Design and Construction of a Waste Heat Recovery System for Electricity Generation

A report was submitted to the Department of Mechanical Engineering, Sonargaon University, Bangladesh, in partial fulfillment of the requirements for the award of the Bachelor of Science in Mechanical Engineering degree.

Submitted By

MD. Aktaruzzaman
MD.Anisur Rahman
MD.Tanvir Mahamud
Mohammad Monirujjaman
Supria Rani Bhowmick

Supervised by

Md. Navid Inan
(Lecturer)
Department of Mechanical Engineering (ME)
Sonargaon University (SU)
147/I, Panthapath,
Dhaka-1215, Bangladesh

May 2025

Declaration

We solemnly declare that we have carried out the work presented in this project report and has not been previously submitted to any university or organization for the award of any degree or certificate.

We hereby ensure that the work presented here does not breach any existing copyright.

We further indemnify the university against any loss or damage arising from a breach of the foregoing obligation.

……	……
MD. Aktaruzzaman	MD.Anisur Rahman
……	……
MD.Tanvir Mahamud	Mohammad Monirujjaman

……

Supria Rani Bhowmick

Under the Supervision of

……

Md. Navid Inan

Lecturer

Department of ME

Sonargaon University (SU)

Certification

This is to certify that the following students, under my direct supervision, completed this project entitled “Electricity Generation from Waste Heat.” They carried out this project work in the laboratories of the Department of Mechanical Engineering under the Faculty of Engineering, Sonargaon University (SU), in partial fulfillment of the requirements for the degree of Bachelor of Science in Mechanical Engineering.

Supervisor

Md. Navid Inan

Lecturer

Department of Mechanical Engineering (ME)

Sonargaon University (SU)

ACKNOWLEDGEMENT

First and foremost, we would like to thank Almighty Allah for granting us the capability and providing me with health and an opportunity to finish this work. We offer our sincerest gratitude to our supervisor,**Md. Navid Inan,** Lecturer, Department of Mechanical Engineering, Sonargaon University (SU), for his patient guidance, encouragement, and the advice he has provided throughout our time as his student. We consider ourselves very fortunate to be able to work with a very considerate and encouraging person like him. We would also like to express our thanks to the respected Head of Department, **Prof. Md. Mostofa Hossain,** for providing me the opportunity to conduct our research in such an academic environment.

Above all, we wish to convey our heartfelt thanks and love to our parents, to whom we owe everything. We are forever indebted to our parents for their understanding, endless support, and encouragement when it was most required.

Abstract

Availability of electricity in remote areas such as forests and mountains is always doubtful because of various inconveniences caused by both the location and the atmosphere. The use of unconventional methods such as solar panels and generators when electricity is not reachable through transmission lines always clashes with nature in areas like dense forest areas, and noise or air pollution due to the generators in these areas, so a suitable solution is needed. A device running on solid state devices like a Peltier module can be handy as there is no need for solar rays, and it can provide noiseless energy as per the need with very little use of sources and with less or zero effect on nature. These elements work on the Seebeck effect, in which the difference between two dissimilar electrical conductors or semiconductors produces a voltage difference between the two substances. Peltier modules can run on the latent heat generated by the candles or campfires, and on the other side heat sink or chilled water/ice can be used for heat dissipation. By providing heating on one side and cooling on the other side, a temperature difference is created, which plays an important role in voltage generation. Generated voltages can be high or low depending on the needs of the user and the number of connected Peltier modules, but they can be controlled and stabilized with the help of DC choppers.

Table of contents

Declaration		Ii
Certification		Iii
Acknowledgement		Iv
Abstract		V
List of Figures		Vi
List of Tables		Vii
Chapter-1 : Introduction		
1.1	Introduction	01
1.2	Thermal Technologies	02
1.3	Non-Thermal Technologies	02
1.4	Objective	02
1.5	Methodology	02
Chapter-2 :Methodology		
2.1	Waste Heat Resources in Bangladesh	03
2.2	Construction	03
2.3	Diagram	05
2.4	Block Diagram	06
2.5	Circuit Diagram	07
2.6	Working principle	07

Chapter -3 Key Components

3.1	Peltier module	09
3.2	Heat sink	10
3.3	Heating system	10
3.4	Cooling system	11
3.5	Gas Cylinder	11
3.6	Gas stove	11
3.7	Microcontroller	12
3.8	AVO meter	12
3.9	Load	12

Chapter 4: Results & Discussion

4.0	Performance And Efficiency Calculation	13

Chapter -5: Conclusion

5	Advantage	15
5.1	Disadvantage	15
5.2	Application	16
5.3	Conclusion	16
	References	17

List of Tables

Table No.		Page No.
4.1	Temperature, Voltage & Current Measurement	14

List of Figures

Figure No.		Page No.
2.1	Peltier modules connected in series	03
2.2	Electricity generates waste Heat	05
2.3	Block diagram of Electricity Generation from Waste Materials	06
2.4	Circuit diagram	07
3.1	Peltier module	09
3.2	Heat sink	10

Chapter-1

Introduction

1.1 Introduction

Around 1.3 billion people live without electricity in the world. Rural and isolated areas are highly affected by this, and it will normally take a long time before electricity reaches them through the transmission and distribution system. The remotely isolated areas of forests and mountains do not have access to electricity in many cases; hence, an independent energy source is necessary. The device made from Peltier modules tries to provide energy by converting thermal energy into electrical energy. The sources of thermal energy are easily available around these places, and their use does not affect the environment in a harmful manner. It is possible to run various devices used for lighting and other needs with the help of this device by converting the generated voltages with the use of various converters, such as choppers and inverters. The key element Peltier module, a thermoelectric module,
can convert thermal energy into electrical energy. They are made of two unique semiconductors, one being p-type and another being n-type, and they are static. The working operation is based on the Seebeck effect (conversion of heat into electricity), which occurs inside the Peltier modules. As the heat spreads and starts flowing, so do the free charge carriers from the hot side to the cold side. The end voltages are proportional to the temperature difference, and the system keeps on generating voltage as long as the temperature difference remains intact. Generated voltages from each Peltier module increase with time and temperature difference. They are connected in series so that the end voltages will be high. The temperature keeps changing, so instability may damage the connected equipment. A chopper is connected before connecting the device to the system, which provides pure and stable DC voltages. The device is not only useful for isolated areas, but it can also be used in the industrial sector where latent heat is produced, which can be used as a source of heating, and an extra amount of energy can be produced with it.

Energy production from waste can be categorized in two ways:

1) Thermal Technologies

2) Non-thermal technologies.

1.2 Thermal Technologies (TT)

(TT) These are processes that create energy in the form of electricity, fuel, or heat from the thermochemical processes of municipal solid waste. The thermal treatment of solid waste is only one part of an integrated waste management system and plays several important roles in an integrated waste management system. Thermal treatment covers a range of technologies that extract energy from the waste while reducing its volume and rendering the remaining fraction mostly inert.

Thermal treatment can:

i)Reduce the volume of waste, preserving landfill space

ii)Allow for the recovery of energy from the solid waste stream

iii)Allow for the recovery of minerals and chemicals from the solid waste.

iv)Destroy several contaminants that may be present in the waste stream

v)Reduce the need for the long-hauling of waste

These technologies can be generally grouped into two main categories: conventional combustion and advanced thermal treatment.

1.3 Non-thermal technologies

i) Anaerobic digestion (Biogas rich in methane)

ii) Fermentation production (examples are ethanol, lactic acid, and hydrogen)

iii) Mechanical biological treatment (MBT)

iv) MBT + Anaerobic digestion

1.4 Objective

The main objective of his projects is below,

i)To study electricity generation from a waste heat system

ii)To construct an electricity generation mechanism from a waste heat system

iii)To study the Peltier module's working principle

1.5 Methodology

First, the requirements of the project were carefully analyzed to design the Waste Energy generation system. Information was collected from reference books and websites to find out the possible improvements. Required components have been purchased from the local market.

Chapter-2

Methodology

2.1 Waste Heat Resources in Bangladesh

i) Textile Industry

ii) Industrial Process

iii)Power plants

iv)Automobile waste heat

v) Gas stove, etc

vi) Electronic device (Oven, Freezer)

2.2 construction

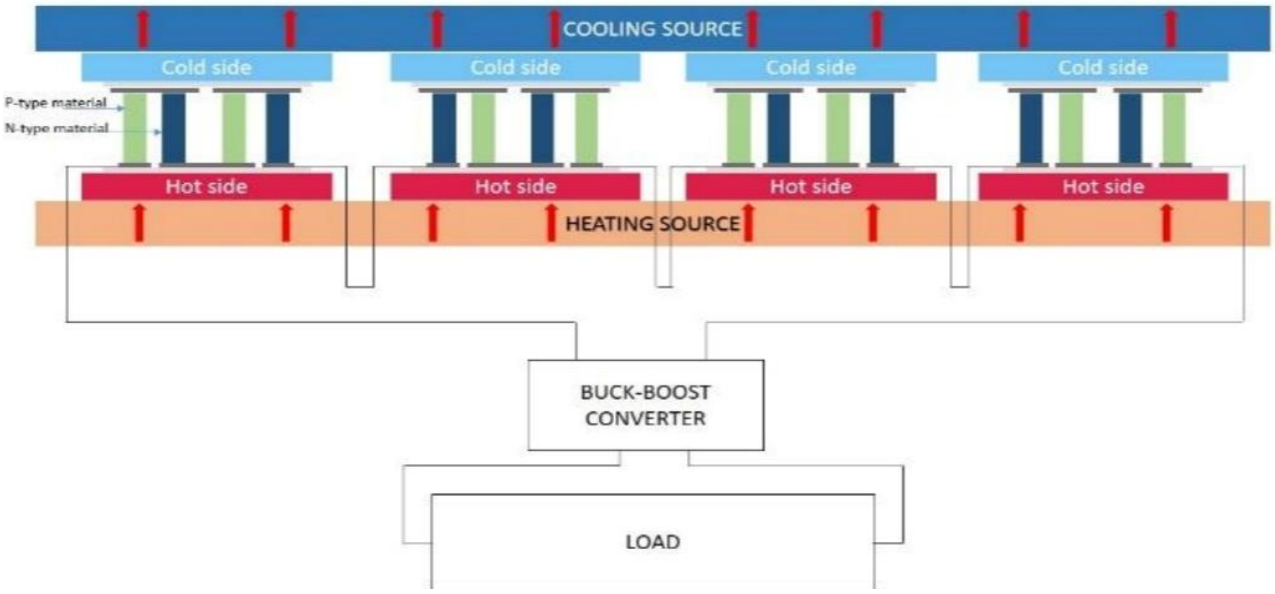


Fig. 2.1: Peltier modules connected in series

Modules provide voltages using nothing but the heat emitted from various sources such as wood burning, candle flames, latent heat from industries, or the heat produced from residential areas while cooking. The temperature difference between the hot and cold sides generates electricity. It can be instrumental in forest and mountain areas as well as in homes in case of power outages and in these situations, we can use candle flames or wood as a heating source for the hot side and chilled water or ice as a cooling source for the cold side also we can use a heat sink on the cold side to increase and improve the speed of process. The core of the device is a significant number of Peltier modules; for general needs, around ten are sufficient. They work by essentially moving heat from one side to the other side when heat is applied using Peltier, and the other side is kept cool with a heat sink or chilled water and ice. This generation of electricity is caused by the temperature difference between two dissimilar semiconductors, causing a voltage difference. A metal tray is also needed to hold the cooling source in case it is water or ice, and if the heat sink is used, then they are attached to the cold side of the Peltier module and they are large enough to accommodate all the Peltier plates on the base with its printed text being upwards. Thermally conductive glue is used to join them strongly to the base of the cooling source. In the case of using a metal tray to store the cooling source, the outside walls of the tray are covered by plastic tapes to prevent shorting and other harm, and modules are fixed at the bottom. The modules are connected in series with each other by connecting the positive (red) and negative (black) ends of the wires. The opposite wires at the end are left loose as they will help obtain the blooming but unstable voltages. End voltages will be high and unstable because of Peltier module is being connected in series and a gradual change in temperature difference over a period, hence a voltage regulating device-chopper is needed, which provides stable and controlled voltages ranging from 5 volts to 35 volts. The regulator happens to be mounted far from the sources of heating and cooling so that it can be protected from heating and shorting. Heating might happen inside the chopper so that a heat sink can be attached for proper dissipation of heat. Also, to get more heat concentrated equally on the module, a metal plate is used, which spreads the heat. To provide external support, all the elements are fitted inside a box. Heating, an important phenomenon, is provided with the help

of byproducts from both industries and domestic areas, and in the absence of byproducts, candle flames or wood can be used as the source. It is provided to the Peltier modules, which are connected to the cooling source. Cooling can be provided by chilled water or ice stored in a metal tray, or a heat sink can be fixed with the Peltier modules and use of a fan used to dissipate the heat and provide cooling. This arrangement starts producing a voltage in some time, and that too without making any noise. Also, the rigid construction can withstand a much, and the Peltier modules themselves can easily work for a long life span without any failures.

2.3 Diagram

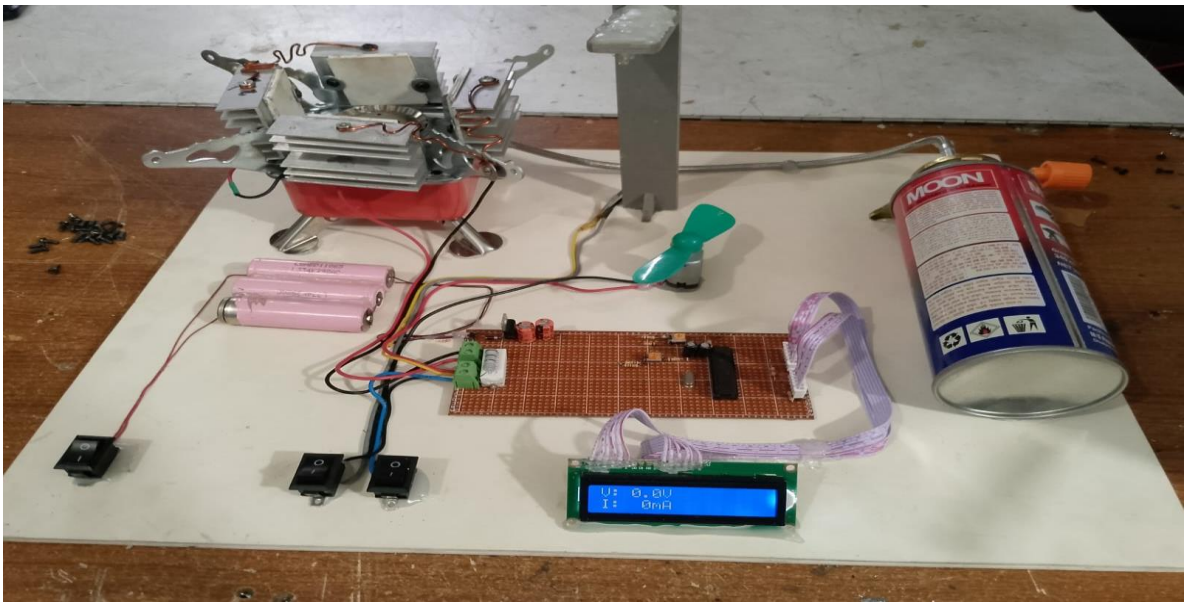


Fig. 2.2: Electricity generates waste Heat

2.4 Block Diagram

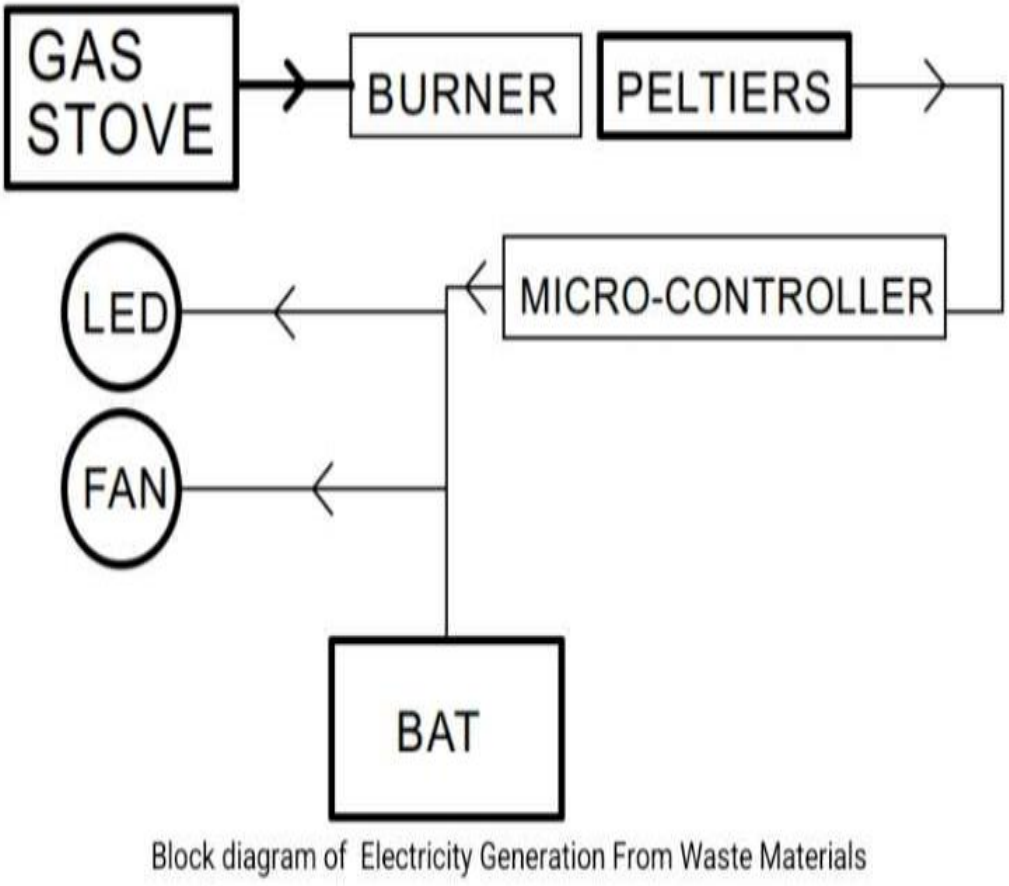


Fig. -2.3 Block diagram of Electricity Generation From Waste Materials

2.5 Circuit diagram

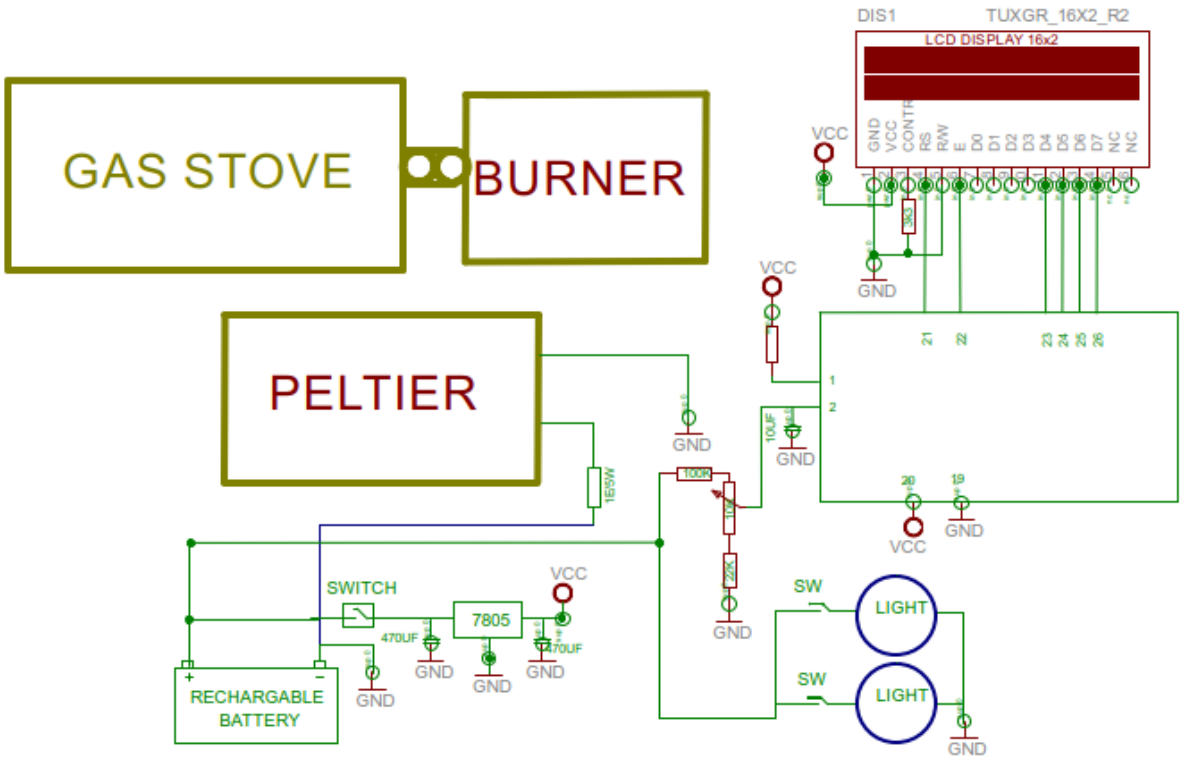


Fig-2.4 Circuit diagram

2.6 Working Principle

The Peltier modules are fitted below the cooling source, which can be a heat sink and cooling fan or a metal tray containing a cooling source, and they are fitted inside a wooden box. Peltier modules are fixed with the help of thermal grease, and their hot side is also covered by a metal plate to spread the heat and protect the Peltier module from the fumes. The process starts with providing a cooling source first and then a heating source for the Peltier modules. Sometime later, Peltier modules start producing voltages as the thermal energy is converted into electrical energy. The whole operation happens to be noiseless. The generated voltages are in proportion to the number of modules connected in series, and they are also dependent on the temperature difference. As soon as heat reaches the Peltier modules, the temperature difference is imposed across them, and the heat passing through the device is converted to electrical power. As heat travels through the Peltier module, more power is extracted from the heat, with an increase in temperature difference, and power output also increases. Peltier modules are thermoelectric

devices made from the semiconductive elements Bismuth Telluride and Lead Telluride, and in them, some electrons are bound to the nuclei and some are free to move. Being confined to semiconductors,

Peltier modules contain charges that can flow from high energy to low energy thus taking a Peltier module and providing heating and cooling on the opposite surfaces will create a temperature difference and then we can get a negative charge on one side and a positive charge on the other side, the difference between the charges cause a potential difference which is also known as voltage and it happens to be a measure of electricity. Later, to get a stable DC voltage, the buck-boost converter is connected to the arrangements. As the name indicates, the buck-boost converter will provide a higher output than the input voltage from the source or the supply, which are Peltier modules in this arrangement. The circuit consists of the voltage source, which must be DC, boost inductor, controlled switch, diode, filter capacitor, and load resistance. In the initial stage, the switch will be open, and the current through the inductor will be zero. When the switch is closed for the first time, the blocking diode interrupts current from flowing into the RHS of the circuit, so it mandatorily flows through the passive element inductor. A rapid current change is rare in the inductors, so it keeps the current low by dropping most of the voltage from the source. Gradually, the inductor will let the current slowly increase by decreasing the voltage drop, and at the same time inductor stores energy in the form of a magnetic field. Later, the energy is released through the diode to the output RC circuit.

Chapter-3

COMPONENTS

3.1 Peltier module

A sandwich-shaped device that can convert heat energy into electrical energy is the fundamental introduction of Peltier modules. Working on both the Seebeck effect and the Peltier effect, Peltier modules can generate voltages to provide heating or cooling depending on the need of the user.

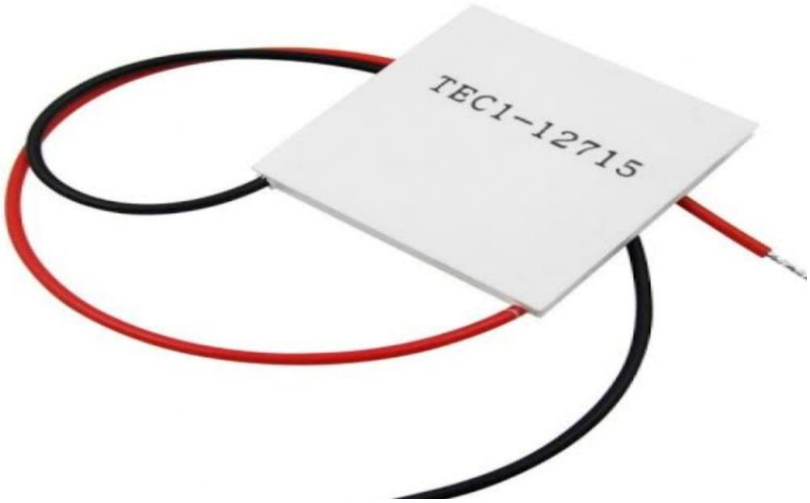


Fig-3.1 Peltier module

The construction of the module contains a couple of ceramic plates inside, where an array of small bismuth telluride cubes is stored. The charge carriers inside the material and the semiconductors move freely while carrying both charge and heat. Creating a temperature difference causes the carriers at the hot end to diffuse to the cold end. This buildup of carrier charge at the hot results in a buildup of net charge at the cold end, thus resulting in voltage production. The semiconductors are highly doped with pollutants to increase the electrical conductivity. One thing that must be kept in mind while selecting the material for the module is that it must be able to withstand high temperatures. Bismuth Telluride is one of the materials that exhibits the Seebeck effect, hence, a module made of it produces the voltage. However, one must note that they have high electrical conductivity and low thermal conductivity. Modules have a very high operating temperature.

3.2 Heat sink

In thermodynamics, a heat sink is a heat reservoir that can absorb any desired amount of heat temperature change, without a significant

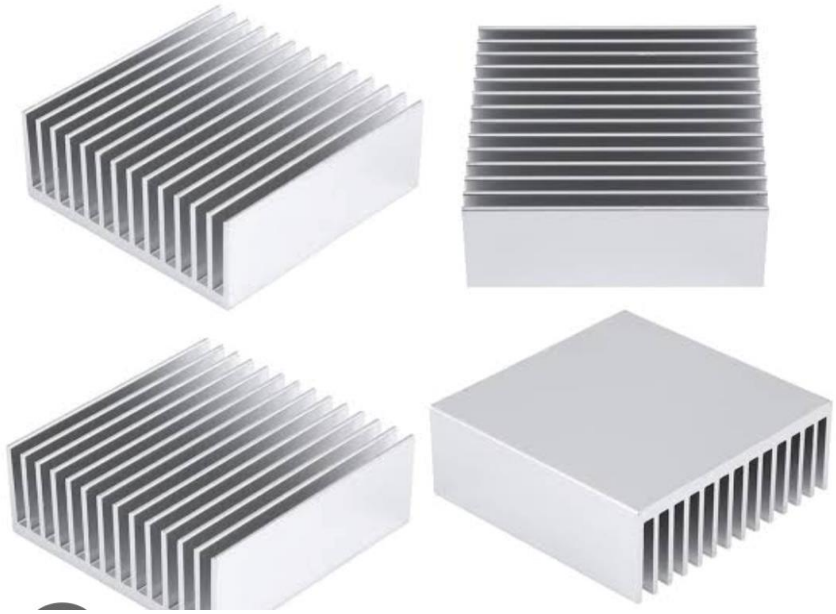


Fig-3.2 Heat sink

Practical heat sinks for electronic devices must have temperatures higher than ambient temperature to allow heat transfer by convection, radiation, and conduction.

3.3 Heating System

Heating, a necessary phenomenon, can be provided from the waste heat of industries or heat generated for various purposes, such as cooking in domestic areas. In. The absence of waste heat, candle fumes, or wood can be used as the heating source, and they are contained in some metal tray and put below the Peltier modules so that the Peltier module's one side gets hot, and to spread the heat equally a metal plate is used to cover hot side equally. Also, hot vapor can be used as a heating source, which is an important byproduct in many industries. Different sources provide different temperatures to the Peltier modules, and also, it should be noted that Peltier modules can withstand temperatures up to a certain point, and after that chances of their damage increase, so one must be careful while dealing with the temperature.

3.4 Cooling System

Cooling systems for Peltier modules are as necessary as the heating system, and they are provided so that a temperature difference remains intact between the two sides of the Peltier module. The cooling source can be chilled water or ice in most cases, but we can also use Nitrous oxide. Peltier modules are fitted below the cooling sources so that heat can be transferred easily from the hot side to the cold side and later to the cooling source, which dissipates it. We can also use a heat sink with a cooling fan in case other cooling sources are unavailable, a small amount of energy generated from the Peltier module can be used to run the cooling fan but when we connect many Peltier modules then it cannot provide expected cooling and in that cases, we must use chilled water and ice as the source of cooling.

3.5 Gas Cylinder

A gas cylinder stores gases, typically at above atmospheric pressure, and utilizes a valve system and often a regulator to control the release of the gas. When the valve is opened, the gas, often a liquid like LPG, is released, vaporizing and flowing through the regulator and out of the outlet**.**

3.6 Gas stove

A gas stove operates by using gas as a fuel source to generate heat for cooking. It works by mixing a controlled amount of gas with air and then igniting the mixture to create a flame, which is used to heat cookware. The heat output is regulated by adjusting the gas flow to the burner(s).

Here's a more detailed breakdown:

i) Gas Supply: Natural gas or LPG (propane) is piped to the stove from a gas line.

ii) Regulation: A regulator reduces the gas pressure to the appropriate level for the stove.

iii) Burner: The gas flows through the burner, where it mixes with air to create a combustible mixture.

iv) Ignition: A spark generator or pilot flame ignites the gas mixture, creating a flame.

v) Heat Generation: The flame heats cookware placed on the burner.

vi) Control: Knobs or buttons on the stove's control panel allow you to adjust the gas flow, controlling the heat output.

3.7 Microcontroller

A microcontroller is a small computer on a single integrated circuit that controls embedded systems. It combines CPU, memory, and input/output (I/O) interfaces on one chip. The working principle involves receiving inputs, processing data, and generating outputs based on a program stored in memory.

3.8 AVO Meter

An AVO meter, also known as a multimeter, is a crucial measuring instrument in the field of electrical engineering and electronics. It is used to measure three key electrical parameters: current (ampere), voltage (volt), and resistance (ohm)

3.9 Load

We used this Fan, LED bulb, Battery, and components for the load

Chapter -4

RESULT & DISCUSSION

4. PERFORMANCE AND EFFICIENCY CALCULATION

The heat is provided to one side of the module, and the other side is either connected with the heat sink or something that can dissipate heat, such as ice or chilled water, is connected to the other part, and due to this temperature difference, ΔT is obtained between the two junctions inside the module. The sides of the module are covered by insulated sheaths, so heat flows along the length only. This temperature difference, due to heat provided on the hot junction, causes the electrons in the n-type block and the holes in the p-type block to flow from the hot side to the cold side of the module, thereby producing an electrical potential difference. The inner circuit completes when a load resistance RL is connected, and current starts flowing through this load resistance. The potential difference occurring between the two junctions can be given by V = α ΔT, where α happens to be the Seebeck coefficient and ΔT happens to be the temperature difference between the hot junction and the cold junction. If R is the internal resistance of the system, then the current flowing through the load resistance RL can be given by

$$I = \frac{V}{R + R_L}$$

Substituting the value of voltage in the above equation, we get current,

$$I = \frac{\alpha \Delta T}{R + R_L}$$

We are aware that the power flow to the external load is given by,

PL = I2RL and substituting the value of I

$$P_L = \left(\frac{\alpha \Delta T}{R + R_L}\right)^2 R_L$$

This power will be maximum when the internal resistance and

load resistance will be the same, R=RL, and in that case,

Maximum power can be given by

$$P_{max} = \frac{(\alpha \Delta T)^2}{4R}$$

The term (α2 / R) can be called a figure of merit, and for

power to be maximum, the temperature difference between

The surfaces should be as large as possible. Internal resistance should be as low as possible if we want to harness the maximum power, and this can be done by increasing the length and the diameter of the modules. The efficiency of the system can be defined by the ratio of power developed, PL, across the load resistance and the

heat flow Q, from the source.

$$\eta = \frac{Power\ developed}{Heat\ flow} = \frac{P_L}{Q}$$

$$\eta = \frac{I^2 + R_L}{Q}$$

$$\eta = \frac{\left(\frac{\alpha\,\Delta T}{R + R_L}\right)^2 R_L}{Q}$$

Calculation

Temperature, Voltage & Current Measurement

SN	Time(s)	Heat source	Temperature of hot surface(°C)	**Temperature of cooler surface (°C)**	ΔT(°C)	Voltage (V)	**Current (Unit)**
1	13	Gas stove	56	37	19	3.8	8
2	15	Gas stove	57	39	18	4	9
3	20	Gas stove	60	45	15	4.5	10

Chapter -5

Conclusion

Advantages of Waste Heat Recovery Systems:

i) Improved Energy Efficiency:

Converts otherwise wasted thermal energy into electricity, improving overall system efficiency.

ii) Cost Savings:

Reduces fuel consumption and energy bills by utilizing waste heat.

iii) Environmental Benefits:

Lowers greenhouse gas emissions and reduces dependency on fossil fuels.

iv) Extended Equipment Life:

Reducing heat waste can lower operating temperatures and stress on equipment.

v) Scalability:

Applicable to various industries (steel, glass, cement, chemical, internal combustion engines, etc.) and different scales.

vi) Support for Renewable Integration:

Can complement renewable energy sources by providing additional energy without new fuel input.

5.1Disadvantages

Disadvantages of Waste Heat Recovery Systems

i) High Initial Investment:

Equipment, installation, and integration into existing systems can be costly.

ii) Complex Design and Engineering:

Requires customized design for each application, making standardization difficult.

iii) Low-Quality Heat Limitations:

The efficiency of conversion is lower when the waste heat is at a low temperature.

iv) Maintenance Challenges:

Systems can be complex and require regular maintenance and skilled personnel.

v) Space Constraints:

May require additional space, which might not be available in existing facilities.

vi) Economic Viability:

The payback period can be long, especially if energy prices are low.

5.2 Applications

i) DC voltage generation

ii) Waste heat utilization and removal

iii) It can be used in Transportation systems,

iv) Domestic Buildings, Industries, and Power plants.

5.3 Conclusion

Designing and constructing a waste heat recovery system for electricity generation represents a sustainable and efficient approach to improving energy utilization. By capturing and converting waste heat—typically lost in industrial processes—into usable electrical energy, this system not only enhances overall energy efficiency but also contributes to reducing environmental impact and operational costs.

The project successfully demonstrated the feasibility of harnessing waste heat through thermoelectric modules and/or Organic Rankine Cycle (ORC) technologies, depending on the chosen method. The system design considered key parameters such as temperature gradients, heat exchanger efficiency, material selection, and system integration, ensuring optimal performance and safety.

Implementation of this technology can lead to significant energy savings, reduced greenhouse gas emissions, and improved economic performance, especially in industries with high thermal waste. Further optimization, scalability assessments, and integration with smart energy systems could enhance its effectiveness and adoption in a wide range of applications.

REFERENCES

01 Suresh S. Balpande, Rajesh S. Pande, Rajendra M. Patrikar, Design and Low-Cost Fabrication of Green Vibration Energy Harvestor, Elsevier, Sensors and Actuators, A: Physical, Volume 251, 1 November 2016, Pages 134-141, ISSN 0924-4247, http://dx.doi.org/10.1016/j.sna.2016.10.012

02 Surash Balpande, Manish Bhaiyya, Dr Rajesh S. Pande, Low Cost Fabrication of Polymer Substrate Based Piezoelectric Micro-Generator With PPE, IDE and ME, Accepted Manuscript, IET Electronics Letters, ISSN 1350- 911XPrint ISSN 0013-5194 DOI: 10.1049/el.2016.4099

03 Sarinee Ouitrakul, Preliminary Experiment for Electricity Generation using Peltier Modules, 78 1-4799-2993-1/14/$31.00©201IEEE

04 WebSource:www.reuk.co.uk/wordpress/thermoelectric/what-is-a-peltier-cooler

05 P.M. Solanki, Dr. D.S. Deshmukh, Dr. V. R. Diware, A Review on factors to be considered for a thermoelectric power Generation System Design, International Conference on Global Trends in Engineering, Technology and Management (ICGTETM-2016), ISSN: 2231-5381

06 Allwin Jose, Alan D'souza, Sarvesh Dandekar, Jitesh Karamchandani, Pavan Kulkarni, Air Conditioner using Peltier Module, 2015 International Conference on Technologies for Sustainable Development (ICTSD-2015), 978-1-4799-8187-8/15/$31.00 ©2015 IEEE

07 Takafumi Hatano, Mingcong Deng, and Shin Wakitani, A Cooling and Heat-retention System Actuated by Peltier Device Considering Fan-motor Control, 2014 IEEE International Conference on Automation Science and Engineering (CASE) Taipei, Taiwan, August 18-22, 2014, 978-1-4799-5283-0/14/$31.00 ©2014 IEEE

08 Dr. Steven O'Halloran, Mr. Matthew Rodrigues, Power and Efficiency Measurement in a Thermoelectric Generator, AC
2012-3976

09 Shigenao Maruyama, Atsuki Komiya, Hiroki Takeda, and Setsuya Aiba, Development of Precise-temperature-controlled Cooling Apparatus for Medical Application by Using Peltier Effect- 2008 International Conference on Bio-Medical Engineering and Informatics- Institute of Fluid Science, Tohoku University- 2008 International Conference on Bio-Medical Engineering and Informatics, 978-0-7695-3118-2/08 $25.00 © 2008 IEEE/DOI 10.1109/BMEI.2008.239

10 Mohak Gupta, Review on Heat Recovery Unit with Thermoelectric Generators, International Journal of Engineering and Innovative Technology (IJEIT) Volume 4, Issue 4, October 2014, ISSN: 2277-3754