Performance Analysis of Phase Change Material for Gas Stove

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ABSTRACT

The main aim of our project is to utilize the heat which is wasted from the gas burner in the kitchen to clean the dishes from hot water. The copper tubes are mounted below the gas burner. The water will be passed through these tubes. Then the water coming out from the copper tubes will be hot as the heat will be transferred from the gas burner and then through the copper tubes to the water. This hot water will be then passed through the PCM i.e. Phase change material. The heat will be transferred from the water to the PCM so that temperature of PCM gets increased and after some time it will change its phase. The water will be then collected in the tank. The flow control valve will be used to control the flow rate of water. The pump will be placed after the tank and the nozzle will be placed so that the water will be sprayed on the dishes to clean.
When the burner is in off condition then at that time the heat will be transferred from the PCM to the water so that temperature of PCM will be decreased. But the temperature of water will be increased so that we will get the required output temperature of water to clean the dishes. The 3D model will be drawn with the help of CATIA software. The analysis will be carried out on ANSYS software. The experimental testing will be carried out and then the result and conclusion will be drawn.

***Keywords** — Gas Burner, WAX (Phase Change Material) and pump.*

INTRODUCTION

Due to the increase of energy costs, buildings energy consumption has tended to decrease in the past decades. This gives an opportunity for developing innovative renewable technologies that are more adapted to recent buildings with low energy demand. So, the main challenge is to manage non-simultaneous availability of heat source or sink and the energy demand of buildings. Hence, different technologies dedicated to energy storage have been developed recently; one of them is the use of Phase Change Materials (PCM). These materials are considered because they exhibit a higher heat storage capacity than sensible storages and a tunable phase change temperature according to their composition. PCM are used in many applications, for instance, Campos-Celador et al. (2014) designed a finned plate PCM energy storage for domestic application using RT60 and water. They developed and validated a mathematical model to cover the simulations of the system. They finally compared their prototype with a conventional 500 l hot water tank and concluded that the PCM storage can allow a volume reduction of more than 50% which leads to lower heat losses at the same time. The project focuses only on PCM heat exchanger. In the last decades, many researchers studied this type of heat exchanger. Ten years ago, Zalba et al. (2004) studied an air- PCM heat exchanger for free-cooling application. They determined the thermo physical properties of two different PCM and developed an empirical model. They showed that this kind of system is technically feasible and economically advantageous.

Due to the increasing gap between the global energy supply and demand, reaching a thermally efficient and cost optimized thermal energy storage system has received considerable attention among researchers. There are three methods for storing thermal energy: sensible, latent and thermal–chemical. Among these methods, latent heat thermal storage (LHTS) using phase change materials (PCMs) is known as the most favorable for its high energy storage density with small temperature variation (Mehling and Cabeza, 2007). In other words, PCMs are attractive as they are capable of absorbing and releasing a considerable amount of energy at a nearly constant temperature during

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melting and solidification processes. Latent heat energy storage systems can be used to store a considerable amount of available thermal energy to be utilized during the energy demand period, hereafter providing a promising solution for smoothing the discrepancy between energy supply and demand. Thus, many authors have reported their results of researches on PCM thermal storage during melting and

Fins, or more generally extended surfaces, are used to provide additional heat transfer surfaces in thermal systems. In LHTS systems, various researchers extensively studied the role of different configurations of fins on the performance improvement characteristics of LHTS systems. Subsequently, different numerical studies looking at the impact of fins on overall PCM melting and solidification can be found in literature (Ogoh and Groulx, 2012; Seeniraj and Narasimhan, 2008; Shatikian et al., 2005); typically, those studies still neglect natural convection in the liquid PCM phase. Although the cited numerical studies provide the tool to determine optimum fins geometry and LHTS configuration, the defect in natural convection simulations brings about the need to perform experimental studies.

In the present study, melting and solidification of a specific PCM is explored in a finned shell and tube heat exchanger for two fin heights and three Stephan numbers to study the effect of these two variables on some decision-making parameters. These criteria include temperature distribution, melting and solidification front and total melting and solidification time. There are three types of thermal energy storage process, namely sensible heat storage, latent heat storage and thermo-chemical storage. Latent heat storage materials that are used to store thermal energy through change of state are known as phase change materials (PCMs). Latent heat-based TESs (LHTESs) show advantages of high storage density and small temperature swing. As an example, for the same amount of stored thermal energy, an ice storage unit would require 8 times less volume as compared to a typical water storage unit storing with 10°C temperature change. Furthermore, the wide variety of PCMs' phase change temperatures makes it possible to tailor each of the specific applications with suitable working conditions.

Nevertheless, only limited results have been shown in making high capacity and high thermal storage/extraction rated systems. One major issue with use of PCMs is the heat transfer difficulty in charging and discharging of thermal energy. A typical thermal conductivity of PCM is in the range between 0.2W/m-K and 0.7W/m-K. Advanced design of heat exchangers and accurate numerical evaluation may shed light to high performing TES systems. In parallel, subcooling and phase separation properties as well as inflammability and corrosion issues are other technical bottlenecks to be overcome.

I. OBJECTIVE

1. To harness the untapped heat energy liberated from the gas.
2. To study the radiative, heat transfer and design the system accordingly.
3. To design the dishwasher which uses hot water.
4. To design the system which helps to conserve the energy.
5. To utilize wasted energy.
6.

II. LITERATURE SURVEY

Ventilated window with a Phase Change Material (PCM) heat exchanger as a new window application.[1] In summer, night ventilation mode is operated to discharge energy stored in PCM by the ambient cold air, which can be reloaded again, when ventilation pre-cooled air is provided. Numerical models are built and verified by full-scale experiment to evaluate the PCM ventilation system.[1]

The nonlinear properties and hysteresis of PCM are set in the model. The conclusion is that the configuration optimization should be based on different climates. In the case study in Copenhagen, the heat exchanger with 10 mm plate thickness is optimized.[1] It can cool down the ventilated air 6.5 ºC on average in 3.9 h pre-cooling effective time with 3.19 MJ/day energy saving. The material cost saving is 16.87% compared to 20 mm plate thickness which has similar discharged heat amount. Nevertheless, the heat exchanger with 5 mm plate thickness has a faster thermal response and a higher cost saving ability, which is good for the climate when the period of outdoor air temperature

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suitable for night ventilation in a day is short.

The present study focuses on the design and fabrication of passive solar still system with phase change materials (PCM). [In order to improve the distillate, PCMs (paraffin wax, stearic acid, and lauric acid) have been stored in a copper cylinder. The effects of basin water depth on total distillate have been studied for all three cases.[2] The maximum distillate has been obtained at 1 cm depth for all cases with three PCMs used in this study. Total distillate decreased linearly with water depth for all three PCMs. There has been a 9.2% drop in the maximum water basin temperature in paraffin wax as compared to stearic acid (17.6%) and lauric acid (21.5%) with an increase in water depth from 1 to 5 cm.[2] Heat transfer and energy balance equations involved in the present solar still system have been stated. Variation of some heat transfer coefficients with time has also been studied for three different PCMs. The total distillate has been found to be increased by 1202, 1015, and 930 ml/m2-day for paraffin wax, stearic acid, and lauric acid, respectively stored in a copper cylinder.[2] The performance of lauric acid for total distillate has been comparable with the other two PCMs.

Water basin temperature decrease with an increase in water depth using paraffin wax, which is being least affected due to high heat storing capacity as compared to stearic and lauric acid. Total distillate decreased linearly with the water depth in all three PCMs. The maximum distillate has been obtained using paraffin wax as compared to stearic acid and lauric acid. This has been due to the high latent heat of capacity of paraffin wax as compared to the other two PCMs. However, lauric acid still also performed well as the other two PCMs when stored in a copper cylinder. Cylindrical storage for PCM has rendered better results as compared to spherical storage due to its high surface area.

The temperature variation test is an alternative simple method of determining the melting point of paraffin wax by studying the temperature of a melding paraffin wax at a regular intervals of one minute until the temperature of the melting were remains steady with time. This work aimed at determining the melting point of paraffin wax using
T.V.T. method, highlighting the critical issues related to the determination and suggesting a suitable way of improving the melting point of paraffin wax to suit a latent heat and thermal energy storage application. The experimental results also conform that paraffin wax is a crystalline solid.[3]

An experimental study has been conducted to determine the melting point of paraffin wax by temperature variation test. The melting point of paraffin wax is the main property that enables its engineering latent heat and thermal

energy storage applications.[3] The result obtained from this study also agreed with other researchers who used different method. The melting point of paraffin can also improved by adding paraffin wax with disulphurdi-chloride liquid S2Cl2.

According to the study conducted by the authors the results were interpreted as , when the mixture of LA-TD binary solution presents the eutectic behavior for solid – liquid equilibrium line.[4] The eutectic melting point is 24.33℃ and latent heat of melting of eutectic mixture is 161.45 J/g . Therefore, the LAeTD eutectic mixture has potential as phase change material for energy storage. After 30 and 90 thermal cycles, the changes in the melting temperature, the latent heat of melting and the specific heat of eutectic mixture are in acceptable level.[4]

Phase change materials (PCM) are capable of storing thermal energy within a small temperature range due to their high latent heat. When designing a thermal energy storage (TES) system with PCMs, besides the phase change enthalpy, thermal conductivity and density, viscosity based on temperature must be characterized to take into account natural convection.[5] Taking advantage of the facilities of the different research groups working within an international network, a set of Inter comparative tests were executed to determine the viscosity based on the temperature of two[PCMs: octadecane and the commercial paraffin RT70 HC. Three laboratories have participated, which have used three different rheology equipment's : two controlled stress rheometers, AR-G2 from TA Instruments and MCR 502 from Anton Paar and a translational rheometer, IMETER.[5] The interoperative tests were executed based on a starting methodology approach defined previously by some of the authors. The highest deviations were observed when temperature-controlled geometries or temperature hoods were not used at elevated test temperatures due to the temperature gradients within the sample, as consequence of the heat losses due to the room temperature. Consequently,

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special attention must be focused on the temperature control, since a uniform temperature throughout the sample should be guaranteed.

In the present study, numerical simulation of refrigeration cycle incorporated with a PCM heat exchanger is carried out. To this end, the refrigeration cycle without PCM has been simulated and then, the performance coefficients of the refrigerator in either with and without PCM are evaluated.[6] The PCM heat exchanger is located in the refrigeration cycle, at a location after the condenser and before the expansion valve. The utilized PCM is N- Octadecane with fusion temperature of 27.5 °C. The simulation of heat exchanger is based on computational fluid dynamics (CFD) in which the flow inside the pipe is considered one dimensional in the axial extension and PCM surrounding it, is considered two dimensional.[6]

Numerical simulation is carried out using MATLAB software. Simulation results show that utilizing PCM in refrigeration cycle of a refrigerator causes an improvement in the convection procedure and results a 9.58% increase in performance coefficient of refrigerator.

Liquid-flow window is a multi-glazing system with a flowing liquid layer in the window cavity. Thermal transmission is largely restricted and warm water can be produced. These lead to considerable energy saving in buildings with daytime hot water demand.[7] For service extension, it is necessary to enhance the thermal storage capability of the system as solar energy is an intermittent heat source.In this study, the potential advantage of applying PCM onto the double-pipe heat exchanger of liquid flow window was evaluated for different situations, including the unfavorable case with night-time hot water demand. The enthalpy-based method was adopted for precise modelling of the heat transfer process in the PCM layer. The validity of the numerical model was confirmed by experimental comparison with published data.[7]

Numerical studies were then conducted based on different design positions of the PCM layer at the heat exchanger, and for use in residential and office buildings. The results show that comparatively, the design with PCM located at the outermost layer of the heat exchanger has the best energy storage performance. For the case with PCM sealed in the middle annular space, the inner PCM layer is heated up rapidly, while the outer PCM layer remains at low temperature because of the continuous heat release to the cold-water stream. With the use of PCM, 31.4% and 11.4% more hot water can be harvested during off-work hours for residential use in typical summer and winter weeks. And as a whole, the energy saving potential is greater in summer than in winter.

The present study focuses on the thermal performance of encapsulated phase change material (PCM) based heat exchanger for thermal management of building in Indian conditions. Heat transfer characteristics of the encapsulated PCM based heat exchanger is investigated experimentally and compared vis-à-vis thermally activated roof and radiant panel systems.[8] Experiments are performed on a scaled down concrete cubical test chamber with a window facing the north direction. It is found that the encapsulated PCM based heat exchanger is able to reduce heat gain of the test chamber by approximately 50% as well as mean air temperature by more than 6 ^{0} C. The encapsulated PCM based heat exchanger is found more beneficial in flattening the peak for longer duration and reducing the fluctuation in mean air temperature of the test chamber. The developed building simulation model is validated with the experimental results, which is used in parametric studies to identify the effect of different parameters on the average air temperature in the test chamber. The duration of stabilization period can be kept constant by increasing PCM thickness linearly with the increment in thermal load of the test chamber. The inlet water temperature to the PCM based heat exchanger is found to be the most influential parameter affecting the mean air temperature of the test chamber, whereas thermal conductivity of walls and length of pipe in heat exchanger have minimal effect

comparatively.[8] Further, a ground heat exchanger is incorporated with the encapsulated PCM based heat exchanger to investigate the effectiveness of ground heat exchanger in discharging the heat load carried by the working fluid.

Buildings are exceptionally high electrical consumers and expend as much as 45% of total energy consumed globally. Amongst passive cooling methods, phase change materials (PCM) are implemented in buildings to prevent heat accumulation, enhance heat absorption, promote temperature moderation and mitigate indoor heat gain.[9] Thermal energy storage using PCM

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constitutes an effective method to raise the overall heat capacity of buildings. PCMs with immense energy density have brought about strong interests in developing high thermal inertia buildings with high energy savings. One main disadvantage of PCM is their poor thermal conductivity that delays their energy charging/discharging process and storage performance. Consequently, one major focus of PCM research has been the enhancement of PCM's thermal conductivity using nanotechnology and nanomaterials. Recently, fast growing advancements in the field of nano materials have led to a cutting-edge technology frontier of developing new ultra- small nanosized particles to enhance the thermo physical properties of conventional PCMs. Dispersing thermal conductive nano particles such as nanometals, nano metal-oxide and Nano carbon can vastly improve PCM's thermal and physical attributes such as super-cooling, viscosity, heat capacity and thermal conductivity.[9]

This article reviews recent reports on these emerging functional nanomaterials (type of material used, synthesis method, morphology and enhancement effect) used in nano-enhanced PCMs (nePCMs) to achieve superior thermal performance suitable for passive-cooling applications in the built-environment.[9]

III. METHODOLOGY

Setup :

We manufactured the whole setup by using a mild steel L-shape bar, copper tube, external Gas stove and Pump.

As shown in the fig our setup consists of two containers, 1st is PCM material storage tank and 2nd is hot water storage tank, one gas stove, copper tube for circulation of hot water and to absorb heat. We covered all containers and insulated them to resist heat loss from PCM material. In our setup we used copper tube coils below the gas stove and also wound in parallel in the PCM material tank.

We used a pump to circulate water and the outlet of the cold water tank pipe is connected to a copper tube coil which is just below the Gas stove (Because we use the wasted heat which is available below the gas stove). Then we took the stainless steel container and inside that container we arranged the copper tube in the zigzag style just above the surface of the container by keeping some gap and filled PCM material in the container. Then that tube is connected to the hot water storage tank to store the hot water.

Working:

Water starts flowing from the cold water storage tank through the copper tube coils which are mounted below the gas stove burner. Cold water absorbs that wasted heat from the burner due to that temperature of the water increases. Copper tube is used because it has more heat conductivity. Then this warm water is passed through the PCM, here PCM absorbs the heat from water flowing from the copper tube due to this PCM changes its phase. This PCM has the ability to absorb the heat at constant temperature. Because of this characteristic of PCM even if we shut off the gas stove we can get warm water until the PCM comse to its original phase. Then this warm water is stored in the hot water tank which is insulated. From that tank warm water is further used for different applications.

This system is useful to use wasted heat from a gas stove to conserve the energy which we use to heat the water.

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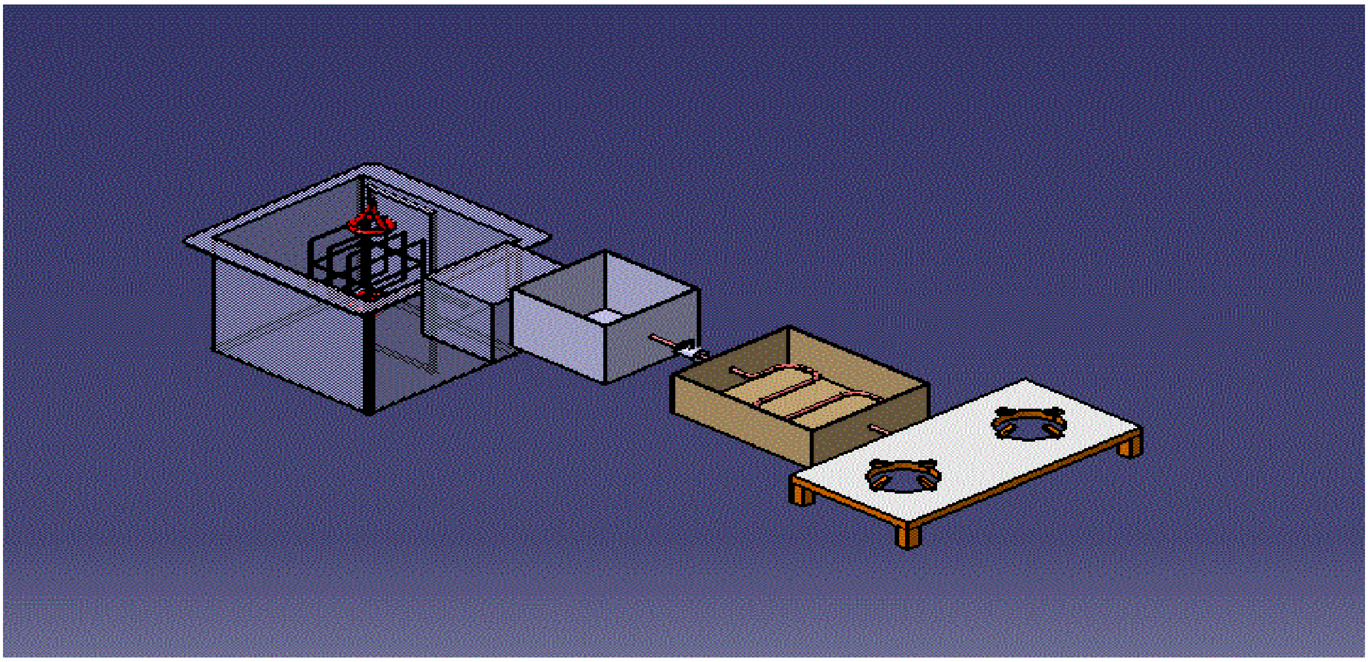

Fig.1: Assembly of Setup

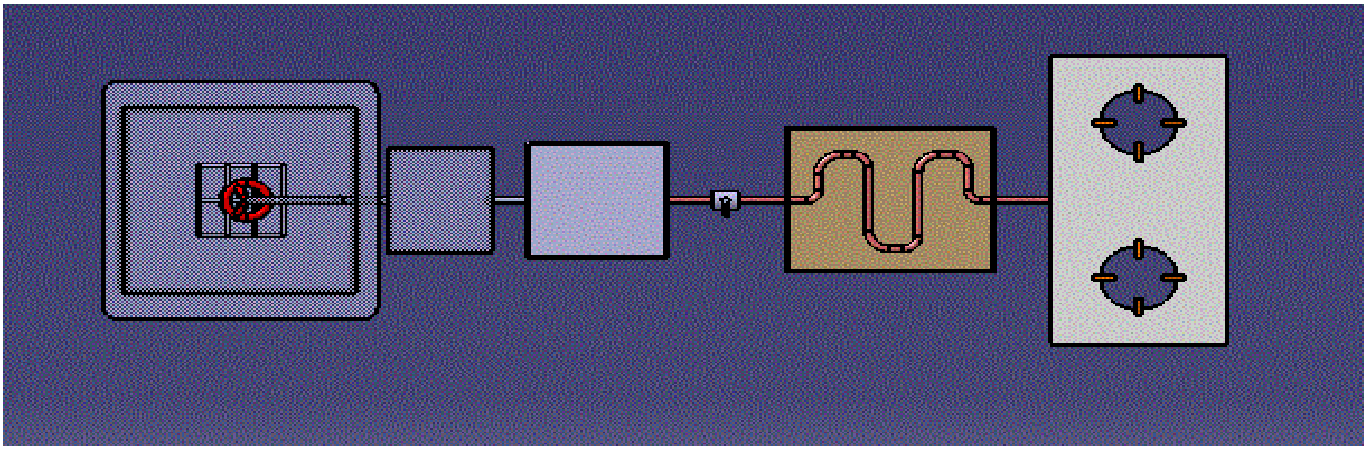

Fig.2: Top view of Setup

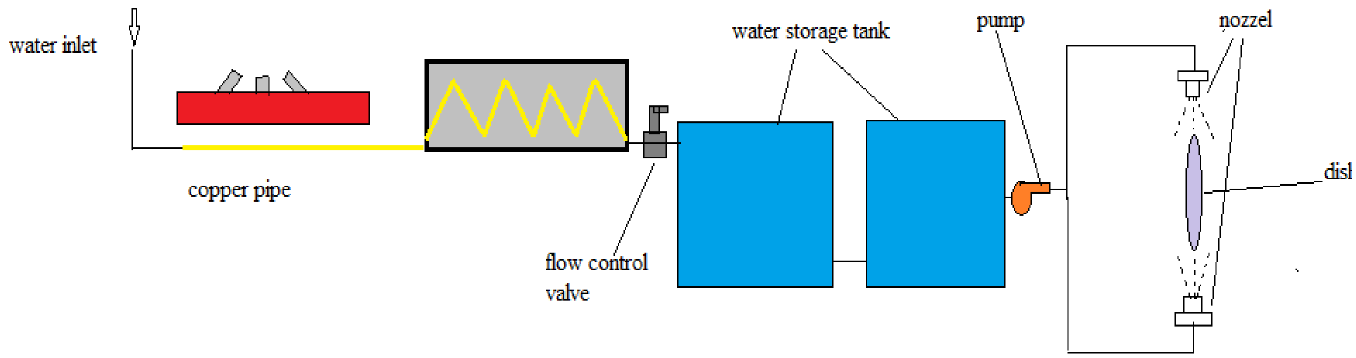

Fig.3: Block Diagram of System

IV. CONCLUSION

1. Using this system we can conserve the energy. Here we conserve energy in two ways, one which we previously used for water heating by electrically or by conventional method and another one is heat wasted from the gas stove.
2. This setup can successfully heat the water even after we shut off the gas stove, due to characteristics of the Phase Change Material and use copper for circulating water from tubes. We used PCM to increase the efficiency of this system.
3. In the industry like restaurants where bigger gas stoves are used and where large quantities of food is cooked on a regular basis, this system will help a lot to conserve energy as well as it will help the economy of the business.
4. From this study we understood that the Wax has required characteristics of PCM for this system.
5. The aim of the optimization of the PCM-heat exchanger was to enhance the volume of available hot water in this system
6. The aim of this paper was to study the discharging performance of expanded paraffin PCM-heat exchangers. To ascertain whether the rapid discharging performance of the PCM-heat exchanger was capable of heating the cold water to the required temperatures of domestic water, several vital parameters were observed experimentally.

REFERENCES

[1] A A new ventilated window with PCM heat exchanger – performance analysis and design optimization .Yue Hu1, Per Kvols Heiselberg

[2] Solar distillation using three different phase change materials stored in a copper cylinder Varun Kumar Sonkera, Jyoti Prasad Chakrabortyb,
Arnab Sarkara , Rishikesh Kumar Singha

[3] Determination of the Melting Point of Paraffin Wax Using Temperature Variation Test Method .Ozioko R. E.1, Ogbonna I. D.2, Ugwu K. C

[4] THERMAL PROPERTIES OF LAURIC ACID / 1- TETRADECANOL BINARY SYSTEM FOR ENERGY STORE. JIANGUO ZUO , WEIZHONG LI , LINDONG WENG.

[5] Interoperative tests on viscosity measurements of phase change materials

[6] Mónica Delgadoa, Ana Lázaroa, Michael Biedenbachb, Sebastian Gamischb,

[7] Parametric analysis of domestic refrigerators using PCM heat exchanger S. Bakhshipour, M.S. Valipour , Y. Pahamli.

[8] Numerical analysis on the advantage of using PCM heat exchanger in liquid-flow window,Tin-Tai Chow and Yuanli.
[9] Design and Analysis of PCM Based Radiant Heat Exchanger for Thermal Management of Buildings. Himanshu Garga, Brijesh Pandeya, Sandip K. Sahab,†, Suneet Singha, Rangan Banerjee
A Review on Enhancement of Phase Change Materials – A Nanomaterials Perspective . Kwok Wei Shah