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THERMOELECTRIC GENERATOR

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ABSTRACT Waste heat is created as an outgrowth in many processes such as by sun, driving vehicles, cooking, electricity generation, working on computer etc. if we perform any task in the result decay warmth is created. Now large amount of spend warmed is create by the industries. Thermoelectric generator is one of the systems of the power generation. Thermoelectric generator is a system which change warmed straight forwardly into electricity by utilizing a procedure called the "See beck effect". There are three types of thermoelectric effect: The See beck effect, the Peltier effect, the Thomson effect. From these three effects, thermoelectric generator works on the See beck effect; which states that conversion of heat directly into electricity at the junction of dissimilar electrical conductors.

The objective of this project work is

The primary objective of a thermoelectric generator is to convert waste heat into usable electrical power.

Another objective of TEGs is to improve the overall efficiency of systems by harnessing waste heat that would otherwise be dissipated into the environment.

TEGs are designed to operate reliably under different environmental conditions and temperature gradients.

KEY WORDS; Thermoelectric generator, See beck effect, Waste heat

NOMENCLATURES

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

S = the average Seebeck coefficient in volts/°K

DT = the temperature difference across the couple in K where DT = T_h-T_c

I = the generator output current in amperes

R_C = the average internal resistance of the thermoelectric couple in ohms

R_L = the load resistance in ohms

Q_h = the heat input in watts

K_c = the thermal conductance of the couple in watts/°K

T_h = the hot side of the couple in °K

P_{out} = the output power in watts

I = the generator output current in amperes

R_L = the load resistance in ohms P_{max} = maximum power in watts ρ = electric resistivity in Ohm

The main objective of the Thermoelectric Generator project is to convert waste heat into usable electrical power. Additionally, the project aims to improve the overall efficiency of systems by Semiconductor devices in thermoelectric generators are primarily used to exploit the thermoelectric effect, which allows for the conversion of temperature differences into electrical energy. Specifically, the following points highlight their uses:

1. Thermoelectric Modules: Semiconductor materials, such as Bismuth Telluride, are used to create thermoelectric modules that can generate electrical power when a temperature differential is applied across them. These modules consist of N-type and P-type semiconductor elements connected in series.

2. Power Generation: When a temperature difference is established between the hot and cold sides of the thermoelectric module, the semiconductor materials generate an electrical voltage. This process is the basis for power generation in thermoelectric generators.

3. Efficiency Improvement: The properties of semiconductor materials can be optimized to enhance the efficiency of the thermoelectric conversion process. The performance of thermoelectric generators is highly dependent on the thermoelectric materials used, which are characterized by their Seebeck coefficient, electrical conductivity, and thermal conductivity

4. Modularity and Versatility: Semiconductor devices allow for the design of modular systems that can be easily integrated into various applications, making them suitable for waste heat recovery in industrial processes and other heat sources.

Overall, semiconductor devices are crucial for the functionality and efficiency of thermoelectric generators, enabling the conversion of waste heat into useful electrical energy. Harness Doping is a process used in semiconductor manufacturing to intentionally introduce impurities into an extremely pure semiconductor material (also known as intrinsic semiconductor) to modify its electrical properties. The main objectives of doping are to increase the number of charge carriers (electrons or holes) in the semiconductor, thereby enhancing its conductivity.

THERE ARE TWO PRIMARY TYPES OF DOPING:

1. N-Type Doping: This involves adding donor atoms (such as phosphorus or arsenic) to the semiconductor. These donor atoms have more valence electrons than the semiconductor material (like silicon), which results in extra electrons that can move freely, increasing the material's conductivity. In N-type semiconductors, electrons are the majority carriers, while holes (the absence of electrons) are the minority carriers.

2. P-Type Doping: This process involves adding acceptor atoms (such as boron) to the semiconductor. These acceptor atoms have fewer valence electrons than the semiconductor, creating "holes" where an electron is missing. In P-type semiconductors, holes are the majority carriers, while electrons are the minority carriers.

Doping is crucial for creating various semiconductor devices, including diodes, transistors, and thermoelectric materials, as it allows for the control of electrical properties and the enhancement of device performance. Materials for thermoelectric devices are critical for their performance in converting temperature differences into electrical energy. The effectiveness of these materials is often characterized by a dimensionless figure of merit, ZT, which combines the material's Seebeck coefficient, electrical conductivity, and thermal conductivity. Here are some key materials used in thermoelectric devices:

1. Bismuth Telluride (Bi2Te3): This is one of the most widely used thermoelectric materials, especially for applications around room temperature. It exhibits a high ZT value, making it efficient for refrigeration and power generation. Bismuth telluride can be alloyed with other elements like antimony or selenium to enhance its thermoelectric properties.

2. Bismuth Chalcogenides: Materials such as Bi2Se3 and Bi2Te3 are known for their excellent thermoelectric performance at room temperature. They can be nanostructured to create superlattice structures that improve electrical conductivity while reducing thermal conductivity, leading to enhanced ZT values.

3. Silicon-Germanium Alloys: These materials are used for high-temperature thermoelectric applications, such as in space missions. They maintain good thermoelectric performance at elevated temperatures, making them suitable for converting waste heat into electricity in high-temperature environments.

4. Skutterudites: These complex crystal structures can be doped with various elements to optimize their thermoelectric properties. They are known for their low thermal conductivity and high electrical conductivity, making them promising candidates for thermoelectric applications.

5. Half-Heusler Alloys: These materials are also being explored for high-temperature thermoelectric applications. They offer a good balance of mechanical strength and thermoelectric performance.

The choice of materials is crucial for the efficiency and application of thermoelectric devices, and ongoing research aims to discover and develop new materials with improved thermoelectric properties. Lead Telluride (PbTe) is a semiconductor material that is widely used in thermoelectric applications, particularly for high-temperature power generation

Overall, lead telluride is a significant material in thermoelectric technology, especially for applications that operate at elevated temperatures. Ing waste heat that would otherwise be dissipated into the environment. The thermoelectric effect refers to the direct conversion of temperature differences into electrical voltage and vice versa. It encompasses three main phenomena:

1. Seebeck Effect: This is the generation of an electric voltage when there is a temperature difference across two dissimilar conductors or semiconductors. When one junction is heated while the other is kept cool, charge carriers (electrons or holes) diffuse from the hot side to the cold side, creating a voltage difference. The magnitude of this voltage is proportional to the temperature difference and is characterized by the Seebeck coefficient.

2. Peltier Effect: This effect is the reverse of the Seebeck effect. When an electric current is passed through a junction of two different conductors, heat is absorbed at one junction (cooling) and released at the other (heating). This effect is utilized in thermoelectric coolers (TECs) for refrigeration and temperature control applications.

3. Thomson Effect: This phenomenon describes the heating or cooling of a current-carrying conductor when there is a temperature gradient along its length. The effect can either absorb or release heat depending on the direction of the current flow relative to the temperature gradient.

The thermoelectric effect is harnessed in thermoelectric generators (TEGs) for power generation from waste heat and in thermoelectric coolers for refrigeration. The efficiency of thermoelectric devices is often evaluated using the figure of merit (ZT), which combines the material's Seebeck coefficient, electrical conductivity, and thermal conductivity. Transport properties the thermoelectric phenomena are reversible in the sense that they do not of themselves give rise to thermodynamic losses. However, they are always, in practice, accompanied by the irreversible effects of electrical resistance and thermal conduction. It turns out that the performance of any thermocouple as an energy convertor can be expressed in terms of the differential Seebeck coefficient and the thermal and electrical resistances of the two branches. These resistances depend on the thermal and electrical resistivities and the ratios of length to cross-sectional area. The electrical resistivity ρ is the reciprocal of the electrical conductivity, which is defined by the real Contact resistances within a thermoelectric (TE) module refer to the resistance encountered at the interfaces between different materials, such as between thermoelectric legs and metal connectors or ceramic substrates. These resistances can significantly affect the overall performance and efficiency of the thermoelectric device. Key points about contact resistances include:

1. Nature of Contact Resistances: Even when surfaces appear smooth, microscopic roughness can create air-filled voids at the interface, reducing the actual contact area. This leads to increased thermal and electrical resistance, which can hinder the performance of the TE module.

2. Impact on Performance: High contact resistances can lead to significant energy losses, reducing the efficiency of thermoelectric energy conversion. They can also cause localized heating, which may affect the temperature gradient necessary for optimal thermoelectric operation.

3. Mitigation Strategies: To minimize contact resistances, several strategies can be employed:

- Surface Preparation: Smoothing or polishing surfaces can reduce roughness and increase the contact area.
- Contact Pressure: Increasing the pressure at the interface can help eliminate voids and improve contact.
- Thermal Interface Materials: Using materials with high thermal conductivity, such as thermal grease or graphite, can fill voids and enhance thermal contact.

4. Electrical Contact Resistance: Similar to thermal contact resistance, electrical contact resistance can be reduced by using soft, conductive materials that resist oxidation, ensuring better electrical connectivity between components.

5. Importance in Design: Understanding and managing contact resistances is crucial in the design of thermoelectric modules to ensure efficient heat and electrical transfer, ultimately enhancing the overall performance of the thermoelectric system. Tion,

$I=(\sigma VA)/L$ Eq 2.2.a Where, 'I' is the electric current through a specimen of constant cross-sectional area A and length L when a voltage V is applied. Likewise, the thermal conductivity, K is defined by the equation,

$q = -(KA\Delta T)/L$ Eq 2.2. where, q is the rate of heat flow through a similar specimen that has a temperature difference T between its two ends. We shall refer to the thermoelectric coefficients and the electrical and thermal conductivities of

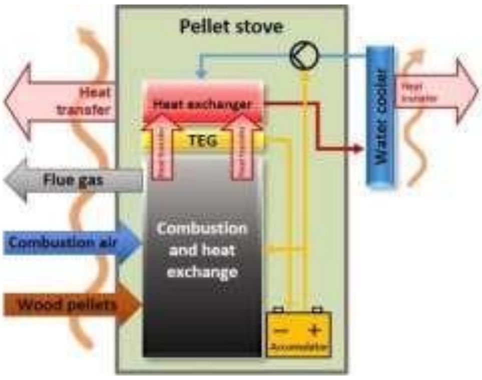
a given material as its transport properties. All these properties will generally be temperature-dependent Contact resistances within a thermoelectric (TE) module refer to the resistance encountered at the interfaces between different materials, such as between thermoelectric legs and metal connectors or ceramic substrates. These resistances can significantly affect the overall performance and efficiency of the thermoelectric device. Key points about contact resistances include:

Advantages of Thermoelectric Generator

Thermoelectric power generators offer several distinct advantages over other technologies, one of them are these:

• 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;
• They are simple, compact and safe;
• They have very small size and virtually weightless;
• They are capable of operating at elevated temperatures

Thermoelectric generators (TEGs) have significant applications in steam boilers, primarily for harnessing waste heat and converting it into usable electrical power. Here are some key points regarding their applications:



1. Waste Heat Recovery: Steam boilers generate a substantial amount of heat during operation, much of which is often lost through flue gases. TEGs can be integrated into the boiler system to capture this waste heat and convert it into electricity, improving overall energy efficiency.

2. Efficiency Improvement: By utilizing TEGs, the efficiency of steam boilers can be enhanced. The electricity generated can be used to power auxiliary systems within the boiler or other connected processes, reducing reliance on external power sources and lowering operational costs.

3. Sustainability: The use of TEGs in steam boilers contributes to sustainability efforts by converting waste heat into renewable energy. This aligns with global initiatives to reduce carbon emissions and promote energy-efficient technologies.

4. Versatility: TEGs can be applied in various types of steam boilers, including those used in industrial processes, power generation, and heating applications. Their adaptability makes them suitable for a wide range of operational environments.

5. System Integration: TEGs can be effectively integrated with heat exchangers and other components of steam boiler systems to optimize heat transfer and maximize energy recovery. This integration is crucial for achieving the best performance from the thermoelectric modules.

COMPONENTS USED

The main components of the thermoelectric generator include:

- Thermoelectric module
- Voltmeter
- Thermal Grease

Thermal Conductivities

For comparison, the approximate thermal conductivities of various materials relevant to heatsinks in W/mK are:

➢ Air 0.034

➢ Thermal grease about 0.5 to 10

➢ Unbranded grease typically 0.8; some silver-and graphite-based greases claim about 9

➢ Aluminium oxide (surface layer on aluminium) 35

➢ Steel About 40, varies for different types

➢ Aluminium 220

➢ Copper 390

➢ Silver 420

These are bulk thermal conductivities; the thermal resistance of a particular interface (e.g., a CPU, a thin layer of compound, and a heatsink) is given by the thermal resistance, the temperature rise caused by dissipating 1 W, in K/W or, equivalently, °C/W

COSTANALYSIS

MATERIAL	**COST**
TEG modules (4 nos.)	Rs. 800
Voltmeter	Rs. 500
Thermal paste	Rs. 345
Aluminium sheet	Rs. 155
NET TOTAL COST	**Rs.1800 /-**

CONCLUSION Waste heat from steam boilers, when are not captured, are useless and contribute to global warming, there are a lot of methods to recover the waste heat generated from thermal power plants but here in this project, research was made on thermoelectric generator for waste heat recovery; which is the renewable energy source.

Thermoelectric effect is the way electrical potential is generated, by presence of temperature difference and vice versa, and this result depend on material properties of thermocouples and their size, I mean areas and lengths; High manganese silicide (HMS) has been used to make thermoelements materials.

Design which has been done, including the design and modelling of thermoelectric generator.

Results found are good and there are showing that once temperature difference increases output also increase, the generated electrical power changes with change in temperature differences, so this can be conditioned (boost converter) and supplied to the electronics devices or can be used for other purposes to increase the overall efficiency in the plant, this shows that manufacturing and production industries, should use or adopt this system to save environments. **REFERENCES**

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