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Energy Storage System for Heating and Cooling Application Using PCM

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Abstract — Energy storage system is a system built to store high grade or low grade energy of a system, which can be utilized in near future. Energy storage becomes a key element in achieving goals in energy sustainability that lead to energy and cost savings. A device that stores energy is sometimes called an accumulator.

This Accumulator can be used to store waste heat energy, of waste water of a system, by a process called Waste Water Energy Recovery (WWER). Waste heat is the unused heat (secondary/low-grade heat) of a system, which is given to the surrounding (in the form of thermal energy) by a heat engine in a thermodynamic process. This heat can be useful in the majority of heating applications; however, difficulty is faced for storage and transportation of waste heat. Power stations, Industries, and electronics market are the major sources of waste heat.

The Heat Accumulator or Thermal energy storage (TES) system to be used is a Double tube Heat Exchanger with Phase Change Material (PCM) as one of its crucial components. PCM is a 'latent' heat storage material which works on its solid-liquid phase cycle.

Keywords- Phase Change Material, Latent Heat, Thermal Energy Storage (TES), Efficiency, Energy Storage System, Heat Exchangers, Phase change, Waste Water Energy Recovery (WWER).

I. INTRODUCTION

Phase change materials (PCM) are material used as 'Latent' heat storage materials in heat storage units. The heat transfer takes place, when this material undergoes phase change from solid to liquid, or liquid to solid. Basically, PCMs perform like conventional storage materials; but their temperature does not rise as they absorb heat energy from a heat source. Unlike conventional (sensible) storage materials, PCM absorbs and reject thermal energy at approximate constant temperature. PCM can absorb and store 5–14 times more heat energy per unit volume in comparison to sensible storage materials such as water, masonry, or rock. PCMs are available in large number of heat of fusion range in market, so they can be used for many applications of various temperature ranges.

Thermal energy storage (TES) is a system which can store high-grade or low-grade heat energy of a system, which can be used in near future. A device which stores energy is called an Accumulator. In today's scenario, in any system such as power generation, industrial processes and electronics; out of total energy available, only 35%-48% is converted to useful work and remaining 52%-64% is available waste heat, which can be utilised using proper TES process. TES system is of two types:

1) Sensible Heat Storage (SHS)

This system absorbs, stores and releases heat energy in form of sensible heat (no phase change occurs). This is conventional method of thermal energy storage. As the amount of heat to be stored increases, temperature of system increase; which is a limitation of this system along with large space occupancy and transportation issues. Examples of sensible heat storage materials are water, masonry, rocks, sand, etc.

2) Latent heat storage (LHS)

It works on the phenomenon of heat absorption or release when a storage material (PCM) undergoes a phase change. This system using PCM is a functional and productive way of storing heat and gives advantages of high-energy storage density and isothermal nature of the storage process. There are large numbers of PCMs that melt and solidify at a wide range of temperatures, making them attractive in a number of applications.

So, based on above mentioned previous work, A LHS system using PCM can be developed to store waste heat, of waste water of a system by Waste water energy recovery (WWER) process.

II. OBJECTIVE & ADVANTAGES

Heat Accumulator will be designed using Phase Change Material as latent heat storage material. This accumulator will be used for secondary or low-grade heat storage from waste water of a system by the process of Waste Water Energy Recovery (WWER). As the total waste heat obtained in any existing system; like Power plants, Industrial processes, Electronics is above 50% of total energy available, this recovered energy can make a major difference for improving system efficiency without changes energy inputs and it will act as an alternative to renewable recourse available.

Here, heat accumulator is a shell and tube (Double tube) heat exchanger with PCM filled in the heat exchanger cylinder. PCM used is Paraffin Wax RT50. Heat transfer fluid will pass through the inner tube of heat exchanger.

As the hot fluid passes through double tube, heat from it will be absorbed by PCM (it is called charging process), and temperature of hot fluid decrease. Heat could be stored in PCM for long duration of time. Now, when the cold fluid passes through double tube, heat is rejected by PCM (discharging process), temperature of cold fluid is raised. This whole system work as thermal energy storage (TES) units.

Advantages of using PCM heat exchanger over conventional methods are

PCM absorbs and release heat at a nearly constant temperature.

PCM stores 5 to 14 times more heat per unit volume then sensible storage material such as water, masonry, or rock.

They can be used under renewable energy. Renewable and alternative energy sources provide a method of energy generation that does not rely on fossil fuels.

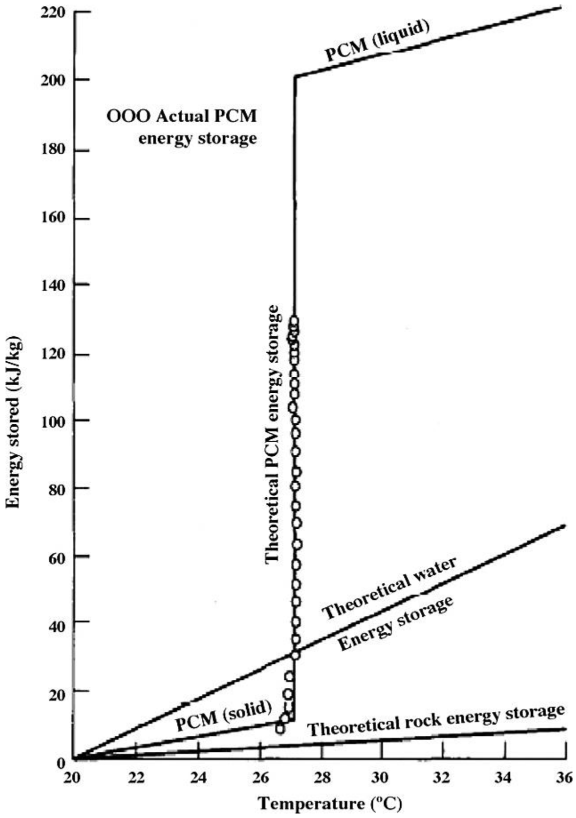

Figure 1. Performance comparison of PCM, water, and rock storage system.

III. METHODOLOGY

In the present model, water is heated with help of electric heater (to demonstrate heat pump and waste water source) and afterwards it is passed through the heat exchanger (inner Cu tube), where heat will be absorbed by PCM and data for analysis is noted down. After whole volume of PCM in heat exchanger is melted, cold water (as clean fluid) is supplied to the heat exchanger and it will absorbed heat from PCM. The submersible pumps are used for water circulation and valve system is used for changing flow rate. K type thermocouples are used for temperature measurement at various locations and flow meter is used for flow rate measurement.

Paraffin wax RT50 is used because Paraffin is safe, reliable, predictable, less expensive, and non-corrosive. They are chemically inert and stable below 500 centigrade, show little volume changes on melting and have low vapor pressure in the melt. LTH systems with paraffin generally have very long freeze–melt cycle. They also show congruent melting and good nucleating properties.

IV. DESIGN & ACTUAL WORKING MODEL

Figure 2. Design

Figure 3. Actual Model

V. RESULT

Based on the data collected, graphs are plotted for analysis and observation of experiment.

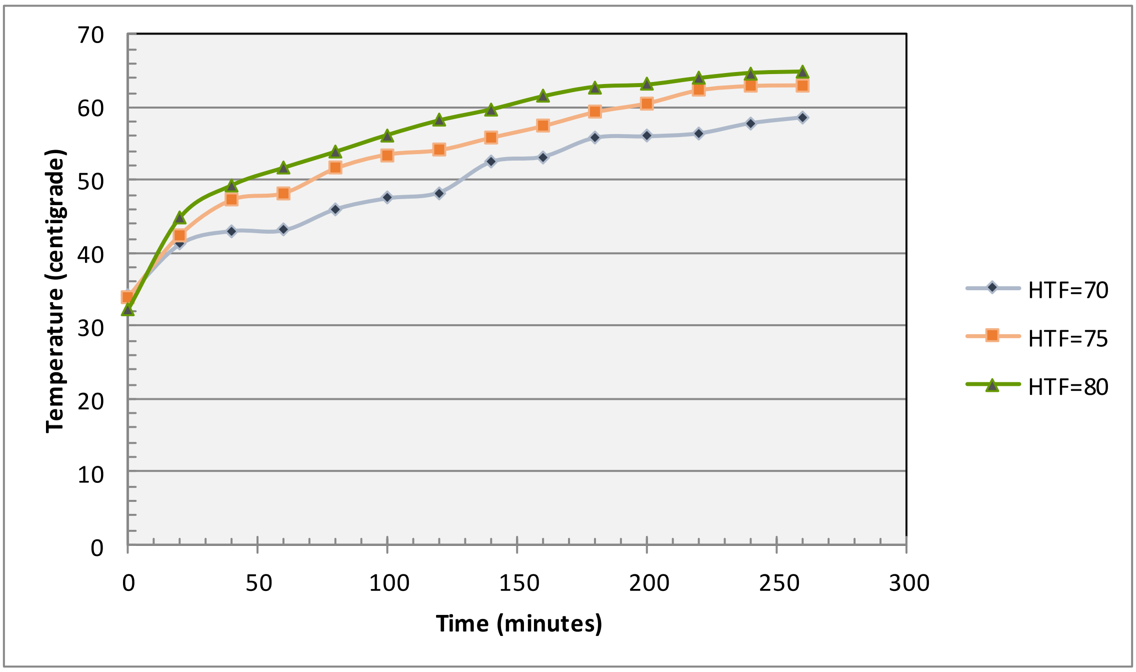

Figure 4. Comparison of PCM's average temperature at different inlet HTF temperatures

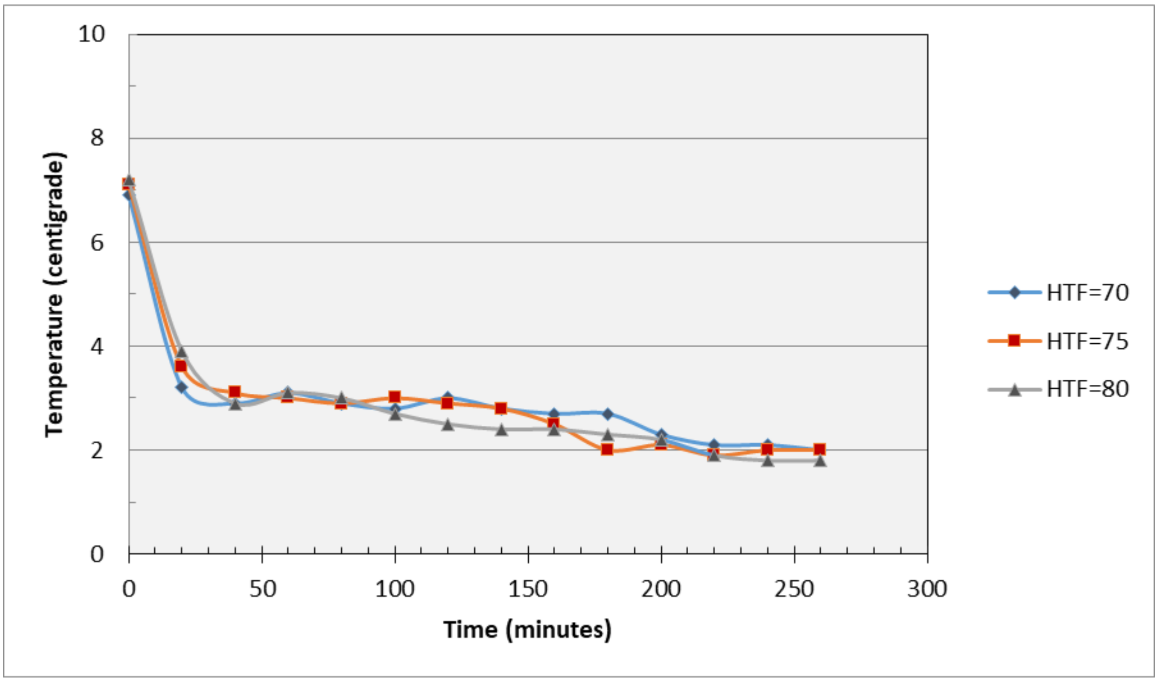

Figure 5. Comparison of water temperature difference (outlet-inlet) at various inlet HTF temperatures

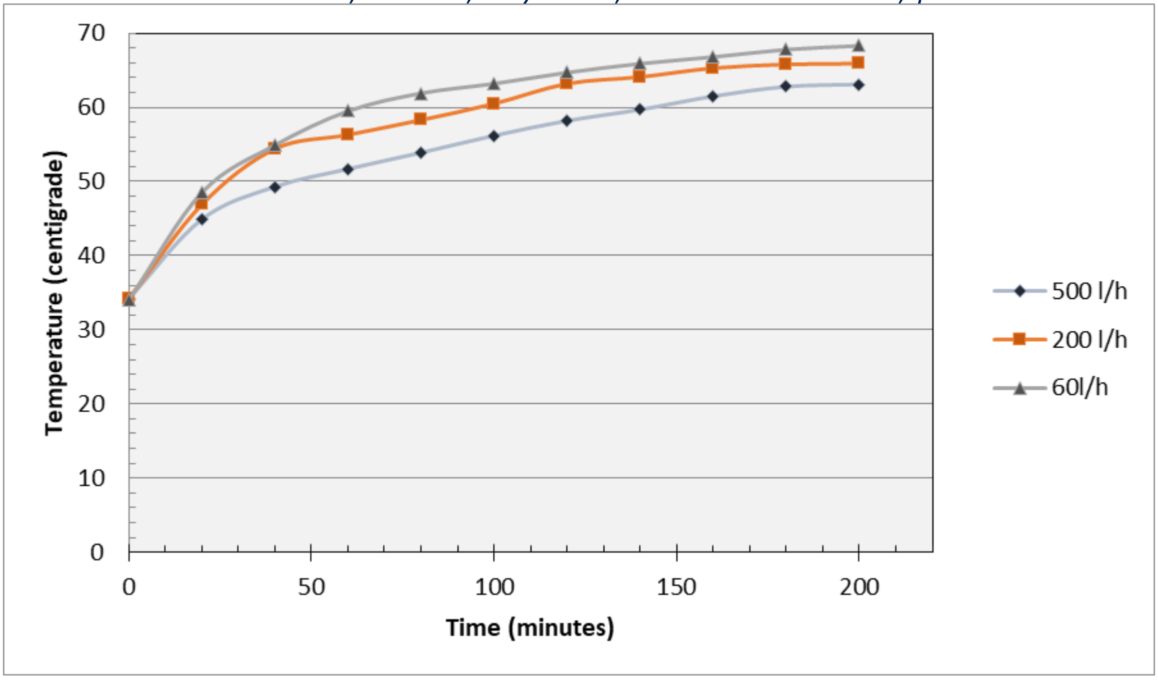

Figure 6. Comparison of average temperature of PCM at various HTF flow rates with Th= 80 Centigrade

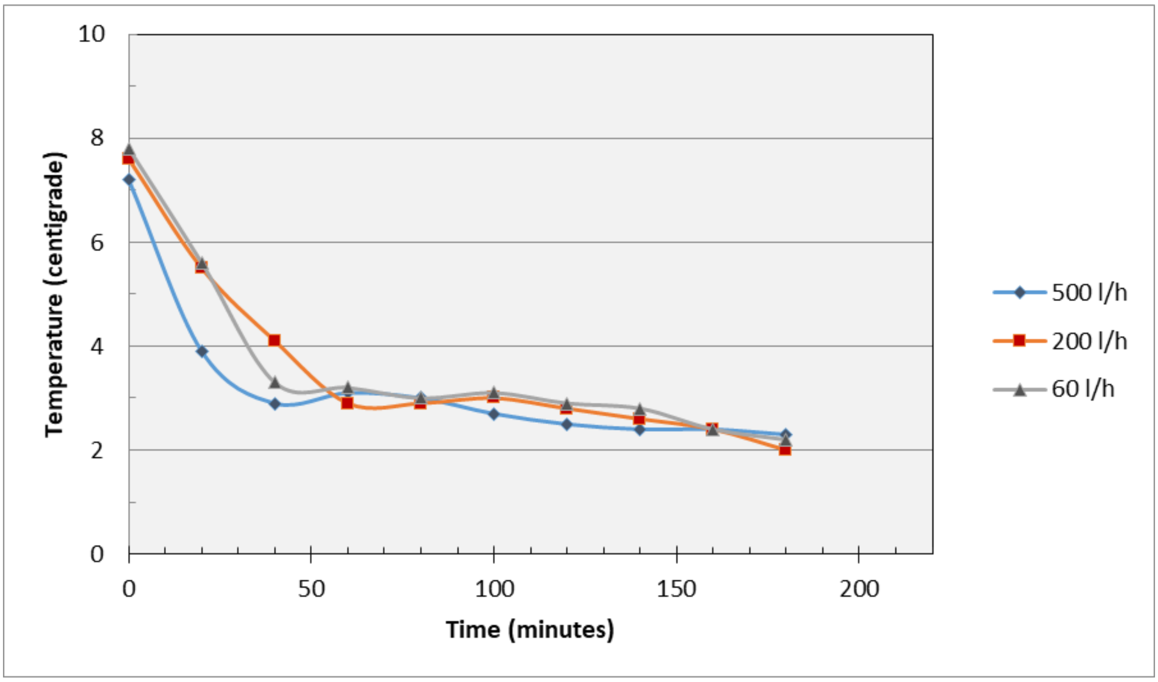

Figure 7. Comparison of water temperature difference (outlet-inlet) at various HTF flow rates with Th= 80 Centigrade

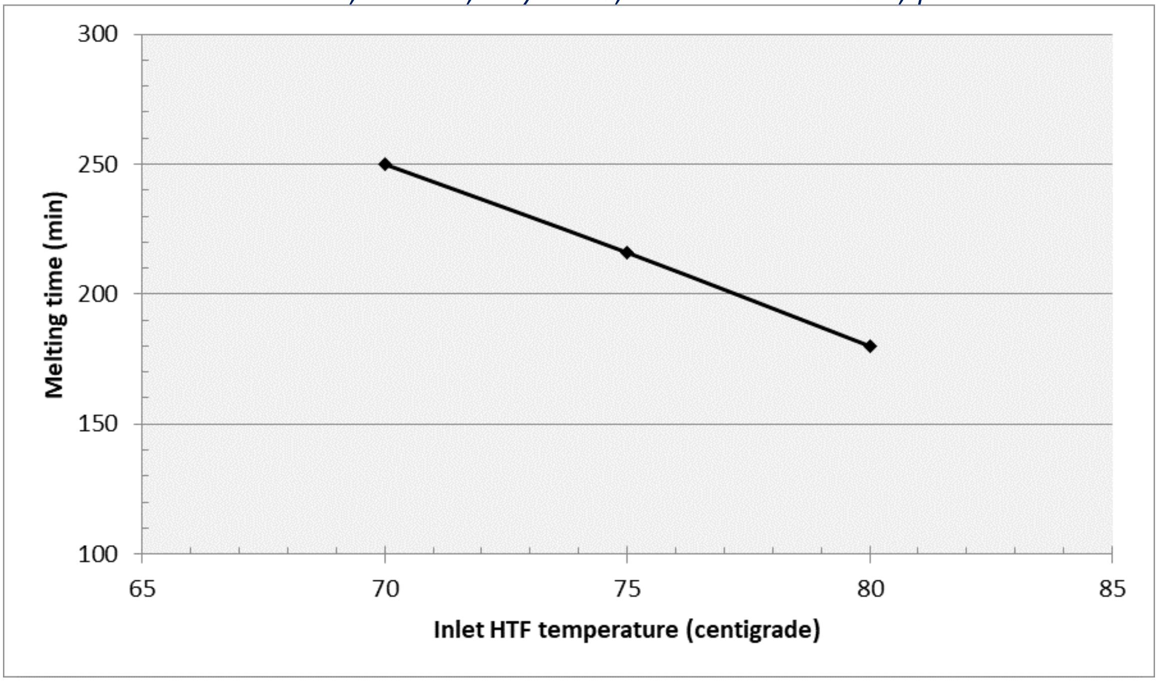

Figure 8. Effect of inlet HTF temperature on complete melting time

III. CONCLUSION

PCM can be used over conventional sensible heat storage systems, as they have comparatively very high latent heat of fusion. Thermal energy storage system (TES) using PCM can work as an alternative to renewable energy sources. In the PCM, heat transfer takes place by combination of convection and conduction phenomenon, but in the melting process heat transfer majorly occur through conduction and after a while, convection governs the heat transfer phenomena. For a WWER System, a heat accumulator with PCM as Paraffin Wax works best when the inlet heat transfer fluid (HTF) temperature is around 75-80˚C or above as the melting temperature range of paraffin wax is 45-54˚C.With our current dimensions of Heat Accumulator, the most efficient flow rate for maximum heat transfer is 60 l/h.

T_h (˚C)		T_{ini} (˚C)	T_{end} (˚C)	Q_{max} (kJ)	Q_{ch} (kJ)	Q_{HE} (kJ)	Q_{PCM} (kJ)	η_{theory} (%)
70		34.1	58.1	245.615	98.24	1	97.24	35.92
75		34	60.5	251.175	102.75	1	101.75	40.50
80	**500 l/h**	34.2	62.8	246.12	110.115	1	109.115	44.74
	200 l/h	34.2	65.7	255.905	131.12	1	130.12	51.23
	60 l/h	34	68.3	267.948	155.95	1	154.94	57.82

Table 1. Performance parameters measured

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