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Experimental Analysis of Thermal Energy Using Phase Change Material

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***Abstract*- This experimental investigation deals with the performance evaluation of the of a phase change material (PCMs) using Copper tubes and using this energy to heat water and store it for domestic purposes. The storing unit stores the heat in PCMs effectively due to Copper tubes. The water in the storing unit gets heat from the heater and transfers it in less time due to Copper tube to the PCM. The PCM undergoes change of phase by receiving latent heat, surplus heat being stored as sensible heat. The comparison is made between arrangements of a tank which can be used as normal domestic tank and the same can be used as PCM tank with copper tubes. The results based on the Temperature, Time, Heat stored is elaborated.**

***Key words*- Phase change material, Thermal energy storage, Latent heat, heat transfer.**

1. INTRODUCTION

Now a day, due to increase in energy consumption, a great deal of fossil fuels is being used. Use of renewable energy sources can decrease these problems. Despite of solving this problem renewable energy sources, has limitations that they do not cope-up with existing demand. To ensure to adjust supply and demand of energy, the usage of phase change thermal energy storage systems is essential. Thermal energy storage (TES) ascertains to be a smart and inexpensive substitute for large-scale use. Energy is stored in a storing medium, and the storing device can be categorized as sensible heat, latent heat, or chemical storage.

The most popular sensible thermal storage systems practice molten salts. Thermal energy storing systems offer the prospective to achieve energy savings, which in Turn decrease the environment effect related to energy use. Latent heat storage materials or Phase Change Materials (PCMs) can store comparatively great extents of energy in lesser volumes, and hence have some of the lowermost storage material costs. Most PCMs functions between solid-liquid transitions, and is therefore most opted as an indirect storing concept. According to past research utmost of the possible salt-based PCMs possesses low thermal conductivity and need extensive material or heat exchanger modifications to be implemented to produce practicable storing systems. This nullify the saving of cost through material reduction. This experiment has been undertaken to study the feasibility of storing the energy using Phase Change Materials (PCMs), utilizing copper pipes to transfer energy of hot water. This confirm that hot water is available continuously. The PCM absorbs latent heat and undergoes a phase change. Surplus heat is stored as sensible heat. In this manner, an investigation of Latent Heat Thermal Energy Storage with Copper pipes in domestic applications is done.

The objective of the experiment is to find effectiveness of paraffin wax as PCM and to compare Latent heat thermal energy storage and sensible heat thermal energy storage system viz. one with PCM and Copper pipes and other without PCM and Copper pipes.

The results are drawn based on the Temperature, Mass Flow rate conditions, Time.

2. EXPERIMENTAL SETUP

Experimental setup consists of a Water Heater of 2000 watt, two Latent Heat Thermal Energy Storage Tanks of diameter 280 and height of 290 mm, one having Phase changing material Paraffin and copper tubes and the other without PCM and copper tubes. The stainless steel TES tanks have capacity of about 20 liters, excluding volume of copper pipes. With an internal diameter of 280mm and a height of 290mm, it houses the copper pipes and PCM which allows heat transfer between the copper pipes having PCM and water. Precaution is taken for PCM present in the copper tube of the tank will not be mix with water. To confirm maximum heat transfer between water and PCM copper tubes of ASTM standard with 99.9 % purity is used. These copper tubes are joined to tank by brazing. The PCM used in the Tank is industrial grade granulated paraffin wax with a melting point range of 50-55°C and water is used as the HTF. Thermometer is provided at the head of the storage tank. The temperatures of the water are continuously measured by digital thermometer. The tank setup is covered with insulation of glass wool to avoid any heat loss.

Table 1: Components of experimental set up

	Outer diameter (mm)	Inner diameter (mm)	Length (mm)	Thickness (mm)
Tank	290	280	290	3
Copper tube	17	16	28	1
steel plate	270	-	-	3

Table 2: Thermo physical Properties of PCM

Melting temperature of PCM	50º C
Latent heat of Fusion	184.48 KJ/kg
Density of PCM(Liquid Phase)	775 kg/m3
Density of PCM (Solid Phase)	883.60 kg/m^3
Specific heat of PCM(Solid Phase)	2.384 KJ/kg ºC
Specific heat of PCM(Liquid Phase)	2.44 KJ/kg ºC
Thermal conductivity	0.15 W/mk
Viscosity	$6.3x10^{-3}$
Kinematic viscosity	8.31xx
Prandtl no.	1001.23
Thermal Expansion coefficient	$7.14x10^{-3}$

3 OBSERVATIONS:

Case 1:

Water in tank having no wax containing copper tubes is heated up to 70°C and temperatures readings are noted after every 15 minute.

Table 3: Temperature Readings of Sensible Heat Thermal Energy Storage (SHTES)

Time(min)	Temp(°c)
0	70
15	64
30	61
45	57
60	53
75	49
90	45
105	40
120	35

Case 2:

Water in tank having wax containing copper tubes is heated up to 70°C and temperatures readings are noted after every 15 minute till 40^0 C water temperature is achieved.

Table 4: Temperature Readings of Latent Heat Thermal Energy Storage (LHTES)

Time(min)	Temp(°c)
0	70
15	68
30	65
45	63
60	62
75	61.5
90	60.5
105	58
120	58

Table 5: Comparison of SHTES and LHTES Temperature readings

Time(min)	Case I Temp(°c)	Case II Temp(°c)
0	70	70
15	64	68
30	61	65
45	57	63
60	53	62
75	49	61.5
90	45	60.5
105	40	58
120	35	58

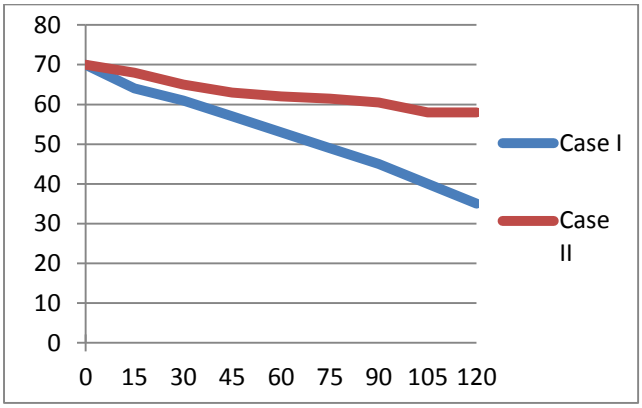

Figure 1: Comparison of SHTES and LHTES Temperature readings.

4. CALCULATIONS

a. The heat absorbed and rejected as Latent heat by the PCM (with the use of copper pipes) in the charging and discharging process can be calculated as,

Heat absorbed by PCM (Qa) = Sensible Heat of PCM (Heat of solid medium) + Latent Heat of PCM + Sensible Heat of PCM (Heat of liquid medium)

Q= m$Csp\Delta$T + mamhm + $mClp\Delta T$

Where,

Csp = specific heat of solid medium

Clp = specific heat of liquid medium

am= melting fraction of PCM

hm= Latent heat of fusion

$Lpcm$=Latent heat of PCM

Q = 522.752 KW/day

b.Heat transfer from fin(Cu Tubes)

q = hAΔT q = 357.75 W

From calculations it is found that water can be stored at 40^0 C for 6.64 Hrs.

5. RESULTS AND CONCLUSION:

From theoretical calculations it is found that water can be stored up to 6.64Hrs at 40^0 C and from experimental setup it is observed that water can be stored up to 5Hrs at 40^0 C.

The difference in theoretical calculation and experimental readings may be due to losses from convection and conduction to other parts of tanks and atmosphere. With perfect insulation condition this difference can be minimized.

With experimental investigation it is proved that PCM are useful in decreasing the energy consumption.

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