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ScienceDirect
Energy Conversion and Management 49 (2008) 1715–1723
ENERGY CONVERSION & MANAGEMENT
www.elsevier.com/locate/enconman

Methodology on sizing and selecting thermoelectric cooler from different TEC manufacturers in cooling system design

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Received 19 July 2006; received in revised form 30 March 2007; accepted 22 November 2007
Available online 9 January 2008

Abstract

The search and selection for a suitable thermoelectric cooler (TEC) to optimize a cooling system design can be a tedious task as there are many product ranges from several TEC manufacturers. Although the manufacturers do provide proprietary manuals or electronic search facilities for their products, the process is still cumbersome as these facilities are incompatible. The electronic facilities often have different user interfaces and functionalities, while the manual facilities have different presentations of the performance characteristics. This paper presents a methodology to assist the designer to size and select the TECs from different manufacturers. The approach will allow designers to find quickly and to evaluate the devices from different TEC manufacturers. Based on the approach, the article introduces a new operational framework for an Internet based thermoelectric cooling system design process that would promote the interaction and collaboration between the designers and TEC manufacturers. It is hoped that this work would be useful for the advancement of future tools to assist designers to develop, analyze and optimize thermoelectric cooling system design in minimal time using the latest TECs available on the market.

Keywords: Thermoelectric cooler (TEC); Thermoelectric cooling; TEC sizing and selection; Cooling system design

1. Introduction

Heat can be transferred through conduction, convection and radiation. Based on these three basic fundamental principles, many practical cooling systems utilizing fans, heat pipes, liquid and thermoelectric cooling devices have been developed. Among all these cooling innovations, thermoelectric cooling [1–4] has become increasingly popular due to the rapid discovery and development of novel thermoelectric materials.

Thermoelectric cooling is increasingly used in a variety of new products, which include picnic boxes, water coolers, laser devices, micro-electronics and optoelectronics appliances, highly specialized instrumentation and testing equipment. Thermoelectric cooling devices offer many advantages, which include good compactness, high reliability, long life span, fast thermal response (i.e. compared to air cooling fans and liquid heat exchangers) and excellent flexibility. Thermoelectric cooling can be used in refrigeration while generating direct current (DC) power in special circumstances (e.g, conversion of waste heat).

Thermoelectric cooling designs are accomplished using a thermoelectric cooler (TEC) [5], which is a solid state electrically driven heat exchanger that can pump heat in a direction depending on the polarity of the applied voltage. When the TEC is used as a cooler, it absorbs heat from the surface or object to be cooled and transfers the energy by conduction to the finned or liquid heat exchanger, which ultimately dissipates the waste heat to the surrounding ambient air by means of convection. The TEC operates by the Peltier Effect, which induces a temperature difference when an electrical current flows through a junction of dissimilar materials.

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0196-8904/$ - see front matter © 2007 Elsevier Ltd. All rights reserved.
doi:10.1016/j.enconman.2007.11.001

Nomenclature

ΔT	temperature difference across TEC (K)
Q, Q_c	heat input at cold side of TEC (W)
Q_h	heat dissipated at hot side of TEC (W)
Q_{max}	maximum heat input at cold side of TEC (W)
I	electrical current (A)
R	TEC device electrical resistance (Ω)
ΔT_{max}	maximum temperature difference across TEC (K)
T_{cold}, T_c	TEC cold side temperature (K)
T_{hot}, T_h	TEC hot side temperature (K)
T_{load}	temperature of load being cooled (K)
T_{amb}	ambient temperature (K)
T_{HS}	temperature at heat sink (K)
θ_{load}	thermal resistance of heat spreader (K/W)
θ_{HS}	thermal resistance of heat sink (K/W)
θ_{TEC}	thermal resistance of TEC (K/W)
S	TEC Seebeck coefficient (V/K)
V	supplied voltage (V)

In the world of thermoelectric cooler design and manufacturing, the designer does not usually custom make a TEC for a specific application. With modern technology, TECs are mass produced to deliver efficient solid state heat pumping for both cooling and heating purposes. Varieties of standard TECs having specified characteristics are available in the markets from many different TEC manufacturers.

Although the function of the synonymous types of standard TECs made by different manufacturers is the same, the geometry, specifications and characteristics may not be similar due to variations in design and manufacture. The designer has to select suitable TECs from among these manufacturers to meet the design requirements. Searching for a suitable TEC to optimize a design can be a tedious task as there are many global TEC manufacturers, each of whom has a large collection of products ranging from low cost commercial to high performance TECs. To complicate matters, different manufacturers use different formats to present their product performance characteristics. To facilitate the search, a few major TEC manufacturers offer software search facilities based on their proprietary products. These facilities are not compatible and cross searching for TECs from different companies is not supported. Furthermore, different manufacturers have different user interfaces based on different inquiry methodologies. Features such as component sizing and design analysis are often unsupported. As various operating conditions and geometry constraints are possible in the design of thermoelectric cooling systems, designers often have to search separately through the products from several manufacturers. This can be a cumbersome process. To facilitate the design task further, it is desirable to have a uniform electronic search and analysis facility with integrated functionalities and accessibility to the various manufacturers' product data on their TECs.

This paper presents the development of a methodology that can assist the designers in the selection and sizing of suitable TECs available from several TEC manufacturers. The search and analysis is based on the user input design specifications.

2. Search and analysis of TECs for cooling systems

This section provides the basic steps required in the search and analysis of appropriate TECs for a cooling system. Fig. 1 shows a typical assembly of a thermoelectric cooler in which the heat load is mounted on a sandwich consisting of a "load plate" or "heat spreader", a TEC or an array of TECs and a finned heat sink. This typical assembly is used to illustrate the TEC search process. Because of the non-linear behavior of thermoelectric coolers and the number of variables involved in their analysis, the steps presented here are mainly applicable for single and two stage thermoelectric coolers. For thermoelectric coolers with more than two stages, the accuracy of the results might be affected.

Every thermoelectric cooling application is characterized by a set of operational parameters and restrictions, which dictate the accurate selection of the optimal TEC type from among a wide range of single and multi stage TECs. The minimum specifications for finding a suitable TEC are:

- Heat load or the amount of heat to be absorbed at the TEC's cold surface (Q_c).
- Operating temperature difference (ΔT), which is the temperature difference between the hot and cold side of the TEC.

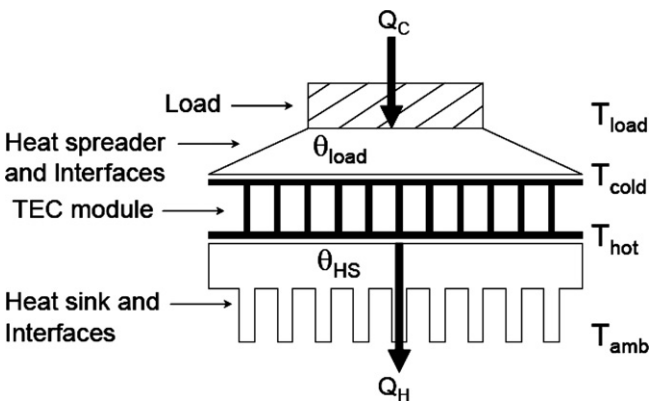

Fig. 1. A typical TEC assembly.