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# Experimental Investigation of Solar Energy Storage device with CFD analysis

Sachin Jagadale[1], Prof. Saurabh Gupta [2]

*Department of Mechanical Engineering, G. H Raisoni COEM Pune University, India [1,2]*

**Abstract -** *The Phase change material is based with high temperature solar energy storage device is used to attend electricity by means of many processes heating use. The energy storage is taken place by means of application of latent heat of fusion of material put in storage inside the unit. The technique is mainly a selection of because its capability to producing high energy density and store energy can be positively extracted with very small difference in temperature. This adds most important role in the entire processing. The reason on selection made for phase change material is discussed; the layer of insulating material is applied on system under thermal consideration analysis and optimization. The application of layer shows heat loss to surrounding and thus supports further major temperature. This demonstrates comparison between results, one obtained via trial set up, calculation performed and observation noting and other by computer simulation, where the method is centric about computerized model formed and performance evaluation measure of prototype system.*

***Keywords* -** *Latent Heat, Phase change Materials, Solar Thermal Energy storage, Caustic Potash, Specific Heat, Thermal Conductivity.*

*NOMENCLATURE*

| | |
|---|---|
| *TES* | *Thermal energy storage* |
| $\rho$ | *Density* |
| *m* | *Mass* |
| *V* | *Volume* |
| *Cp* | *Specific heat capacity* |
| *k* | *Thermal conductivity* |
| *KoH* | *Potassium Hydroxide* |

## I. INTRODUCTION

The energy consumption in very high level worldwide & environmental awareness headed to propose requirement of use of renewable energy sources & hypothetically to be less pollutant and environmental friendly.

Solar energy is considered in the situation fulfillment as explained above, the main purpose is to select source since its environmentally clean, abundant etc. The source of solar energy is powerfully influenced by the aspects like seasonal and atmospheric condition of the respective physical location. During day and night time its performance adaptability can be noted down, it is available to the extent fulfilling all needs in day time come reach but during night it's presence of same found null. The requirement to overcome constraint comes arrive, come to notice, storage of solar energy to use it by the time of shortage.

Solar energy is mainly take on by two methods as below,

a) **Thermal method:** The solar radiations are concentrated to heat the energy used for further application purpose.
b) **Photovoltaic method:** The radiations are used to produce current electricity by solar cells. Such source to be used during day time & it kind of functionality is null during night time, even use of battery is not reasonable at commercial basis and thus 'Solar Thermal Approach' is the better alternative can be considered at such fronts [1].

Present time the utility of solar concentration systems such as parabolic through and solar power towers for storing the heat in molten salts is accomplishment general widely. The big land in the set up system and supplementary accessories like compound piping and pumping systems used to restrict temperature losses occurred and corrosion is the kind of disadvantage of such system. The scenario mentioned as before requires active sun tracking for full day and going to increase the system complexity as well as cost [2, 3].

This investigation work recommends use of Thermal Energy Storage Unit to overcome numerous limitations come occurred with respect to old system and respective moving approach.

## II. THERMAL ENERGY STORAGE METHODS

There are three methods and explained further about to storing of thermal energy is explained in brief. Sensible heat storage, Latent heat storage is the main two methods widely used for storing thermal energy. Third and quite popular method is Thermochemical storage.

Liquid-gas conversions contain of phase changing heat in huge amount; however the enormous density changes taken place through invent the system difficult to materialize to increase definite output from it onwards, and that is the reason, why solid to liquid phase change is replaced by and work approach of which is just discussed below [1].

In latent heat storage method, the phase change generally taken place to liquid from solid phase by the material heating process. In phase change occur material extent to fusion temperature and absorbs large amount of heat leading material phase change, and that is how energy storage will be taken place [4].

## III. SOLAR THERMAL COLLECTORS

There are two components are required to store solar energy. First one is storage unit and second one is collector unit. The collector unit purely collects the solar radiation falls on it and transforms fraction of it into an other forms of energy (either heat or electricity). The storage unit is needed because non constant nature of solar energy, and at certain times small amount of radiation will be received (At night or during cloud cover).

In general, there are three types of collectors they are flat-plate collectors, focusing collectors, and passive collectors.

### a) Flat-plate collectors:

A flat-plate collector is a large, shallow box—typically mounted on a roof—that heats water using the sun's energy. A flat-plate collector is a metal box with a glass or plastic cover (called glazing) on top and a dark-colored absorber plate on the bottom. Their productivity is directly relates to few parameters such as size, facing, and cleanliness. These parameters affect the amount of radiation that falls on the collector. Frequently these collector panels have automated systems that keep them facing towards sun.

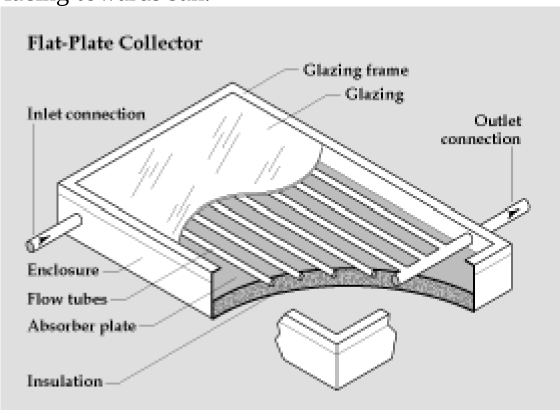


**Fig.1:** Flat plate solar collector

### b) Focusing collectors:

These collectors are large parabolic dishes composed of some reflective material that focus numerous, parallel beams of light on a single focus. They can deliver larger amounts of energy at a single point than the flat-plane collectors; they drop some of the radiation that the flat-plane panels don’t.

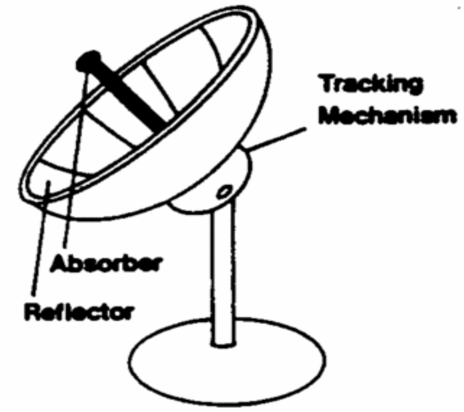


**Fig.2:** Focusing collector

**c) Passive Collector**

The passive collectors absorb radiation and convert it to heat unsurprisingly, without being designed and built to do so. All objects have this property to some amount, but only some objects (like walls) will be able to produce enough heat to make it valuable. Often their natural ability to convert radiation to heat is boosted in some way or another (by being painted black, for example) and a system for conveying the heat to a different location is generally added.

## IV. THERMAL ENERGY STORAGE METHODS

The phase change element should with group of basic properties like chemical, thermos-physical and kinetics etc. [5, 6]. Phase change material is a substance which absorbed or released heat during a phase change from solid to liquid or liquid to gas or vice versa. The PCM are Latent heat storage materials. The phase change used for PCMs is the solid-liquid or liquid-solid change. Liquid –gas phase change are not practical for use as a thermal storage due to their large volume or high pressure required to store the materials when they are in gas phase. Initially, these solid–liquid PCMs perform like conventional storage materials; their temperature rises as they absorb heat. Unlike conventional (sensible) storage materials, PCM absorbs and release heat at a nearly constant temperature. They store 5–14 times more heat per unit volume than sensible storage materials. The PCM to be used in the design of thermal-storage systems should passes desirable thermo physical, kinetics and chemical properties.

The PCM consider for experimental investigation is, article Potassium Hydroxide (KoH) and also known as Caustic Potash. The Thermo physical properties listed in Table 1.

**Table1:** Thermo physical Properties of PCM (Caustic Potash) [7]

| Sr. No. | Performance affecting Parameters | Values and quantity measuring units |
|---|---|---|
| 1 | Density | 2120 kg/m$^3$ at 25°C |
| 2 | Melting point | 380°C |
| 3 | Thermal conductivity | 0.5 w/mk |
| 4 | Specific Heat | 1.1739 kJ/Kg k at 25°C |
| 5 | Heat of Fusion | 149.7 kJ/kg |

## V. EXPERIMENTAL SETUP AND WORKING

The design of storage unit in the form of thermal energy divided in to two segments as, first is, the materials research part related to storage media selection, and the second one is, design of the heat transfer components and structuring the PCM. The TES unit contains of TES material, receptor-transmitter structure of energy, TES material container, thermal insulation & steel container. Thermal insulation supports to reduce the heat loses and a steel container is to support to entire TES unit mechanically.

An average requirement level the TES unit is projected to accumulate to perform for the set of characteristics like, chemical alert but no side effects during performance, nontoxic, chemically stable, slight deviation in the volume noted down as TES material receives or releases the energy at regular basis, high value of latent heat or sensible heat per unit of mass or per unit volume, high thermal conductivity, low cost, available abundantly, long reliable and well-suited with TES container [8].

The container should constructed with set of characteristics on fixed basis and they are directed as, slight variation in the volume with respect to change in temperature, thin wall as long as possible, chemically steady, flameproof, nonhazardous, material used in designing should environment friendly and available at less cost [8].

The receptor and transmitter of energy needs to have high thermal conductivity, rate of absorption of solar radiation should as high as possible (High coefficient of thermal absorption with very less loss of energy to occurred to surrounding), It should be chemically constant during high temperature surroundings and when approaches in environmental contact.
The TES unit collects heat from gas furnace with air blower and then the temperature of TES unit is measured by temperature indicator as shown in fig. 3

The constructed prototype modeled with specifications such as, material caustic potash as PCM, copper as a receptor – transmitter of energy and its properties shown in Table 2.

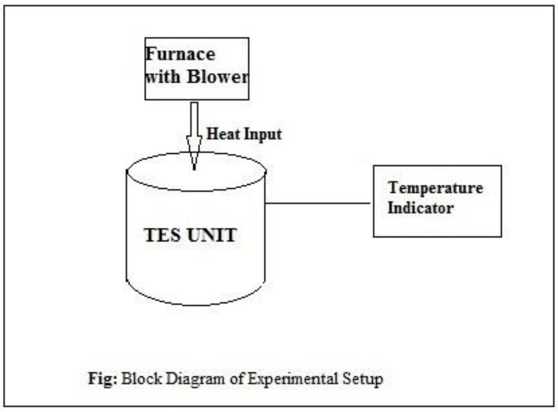


**Fig.3** Block diagram of Experimental setup

Table 2: Thermo physical Properties of Copper [9,10,11,12]

| Sr. No. | Performance affecting Parameters | Values and quantity measuring units |
|---|---|---|
| 1 | Density | 8960 $kg/m^3$ at 20°C |
| 2 | Melting point | 1083°C |
| 3 | Thermal conductivity | 401 w/mk at 20°C |
| 4 | Specific Heat | 383.48 J/Kg k at 20°C |
| 5 | Thermal Expansion Coefficient | $15.40*10^{-6}$ m/m-k |

TES container crucible steel is internally lined with high refractory Zircon based material. The thermal insulation of ceramic wool 0.2M thickness and is used to avoid heat dissipation to surrounding which is covered by steel container as shown in fig 4.

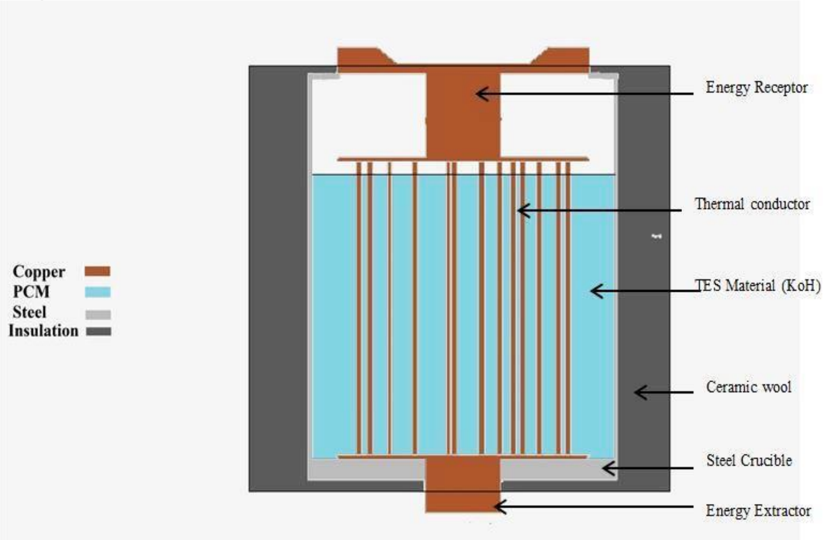


**Fig.4:** Prototype of Thermal Energy Storage (TES) Unit [13]

The copper is selected as an energy receptor & transmitter since its having property of higher thermal conductivity and presenting some oxidation at surface exposed to air. The selected PCM is corrosive with copper but possesses good Thermo physical properties as per the requirement and confirm its availability at enough possible level and thus selected in to experimental work.

When operating within the Combined cooling and Heating system there is no charging period, instead charging and discharging are simultaneous., Approximately 8 hours or 1/3 day During daylight hours, the storage unit receives energy; it is responsibility of the internal thermal conductor to allocate 2/3 of the received energy to the PCM for it to absorb only and store for supporting the operation during night-time (the remaining 2/3 of the day) and to let 1/3 of the heat to flow freely for the Stirling engine to keep generating electricity or for process heating. In other words, during daytime the unit is charged while being discharged at a slower rate, meanwhile during night-time the unit is purely discharged [14].

## VI. MATHEMATICAL MODEL

The variation of specific heat and thermal conductivity of copper relating to the temperature is inline and are stated through next relationship,

$$K = 420.75 - 6.8493 * 10^{-2}T \qquad (1)$$

$$C_p = 316.21 + 0.3177T - 3.4936 * 10^{-4}T^2 + 1.661 * 10^{-7}T^3 \qquad (2)$$

## VII. RESULT AND DISCUSSION

The built TES unit has capacity of storage 10 lit of caustic potash (KOH) and maximum work temperature is equal or more than 325°C.

The variation in thermal conductivity and specific heat for copper probably we will get by using the equation 1&2 and refer fig.3 showing relation between temperature, thermal conductivity and specific heat of copper.

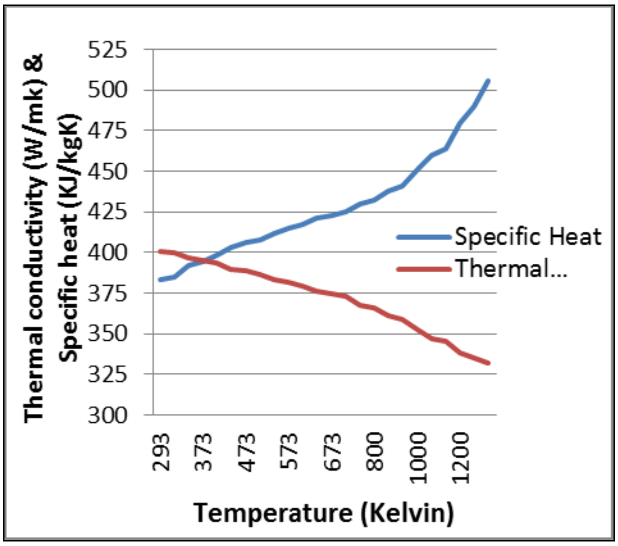


**Fig.5** Graph showing relation between, Temperature, Thermal Conductivity and Specific heat of Copper

The system is integrated with total 10 nos. (K-Type) Thermocouples to measure the temperature at various locations are placed at various locations during charging and discharging of prototype. T1 is located at receptor to measure the input temperature and T2 is placed just above to the upper plate, T10 at energy extraction zone and T3 to T9 are immersed in PCM kept at specific height and specific depth and these are arranged in circumferential manner.

For experimental testing the TES unit has heated by gas furnace for 8 hours in continuation. During heating, observations were noted down for more than 10 different places on the prototype with the break of 30 minutes preserved during each subsequent observation made as such. The work is performed in the said method to study the performance in terms the function of the energy input given. Figure 6 & 7 shows a graph of such measurements taken during experiment; it is the result 10 thermocouples considered during experimentation work.

 

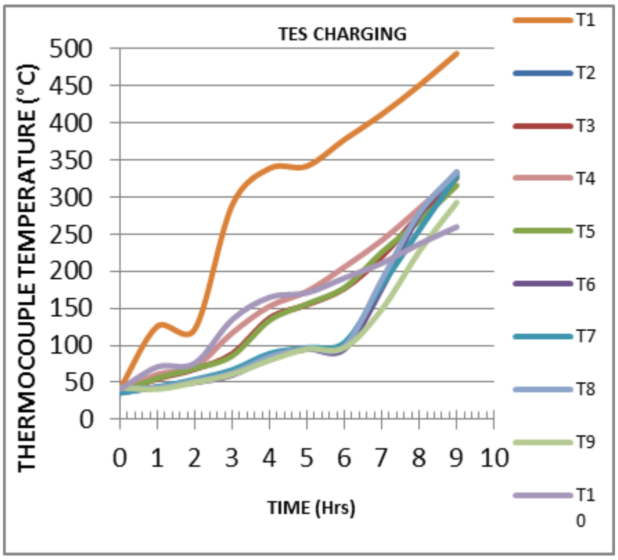


**Fig.6** Characteristic graph showing behavior of Prototype heating process

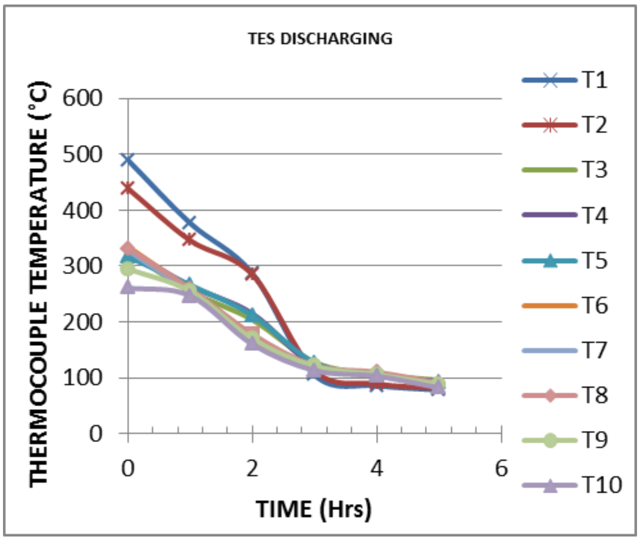


**Fig.7** Characteristic graph showing behavior of Prototype cooling process

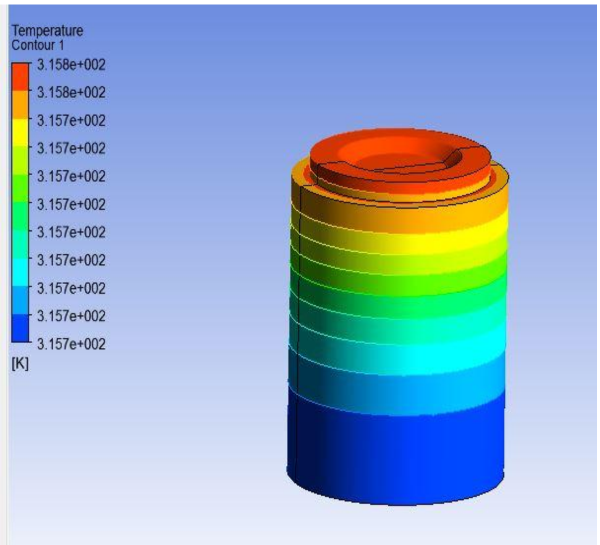


**Fig.8** Computer simulation of temperature distribution inside TES unit

 

## VIII. CONCLUSION

Solar Thermal energy storage is a auspicious technology to address raised energy demand in the future and thus solar thermal plants have proven, it is cheaper and easier way to store heat in thermal storage which are being used for electricity generation and further for process heating and as well, and this all important to increase an efficiency of solar system which keep operation running in continuation during day and night time as well.

A very low temperature difference between the PCM placed within top region of container and bottom of container as well. The measurement reveals that the internal thermal conductor capability.

The system is capable of storing 2KWh of energy and the temperature at various locations during observation is linked with simulation result and shows less deviation between experimental and simulation results.

The option is to increase thermal efficiency by metallic fins, extended surfaces and high conductivity particles which are dispersed in PCM. For increasing efficiency, The TES unit should provide with an insulation which would minimize energy losses occurred to surroundings.

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