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Performance of Thermoelectric (TEG) for DC Electricity Power Source using Application of Stoves Rocket Heats with Resistance Variations

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Abstract— *Rocket Stove is a wood-fired stove that functions to improve the combustion process efficiently and produce high heat. Thermoelectric generators are electrical generator devices that convert heat energy or temperature differences into electrical energy using a phenomenon called the Seebeck effect. The Seebeck effect is a phenomenon that occurs when connecting copper and iron in a circuit. Between the two metals then the compass needle is placed. When the metal side is heated, the compass needle turns to move. This happens because the electricity that occurs in the metal creates a magnetic field. This magnetic field moves the compass needle.*

This study aims to determine the power produced by thermoelectric generators with resistor loads. The thermoelectric generator used in this study was TEG SP1848 with 10 thermoelectric quantities. And the power test is performed with the variable resistor 1 kΩ - 10 kΩ. Parameters measured are electric voltage, electric current, and temperature.

The results obtained in this study are the SP1848 type thermoelectric generator produces the largest electricity voltage at temperature difference is 34.1ºC with an electric voltage of 12.56 volts and produces the largest electric current at temperature difference is 30ºC with an electric current of 0.087 A. the temperature difference of 30ºC with electric power of 1.09794 watts. It can be concluded that the thermoelectric characteristics of the SP1848 type generator when the temperature difference between the heat side of the TEG and the cold side of the TEG increases the electrical voltage, and the electric current will be even greater.

Keywords— *Rocket Stove, Thermoelectric Generator, Seebeck effect, Power, TEG.*

I. INTRODUCTION

Rocket Stove is a wood-fired stove that functions to improve the combustion process efficiently and produce high heat. Several studies have been carried out to utilize the heat produced by combustion in the rocket stove, namely the thermoelectric generator as a power plant. Thermoelectric generators (TEG) are electrical generator devices that convert heat energy (temperature difference) into electrical energy, using a phenomenon called the Seebeck effect [1].

The Seebeck effect is a phenomenon that occurs when connecting copper and iron in a circuit. Between the two metals then the compass needle is placed. When the metal side is heated, the compass needle turns to move. This happens because the electricity that occurs in the metal creates a magnetic field. This magnetic field moves the compass needle. This phenomenon became known as the Seebeck effect.

Thermoelectric technology works by converting heat energy into electricity directly (thermoelectric generator), or vice versa, from electricity to produce cold (thermoelectric coolers). To produce electricity, the thermoelectric material is sufficiently placed in such a way that connects heat and cold sources. From that series, many electricity will be produced according to the type of material used.

In a previous study on the Study of Comparison of thermoelectric characteristics of TEC (Thermoelectric Cooler) and TEG by considering the temperature differences and the resistance variables. The heat used in the study is the heat of the iron and cooler heatsink fan processor the results obtained in the study for the type of TEG thermoelectric is the highest value of electrical voltage = 1.48 V and the highest current value = 0.00141 A so that the power value is 0.00209 Watt [2].

Thermoelectric generators are renewable power plants that utilize temperature differences between the two sides of the thermoelectric element to be used as electrical energy. The greater the temperature difference between the two sides, the greater the energy produced by the element [3].

This study aims to determine the value of voltage and current generated by temperature differences when one side of the TEG type thermoelectric is heated using heat from a rocket stove, in addition to knowing the value of the electrical power produced.

II. RESEARCH METHODS

A. Rocket Stove

Rocket Stove is a wood-fired stove that serves to improve the combustion process efficiently and produce high heat [4].

Figure 1. Rocket Stove with a ratio of upright and horizontal sides is 3: 1

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Rocket stove size in the study will use a ratio of 3: 1 using this comparison, the operation of heat energy in the rocket stove is getting higher [5].

B. Seebeck coefficient

The Seebeck effect is a phenomenon that occurs when connecting copper and iron in a circuit. Between the two metals then the compass needle is placed. When the metal side is heated, there will be a temperature difference between the two metals, so that the compass needle will move. This happens because the electricity that occurs in the metal creates a magnetic field. This magnetic field moves the compass needle. This phenomenon became known as the Seebeck effect [6].

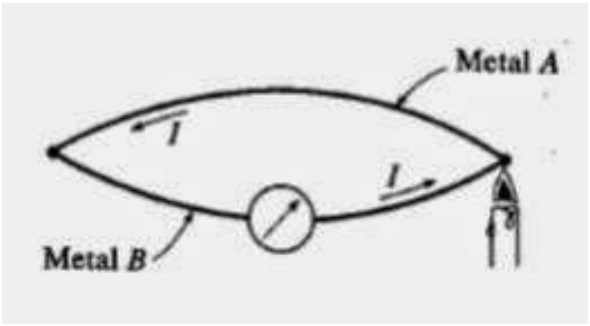

Figure 2. Seebeck effect

The seebeck coefficient depends on the temperature difference and the difference in voltage produced depends on the seebeck coefficient value and temperature difference [7].

C. *Thermoelectric Generator*

Thermoelectric is the technology that works by converting thermal energy into electricity directly (thermoelectric generator), or vice versa, from electricity to produce cold (thermoelectric coolers). To produce electricity, the thermoelectric material is sufficiently placed in such a way that connects heat and cold sources. From that series, many electricity will be produced according to the type of material used.

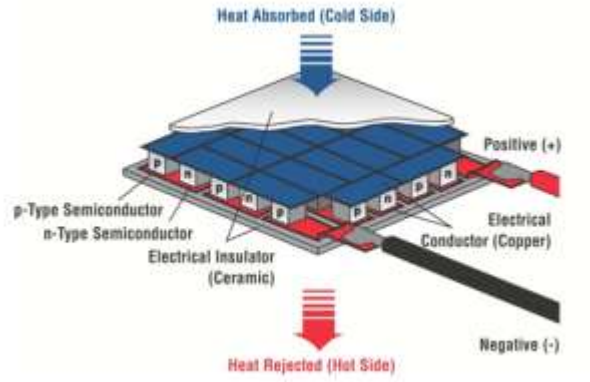

Figure 3. Structure of Thermoelectric Generator Elements

The thermoelectric generator consists of an arrangement of elements of type n (material with excess electrons) and type p (material with a lack of electrons). The heat enters on one side and is discharged from the other side, producing a voltage that passes through the generator thermoelectric connection.

C. Electrical power

Electric power is defined as the rate of conduct of energy in an electric circuit. The SI (International Standard) Unit of electric power is a Watt which states the amount of electric power flowing in time (joule/second) unity [8,9].

$$P = V. I \quad (1)$$

noted :
P = electric power (Watts)
V = voltage (Volt)
I = current (Ampere)
By adding equation 1 to equation 2, it is obtained:

$$P = I^2. R \quad (2)$$

noted :
R: Obstacle (Ohm)

In equation 2, the electric power increases if, the electricity voltage increases, electric current increases and, resistance or resistance increases.

D. Research Flow Chart

In this study, the design of the flow chart is the stage of the research carried out until the stage of data analysis and conclusions. The research scheme (flow chart) can be seen in the following figure:

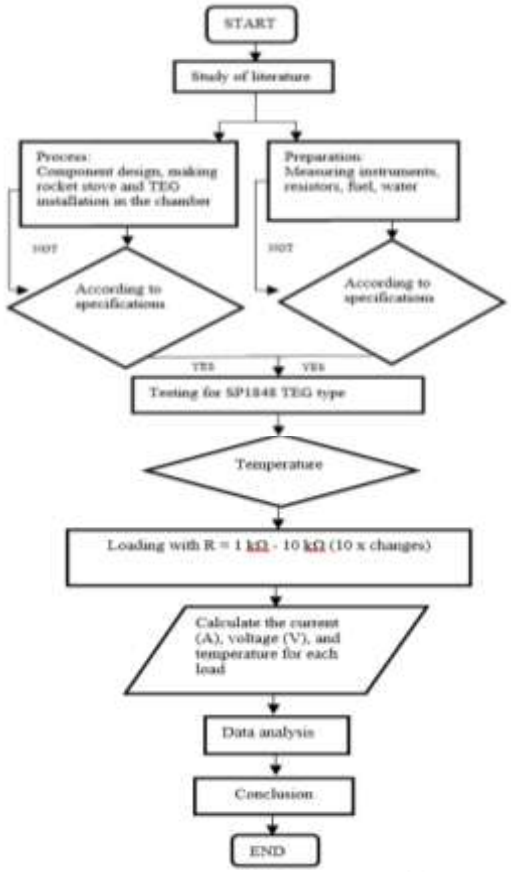

Figure 4. Flowchart of research on the application of SP1848 TEG

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III. Simulation And Data Analysis

After preparations, the next step is to test the TEG SP1848 type thermoelectric from the heat rocket stove. In this study, two data retrieval was carried out, namely temperature data retrieval and power data retrieval generated by TEG by loading potentiometer resistors (1 kΩ - 10 kΩ). Taking temperature data using a digital thermometer with 4 thermocouples, following the thermocouple installation scheme:

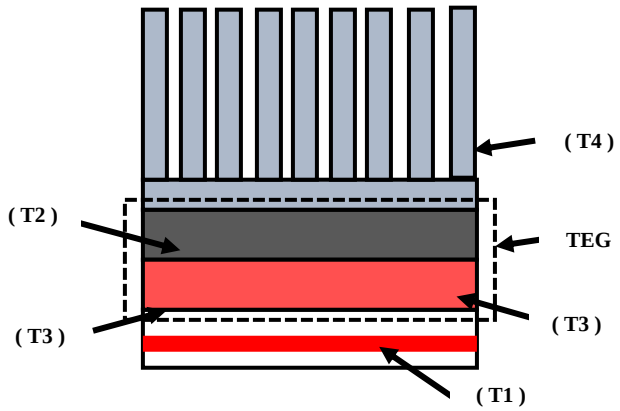

Figure 5. A series of thermocouple installations for temperature measurement

T1 = Measurement of water temperature in the chamber using a thermocouple.
T2 = Temperature measurement with a thermocouple on the cold side of the thermoelectric generator.
T3 = Temperature measurement with a thermocouple on the thermoelectric generator and temperature measurement with a thermocouple on the side of the iron plate in the chamber.
T4 =Temperature measurement with a thermocouple next to the heat sink.

Install all thermocouples in accordance with the planned circuit. Here is the thermocouple installation scheme:

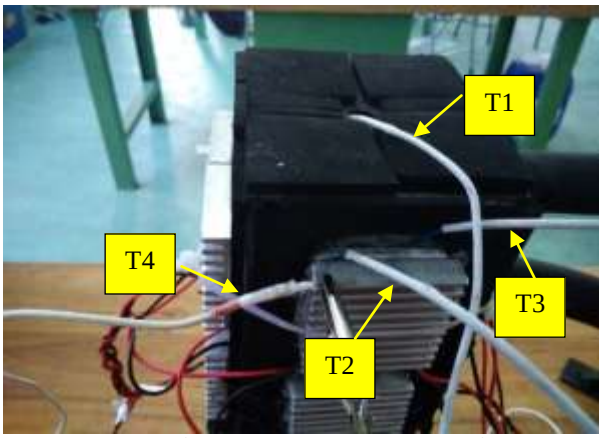

Figure 6. Schematic of a thermocouple mounting circuit for temperature measurement

After installing the thermocouple, then prepare the power data collection scheme with the resistor potentiometer with loading (1kΩ - 10kΩ).

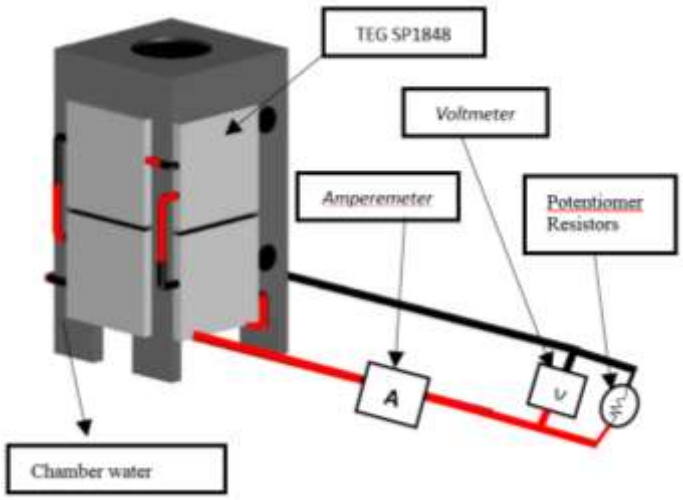

Figure 7. Schematic of a power data collection circuit with resistor potentiometer resistance in TEG

Performing tests and measurements, measurements were made after the temperature at T1, namely water in the chamber worth 90ºC, measuring with resistance from 1 k 1 - 10

Figure 8. TEG SP1848 type thermoelectric testing process

IV. Results And Analysis

Thermoelectric generators are renewable power plants that utilize temperature differences between the two sides of the thermoelectric element to be used as electrical energy. The greater the temperature difference between the two sides (hot vs cold). The energy (watt) produced by the element.

Result data of thermoelectric generator TEG SP1848 type, then the data is calculated according to the procedure in the research methodology. The calculated data is the power data generated from the thermoelectric generator. The following are the test results of 10 series of SP1848 type thermoelectric generators that have been arranged in series:

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Table 4.1 Results of testing the type SP1848 thermoelectric generator

Date :			Location : Lab. Automotive Electricity						
Type : SP1848			Element : TEG						
No.	Resistor (Ω)	Voltage (V)	Electric Current (A)	Power (W)	Temperature (°c)				
					(T1)	(T2)	(T3)	(T4)	ΔT
1	1 kΩ	6,28	0,074	0,46472	90,6	67,6	80,1	65,4	12,5
2	2 kΩ	6,78	0,080	0,5424	95,6	72,1	80,6	68	8,5
3	3 kΩ	6,59	0,082	0,54038	95,3	71,3	80,3	69,6	9
4	4 kΩ	10,94	0,082	0,89708	95,6	50,9	87,5	47,6	36,6
5	5 kΩ	11,01	0,083	0,91383	96,2	55,3	88	50,4	32,7
6	6 kΩ	11,16	0.084	0,93744	96,6	53,7	87,7	44,3	34
7	7 kΩ	12,53	0,085	1,06505	96,9	43	64,7	46,8	21,7
8	8 kΩ	12,56	0,086	1,08016	96,8	53,6	87,7	49,2	34,1
9	9 kΩ	12,62	0,087	1,09794	96,8	50,6	80,6	46,2	30
10	10 kΩ	11,87	0,086	1,02082	96,6	50,6	79,9	49	29,3

Where ΔT in the table above is the difference in temperature between the T3 heat side TEG and T2 the cold side TEG. From the above test the biggest stress is 12,62 Volt and the largest current is 0,087 Ampere. From equation 2.2, the power will be obtained at 1,09794 Watts. Then the results of the data and the results of the thermoelectric calculation of the SP1848 type generator are made in graphical form. In the graph can be seen the characteristics of performance. The test data or the performance characteristics of the SP1848 type thermoelectric generator are as follows:

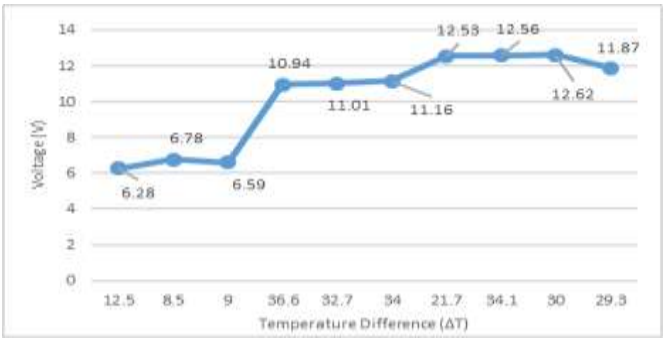

Figure 9. Electric voltage graph of temperature differences

In the graph above, it can be seen that the electricity voltage is relatively rising, the greater the temperature difference on the heat side of the TEG and the cold side of the TEG then the voltage will rise and the largest voltage will be generated when the temperature difference is 34,1ºC 12,56 Volt and the smallest voltage is obtained at when the temperature difference is 12,5ºC which is 6,28 Volt.

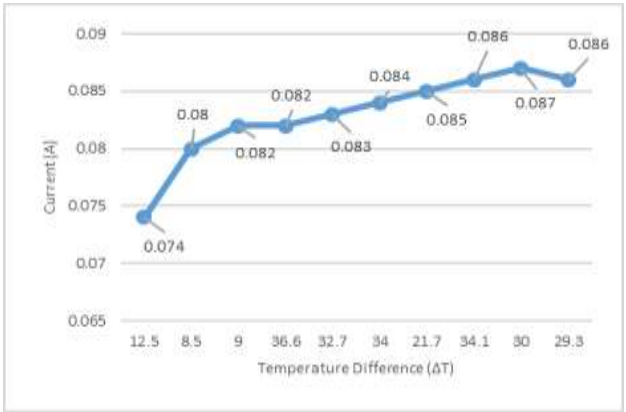

Figure 10. Electric current graph of temperature differences

In the graph above, it can be seen that the greater the temperature difference on the TEG heat side and the TEG cold side, the higher electric current generated from the graph results in the largest current when the temperature difference is 30 ºC which is 0,087 Ampere and the smallest current is obtained at a temperature difference of 12,5 ºC which is 0,074 Ampere.

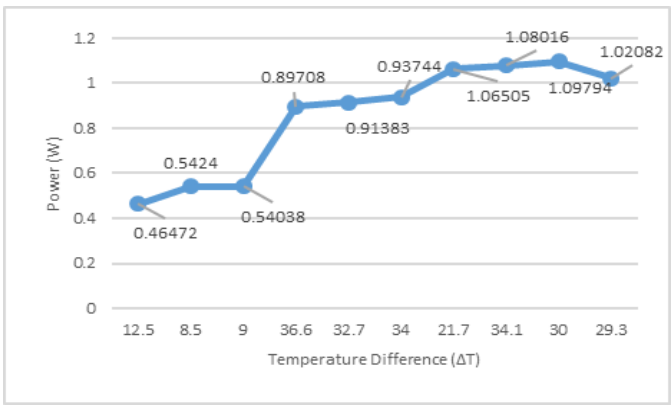

Figure 11. Electric power graph of temperature differences

In the graph above, it can be seen that the electrical power produced is relatively rising, the greater the temperature difference on the heat side of TEG and the cold side of TEG, the higher the power produced and the greatest power produced when the temperature difference is 30 ºC which is 1,09794 Watt and obtained power the smallest when the temperature difference is 12,5 ºC which is 0,46472 Watt. So it can be concluded that the greater the temperature difference on both sides of the thermoelectric generator, the greater the current, voltage and electrical power produced.

V. CONCLUSION

The SP1848 type of Thermoelectric Generator produced an electric voltage (V) characteristic that was relatively rising as the temperature difference on the TEG heat side and the TEG cold side increased and the largest voltage was generated when the temperature difference was 34,1ºC with 12,56 volt electric voltage. The biggest electric current (A) is produced when the temperature difference is 30 ºC with an electric current of 0,087 Ampere. So that the biggest electric power is produced when the temperature difference is 30ºC with electric power of 1,09794 Watts. The results of testing the

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thermoelectric characteristics of the SP1848 type generator show that when the temperature difference between the hot side of TEG and the cold side of the TEG increases, the greater the electric voltage, electric current, and power also follow the temperature difference (ΔT).

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REFERENCES

[1] Sumarjo, Jojo., Aa Santosa., dan Muhammad Imron Permana. 2017. *Pemanfaatan Sumber Panas Pada Kompor Menggunakan 10 Termoelektrik Generator Dirangkai Secara Seri Untuk Aplikasi Lampu Penerangan*. Karawang: Jurnal Mesin Teknologi (SINTEK Jurnal) Volume 11 No 2.

[2] Salim, Alfi Tranggono Agus., Yuli Prasetyo., dan Yoga Akhdiat Fakhrudin. 2018. *Study of Effect Comparison Thermoelectric Characteristics of TEC and TEG by Considering the Difference in Temperatureand Variable Resistant*. Madiun : International Research Journal of Advanced Engineering and Science.

[3] Anwar, Mohammad Choirul dkk. 2016. *Analisis Penerapan Auto Buck/Boost Pada Generator Termoelektrik Sebagai Pembangkit Listrik Alternatif*. Jember: Seminar Nasional Pendidikan 2016.

[4] Schreiner, H .Nicholas. 2011. *Performance Characteristics and Design Recommedations for Biomass-Burning Stoves Using Earthen Construction Materials*. Michigan Technological University.

[5] Tryner, Jessica. 2016. *Combustion Phenomena In Biomass Gasifier Cookstoves*. Colorado: Department of Mechanical Engineering Colorado State University Fort Collins.

[6] Putra, Nandy dkk. 2009. *Potensi Pembangkit Daya Termoelektrik untuk Kendaraan Hybrid*. Depok : Makara, Teknologi, Vol. 13, No 2.

[7] Khalid, Muammar., Mahdi Syukri., dan Mansur Gapy. 2016. *Pemanfaatan Energi Panas Sebagai Pembangkit Listrik Alternatif Berskala Kecil dengan Menggunakan Termoelektrik*. Banda Aceh: Jurnal Online Teknik Elektro.

[8] Salim, Alfi Tranggono Agus dan Bactera Indarto. 2018. *Study Eksperimental Karakteristik Elemen Termoelektrik Peltier Tipe TEC*. Madiun: Journal of Electrical Electronic Control and Automotive Enggineering (JEECAE).

[9] Salim, Alfi Tranggono Agus Salim, Yuli Prasetyo, Bachtera Indarto, Muhammad Aji Pangestu, Muhammad Ruston Habibi, Muhammad Nur Cahyanto, Hilman Naufal Rafi. 2019. *Karakteristik Termoelektrik TEC Bervariasi Tipe Sebagai Pembangkit Listrik DC*. Madiun : Jurnal Energi dan Teknologi Manufaktur (JETM).