

# Investigation of Thermal Energy Storage System for Steam Generation Using Heat Exchanger

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**ABSTRACT:** In today's scenario, energy has diverse applications in food, automobile and medicine industries. India is one of the most populated countries in the world, hence there is always an increase in demand for energy. Hence it is imperative to focus on conservation of energy to meet the demands. Energy storage has crucial role to play to ensure the supply on demand, to improve the performance, reliability and to conserve energy. Thermal energy storage (TES) systems can use phase change materials (PCMs) to store a significant amount of thermal energy. Energy can be stored and retrieved in the form of change in internal energy of a material as sensible heat, latent heat and also in thermo-chemical reactions or combination of these. The different forms of energy that can be stored include mechanical, electrical and thermal energy.

**KEYWORDS:** Thermal energy storage, phase change material, sensible heat, latent heat.

## I. INTRODUCTION

Thermal energy storage can be stored as a change in internal energy of a material as sensible heat, latent heat and thermo chemical energy. In sensible heat storage (SHS), thermal energy is stored by raising the temperature of a solid or liquid. SHS system utilizes the heat capacity and the change in temperature of the material during the process of charging and discharging. The amount of heat stored depends on the specific heat of the medium the temperature change and the amount of storage material. The amount of energy stored (Q) in a sensible heat storage system is given by

$$Q = m C_p (T_f - T_i)$$

where, Q= Amount of energy stored in the heat storage system

T<sub>f</sub> = Final Temperature of the material

T<sub>i</sub> = Initial Temperature of the material

Moreover, energy can be stored in the form of latent heat. Latent heat storage (LHS) is based on the heat absorption or release when a storage material undergoes a phase change from solid to liquid or liquid to gas or vice versa. The amount of energy stored (Q) in a latent heat storage system is given by,

$$Q = m.C_p (T_m - T_i) + m a H + m.C_p (T_f - T_m)$$

Where, C<sub>p</sub>= Specific heat capacity

H = Latent heat of Steam

Amongst above thermal heat storage techniques, latent heat thermal energy storage is particularly attractive for steam generation due to its high-energy storage density and its characteristics to store heat at constant temperature

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corresponding to the phase transition temperature of phase change material(PCM).In such systems, energy is stored by taking advantage of the melting process of phase change material (PCM).

## II. RELATED WORK

In related work, Prieto et al.[1] studied use of PCM and analysis of thermal performance of the flat plate heat exchanger for heating systems. Arsenyeva et al.[2] developed a optimal design of plate and frame heat exchanger for efficient heat recovery in process industries. Kumbhare et al.[3] summarized the performance evaluation of plate heat exchanger in laminar and turbulent conditions. Nkwetta et al.[4] accounted for existing approaches in the design, integration and application of phase change materials(PCMs) in domestic water tanks. Mazzucco et al.[5] numerically investigated solid thermal storage with PCM materials. Khorshidi et al.[6] analysed the performance and applications of a Spiral Plate Heat Exchanger. Eric Johnson[7] analysed performance of Plate and frame heat exchanger. Ramachandran et al.[8] analysed heat transfer in Spiral Plate heat exchanger for water palm oil two phase system. Amala et al.[9] analysed performance of plate heat exchanger using different chevron angles. Johnston[10] studied performance of plate heat exchanger.

## III. PHYSICAL LAYOUT

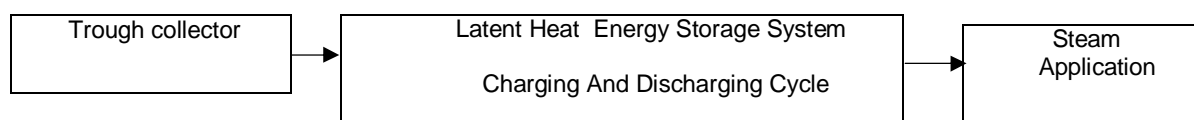


Fig. 1 Physical layout of thermal energy storage system

In the above figure, the physical layout of thermal energy storage system has been described briefly. The layout mainly consists of a trough collector, which is used to collect the heat from the sunlight. The collected heat is further sent to energy storage system which is used to supply latent heat which further converts into a steam.

## IV. COMPONENTS OF THERMAL ENERGY STORAGE SYSTEM

The thermal energy storage system mainly consists of four major sub systems

1. Trough solar collector.
2. Absorber Pipe
3. Phase Change Material Storage system.
4. Heat Exchanger

## V. SELECTION CRITERIA OF PHASE CHANGE MATERIAL

There should be predefined criteria to select right Phase Change Material for steam generation. The criterias are

1. High Latent Heat of Fusion
2. Uniform Melting
3. Non Corrosiveness
4. Easy Accessibility
5. Low Cost
6. Chemical Stability
7. High Specific Heat
8. High Thermal Conductivity

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Table 2. Selection Criteria For Phase Change Material

PCM MATERIAL	LATENT HEAT OF FUSION(kJ/kg)	SPECIFIC HEAT (kJ/kg.K)	MELTING POINT (°C)	COST USD/kg (Rs)
water	333.6	2.05	0	0.001
Aluminium	396.9	0.89	660	2.05
Palm oil	180	2.65	25	0.5
Erythritol	340	1.35	121	1.5
copper	208	0.38	1085	6.81
Lauric Acid	211.6	1.76	44.2	1.6

Based on the above table, Erythritol is the most feasible Phase Change Material which can be selected owing to its High Latent Heat of Fusion, low cost and easy accessibility. Quantity of Erythritol varies depending upon the desired application.

## VI. DIFFERENT TYPES OF HEAT EXCHANGERS

Energy stored can be transferred using Spiral plate, shell and tube and gasketed plate heat exchanger. It is important to select right plate heat exchanger based on their specifications and relative merits.

### 6.1 SPIRAL HEAT EXCHANGER:

Spiral plate heat exchanger is formed by rolling two long, parallel plates into a spiral using a mandrel and welding the edges of the adjacent plate to form channels. Spiral plate heat exchangers differ in 2 types. It is made by rolling 2 long plates around the centre core to form 2 concentric spiral flow passages for each fluid.

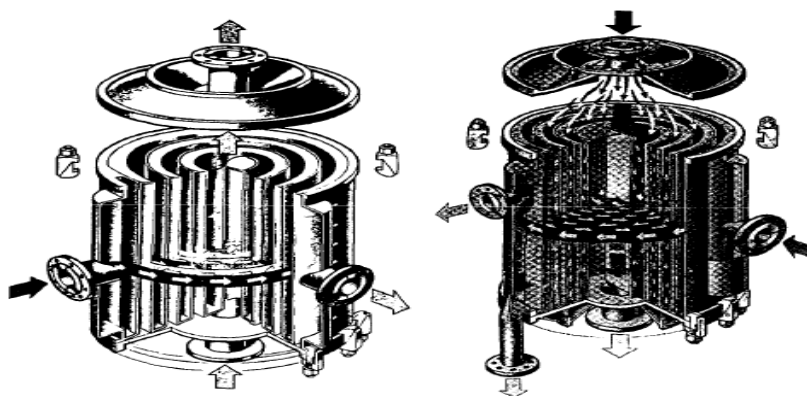


Fig. 2 Spiral Plate Heat Exchanger

These heat exchangers are compact and relatively expensive compared to plate and frame heat exchangers as they require careful maintenance and proper fabrication. Further, the manufacturing cost for spiral heat exchanger is very expensive. Hence, Spiral plate heat exchanger is not a viable option for storing heat energy.

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### 6.2 GASKETED PLATE HEAT EXCHANGER:

Gasketed plate heat exchanger consists of series of this plates with corrugations or wavy surface which separates the fluids. Gaskets prevent leakage to outside and direct the fluids as desired. Gasketed plate heat exchanger is used to exchange heat between two liquid streams. These heat exchangers provide relatively compact and light weight heat transfer surface.

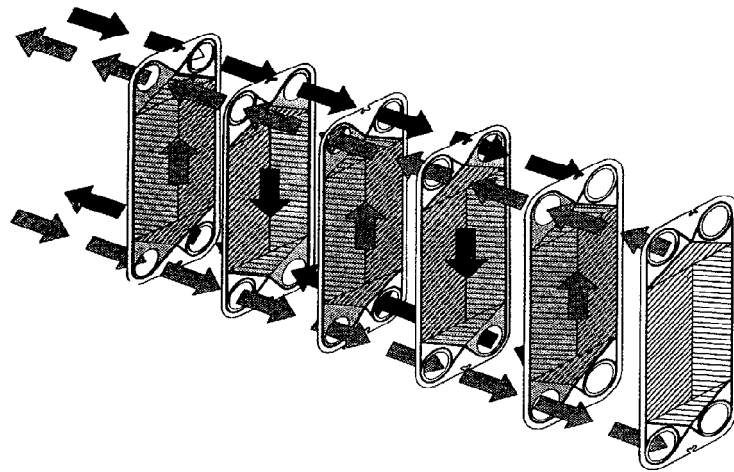


Fig. 3 Gasketed Plate Heat Exchanger

In gasketed plate heat exchanger, the fluid spreads over the entire plate area. As a result heat transfer can be improved drastically for the given quantity of fluid. Further, gaskets are used in plate heat exchanger to prevent heat loss. This makes sure that efficiency of the heat exchanger is increased drastically.

### 6.3 SHELL AND TUBE HEAT EXCHANGER:

Shell and tube heat exchanger is a device which can exchange heat with the surrounding medium with the help of the tube. It consists of two fluids of different temperatures, flowing through heat exchanger.

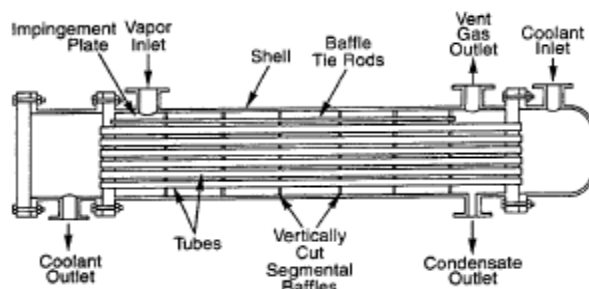


Fig. 4 Shell And Tube Heat Exchanger

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One fluid flows through the tube and the other flows outside the tube. Heat is transferred between the two fluids due to temperature difference. These heat exchangers are suitable for chemical industries and oil refineries. Moreover, it must be ensured the tubes used inside heat exchanger must be of high quality to withstand high temperature.

Table 2. Selection Criteria For Heat Exchanger

Maximum Operating Temperature	HEAT EXCHANGER	OPERATING PRESSURE	COST	ROBUSTNESS
500°C	Spiral Heat exchanger	20 bar	40000/unit	Robust
250°C	Gasketed Plate Heat Exchanger	25 bar	28000/unit	Light and Compact
800°C	Shell and Tube Heat exchanger	15 bar	25000/unit	Robust

Based on the above table Gasketed Plate heat exchanger can be selected owing to its compactness and relative ease of operation. Moreover, gasketed plate heat exchanger can be utilized under high pressure conditions. This property ensures that it can be used in food industries.

### VII. STEPS INVOLVED IN DESIGNING ENERGY STORAGE SYSTEM USING HEAT EXCHANGER

1. Find Heat load calculation for the required application.
2. Input the inlet conditions of the system.
3. Design the plate heat exchanger based on number of plates required for the given application.
4. Model the heat exchanger using CFD analysis.
5. Test and fabricate the plate heat exchanger as per the requirements and compare the results with CFD analysis.

### VIII. CONCLUSION

We have discussed different energy storage systems. Plate heat exchanger along with phase change material can be used as thermal energy storage device to absorb and transfer heat compared to other heat exchangers. Further, steps involved in designing energy storage system using plate heat exchanger has been discussed briefly.

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