Peltier Cooling Device (PCD): Assembly and Configuration of the Device for Reducing Temperature of Building Spaces

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ABSTRACT

Peltier cooling devices (PCDs) are well-known for their widespread cooling applications innumerous fields. They possess a great potential to function as an alternative to conventional air-conditioning systems. However, academic studies on the utilization of PCD for building space cooling are rare. Thus, there are several cooling effect production failures due to erroneous configuration and assembly of the device. In this paper, the process of assembly and the extent of enclosure temperature reduction of PCD were studied. The methods considered the practicality of the device based on previous theoretical studies meant for building situation. The results of the experimental work demonstrated that, the numbers of PCDs, the size of inner/outer heat sink and their assembly method for the space to be cooled influences the amount of temperature reduction. Moreover, the orientation of the peltier device and the quantity of conductive cream based on indoor/outdoor usage might cause operational failures. Therefore, certain pragmatic instructions were derived from the findings to intercept analogous inaccuracy in future research of the Peltier cooling device in space cooling.

INTRODUCTION

Peltier coolers are solid state devices, which adopt “Peltier effect” to build temperature gradient and generate cooling [1]. The core element of PCD is the “Peltier device” which employs the basic Peltier effect to yield heating at one side and cooling on the other side” [2]. Hence, the temperature differences occur at two opposite junctions of the Peltier module; when direct current passes through semiconductor materials [3]. A module of PCD consists of a Peltier device, a heat sink connected to the hot side, and a cooling-load heat exchanger connected to the cold side. This technology could be an alternative to air-conditioning, and a solution for all environmental complications caused by the CFC release of the refrigerants used in the existing cooling systems [4]. Close attention must be paid to the configuration of the device as the cooling generation of PCDs can be adjusted through various application strategies [5]. Additionally, it has been stated that increasing the ability of heat sink to reject heat to ambient has a direct effect on the cooling generation of the device [6]. Hence, in this paper the differences between the extents of temperature reductions by two types of PCD configuration were studied. Moreover, the temperature reduction failures due to wrong assembly was observed. Consequently, the correlation between the numbers of the PCDs on enclosures temperature reduction was accomplished.

Methodology:

The temperature control of the Peltier cooling device is more accurate, when the effect of thermal masses on the cold and hot sides of the PCD module is known [7]. Hence, the physical experiment was carried out in an Environmental chamber at school of mechanical engineering lab at the Universiti Sains Malaysia constructed by [8], which facilitated an environment with controlled ambient temperature. Figure 1 shows two types of PCD...
assemblies on enclosure A and enclosure B; one with bigger heat sink placed on the outer side and the other with a smaller outer heat sink respectively called as configuration one and configuration two.

![Diagram](image)

**Fig. 1:** Cross section through enclosure A and enclosure B with respectively; configuration one PCD and configuration two PCD.

In order to minimize the influence of ambient temperature on indoor temperature of enclosures; the experiments were carried out in the environmental chamber. In this kind of experimental environment the temperature reduction ability of PCDs can be measured with higher level of accuracy. The experimental setup consisted of two polystyrene enclosures, “Babuc M (BSA020, LSILastem, Italy), two temperature sensors (LSILastem, Italy), an AC to DC inverter. In addition, the PCDs module (TEC1-12705; Hebeiltd, China) used in experiments were made of aluminum spacer blocks, outer heat sinks, inner heat sinks, outer fans and inner fans. The instrumental arrangement of the experiment is depicted in figure 2.

![Experimental setup](image)

**Fig. 2:** Experimental set up and instruments of the pilot study one; (1) Babuc M, (2) average temperature sensor, (3) AC to DC inverter.

**RESULTS AND DISCUSSIONS**

(i) **Appropriate heat sink configuration of TECO:**

The result of the physical experiments revealed that, the indoor temperature of “enclosure A” with configuration one PCD assembly was decreased. On the contrary, the indoor temperature of enclosure B with configuration two PCD assembly was increased. The start temperatures, end temperatures, and their differences in both enclosures has been summarized in Table 1. It is important to note that, the differences in heat sink configuration have been responsible to produce cooling effect in one enclosure and heating effect in other with up to 17.69 °C differences in temperature in enclosures.

<table>
<thead>
<tr>
<th>Temperatures °C</th>
<th>Enclosure A with config. 1</th>
<th>Enclosure B with config. 2</th>
</tr>
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<tbody>
<tr>
<td>Start</td>
<td>TS1 = 29.78 °C</td>
<td>TS2 = 30.42 °C</td>
</tr>
<tr>
<td>End</td>
<td>TE1 = 8.85 °C</td>
<td>TE2 = 37.18 °C</td>
</tr>
<tr>
<td>Difference</td>
<td>T1= -10.93 °C Reduction</td>
<td>T2=6.76 °C Increase</td>
</tr>
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Table 1: Indoor Temperature reduction by two types of TECO configurations.
Additional observations from Figure 1 shows that the device drops the indoor temperature to its first minimum in lesser than 45 minutes and steadily drops it to the second minimum temperature with small variations of about one degree Celsius; hence the PCDs are expected to reduce the temperature of indoor spaces in the early 50 minutes to one hour and maintain that temperature throughout their operation.

**Fig. 3:** Indoor temperature of enclosure A, enclosure B and the environmental chamber.

The analysis has made it quite evident that the PCD on the enclosure A is able to reduce the indoor temperature, hence configuration one is the appropriate assembly of heat sinks for the cooling device.

(ii) Influence of number of PCDs on Temperature reduction:

The exact range of temperature reduction in an enclosure is influenced by the number of PCDs. Two enclosures of identical material, but of different volumes of 0.125 m$^3$ and 1 m$^3$ were tested consequently. Both enclosures with one to five modules of PCD operating on them, while these enclosures were placed inside a room with small temperature variation of 0.87 °C to 1.37 °C. The results of temperature reductions achieved by a certain number of PCDs in each volume of space have been summarized in Table 2.

**Table 2:** Temperature reduction by PCDs in enclosures of different volumes recorded on ambient temperature of 29.46 °C.

<table>
<thead>
<tr>
<th>Number Of PCDs</th>
<th>Temperature Reduction (°C)</th>
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<tbody>
<tr>
<td>1</td>
<td>0.43</td>
</tr>
<tr>
<td>2</td>
<td>1.03</td>
</tr>
<tr>
<td>3</td>
<td>2.05</td>
</tr>
<tr>
<td>4</td>
<td>3.49</td>
</tr>
<tr>
<td>5</td>
<td>4.81</td>
</tr>
</tbody>
</table>

The results of the experiment as seen in Table 2 showed that the temperature reduction increases by adding to the number of PCD modules, this is true for both enclosures one and two with different volumes. The exact relationship between the number of PCD modules and the temperature reduction achieved in each volume of space is demonstrated in figure 4.

**Summary:**

The results of this study show that the configuration, the assembly and the number of PCDs could influence the extents of temperature reductions of enclosures. Moreover, the heat sink placed at the outer side of PCD must be bigger than inner sink to reduce temperature. Whereas, the upturned assembly of the heat sinks increases the enclosure’s temperature. Higher number of PCDs can reduce the temperature to a greater extent. Besides that, doubling the sides of a cubical enclosure, reduces the effect of temperature reduction to half. Furthermore, temperature reduction failures were experienced due to the incorrect orientation of cathode and anode side of Peltier device and also the evaporation of conductive cream in higher ambient temperatures. It is
worth mentioning that, the accuracy of insulation around PCD’s spacer block plays a crucial role in showing the accurate temperature reduction, which represents the factual ability of device in producing cooling effects.

Fig. 4: The relationship between the number of PCDs and temperature reduction in enclosure one and enclosure two.

The equations derived from the relationship between the numbers of PCD modules can be used to calculate; the amount of temperature reduction by certain number of PCD in the specific volume of space instead conducting physical measurements. The equation one and two are to be followed:

| Tredc2     | 0.1329 (N module)² + 0.3249 (N module) - 0.074 | Equation 1 |
| Tredc1     | 0.2979 (N module)² + 0.5379 (N module) + 0.078  | Equation 2 |

REFERENCES