International Journal of Research in Engineering, Science and Management
Volume 4, Issue 7, July 2021
https://www.ijresm.com | ISSN (Online): 2581-5792

A Study on Thermal Energy Storage Tank with Phase Change Material in Solar Heating System

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***Abstract*: The phase change material (PCM) for thermal energy storage (TES) has the characteristics of high heat storage density and great thermal storage capacity, and can effectively store solar energy resources. To put it simply a thermal energy storage captures heat from a hot fluid, and stores the energy for later use. The primary components in the thermal energy storage consists of the following: Storage medium, heat transfer fluid, and the insulation. The heat transfer fluid captures heat from solar irradiation, and transfers portion of the heat to the storage medium. When the heat transfer fluid goes cold after sunset, the storage medium replaces the sun as a heat source and heats the fluid.**

***Keywords*: PCM, Paraffin wax, CSP, TES.**

1. Introduction

Recent projections predict that the primary energy consumption will rise by 48% in 2040. On the other hand, the depletion of fossil resources in addition to their negative impact on the environment has accelerated the shift toward sustainable energy resources. Renewable energies such as solar radiation, ocean waves, wind, and biogas have been playing a major role in reforming the natural balance and providing the needs of the growing population demand.

With the development of society and the improvement of people’s living standard. People’s demand for indoor thermal comfort will be improved, building energy consumption in winter will increase, and the energy shortage will become more and more serious. Therefore, it is urgent to find an efficient and clean way of heating. As kind of clean energy, solar energy can be explained, promoting solar energy development and application is important for energy saving and emission reduction.

However, the non-uniformity and instability of solar energy lead to a supply-demand mismatch between the heat source and people’s heating load. Therefore, the combination of thermal energy storage technology and solar heating system can effectively bridge the gap between heat supply and demand.

According to the mechanism of energy storage, thermal energy storage can be divided into three categories: sensible heat storage, latent heat storage and chemical heat storage.

Among them, latent heat storage can save energy by endothermic in phase change process. Compared with sensible and chemical heat storage, latent heat has higher heat storage density, and there is no hidden danger in the process of phase change, which makes it good choice for building energy storage. In recent years, the research and application of PCMs in thermal storage attracted much attention.

The preferred phase change material the project is paraffin wax. Paraffin wax is one of the safest materials to work with, as a wide range of melting temperatures comes at a reasonable price, and does not create high pressure during phase change. Due to the fact that paraffin wax is nontoxic, this reduces potential hazards to the environment if any leakage occurs. Volumetric change between its solid phase and liquid phase is minimal. The manufacturer we choose produces melting temperatures that range from -37-degree C to 151-degree C.

2. Literature Review

TES systems can help balance energy demand and supply on a daily, weekly and even seasonal basis. They can also reduce peak demand, energy consumption, emissions and costs, while increasing overall system efficiency. The conversion and storage of solar and wind energy helps to further increase the share of renewable in the energy mix.

TES is becoming particularly important for electricity storage in combination with concentrating solar power (CSP), where by solar heat can be stored for electricity production when sunlight is not available.

Successive technology briefs have highlighted a wide range of renewable energy solutions. Each brief outlines technical aspects, costs, market potential and barriers, combined with insights for policy makers on how to accelerate the transition to renewable.

Phase change materials (PCMs) have been encapsulated in spheres to form packed beds of encapsulated PCMs. Heat-transfer fluid can be passed through the packed-bed of spheres to charge or discharge energy to/from the encapsulated PCMs. The phase change occurs at nearly isothermal conditions, so this method is useful for applications where the heat addition needs to occur at a specific temperature. At larger temperature ranges, cascaded PCM systems can be designed, but with additional

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complexity and cost. To date, encapsulated PCM systems have been tested and demonstrated at small scales. Commercial systems have not been demonstrated.

3. Problem Statement

The idea behind TES is changing the way users generate the vast amount of heating and cooling capacity that eats up so much conventional energy from the grid. The problem is that much of the grid power used for heating and cooling buildings is generated by energy from fossil fuels such as coal, oil and natural gas. This can be addressed using TES, which can provide heating and cooling solutions simply by evening out the distributed heat in a natural landscape or cycle, for example, by applying heat stored in solar collectors or by distributing cold water or air from underground to cool a building space. Scientists and engineers are hard at work on new thermal energy storage solutions to replace fossil fuel-driven HVAC systems.

4. Objective

To develop the environment friendly thermal energy storage tank by which we can store renewable energy by giving heat to heat transfer fluid and that will transfer its heat to working fluid which will store energy for later use.

5. Working Principle

The basic principle is the same in all TES applications. Energy is supplied to a storage system for removal and use at a later time.

What mainly varies is the scale of the storage and the storage method used. The process of storing thermal energy can be described in three steps, referred to as a cycle. These steps are charging, storing and discharging. The storage cycle applies to sensible, latent and chemical storage; the differences between these methods are the material, the temperature of operation and a few other parameters.

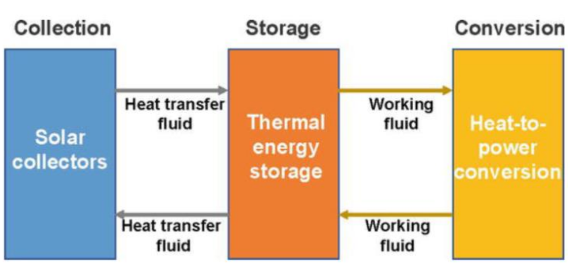

Fig. 1. Collection, Storage and Conversion

6. Practice, Theory and Methodology

As a part of a solar powered water desalination unit, the primary goal of thermal energy storage tank is to store heat for heating up water after the sun goes down for as long as needed. Upon discharging water absorbs the latent heat from our solidifying phase change material, then it will be stored in a water tank before the Reverse Osmosis (RO) process extracts it.

Figure 2 shows the overall layout of the solar RO water desalination unit. During the day, part of hot water coming out of the concentrated solar panels (CSP) will flow through the TES (which melts the phase change materials), and the remaining water will flow directly to the water storage tank. A primary pump will produce the required head for the flow to overcome friction loss (though if required, additional pumps can be added along the flow path). After the sun is set, the value on the direct route to the water tank will be closed. All water flowing out of the water tank will pass through the charged thermal energy storage (TES) and be heated.

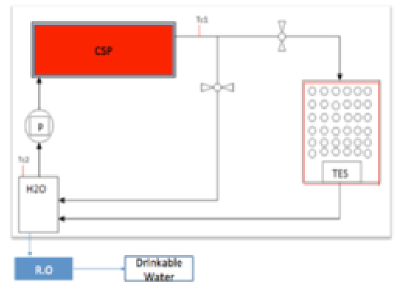

Fig. 2. Schematic of the solar powered RO water desalination unit

The design of the TES is similar to a shell-and-tube heat exchanger. The phase change material (PCM) is encapsulated in bundles of tubes fixed within the shell by multiple layers of baffles, which also promote cross flow in the water to enhance the heat exchanging process. The tubes are to have thin walls and are made of highly conductive material such as copper or aluminum. Any seals in the phase change material (PCM) tubes must be leak proof so phase change material (PCM) are allowed to escape and contaminate the water.

Since the heat exchange process in the TES is in the transient stage, the Lump Capacitance Method and the Finite Difference Method will be utilized to theoretically approximate the transient behavior of the unit.

A. Charging of Thermal Energy Storage

The procedure of testing in charging mode is as follows:

a) The water of storage tank is heated to the range of 85-85ºC, using the heating arrangement.
b) The flow control valve is adjusted to a suitable mass flow rate of heat transfer fluid.
c) The initial readings of the temperature indicator are recorded.
d) The pump is switched on to initiate the flow in the circuit.
e) The readings of temperature indicator i.e., temperature at the predetermined points are then taken at an interval of 2 minutes, for ground 40 to 60 minutes.
f) The temperature variation at each point of the wax is plotted with the time spent.

B. Discharging of Thermal Energy Storage

a) The heating arrangement of the storage tank is kept off.
b) The initial readings of the temperature are recorded.
c) The water in the storage tank at ambient temperature is circulated using the pump.

d) The readings of temperature indicator i.e. temperature at predetermined points are taken at an interval of 2 minutes for around 40 to 60 minutes.
e) The variation of temperature at each point in the wax is then plotted against the time elapsed.
f) The loading and unloading procedure is repeated for different levels of mass flow of the heat transfer fluid and thus obtaining temperature change parameters for varying flow rates.

7. Design and Parts

A. Materials and properties

1) Copper tubes – 7cm in diameter

Fig. 3. Thermal energy storage tank fully assembled with all PCM inserted

These copper tubes are filled with phase change material (PCM). Approx. 20 tubes are used in the thermal energy storage tank for the project. Tubes can also be of aluminum as well but due to reasonable item copper is preferred. Copper is used as a conductor of heat and electricity.

2) Paraffin wax

Fig. 4. Paraffin wax

Paraffin wax is mostly found as a white, odorless, tasteless, waxy solid, with a typical melting point between about 46 and 68 °C (115 and 154 °F), and a density of around 900 kg/m^3. It is insoluble in water, but soluble in ether, benzene, and certain esters.

Boiling point**:** > 370 °C (698 °F)

Physical properties	Paraffin RT58 [18]
Density [kg/m^3]	840
Specific Heat [J/kg K]	2100
Thermal Conductivity [W / m K]	0.2
Dynamic Viscosity [kg/m s]	0.0269
Thermal expansion coefficient [1/K]	0.00011
Melting Heat [J / kg]	180000
Solidus Temperature [K]	321
Liquidus Temperature [K]	335

3) Plastic

Plastic, polymeric material that has the capability of being molded or shaped, usually by the application of heat and pressure.

Here, the plastic drum is being used in white color which is fitted with two valves at the top and lower bottom.

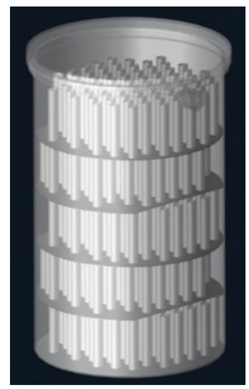

Fig. 5. The outer covering is of plastic

4) Steel sheet

Sheet metal is metal formed by an industrial process into thin, flat pieces. Sheet metal is one of the fundamental forms used in metalworking, and it can be cut and bent into a variety of shapes. Countless everyday objects are fabricated from sheet metal.

8. Result

This project work results in that the thermal energy storage has high storage capacities. The heat transfer fluid water transfers the heat to working fluid which paraffin wax absorbs it. The absorbed heat is used for future. The amount of heat stored can be used for 50 minutes approx. for this small size project.

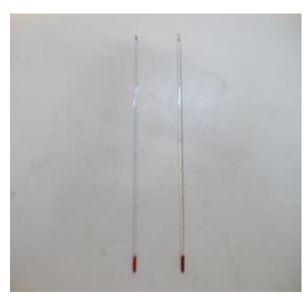

Fig. 6. Thermometer

Thermometer is used to measure inlet water temperature and the water coming out of thermal energy storage tank. By this, we are able to calculate the temperature difference and energy stored by paraffin wax.

9. Conclusion

By the present model, we are able to conclude that thermal energy storage tank is able to store energy for further use and comes at a reasonable price. Paraffin wax is insoluble in water and results in non-hazardous, odorless, and one of the safest phase change materials to work with. We also conclude that the hot water can be cross flowed in the middle of the tubes by which they are able to conduct heat energy in more effective way. At last, when hot water stops coming from inlet we start flowing cold water and working fluid (PCM) transfers its heat to cold water which in turns to become hot at the end of the discharge from the bottom valve.

Acknowledgment

We would like to express our special thanks of gratitude to Mr. Gautam Gunjan Sir who gave us the golden opportunity to do this wonderful project on the Thermal Energy Storage Tank, which also helped us in doing a lot of Research and we came to know about lot of things we really thankful to them.

Secondly we would like to thanks our parents and friends who helped us a lot in finalizing this project within a limited time frame.

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