DEVELOPMENT OF A HOME-GROWN ELECTRICAL POWER CHARGER FOR CELLPHONES FROM COOKING HEAT.

Submitted to

Nigerian Communication Commission, NCC,

Plot 423 Aguiyi-Ironsi Street, Maitama District, Abuja-Nigeria.

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Title of Project: ***DEVELOPMENT OF A HOME-GROWN ELECTRICAL POWER CHARGER FOR CELLPHONES FROM COOKING HEAT.***

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SUMMARY OF RESEARCH REPORT

PROBLEM STATEMENT: - Cell-Phones services have become unavoidable necessities; and are fast becomming indispensable companions to the urban dwellers, rural dwellers and nomadic group of Nigerian populace. The simplest of these cell-Phones has important features like touch-lights, radio reciever, time piece, maillings facility apart from the normal making and answering of voice calls. These cell-Phones are battery powered and thus need constant power to function. To charge those cell-phones batteries, people use to walk for miles to some common charging centers. In most cases people are compelled to visit other villages and stay back for hours for the cell-Phones to charge. This is because the effectiveness of the cell-phones depends largely on the condition of their batteries, which are charged using electricity from public power supply, generating sets and solar. Currently, the available cell-phone battery charging devices are foreign-based and therefore import-oriented. Most of them are expensive and depend on non-renewable electrical energy, which is currently epileptic in supply and unreliable in most areas.

PROPOSED APPROACH: - This research work therefore is aimed at producing charging devices for cell-Phones. It is poised towards harvesting and converting waste cooking heat energy to required electrical energy. In this research project, we are harvesting and directly converting waste-cooking heat into electrical energy to charge our cell-phones batteries. The project, which is based on the concept of thermoelectricity, involves research and development of a prototype thermoelectric technology, capable of charging cell-phones.

VALUE PROPOSITION SOLUTION: - It is understandable that telephone services have become part and parcel of Nigerian populace even in the rural and nomadic settings. Some of the values are:-

1. There will be increased usage and utilization efficiency of cell-phones because even the nomadic settlers in remote areas of the country will be able to use telephones more effectively.
2. It has the potential to replace foreign and import-based conventional cell-phone battery chargers currently in use in the country.

3. This study provides alternative, reliable, renewable and cheap power source for charging cell-phones.
4. The study enhances cell-phone services in Nigeria as well as conservation of national foreign exchange reserve being spent in importing products like cell-phone chargers.

NOVELTY OF THE RESEARCH PROPOSAL: - The Technology is new, achievable and affordable within our local content. This technology was invented since 1885 and many developed nations use it in various manners to improve on their technology. Our team has investigated upon this technology with the aim of using it to improve our local telephone charging technology. Presently, there is no smart-phone battery charging device working on this technology in Nigeria. It is simple, affordable, and generally acceptable.

Thermoelectric power generators offer several distinct advantages which include that:

1. They are extremely reliable (typically exceed 100,000 hours of steady-state operation) and silent in operation since they have no mechanical moving parts and require considerably less maintenance.

2. They are simple, compact and safe.

3. They have very small size and virtually weightless;

4. They are capable of operating at elevated temperatures;

5. They are suited for small-scale and remote applications typical of rural power supply, where there is limited or no electricity;

6. They are environmentally friendly;

7. They are not position-dependent; and

8. They are flexible power sources.

STAGE I

Design and Development of the Heat-based Electrical Power Generator.

RESEARCH PROJECT KICK-OFF REPORT

Inception Report

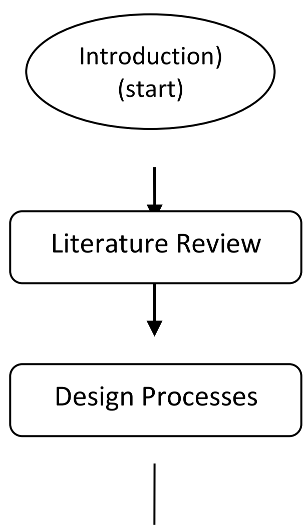
This inception report presents the methodology we tend to apply in this project. The materials, components and the devices necessary for this work were briefly introduced. The block diagram, algorithm methodology was as well briefly highlighted. The electrical design is introduced. This device is called thermo-electric generator or thermo electric conversion system. This generator has being designed in this stage. The necessary components and devices has established by designed and arranged in the stage.

Introduction

Cell Phones are fast becoming indispensable companions to both the urban and rural dwellers. The simplest of these Cell Phones has important features like touch-lights, radio receiver, and time piece, mailings facility apart from the normal text messaging, making and answering calls. These phones are battery powered and thus needs constant power to function. However, there is never constant power to charge them especially in the rural and nomadic settings.

Alternative source like solar devices could not help either as the sun is not usually intense enough. Cooking heat on the other hand can always be made available at will in those settings any time even as they cook foods and or make fire with woods to warm themselves. Some of these heats could be harvested to charge cell phones. This harvesting of heat energy and converting them into electrical energy to charge cell phones is the aim of this work. The major objective therefore is to design and develop a device that has the capacity of harvesting and converting the heat to cell phone chargers.

Implementation algorithm



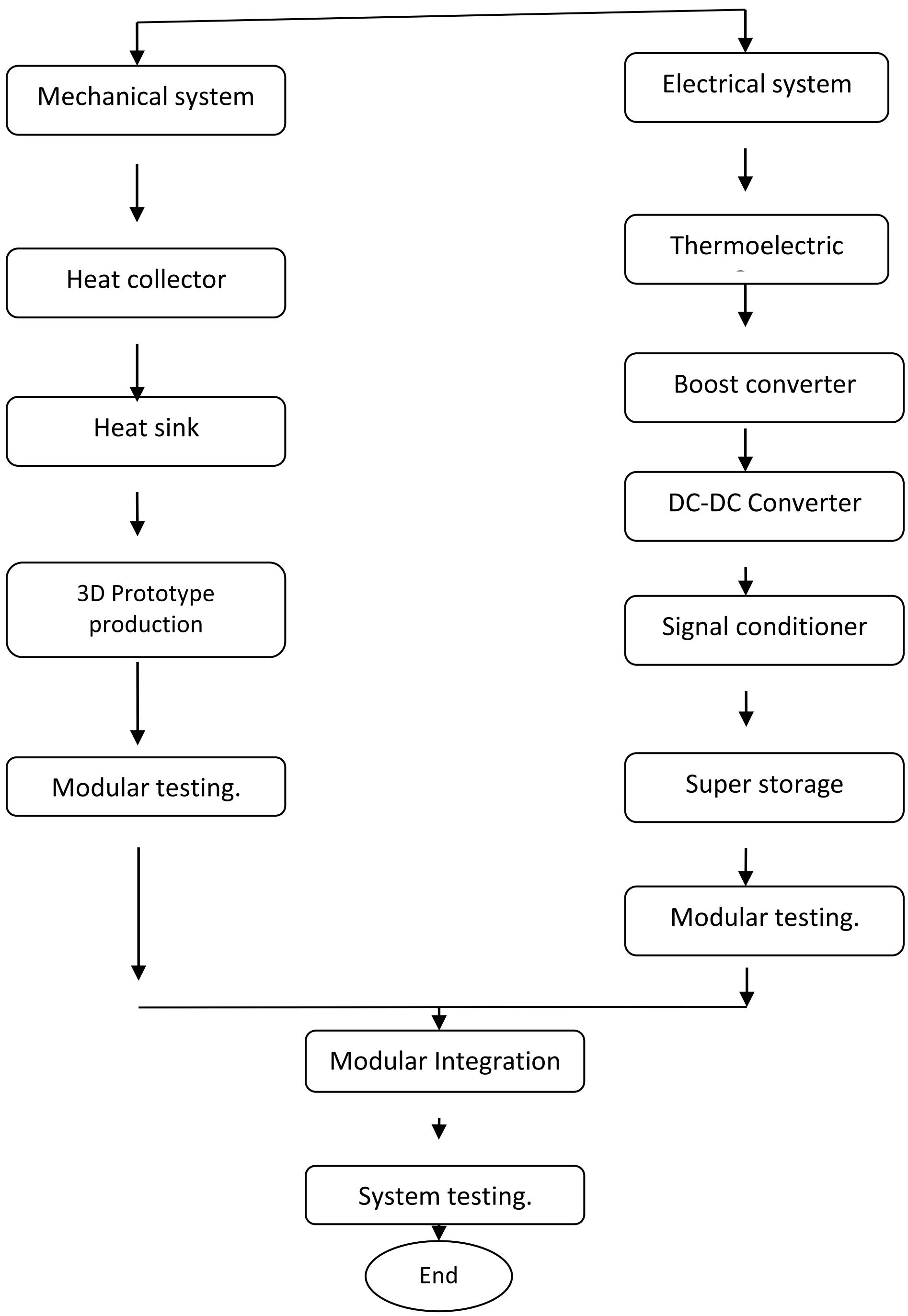


Figure 1: Proposed implementation methodology.

Generator design.

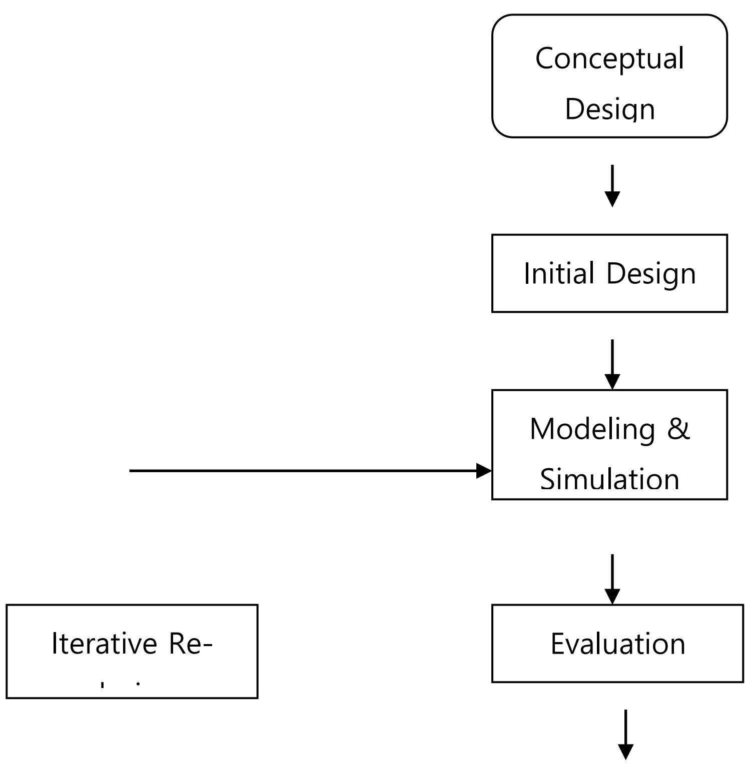
Design, generally can be defined as a creative process by which new methods, devices, and techniques are developed to solve new or existing problems. Here, we are developing a new technique of charging cell phones especially when the usual types are not readily available. Due to increasing worldwide competition and the need to develop new, improved and more efficient processes and techniques, a growing emphasis is being placed on design (Jaluria, Yogesh, 2007). This design work is carried out using three principal points: Specifications, Material parameters and Design parameters.

Specifications: the operating temperatures TC, TH and the required power output P (and or output voltage or current I).

Materials parameters: the thermoelectric properties of thermo element materials Z (α ρ), and the electrical and thermos contact properties of the module. ·

Design parameters: the thermo element length L, the cross-sectional area A and the number of thermocouples N.

Electrical system design:-



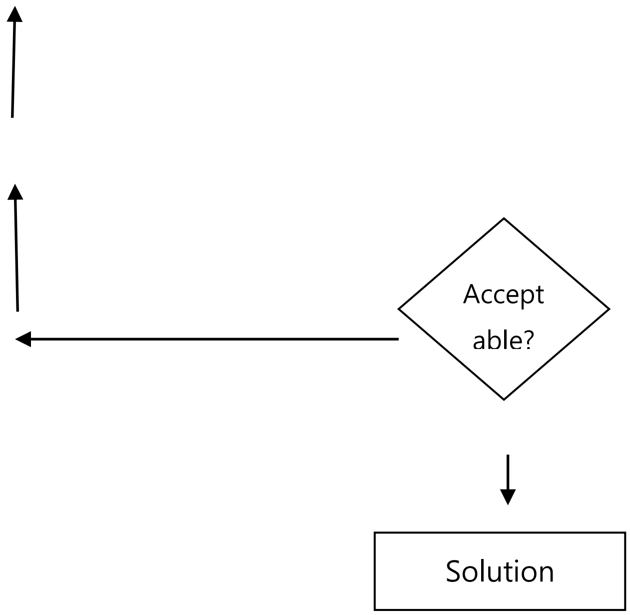


Figure 2: Flow Chart of Electrical design process.

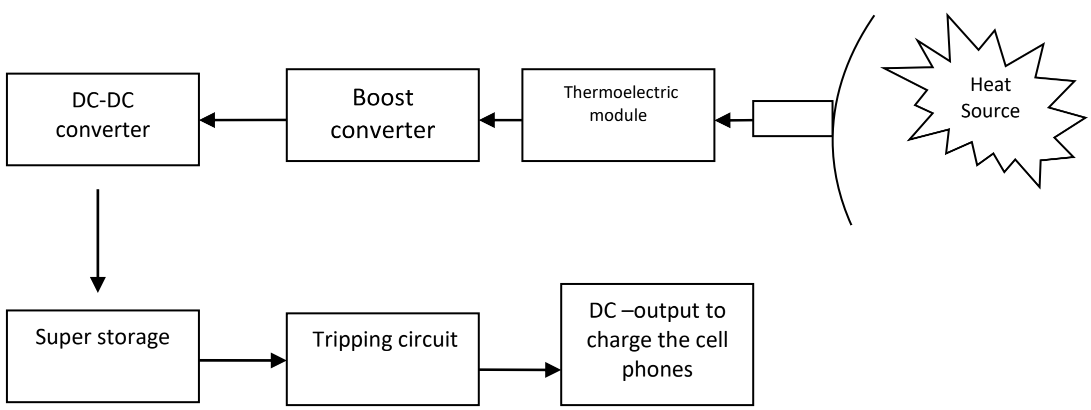


Figure 3: Block diagram of the 6volts, 1.5Amp cell phone charger.

Heat source (cooking heat)

There many sources of heat but the one used in this work is cooking heat. This is to extend the users of the generator to include anyone who can have access to cooking heat and other controllable sources of heat.

Thermoelectric module

This system consists of heat absorbers that function as heat collectors to heat up the TEG; TEG modules, and heat sinks whose function is to dissipate heat from the cold end of the TEG module as rapidly and efficiently as possible to widen the temperature difference between the hot and cold faces, to enhance performance of the TEG module.

N-type and **P**-type, and are so named because either they have more electrons than necessary to complete a perfect molecular lattice structure (N-type) or not enough electrons to complete a lattice structure (P-type).

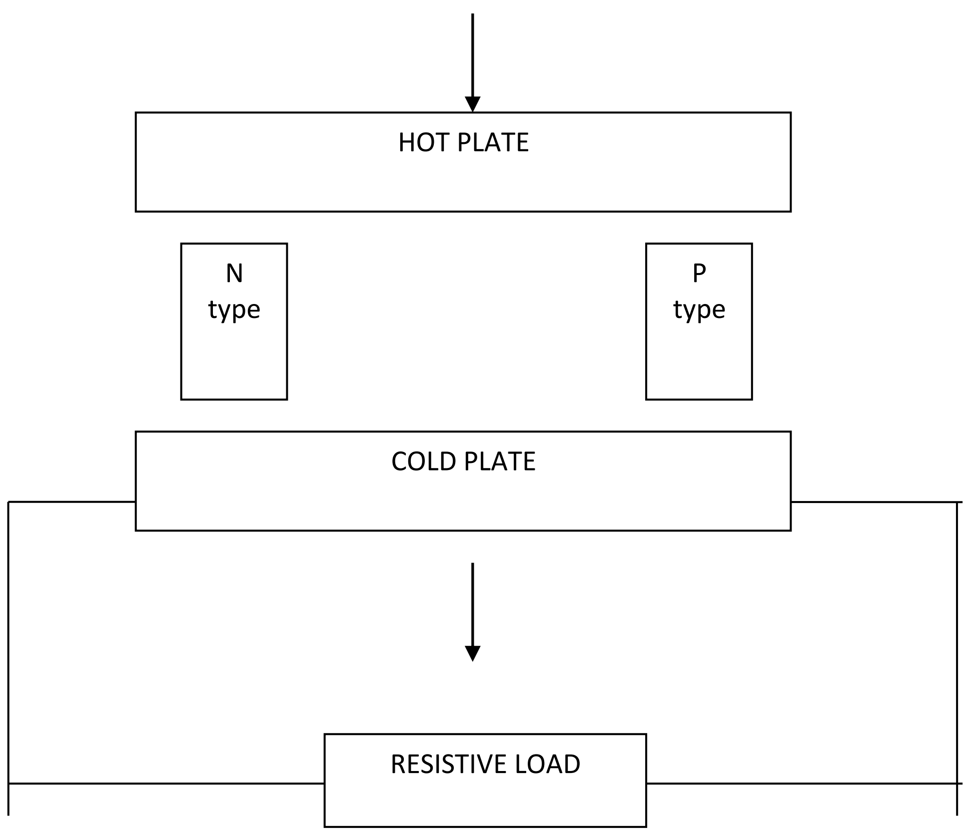


Figure 4. Single Thermoelectric Couple (Th > Tc).

Thermoelectric Power Generator.

The thermoelectric effect is the direct conversion of temperature differences to electric voltage. All thermoelectric power generators have the same basic configuration. A heat source provides the high temperature, and the heat flows through a thermoelectric converter to a heat sink, which is maintained at a temperature below that of the source. The temperature differential across the converter produces direct current (DC) to a load (R_L) having a terminal voltage (V) and a terminal current (I).

There is no intermediate energy conversion process. For this reason, thermoelectric power generation is classified as direct power conversion. The amount of electrical power generated is given by I^2R_L, or VI. According to Joule's law, a conductor carrying a current generates heat at a rate proportional to the product of the resistance (R) of the conductor and the square of the current.

With no load (RL not connected), the open circuit voltage as measured between points ‘a’ and ‘b’ is:

$$V = S \times DT$$

Where:

V is the output voltage from the couple (generator) in volts

S is the average Seebeck coefficient in volts/°K

DT is the temperature difference across the couple in °K (DT =

Th-Tc). When a load is connected to the thermoelectric couple the output voltage (V) drops as a result of internal generator resistance. The current through the load is:

$$I = S \times DT / R_C + R_L$$

Where:

I is the generator output current in amperes

RC is the average internal resistance of the thermoelectric couple in ohms

RL is the load resistance in ohms

The total heat input to the couple (Qh) is:

$$Q_h = (S \times T_h \times I) - (0.5 \times I^2 \times R_c) + (K_c \times DT)$$

Where:

Qh is the heat input in watts

Kc is the thermal conductance of the couple in watts/°K

Th is the hot side of the couple in °K

The efficiency of the generator (Eg) is VI / $Q_{h.}$

We have thus far discussed an individual thermoelectric couple, but since a complete module consists of a number of couples, it is necessary to rewrite our equation for an actual module, as follows:

$$V_C = S_M \text{ x } DT = I \text{ x } (R_M + R_L)$$

Where:

Vo is the generators output in volts

SM is the module's average Seebeck coefficient in volts/°K

RM is the module's average resistance in ohms

The power output (Po) from the module in watts is:

$$P_o = R_L \text{ x}$$

It is possible, but unlikely, that the precise conditions will exist within a given generator application whereby one module will provide the exact output power desired. As a result, these thermoelectric generators contain a number of individual modules which may be electrically connected in either series, parallel, or series/parallel arrangement.

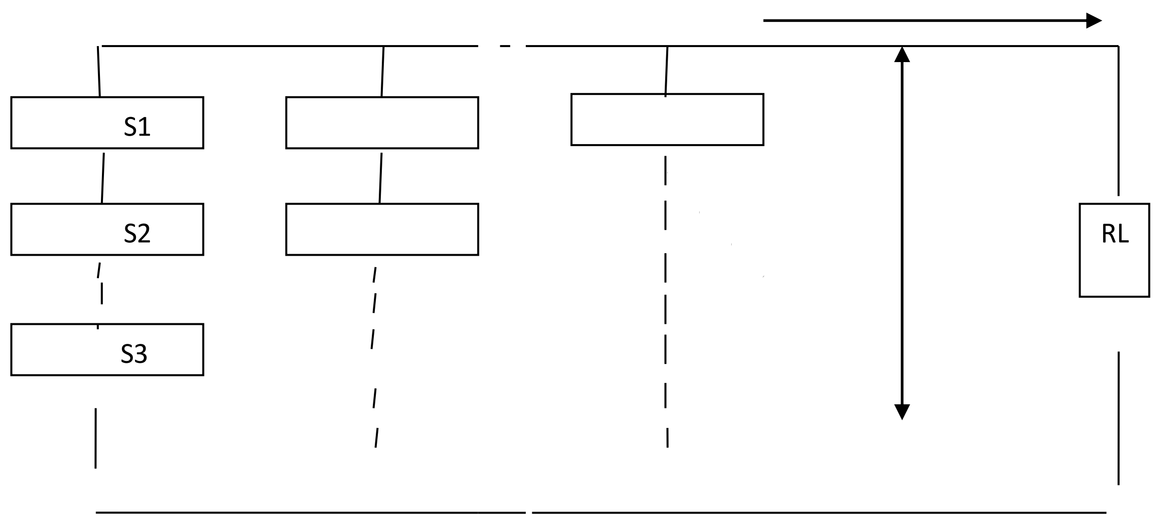


Figure 5. Our Thermoelectric Generator with a Series-Parallel Arrangement of Modules.

The current (I) in amperes passing through the load resistance RL is:

$$\mathbf{I = NS \times S_M \times DT / NS \times R_M}$$

The output voltage (V_o) from the generator in volts is:

$$\mathbf{V_o = S_M \times DT = I \times (R_M + R_L)}$$

The Output Power (P_O) from the generator in watts is:

$$\mathbf{P_o = V_o \times I = NT \times (S_M \times DT)^2 / 4 \times R_M}$$

The total heat input (Qh) to the generator in watts is:

$$\mathbf{Q_h = (S \times T_h \times I) - (0.5 \times I^2 \times R_c) + (K_c \times DT)}$$

The efficiency (Eg) of the generator is:

$$\mathbf{E_g = P_o / Qh \times 100\%}$$

Maximum efficiency occurs when the internal resistance of the generator (RGEN) equals the load resistance (RL). The generator resistance is: $\mathbf{R_{GEN} = NS \times R_M / NP}$

The generator is needed to power smart phones and some other electronics devices. Our aim is to design a 3.7 to 5-Volt, 1.5 to 2.1 Ampere thermoelectric power generator. The generator is needed to power a range of cell phones. We following steps were used:

Design process:

Step 1

1. The estimated maximum heat from the cooking process produces a 130°C temperature.

2. The idle temperature of the kitchen environment is 10°C.

3. Cold-side temperature of our generator is +30°C.

We obtain the values of SM, RM, and KM for our calculations from thermoelectricity material data book.

Where

1. SM is average Seebeck coefficient in volts/°K.

2. RM is average resistance of the module in watts/°K.

3. KM is thermal conductance of the module in watts/°K.

Step 2

We review the system parameters and make some preliminary calculations.

Given:

$Th = + 130°C = 403.2K$;

$Tc = + 30°C = 303.2K$;

$Vo = 5$ volts;

$I = 2.1$ amperes

Therefore:

$Tav = (Th+Tc)/2 = (403.2+303.2)/2 = 353.2K$;

$RL = Vo/I = 5 / 2.1 = 2.38.0$ ohms. $Po = Vo \times I = 5 \times 2.1 = 10.5$ watts.

$DT = Th-Tc = 403.2 - 303.2 = 100K$.

It is usually desirable to select a relatively "high power" thermoelectric module for generator applications in order to minimize the total system cost. For this reason we will choose a 127 couple, 6-ampere module to be used in our design.

From material data book our selected 127-couple, 6 ampere module, the following values are obtained at Tav = 353.2K:

SM = 0.05544 volts/K (SM is average Seebeck coefficient in volts/°K). RM = 3.0994 ohms (RM is average resistance of the module in watts/°K). KM = 0.6632 watts/K (KM is thermal conductance of the module in watts/°K).

The required power for the load has been calculated as 18 watts. It is now necessary to determine the minimum number of modules needed to meet this load requirement.

The maximum output power from one module is:

Pmax = (SM x DT) 2 /4 x RM = (0.05544 x 100)2 /4 x 3.0994 = 2.479 watts

The minimum number of modules needed is:

NTmin = Po / Pmax = 18 / 2.479 = 7.3 or 8 pieces.

DELIVERABLES

Table 1: deliverables with periods and task schedules.

s/n	**Stages**	**Task/Schedule**

1.	Preliminary	Submission of Inception Report
2.	Stage One (1-6 Months)	Submission of Inception Report
3.	Stage Two (7-8 Months)	Testing and performance evaluation of the thermoelectric device.
4.	Stage 3 (9-16 Month)	Analysis, and prototype production and testing.
5.	Stage 4 (17-22 Month)	Development of user-friendly manual and publishing.
6.	Stage 4 (23-24 Month)	Analysis of results, and submission of final Reports and approved prototype to the Nigerian Communications Commission.

Table 2: Deliverables on stage by stage basis.

Stages (Duration)	Tasks/Schedules	Expected Deliverables to be submitted to NCC
Preliminary	Submission of Inception Report	Report showing stage by stage realizable implementation of the project.
Stage One (1-6 Months)	Design and Development of thermoelectric device.	**Progress Report 1** Submission of follow up report.
Stage Two (7-8 Months)	Testing and performance evaluation of the thermoelectric device.	**Progress Report 2** CD providing evidence of the some testing and evaluation of the thermoelectric device. Sample of paper submitted for publication/published in either a reputable journal or international conference proceeding with NCC duly acknowledged.
Stage 3 (9-16 Month)	Analysis, and prototype production and testing.	**Progress Report 3** Official report and presentation of a produced prototype of Home-Grown Electrical Power Charger for Cellphones from cooking heat.
Stage 4 (17-22 Month)	Development of user-friendly manual and publishing.	**Progress Report 4** Official presentation and hand over of the prototype device, friendly instructional manual and Published articles.
Stage 4	Analysis of results,	**Progress Report 5**

(23-24 Month)	and submission of final Reports and approved prototype to the Nigerian Communications Commission.	Submission of final Reports and approved prototype to the Nigerian Communications Commission.

STAGE II

Testing and Performance Evaluation of some Thermoelectric Device.

INTRODUCTION

Testing and performance evaluation of the Thermoelectric Generator, (TEG) device used in this research protect constituted the second stage research report. The tests are on the Heat source; (cooking heat; firewood, charcoals and cooking gas), Temperature ranges, Rate of heat exchanges across the device, Relationship between heat exchange and the electrical parameters (i).Voltage. (ii). Current. (ii). Power. Testing points and aims are clearly indicated in the test-bed. Readings were taken from each point, evaluated and necessary adjustments made in order to get the aimed parameters. The thermoelectric Device material employed in this research work is based Intermediate temperature (up to 850K). Such materials are based on alloys of Lead, (Pb) i.e lead and copper alloy. The intermediate temperature range of operation of about 850 Kelvin, and the regime Lead alloy-based materials simply qualifies our research work. This is because temperature of the research cooking heat is in this range. The thermoelectric material, alloys of lead (pencils) is easily available in our environment.

METHODOLOGY

In this work, we are looking at harvesting some heat and directly converting *heat* into *electrical energy* enough to charge our smart-phones batteries. Many thermoelectricity developers have produced different kinds of power supply units using this same principleWeiling L etl(2003). An arrangement for the developmental processes of harvesting heat from open fire to electricity is shown in figure one.

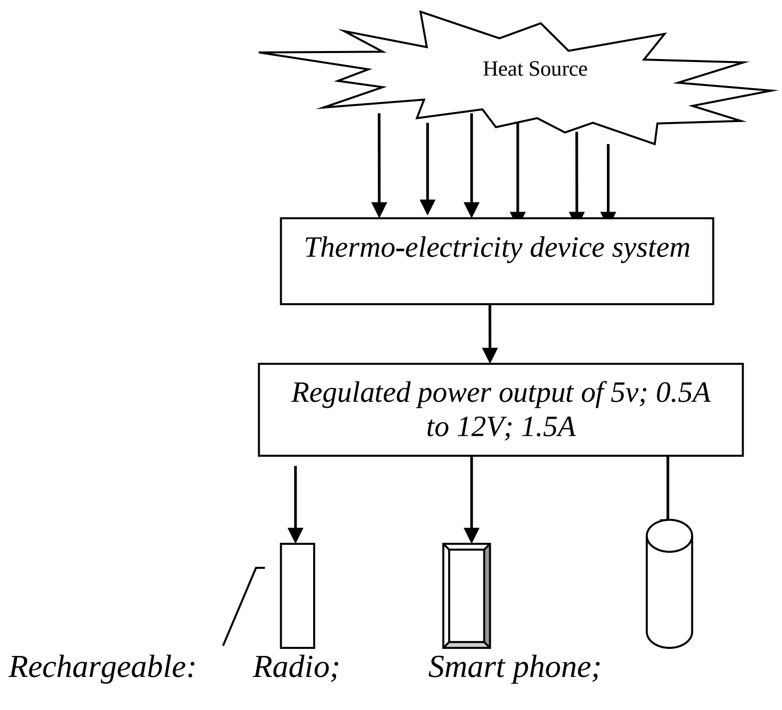


Figure 1: Operational arrangement of heat-to-electrify charger.

BLOCK DIAGRAM OF THE RESEARCH WORK.

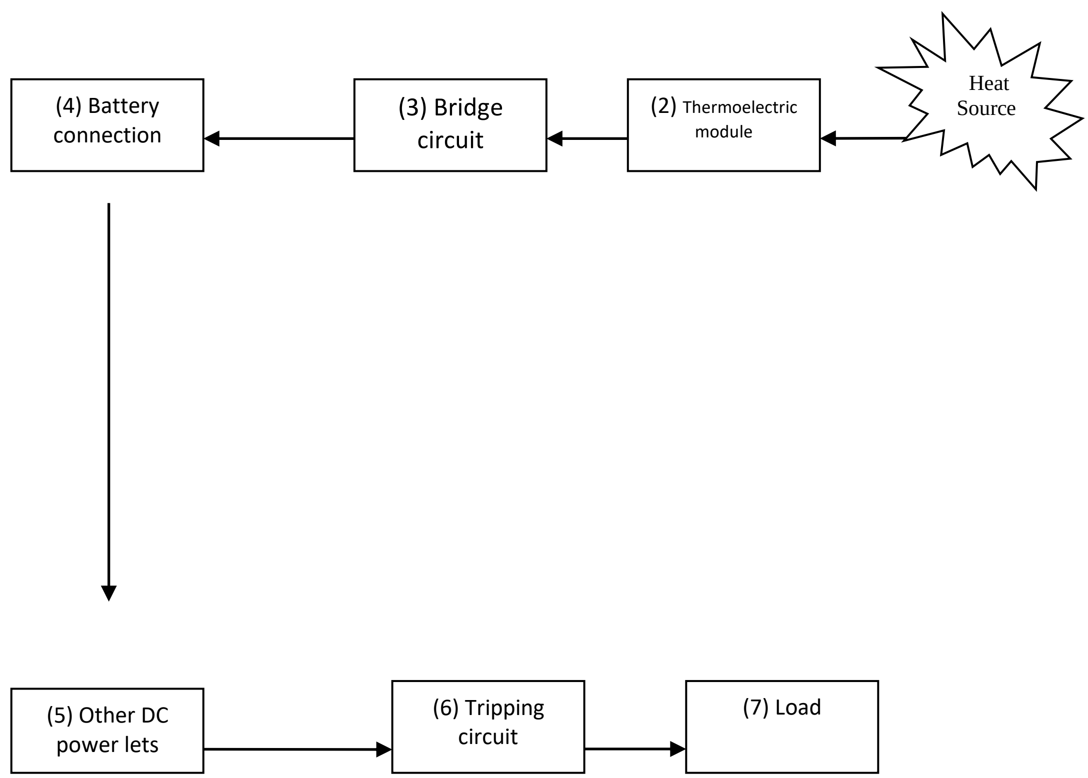


Figure 2: Block diagram of the 12volts, 1.5Amp cell phone charger.

a. **Heat Collector:**

The heat collector arm of this device is constructed with a copper plate. It is designed in form of fire wood so that it can be plugged into the cooking fire or stove freely like every other fire stick. However instead of burning like the woods, it will be absorbing heat into the thermoelectric module (see figure 3.1). Also to enhance the quantity of heat reaching the thermoelectric module is aluminum concave plate directly in contact with the hot side of the thermoelectric module.

b. Thermoelectric Module:

This physical phenomenon where materials develop an electric potential due to temperature difference is known as thermoelectric effect. Here, the thermoelectric modules are positioned in-between the heat harvester. The temperature differences the hot and the cold sides of the heat harvester produce some quantity of electricity.

Thermoelectric modules simply convert a temperature differential across the device, and resulting heat flow through it, into a voltage via the Seebeck effect. The polarity of the output voltage is dependent on the polarity of the temperature differential across the thermoelectric modules. Reverse the hot and cold sides of the thermoelectric modules and the output voltage changes polarity. Thermoelectric modules are made up of pairs or couples of N-doped and P-doped semiconductor pellets connected electrically in series and sandwiched between two thermally conductive ceramic plates. The most commonly used semiconductor material is bismuth-telluride (Bi2Te3).

Thermoelectric modules come in a wide variety of sizes and electrical specifications. The most common modules are square, ranging in size from about 10mm to 50mm per side. They are usually 2mm–5mm thick.

A number of variables control how much voltage a Thermoelectric module will produce for a given ΔT (proportional to the Seebeck coefficient). Their output voltage is in the range of 10 mV/K to 50mV/K of differential temperature (depending on the number of couples), with a source resistance in the range of 0.5Ω to 5Ω.

In general, the more couples a TEG has in series, the higher its output voltage is for a given ΔT. However, increasing the number of couples also increases the series resistance of the TEG, resulting in a larger voltage drop when loaded. Manufacturers can compensate for this by adjusting the size and design of the individual pellets to preserve a low resistance while still providing a higher output voltage.

c. Bridge Circuit:

In DC generation the proper polarity connection is necessary so for this purpose we use bridge circuit to correct polarity instantly.

A diode bridge is an arrangement of four (or more) diodes in a bridge circuit configuration that provides the same polarity of output for either polarity of input. When used in its most common application, for conversion of an alternating current input into a direct current a output, it is known as a bridge rectifier. A bridge rectifier provides a full-wave rectification from a two-wire AC input, resulting in lower cost and weight as compared to a rectifier with a 3-wire input from a transformer with a center-tapapped secondary winding. The essential feature of a diode bridge is that the polarity of the output is the same regardless of the polarity at the input. Battery Connection: Battery is used to store the extra generated power when we need then we use it.

d. Other DC Power Lets: This electricity generator has a controller with dual outputs points. A 5V USB charging port, coupled with a screw terminal that can be wired simultaneously to charge any battery from 1.5v up to 12v and also run LED lighting in Emergency situations when the grid is down.

e. Tripping Circuit:

Tripping circuit which contains (solid state relay, operational amplifier and potentiometer) is used to provide protection to the generation section in case of fault on load side and also stops the battery from the release.

f. Load Points:

With today's larger screen cell phones and rapid charging power requirements this generator is uniquely designed to charge these devices rapidly and effectively.

Test Beds.

Test beds are set up areas and points in this equipment for the purposes of taking readings.

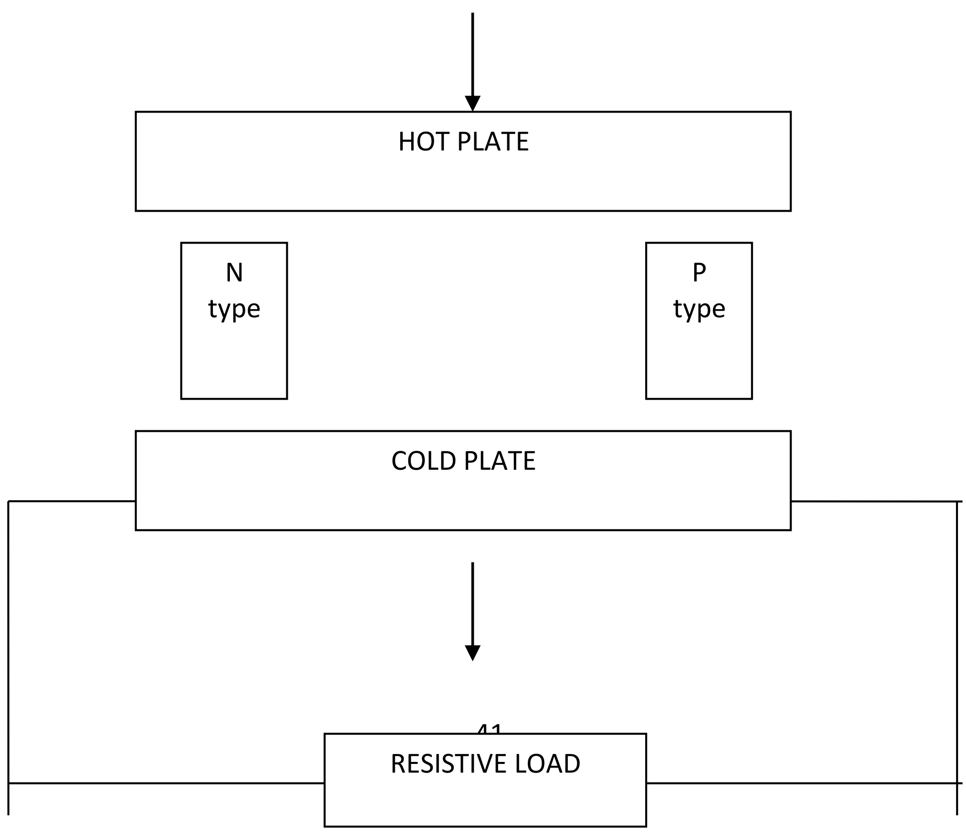


Figure 4a. Schematic diagram of the Thermoelectric Couple.

The aim of this work is to generate much electrical energy from every available heat exchange in this arrangement. The thermoelectric generators are arranged thermally parallel and electrically in series. The electrical efficiency is dependent on the thermal efficiency (i.e. rate of heat exchange across the thermoelectric generator). Although the thermal efficiency is material dependent, this work enhanced it by considering the ambient temperature of the cooking stove. The temperature difference between the two parts of the thermoelectric generator is increased using an additional thermoelectric device to heat the hot part, and an aluminum cooler for maintaining the cold part at quasi constant temperature.

In this research work, some liberated waste heat energy is harvested for the generation of electricity with the help of a thermoelectric generator. A power of about 5W is achieved through the thermoelectric generator. The generated electricity is stored in rechargeable batteries and used further for running a direct current devices like, fan, lighting a LED light, and charging a mobile phone.

Definition of some terms used here:

1. Source temperature (Ts). This term is used to describe the cooking heat and its average temperature. In this case it is the heat generated by the woods and or the charcoal used in the cooking.

2. Hot side temperature (Th). Heat side temperature is the temperature of hot side of the thermoelectric system. The hot side is positioned to face the heat source to harvest the heat.

3. **Cold side temperature (Tc).**Thisisthe temperature of side of the TEG generator with the surrounding. It is dependent on the rate of heat exchange of the device and the ambient temperature.

4. Ambient temperature: This is the temperature of the surrounding. In this work, tests were carried out at different ambient temperatures. Literally one can observe that we have different ambient temperatures in the mornings and afternoons.

5. Temperature Gradients: In thermoelectric process, the rate of heat exchanges across the thermoelectric device determines the rate of voltage being developed.

Measurements and performance evaluations.

These are measurements and evaluations carried out at an average cooking stove (hot side) temperature of about 1023.75 degrees centigrade and at varying ambient (cold side) temperatures of 29, 30, 32, 33 and 36 degrees centigrade. Their measurements and the accompanying graphs are discussed below.

Table 2.1:- Case one: Ambient temperature of 29degrees centigrade and average source (cooking fire) temperature of 1023.75 degrees centigrade.

Time (minutes)	Developed voltage	Hot side temp. (Th)	Cold side Temp. (Tc)	Temp. difference (Td)
1	0.15	49	45	4
2	0.29	56	50	6

3	0.64	66	53	13
4	0.81	74	54	20
5	1.15	81	58	23
6	1.59	82	54	28
7	2.66	97	58	39
8	2.81	98	60	38
9	3.42	108	64	44
10	3.69	131	57	74
11	4.18	144	56	88
12	4.52	153	58	95
13	4.69	158	58	100
14	4.99	160	58	102
15	5.25	159	67	92

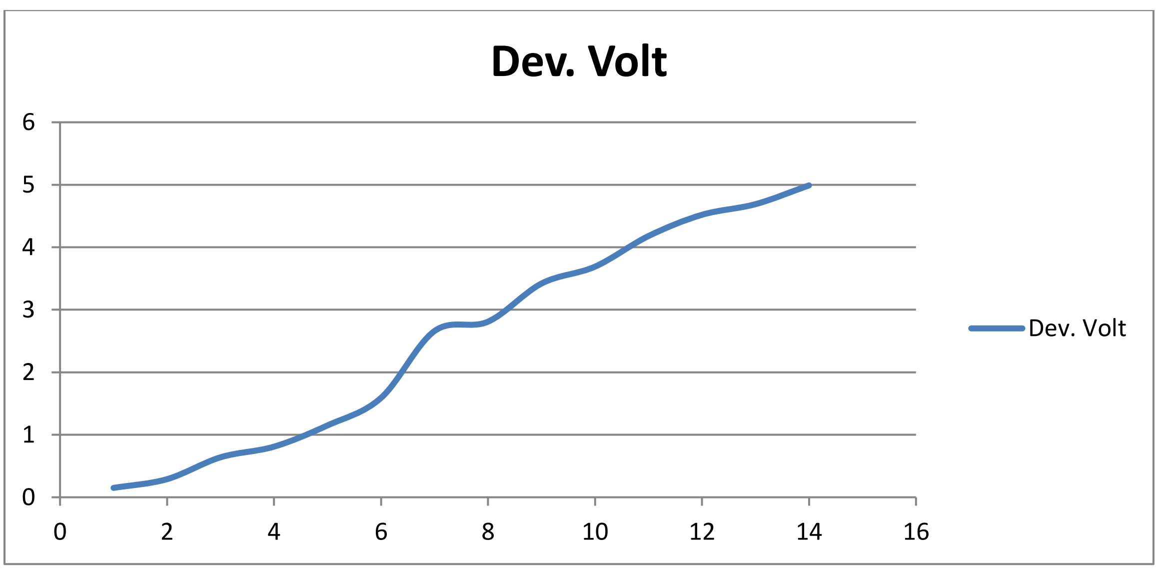


Figure 1a Change in developed voltage with time.

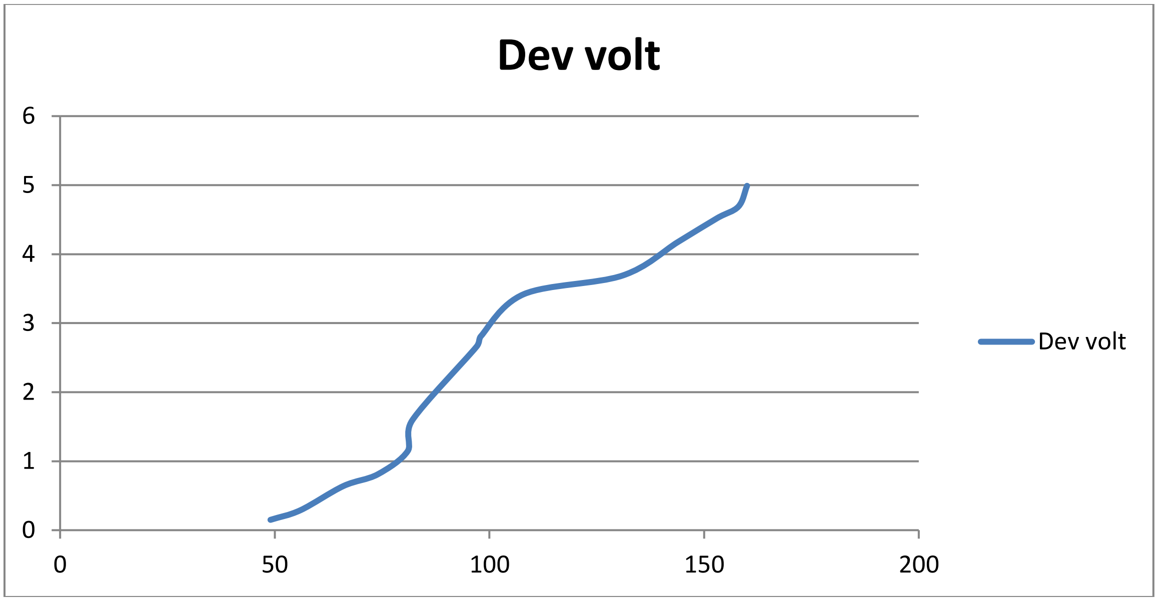


Figure 1b Change in developed voltage with hot side temperature.

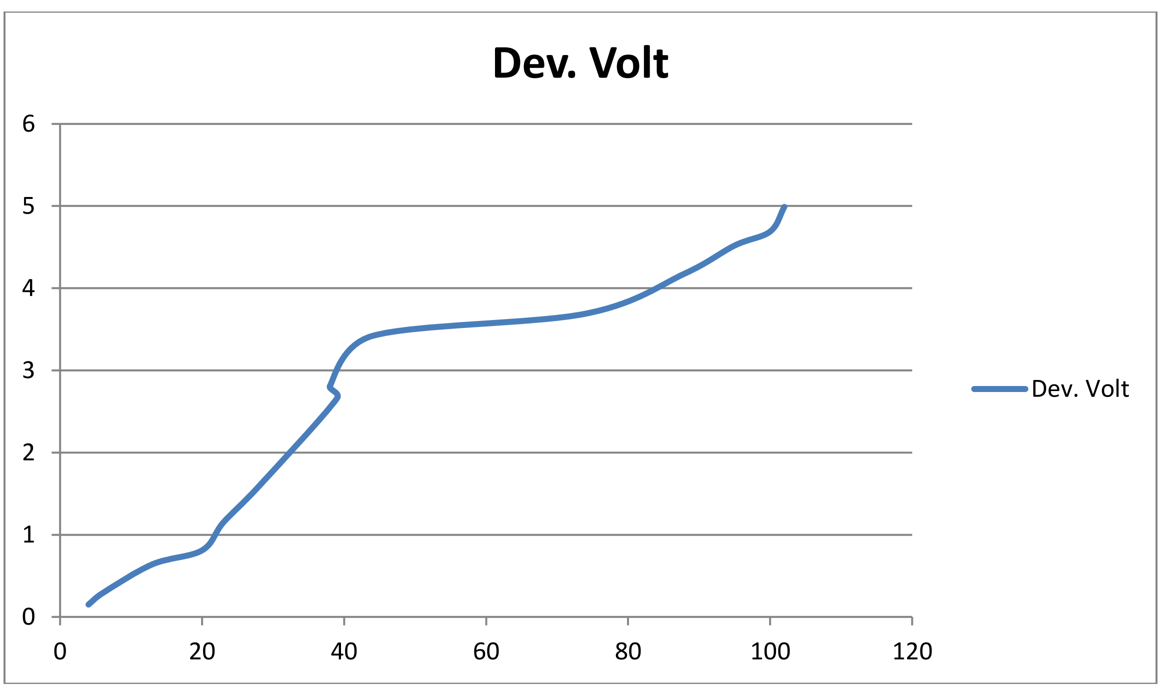


Figure 1c. Change in developed voltage with temperature diff.

Early morning cooking or cool weather, relates to an ambient temperature of 29 degrees centigrade and at source (cooking fire) temperature of 1023.75 degrees centigrade there is a sharp increase in developed voltage and finally it becomes gradual increase. A gradual increase in developed voltage is observed which indicates that there is a corresponding exchange of heat. This indicates that with gradual rise in the hot side temperature, there is a corresponding developed voltage.

Table 2.2:- Case two: - Ambient temperature of 30degrees centigrade and average source (cooking fire) temperature of 1023.75 degrees centigrade**.**

Time (minutes)	Developed voltage	Hot side temp. (Th)	Cold side Temp. (Tc)	Temp. difference (Td)
1	0.25	50	42	9
2	0.39	58	46	12

3	0.60	63	48	15
4	0.67	67	50	17
5	1.01	79	57	22
6	1.09	79	57	22
7	1.30	81	56	25
8	1.87	88	57	31
9	1.97	90	58	31
10	2.31	94	59	35
11	2.50	106	55	51
12	2.86	113	56	57
13	3.50	128	59	69
14	3.66	134	59	74
15	3.98	139	55	84

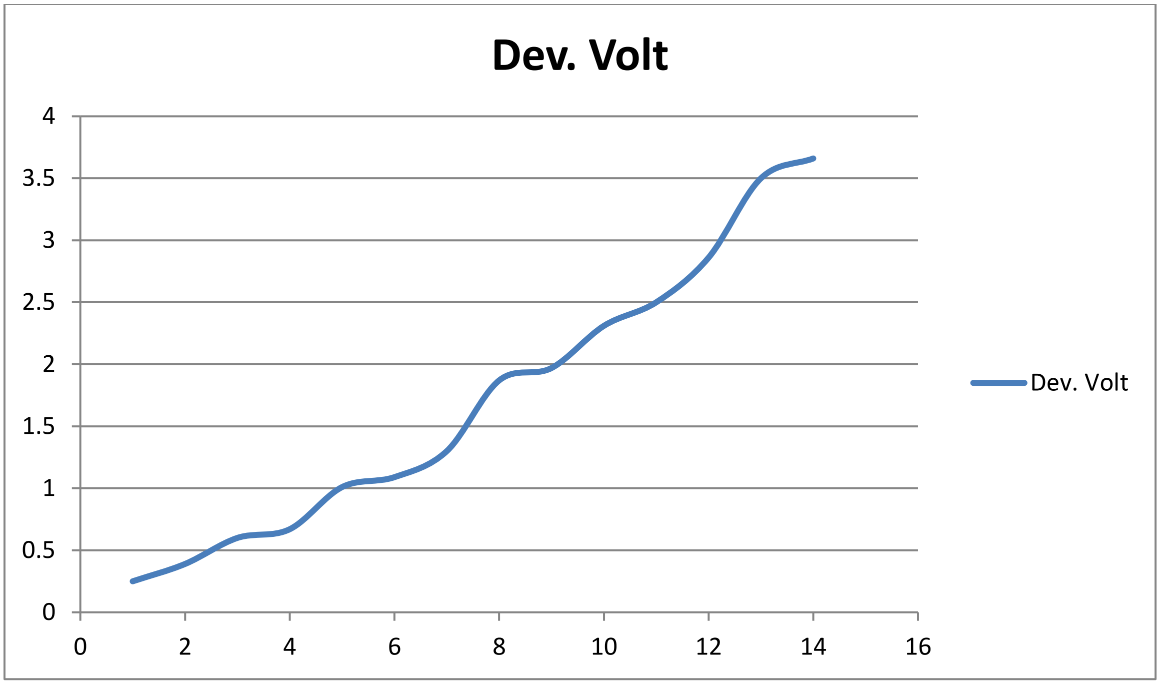


Figure 2a: showing voltage generation with respect to time.

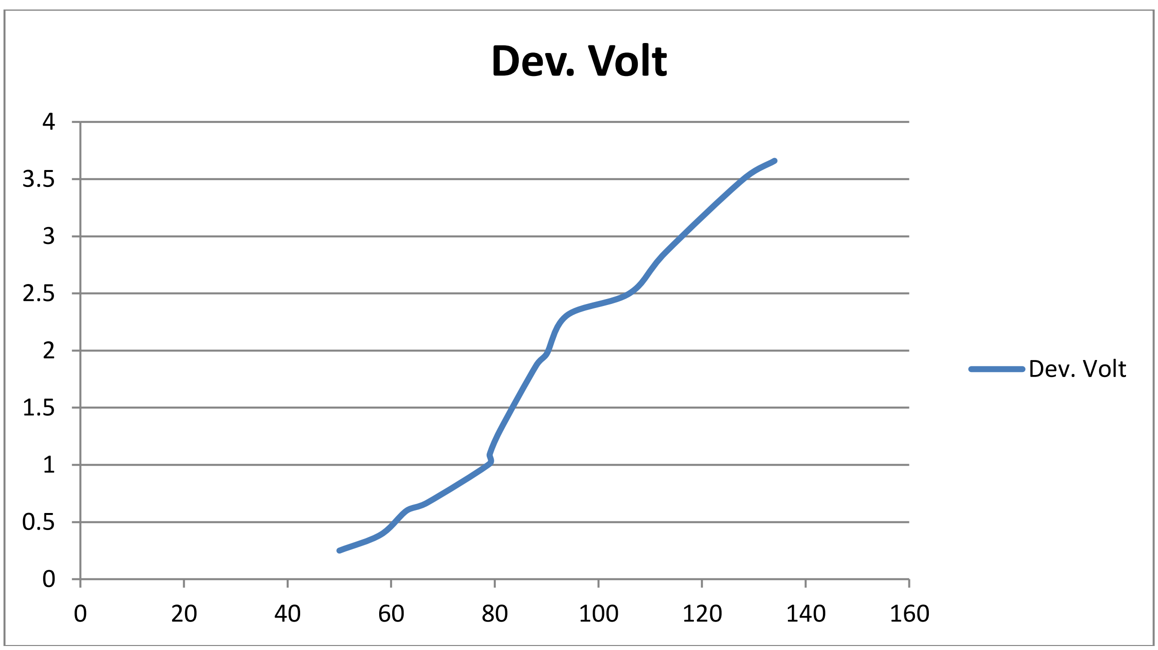


Figure 2b: showing voltage generation with respect to hot side.

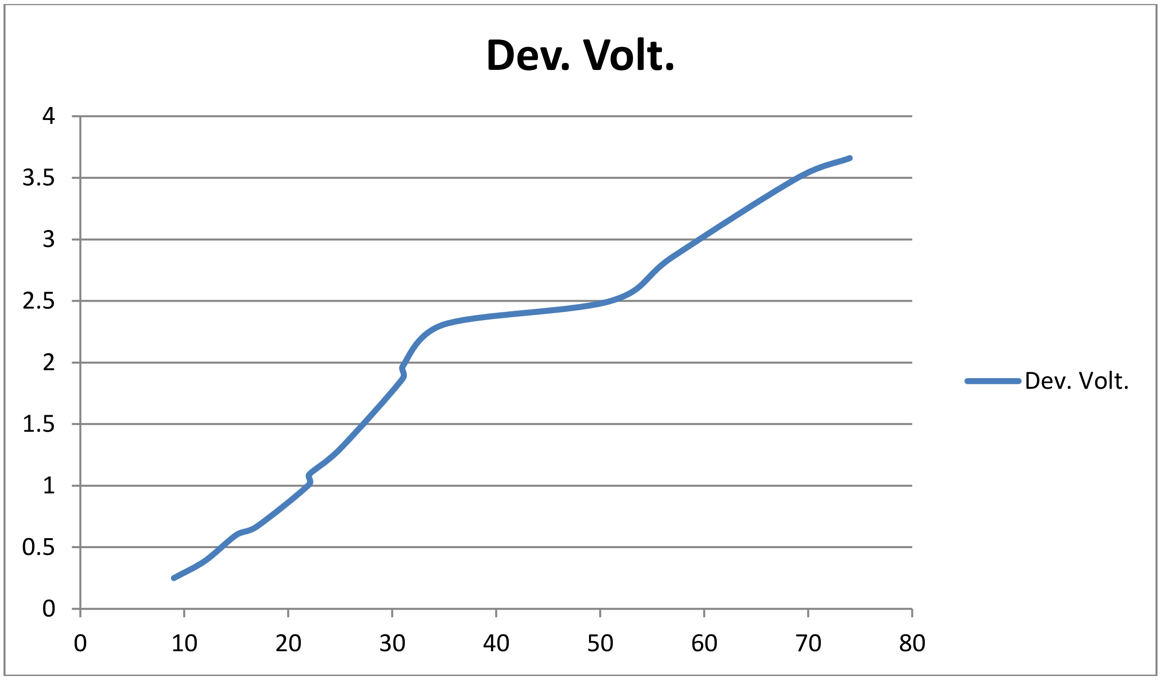


Figure 2c: showing voltage generation with respect to temperature difference.

In figures 2a, b & c, we have plots for developed voltage of the generator with corresponding changes in time, hot side temperature and temperature different respectively. This ambient temperature of 30 degrees centigrade is still taken as cool weather or early morning cooking.

Table 2.3:- Case three: - Ambient temperature of 32degrees centigrade and average source (cooking fire) temperature of 1023.75 degrees centigrade.

Time (minutes)	**Developed voltage**	**Hot side temp. (Th)**	**Cold side Temp. (Tc)**	**Temp. difference (Td)**
1	0.37	51	38	13
2	0.51	60	42	18
3	0.51	59	44	15
4	0.54	61	46	15
5	0.88	78	57	21
6	1.03	80	58	23
7	1.10	80	57	23
8	1.15	81	57	24
9	1.22	80	54	26
10	1.32	81	52	29
11	1.56	83	56	27
12	2.49	103	60	43
13	2.64	110	61	50
14	2.98	119	52	67
15	3.49	141	55	86

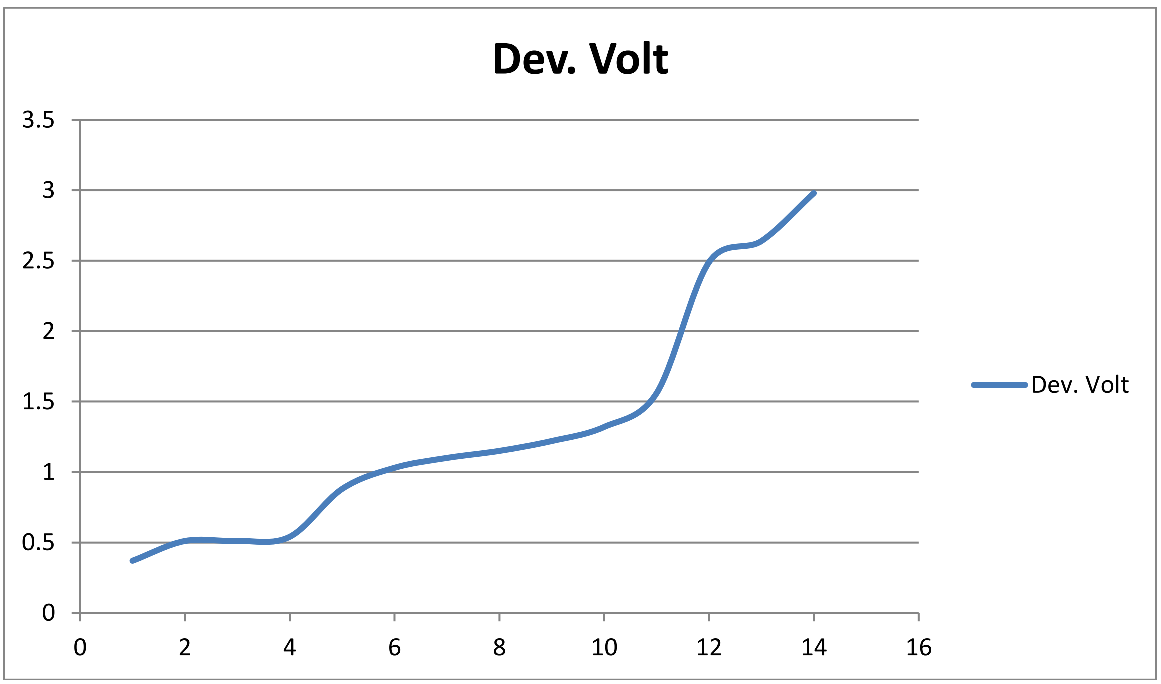


Figure 3a: showing voltage generation with respect to time.

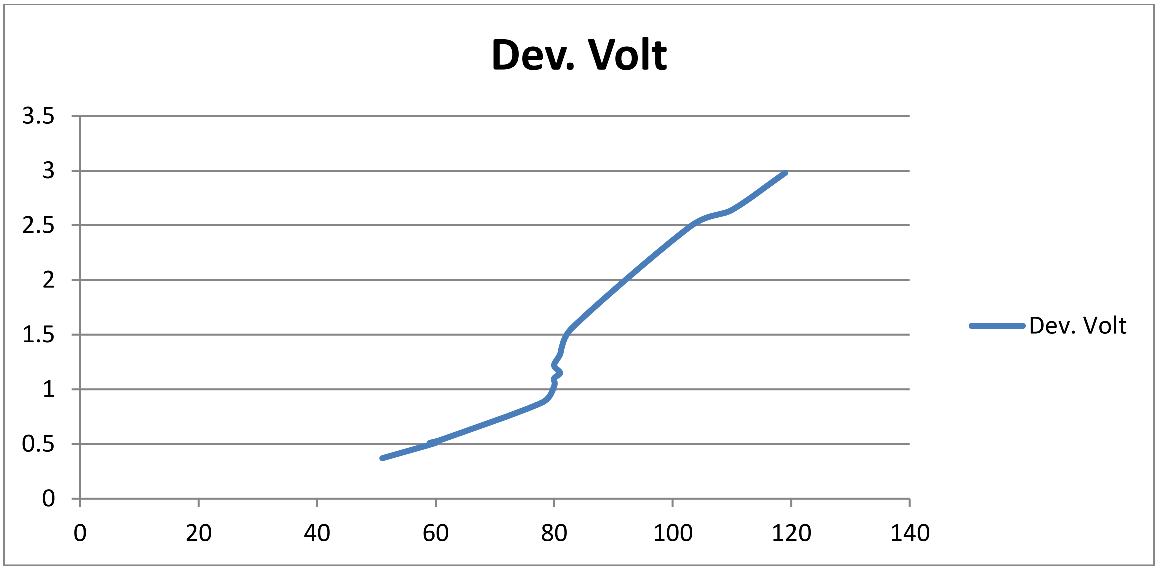


Figure 3b: showing voltage generation with respect to hot side.

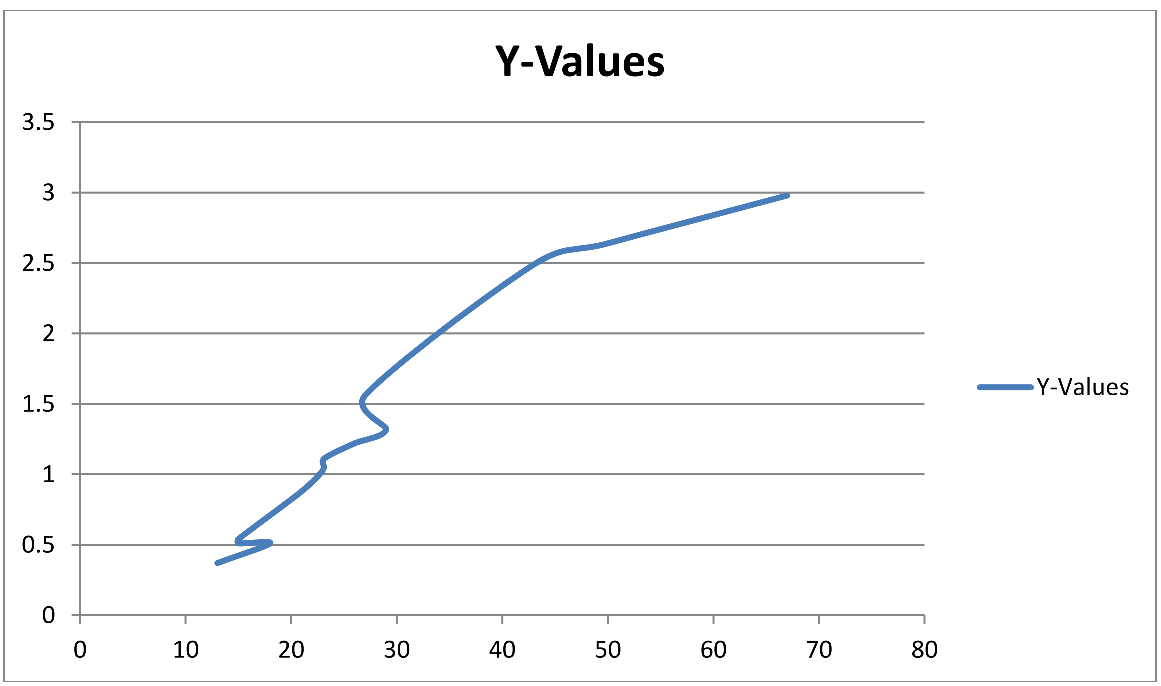


Figure 3c: showing voltage generation with respect to temperature change.

At an ambient temperature of 32degrees centigrade and average source (cooking fire) temperature of 1023.75 degrees centigrade, we are talking about cooking inside a kitchen in the afternoon. The observation here is that temperature different is no longer sharp and so the developed voltage is also no longer sharp.

Table 2.4:-Case four: - Ambient temperature of 33degrees centigrade and average source (cooking fire) temperature of 1023.75 degrees centigrade.

Time (minutes)	Developed voltage	Hot side temp. (Th)	Cold side Temp. (Tc)	Temp. diff. (Td)
1	0.18	48	40	8
2	0.25	53	41	12
3	0.27	52	41	10
4	0.31	54	43	11

5	0.49	62	48	14
6	0.58	64	50	14
7	0.66	65	50	15
8	0.79	70	55	16
9	0.98	74	52	23
10	1.39	82	54	28
11	1.83	93	60	53
12	2.41	110	65	46
13	2.64	123	72	51
14	2.68	128	67	61
15	3.06	136	64	72

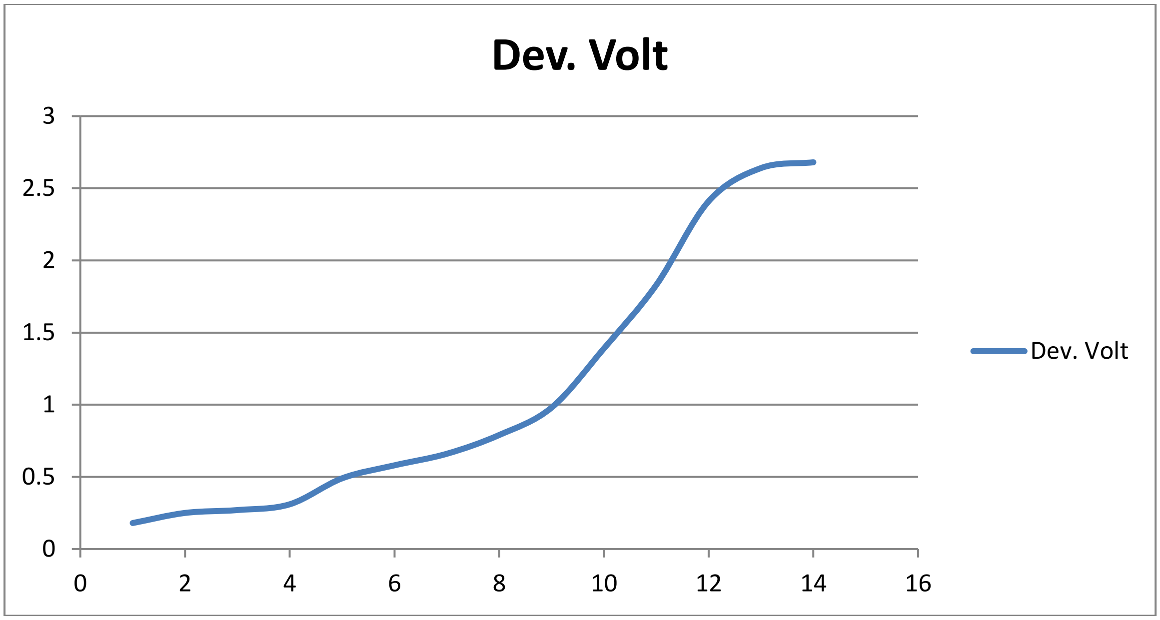


Figure 4a: showing voltage generation with respect to time.

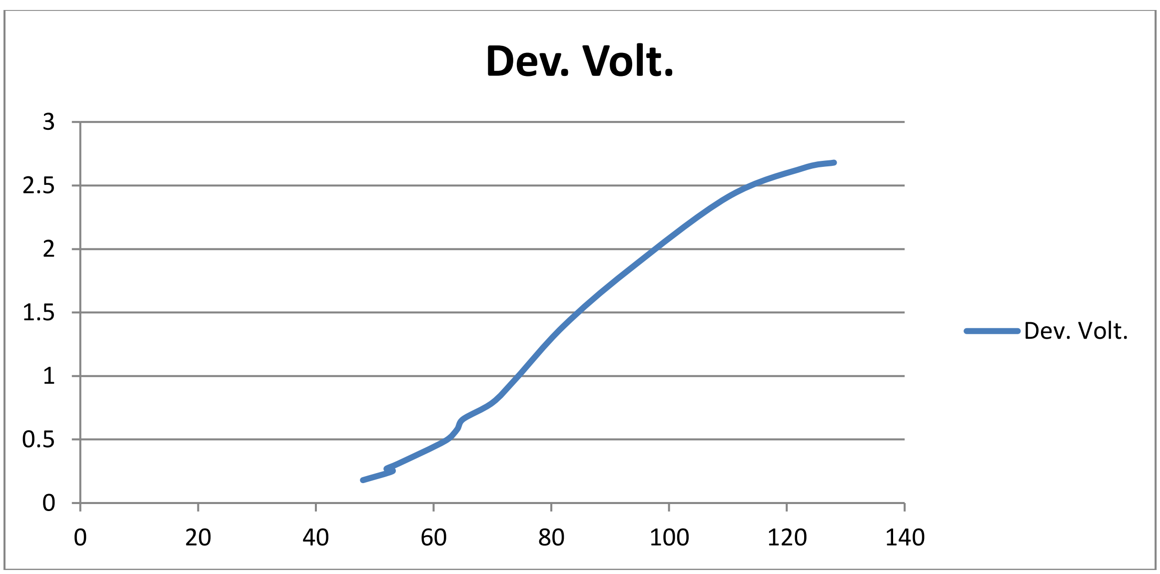


Figure 4b: showing voltage generation with respect to hot side.

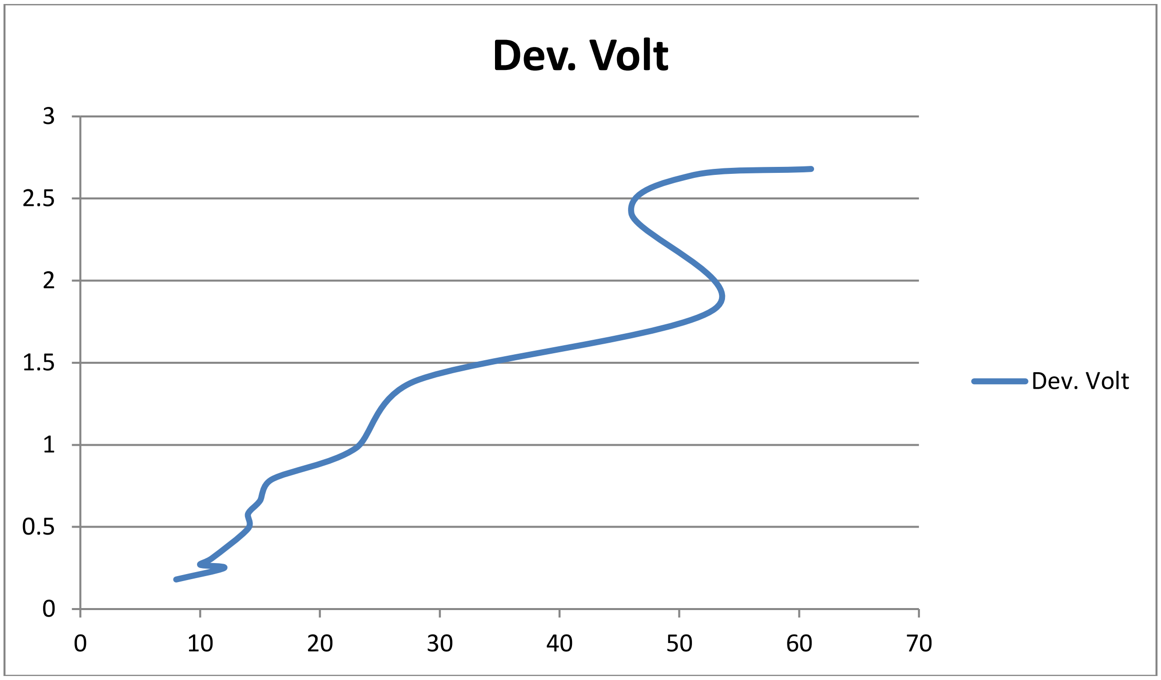


Figure 4c: showing voltage generation with respect to temp change.

Figure 4 shows measurements taken while cooking in the afternoon when the ambient temperature is about 33 degrees centigrade and average source (cooking fire) temperature of 1023.75 degrees centigrade. The observation here is that the temperature different is no longer outstanding and so the developed voltage reduces.

Table 2.5:- Case five: - Ambient temperature of 36 degrees centigrade and average source (cooking fire) temperature of 1023.75 degrees centigrade.

Time (minutes)	Developed voltage	Hot side temp. (Th)	Cold side Temp. (Tc)	Temp. diff. (Td)
1	0.00	47	44	3
2	0.00	48	41	7
3	0.05	47	41	6
4	0.10	49	42	7
5	0.12	49	41	8
6	0.15	50	44	6
7	0.24	52	45	8
8	0.46	63	55	10
9	0.78	72	52	20
10	1.52	87	59	28
11	2.17	107	66	66
12	2.42	122	72	51
13	2.74	141	87	54
14	2.49	141	84	58
15	2.76	136	76	60

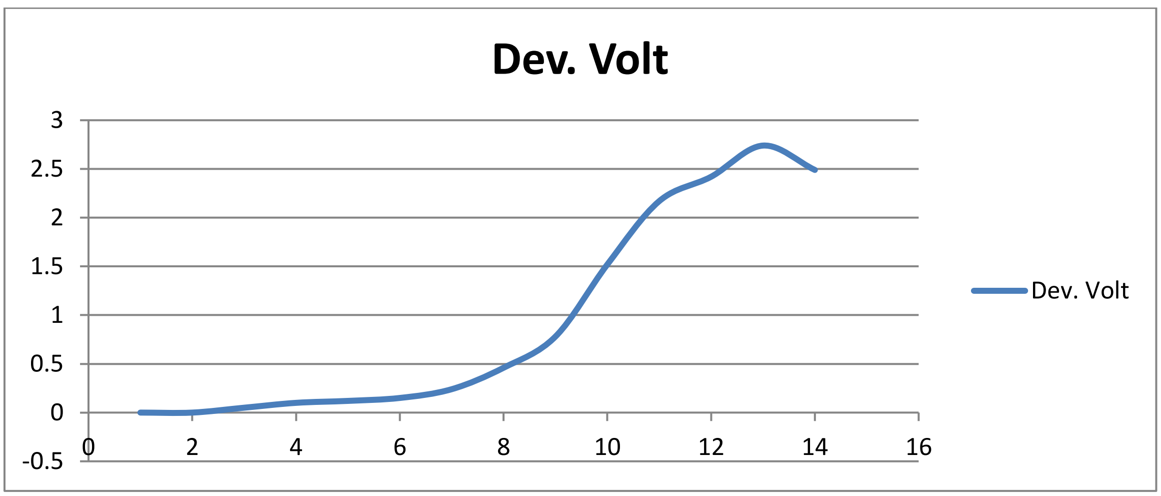


Figure 5a: showing voltage generation with respect to time.

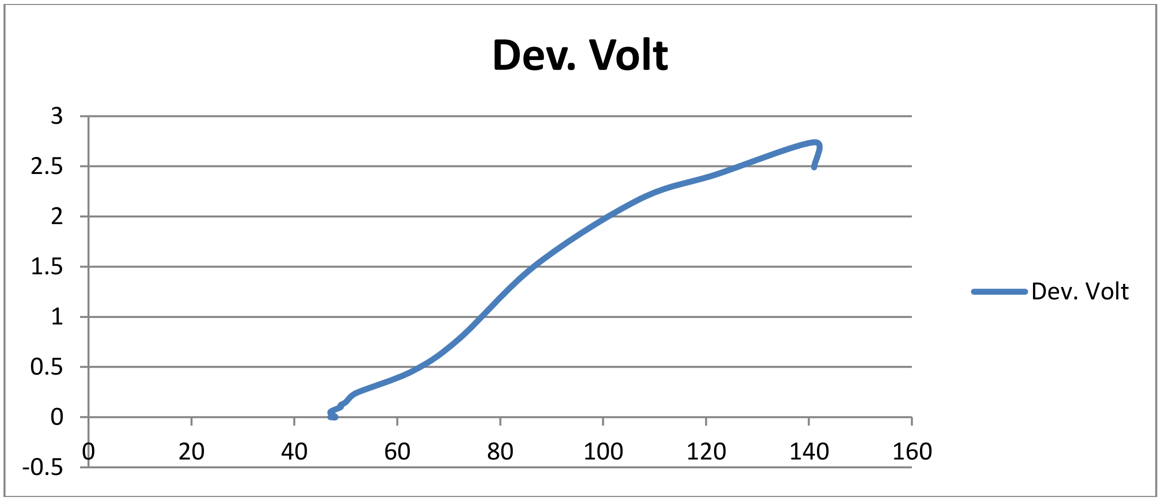


Figure 5b: showing voltage generation with respect to hot side.

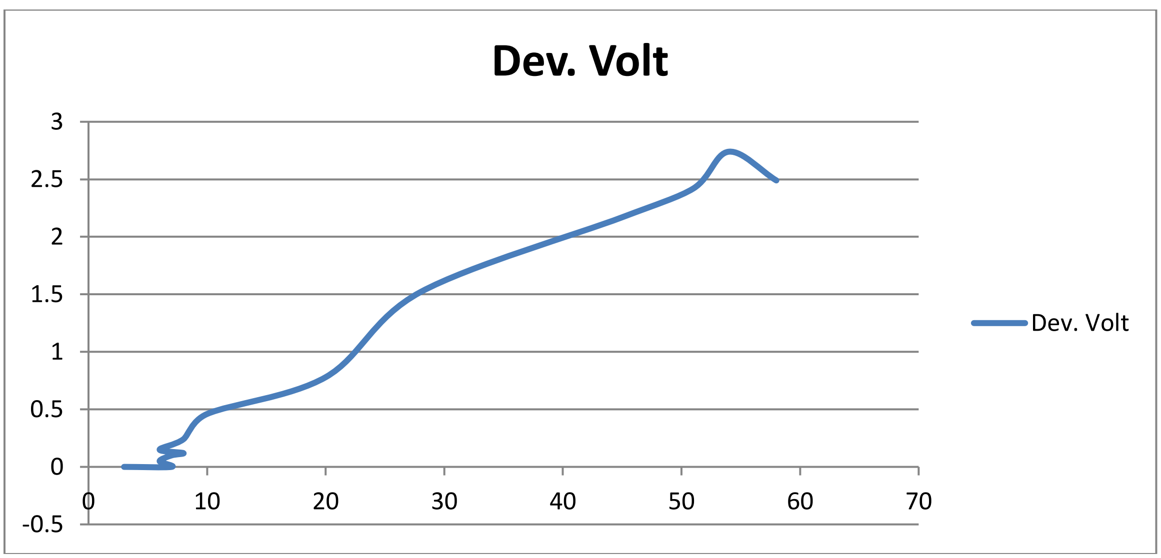
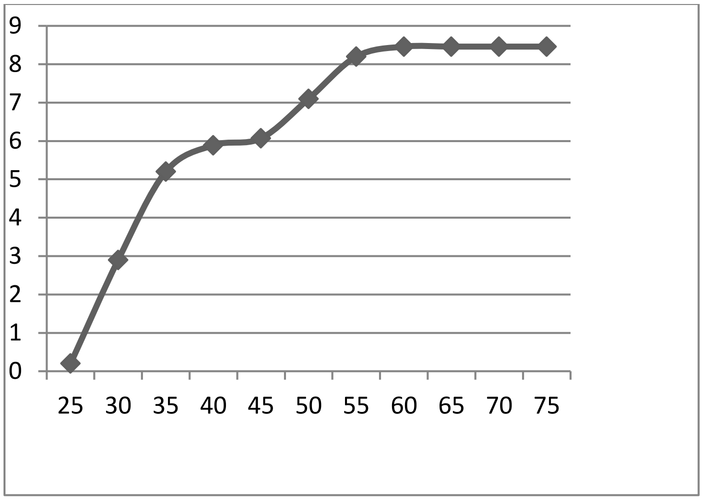


Figure 5c: showing voltage generation with respect to temp change.

Case five: - Ambient temperature of 36 degrees centigrade and average source (cooking fire) temperature of 1023.75 degrees centigrade represents cooking carried out under a very hot weather. The ambient temperature has increased thereby reducing the rate of change in the hot and cold side of the generator. The result includes very low developed voltage with time as can be seen in figure 5a b & c. this situation is palliated wind which blows and brings down the ambient temperature.

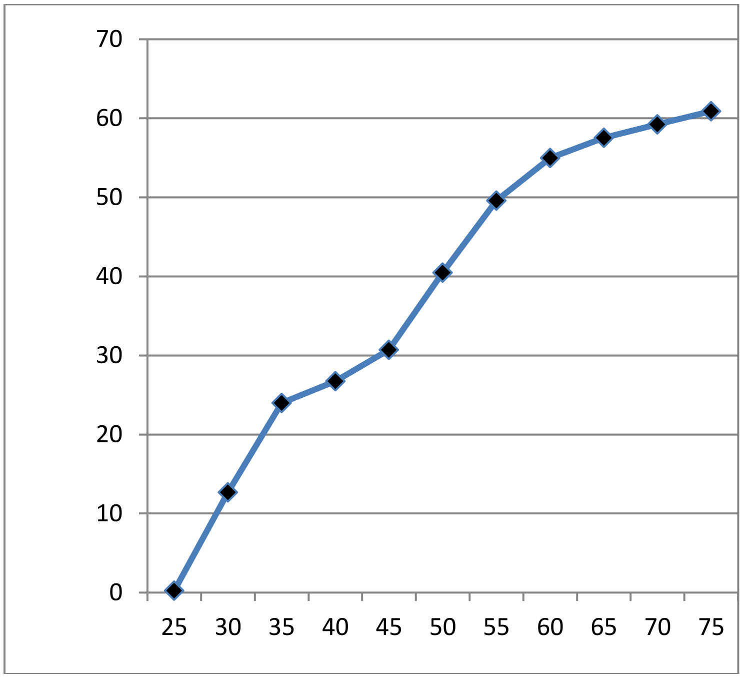


Temp in degrees C	Dev. Voltage
25	0.20
30	2.90
35	5.20
40	5.89
45	6.07
50	7.10
55	8.20
60	8.46
65	8.46
70	8.46
75	8.46

Figure 6:- Relationship between temperature change and developed voltage.

Here we can see an initial sharp rise in developed voltage with reference to rise. At a stage, it dwindles and remains stagnant indicating saturation, indicating the maximum value of voltage the

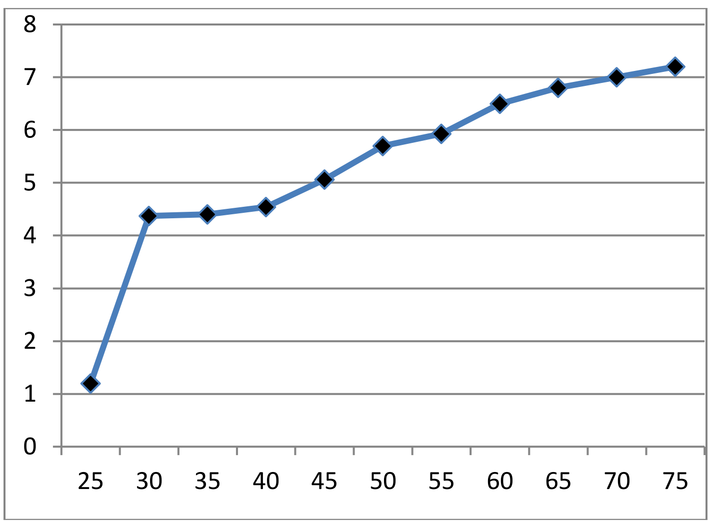
generator can produce. The developed voltage is directly dependent on the temperature till at 55 degrees centigrade when developed voltage remains constant despites temperature increases.



Temp degrees C	**Power in mW**
25	0.24
30	12.67
35	24.01
40	26.74
45	30.721
50	40.47
55	49.60
60	55.00
65	57.52
70	59.22
75	60.90

Figure 7:- Relationship between temperature change and power.

The relationship between temperature change and power was captured with the designed load cell phone (with some internal resistance) was connected. The power rose steadily initially, started dwindling and became constant as can be seen in figure 7. This suggests that the power output dwindles at higher temperatures.



X-axis Temp in degrees C	Y-axis Current in mA
25	1.20
30	4.37
35	4.40
40	4.54
45	5.06
50	5.70
55	5.93
60	6.50
65	6.80
70	7.00
75	7.20

Figure 8:-Relationship between temperature change and current.

The relationship between temperature change and current can be seen in figure 8. The steady rise in current with initial rise in temperatures is clearly shown in this figure. However, this situation was ameliorated by lowering the ambient temperature and hence increasing the change in temperature.

Stage III

Prototype Production and Testing

Introduction

In the first place, it is observed that best results come when the intensity of the heat absorptions and disseminations on the thermoelectric device are maximized. It is therefore recommended that elements like heat blowers and sinks be incorporated in the design and construction. The sizes and capacities of the blowers and corresponding heat-sinks are necessitated by the level of demand and size of devices to be produced. The increasing concern of environmental issues of emissions, in particular global warming and the constraints on energy sources has resulted in extensive research into innovative technologies of generating electrical power and thermoelectric power generation have emerged as a promising alternative green technology.

There are vast quantities of heat waste discharges into the earth's environment much of it at temperatures that are too low to recover using conventional electrical power generators, Min G, (2004). However, thermoelectric power generation comes with a technology of direct conversion of waste-heat energy, into electrical energy and hence power. This technology is being utilized in a number of useful applications due to their distinct advantages. There are micro- and macro-scale applications depending on the potential amount of heat waste energy available for direct conversion. Micro-scale applications included those involved in powering electronic devices, such as microchips. Since the scale at which these devices can be fabricated from thermoelectric materials and applied depends on the scale of the miniature technology available. Therefore, it is expected that future developments of these applications tend to move towards nano-technology.

Production Tests

Many tests were carried out in order to ascertain the proper arrangement and settings for the production.

Figure 3.1 One of the test-beds using a popular charcoal stove.

Figure 3.2:- Prototype I of the generator.

TESTS CARRIED OUT ON PRODUCTION

This analysis and subsequent production /testing was done under by considering the following:

1. The ambient temperature at time of testing.

2. The source temperature used in testing

3. An external action/device employed to enhance heat exchange between the source and the ambient.

4. The number and arrangement of the devices.

1. The ambient temperature at time of testing analysis.

This is the temperature of the surrounding. In this work, tests were carried out at different ambient temperatures. Literally one can observe that we have different ambient temperatures in the mornings /afternoons, in the winter/summers and also in cold/hot regions of the earth.

Table 3.1: Developed Voltages at different Ambient Temperatures of 29C, 30C, 32C, 33C, and 36C taken at intervals of time.

Time	29 C	30 C	32 C	33 C	36 C
1	0.15	0.25	0.37	0.18	0
2	0.29	0.39	0.51	0.25	0
3	0.64	0.6	0.51	0.27	0.05
4	0.81	0.67	0.54	0.31	0.1
5	1.15	1.01	0.88	0.49	0.12
6	1.59	1.09	1.03	0.58	0.15
7	2.66	1.3	1.09	0.66	0.24
8	2.81	1.87	1.26	0.79	0.46
9	3.42	1.97	1.39	0.98	0.78
10	3.69	2.31	1.43	1.21	1.11
11	4.18	2.5	2	1.83	1.61

12	4.52	2.86	2.49	2.11	1.89
13	4.69	3.5	2.64	2.31	2.1
14	4.99	3.66	2.98	2.68	2.49
15	5.25	3.98	3.49	3.06	2.76

Table 3.2. Ambient temperature of 29degrees centigrade and average source (cooking fire) temperature of 1023.75 degrees centigrade.

Time (minutes)	Developed voltage	Hot side temp. (Th)	Cold side Temp. (Tc)	Temp. difference (Td)
1	0.15	49	45	4
2	0.29	56	50	6
3	0.64	66	53	13
4	0.81	74	54	20
5	1.15	81	58	23

6	1.59	82	54	28
7	2.66	97	58	39
8	2.81	98	60	38
9	3.42	108	64	44
10	3.69	131	57	74
11	4.18	144	56	88
12	4.52	153	58	95
13	4.69	158	58	100
14	4.99	160	58	102
15	5.25	159	67	92

Table 3.4:- Ambient temperature of 30degrees centigrade and average source (cooking fire) temperature of 1023.75 degrees centigrade.

Time (minutes)	Developed voltage	Hot side temp. (Th)	Cold side Temp. (Tc)	Temp. difference (Td)

1	0.25	50	42	9
2	0.39	58	46	12
3	0.60	63	48	15
4	0.67	67	50	17
5	1.01	79	57	22
6	1.09	79	57	22
7	1.30	81	56	25
8	1.87	88	57	31
9	1.97	90	58	31
10	2.31	94	59	35
11	2.50	106	55	51
12	2.86	113	56	57
13	3.50	128	59	69
14	3.66	134	59	74
15	3.98	139	55	84

Table 3.5:- Ambient temperature of 32degrees centigrade and average source (cooking fire) temperature of 1023.75 degrees centigrade.

Time (minutes)	Developed voltage	Hot side temp. (Th)	Cold side Temp. (Tc)	Temp. difference (Td)
1	0.37	51	38	13
2	0.51	60	42	18
3	0.51	59	44	15
4	0.54	61	46	15
5	0.88	78	57	21
6	1.03	80	58	23
7	1.10	80	57	23
8	1.15	81	57	24
9	1.22	80	54	26
10	1.32	81	52	29
11	1.56	83	56	27
12	2.49	103	60	43
13	2.64	110	61	50
14	2.98	119	52	67
15	3.49	141	55	86

Table 3.6:- Ambient temperature of 33degrees centigrade and average source (cooking fire) temperature of 1023.75 degrees centigrade.

Time (minutes)	Developed voltage	Hot side temp. (Th)	Cold side Temp. (Tc)	Temp. diff. (Td)
1	0.18	48	40	8
2	0.25	53	41	12
3	0.27	52	41	10
4	0.31	54	43	11
5	0.49	62	48	14
6	0.58	64	50	14
7	0.66	65	50	15
8	0.79	70	55	16
9	0.98	74	52	23
10	1.39	82	54	28
11	1.83	93	60	53
12	2.41	110	65	46
13	2.64	123	72	51
14	2.68	128	67	61
15	3.06	136	64	72

Table 3.7:- Ambient temperature of 36 degrees centigrade and average source (cooking fire) temperature of 1023.75 degrees centigrade.

Time (minutes)	Developed voltage	Hot side temp. (Th)	Cold side Temp. (Tc)	Temp. diff. (Td)
1	0	47	44	3
2	0	48	41	7
3	0.05	47	41	6
4	0.1	49	42	7
5	0.12	49	41	8
6	0.15	50	44	6
7	0.24	52	45	8
8	0.46	63	55	10
9	0.78	72	52	20
10	1.52	87	59	28
11	2	107	66	41
12	2.42	122	72	51
13	2.74	141	87	54
14	2.49	141	84	58
15	2.76	136	76	60

STAGE IV

ANALYSIS OF RESULTS

AND PROTOTYPE

Introduction

Prototype production and testing of this project have been thoroughly carried out as is being reported. Here we are discussing an assemblage used in evaluating the product performances like endurance test among other functionalities. Typically the production of prototype included all product features designed or required for the target manufacturing process and full product. We verified the functionality of the design, the engineering and review the appearance of the product for necessary updates in the full mass production. The tests and analysis enable the presentation of the product more effectively to customers and consumers without the full production or final tooling costs and challenges. This is a representation of our work before the final production. It allows for better understanding by consumers to understand the product. The results of the tests, experiments and analysis prove that this heat-to-electricity conversion device authentic. Observations made during these analyses are discussed here.

Chart Graphical analysis

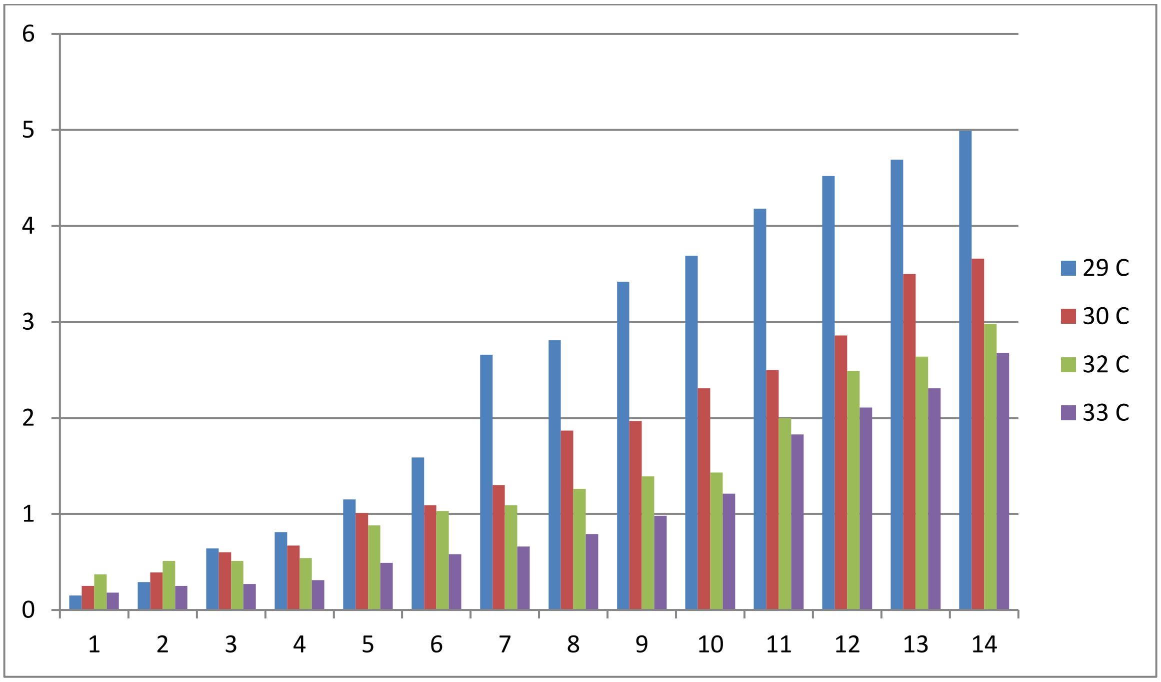


Figure 5.1: Chart analysis of the developed voltages at various ambient temperatures with time.

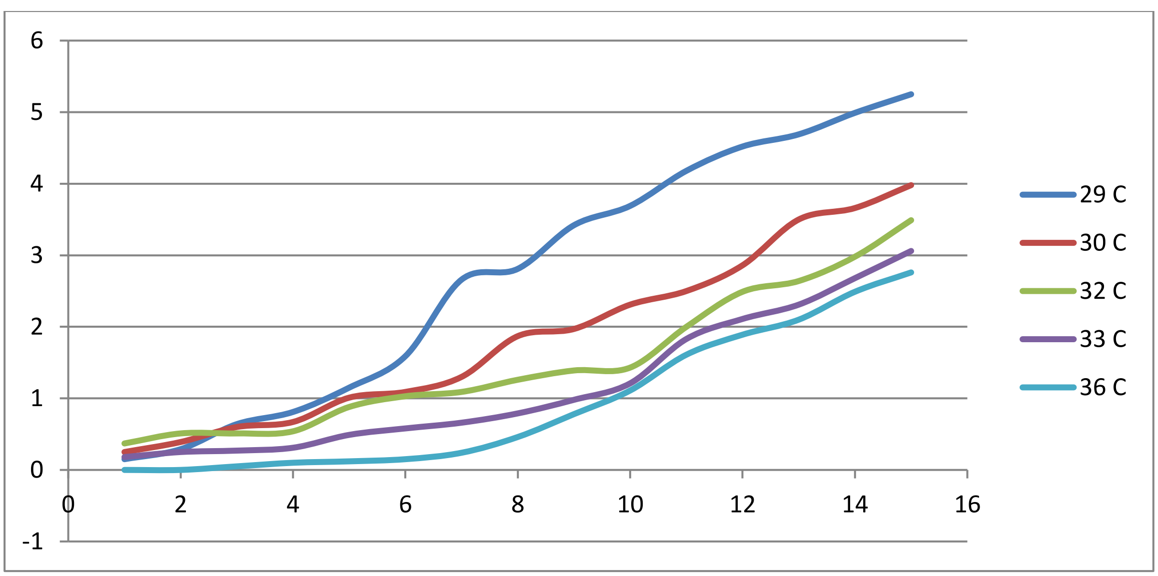
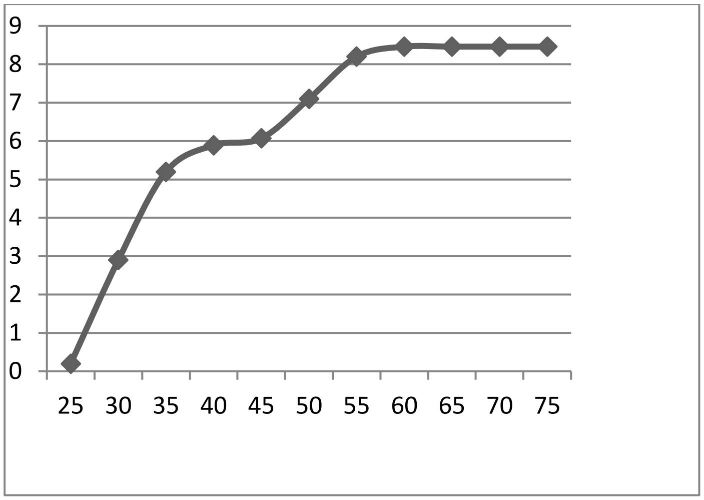
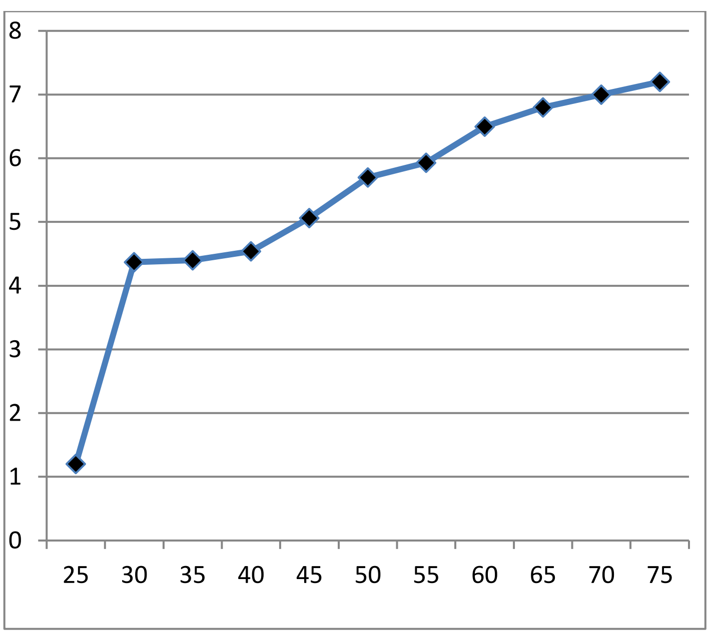


Figure 5.2: Graphical analysis of the developed voltages



Temp degrees C	Y-axis output Voltage
25	0.20
30	2.90
35	5.20
40	5.89
45	6.07
50	7.10
55	8.20
60	8.46
65	8.46
70	8.46
75	8.46

Figure 5.3 Relationship between source temperature and voltage.



X-axis source temp **in degrees C**	**Y-axis** current ou **in mA**
25	1.20
30	4.37
35	4.40
40	4.54
45	5.06
50	5.70
55	5.93
60	6.50
65	6.80
70	7.00
75	7.20

Figure 5.4: Relationship between source temperature and current output.

Source temp. in degrees C	Power output in mW
25	0.24
30	12.67
35	24.01
40	26.74
45	30.721
50	40.47
55	49.60
60	55.00
65	57.52
70	59.22
75	60.90

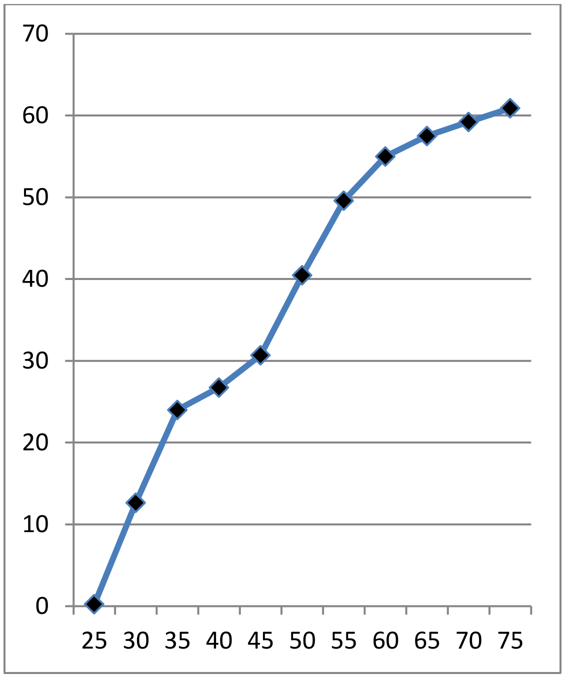


Figure 5.5:- Relationship between source temperature and power output.

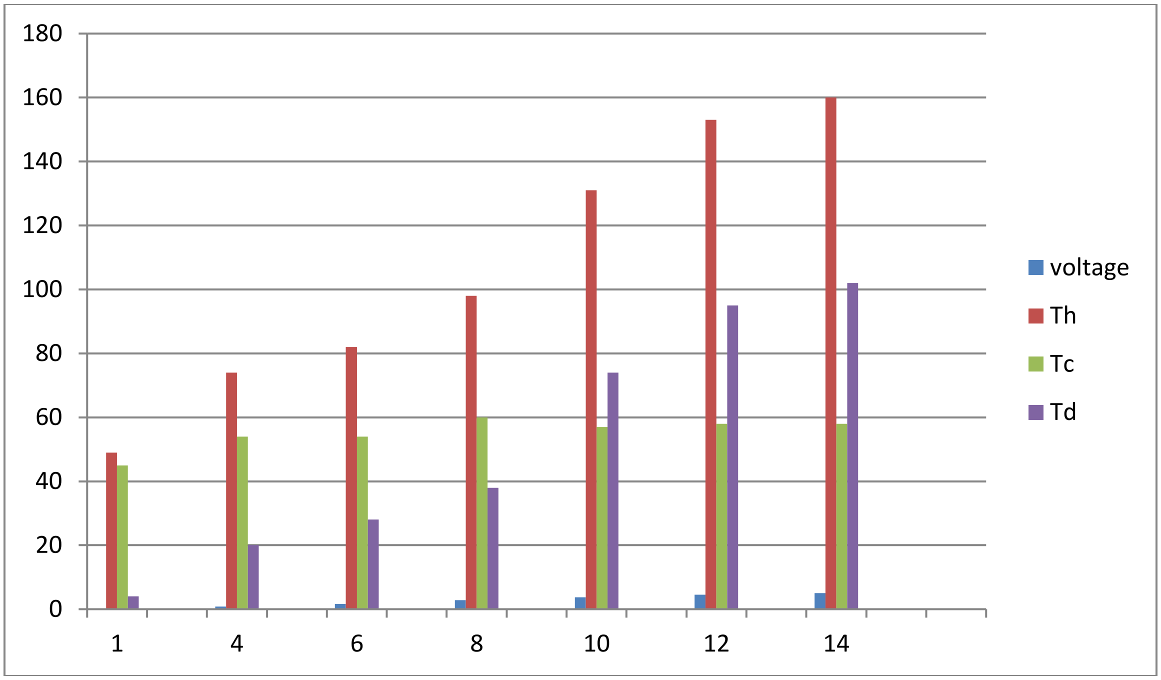


Figure 5.6:- Relationship developed voltage and temperature difference at ambient temperature of 29 C.

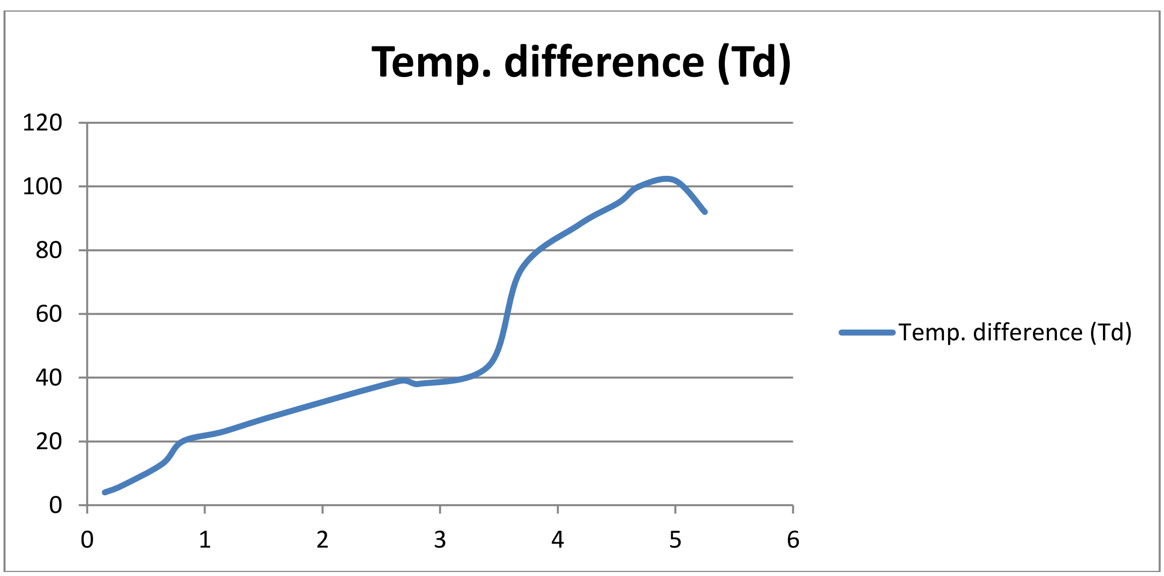


Figure 5.7:- Relationship developed voltage and temperature difference at ambient temperature of 29 C.

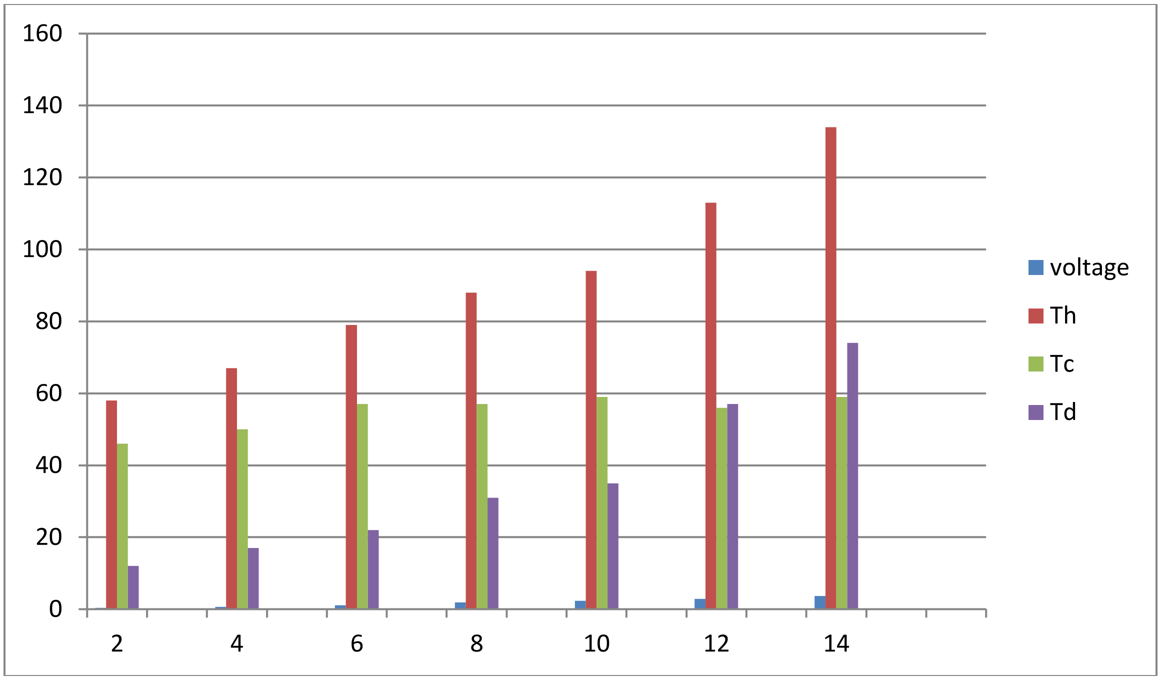


Figure 5.8:- Relationship developed voltage and temperature difference at ambient temperature of 30 C.

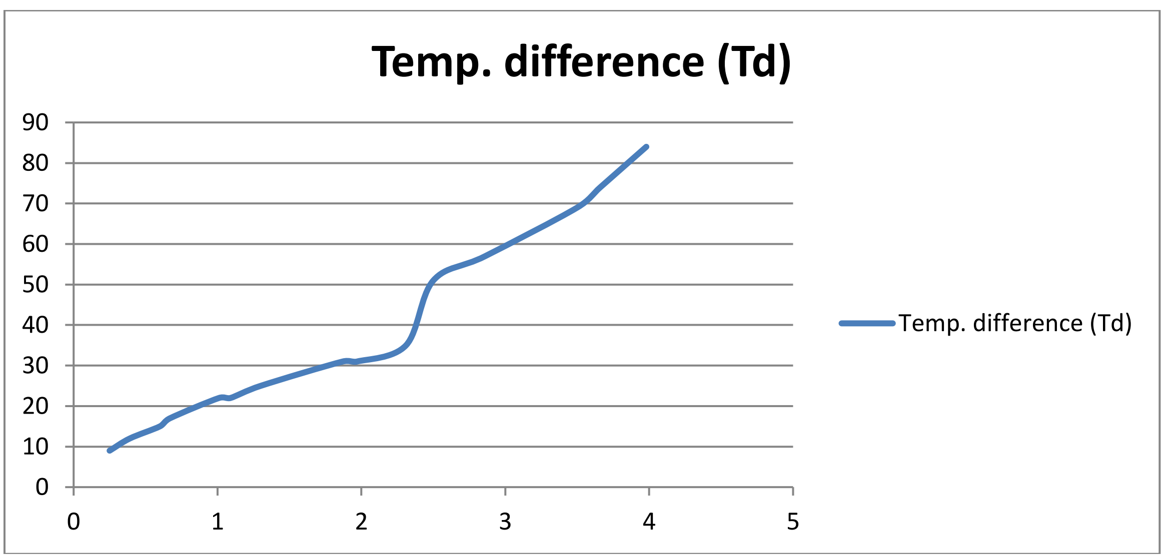


Figure 5.9:- Relationship developed voltage and temperature difference at ambient temperature of 30 C.

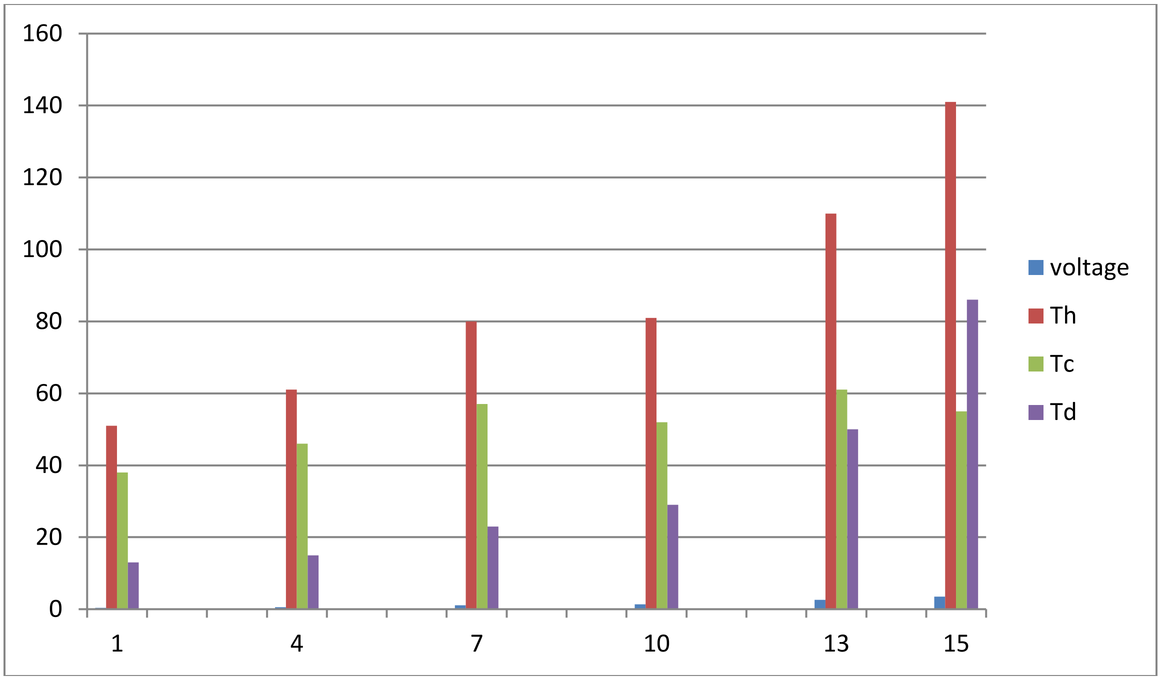


Figure 5.10:- Relationship developed voltage and temperature difference at ambient temperature of 32 C.

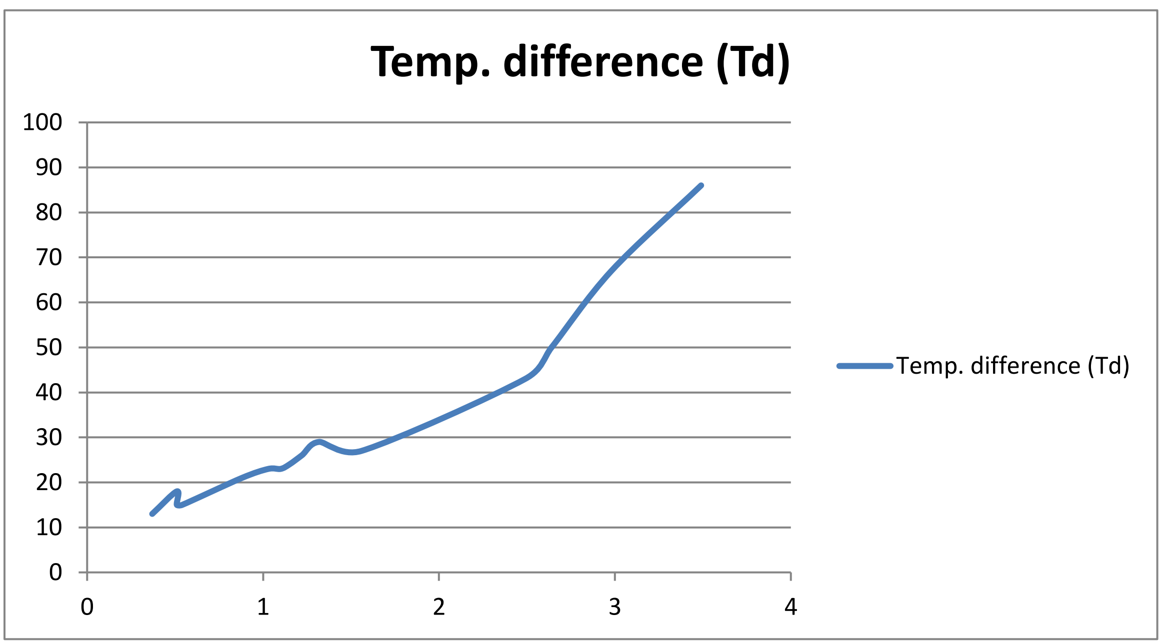


Figure 5.11:- Relationship developed voltage and temperature difference at ambient temperature of 32 C.

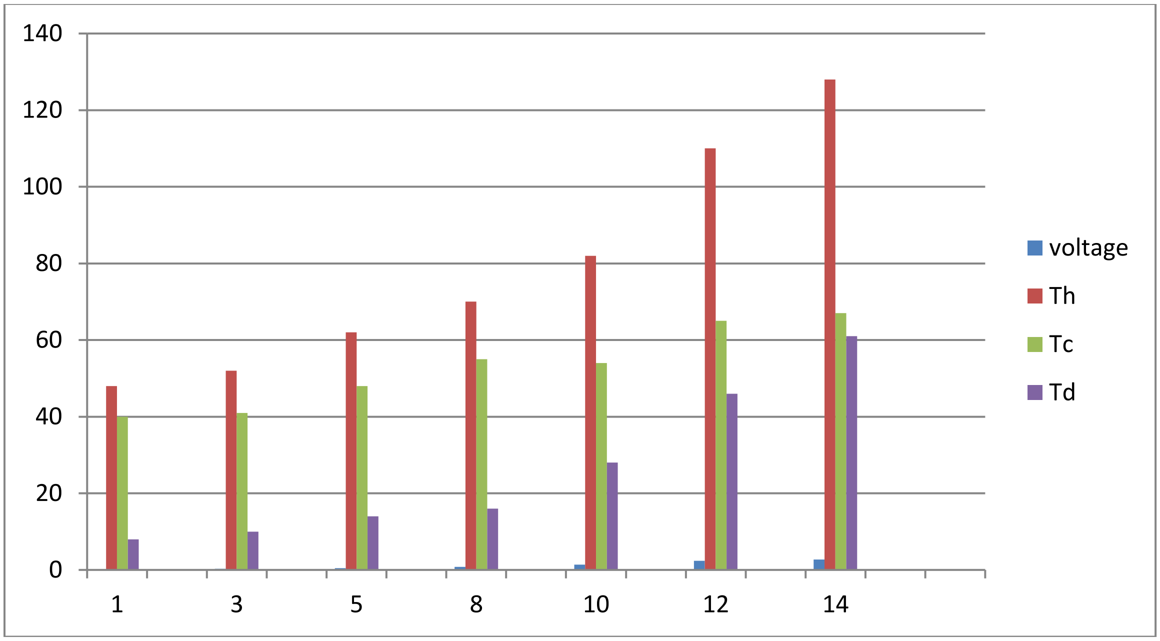


Figure 5.12:- Relationship developed voltage and temperature difference at ambient temperature of 33 C.

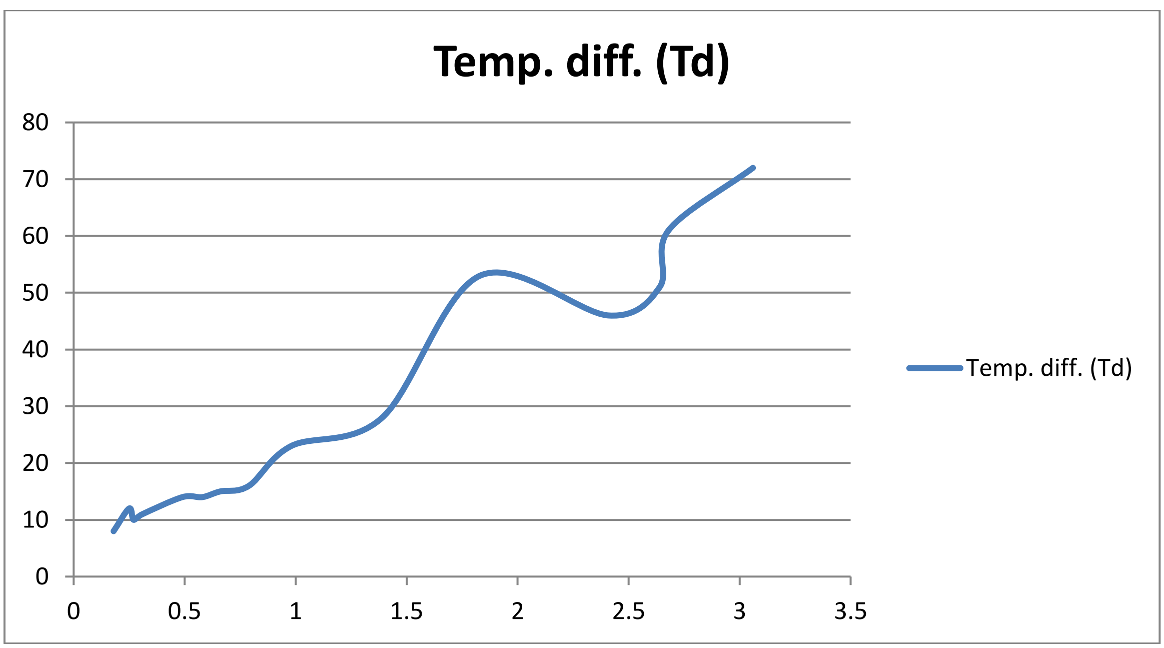


Figure 5.13:- Relationship developed voltage and temperature difference at ambient temperature of 33 C.

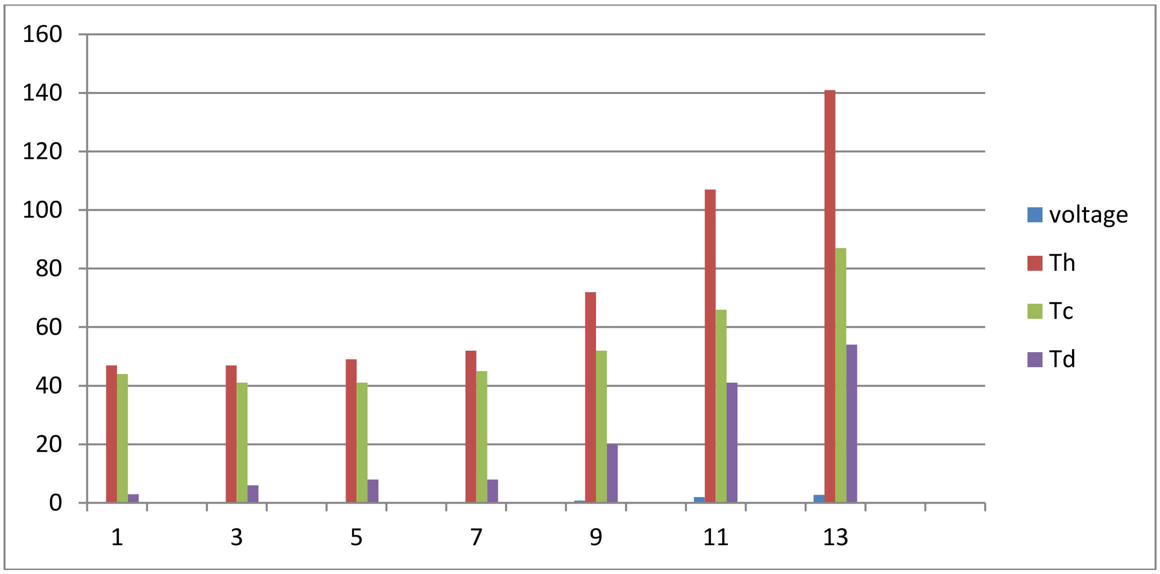


Figure 5.14:- Relationship developed voltage and temperature difference at ambient temperature of 36 C.

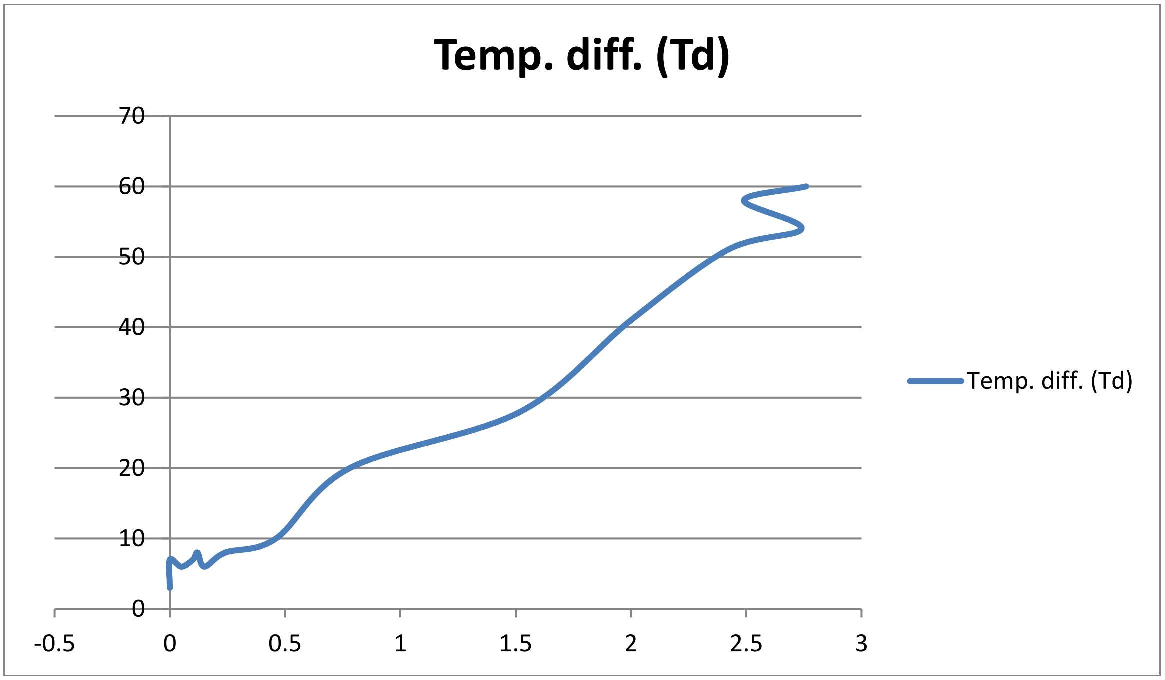


Figure 3.15:- Relationship developed voltage and temperature difference at ambient temperature of 36 C.

The tests and experiments carried out here prove that this heat-to-electricity conversion device is a reality. Using the new types of materials such as the lead alloy, the efficiency of the thermoelectric generators was increased and then, the number of their application will also notably increase. The commercial thermoelectric generator was analyzed in this work. The current-voltage and power-voltage characteristics at different temperatures were measured and analyzed.

Moreover it is observed that best results come when the intensity of the heat absorptions and disseminations on the thermoelectric device are maximized. It is therefore recommended the elements like heat blowers and sinks be incorporated in the design and construction. The increasing concern of environmental issues of emissions, in particular global warming and the constraints on energy sources has resulted in extensive research into innovative technologies of generating electrical power and thermoelectric power generation have emerged as a promising alternative green technology. There are vast quantities of heat waste discharges into the earth's environment much of it at temperatures that are too low to recover using conventional electrical power generators.

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12. Susan P. Wyche & Laura L. Murphy Powering the Cell phone Revolution: Findings from Mobile Phone Charging Trials in Off-Grid Kenya.

Department of Electrical and Electronics
Faculty of Engineering,
Enugu State University of Science and
Technology, ESUT, Enugu,
Enugu State, Nigeria,
2nd August.2021.

Nigerian Communications Commission, NCC,
Plot 423 Aguyi-Ironsi Street
Maitama District
Abuja. Nigeria.

Attention: - Director Research and Development

Dear Sir/Madam,

Re-NCC/R&D/ESUT/VOL.1/001/05/08/18

REQUEST FOR PAYMENT

We are humbly requesting for third tranche payment of our research grant to enable us to continue on the research grant "***development of a home-grown electrical power charger for cellphones from cooking heat".***

Our University, ESUT account details for this purpose is as follows:-
Account name: -**ESUT Fees Account**.
Account number: - **4010326616.**
Bank: - **Fidelity Bank Plc**.

Thank you,

Yours faithfully,

....

Dr. Cyprain Anayochukwu Mgbachi

(Lead Researcher).

APPENDIX I

JOURNAL ARTICLES EMANATING FROM THE RESEARCH WORK.

1 Dr. Mgbachi C. A, & Prof. Oluka

"Design Analysis of Kitchen-Waste-Heat Energy for the production telephones' chargers as an alternative Grid Technology".

Journal of Multidisciplinary Engineering Science and Technology (JMEST) ISSN: 3159-0040. www.jmest.org.

2. Dr. Mgbachi C. A, & Dr. Nwobodo H. N

“Performance Analysis Of Heat-Based Smart cell Phone Charger”

EPH - International Journal of Science and Engineering. Volume-3 |

Issue-11 | Paper-1 ISSN: 2454.

APPENDIX II

INSTRUCTIONAL AND USER’S

MANUAL

COOKING HEAT-BASED

CELL PHONE CHARGER

Product synopsis

Cooking heat-based cell phone charger is a special battery charger designed and fabricated to compliment the charging process of cell phones especially where electricity services are unreliable. It is a product resulting from Nigerian Communications Commission (NCC) research grants program. This product simply harvests some of the wasting heats on normal cooking activities.

General information

Cooking heat cell phone charger is designed to charge cell phones while the cooking goes on. It is simply designed to harvest and convert waste heat energy into electrical energy. It converts the harvested heat directly into regulated direct current (DC) suitable for charging cell phone and related devices batteries.

Characteristic features.

- ✓ It is extremely reliable and affordable.
- ✓ It is simple, compact and safe.
- ✓ It is capable of operating at elevated temperatures.
- ✓ It is suited for domestic applications.
- ✓ It is user and environmentally friendly.
- ✓ It is not position-dependent (it is portable).
- ✓ It is a flexible power source.
- ✓ It is a renewable energy device.

Specifications

- ✓ Direct voltage, DC electronics charger.
- ✓ USB, Small pin etc interface.
- ✓ Plug and charge.
- ✓ Charging time dependent on available heat.
- ✓ Charging voltage ranges between 0.15v to 3.5v.

✓ Rating is between 1.5v, 400mAh to 3.8v, 300mAh 11.4Wh.

Component parts of this product.

Component parts	Functions
	Stove model of cooking heat-based cell phone battery charger. Works with any type of cooking pot arrangement.

	Pot model of cooking heat-based cell phone battery charger. Works with any type of cooking fire arrangement.
	Power cable conveying the converted electric voltage to the regulator making it suitable for cell-phone battery charging.

	Extension multiple sockets provided so as to charge more phones simultaneously at a regulated voltage value.
	Normal USB Cell-phone battery charging cable.

ASSEMBLING INSTRUCTIONS

The following steps are necessary in assembling the component.

- Plug the male-end of the power cable into the female-end attached to the pot or the stove; and take it far from cooking heat.
- Plug the male-end of the USB cable end of the power cable's female-end; or plug it into the extension box provided.
- Always ensure that there is enough liquid in the cooking pot (if you are using the pot model).
- You can then plug-in your cell phone for charging.

OPERATIONAL INSTRUCTIONS

- **STEP ONE**

  - Assemble the device as explained above.
  - Arrange the fire as in normal cooking activity.
  - Make fire on the stove as in the normal cooking.
  - Allow some minutes for the heat to increase.
  - One can place pot as normal cooking process.

- **STEP TWO**

  - Go on with your normal cooking.
  - Connect the control box to the heat harvester.
  - Plug the cell phone into its slot in the box.

- Switch on the charging button in the box.
- Observe that the indicator LED light is on.
- Confirm that the cell phone is being charged.

- **STEP THREE**

- Observe that the cell phone for charging display.
- Charging slot can be changed if necessary.
- Charging is on as long as heating continues.
- Unplug the cell phone on full charge.

Care and Maintenance

The following care and maintenance actions are recommended to maximize the wonderful features of this device:

- The pot-model must have some liquid content inside the pot before taking it to the cooking stove.
- The cables must be arranged in save routes to avoid being pulled by mistake.
- The cables must be properly arranged and parked even after use because the device is always with some current.

Basic troubleshooting

- If the phone is not charging, change the USB cable.
- If the light indicator is not showing, check the power cable directly from the pot or stove as the case may be.
- If still not charging simply call for technical assistance.