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Performance Improvement of Refrigeration System using Phase Change Materials

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ABSTRACT

The usage of Phase Change Materials (PCM) in refrigeration system improves the system performance. In addition to that recovery of waste heat is obtained in this system. PCM is used in the outside of the condenser as a heat absorbing agent in a vapour compression refrigeration system. Heat which is liberated to the atmosphere by the condenser tubes are absorbed by the PCM used. By using this method of removing heat the condenser outlet temperature is reduced to further extent when comparing to the air cooled condensers. For the reduction of every 2˚C the overall performance of the system is increased by 5.46%.

Key words – Phase change materials, refrigeration, fusion, organic

I. INTRODUCTION

1. Phase Change Material (PCM)

A Phase Change Material (PCM) is a substance with a high heat of fusion which, melting and solidifying at certain temperatures and is capable of storing or releasing large amounts of energy. PCM materials have high heats of fusion so they can absorb a lot of energy before melting or solidifying. A PCM temperature remains constant during the phase change, which is useful for keeping the subject at a uniform temperature.

A large number of PCMs are known to melt with a heat of fusion in any required range. However, for their employment as latent heat storage materials these materials must exhibit certain desirable thermodynamic, kinetic and chemical properties. Moreover, economic considerations and easy availability of these materials has to be kept in mind. The PCM to be used in the design of thermal-storage system

Selecting a PCM for a particular application, the operating temperature of the heating or cooling should be matched to the transition temperature of the PCM. The latent heat should be as high as possible, especially on a volumetric basis, to minimize

the physical size of the heat store. High thermal conductivity would assist the charging and discharging of the energy storage.

2. Classification of PCM

A. Organic

i. Paraffin compounds
ii. Non-Paraffin compounds

B. Inorganic

i. Salt hydrate
ii. Metallic

C. Eutectics

i. Organic- Organic
ii. Inorganic- Inorganic
iii. Inorganic- Organic

3. Properties of PCM

a. Chemical properties:

i. No chemical decomposition, so that the latent TES system life is assured
ii. Non-corrosiveness to construction material
iii. Long term chemical stability
iv. Non-poisonous; Non-toxic
v. Non-explosive, non-dangerous
vi. Non-flammable

b. Physical properties

i. Limited changes in density to avoid problems with the storage tank
High density with low density variation
ii. Small units size
iii. Low vapour pressure
iv. Favourable phase equilibrium

c. Economic Aspects

i. Available in large quantities
ii. Cheap in order to make the system economically feasible

4. Application

i. Building applications
ii. Solar wall
iii. PCM filled glass windows
iv. PCM Assisted Sun-Shading
v. PCM Integrated Roof
vi. PCM Assisted Ceiling
vii. PCM Integrated In Combined Heating and Cooling System

II. HEAT RECOVERY SYSTEM

Large amount of heat is sent to the atmosphere as waste heat. Those can be reused in process for reducing the cost of the system and further improving the efficiency of the system.

In this the waste heat to the atmosphere from the condenser is stored in the PCM box and the same is used for other process.

III. EXPERIMENTAL SETUP

Vapour compression refrigeration system is the most commonly used system for the refrigeration purposes. In this the working substance used is the refrigerant, which boils and condense at lower temperatures. The construction is simple compared to other refrigeration system. This system consist of

i. Compressor
ii. Condenser
iii. Expansion valve
iv. Evaporator

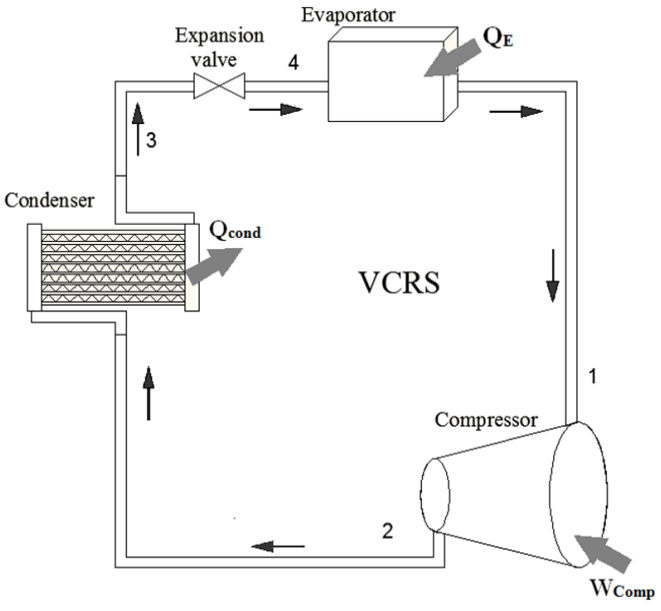

Figure 1 - Schematic view of vapour compression refrigeration system

i. Air cooled condenser

Figure 2- Air cooled condenser

In air cooled condenser the circulation may be natural or forced convection. These are used in smaller capacities such as freezers and refrigerators. In these for higher temperature forced convection system is used with the help of fan.

The air is made to flow across the tubes and heat is carried out by the flowing air. With this way the air cooled condensers are used.

ii. PCM based condenser

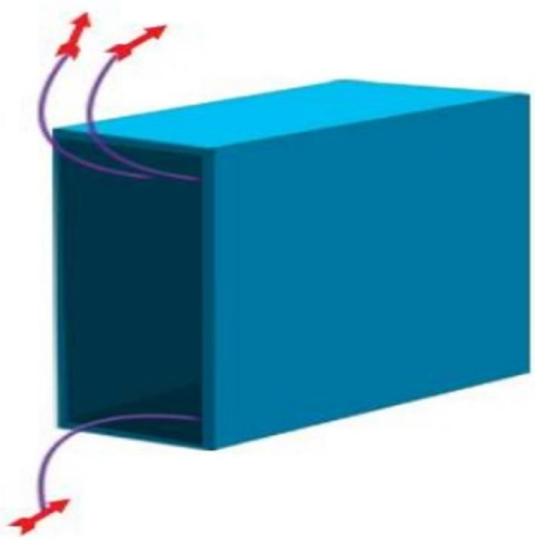

Figure 3 – PCM based condenser

The condenser tubes are made to pass inside the PCM box. In this the heat is absorbed by the PCM material and is liberated outside. Those heat liberated outside can be recovered and used for various other heating purposes.

IV. THEORETICAL ANALYSIS OF THE SYSTEM

A theoretical analysis is performed for the system by considering the refrigerant used is R134a. The temperature of the condenser is maintained at 42˚C and the evaporator temperature at -12˚C. The properties of the refrigerant are given in table 1

Table 1 - Properties of the refrigerant

T3	P	V_g	h_f	h_g
˚C	bar	m^3/kg	kJ/kg	kJ/kg
-12	1.85	0.1074	183.93	391.46
42	10.72	-	258.46	420.28
40	10.17	-	255.52	419.43

s_f	s_g	cp_l	cp_g
kJ/kg.K	kJ/kg.K	kJ/kg.K	kJ/kg.K
0.9406	1.7348	-	-
1.1999	1.7103	1.5105	1.1626
1.1905	1.7111	1.4984	1.1445

V. RESULTS AND DISCUSSION

With the properties of the system the following calculations were done. In this various parameters were calculated and are given in table 2

Table 2 – Properties of the system

T3	T2	h2	h1	h3
˚C	(˚C)	(kJ/kg)	(kJ/kg)	(kJ/kg)
42	46.55	426.9254	391.46	255.52
40	48.71	428.0794	391.46	258.46

Table 2 contd				
ɳ vol	m	COP	Pr ratio	VCC
(%)	(kg/s)	-	-	(kJ/m³)
0.89	0.1350	3.83	5.79	1129.38
0.89	0.1340	3.63	5.49	1096.77

i. Coefficient of performance

With the reduction of condenser temperature the performance of the system increases with a percentage of

$$\% \text{ increase} = \frac{5.79-5.49}{5.49}$$

$$= 5.46\ \%$$

VI. CONCLUSION

PCM is an emerging technology in which they are used in different categories for the performance improvement and the use of heat. In this the PCM is used for removing heat in the condenser tubes of the refrigerator. In addition with that the removed heat is stored in the PCM box and is further used for other process. With the usage of PCM the temperature of the refrigerant coming out from the condenser tubes are reduced to some extent. Reducing the temperature result in increase of COP of the system. The percentage increase in COP for every 2˚Cresult in 5.46%.

VII. FUTURE WORK

With the use of different PCM that has higher rate of heat transfer, the temperature of the condenser tubes can be further reduced and the resulting COP will be higher than the existing one.

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