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Reduction in the Electric Power Consumption of a Thermoelectric Refrigerator by Experimental Optimization of the Temperature Controller

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Most thermoelectric refrigerators used for food conservation are operated by on/off temperature controllers, because of their simplicity and low cost. This type of controller poses a major problem: when the inner temperature reaches the lower setpoint and the thermoelectric modules are switched off, a great amount of the heat stored in the heat exchanger at the hot end of the modules goes back into the refrigerator, by heat conduction through the modules and the heat extender. This effect significantly increases the electric power consumption of the refrigerator. This work studies experimentally the influence of different temperature control systems on the electric power consumption and coefficient of performance of a thermoelectric refrigerator: an on/off controller, a proportional–integral–derivative controller, and a novel operating system based on idling voltages. The latter provides voltage to the modules once the inner temperature reaches the lower setpoint, instead of switching them off, preventing heat from going back. A prototype has been constructed to compare these operating systems. Results prove that the controller based on idling voltages reduces the electric power consumption of the refrigerator by 32% and increases the coefficient of performance by 64%, compared with the on/off controller.

Key words: Thermoelectric refrigeration, temperature control, electric power consumption, coefficient of performance, idling voltage

List of symbols

COP	Coefficient of performance
D	Difference between limits of the inner temperature (°C)
EPC	Electric power consumption (kWh/day)
I	Electric current through the thermoelectric modules (A)
L	Lower limit of the inner temperature (°C)
$\dot{Q}_C$	Heat flow rate absorbed by the thermoelectric modules (kWh/day)
R_{wall}	Thermal resistance of the wall of the refrigerator (K/W)
T_e	Environment temperature (K)
T_{in}	Inner temperature (K)
T_0	Average inner temperature (K)
V	Voltage supplied to the thermoelectric modules (V)
τ	Time (s)

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INTRODUCTION

Thermoelectric refrigerators are characterized by their robustness and low maintenance requirements, since they require neither real fluids nor moving parts. Furthermore, these devices are free of noise and allow accurate control of the inner temperature. However, their high electric power consumption (EPC) and low coefficient of performance (COP) compared with vapor compression refrigerators act as deterrents to their widespread use in the civilian market.[1–3] A great deal of research on the figure of merit of thermoelectric materials is being carried out in order to increase the COP of thermoelectric