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A Reassess on Phase Change Material Application in Refrigeration and Air Conditioning

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Abstract

Many part of the world are facing energy crises. There is a need of finding solution to overcome from this the problem. PCM (phase change material) has become the most popular solution to overcome from the problem. The aim of this work is to elaborate the use of PCM as a solution for the problem of energy crises. Phase change material is an energy storage device which store energy at a specific load and releases it when it is being required. Maximum use of phase change material are in the field of refrigeration and air condition where it has the capability to make the great impact on the energy saving.

Keywords: Energy storing device, PCM, applications, Air conditioing, energy saving, Refrigeration

1. INTRODUCTION

In recent decades, the productions of many energy consuming devices are increases drastically. This energy consuming device needs energy for maintaining them in a working condition. Some of them needs large amount of energy and they work continuously day and night hence consumes lot of energy for example refrigerators, air conditioner, cold storage systems etc [1]. The phase change material PCM emerges as an energy storage device which has the capability to store the energy. PCM store the energy by changing its phase and return it when there is a requirement via regaining its original state. PCM is being used in the field of refrigeration and air conditioning in great extent. PCM has wide applications in devices like refrigerators, air conditioners, cold storage devices etc. these devices consumes large amount of

energy which will never be easy to predict [2]. Phase change material does not require much more space so can be used in any place inside the device. Optimization of the use P.C.M. in such technologies and related field can make the most valuable contribution in the field of energy saving and has the capability to turn the entire world in to renewable energy sources [3].

2. REVIEW

2.1 S. Rajendra sival et al (2015), [1] they found that, the use of a latent heat storage system using phase change materials (PCMs) is an effective way of storing thermal energy. It has the advantages of high-energy storage density. They also summarize the investigation and analysis of the available thermal energy storage systems incorporating PCMs for use in different applications. They did assessment of the thermal properties of various PCMs. They also presented the paraffin melt fraction studies of the few identified PCMs used in various applications for storage systems with different heat exchanger container materials. Figure 1 shows flow chart showing different stages involved in the development of a latent heat storage system.

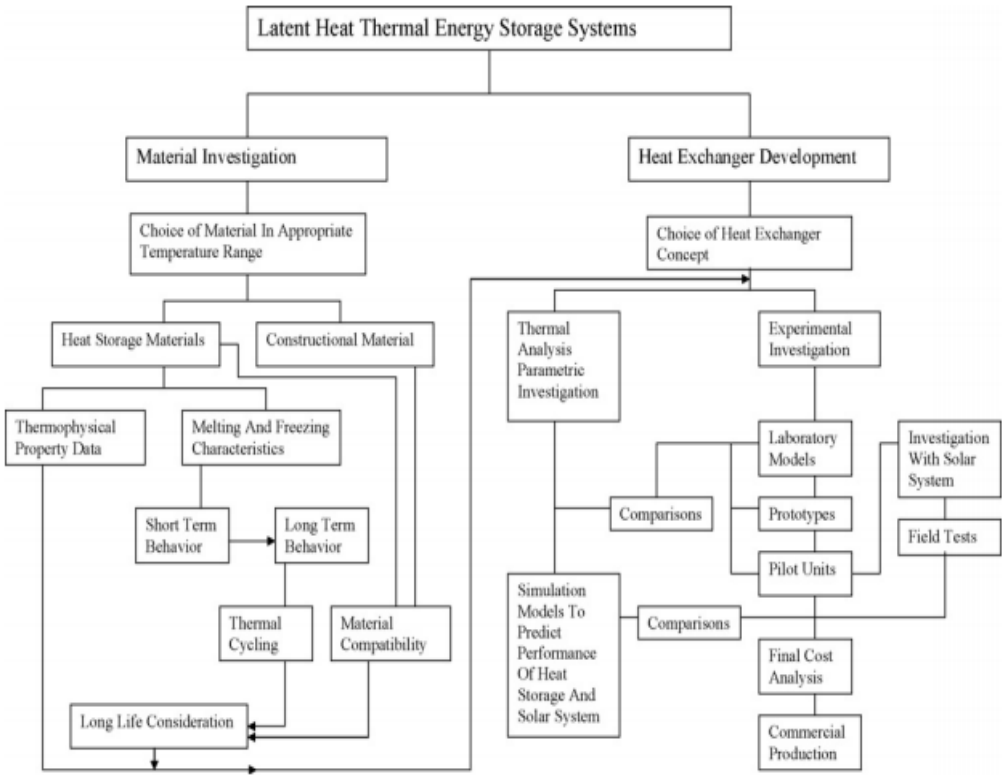
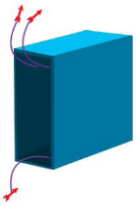


Figure 1: Flow chart showing different stages involved in the development of a latent heat storage system

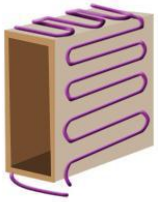
2.2. Md. Imran Hossen Khan et al. (2014) [2], they found that, the effect of phase change material (PCM) on temperature fluctuation inside the evaporator cabinet of a household refrigerator. They uses different thermal loads with two different PCMs (Water and Eutectic solution (90% H2O + 10% NaCl)). Figure 2 shows an arrangement of the PCM based evaporator. The evaporator coil is immersed in PCM which is placed around the five sides of cabinet. This result in the reduction of temperature fluctuation for Eutectic solution is better than water. PCM which improves the refrigerator food preservation quality. Temperature fluctuation reduces between two PCM; Eutectic solution is higher than Water.

Step 1- Conventional Evaporator



Step- 2 PCM box with PCM passage

Step 3- Heat releases from PCM (Compressor On)



Step 4- Heat taken from the food

Figure 2: The arrangement of the PCM based evaporator

2.3. Rezaur Rahman et al. (2013) [3], they obtained the performance improvement provided by a phase change material associated with the evaporator in a domestic refrigerator. The coefficient of performance of the conventional refrigerator was increased by 55-60% by using water as PCM. This improvement can be done for Single evaporator refrigeration system. There is prolonging of the compressor off time due to using the latent heat of energy of the PCM capsulated ice. The food quality increases due to lower hysteresis cycles of on/off for a given period of operation. These results in higher C.O.P.in case with PCM as compare to without P.C.M. At low thermal load while it decreases with the increase of thermal load. The Use of PCM decreases the fluctuation of the cabinet temperature.

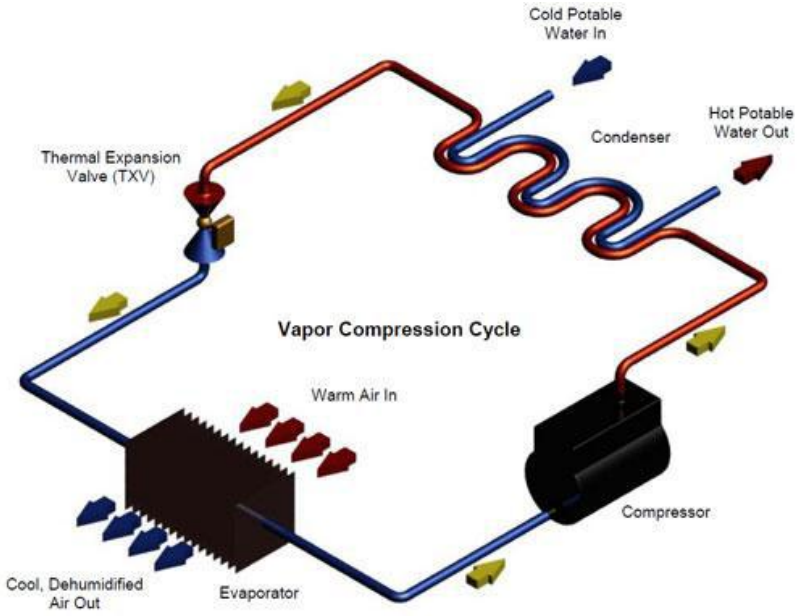


Figure 3: Vapor compression refrigeration system

2.4 A. Safaria et.al. (2011) [4], they investigated a common problem of super cooling of Phase Change Materials (PCM). The thermo physical property of PCMs in super cooling creates problem in thermal storage applications. Figure 4 shows super cooled liquid and its solid state. Super cooled liquids are reliable substitutes to be used directly to a process in various applications such as refrigeration and air conditioning. Feasibility of integrating super cooled PCM into industrial applications also depend on modifying existing energy systems, heating and cooling demand analyses. The economic outlook for these systems is more admirable when the system is operating in remote regions where there is no access to a reliable stable energy sources.

Figure 4: super cooled liquid and its solid state.

2.5. Amrit Om Nayak et al. (2011) [5], they found that, the phase-change material is a substance that contains high latent heat storage capacity which on melting and solidifying at a certain temperature and it is capable of storing and releasing large amounts of energy. The various PCM are used to absorb heat from the coolant water from the engine like Paraffin wax, sodium acetate tri-hydrate and phenolphthalein. They observed that the heat absorption in the PCM material decreases gradually as we travel from the inlet of coolant water towards the outlet of coolant water.

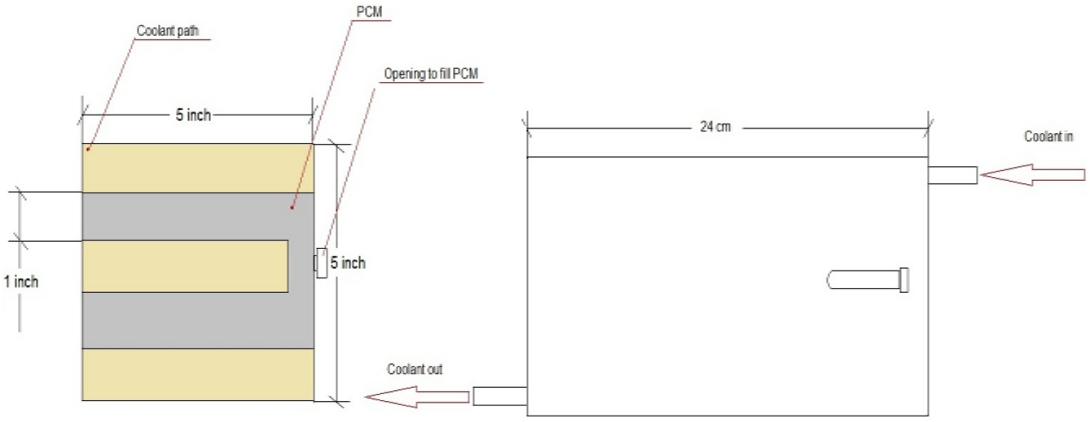


Figure 5: Schematic view of the TESD

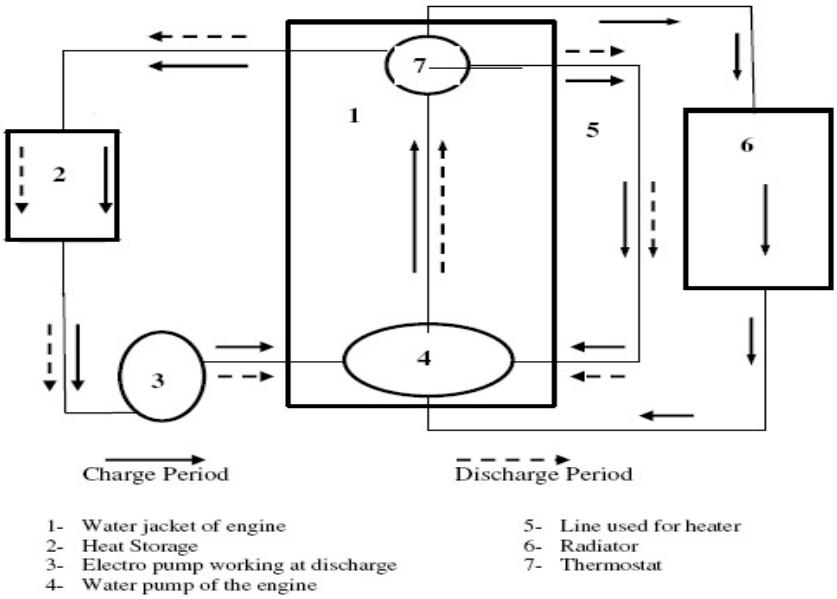


Figure 6: Position of TESD in Engine System

2.6. Niccolò Aste et al. (2017) [6], they found that, the Food preservation is one of the most neglected pillars of food security in humanitarian context. The few preservation practices for both raw and cooked food are in place, due to the lack of appropriate technologies, very limited access to energy, especially electricity, and affordability. In common, food preservation in areas without access to power grid can be provided through active/passive refrigeration, characterized respectively by the use or not of an energy source such as electricity or fuels to run the refrigeration process. In present off-grid active refrigeration technologies have a high potential, but in commercial solutions there are still room for improvement. They demonstrated that vapour-compression solar refrigeration is presently one of the most promising and cost effective solutions where solar radiation is widely available. Absorption systems powered by fuels are still the best option where good performances have to be ensured independently from the availability of non-programmable energy sources (e.g. sun and wind), provided that a reliable supply-chain of fuels can be guaranteed. Thermoelectric technology is instead particularly suitable to preserve tropical fruits or vegetables suffering chilling injury, in temperate climatic conditions, and represents a good solution for portable applications.

2.7. Gang Tan et al (2015) [7], they found that, the thermoelectric cooling system integrated with phase change material (PCM) can be used for space cooling which stores cold thermal energy at night and functions as a heat sink to reduce hot side temperature of thermoelectric modules during daytime cooling period which increases performance efficiency of the system. Figure 7 shows schematic diagram of the experimental setup for the prototype thermoelectric cooling system. The cooling power output, COP and cost are the most important three factors that determine the selection of thermoelectric modules (TEM) from market available products and the accumulated heat dissipation of the cooling system determines the volume of PCM while local weather condition also needs to be evaluated to ensure PCM will be fully discharged at night.

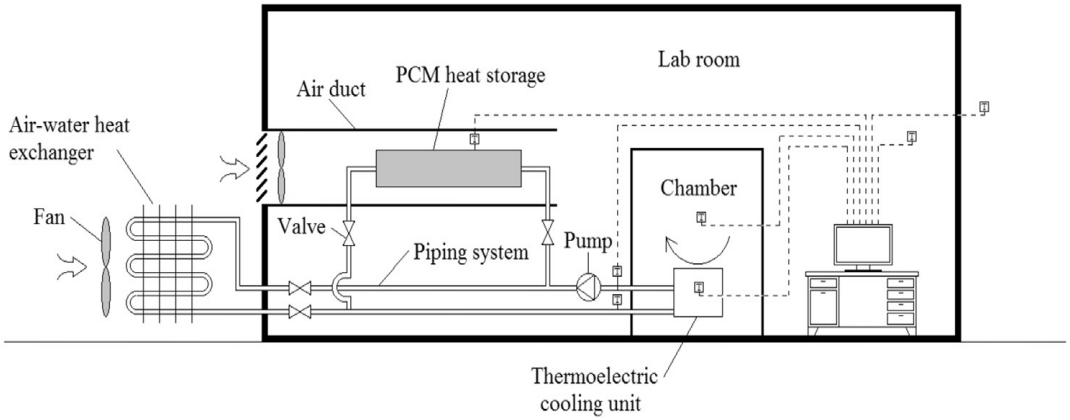


Figure 7. Schematic diagram of the experimental setup for the prototype thermoelectric cooling system.

2.8 Diana Enescu et al (2017) [8], they found that, **t**he use of thermoelectric cooling shown in figure 8, appears as an effective refrigeration technology, and its positive characteristics (e.g., absence of refrigerant and mechanical vibrations, easy to be moved, flexibility of usage, low noise, possibility to be operated in any position, accuracy of the temperature control). They focused on the electrical characteristics of a TER connected to the power grid in a micro grid-like installation particularly useful for humanitarian context. A sustainable solution in which the TER is supplied by a photovoltaic plant and equipped with an electric storage system has been identified. Sizing and simulation of this solution have been carried out. These results may be useful to deal with a particular type of local energy system, such as the temporary camps used in the humanitarian context.

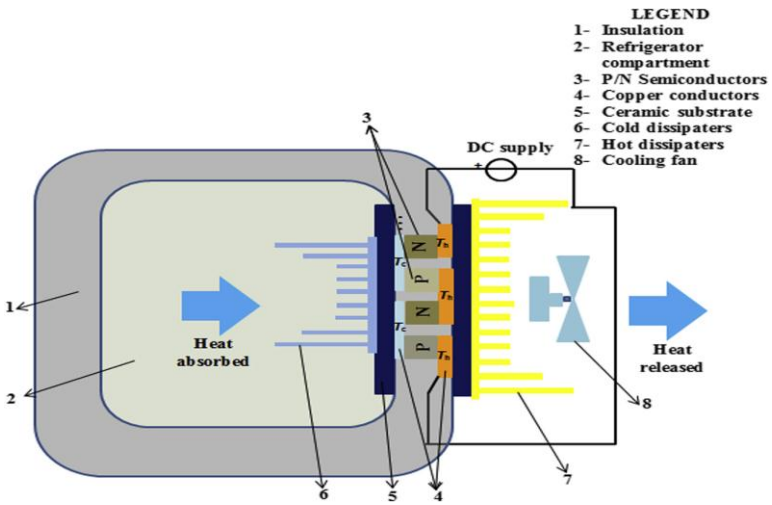


Figure 8. Schematic of a TER.

2.9. Zhongbao Liu et al (2017) [9], found that, the air cooled frost-free household refrigerators have become popular in the market because of the advantages of large storage volume and frost-free compartment(s).The large power consumed by the process of defrosting the evaporator restricts the wide spread application of such refrigerators. In this study, a new type of thermal storage defrosting system combined with bypass cycle is presented. The four kinds of different PCMs are tested, the operation modes of the overall system are proposed, and the structure of the heat storage exchangers is designed and optimized. And the experimental study is carried out for different defrosting modes. The optimal experimental results increase approximately 50% of the speed of the original defrosting mode of the electric heater. The defrosting system of the thermal storage can effectively save the defrosting power consumption by 71% compared with the original defrosting mode of the electric heater.

2.10. Wen-long Chenga et al. [2017], they found that, the heat transfer performances of evaporators and condensers significantly affect the efficiency of household refrigerators. For enhancing heat transfer of the condensers and evaporators, a novel dual energy storage (DES) refrigerator with both heat storage condenser (HSC) and cold storage evaporator (CSE) is proposed. Figure 9 shows schematic representation of the cold storage evaporator with PCM. The performance comparisons of three kinds of energy storage refrigerators are analyzed by establishing dynamic simulation models are HSC refrigerator, CSE refrigerator and DES refrigerator. According to the simulation results, the DES refrigerator combines the advantage of HSC refrigerator and CSE refrigerator; it has a more balanced operational cycle and higher evaporation pressure and temperature. The DES refrigerator has the best heat transfer and operational performance, The DES refrigerator can achieve continuous heat/cold rejection from condenser/evaporator during the entire cycle.

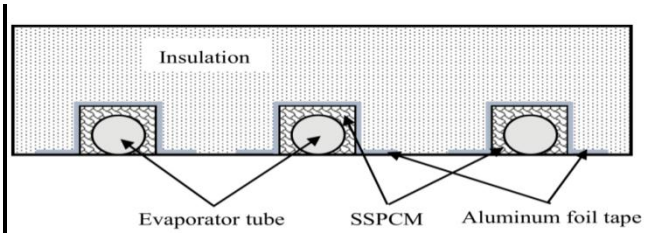


Figure 9. Schematic representation of the cold storage evaporator with PCM

3. CONCLUSION

From the theoretical and experimental data which is being available analytically, experimentally and by preferring science journals, it is being concluded that the use of P.C.M. nergy storage device in the field of refrigeration and air conditioning can

make the significant impact on the problem of energy consumption and has the capability to save the energy in large amount by increasing the efficiency and performance. Hence, optimization in the use of phase change material can lead to greater results in the field of energy saving and can turn the thinking of the common people into renewable energy sources.

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