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DESIGN, FABRICATION AND TESTING OF A CHIMNEY TO CONVERT THERMAL ENERGY TO ELECTRICAL ENERGY USING TEG'S

Mr. Manjesh B C,

Asst. Professor & Alumni Officer, New Horizon College of Engineering, Bangalore, India,
Email: manjushekar2@gmail.com

ABSTRACT: As a result of depleting reserves of fossil fuels, conventional energy sources are becoming less available. In spite of this, energy is still being wasted, especially in the form of heat. The energy efficiency of the process may be increased through waste heat utilization, thereby resulting in primary energy savings. In any thermal industry there is generation of flue gases which holds significant amount of heat which could be recovered.

In this project our approach is to capture the heat from the flue gases which is being wasted otherwise. Our methodology includes the use of thermoelectric generator (TEG) modules to convert the waste heat directly into electrical power. These TEG modules are clamped onto the required region and a cooling system is provided on one side of the TEG module to produce electricity, which is then passed through a booster / joule thief circuit.

The thermoelectric generator provides electric power which may be used to operate the motor which drives the blower and also to charge a battery which is used when the furnace is started up. In the event that the power is interrupted, as occurs during storms or fault conditions in the public utility power distribution system, the furnace continues to run uninterruptedly. This high voltage output can thus be utilized for various purpose, thereby reducing the load on auxiliaries and increasing the overall efficiency

Key Words: Thermoelectric generator, Furnace, Thermal Paste, Cooling Duct, Blower

I INTRODUCTION

A Thermoelectric Generator is a solid state electrical device that converts Thermal energy produced from the heat source directly into the electrical energy based on ''See beck Effect".

A thermoelectric power generation system takes in heat from a source such as hot exhaust, and outputs electricity using thermoelectric modules.

A thermoelectric module needs a large temperature gradient to generate electricity. In a power generation system, the heat for the hot side of this temperature gradient must be supplied efficiently from a heat source such as an exhaust flue. The cold side must be cooled by air, water, or another suitable medium.

II EXPERIMENTAL SETUP AND WORKING PRINCIPLE

Bottom part of furnace

The whole furnace is made up of mild steel due to its advantageous characteristics. There is an opening at lower end for ash removal and at the top end grills are provided tor feeding coal / fuel to fire the furnace. An outlet is provided .at one end for connecting blower.

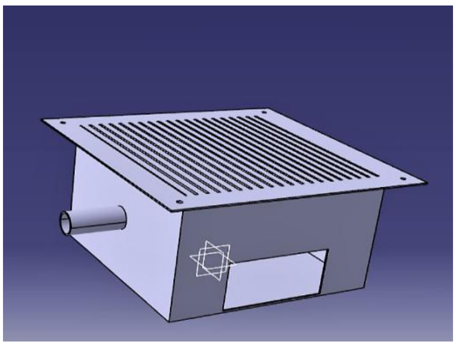


Fig: 1.1 Bottom part of furnace

Top portion of the furnace

The top portion of the setup consist of two parts the body (furnace) and the chimney. It is also provided with an opening to feed coal onto the grills. The flue gases escape through the chimney. Firing coal or any fuel leads to the temperature raise of furnace, thus the chimney is also heated by escaping flue gases. The temperature to which the furnace gets heated depends upon the quantity and quality of coal or fuel used. Thus, a good quality fuel should be used to heat the furnace which helps in increasing the efficiency of running the process.

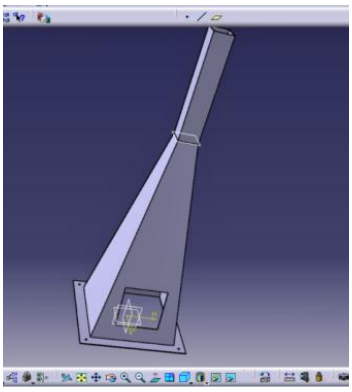


Figure 1.2: Top Part of Furnace

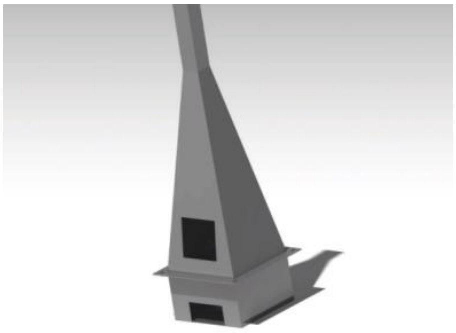


Figure 1.3: 3D Assembly of Furnace

Assembly of Furnace

The top and bottom portion are brought together and clamped using nuts and bolts of required dimensions with insulation between the parts to avoid any leakage through loose joints.

Installation Procedure:

The module will generate electricity only if there is a temperature difference across the module. So, attach one side of the modules to a heat source and the other side to a cool source like heat sink to dissipate the heat coming from heat source through the module.

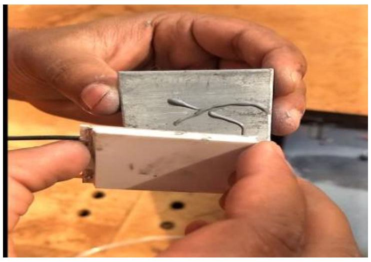
The module has cold side and hot sides. The cold side should be attach to the heat sink and hot side to the heat source. Then the positive output is in red wire, if reversed, then in black wire.

The temperature on the hot side of the module can work at as high as 200^{o}C. If the mounting is reversed, the module will degrade quickly or fail immediately.

III WORKING SETUP

Application of Thermal Grease onto TEG module

A small amount of thermal grease\ thermal paste is applied on the hot side of TEG module. With the help of another TEG module or an aluminium block the thermal paste is spread evenly on both the surfaces of TEG modules.



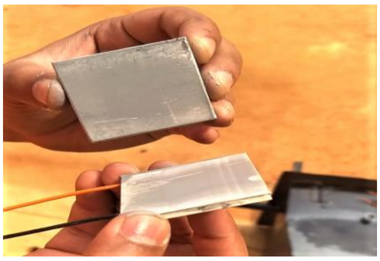


Figure 1.4: application of thermal grease onto TEG module.

Applying thermal grease on Cooling duct and TEG Placement

Once the thermal paste is applied on all the TEG modules and aluminium blocks on both the sides, the thermal paste is now applied on the chimney surface and cooling duct surface. Thus, the aluminium blocks are mounted on the desired chimney surface and the TEG modules are placed on the aluminium blocks, then the copper cooling duct is placed onto the top surface of TEG modules. This setup is then held in position with the help of clamping arrangement made onto the furnace. The inlet pipe of the copper cooling duct is attached to a submersible electric pump which is placed in a bucket with cold water, the outlet is placed in another bucket. An electric blower is attached to the outlet of the furnace provided.

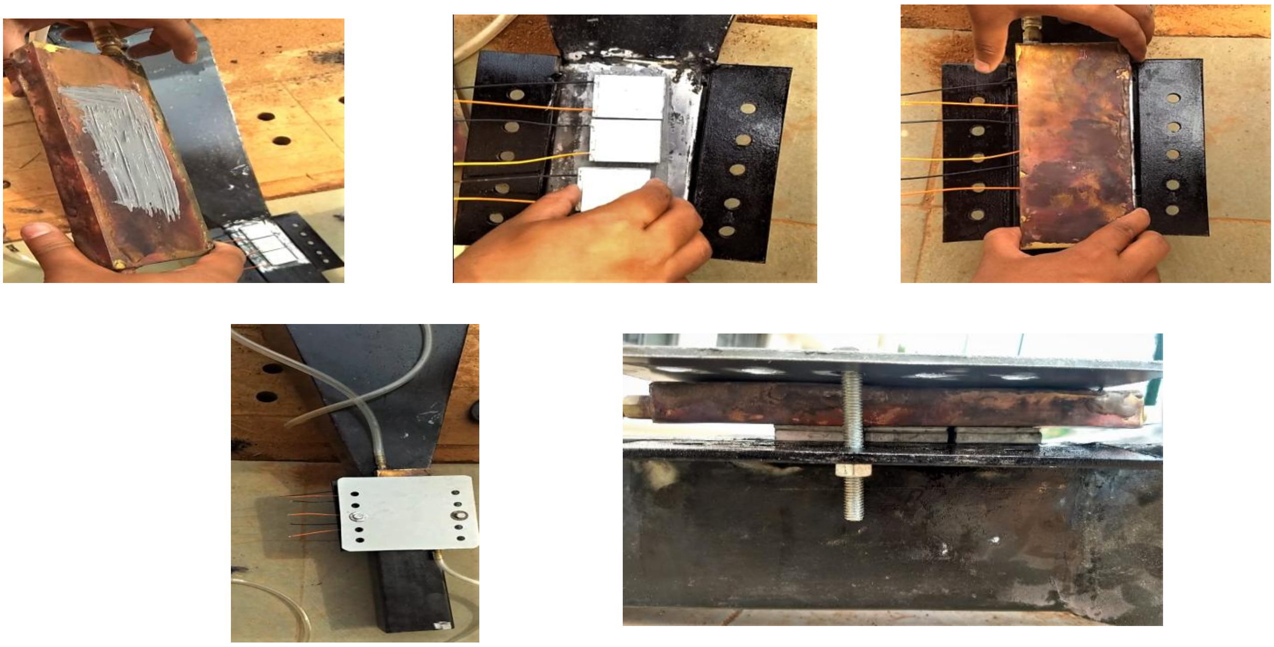


Figure 1.5: Applying thermal grease on cooling duct and TEG placement

Firing of furnace and recording the readings.

Once the setup is finished furnace is fired using coal with kerosene or petrol to ignite it. The coal burns slowly and the flue gases move upwards towards chimney and thus, the chimney heats up. The amount of heat developed is increased by feeding more amount of coal and by providing an electric blower with variable speed, forced draught is created.

As the temperature of the furnace increases the TEG module produces electricity whose voltage and current values are noted down in a tabular column with the help of multimeter. The TEG modules are connected in series. A 2-volt LED is connected as a load to the two terminals of TEG modules. When the voltage output from TEG raises to 2-volt the LED starts to glow, indicating successful power conversion of thermal energy to electrical energy.

For increasing the output voltage, a booster circuit which is a DC-DC converter is attached to the terminals of TEG modules. A load of 12-volt LED bulb is attached and due to the booster circuit, this bulb also glows. The corresponding voltage and current values are noted down using a multimeter.

The cooling duct is supplied with cold water to maintain a larger temperature difference for maximum output. Finally, voltage and current are noted after attaching a booster circuit. The above procedure is followed at different temperature, the readings are tabulated and graphs are plotted accordingly with different parameters on X&Y axis.

Figure1.6: 2-Volt LED bulb glows.

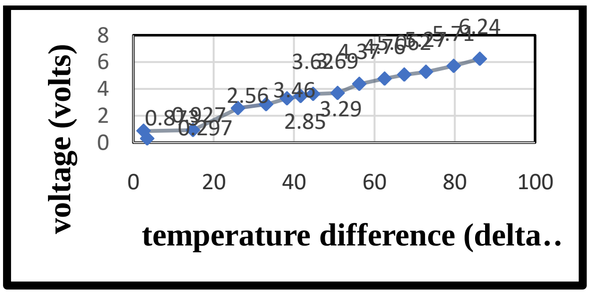
Figure 1.7: 12-Volt LED bulb glows.

CALCULATION AND RESULTS TABULAR COLUMN

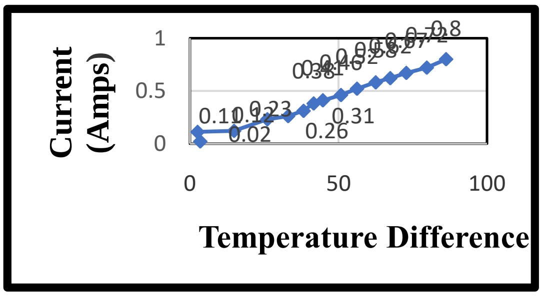
Table 1.1: voltage, Current & Power output at different temperatures

Sl. No	**(hot side)** (°C)	**(cold side)** (°C)	**Temp. Difference** (°C)	**Voltage Output (Volts)**	**Current Output (Amps)**	**Power output (Watt)**
1	29.6	26.2	3.4	0.297	0.02	0.0594
2	41.3	38.8	2.5	0.873	0.11	0.096
3	46.4	31.6	14.8	0.927	0.12	0.111
4	60.3	34.3	26	2.56	0.23	0.588
5	72	39	33	2.85	0.26	0.741
6	82.5	44.3	38.2	3.29	0.31	1.019
7	86.7	45.1	41.6	3.46	0.38	1.314
8	90.5	45.8	44.7	3.62	0.41	1.484
9	98.1	47.3	50.8	3.69	0.46	1.697
10	106.3	50.1	56.2	4.37	0.52	2.27
11	114.8	52.3	62.5	4.76	0.58	2.76
12	120.6	53.2	67.4	5.062	0.62	3.138
13	128.4	55.6	72.8	5.27	0.67	3.53
14	136.8	57.1	79.7	5.71	0.72	4.111
15	145.4	59.2	86.2	6.24	0.8	4.992

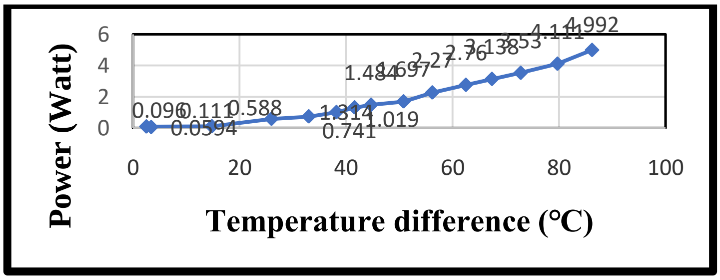
GRAPHS 1.1



Graph 1.1: Voltage (Volts) vs Temperature difference (°C)



Graph 1.2: Current (Amps) vs Temperature difference (°C)



Graph 1.3: Power (Watt) vs Temperature difference (°C)

Readings with application of power boosters:

Table 1.2: Power output using booster circuit.

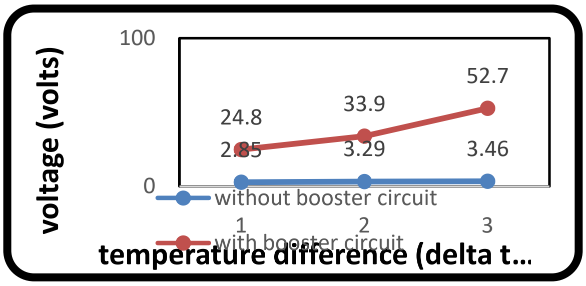
Sl. No.	without booster circuit Voltage (V)	Current (I)	Power (W)	With booster circuit Voltage (V)	Current (I)	Power (W)	% increase In power
1.	2.85	0.26	0.741	24.8	0.24	5.952	703.2
2.	3.29	0.31	1.019	33.9	0.30	10.17	898.03
3.	3.46	0.38	1.314	52.7	0.31	16.337	1143.30

Table 1.3: Per cent increase in power using booster circuit.

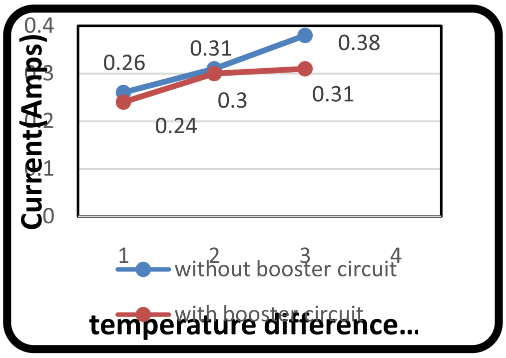
Sl.no	(Hot side) (°C)	(cold side) (°C)	Temp. Difference (°C)	Booster Voltage (Volts)	Booster Current (amps)	Booster Power (W)
1.	72	39	33	24.8	0.24	5.952
2.	82.5	44.3	38.2	33.9	0.30	10.17
3.	86.7	45.1	41.6	52.7	0.31	16.33

*readings for temperature difference 33, 38.2 & 41.6 °C

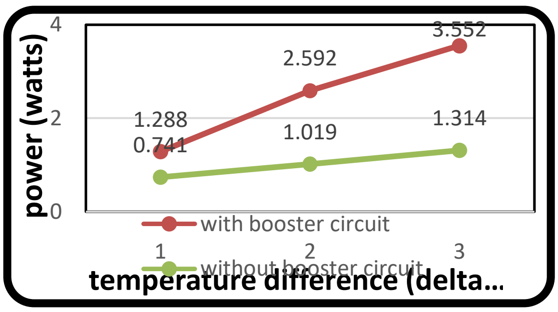
With the use of booster circuit there is a significant raise in voltage and power and very negligible drop in current comparatively to voltage. Thus, the boosted voltage can be used as required.



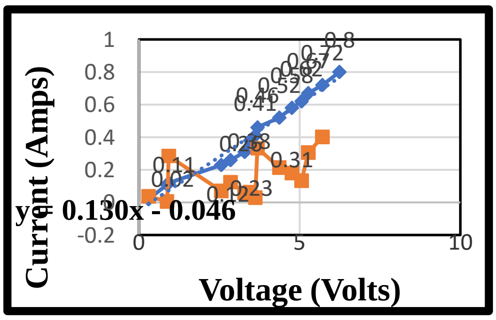
Graph 1.4: Voltage (Volts) vs Temperature difference (°C)



Graph 1.5: Current (Amps) vs Temperature difference (°C)



Graph 1.6: Power (Watt) vs Temperature difference (°C) (Volts)



Graph 1.7: Current (Amps) vs Voltage

Significance of Current vs Voltage graph

- The slope of the graph gives (1/ resistance) that is conductance.

  The equation of the line is given as y = 0.1304x -0.0467, which

  Resembles the equation y = mx + c where,

  m- is the slope of the line.

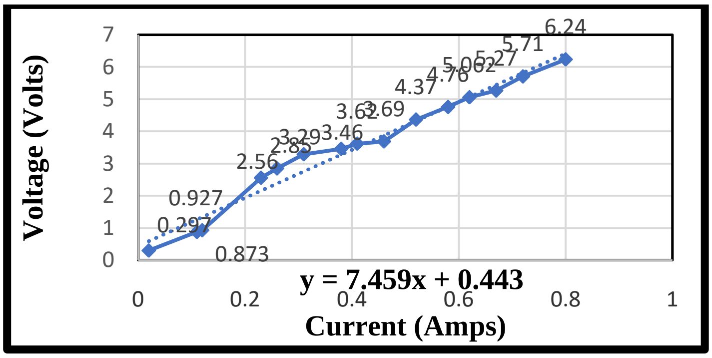
  c- is the intercept.

  Therefore, the conductance(G): 0.1304 mho (siemens, S).

- The area under the graph Current vs Voltage gives power in Watts.

  Therefore, the area here is 2.249 under the graph

  POWER = 2.249 Watts.



Graph 1.8: Voltage (Volts) vs Current (Amps)

Significance of Voltage vs Current graph

- The slope of the graph gives resistance.

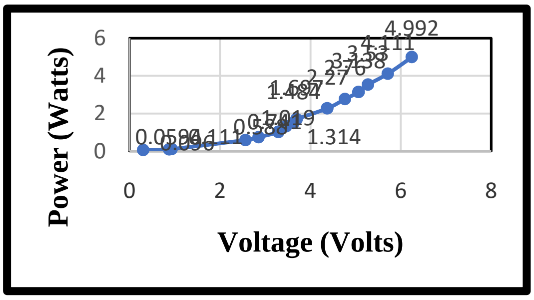
  The equation of the line is given as y = 7.4598x +0.4436, which

  Resembles the equation y = mx + c where,

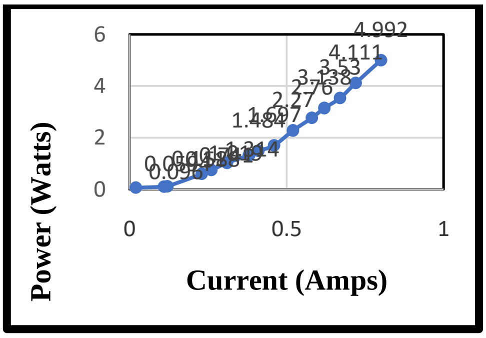
  m- is the slope of the line.

  c- is the intercept.

  Therefore, the Resistance: 0.4436 ohm.



Graph 1.9: Power (Watts) vs Voltage (Volts)



Graph 1.10: Power(Watt) vs Current (Amps)

CONCLUSION

With reference to the observations made in the above conducted test, we observe that the maximum electrical power is being generated at maximum temperature difference on Aluminium block.

From the experiment conducted using 3 TEG modules, it is understood that the output power generated is directly proportional to temperature difference (Hot side – Cold Side). As the temperature difference increases the output voltage also increases thereby, increasing the power output.

With the use of Booster Circuit, it is observed that the small output voltage from the TEG is significantly stepped up to higher voltage with negligible decrement in current output.

The maximum voltage obtained in our experiment was 3.46 Volts at a temperature difference of 37.9 °C which was boosted to 11.46 Volts with 12 Volts LED bulb as load and to 52.7 Volts without load.

Therefore, with the use of multiple TEG's the output can be increased significantly.

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