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Overview of the use of Peltier's modules in technology

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Abstract

In this article, design and analysis study of thermoelectric generation reactor and its applications are described, Thermoelectric (TE) Heating and Cooling technology has many advantages in power generation and industrial purposes.This paper introduces a new cooling system approach that extracts heat from outer surface space to get it to a lower temperature than the air surrounding it. This system uses the "Thermoelectric Generator module (TEG)" which works on thermoelectric cooling, with the goal of cooling by using thermoelectric effect. Effect which states that when DC voltage is applied across two junctions of significantly different electrical conductors; heat is absorbed from one junction and heat is discharged at another junction which causes a temperature difference. A difference in temperature applied at the atomic scale allows the carriers of charge in the substance to migrate from the hot side to the cold side. This process requires electrical and thermal conductivity for the metals to supply the water using heat exchangers that reduces power consumption. In order to improve theperformance of the TE cooling systems, the hot side of the TE should be directly connectedto efficient heat exchangers for dissipation of the excessive heat.

Keywords: thermoelectric generators, Peltier modules, heat sinks

1 Introduction

Refrigeration is the process of removing heat out of atmosphere to get it to a lower temperature than the temperature around it. This paper deals with the study of "Peltier modules and Thermoelectric Generators" which operates on thermoelectric cooling, aims to provide cooling by using thermoelectric effects rather than conventional methods such as the "vapor compression process" or the "vapors absorption cycle" more prevalent. Energy production is the focal point of researchers worldwide. It is due to the installation of millions of sensor nodes and bottleneck batteries. This approach employs various methods of transduction, such as piezoelectric, electromagnetic, solar and thermoelectric.

Thermoelectric Generator works on the Peltier effect from these three effects; thermoelectric cooling technology produces thermoelectric coolers (TECs), has advantages of high durability, no mechanical moving parts, compact size, light weight, and no operating fluid.The generation of electricity and heat has stimulated the development of alternative efficient and clean-energy generation systems, including waste heat recovery in electricity. Countless power generation projects, such as Power Reactors, solar panels, wind turbines and geothermal power plants, use renewable energy, have been designed to reduce dependence on fossil fuels, reducing greenhouse gas emissions as a result. These electricity generation systems therefore require high maintenance and are often expensive compared to thermoelectric generator (TEG) devices. Thermoelectric power generator (TEG) is a device that converts heat directly into electricity [1, 3–9, 12–14, 16].

1.1 Thermoelectric Generators

Robert W. Fritts summarized the development of gas-fired thermoelectric plants for the period 1962 to 1966. Present-day thermoelectric generator equipment is portrayed showing the simplicity of operation with a description of good site preparation and installation steps. With today's equipment the power cost per kilowatt hour is represented and contrasted with conventional power sources. All possible applications are summarized, and there is a prediction for the power range that thermoelectric generators will occupy in the foreseeable future in competition with other direct energy conversion products [2].

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Automotive engines by means of the exhaust gas reject a large amount of energy into the ambience. Recovering exhaust heat by using thermoelectric generators could achieve a significant reduction in engine fuel consumption. One of the most important issues is the development of an efficient heat exchanger which offers optimum heat recovery from exhaust gases. The designed heat exchanger model allowed 0.6 to 5.0 kW of exhaust gas energy to be used, depending on the engine's operating parameters. However, the temperature distribution analysis points out that even 25 kW can be recovered when specific changes are introduced into the design [15].

Suwit Jugsujindaet carried out a report on the analysis of the efficiency of thermoelectric refrigerators. We produced a 25x25x35 cm^3 thermoelectric refrigerator (TER), using a 4x4 cm^2 Peltier assembly. When the TER power input of 40W was decreased in 1 hour from 30^oC to 20^oC, the temperature slowly decreases later in 24 hours. We achieved a combined TER and TEC COP of 0.65 and 3.0 [11].

Ruciński and Rusowicz provides some thermoelectrical information. Some new materials are presented, with improved merit figures. Thanks to a temperature difference, these materials in Peltier modules allow the generation of electric current. The paper outlines possible applications of thermoelectric modules as interesting tools for using different sources of waste heat. Some zero-dimensional equations are given which describe the conditions for generating electric power. Operating parameters for Peltier modules are also evaluated, such as voltage and electric current. The paper discusses selected characteristics of the parameters for power generation [10].

2 Peltier module

The Direct conversion of temperature differences to electric voltage and vice-versa. A Thermoelectric device creates voltage when there is a different temperature on each side conversely, when a voltage is applied to it, it creates a temperature difference. The both temperature forms that creates the temperature gradient, that describes in which direction and at what rate the temperature changes the most rapidly around a particular location. This effect can be used to generate electricity measure temperature or change the temperature of objects. Because the direction of heating and cooling is determined by the polarity of the applied voltage, thermoelectric devices can be used as a temperature controller. The term thermoelectric module has a three different physical effect process.

- Seebeck effect;
- Peltier effect;
- Thomson effect.

2.1 Seebeck effect

The Seebeck effect is the conversion of heat directly into electricity at the junction of different types of wire. The compass needle would be deflected by a closed loop formed by two different metals joined in two places with a temperature differences between the two joints.

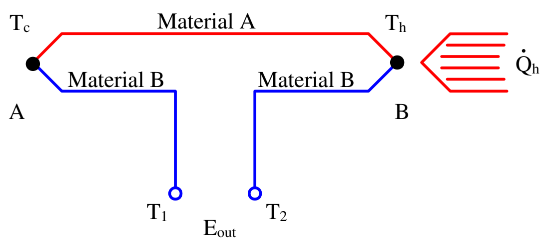

Figure 1. The Seebeck effect

This situation occures because the electron energy levels in each metal shifted differently and a potential difference, that means voltage, electric potential difference, electric pressure or electric tension (denoted by ΔU or ΔV) and this differences between the junctions created an electric current and therefore a magnetic field around the wires. Seebeck did not recognize that there was a electric current involved, so this effect is called the phenomenon thermomagnetic effect. Seebeck effect is also knows as classic example of an electromotive force (EMF).

2.2 Peltier effect

The Peltier effect is the presence of heating or cooling at an electrified junction of two different conductors and is named after name Peltier. When a current is made to flow through a junction between two conductors A and B heat may be generated or removed at the junction. Te Peltier heat generated at the junctions per unit time is

$$\dot{Q}_h = (\Pi A - \Pi B)I \tag{1}$$

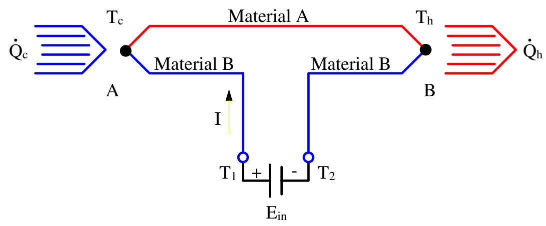

Figure 2. The Peltier effect

The Seebeck effect is used in thermoelectric generators, which function like heat engines to recover waste heats, but are less bulky have no moving parts, and are typically more expensive and less efficient.

2.3 Thomson effect

According to the Thomson effect, heat will either be absorbed or expelled from the conductor when an electric current is passed through a conductor having a temperature gradient over its length. The direction of both the electrical current and the temperature gradient depends on whether heat is absorbed or expelled. This phenomena is known as the Thomson Effect.

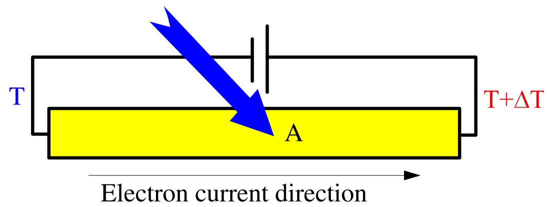

Figure 3. The Thomson effect

3 Thermoelectric materials

TEG's are composed of multiple legs (slabs) made of thermocouple-forming p-and n-type semiconductors, all bound electrically in series and thermally in parallel. Via conductive copper tabs, the semiconductor legs are attached to each other and sandwiched between two ceramic plates, which conduct heat, but serve as insulators to electric current.Figure 4. displays a schematic diagram of the thermoelectric generator with three-dimensional (3-D) multi-element.The top ceramic plate of TEGs can be supplied with waste heat from various sources, such as automotive exhaust engines, industrial and infrastructure-heating activities, geothermal, and other.Effect Thomson. Figure 3. Heating joule.464 Power generation thermoelectric — A look at technology trends as shown in Figure 4., heat flows through ceramic plates and copper-conductive tabs until reaching the top surface of p-and n-type legs made of proper semiconductors known as the TEG hot side. Energy flows through both the legs of the semiconductor, and again through the copper-conductive tabs and the ceramic layer at the bottom.By heat sink, the bottom ceramic plate is held at significantly lower temperatures than the top ceramic to create a gradient of high temperatures, which will result in high power output. The allowed temperature on upper and lower ceramic plates differs on p-and n-type leg materials.In addition, p-and n-type materials are engineered to have low thermal conductivity to reduce heat flow into semiconductors as much as possible, and to preserve temperature differences between the hot and cold sides of TEG.

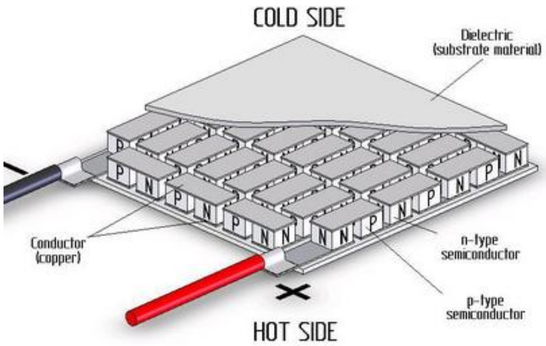

Figure 4. TEG structure [14]

3.1 Thermoelectric Semiconductors

For many years, bismuth telluride (Bi2 Te3), lead telluride (PbTe), and silicon germanium (SiGe) were the major three semiconductors known to have both low thermal conductivity and high-power factor. These are following elements that make compounds very expensive to them.

Bismuth Telluride Bismuth telluride is a gray powder, known as bismuth telluride, which is a combination of bismuth, and tellurium. It is a semiconductor, which is an efficient thermoelectrical material for refrigeration or portable power generation when alloyed with antimony or selenium.

Lead Telluride It is known as lead telluride, and it is a combination of lead and tellurium. It is a crystal structure that includes Pb atoms that occupy and form the anionic lattice. By increasing the power factor by band engineering the (PbTe) device can be optimized for power generation applications. It may be doped with sufficient dopants, either n-type or p-type. Halogens are commonly used as doping agents of the type n.

Silicon Germanium Using conventional silicone processing tool sets, the use of silicon germanium as a semiconductor was produced on silicon wafers. Today, using nanotechnology, the thermal conductivity of semiconductors can be diminished without affecting their high electrical properties. This can be accomplished by producing nanoscale features in bulk semiconductor materials such as particle wires, or interfaces.

Efficiency TEG's average output is around 5-8%. Older devices used bimetallic junctions and were very voluminous. Depending on temperature, more recent devices use highly doped semiconductors made from bismuth telluride (Bi2 Te3), lead telluride (Pb Te), calcium manganese oxide (Ca2Mn3O8), or combination thereof. These are solid state devices, and unlike dynamos, they do not have moving parts with the occasional exception of a cooling fan or pump, to discuss the factors that determine and limit efficiency, and to continue improving efficiency.

Energy Generation When an element of type P connects electrically to the element of type n, the mobile holes in the element of type p. In the n-type element the mobile electrons migrate just to the other side of the junction. When one connects a p-type element electrically to the n-type element, the p-type mobile holes. For every hole that migrate into the n-type element, the n-type element electron will soon migrate into the p-type element, each hole and electron that "switches sides" will be in equilibrium and act as a barrier, preventing further electrons and holes from migrating. This Zone of Depletion is called.

The thermoelectric generator used the temperature differential between the hot side heat sink and cold side heat sink to produce approximately 14.6 Volts and 0.6 amps DC or 8.76 Watts (ten individual thermoelectric generators supplying approximately 1.5 Volts and 0.6 amps each assuming a temperature difference of 50 degrees Celsius all ten places in series) Preliminary testing of the first thermal electric generator suggested that each generator could produce around 7V and 4.6A out of a differential of 130 degrees Celsius.In the module configuration the thermal electric generators were designed to have an output of approximately 14V and 23A.

3.2 Thermoelectric Applications

- Thermoelectric Peltier is used in medical and pharmaceutical devices, spectroscopy systems, different types of detectors, electronic equipment, portable refrigerators, chilled food and beverage dispensers, and drinking water refrigerators.

- Requiring highly reliable cooling devices which fit into small spaces, powerful integrated circuits often employ thermoelectric coolers on today's personal computers.
- Thermoelectric generator systems are also under review for larger spaces, such as idling aircraft passenger compartments parked at the doors, using solid-state heat pumps that use the Peltier effect.

Some of the other potential and current uses of thermoelectric systems are:

Military/Aerospace

Inertial Guidance Systems, Night Vision Equipment, Electronic Equipment Cooling, Cooled Personal Garments, Portable Refrigerators.

Consumer Products

Recreational Vehicle Refrigerators, Mobile Home Refrigerators, Portable Picnic Coolers, Wine and Beer Keg Coolers, Residential Water Coolers/Purifiers.

Laboratory and Scientific Equipment

Infrared Detectors, Integrated Circuit Coolers, Laboratory Cold Plates, Cold Chambers, Ice Point Reference Baths, Dewpoint Hygrometers, Constant Temperature Baths, Thermostat Calibrating Baths, Laser Collimators.

Industrial Equipment's

C Computer Microprocessors, Microprocessors and PC's in Numerical Control and Robotics, Medical Instruments, Hypothermia Blankets, Pharmaceutical Refrigerators - Portable and Stationary, Blood Analysers, Tissue Preparation and Storage, Restaurant Equipment, Cream and Butter Dispensers.

Miscellaneous

Hotel Room Refrigerators, Automobile Mini – Refrigerators, Automobile Seat Cooler, Aircraft Drinking Water Coolers.

Industrial waste heat recovery

Various cooling methods have been tested and experimented which do not require an external power supply to remove heat from the sink. We have this simple demonstration setup. Due to the enormous amount of industrial waste oil, we used candles to illustrate this heat as the heat source is applied to one side of this thermoelectric system which allows electrons to flow through the completed circuit resulting in sufficient power to energize the LED.The power generation effect is made possible by creating a temperature difference between two surfaces of the thermoelectric unit, similar to the electrical generation arising from the movement of a magnetic field across the conductor, it is the heat movement that allows the electrons to move just as when the magnetic field stops moving the electron flow when the heat stops moving.

Heat recovery from Internal Combustion Engine

We used the heat from the vehicle exhaust pipe as source of heat. One side of the panel was kept in contact with the exhaust pipe, while the other side was fitted with the pure aluminium heat sink that was cooled with a free spinning mechanical fan (no electric fan). This system was installed at the car. As the vehicle travels, the exhaust pipe starts heating up and hitting about 150^{o}C. This provides a good temperature gradient of approximately 70-80 ^{o}C, thus giving enough power output to run small devices.

Table 1. Output voltages for different heat source

No.	Heat source	Heat source temperature	Heat sink temperature	ΔT	Voltage generated
-	-	[$^\circ C$]	[$^\circ C$]	[K]	[V]
1	Industrial waste	150	70	80	3.05
2	Heat from vehicles	135	68	67	2.68

4 Research motivation

Recently, TEGs developed through the use of these technologies are at best only about 10 % effective. But even at this early stage, this could still lead to a major fuel saving in industries on the scale of an electric power station. Another area which could seem to benefit from this technology is the automotive industry. Just as a power plant has wasted heat over 70 % of the energy locked up in the fuel that you put up in the car exits along the exhaust pipe. As a result, a number of car manufacturers are now researching prototype TEGs that can scavenge some of this wasted exhaust heat back and use it to run things like the lights or charge the batteries in hybrid vehicles. Experts in the industry predict that willsee the first mainstream tag equipped cars as soon as 2020.

But there is one location where TEGs are proving their worth— Space Exploration already. Especially on board probes which go so far away that solar power is not an option. Space provides an excellent working environment for TEGs, because the average space temperature is only 3 degrees above absolute zero which takes care of the generative cold side very nicely. Meanwhile, a radioactive source like strontium-90 provides the hot side which produces the heat as it decays. This type of TEG radio-isotope was used in the Apollo missions and is currently powering millions of miles from home for the Cassini and Voyager spacecraft missions, recent research proves that we can generate power using thermoelectric modules for power reactor in space and space ships for future Interstellar travel, that would be used for Space station and Technologies.

5 Conclusions

In spite of their low efficiency, thermoelectric devices provide an advantage over traditional resources.In addition, their flexibility in cooling and power generation applications also makes them significant over electrically powered devices. Since the voltage obtained from a thermoelectric generator is tiny, some series and parallel combinations of modules make power generation comparatively efficient. Coming to the cost considerations, thermoelectric are more costly than the other techniques of power generation, but one can always trade-off between the cost and conventional energy resources.In accordance with the principle of energy conservation, the use of part of the thermal waste energy can be done at the same place that this waste is generated. The reuse of part of this remaining energy will therefore optimize device yield as a whole. It is also worth noting that the recovery of residual energy for energy cogeneration through the Seebeck effect is feasible, in addition to its ease of operation, weight and size, it also contributes to the sustainable and transparent generation of electricity. The application of the proposed thermoelectric generator can therefore be carried out in places such as a thermoelectric plant, where the residual energy produced by the generation is produced.

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