

Effect of Vapour Compression Refrigeration System with Liquid Suction Line Heat Exchanger and Phase Change Material (PCM) in Evaporator

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ABSTRACT: In this application the liquid line is usually placed in contact with the suction line, forming a counter flow heat exchanger. The liquid line is welded to the suction line in the lateral configuration. The temperature of the vapour refrigerant coming out from the evaporator is less than the temperature of the liquid coming out from the condenser.

Before the expansion process, heat is transferred from the liquid line to the suction line. As a consequence this in turn reduces the refrigerant quality at the inlet of the evaporator and therefore increases the refrigerating capacity. The suction line exit temperature also increases, eliminating suction line sweating and preventing slugging of the compressor.

The main objective of this project is to evaluate the performance of refrigerator with liquid suction line heat exchanger by using R134A as refrigerant with liquid line- suction line heat exchanger and PCM material in evaporator.

KEYWORDS: VCR system, PCM in organic material, Heat Exchanger, PCM Box.

I. INTRODUCTION

The most alarming environmental disorder namely “Global Warming” refers to the rising temperature of Earth’s atmosphere and ocean and its projected continuation. The heat from the Sun is entrapped in the Earth and thus increases the temperature of the atmosphere by Greenhouse Effect. Refrigeration system is directly and invisibly responsible for Global Warming problem. For the typical home of the early 1990s, a frost-free refrigerator or freezer was the second most expensive home appliance to operate besides the water heater.

Appliance makers were required to include labels listing an estimate of the annual cost of running each appliance so consumers could compare costs and energy usage. A refrigerator (colloquially fridge) is a common household appliance that consists of a thermally insulated compartment and a heat pump (mechanical, electronic, or chemical) that transfers heat from the inside of the fridge to its external environment so that the inside of the fridge is cooled to a temperature below the ambient temperature of the room.

Domestic refrigerators are among the most energy demanding appliances in a household due to their continuous operation. The domestic refrigerator is one found in almost all the homes for storing food, vegetables, fruits, beverages, and much more. Materials that can store thermal energy reversible over a long time period are often referred to as latent heat storage materials. It also helped in heat transfer via conduction.

The objectives of the performance improvement of the domestic refrigerator by using the phase change Material (PCM) and Heat exchanger are given below,

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1. To fabricate the experimental set up by modifying the domestic refrigerator with PCM and Heat exchanger based refrigerator.
2. To observe the effects of phase change material (PCM) in compressor effect on COP.
3. To observe the difference on the Coefficient of performance (COP) of the refrigerator cycle with PCM and without PCM.

Overview of Phase Change Material (PCM)

PCMs latent heat storage can be achieved through solid– solid, solid–liquid, solid–gas and liquid–gas Phase change. However, the only phase change used for PCMs is the solid–liquid change. Thermal Energy Storage through Phase Change material has been used for wide applications in the field of air conditioning and refrigeration especially at industrial scale. A phase-change material (PCM) is a substance with a high heat of fusion which, melting and solidifying at a certain temperature, is capable of storing and releasing large amounts of energy.

II. LITERATURE SURVEY

Use of Phase change material (PCM) for the latent heat storage in household refrigerators is one of the upcoming technologies in the field of refrigeration. A phase-change material (PCM) is a substance with a high heat of fusion which, melting and solidifying at a certain temperature, is capable of storing and releasing large amounts of energy. Heat is absorbed or released when the material changes from solid to liquid and vice versa; thus, PCMs are classified as latent heat storage (LHS) units. The survey of literatures regarding the use of Phase change materials in household refrigerators are listed below.

K.Azzouz, D.Leducq, D.Gobin (2007) presented a dynamic model of vapour compression refrigeration system using Phase change material as latent heat storage medium. This paper studies 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 was 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.

K.Azzouz, D.Leducq, D.Gobin (2010) presented a paper that shows the results of experimental tests carried out to investigate the performance of a house hold refrigerator using a Phase change material (PCM).The PCM is located on the back side of the evaporator in order to improve its efficiency and to provide a storage capacity allowing several hours of refrigeration without power supply. The system has been tested with water and eutectic mixture (freezing point -3°C) and for various operating conditions (PCM thickness, ambient temperature, and thermal loads). A 10-30% increase in COP depending on the thermal load is observed, and 5-8 hrs of continuous operation without power supply.

Conventional Vapor Compression Refrigeration system:

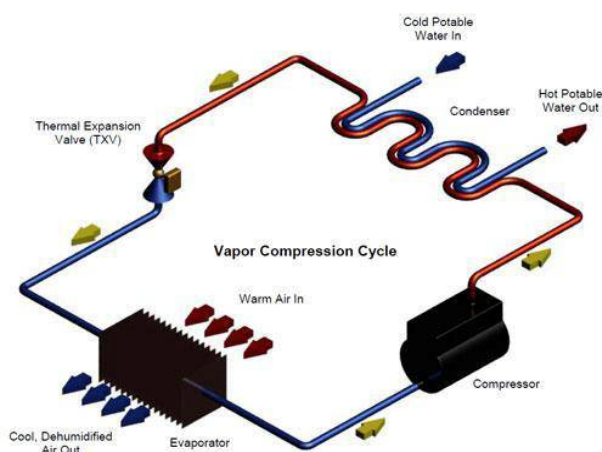
The vapor-compression uses a circulating liquid refrigerant as the medium which absorbs and removes heat from the space to be cooled and subsequently rejects that heat elsewhere. The main heat transfer part is done via convection method between evaporator coil and environment. Figure depicts a typical, single stage vapor- compression system. All such systems have four components: a compressor, a condenser, a Thermal expansion valve (also called a throttle valve) and an evaporator. Circulating refrigerant enters the compressor in the thermodynamic state known as a saturated vapor and is compressed to higher pressure, resulting in a higher temperature as well

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Conventional Vapor compression Refrigeration System

III. EXPERIMENTAL SETUP

A conventional household refrigerator is used in the modified form with PCM box located in the evaporator cabinet to carry out the necessary experiments. It shows that the details of the location of the PCM box with the evaporator cabinet. The PCM box is made up by aluminum sheet.

IV. PHOTOGRAPHS OF ACTUAL SETUP



V. DATA COLLECTION

The following data have been collected for each test run at the steady state condition of the system.

1. P_1 =Compressor suction/Evaporator outlet pressure(bar)
2. T_1 = Compressor suction Temperature ($^{\circ}\text{C}$)

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3. T_2 =Compressor discharge / condenser Inlet Temperature($^{\circ}$ C)
4. T_4 =Evaporator Inlet Temperature($^{\circ}$ C)
5. t=time

Physical Properties of HCF- 134a refrigerant:

Boiling point at 1 atm (101.3k pa or 1.013bar): -26.3 $^{\circ}$ C

Freezing point: -103.3 $^{\circ}$ C

Critical temperature: 101.1 $^{\circ}$ C

Critical pressure: 4060 k Pa

Critical volume: 1.94×10^{-3} m³/kg

Critical density: 515.3 kg/m³

Density (liquid at 25 $^{\circ}$ C): 1206 kg/m³

Table 1 Experimental Data without Phase change material

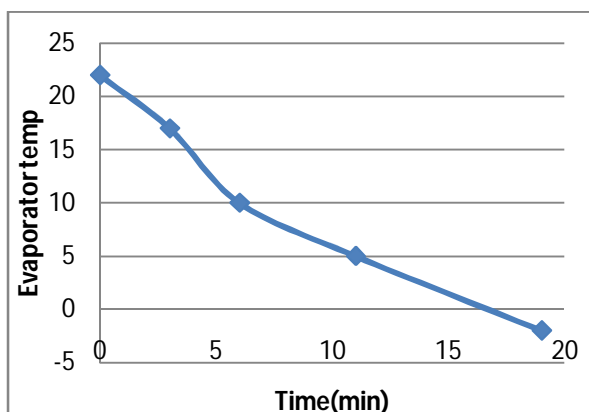
T1($^{\circ}$ C)	T2($^{\circ}$ C)	T3($^{\circ}$ C)	P1(bar)	P2(bar)	T(min)
32	33	22	0.8	10.5	0
31.8	40	17	0.85	10.6	3
31.7	51	10	0.9	11	6
31.5	58	5	0.9	11	11
31.5	63	-2	0.9	11	19

Table 2 Experimental Data with PCM material in evaporator and heat exchanger

T1($^{\circ}$ C)	T2($^{\circ}$ C)	T3($^{\circ}$ C)	P1($^{\circ}$ C)	P2($^{\circ}$ C)	t(min)
29	39	28	1.2	10.5	0
30.9	47.8	17	1.3	11	10
32.1	53.3	10	1.3	11	15
32.7	53.7	5	1.5	12	20
33	54.2	0	1.5	12	25

VI. GRAPHS

Graph between evaporator temperatures vs. time without Phase change material



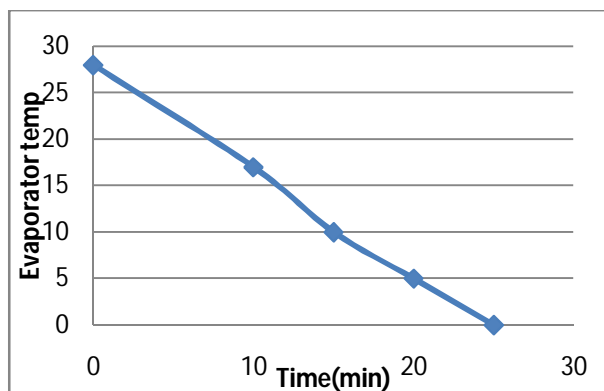
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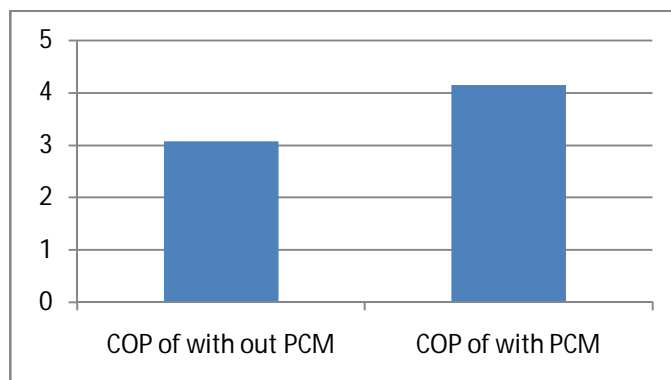
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Graph between evaporator temperatures vs. time with PCM HS01 mat



VII. RESULTS

Comparison of COP chart



VIII. CONCLUSION

Use of HS01 as PCM imposes a great impact on COP improvement at certain thermal loads. Using HS01 as PCM and certain thermal load, it is found that the 30-33% COP improvement has been achieved by the PCM in respect without PCM in conventional refrigerator. Experiment tests have been carried out to investigate the performance improvement of a household refrigerator using phase change material of different quantities at different loads. Depending on the PCM and the thermal load around 30-33% COP improvement has been achieved by the PCM in respect to without PCM.

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