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PERFORMANCE IMPROVEMENT OF A DOMESTIC REFRIGERATOR BY USING PHASE CHANGE MATERIAL

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ABSTRACT

Thermal energy storage through phase change material has been used for wide applications in the field of air conditioning and refrigeration. The specific use of this thermal storage has been for energy storage during low demand and release of this energy during peak loads with potential to provide energy savings due to this. Lately through the application of this type of phase change materials in refrigeration to save energy or operate during the power outage has been under active consideration. The use of latent heat storage is especially suited to the storage of energy to prolong food preservation time and also use the excessive stored energy to improve the freezer cooling cycle by its release at appropriate time. The principle of latent heat storage using phase change materials (PCMs) can be incorporated into a thermal storage system suitable for using deep freezers. The evaporator is covered with another box which has storage capacity or passage through phase change material. The objective of this work is to prolong the food preservation time. The energy stored in the PCM is yielded to the refrigerator cell during the off cycle and allows several hours of continuous operation without power supply. The main objective is to improve the performance , cooling time period, storage capability, and to maintain the constant cooling effect for more time during power off periods using the phase change material (KCl+H2O). The results revealed that the performance is increased from 3.2 to 3.5 by using PCM (KCl+H2O).

***Keywords*: COP, Compressor, House hold refrigerator, Phase change material**

I. INTRODUCTION

As a demand for refrigeration and air conditioning increased during the last decade, large demands of electric power and limited reserves of fossil fuels have led to a surge of interest with efficient energy application. Electrical energy consumption varies significantly during the day and night according to the demand by the industrial, commercial and residential activities. This variation leads to a differential pricing system for peak and off peak periods of energy use. Efficient and economical technology that can be used to store large amounts of heat or cold in a definite volume is the subject of research for a long time. A refrigerator is a common household appliance that consists of a thermally insulated compartment. The domestic refrigerator is one found in almost all the homes for storing food, vegetables, fruits, beverages, and much more.

II. LITERATURE REVIEW

The use of a latent heat storage system using phase change materials (PCM) is an effective storing thermal energy and has the advantages of high storage density and the isothermal nature of the storage process .it has been demonstrated that, for the development of a latent heat storage system, choice of the PCM plays an important role

Sharma et al.[1], suggested various types of latent heat storage materials and advantages of a latent heat storage system. This paper is a compilation of much of practical information on various PCMs and latent heat storage system. Review will help to find the suitable PCM for various purposes , suitable heat exchangers with ways to enhance the heat transfer ,and it will also help to provide a variety of designs to store heat using PCMs for different applications, that is space heating &cooling ,solar cooking, greenhouses ,solar water heating and waste heat recovery systems. Thermo-physical property measurement techniques, thermal cycles testing for stability and enhancement of heat transfer in PCMs are discussed in this paper. This paper contains a list of about 250 PCMs and more than 250 references.

B. Zalba et al. [2], studied the performance of a latent heat storage system with solid, liquid phase change . This paper also provides a review of studies dealing with thermal energy storage (TES) using phase change materials . This paper contains a complete review of the types of material which have been used as latent heat storage materials, their classification. Characteristics, advantages and disadvantages and the various experimental techniques used to determine the behaviour of these materials in melting and solidification. The paper contains listed over 150 materials used in research as PCMs ,and about 45 commercially available PCMs.

M.Cheralathan et al. [3], investigated the transient behaviour of a phase change material based cool thermalenergy storage (CTES) system comprised of a cylindrical storage tank filled with encapsulated phase change materials (PCMs) in spherical container integrated with an ethylene glycol chiller plant. A simulation program was developed to evaluate the temperature histories of the heat transfer fluid (HTF) and the phase change material at any axial location during the charging period. The results of the model were validated by comparison with experimental results of temperature profiles of HTF and PCM. The results showed that increase in porosity contributes to a higher rate of energy storage.

K.Azzouz et al.[4], studied the effect of adding a phase change material (PCM) slab on the outside face of a refrigerator evaporator. A dynamic model of the vapour compression cycle including the presence of the phase change material and its experimental validation is presented. The simulation results of the system with PCM show that the addition of thermal inertia globally enhances heat transfer from the evaporator and allows a higher evaporating temperature, which increases the energy efficiency of the system. The energy stored in the PCM is yielded to the refrigerator cell during the off cycle and allows for several hours of continuous operation without power supply. The phase change material considered in this study is a eutectic aqueous solution whose phase change temperature may be chosen in the range from -9°c to 0°c. The PCM slab is located on the back side of the evaporator, between the insulation and the evaporator, and the surface of the PCM slab is about 0.48m

S. Kalaiselvam et zal[5], analyzes the behaviour of three paraffins, 60% ntetradecane+40% n-hexadecane, n-tetradecane, and n- pentadecane as latent heat storage materials.

J.P.Bedecarrats et al.[6], analyzed an industrial process of energy storage usable for air conditioning or refrigeration. Investigating a test plant which is a tank with a reduced size. Filled with randomly dispersed commercial nodules, placed in a refrigeration loop. The nodules are spherical capsules in which phase change materials (PCM) are encapsulated. This test plant permits the study at length of the behaviour of the tank with, in particular, the charge mode taking into account the under cooling and the discharge mode . A simulation program that considers aspects of both the surrounding heat transfer fluid and the phase-change material packed inside the nodules is developed here in the cases of the charge and the discharge processes, The simulation results are then compared with experimental observations.

III. EXPERIMENTAL SET UP AND PROCEDURE

The experimental set up consists of a domestic refrigerator of 165 liters capacity, designed to work with R-134a refrigerant which has the four main components compressor, condenser, capillary tube and evaporator coil. Theexperimental set up consists of the conventional vapour- compression refrigerating machine with proper instrumentation to measure temperature at evaporator section and to measure energy required by the system.

An energy meter is used to measure the energy input to the compressor motor and temperature indicator is used to measure the temperature inside the evaporator. The schematic diagram of the experimental set up is shown in Fig 1. The PCMs are bonded to the evaporator on the outer surface in order not to reduce storage capacity. The PCM box is made up by galvanised iron (GI) sheet.

Here a measured quantity of 1lit 300ml .solution with proportions of KCl (19.5wt%)+H2O(80.5wt%). The evaporator is covered with another box which has storage capacity or passage through phase change material and in order to prolong the compressor off time and also analyse the energy efficiency of the conventional system. The readings were taken power on and power off condition

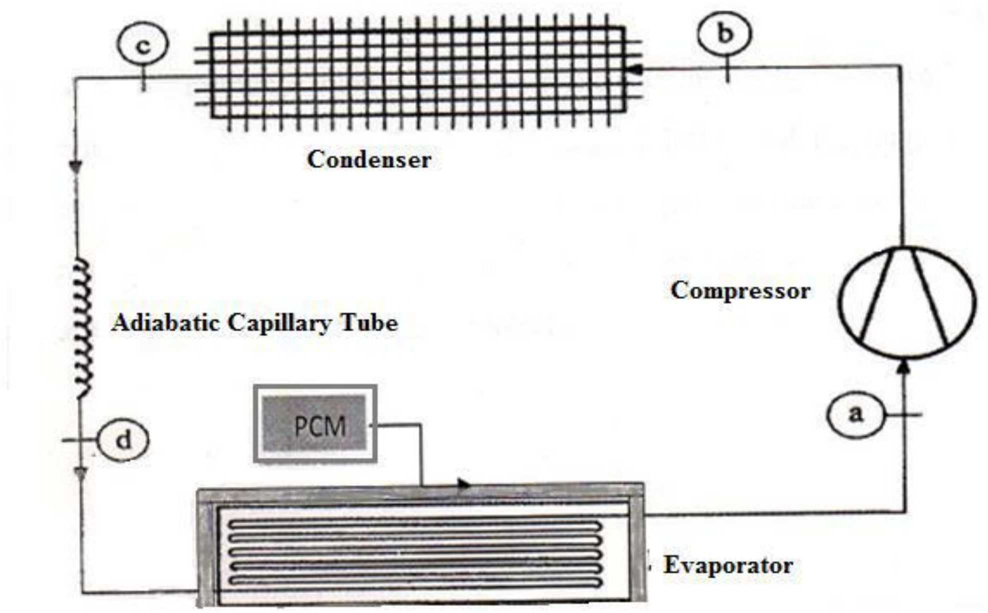

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Fig.1 Line Diagram of Refrigeration Cycle

Fig.2 Experimental Setup

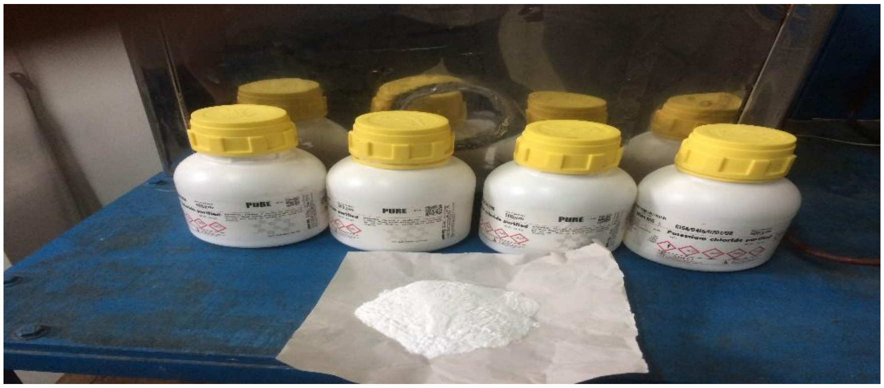

Fig.3 Phase Change Material

TABLE 1: PCM Box Specifications

Particulates	Specifications
Length	33cm
Height	12cm
Width	25cm
Thickness	1.5cm
Melting point temperature	-10.7°C
Melting enthalpy	283kJ/kg

TABLE 2: Specifications of Refrigerator

Refrigerator model	ALLWYN Refrigerator 165 liters
Ice making time	2h 30min
Voltage range	220+10% V 50Hz AC
Rated energy consumption	2.00 kWh/24h max
Rated gross volume	165 Liters
Rated general storage volume	123 Liters
Fuse rating	5A
Refrigerant	R-134a

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PROCEDURE

1. The domestic refrigerator is selected, working on vapour compression refrigeration system
2. Pressure and temperature gauges are installed at each entry and exit of the components.
3. Flushing of the system is done by pressurized nitrogen gas.
4. R134a refrigerant is charged in to the vapour compression refrigeration system.
5. Leakage tests are done by using soap solution.
6. After starting the test unit , pressure and temperatures are recorded

IV. RESULTS AND DISCUSSIONS

By performing this experiment the following results were obtained.

TABLE 3: Coefficient of performance with and without PCM

Performance parameters	Without PCM	With PCM
Refrigerant effect KJ / kg	140	145
Work of compression KJ/kg	44	40
COP (load condition)	3.29	3.5
COP (no load condition)	3.5	3.625

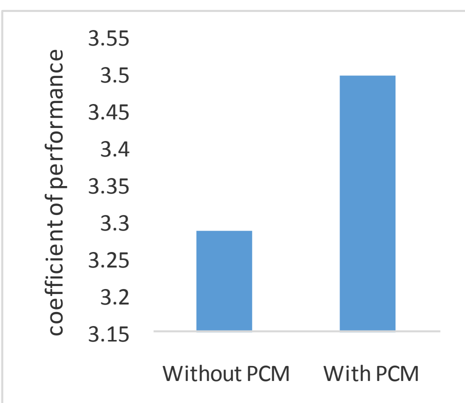

Fig.4 Coefficient of performance with and without PCM at load

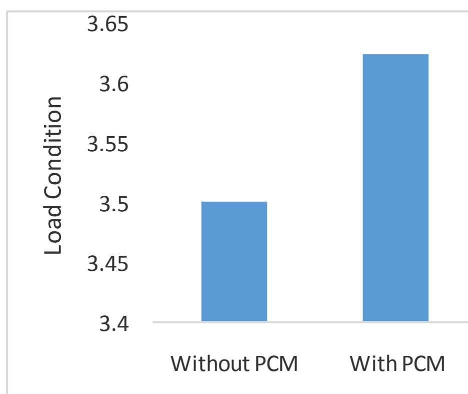

Fig.5 COP comparison of with and without PCM at no load

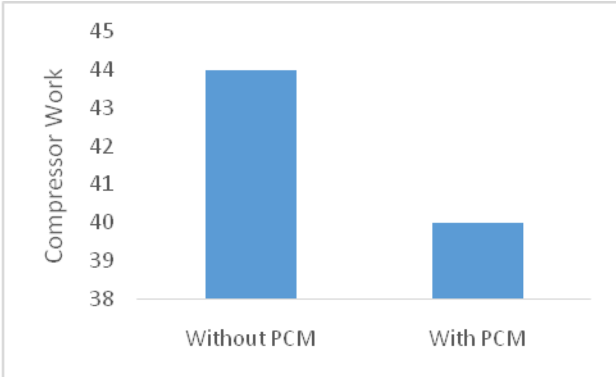

Fig.6 Compressor work with and without PCM

V. CONCLUSIONS

Experiment tests have been carried out to investigate the performance improvement of a house hold refrigerator using phase change material and tested with and without PCM.

- COP Without PCM and with load is 3.29
- COP With PCM and with load is 3.5
- COP Without PCM and without load is 3.5,
- COP With PCM and without load is 3.625

The results showed that cooling effect is maintained inside the chamber without PCM is increased 5 hours 21 minutes to 7 hours 10 minutes during power of periods and increased COP from 3.29 to 3.5 at full load. After switching of the system the time to reach the temperature inside the evaporator from 32 °c to -16.9°c is noted 7hours 10 minutes. This is the time required to store the product without spoiling inside the freezer at power off conditions.

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