DINAMIC BEHAVIOUR OF REFRIGERATOR THERMOELECTRIC ACHIEVEMENT IN GENERAL METHOD

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Abstract : Thermoelectric Refrigeration (TER) is a semiconductor component capable of converting electrical energy into thermal energy in the form of heat and cold. in contrast to the thermoelectric generator (TEG) that generates electrical energy from heat energy. From the scientific side TEG essentially similar to TER. What distinguishes is the heat content and electrical content. TER has more dominant heat content than TEG. The luck level (Figure of Merite = Z) is expressed as TH-TC = (Z / 2). TC2, ZT = between 1.88 to 2.00 depending on the average temperature. The regression equation method can be used to determine Coefficient of Performance (COP).maximum.

$$COP_{\max} = Q_{cold\ Junction} / P_{input\ TE}$$

Key Word: Thermoelectric refrigeration, Figure of Merit, Coefficient of Performance (COP).

INTRODUCTION

Thermoelectric (TE) is a semiconductor device capable of converting electrical energy into heat energy in the form of heat and cold known as Thermoelectric Refrigeration (TER) or otherwise converting heat energy in the form of heat and cold into electrical energy known as Thermoelectric Generator (TEG).[1,2,3]

Each thermoelectric has TER and TEG properties at once, which distinguishes the percentage of TER and TEG content. Thermoelectric refrigeration has greater refrigeration properties than Generator and sebeck. Thermoelectric Generator has greater refrigeration Generator properties. [2,5] .In thermoelectric refrigeration the main function is as refrigeration, the function as a generator is relatively small so it can be ignored. At Thermoelectric Generator main function is as Electric Generator, function as Refrigerators and so small can be ignored. [1,2]

Parameters Figure of merit (Z) is a combination of several parameters related to electrical properties of materials such as; Seebeck coefficient material, material type resistance, as well as material conductivity properties. And expressed in the equation, with α coefficient Seebeck (thermoelectric power) [volt per K, σ = 1 / ρ electrical conductivity properties of material ρ electrical resistivity of material [ohm-cm], r = electrical contact resistance. thermal conductivity [watts per (cm)(K) [4,5,6] The value of the Figure of merit must be in an optimal state considering the condition of each pair of parameters α and σ.

For example in the material coefficient Seebeck α tends to be high but low electrical conductivity. Instead occurs in the metal material (conductor) coefficient Seebeck low electrical conductivity high. Optimum conditions occur in semi conductors

Thermoelectric Refrigerator performance indicator is expressed by Coefficient of Performance (COP) equation. As the model of TE Refrigerator discussion selected the type of observation Thermoelectric typical type CP 1.4-127-06 L Melcor product.[6,7}

Simply Thermoelectric Refrigerator is built from a number of semiconductor thermocouples coupled series like N-P-N-P. In the circuit there are 2 kinds of junction, ie hot junction and cold junction, All hot junction placed in one surface. Likewise with cold junction. The features of both surfaces can be said to be Reversible, ie each surface can be as a hot surface and / or cold surface.

TE thermocouple circuit with TE physical form can be described as below;

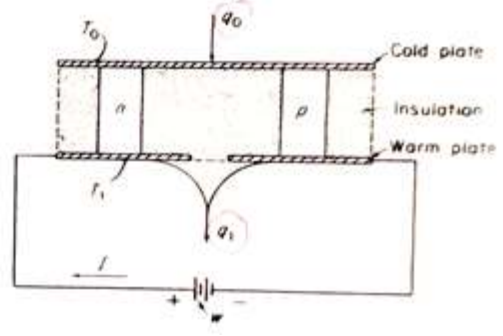

Figure 1. Schematic thermoelectric Cooling System [1]

In practice, TE Refrigerator can be analogous to conventional cooling machine. The cold side of the P-N junction will behave as an Evaporator, while the hot N-P side will act as a Condensor, and DC batteries behave as Condenser. So COP can be a comparison between heat power capable of damping with cold junction with the electrical power required to activate Thermoelectric According to Cadoff and Miller [3.7} The maximum COP is the temperature difference of hot junction and cold junction and Figure of Merite ZT. As Figure 3 follows;

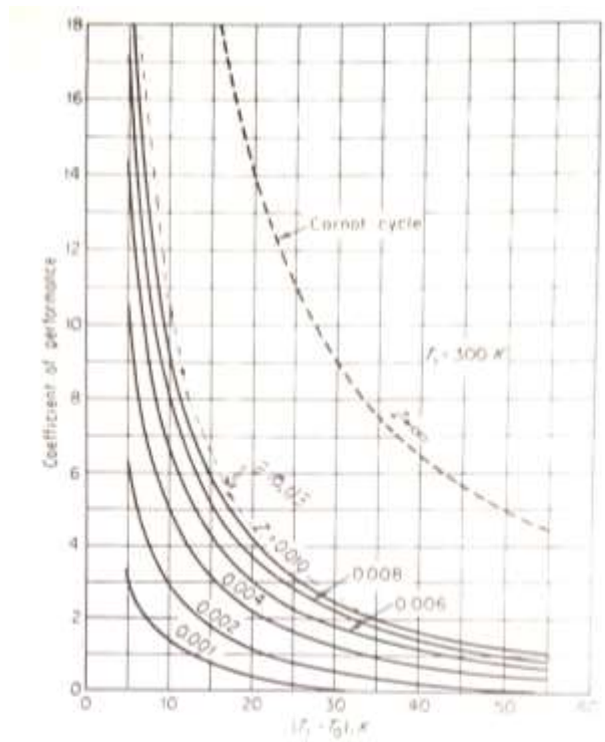

Figure 3. COP versus . ZT [1]

The higher the FOM (Figure Of Merite) Zo constant over a certain temperature range, the higher the TE cooling achievement, which will approximate the ideal COP carnot or

COP. Or in practice the higher the Z constant the ability of TE to cool the material higher. The COP relationship with hot and cold side temperatures is shown in FIG.

Thermoelectric Refrigerator Characteristics.
TER device characteristics are qualitatively expressed by the following equation,

Note ; Voltage V, Current I, Temperature T, Coefficient Of Performance (COP),

$$V = 2N[((I.P)/G)+\alpha.\Delta T]$$

$$I_{\max} = [k.G./A].((1+(2.Z.T_H))^{0.5}-1) \quad [4,6]$$

$$I_{opt} = (k.\Delta T.G(1+(1+Z.T_{AVE})^{0.5}))/(a.T_{AVE})$$

$$\Delta T_{\max} = T_H - (((1+2.Z.T_H)^{0.5}-1))/Z$$

$$COP_{opt} = (\frac{T_{AVG}}{\Delta T}].[((G+ZT_{opt})^{0.5}-1)/(1+ZT_{\max})^{0.5}+1)]^{-0.5} \quad [1,8]$$

$$Q_k = 2.N.[\alpha.I.T_C - ((I^2.p)/(2.G)-k.DTG]$$

....1

$$\alpha = 2.0x10^{-4}$$

$$p = 1.0x10^{-3}$$

$\alpha = 2.0x10^{-4}$ $[volt/Kelvin]\cdots$Seebec constant

$p = 1.0x10^{-9}$ $[ohm.\ cm]$

$k = 1.5x10^{-2}$ $[watt/cm.Kelvin]$ $conductor\ constant$

$Z = 2.67x10^{-9}$ $[Kelvin]$

$T_H = temperature\ sisi\ panas\ [Kelvin]$

$T_C = temperature\ sisi\ dingin\ [Kelvin]$

$\Delta T = T_H - T_C \quad [Kelvin]$

$T_{AVE} = (T_H + T_C)/2 \quad [Kelvin]$

$G = Geometric\ Factor$

$G =$

$N = Thermocouple\ number\ in\ the\ TER$

$I = Current\ [Ampere]$

.......................1.A

$$COP = \frac{Q_C}{I.V} \text{..1.B}$$

And Figure of Merit (FOM) such as ;

$$Z = \frac{\alpha^2}{(\rho.k)} \quad [Kelvin]$$

$$S = Seebeck\ voltage\ on\ device = 2.\alpha.N\ [volt / Kelvin]$$

$$R = Electrical\ Resistance\ on\ device = 2.p.N / G\ [ohm]$$

$$k = thermal\ conductivity\ on\ device = 2.k.N.G\ [Watt / Kelvin]$$

[1,8]

Variables and TER parameters related to thermodynamic, electrical, semiconductor forming characteristics, thermocouple characteristics and device configuration. Figure 4, as follows

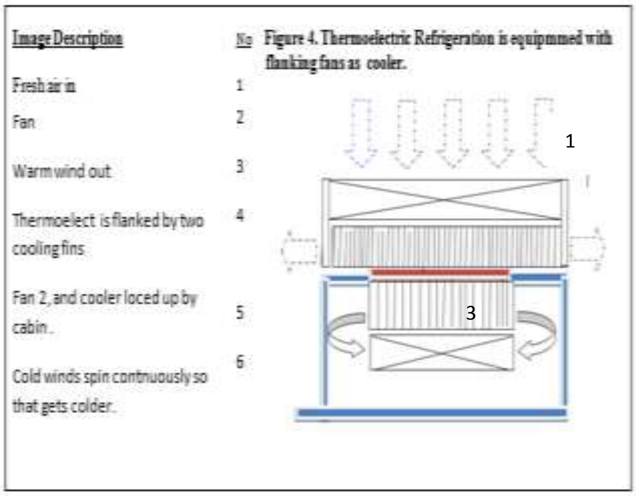

Figure 4. Thermoelectric Refrigeration is equipmmed with flanking fans as cooler.

From equation 1 can be derived cold surface temperature is a function Z which can be expressed as;

$$Z.T_c = \sqrt{(1+2.Z.T_H} - 1, or\ Z.T_C = [\frac{\alpha}{k.G}].I_{max} \quad ....2.$$

[1,8]

Furthermore, the heat temperature equation is obtained as a function of the cold surface temperature expressed in the equation

$$T_H = \frac{Z}{2} T_C^2 + T_C \quad ....3$$

So we get again the difference of heat temperature with cold surface in the form

$$\Delta T = \frac{Z}{2} . T_C^2 \quad ....4$$

In connection with the use of DC electrical energy used for TER activation, the required electrical power is

$$P_{input\ TE} = Q_{heat\ pump} + Q_{Joule}(I^2.r)$$

$$I.E_{power\ sup\ ly} = I.V_{TE} + I..V$$

[4,8]..................................

.............................5

Decrease in COP values caused by joule heat can be expressed as;

$$COP_{max} = \frac{Q_{cold\ Junction}}{P_{input\ TE}}$$

[1,3,8]...6

To calculate the parameter of Figure of Merit Z, required good quality observation data. The existence of storage of observation data will result in deviation of Z parameter and COP.Thermoelectric Type Cp parameters 1.4-127-06 L. (TE.CP1.4) Melcor Production [6,7]. In this study, the type of CP 1.4 was used, Melcor production has the ability to produce hot junction junction with cold junction 67 0C, with maximum current consumption of 6 Amper at 15 Volt DC power supply voltage, Number of thermocouple 127 fruit, with gometry factor 0.12 and heat flow rate 51 , 4 watts.

OBSERVATION RESULT AND PREDICTION OF DATA PROCESSING.

Thermoelectric Tertiary Data (Peltier) Heat Pump type CP 1.4-127-06 L,
Voltage Catu: 12 Volt DC, operating time: August 15, 2002 Name of observer: Yudanto Duration of Observation: 5 Hours, Temperature Environment: 25 OC, Electric Current Activation: 2.9 Ampere DC Power: 34.8 Watt. Cooling system: Fins and vent exhaust.

Table 1.Surface Temperature Measurement Data of hots and cold (TER) in Mini Refrigerator.

No	T_H (K)	T_C [K]	ΔT
1	298	297	1
2	314	284	30
3	314	283	31
4	314	282	32
5	31	282	32
6	315	282	33
7	316	281	35
8	315	281	34
9	315	81	34
10	315	281	34
11	315	281	34
12	315	280	35

13	315	280	35
14	315	280	35
15	3 5	280	Us
16	315	280	35
7	315	280	35
18	31	279	36
19	315	279	36
20	315	279	36

Tabel 2. Calculation of COP maximum and ZT relation ship with equation 1.

No	Th [K]	Tc[K]	ΔT[K]	ZT	COP_{teori}
1	288	297	1	2	79.519
2	314	284	30	1.91	2.167
3	314	283	31	1.9	2.08
4	314	282	32	1.9	.001
5	314	282	32	1.9	2.001
6	315	282	32	1.9	1.925
7	316	281	33	1.9	1.853
8	315	281	35	1.89	1.853
9	315	281	34	1.89	1.853
10	315	281	34	1.89	.853
11	315	281	34	1.89	1.853
12	315	281	34	1.89	1.853
13	315	280	34	1.89	1.786
14	315	280	35	1.89	1.786
15	315	280	35	1.89	1.723
16	315	280	35	1.89	1.786
17	315	280	35	1.89	1.786
18	315	279	36	1.88	1.723
19	315	279	36	1.86	1.723
20	315	279	36	1.86	1.723

By using the equation T and L obtained parameters Q = 0.003373, Z = 0.006746, ZT = between 1.88 to 2.00 depending on average temperature (see table 2).The use of quadratic regression analysis method can be obtained as follows;

1. TE elementary parameters Figure of Merit Z = 0.0067

2. Average Temperature (TAvrage) = 297.8 K

3. COP is optimal in the range 1.582 - 79.3, depending on the temperature of the junction junction Hot and cold junction surfaces. Hot junction temperature difference with cold junction 315K-279 k

4. Working voltage of PN junction can be predicted after ZT parameter and electric current I optimally predicted first as equation i. Supplied working voltage ranges from 6.29 volts - 8.071 volts DC

Thermal surface temperature measurements of Th and cold surfaces of Tc and COP calculations are optimum, heat flow rate absorbed by cold junction -Qc [Watt], refrigeration cooling load of 3.08 Watt Power from power supply adapter. In Table 3, a COP refrigeration calculation is shown after the TER is activated for 15 minutes (measuring the second temperature). COP refrigeration is calculated by comparing the heat flow rate with the AC power DI activatio

.During the activation of the DC power source there is no significant change in both voltage and electric current, so that the electric power is considered constant at 12 volts, 2.9 Ampere (34.8 Watt).

$COP_{refrigeration}=(Q_C/34.8)$ Watt

T denotes activation time as well as time interval measuring temperature ΔT and TC

Table 3. Results of COP TER with Mini Fridge 3.08 Watt

No	Durasi (Menit)	ΔT	T_C	Q_C	$COP_{refrigeration}$
1	15	30	285	19.46	0.56
2	30	31	284	18.85	0.54
3	45	32	283	18.26	0.52
4	60	32	283	18.26	0.52
5	75	33	283	17.81	0.51
6	90	35	282	16.77	0.48
7	105	34	282	17.22	0.49
8	120	34	282	17.22	0.49
9	135	34	282	17.22	0.49
10	150	34	282	17.22	0.49
11	165	33	282	17.22	0.51
12	180	35	281	17.66	0.48
13	195	35	281	16.62	0.48
14	210	36	281	16.62	0.48
15	225	35	281	16.62	0.48
16	240	35	281	16.62	0.46
17	255	36	280	16.62	0.48
18	270	36	280	16.62	0.46
19	285	36	280	16.62	0.46
20	300	36	280	16.62	0.46

Analysis

Quadratic regression analysis, among others, gives estimated parameters of Thermoelectric.. Thermoelectric, typecally, (Z) = 0.0067 [K * 1] and ZT of 1.88 - 2.00 for hot junction 315 K, with average temperature difference 30 K. Based on the COP versus ΔT graph (figure 3) the COP of TER is 1.7 whereas based on the regression estimate based on ΔT = 30, COP At a temperature of 296 K The typical TE material has thermocouple elementary parameters, among others;

α = 2.0x10-4 [volt / K], ρ = 1.0x10-3 [ohm cm] k = 1.5x10-2 [watts / (cm K)
Z = 2.67x10-3 [K-1], Thus obtained ZT = 0.79

As a TER guide constructed from a semiconductor having a thermal conductivity parameter K = 4.0x10-3 [watt / cm.K] at a temperature of 300 K has a parameter ZT = 1.9, [3],While the average temperature rise results in an increase in the ZT parameters that result in an increase. If the heat flow occurs due to the small temperature difference with large Z value then COP is included in COP heat pump category. but if the flow of heat occurs at large temperature differences,

while the value of the small Z parameter then COP is COP refrigeration. In that condition the flow of heat moves from the low temperature region to the higher tempered area, so it takes the outside energy to move it. Thus TER aside as a heat pump but also as Refrigerator device [3.8]

Table 2 also shows optimal COP. TER which ranges from 1.723 to 79.8 with temperature difference ΔT 30 K to 1K., Means that at the beginning of TER activation as Heat Pump Device and then as Refrigerator Device, but heat pump properties occur in a relatively short time,

In figure 3, the maximum COP graph occurs at a value of Z = 0.0067 with maximum COP ranging from 2.4 to 9 with a range of ΔT 30 K, so the optimum COP is proportional below 2.

At the average temperature the value Z = 2.0069 ΔT = 1, ZTAVE = 2.0069, COP maximum = 3.4, whereas at ΔT = 30 K COP maximum 1.7, it matters that the data and regression analysis show strong consistency.

CONCLUSIONS .

Quadratic regression analysis is effective in helping to obtain a single thermoelectric Figure of Merite (Z) parameter in sufficient quantities of data. The values of Z and ZT parameters can be used to determine COP, either calculated by equation method or by graphical reading method as proposed by Cadoff and Miller.

Thermoelectric (Peltier) heat Pump, CP type 1.4-127-06 L, is an example of a solid substance having relatively high parameters of Figure of Merit and has properties as a Refrigerator Device and as a Heat Pump, which can be expressed quantitatively from Z, ZT and COP.

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REFERENCES

1. James L. Threlkeld ., Thermal Enviremental Engineering., Prentice-Hall, Inc, New Jersey
2. Charles Belove, Handbook of Modern Electronics and Electrical Engineering., John Wiley & Sons, New York, 19862.
3 D.M. Rowe MSc.pHd, C.M.Bhandari MSc.PhD ,. Modern Thermoelectric., Holt Rinechard And Winston, London and Newyork 1990.
4. Donald G.Fink, H.Wayne.B., Standard Handbook For Electrical Engineer., Mc.Graw Hill book Company, Newyork.
5. H.Aspden., Solid State Thermoelectric Refrigeration, .w.w.w Energy Science Org Essay no -17 htm.
6. IB Cadoff and Miller., Thermoelectric Materials And Device., Reinhold Publishing Corporation, New York, 1983
7. Melcor., Solid State Cooling With Thermoelectric., New Jersey.
8 Calculation . www. Melcor.com., Performance Formula,.

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