



LATENT HEAT THERMAL ENERGY STORAGE USING HEAT PIPE

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Abstract

A creative, original thought of blending heat funnels with warm vitality stockpiling (LHTES) for concentrating elective vitality applications is investigated. The low warm conduction of movement materials (PCMs) utilized in LHTES presents a style challenge on account of moderate warmth exchange rates all through warming and cooling of the texture. Warmth channels act to diminish the warm protection inside the PCM, expanding the general warmth exchange rate adequately to be utilized as a part of CSP. Initial, a research facility scale try is given to approve the possibility of abuse warm pipes in LHTES to downsize warm protection in PCM. a blurb scale LHTES with installed gravity helped warm pipes and a value examination is directed to work out battle with elective sorts of warm vitality stockpiling by and by utilized in the CSP business. LHTES using heat pipes or balances is researched through an analysis. Photographic perceptions, liquefying and activity rates, and PCM vitality stockpiling amounts square measure announced . A variable, pipe adequacy, is illustrated and wont to measure the relative execution of warmth pipe-helped and blade helped arrangements to things including neither warmth funnels nor balances. For the exploratory states of this examination, consideration of warmth funnels will expand PCM dissolving rates by around hour, while the balances don't appear to be as viable. all through activity, the glow pipe- helped design exchanges around twofold the vitality between a warmth exchange liquid and furthermore the PCM, in respect to each the

blade helped LHTES and furthermore the non-warm pipe, non-balance setups

Key Words: Concentrating Solar Power, Latent Heat Thermal Energy Storage, HeatPipe, Phase Change Material

I. INTRODUCTION

These days, because of increment in vitality utilization, a lot of non-renewable energy sources is being utilized. This last is a result of the present natural issues, for example, an Earth-wide temperature boost, corrosive rain, and so on. So as to diminish these issues, the utilization of sustainable power sources is being advanced. In any case, the sustainable power sources, especially sunlight based vitality, introduce the disadvantage that there is a befuddle between the vitality request and supply. To cover this confound, the utilization of stage change warm vitality stockpiling frameworks is required. Expanding vitality utilization, contracting assets and rising vitality expenses will have huge effect on our way of life for who and what is to come. In this circumstance, the improvement of option, financially savvy wellsprings of vitality for private lodging must be a priority. Scientists everywhere throughout the world are looking for new and sustainable power sources. One of the alternatives is to create vitality stockpiling gadgets, which are as critical as growing new wellsprings of energy. Solar warm power age could be doable as a wellspring of base load control in parched nations, yet because of its irregular and variable nature, a vitality stockpiling framework is required. Warm vitality stockpiling (TES) ends up being an alluring and practical option for substantial scale utilize. Vitality is amassed in a

capacity medium, and the capacity component can be named sensible warmth, inert warmth, or synthetic stockpiling. Considering a survey paper by Medrano et al., obviously all operational sun oriented warm power stations utilize sensible warmth warm capacity. The most prevalent sensible warm stockpiling frameworks utilize liquid salts.

II. LITERATURE REVIEW

A. Thermal Energy Storage

Thermal Energy Storage (TES) is the temporary storage of high or low temperature energy for Later use. It bridges the time gap between energy requirement and energy use While the output of the TES is always thermal energy, the input energy may be Thermal or electrical[8] A solar thermal power plant could have four elements: Solar field, heat transfer fluid (HTF), thermal storage system and finally power generation system The thermal storage system allows use the excess of energy at night and/or cloudy days to increase plant performance[4].

TYPES OF THERMAL ENERGY STORAGE (TES):

- LATENT HEAT TES
- SENSIBLE HEAT TES
- CHEMICAL TES

In sensible heat storage, the temperature of the storage material varies with the amount of energy stored.[2] The amount of thermal energy that is stored depends on its specific heat and on the temperature variation. It has been implemented in thermal solar power plants through thermocline or two tanks systems using molten salt as storage medium.[3] Latent heat thermal energy storage is attractive due to its high energy storage density. When compared to conventional sensible heat energy storage systems, latent heat energy storage system requires a smaller weight and volume of material for a given amount of energy[4]. Furthermore, latent heat storage stores fusion heat at a constant or near constant temperature which correspond to the phase transition temperature of the PCMs. In practice, solid-liquid phase change is preferred because of simultaneous slight volume variation and high enthalpy variation. The last approach for thermal storage is based on thermochemical reactions. This storage method could allow long-term storage but its technical complexity and high costs is not easily compatible with cost-effective solar electricity product.[7-8] Latent heat thermal energy storage

(LHTES) is becoming more and more attractive for space heating and cooling of buildings.[6]

B. Heat Pipe:

A heat pipe or heat pin is a heat-transfer device that combines the principles of both thermal conductivity and phase transition to efficiently manage the transfer of heat between two solid interfaces. At the hot interface within a heat pipe, which is typically at a very low pressure, a liquid in contact with a thermally conductive solid surface turns into a vapor by absorbing heat from that surface. The vapor condenses back into a liquid at the cold interface, releasing the latent heat. The liquid then returns to the hot interface through either capillary action or gravity action where it evaporates once more and repeats the cycle. In addition, the internal pressure of the heat pipe can be set or adjusted to facilitate the phase change depending on the demands of the working conditions of the thermally managed system. A typical heat pipe consists of a sealed pipe or tube made of a material with high thermal conductivity such as copper or aluminum at both hot and cold ends. A vacuum pump is used to remove all air from the empty heat pipe, and then the pipe is filled with a fraction of a percent by volume of working fluid (or coolant) chosen to match the operating temperature.[9]

C. Phase Change Materials

Most early studies of latent heat storage focused on the fusion-solidification of low cost, readily available salt hydrates initially showing the greatest promise. Upon phase change, they have a tendency to super cool and the components do not melt congruently so that segregation results. Hence, the phenomena such as super cooling and phase separation often plague the thermal behavior of these materials and cause random variation or progressive drifting of the transition zone over repeated phase-change cycles.[1] Although significant advances were made, major hurdles remained towards the development of reliable and practical storage systems utilizing salt hydrates and similar inorganic substances. PCMs have not always resolidified properly, because the chemicals in some PCMs separate and stratify when in their liquid state.[7] When temperature dropped, they did not completely solidify, reducing their capacity to store latent heat. These problems have been addressed by

packaging phase change material in thin or shallow containers and by adding thickening and clumping agents.[5] These types of PCMs, however, compare unfavorably with the newer generation of low-cost, highly efficient, linear crystalline alkyl hydrocarbons. Researchers now label these older compounds as “limited utility PCMs”.

III. EXPERIMENTAL SETUP

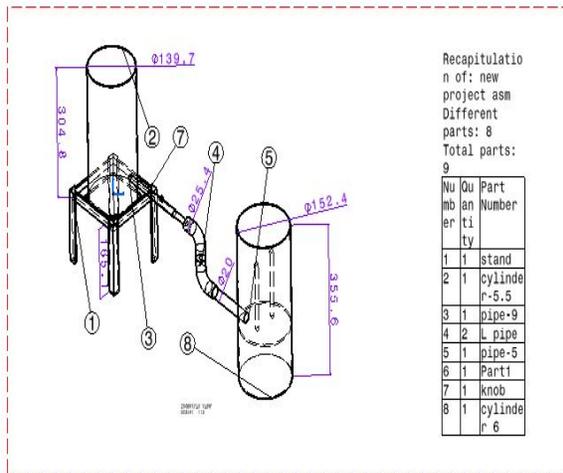


Fig -1: Experimental setup

Two heat exchangers were utilized, the first with a plane top surface for benchmark experiments involving neither heat pipes. The section of the heat exchanger was constructed of mild steel (6061). HTF flow channels of width 18 mm and depth 20 mm were milled into the block. An 8-mm thick wood top plate was attached to the block to complete the heat exchanger assembly. Leaks were prevented by using the M-seal and Teflon tape. The second heat exchanger incorporated a top plate that was modified to accommodate heat pipes. Specifically, five 15-mm diameter threaded holes that were, in turn, used to secure either heat pipes that penetrated through the top plate. Five 150-mm long, 14-mm outer diameter copper-water heat pipes were installed during the heat pipe-assisted experiments. Two heat pipes were placed in the cylindrical test cell. During charging or discharging LHTF = 75 mm sections of the heat pipes were inserted within the HTF flow channels, in direct contact with the HTF. Heat pipe lengths of LPCM = 75 mm were exposed to the PCM. Distilled water was used as the HTF its temperature measured by Thermometer. However, for each experiment the flow rate was independently determined using a simple

weight-over-time method and the variation during the course of a single experiment was found to be 0.0001 kg/s.

IV. EXPERIMENTAL PROCEDURE

A. Charging

Melting experiments were conducted for benchmark cases involving neither heat pipes nor fins, for heat pipe-assisted charging. The HTF flow rate was set to $m \cdot \text{HTF} = 0.0026 \text{ kg/s}$ and inlet temperatures of either 45°C or 55°C were employed. HTF inlet temperatures were selected to provide sufficient temperature difference between the HTF and the PCM while the HTF flow rate was specified to minimize the measurement error of the temperature drop through the heat exchanger. The PCM mass was approximately 1000g in each experiment. The amount of total PCM used was measured with 500 ml flask. The charging experiments involved a uniformly-solid PCM, relatively free of internal voids and air pockets. This was achieved by initially melting the PCM under vacuum, removing dissolved air from the PCM. Approximately 0.10 kg of de-gassed liquid PCM was added to the test cell as HTF at $T_{\text{HTF}} = 2^\circ\text{C}$ was circulated through the heat exchanger to induce solidification. After the initial layer of PCM solidified, another 0.10 kg of liquid PCM was added. The filling process continued in a layer-by-layer manner until the desired mass of PCM was in the test cell, after which circulation of the cold HTF was curtailed and the entire apparatus was allowed to equilibrate to room temperature 25°C for at least 12 h. The rather involved PCM filling and conditioning process limited the total number of experiments that were performed. To compensate for unavoidable variations in the ambient temperature, HTF at $T_{\text{HTF in}} = 26^\circ\text{C}$ was circulated in the heat exchanger prior to the start of each experiment. Subsequently, the flow of HTF to the heat exchanger was terminated and the set point of the water bath was increased to the desired level. Once the water temperature reached the set point, the heat exchanger was re-connected and the HTF flow controller was adjusted to the desired flow rate, marking the start of an experiment. Temperature and flow rate data were acquired at intervals of $\Delta t = 5 \text{ s}$. The insulation was periodically removed and photographs were taken at intervals of approximately 30 min. Each charging

experiment concluded when the PCM melted completely.

B. Discharging

Solidification experiments began with liquid PCM. Approximately 1000 gm of n-octadecane was melted in the vacuum flask and then poured into the test cell. Discharging experiments were all conducted with a HTF temperature and flow rate of THTF, in = 10 °C and m HTF= 0:0022 kg/s, respectively. A limited number of experiments were performed since each experiment consisted of sub-experiments of duration 30, 60, 90, 120, 180, and 240 min. That is, 6 separate tests were conducted for each experimental condition in order to accurately measure the amount of solidified PCM at discrete times. To do so, liquid PCM was siphoned from the test cell photographs were also taken at the end of each sub-experiment. The thickness of solid PCM layers that formed on the heat exchanger surface and along the heat pipes was measured with a of 1 mm at the end of each sub-experiment.(The sub-experiment approach was not used during charging since it would have prolonged an already lengthy PCM filling and conditioning process.)

V. RESULT

Average melting rates for benchmark, heat pipe-assisted, melting for THTF,in = 45°C and 55°C and m HTF = 0.0026 kg/s.

Experiment	Avg Melting Rate
45°C Benchmark	3.8 g/min
45°C Heat pipe	6.4 g/min
55°C Benchmark	6.6 g/min
55°C Heat pipe	11.5 g/min

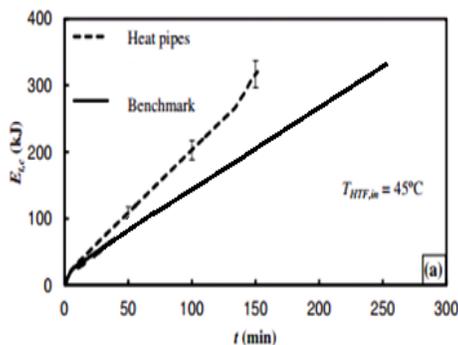


Fig -2 Energy Storage for 45°C

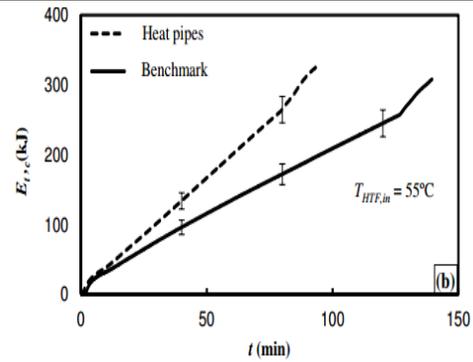


Fig -3 Energy Storage for 55°C

VI. CONCLUSION

Charging (melting) experiments have yielded photographic evidence showing more extensive and complex melting phenomena for heat pipe-assisted melting, relative to both benchmark and fin-assisted cases. The overall melting rates for the heat pipe assisted cases were, on average, 70% greater than the benchmark and 50% greater than the fin-assisted scenario. The heat pipe effectiveness, defined as the ratio of stored energy in the heat pipe-assisted case relative to stored energy in the benchmark case, attained at a maximum value of 1.6, while the maximum effectiveness associated with use of fins was approximately 1.1. For the discharging (solidification) case, complex freezing phenomena were observed for the heat pipe-assisted scenario. The heat pipes nearly doubled the solidification rates, relative to the benchmark case. The fins exhibited limited effectiveness in enhancing heat transfer and energy storage rates. The experiments conducted and analyzed do not correspond to optimized conditions. Further investigation is necessary to determine how heat pipes might be incorporated in LHTES systems to improve phase change rates beyond those measured here, reduce temperature differences between the HTF and PCM (which has a direct and beneficial impact on the Rankine cycle efficiency of concentrating solar thermal electric power stations), and occupy minimal volume within the LHTES storage vessel. The Chapter 2. Experimental Investigation 43 observed phenomena and measured values can be used to guide model development for purposes of simulating the discharging and charging processes in both laboratory- and large scale systems.

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