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Optimal Usage of Dissipated/Wasted Thermoelectric Energy (Including Human Heat) On a Small Scale through Harvesting

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Abstract: The demand for fleet portable energy has risen in the past decade. The article explores the usage of Thermoelectric Modules to generate low-voltage current in order to power small scale utilities such as Smartphones, Remotes, Flash-Lights, Watches etc. Common application is the use of thermoelectric generators on gas pipelines. The total global market for thermoelectric generators is expected to be US$320 Million with North-America holding 66% of it. They are used to capture the dissipated heat energy from various large-scale contributors such as Military and Space, where mobile energy has a slated demand. However, the necessity for low-power "sub-watt" Thermoelectric Energy has found its place in the evolution.

Keywords: Thermoelectric energy, Peltier, TEG, TEC, See beck effect, Mobile energy, Eco-friendly

I. Introduction

The Seebeck effect is a phenomenon in which a temperature difference between two dissimilar electrical conductors or semiconductors produces a voltage difference between the two substances. In 1821, Thomas Johann Seebeck Discovered Thermoelectric Energy. He observed that in a circuit when two dissimilar metals were placed at different temperatures, would create a deflection in the magnetic compass. Seebeck initially believed this was due to magnetism induced by the temperature difference. However, it was quickly realized that it was an electric current that is induced, which by Ampere's law deflects the magnet.

Conversely in the Peltier Effect when a current is passed through a device typically made of a metal with excellent electrical conductivity and the semiconductor material between the electrodes creates two junctions between dissimilar materials, one side would produce a high temperature (Hot) whereas the other would produce a low temperature (Cold).

Further research led to the creation of Thermoelectric Conductors (TEC) and Thermoelectric Generators (TEG).
TECs are designed to utilize energy whereas TEGs are designed to produce energy efficient [1,2].

II. Mechanism Of Thermoelectric Modules

Thermoelectric Conductors (TEC)

Two conducting plates which are made of ceramic substrates are separated by a Direct Bonded Copper Substrates (DBC) and Semiconductors (N and P) placed parallelly and at alternate positions [3]. The semiconductors of different type have complementary Peltier coefficients.

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When a current is induced through the system, it brings heat from one side to the other, so that one side gets cooler while the other gets hotter. Two unique semiconductors, one n-type and one p-type, are used because they need to have different electron densities.

Thermoelectric Generators (TEG)

Structurally TEGs are same as TEC the only difference is that TEGs are materially optimized to work at lower temperatures [4]. When there is a temperature difference between the two ceramic plate there is a current induced which can be utilized to power a device.

III. CALCULATIONAL ANALYSIS FOR THERMOELECTRIC EFFECT

Seebeck Effect

To calculate the voltage produced by Seebeck effect

$$V=a\,(T_h - T_c) \qquad (1)$$

Where,
V= Voltage
$T_h - T_c$ = Temperature Difference between Hot and Cold Junction
a = Seebeck constant

The SEEBECK CONSTANT is defined as the difference between EMF induced to the temperature difference between hot and cold terminals.

Peltier Effect

The heat produced is when a current is passed through the module is

$$Q= p\,I \qquad (2)$$

Where,
Q = Heat produced
P = peltier coefficient
I = current passed through it
The peltier coefficient depends on the material of the peltier plates.
Work Done is

$$H = I\,V \qquad (3)$$

Where,
V is the potential difference
I is Current
H in Joules is the Heat Produced.
Since WORK DONE = HEAT ABSORBED
We can say that Peltier coefficient p = potential difference v
p = V

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Thomson Effect

The absorption or evolution of heat energy, if a current is allowed to flow in a conductor having its different parts at different temperatures is known as Thomson Effect [4].

The only difference between Thomson and the other two effects is that Thomson Effect involves use of only a single metal [5]. Assume a current density J passes through a conductor then the amount of heat (H) produced is equal to:

$$H = -KJ.\ \Delta T \qquad (4)$$

Where ΔT is the temperature gradient and K is the Thomson coefficient.
In 1854, Lord Kelvin found relationships between the three coefficients, implying that the Thomson, Peltier, and Seebeck effects are different manifestations of one effect.

The second equation states that:

$$\Pi = TS \qquad (5)$$

Positive Thomson Effect

For metals like copper silver, zinc, Antimony and cadmium etc. portion at high temperature is considered at high potential than a portion at lower temperature. Hence heat energy is absorbed when current flows from a point at lower temperature to a point at higher temperature.

Negative Thomson Effect

For metals like Bismuth, Cobalt, platinum and Nickel portion at high temperature is considered at lower potential than a portion at lower temperature. Hence heat energy is absorbed when current flows from a point at higher temperature to a point at lower temperature.

IV. USAGE OF VARIOUS MATERIALS IN MODULES

A good thermoelectric material should have a high electric conductivity and a low thermal conductivity. Some of them are listed below.
Bismuth chalcogenides- Bi_2Te_3 and Bi_2Se_3 act perform best at room temperature. However, when a layered superlattice, Structure of the former compounds is made it results in great electric conductivity but poor thermal conductivity, Lead telluride-Bismuth telluride (Bi_2Te_3), lead telluride (PbTe), and silicon germanium (SiGe). These materials have very rare elements which make them very expensive compounds, Skutterudite thermoelectric, Half Heusler alloys, Sodium cobaltite, Graphene: Superlattices of many elements and compounds- However superlattices have multiple drawbacks such as: Reduced electrical conductivity, Superlattice structure counteracts and Phonon confinement counteracts.

V. APPLICATION OF VARIOUS THERMOELECTRIC ENERGY HARVESTING MODELS

Coming to the most important aspect of this paper. The practical aspect of applying Thermoelectric Energy Harvesting on various devices. We first start by understanding the material science behind a TEG [6].
Working of a Thermoelectric Module:

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Two Thermoelectric plates are taken. A thermally efficient alloy is sandwiched between the two plates. The alloy should must have both high electrical conductivity and low thermal conductivity to be good thermoelectric material. Low thermal conductivity makes sure that when one side is made hot, the other side stays cold, which helps to generate a large potential difference while inside a temperature gradient. Materials that can be used to make the two plates in order to achieve greater efficiency are: Alloys, Complex Crystals, Multiphase nanocomposites, Superlattices, Silicides and many more. The Thermoelectric module can be placed on any heat producing agent to trap dissipated heat.

Mobile Phones
The heat from the phone and the hand will hot to the hot terminal whereas the atmosphere will cool the alloy and therefore the cold terminal.

Automobile Engines
The Thermoelectric Module can be place in the engine compartment to collect the dissipated heat.

Chairs
A person seated on a chair can produce a sustainable amount of heat.

Kitchens
Kitchen Stoves produce heat. A module can capture the dissipated heat.

Laptops
Modules can be attached to laptop bases.

Low Temperature Clothing Gear
Low temperatures used in extremely cold places where the cold terminal will be on the outside getting low temperature from atmosphere where as the hot terminal would be inside absorbing human heat.

Table Tops
Warm food placed on table tops along with hands that are placed on them will produce heat.

Animals and Pets
If you would have observed that body temperature of animals is more than that of human so obviously they are likely to produce more energy than humans.

Use of Thermoelectric Modules in Outer Space
Thermoelectric modules can be attached to space crafts since the temperature in the space can fall down till -200°C It becomes easy to generate energy. Since the space craft emits a lot of heat. This heat combine with the temperature in space creates a huge potential and hence it becomes easier to produce electricity.

VI. CONCLUSION

The most important thing is that we understand that a thermoelectric module cannot be used to “produce” energy. Since the efficiency of a module would be less. We are simply trying to utilize dissipated or wasted energy in the most practical way possible. The reason for the inefficiency is the unavailability of a suitable material that can act as thermoelectric generators. Moreover, we know that heat is the most unstable form of energy when it comes to the production of useful energy.

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Considering recent inventions Ann Makosinski created the "Hollow Flash Light" which utilized Hand's Heat in order produce current. She also created eDrink, a mug that converts heat from your drink into an electric current to charge your phone.

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