



Performance improvement and energy consumption reduction in refrigeration systems using phase change material (PCM)

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HIGHLIGHTS

- A review of PCM applications in refrigeration systems is presented.
- Effects of using PCM in the evaporator, condenser, compartment and compressor are evaluated.
- Using PCM on refrigerators shows positive effects on reduction of electricity consumption.

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ABSTRACT

This paper presents a review of various research investigations on the application of phase change material (PCM) in refrigeration systems. Application of PCMs mostly in vapor compression refrigeration systems have illustrated significant effects on the performance of the system, compressor on-off cycle and electricity consumption reduction. Since PCM must be chemically and thermally stable over a large number of freezing/melting cycles to be applicable for thermal energy storage in refrigerators, PCM selection for refrigeration systems is discussed as an important issue. Moreover, influences of some parameters such as PCM thickness and phase change temperature of PCM on the performance of refrigeration systems are reviewed. The advantages and drawbacks of using PCM in the evaporator, condenser, compartment section and compressor are evaluated. Using PCM at the evaporator section minimizes the fluctuation of compartment temperature and provides stable conditions against thermal load variations. Since incorporation of PCM at the evaporator increases the compressor running time initially and raises the condensation temperature, several investigations were performed to incorporate PCM at the condenser section. With an alarming rate of rise in the use of refrigerators, along with their total electrical consumption in today's world, the application of PCM on refrigerators looks like a viable measure to increase the efficiency of refrigerators and reduce the energy consumption.

1. Introduction

Electrical power is the backbone of modernization as nearly all appliances consume electricity to perform certain processes or operations. Due to rapid industrialization and progress in the standard of living, the consumption of electricity, without a doubt, is increasing day by day [1]. Among all the appliances, domestic refrigerators and freezers are the most energy demanding appliances in a household because of their continuous operation [2]. Refrigerator is regarded as one of the most popular household appliances, where the number of domestic refrigerators in the world has been estimated about one billion, which consume a considerable part of supplied electricity [3]. China is

estimated to have 0.2 billion refrigerators, which consumes around 30–40% of its residential electrical power demand [4].

Enhancement of the household refrigerators' efficiency plays a crucial role in appeasing the rate of electricity consumption which mostly depends upon the refrigerator's compressor efficiency, thermal load, ambient temperature, refrigerant used and door openings [5]. The inconsistency between the demands of increasing efficiency and decreasing cost is a dilemma. Performance improvement and enhancement of the energy saving of household refrigerators can be implemented by [6]:

- Employing high efficiency compressors.

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Nomenclature

ρ	density
λ	enthalpy of fusion
E	energy
T	ambient temperature
T_{cold}	cold compartment temperature
t_{OFF}	compressor OFF time
UA	overall heat transfer coefficient
V	volume

Abbreviation

COP	coefficient of performance
CFC	chlorofluorocarbon
GHG	greenhouse gases
EP	expanded perlite
PCM	phase change material
PCT	phase change temperature
SSPCM	shape stabilized PCM

- Optimization of the control system by applying advanced circulation.
- Upgrading thermal insulation of the system by increasing the thickness of the insulation or applying advanced thermal insulation materials.
- Improving the heat-transfer in the condenser and evaporator.

Refrigeration and air-conditioning systems have an important impact on the environment and actively participate to the global warming [7]. Nevertheless, environmental regulations established by the Montreal Protocol has relatively decreased the use of some chlorofluorocarbon refrigerants (CFCs) that strongly attack the atmospheric ozone layer. Additionally, their directly emitted greenhouse gases (GHG) have been mitigated by the hydrocarbon refrigerants. However, their indirect emissions are high due to the ever-increasing energy consumption of these appliances. Special attention to the global environmental issues and rapidly increasing cost of electricity are driving the demand for finding a frugal and viable solution for energy saving

[8]. Because of the extreme necessity to diversify energy sources, the search for energy recycling methods through the utilization of thermal losses from equipment has become fundamental [9,10].

Energy efficiency and standard of eco-friendliness are the two important issues confronting the refrigerator manufacturers. Hence, rigorous evaluation of domestic refrigerators for checking the energy efficiency and its sensitivity to variables such as type of refrigerant, size of compressor, ambient temperatures and type of insulation is necessary [11].

This is where the application of phase change material (PCM) in refrigerators is highlighted to enhance their performance. The heat energy associated with PCM is more like a natural phenomenon and can be called green energy [12]. Because of the high-energy storage density of PCM and the isothermally process of the energy storage, the PCM's enthalpy of fusion can be employed in different thermal applications. Today, the use of PCM holds the key to one of promising sustainable energy techniques of storing thermal energy. This thermal energy can be used on domestic refrigerators to increase their performance and the

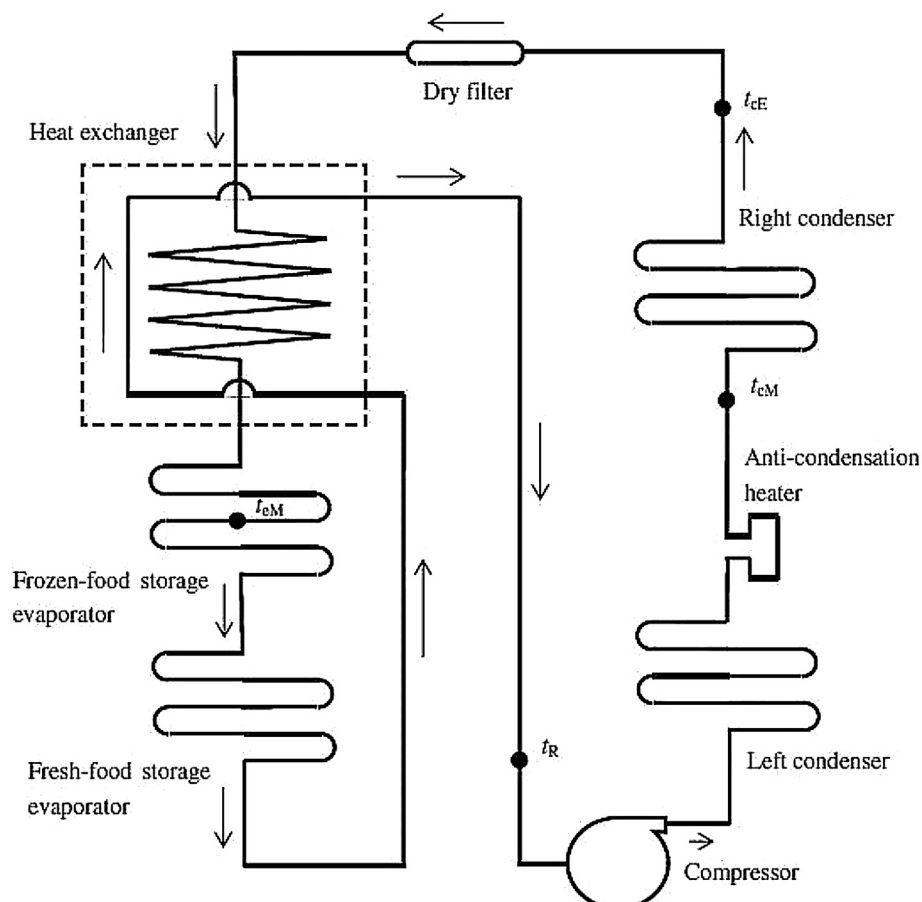


Fig. 1. Schematic diagram of a domestic refrigerator [17].

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