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# Experimental investigation of the performance of a thermoelectric generator based on Peltier cells

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ABSTRACT

An experimental investigation is carried out to characterize the performance of thermoelectric modules used for electric power generation over a range of different resistance loads. The performance of a Peltier cell used as a thermoelectric generator is evaluated in terms of power output and conversion efficiency. The results show that a thermoelectric module is a promising device for waste heat recovery.



## 1. Introduction

Thermoelectric conversion may be defined as the result of a process by which heat is converted into electricity through the use of a heat-to-electricity conversion device. Thermoelectric conversion, besides occurring in simple thermocouples, forms the basis of reversible thermoelectric modules (TEMs), which can work either as coolers when supplied with electricity, or as generators when supplied with heat.

A TEM consists of alternate ingot-shaped n- and p-type semiconductor thermoelements, which are connected electrically in series with metal connecting strips, sandwiched between two electrically insulating but thermally conducting ceramic plates [1].

The utilization (generator or cooler) determines the temperature under which the thermoelements operate, and hence the choice of materials for the thermoelements. For low temperature applications (commonly coolers) BiTe alloys are used; in contrast high temperature materials such as PbTe or SiGe alloys, are used in thermoelectric generators [2]. However, the BiTe alloys used in conventional coolers have recently become relatively cheap, suggesting their use also in thermoelectric generators [3].

Recent review papers (Riffat and Ma [4], Bell [5], Kajikwa [6], and for the automotive sector Vázquez et al. [7]) summarize the potential applications in power generation of thermoelectric devices. These works make it evident that recent advances in materials and material processing have led to higher theoretical thermoelectric conversion efficiencies. However, when using TEMs in the power generation mode the final thermal efficiency is limited also by other factors: the reduction of the heat losses, the design optimization to reduce the parasitic losses and the appropriate choice of materials.

In the literature only a limited number of papers are available dealing with the thermal experimental performance of a thermoelectric generator. Some authors investigate directly the performance of TEMs. Leavitt et al. [8] discuss the critical requirements for accurate testing of a TEM and Takazawa et al. [9] report the design and development of a testing system for TEMs operating at high temperature. Rauscher et al. [10] present an apparatus for measuring the conversion efficiency and other key properties of TEMs; experimental data for a high efficiency $Bi_2Te_3$ module are discussed and compared with the results obtained from a theoretical model. From their experimental data Sandoz-Rosado and Stevens [11] analyze a TEM under a wide range of temperature and loading conditions. Their attention focused on the measurement of the heat flow into the module and the parasitic losses inside the TEM. Gou et al. [12] study experimentally a low-temperature waste heat thermoelectric generator. The data are used for the validation of the model used to guide the analysis and the optimization of the generator.

Other authors carry out direct investigations on specific applications of TEMs. Crane and Jackson [13] study the behaviour of a thermoelectric generator heated by a hot liquid flow and cooled by an air stream. Saqr et al. [14] report the application of an exhaust-based thermoelectric generator in the thermal design of an automobile. For three different examples they obtained data for the overall efficiency, the temperature difference across the TEMs

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