



The Use of Thermoelectric Devices for Power Generation



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Abstract

One of the newer technologies for power generation is thermoelectric devices. Thermoelectrics take advantage of the Seebeck effect which allows for power generation when given just a temperature difference. They work by using two dissimilar semiconducting materials along with a temperature difference to create an electromotive force which then generates power. They also have no moving parts which gives them very long life spans even up to 30 years. This makes them ideal candidates for almost any application where waste heat is not being utilized. However, since this technology is relatively new the cost usually doesn't justify their installation. However, in applications where cost is not the main concern, such as in spacecraft, thermoelectric devices are very promising. In this project, a system was designed around a heat pipe and a thermoelectric element in order to produce power. The first step was to design a system that meets various requirements in order to simulate the environment in which it will be used. Next the design was created and tested to ensure optimization. Finally the thermoelectric device was tested at Johnson Space Center for different temperature differences and data of the power, voltage, and current outputs were recorded in order to determine the usefulness of this technology.

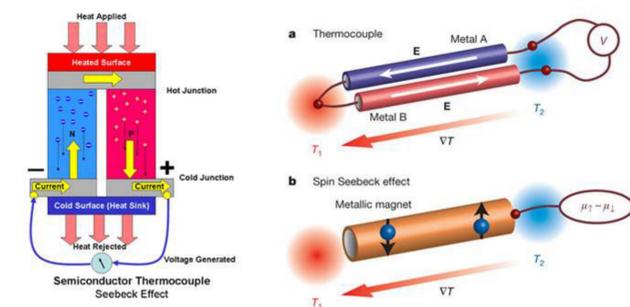


Fig. 1. Diagrams of the Seebeck effect, courtesy of Engadget and Talimba, <http://www.engadget.com/2008/10/09/researchers-say-spin-seebeck-effect-could-lead-to-new-batterie/>

Introduction

The purpose of this project, as stated earlier, is to determine the effectiveness of using thermoelectric devices to recover waste energy from a 1/2" heat pipe that is being used to cool a nuclear reactor. This recovered waste heat will then be fed back into the spacecraft power systems to run any devices that are needed.

Hypothesis

The main concern for this project is the only way to effectively cool a device without using any power is through natural convection or heat pipes. While natural convection is nonexistent in space, heat pipes do provide heat transfer even without a gravitational field, although it is significantly reduced. So in this project several different cooling methods were tested to determine the effectiveness of each. The main concern is will the thermoelectric devices produce more power than is required to cool them. While in the case of a heat pipe the answer is yes due to an input of cooling power being unnecessary however the power outputs will be significantly lower than active cooling. Therefore, active cooling was also tested to determine if more power could be generated than used for cooling. The active cooling devices that were tested were forced convection and water cooling. The hypothesis for this project was that the active cooling devices would in fact produce more power than the passive heat sinks but would require too much power input to be feasible.

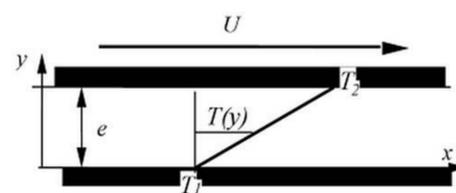


Fig. 2. Heat transfer diagram between two walls with a profile in the gap, Convective Heat Transfer, Michel Favre-Marinet, Sedat Tardu, John Wiley & Sons (2010)

Relevance

The relevance of this project is very clear. Any waste energy that can be effectively collected and reused reduces the initial battery requirements of the mission and extends the overall mission life.

In this instance, the thermoelectric device setups also act as the cooling device for the heat pipes fulfilling another required aspect of the overall design. This technology coupled with other forms of reusing waste heat could potentially decrease the power requirements of batteries or nuclear reactors by a significant factor.

Research Methods

In order to convert the rounded area of the 1/2" heat pipe to the flat surface of the thermoelectric, aluminum blocks were manufactured with a 1/2" channel. Each of these blocks has mounting holes to attach the entire setup to the heat pipe through compression.

On top of the thermoelectric each type of cooling device was attached and run with a power output from the heat pipe of approximately 100 and 200 Watts. The power, current, and voltage outputs were then recorded until reaching approximately steady state which occurs around 25-40 minutes depending on the cooling method.

Acknowledgements

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Conclusions

In conclusion, the limiting factor in this setup is the thermoelectric devices themselves as well as the power output from the 1/2" heat pipe. The thermoelectric devices work with higher temperatures and high temperature differences both of which are hard to obtain with the fixed 100W output from the heat pipe and the inefficiencies in the thermoelectric device. Since the thermoelectric technology is still somewhat new, there is a large space for improvements in the materials and efficiencies (currently 1-2%)

Results

The results of the experimentation agreed with the original hypothesis. The heat pipe configuration was capable of producing approximately 1.1 Watts of power without using the assistance of gravity and approximately doubles with the assistance of gravity. The forced convection and water cooling methods were able to produce approximately 4 and 5 Watts respectively while consuming 12 and 20+ Watts respectively. As predicted in the hypothesis the active cooling methods were superior but not feasible while the heat pipe configuration is more feasible but less effective at cooling and power generation.

Future Work

While in this application it would appear improvements are prohibited by our current understanding and technologies, thermoelectric devices should still be pursued for other applications especially in applications where waste heat occurs at very high temperatures.