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THERMOELECTRIC POWER GENERAION FROM WASTE HEAT OF GAS STOVE BY USING THE THERMOELECTRIC GENERATOR

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ABSTRACT

The objective of this research is set to produce energy by utilizing the unused heat of gas stove through thermoelectric generator. Currently, an increasing concern of environmental issues of emissions like greenhouse effects and the scarcity of fossil fuel has resulted in extensive research into the alternative ways of generating electrical power. Thermoelectric power generator has been considering as one of the promising alternatives due to its advantages. The application of this alternative option in converting waste-heat energy directly into electrical power that may also enhance the overall efficiencies of energy conversion systems. In this study, a gas burner was set to generate electricity that will produce waste heat. One thermoelectric unit is installed underneath the burner cap of the gas burner. Gas flame at the edge of the burner cap creates heat sources (hot side) for the thermoelectric unit. A gas-mixing chamber underneath the thermoelectric unit functions as heat sink (cold side) for the thermoelectric unit. An insulation plate is inserted in between the thermoelectric unit and the burner cap to control the hot side temperature. The thermoelectric unit generates electricity while the gas burner is in use and the flame heats up the burner cap. The thermoelectric unit connects to an electric circuit and provides electricity to power devices.

INTRODUCTION

A thermoelectric generator, or TEG is a solid state machine that converts heat (temperature differences) directly into electrical energy through a process called the See beck effect (a form of thermoelectric effect). Thermoelectric generators function like heat engines, but are less bigger in size without moving parts (Singh et al., 2013). The thermoelectric power cycle, with charge carriers (electrons) serving as the working fluid, follows the fundamental laws of thermodynamics and intimately resembles the power cycle of a conventional heat engine. Thermoelectric power generators offer several distinct advantages over other technologies (Yadav et al., 2008). Advantages of Thermoelectric power generators over other technologies (Peter et al., 2013):

- User friendly and smooth in operation since they have no mechanical moving parts and require less maintenance;
- Safe to operate;
- Small and light weight;
- Can operate at high temperature;
- Can operate remotely and at small-scale;
- Less pollution emission;
- Location independent; and
- Flexible power sources.

Most of the areas in Bangladesh are facing electricity problem due to global fossil fuel crisis. Converting waste heat to thermoelectric power could be one of the best alternatives to mitigate the present situation. The waste heat of the cook stove can be utilized for the generation of electricity using a commercial thermoelectric generator (TEG). The heat from the fuel burnt is used for heating the hot side of the TEG and the cold side is attached with a sink to increase the surface

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area and dissipate the heat keeping the cold side cooler. The principle of TEG is to convert waste heat as heat source into electricity, which is considered to be sustainable technology since the input energy is cost free, and the output of the of the module is of valuable due to its power generating feature and making the cook stove economically viable.

In recent years, sustainable resource for electricity generation has been something of which the society has undertaken to take charge on the emissions and to keep up with our rapidly growing economy. In every year, significant amount of waste heat from both commercial and residential appliances is lost into the atmosphere, from which the potential never gets harnessed. In this paper, with limited technology of waste heat recovery systems around, an alternative green, we studied a reliable and cost effective method is by the use of thermoelectric technology, which utilizes a solid state device, capable of converting temperature gradients into electric power.

LITERATURE REVIEW

The concept of TEG integrated stove research was first introduced by J .C Bass and Killander in 1996. The stove performances from different literatures according to the power output and the cooling type are summarized in the Table 1. The production of stove concept is based on Biolite. The basic aim this concept is to make the stove very affordable to rural people and those who are facing scarcity of electricity. There are many ways of cooling the TEG such as: heat sink attachment and ambient cooling, heat sink and fan mounted on top (forced convection), water cooling, forced water cooling, water cooling and fan mounted above.

Table 1. Thermoelectric power generation from waste heat in literatures

Previous Studies	Heat/cold sink	Module type	Power
Nuwayhid, 2003	Natural air cooling	Peltier	1W
Mastbergen, 2008	Forced air cooling (1 W)	Seebeck	+4 W
Champier et al., 2010	Water cooling	See beck	5W
Champier et al., 2011	Water cooling	Seebeck	9.5W 7.5W regulated

Study revealed that the use of thermoelectric generators to convert about 6% derived waste heat will reduce fuel consumption by up to 10%. The use of thermoelectric generators to convert about 6% derived waste heat will reduce fuel consumption by up to 10% (Sztekler et al., 2017).

MATERIALS AND METHODS

Thermoelectric Module

The thermoelectric module consists of thermocouple formed by pairs of P-type and N-type semi- conductor thermos element which are electrically connected in series configuration and thermally connected in parallel configuration. The effect creates a temperature difference by transferring heat between two electrical junctions. A voltage is applied across joined conductors to create an electric current.

Figure 1. Thermoelectric module Table

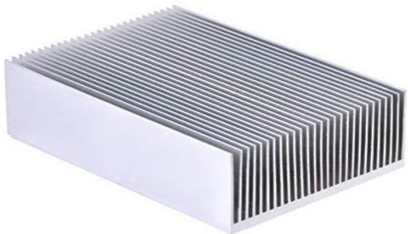

Figure 2. Heat sink

Table 2. Specifications of thermoelectric Module

Manufacturer PN	TEC1-12706
Weight	**27g**
Material	**Al2O3 (aluminum oxide)**
Max. Temperature	**138°C**
Max. Voltage	**15.4V**
Max. Current	**6.4A**
Qmax. @ Delta T=0	**63W**

Heat Sink

Heat sink is a heat reservoir that can absorb an arbitrary amount of heat without significantly changing temperature. Practical heat sinks for electronic devices must have a temperature higher than the surroundings to transfer heat by convection, radiation, and conduction. Aluminum material is used as heat sink because of its high conductivity, availability, light in weight. Aluminum heat sink is the main part of this system. There are two types of sink are used in this system. Hot sink and cold sink.

Properties of Heat Sink

- Good thermal and electrical conductivity.
- Low density with a density ~ 2,700 kg/m^3.
- High strength of between 70 and 700 MPa.
- Easy malleability & Easy machining.
- Excellent corrosion resistance.
- Non-magnetic which avoids interference of magnetic fields.
- Easy to recycle.

LED Digital Voltmeter Ammeter

A voltmeter and ammeter are to an electrical system what a pressure gauge and a flow gauge are to anoil pressure system: A voltmeter measures electrical pressure in volts; an ammeter measures electrical flow in amps. An ammeter is a measuring device used to measure the electric current in a circuit.A voltmeter is connected in parallel with a device to measure its voltage, while an ammeter is connected in series with a device to measure its current.

Figure 3. Digital Voltmeter Ammeter

Figure 4. Temperature meter

Figure 5. Battery

Properties of LED Digital Voltmeter Ammeter

- High precision, high reliability, suitable for high-end applications
- With reverse protection, then anti-burn
- 10A voltage current meter itself built-in shunt, 50A / 100A voltage current meter headdistribution shunt (pay attention to the power supply must be connected before the splitter)
- Voltage measurement range: DC 0-100V
- Current measurement range: 0-10A, 0-50A, 0-100A.

Temperature Meter

AR867 humidity temperature meter has -10℃~50℃ indoor temperature measuring range, -50℃~70℃ outdoor temperature measuring range, humidity measuring range 20%RH~99%RH, accuracy of temperature ±1°C ±1.8°F, accuracy of humidity ±5%RH, ℃/°F selection, temperature resolution 0.1℃/°F, humidity resolution 1%RH, 1*1.5AAA battery.

Battery

A battery is a device that produces electrons through electrochemical reactions, and contains positive (+) and negative (-) terminals. A battery consists of one or more electrochemical cells, which transform stored chemical energy directly into electrical energy. When an external load connects to a battery, electrons cross from the negative to the positive terminal, creating an electrical current. This current may power a motor, a light bulb, a clock, a computer, a cellphone, and other electronic devices or equipment. Battery flow speed is determined by the battery's internal resistance and outside load.

Common Features Include

- High operating voltage.
- Flexible.
- Similar in all other ways to standard lithium polymer cells.
- High energy density.
- Customizable connection & housing.
- Customizable monitoring (fuel gauge, LED, etc).
- Customizable protection / safety circuitry.
- Constant Current (CC) and / or Constant Voltage (CV) Charging Method.
- Overcharge / Over discharge Detection and Cut-off.
- Overcurrent Detection.
- Multitude of Latest Chemistries.

Gas Hose Pipe

A hose is a pipe made of rubber or plastic, along which a liquid or gas flows, for example from one part of an engine to another.

Figure 6. Gas Hose Pipe

Figure 7. Gas stove

Figure 8. Gas Regulator

Gas Stove

A gas stove is a stove that is fueled by combustible gas such as syngas, natural gas, propane, butane, liquefied petroleum gas or other flammable gas. Before the advent of gas, cookingstoves relied on solid fuels such as coal or wood. Many stoves use natural gas to provide heat.

Features of Gas Stove

- High-performance burners (up to 17,000 Btu)
- A bonus fifth burner.
- A removable stovetop griddle.
- Electronic control panels for programmed cooking times.
- Convection ovens.
- Hidden baking elements for easier cleaning.

Gas Regulator

A pressure regulator is a control valve that reduces the input pressure of a fluid or gases to a desired value at its output. Regulators are used for gases and liquids, and can be an integral device with an output pressure setting, a restrictor and a sensor all in the one body, or consist of a separate pressure sensor, controller and flow valve.

Feature of Gas Regulator

The mini Butane Regulator is suitable for Butane gas and works to an operating pressure of 22 mbar. Key features include a 35mm inlet and an 8mm outlet nozzle.

- Operating pressure: 22 mbar
- 03mm inlet
- 8mm outlet nozzle
- For Butane gas

Insulator

Thermal insulation is the reduction of heat transfer between objects in thermal contact or in range of radiative influence. Thermal insulation can be achieved with specially engineered methods or processes,as well as with suitable object shapes and materials.

Figure 9. Insulator

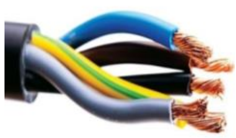

Figure 10. Wire

Figure 11. LED light

Wire

A wire is a single, usually cylindrical, flexible strand or rod of metal. Wires are used to bear mechanicalloads or electricity and telecommunications signals. Wire is commonly formed by drawing the metal through a hole in a die or draw plate.

Properties of Wire

- Conductors are Solid Bare Copper, ASTM B-3.
- The Insulation is SR-PVC 60°C Twisted Pair.
- It has a PVC 60°C gray jacket with rip cord.
- UL CMR/MPR, NEC Article 800, meets UL 444 and CAT 3 Performance Level.
- 28.6 ohms/1000 ft. max DC Resistance.

- 20 PF/FT max Mutual Capacitance.
- Impedance (ohms) at 16MHZ - 100 ± 15%.
- With a Structural Return Loss at 1-16 MHz -1.
- Crosstalk (dB) min:1.0 MHz - 41, 4.0 MHz - 32, 10.0 MHz – 30.

Led Light

Light is electromagnetic radiation that shows properties of both waves and particles. Light exists in tinyenergy packets called photons. In physics, the term light sometimes refers to electromagnetic radiation of any wavelength, whether visible or not.

Features of LED Lights

- Energy Efficient. Immediate reduction of power consumption from much lower wattagerequirements = lower utility bills.
- Maintenance & Safety.
- Durable Quality.
- Design Flexibility.
- Save Money, Use LED Lighting.

Aluminum Pot

This process is called anodization. Anodized aluminum cookware conducts heat as well as ordinary aluminum, but has a hard, non- stick surface which makes it scratch-resistant, durable, and easy to clean.

Material for Cooking Pots

- Stainless Steel. Long-lasting, classic, uncoated stainless steel is a good choice forbrowning and braising.
- Nonstick. Durable nonstick coatings effortlessly release even delicate foods, includingeggs and pancakes.
- Enameled Cast Iron.
- Perfect for fish boils; cooking lobsters, clams or oysters; or cooking pasta for largegatherings

Methods

This study is designed to produce electricity from waste heat of gas stove by the thermoelectric generator (TEG). All experiment should be following some procedure. Our experimental procedures are given below:

- At First design the experimental set up.
- Starting the experiment with care set up the gas stove one the table.
- Gas stove then connected with the gas line.
- The thermoelectric module then placed between two heat sink (For safety and smooth operation).
- Hot side was placed inside the fire and cold side placed in open environment.
- Add a cooling fan to the cold side of the heat sink to increase the thermal difference of the **TEG-12706** module. No external power will be used to run the cooling fan. This fan will run from the **TEG-12706** generated power.
- After that connect with a voltmeter for electrical voltage measurement, an ammeter for current measurement, and two Digital thermometers for (hot & cold side) temperature measurement, cooling fans, and electric led blub to the **TEG**. Attached this to an electric booster that can charge the battery and electric device and will be most helpful during any natural disaster.
- Turn on the gas burner knob & light a fire on the gas stove; there is no power output at the beginning of burning due to the low-temperature difference.
- Our output starts to come in when the temperature difference increases, and as soon as the voltage crosses 1.8 volts, our cooling fan turns on. Now we are using four modules of **TEG-12706**. Our study operation run time was 6 minutes total of **12** times through the luminous procedure, and have collected data repeatedly. Fig. 12 illustrates the full experimental setup.

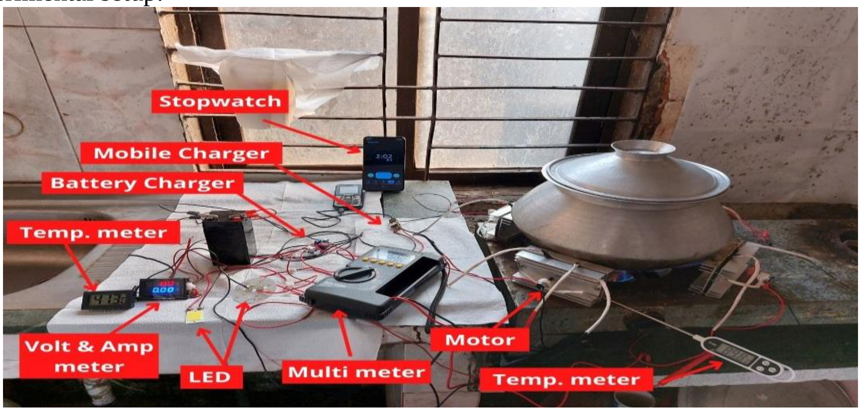

Figure 12. Experimental setup for the study

RESULTS AND DISCUSSIONS

Different measurement procedures were investigated at various condition which have been showing below in different Table (3-10) and these readings are plotted on the graph (Fig. 13-18). When the single module is used maximum temperature difference between hot sink and cold sink is 95°c and minimum temperature difference between hot sink and cold sink is 07 °c. The maximum temperature of hot side is 151°c and the minimum temperature of cold side is 39°c. The maximum current flow of the thermoelectric generator is 0.86A. The thermoelectric generator maximum power output is 08.61watt. The summarize result of cooling and heating effect of thermoelectric module at various situation are given below.

Table 3. Overall result of thermoelectric module & sink

SN	Time(min)	Hot Sink temp.	Cold sink temp.	Temperaturedifference between hot & cold sink	Voltage (V)	Curren t(A)	Power (W)
1	0.5	39	32	7	1.81	0	**0**
2	1	55	33	22	2.5	0.12	**0.34**
3	1.5	72	35	37	3.2	0.23	**0.736**
4	2	87	37	50	3.9	0.30	**1.17**
5	2.5	99	38	61	4.4	0.46	**2.024**
6	3	109	39	70	5.6	0.51	**2.856**
7	3.5	119	41	78	6.7	0.58	**3.886**
8	4	128	42	86	7.8	0.65	**5.07**
9	4.5	136	46	90	8.6	0.71	**6.106**
10	5	142	52	90	9.2	0.76	**6.992**
11	5.5	147	53	94	9.8	0.79	**7.742**
12	**6**	**151**	**56**	**95**	**10.5**	**0.86**	**8.61**

Table 4. Load Calculation

Name of Electronics Components	Quantity	Voltage per Components (V)	Maximum Load capacity of Components(volts)
Cooling fan	04	0.8	3.20
Led Lights	03	2.1	6.3
Battery Charger	01	1.6	1.6
Mobile Charger	01	06	6.00
System Losses (Wire, Switch, Joints & Circuits)	-	-	4.00
Total Voltage generate with System losses			**21.1**

There are various types of reading performed during investigation. Sequentially all the situations are represented below in figures (Figure 13-18). All the parameters are variables with respect to different conditions.

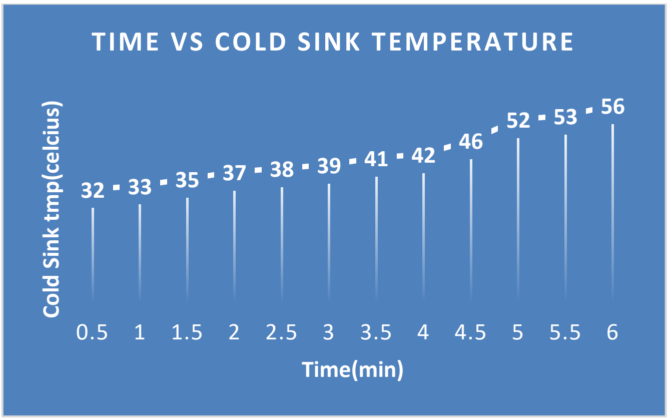

Figure 13. Time with Cold Sink Temperature

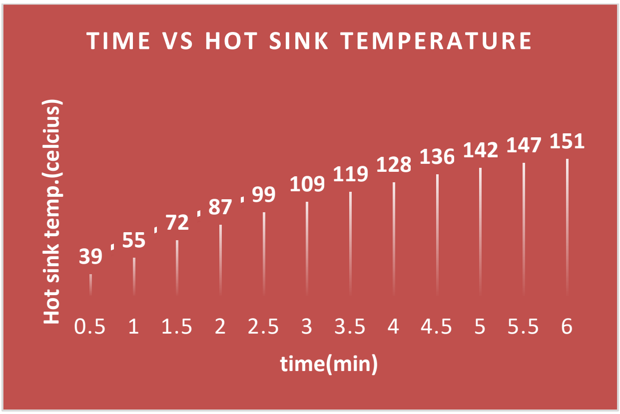

Figure 14. Time with Hot Sink Temperature

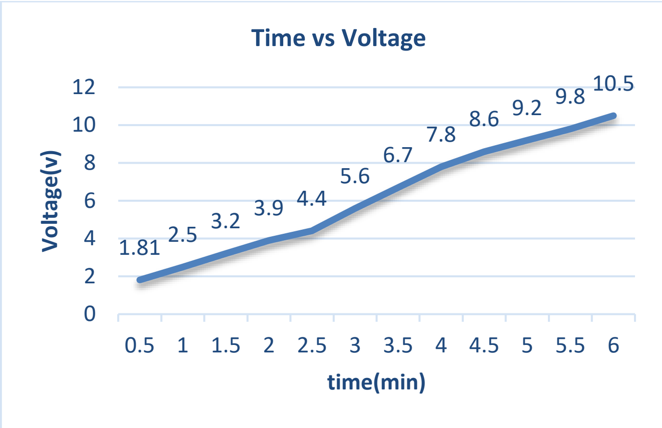

Figure 15. Time with Voltage

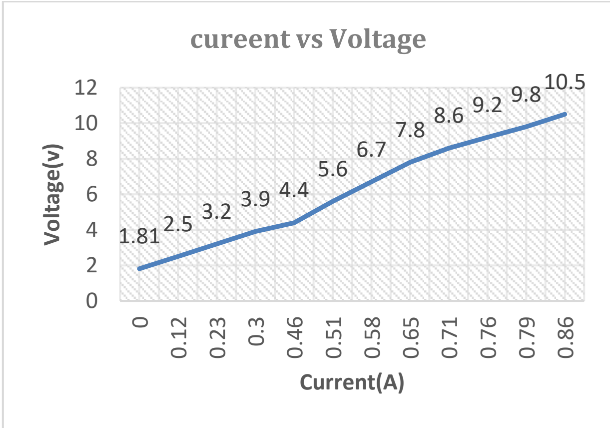

Figure 16. Current with Voltage

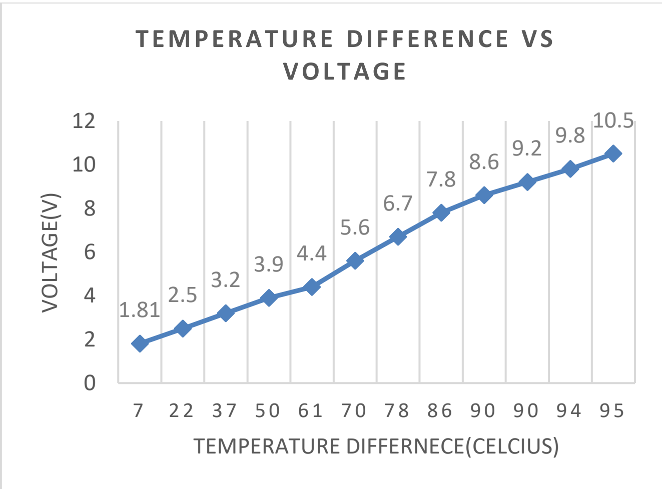

Figure 17. Temperature Difference with Voltage

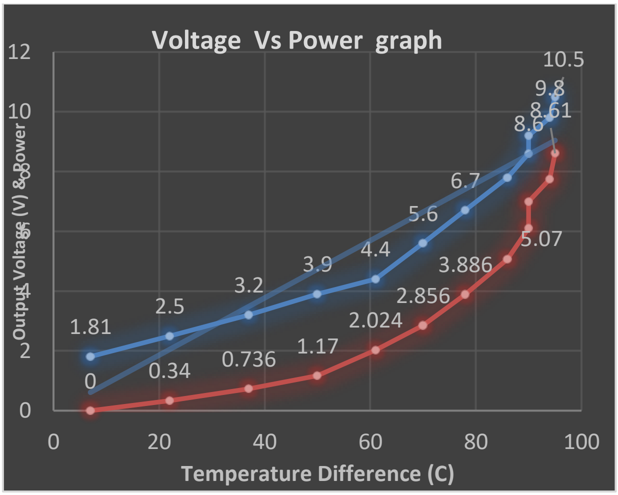

Figure 18. Temperature difference between Voltage & Power

Discussions

From the upper results, following findings can be obtained from this study-

- The electricity product depends on temperature difference between hot sink temperature and cold sink temperature.
- At first there is no electricity production because temperature difference is very low between hotsink and cold sink.
- After certain time, temperature difference increases then the electricity production has started. The current flow through the thermoelectric module is constant due to fixed output voltageof DC source.
- Cooling effect of thermoelectric module depends on heat released of hot side of module. For increasing heat transfer on heating side of module, a heat sinks and there is no use of cooling fan.
- Insulator is used on the cooling side of the system for reducing heat transfer of cooling side.
- Some variation of reading is occurred during the experiment because of difference in weather condition, insufficient insulation, improper thermal paste between hot sink and cold sink.
- Finally, it was observed in the temperature difference with voltage and current graph is that the increasing the value of voltage & current is increasing due to temperature difference.

CONCLUSIONS

This work has demonstrated the potential of the electric power generation using the thermos electric generator. The heat source proposed in this study is the exhaust waste heat from the domestically available gas stove where, significant amount of energy from the combustion is wasted. From this study the following conclusive points are-

- A thermoelectric module is tested its performance. The hot sink and cold sink temperaturedifference maximum is 95°C and minimum is 07 °C at six minute.
- The maximum temperature difference between hot sink and cold sink is 95°Celsius thenthe output power is 8.61Watt.
- The minimum temperature difference between hot sink and cold sink is 07°Celsius theoutput power is 0.0 W.
- The performance of this system were altered with the variation number of module andaccessories which

are used in the hot side for increasing heat transfer

- The heating and cooling effect is utilized; the performance of the whole system is increase and decrease.

There are some good scopes of this findings for future study. The future scopes are-

- It may be used as the alternative power source of kitchen light.
- It can be used on motorcycle or car and any large type of engine.
- Big industries like Foundry, Brickyard, and Power Plant can be used in places where excessive heat is generated.

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