABLE 2 : OUTPUT VOLTAGES

THERMOCOUPLE	OUTPUT VOLTAGE (mV)
TYPE K	2.3
TYPE S	1.16
TYPE E	3.48
TYPE N	1.53
TYPE T	2.31
TYPE J	2.97
TYPE R	0.32

Since the output voltage of the type E thermocouple is greater than others it is employed in the experiment.

III EXPERIMENTAL ANALYSIS

The general behavior of the e type thermocouple at different temperatures is as in the graph

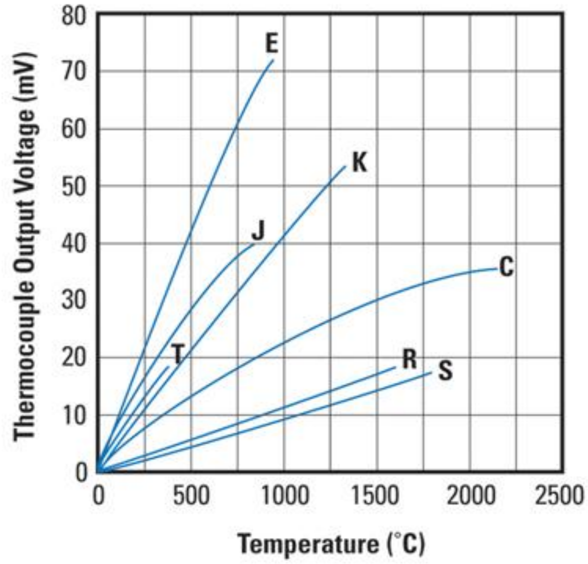

FIG 1 : TEMPERATURE V/S OUTPUT VOLTAGE

The practical results of the output voltages from the Table 2 have been analyzed in FIG :2

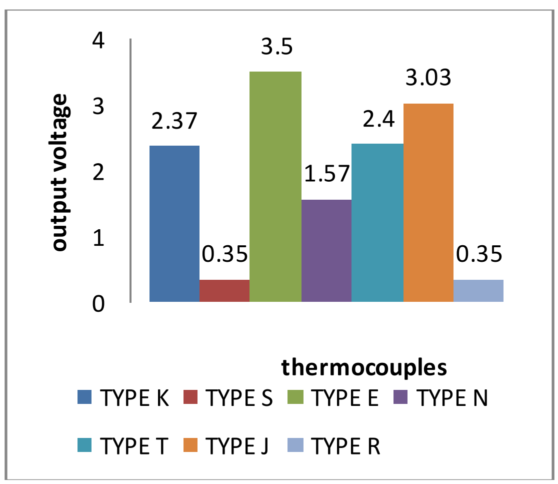

FIG 2 : THERMOCOUPLE V/S OUTPUT VOLTAGE

THREOTICAL CALCULATION

The temperatures at the hot and the cold junctions of the thermopile have been recorded as follows:
Temperature at hot junction = 70^0C
Temperature at the cold junction = 35℃
This gives the resultant temperature gradient ΔT as

$$70 - 35 = 35^0C$$

Output thermoelectric voltage – v
Temperature at cold junction – t_1
Temperature at hot junction – t_2

$V_{OUT} = V_{t2\text{-}t1} = V_{t2} - V_{t1}$ (2)
$V_{OUT} = V_{70} - V_{35}$
$Vt = \sum_{i=0}^{n} Ci \, X \, T^{i}$ (3)
where C_i = thermocouple coefficient

TABLE 3: COEFFICIENTS FOR E TYPE THERMOPILE

Coefficients Ci for the Type E Thermocouple		
Ci Coefficients	Value -270 to 0°C	Value to1000°C
C0	0.00E+00	0.00E+00
C1	5.87E-02	5.87E-02
C2	4.54E-05	4.54E-05
C3	-7.80E-07	2.89E-08
C4	-2.58E-08	-3.31E-10
C5	-5.95E-10	6.50E-13
C6	-9.32E-12	-1.92E-16
C7	-1.03E-13	-1.25E-18
C8	-8.04E-16	2.15E-21

Vout = 4.40 – (2.10)
Vout = 2.3mv/1 thermocouple

Total output voltage = (No. of thermocouples in a thermopile X 2.23)mv

The thermopile panel in this experiment contains 10000 thermocouples though more can be accommodated,

Total output = 2.3 x 10000 = 23000mv
The practical value of output voltage =22300 mv

The theoretically calculated values have been verified by the virtual calculator whose snapshots are presented in Fig 3[5] and Fig 4[5].

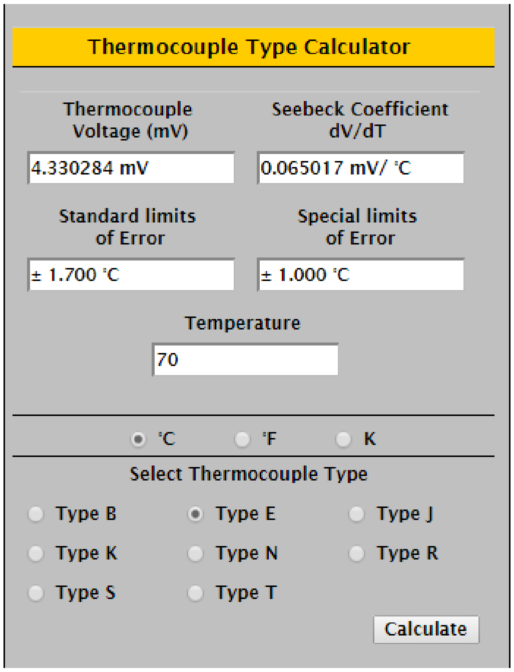

FIG 3: OUTPUT AT 70°C

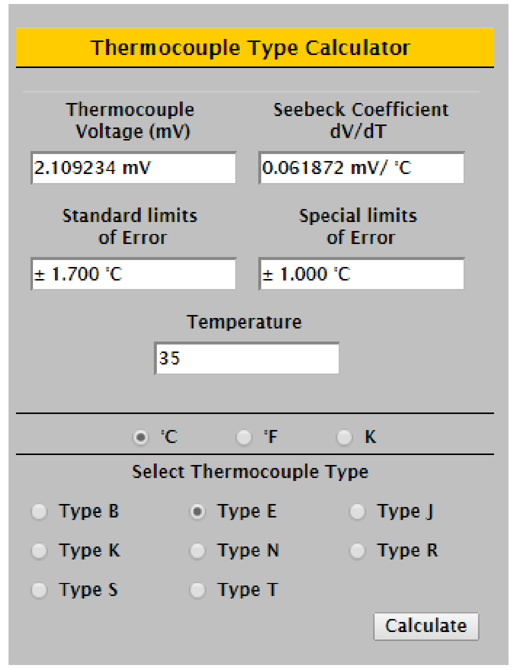

FIG 4: OUTPUT AT 35°C

The error percentage in the experiment $= \frac{23000 - 22300}{23000} X100 = 3.04\%$

IV FUTURE SCOPE

This technique can also be used in other electric appliances either domestic or industrial like the heat generated by the overheating laptops etc. where there is a considerable amount of temperature gradient generated. Employment of this method of harnessing energy help in controlling pollution and saves the energy that is being converted into waste heat hence leading to a greener tomorrow and a greener planet.

V ACKNOWLEDGMENT

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