ABSTRACT

Background/Objectives: The objectives of the present work are focused to investigate the theoretical heat gain, heat loss and instantaneous collector efficiency of cylindrical parabolic concentrating solar water heater over a clear day.

Methods/ Statistical Analysis: The performances of a cylindrical parabolic concentrating solar water heater fitted with copper absorber tube, using water as working fluid are investigated theoretically. The theoretical investigations are studied for water flow rates 0.1 kg/s and 0.15 kg/s between 8:0 h and 16:0 h over a sunny day.

Findings: The theoretical results are showed that intensity of solar beam radiation with respect to time much more at noon than that calculated at 8:0 and 16:0 hours. Theoretical solar beam radiation data obtained are compared and validated with that of experimental based published data. The instantaneous efficiency, useful heat gain, hourly energy collected and heat loss are influenced by water mass flow rate.

Application/Improvements: The theoretical study consumes less time than analytical and experimental studies. The initial capital investment is must to procure the experimental setup, whereas for theoretical work not required neither capital investment nor procurement process.

NOMENCLATURE

1. **A0**:absorber tube cross-sectional area m2
2. **Aap**:reflector Aperture, m2
3. **C**:Concentration ratio
4. **Cp**:specific heat at const. pressure, kJ/kg-o C
5. **Di**:absorber tube inner diameter, m
6. **Do**:absorber tube outer diameter, m
7. **Ec**:energy collected, J
8. **F**:focal length, m
9. **FR**:heat removal factor
10. **F'**:collector efficiency factor
11. **Hf**:inside heat transfer coefficient, W/m2 -o C
12. **Hw**:outside heat transfer coefficient, W/m2 -o C
13. **Ib**:intensity of beam radiation, W/m2
14. **Idn**:intensity of beam radiation in the direction of sun rays, W/m2
15. **Ka** : thermal conductivity of air, W/m-o C
16. **Kp** :thermal conductivity of absorber tube material, W/m-o C
17. **Kw** : thermal conductivity of water, W/m-o C
18. **L** :length, m
19. **M** :water mass flow rate, kg/s
20. **Nu** :Nusselt number
21. **Pr** : Prandtl number
22. **Ql** :heat loss, J/s
23. **Qu** :useful heat gain, W
24. **Re** : Reynolds number
25. **Rb** :tilt factor
26. **S** :heat flux, W/m2
27. **Ta** :ambient temperature, o C
28. **Tfi** :inlet temperature, o C
29. **Tfo** :outlet temperature, o C
30. **Tp** :average temperature of absorber tube, o C
31. **Ul** :heat loss factor, W/m2 -o C
32. **Vm** :mean water velocity, m/s

33. **Vw** :wind velocity, m/s
34. **W** :reflector width, m

CHAPTER 1

INTRODUCTION

Renewable energy sources in general and Solar Energy source in particular, has the potential to provide energy services with zero or almost zero emission. The solar energy is abundant and no other source in renewable energy is like solar energy. It is a non-polluting technology, as it does not release greenhouse gases. However, solar energy is available only during daytime and most load profiles indicate peak load in the evening/night time. This necessitates/requires expensive energy storage devices like battery etc.

Solar energy is associate degree of inexhaustible resource. The sun produces large amounts of renewable alternative energy that may be collected and reborn into heat and electricity. Within the fifth century B.C., the Greeks took advantage of passive alternative energy by coming up with their homes to capture the sun’s heat throughout the winter. The population and world energy demand is increasing fast whereas fuel sources area unit declining quickly. The surroundings is impure by fuel burning and temperature change has changing into immense world downside. This is often principally as a result of the worth of electrical heater is affordable and comparatively simple to put in. However, the globe is facing a large downside currently thanks to declining supply of energy and victimization the valuable power for heating doesn't very a decent plan since heat are often controlled directly from the sun. Alternative energy supply is property, free, clean and infinite. However, current warmer remains valuable, low in potency and massive in size. One in all the effective ways to extend the potency is to interchange the operating fluid with Nano fluids [6]. PCM cash in of heat energy that may be keep or discharged from a cloth over a slender temperature vary. PCM possesses the flexibility to alter their state with a particular temperature vary. These materials absorb energy throughout the heating method as phase transition state takes place and unharness energy to the surroundings within the natural action vary throughout a reverse cooling process. Basically, there are three ways of storing thermal energy: sensible, latent and thermo-chemical heat or cold storage. Thermal energy storage in solid-to-liquid natural action using natural action materials (PCMs) has attracted abundant interest in solar systems because of the subsequent advantages:

(i) It involves PCMs that have high heat energy storage capability.

(ii) The PCMs soften and solidify at an almost constant temperature.

(iii) A little volume is needed for a heat energy storage system, thereby the warmth losses from the system maintains in a very affordable level throughout the charging and discharging of warmth.

Phase Change Materials (PCM) are latent heat storage materials. As the source temperature rises, the chemical bonds within the PCM break up as the material changes phase from solid to liquid (as is the case for solid-liquid PCMs). The phase change is a heat-seeking (endothermic) process and therefore, the PCM absorbs heat. Upon storing heat in the storage material, the material begins to melt when the phase change temperature is reached. The temperature then stays constant until the melting process is finished. The heat stored during the phase change process (melting process) of the material is called latent heat. Latent heat storage has two main advantages: a) it is possible to store large amounts of heat with only small temperature changes and therefore to have a high storage density; b) because the change of phase at a constant temperature takes some time to complete, it becomes possible to smooth temperature variations. The comparison between latent and sensible heat storage shows that using latent heat storage, storage densities typically 5 to 10 times higher can be reached. PCM storage volume is two times smaller than that of water. Latent heat storage can be used in a wide temperature range. A large number of PCMs are known to melt with a heat of fusion in any required range.The PCM to be used in the design of thermal storage systems should accomplish desirable thermophysical, kinetics and chemical properties.

A.PROPERTIES OF PCM

1. Thermo-physical Properties

a) Melting temperature in the desired operating temperature range.

b) High latent heat of fusion per unit volume so that the required volume of the container to store a given amount of energy is less.

c) High specific heat to provide for additional significant sensible heat storage.

d) High thermal conductivity of both solid and liquid phases to assist the charging and discharging of energy of the storage systems.

e) Small volume changes on phase transformation and small vapor pressure at operating temperatures to reduce the containment problem.

f) Congruent melting of the PCM for a constant storage capacity of the material with each freezing/melting cycle.

2. Kinetic Properties

a) High nucleation rate to avoid super cooling of the liquid phase.

b) High rate of crystal growth, so that the system can meet demands of heat recovery from the storage system.

3. Chemical Properties

a) Chemical stability.

b) Complete reversible freeze / melt cycle.

c) No degradation after a large number of freeze / melt cycles.

d) Non-corrosiveness to the construction materials.

e) Non-toxic, non-flammable, and non-explosive materials for safety.

B.CLASSIFICATION OF PCM

There are a large number of PCMs (organic, inorganic and eutectic), which can be identified as PCMs from the point of view melting temperature and latent heat of fusion. However, except for the melting point in the operating range, a majority of PCMs do not satisfy the criteria required for an adequate storage media. As no single material can have all the required properties for an ideal thermal storage media, one has to use the available materials and try to make up for the poor physical properties by an adequate system design. For example, metallic fins can be used to increase the thermal conductivity of PCMs, super-cooling may be suppressed by introducing a nucleating agent in the storage material, and incongruent melting can be inhibited by the use of a PCM of suitable thickness. For their very different thermal and chemical behavior, the list of each sub-group, which affect the design of latent heat storage systems using PCMs of that sub-group, are mentioned below:

a) Paraffins b) Non-paraffins c) Fatty Acids d) Salt Hydrates e) Eutectics f) Cross-linked Polyethylene g) Polyalcohols.

Selection of suitable phase changematerial

Selection of a suitable phase change material is very important and is the fundamental requirement of our project. The following are desirable characteristics of a good phase change material:

a. It should possess high latent heat storagedensity.
b. Thermal conductivity of the PCM should begood.
c. The phase transition temperature should be suitable as per requirements of thesystem.
d. Small volume change should happen during phasechange.
e. It should be chemically stable, less toxic and should be compatible with thecomponents.
f. It should be available andeconomical.

Thermal properties of the paraafin wax used as PCM are listed in Table:1.1

Transition temperature	40^0 C to 50^0 C
Latent heat capacity	206kj/kg
Density	789kg/m^3

Table no.1.1Properties of PCM

CHAPTER 2

LITERATURE REVIEW

Yogesh nayak(2010):-His main area of research activity is Power System, Renewable Energy and Heat Transfer

Performance prediction of absorber tube of Parabolic Trough Concentrator with the enhancement of heat transfer by varying the width of twisted tape inserts. Mathematical expressions have developed for the model to simulate the results for prediction of performance using C++ program. On the basis of simulated results, variation of Nusselt number, Friction factor and overall enhancement with Reynolds number and twist ratio for different values of the width of twist tape inserts have been studied.

Dr. U. K. Sinha(2010):- his research interests are in the area is Renewable Energy

India is the fastest growing country, and Indian industries are growing faster than other developing countries to support Make in India initiative. With the technological advancement, every Indians are using multiple gadgets, applications to ensure their comfortable lifestyles resulted per capita consumption of electrical energy in India is increasing day by day. To meet the industrial, commercial, and residential power demand, India is increasing power generation capacity on every year, but the major challenges to generate the conventional power are sharp depletion of fossil fuels as country like India primarily depends on fossil fuels for power generation.

Dr. P. Kumar(2011):-his research interests are in the areas of Thermal Engineering, Refrigeration & Air Conditioning

Performance prediction of STPTCS has been studied by enhancement of heat transfer rate using nanofluid, plain twisted tape and nail twisted tape inserts. Nanofluid and twisted tape inserts based STPTCS are commonly used in the area as such as industries, heating and cooling for buildings, thermal power plants, solar cooker, automobiles etc. This paper provides enhancement and performance prediction in heat transfer in absorber tube of concentrator using nanofluid and twisted tape inserts.

Nilesh kumar(2011):- His research interest includes Power System and Renewable Energy

The maximized nano-fluid Nusselt number and minimized pressure drops are the most effective options for obtaining the enhanced thermal frontiers in solar parabolic trough collector. Methods/Analysis: In view of this, numerous researches had proposed hybrid algorithms for the optimization of the thermal analysis. Obtaining Pareto optimal solution, tending to local optimum point and the time consumption are the main drawbacks of the previous algorithms. Hence, in order to overcome the above difficulties, present work proposes a new innovative approach for optimization of thermal analysis in SPTC. Particle Swarm Optimization (PSO) based solution methodology is proposed to gain the benefits of the global optimum solution and overcome the difficulties of the previous approaches.

MaximeMussard, Ole JørgenNydal

Two charging experiments of a solar heat storage area unit conferred. The warmth storage is plus a self-circulating solar parabolic trough crammed with thermal oil (Duratherm 630). The absorbent tube isn't insulated within the 1st check (figure1), and insulated with a glass tube throughout the second check (the air Layer insulating the absorbent is seven millimeter thick, embowered between 2 glass cylinders) (figure2). Associate degree electronic system tracks the sun throughout the experiments. The storage is principally oil based mostly however contains a big a part of nitrate salts so as to store energy with heat energy (melting temperatures: 210–220˚C). The results show that at low temperatures, the absorbent while not insulation is far simpler. However once the storage temperature approaches 200˚C, the glass tube becomes a plus and a necessity for the any heat assortment at higher temperatures. Higher than 200˚C, it becomes troublesome to gather while not insulation round the receiver.[3]

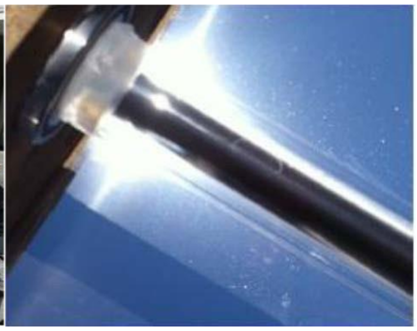

Fig. 2.1. System in use–absorber without insulation coupled with heat storage[3]

Fig. 2.2 Close up view of insulated absorber[3]

Ole JørgenNydal et al.

The system is liquid-based: the collector concentrates the energy on the receiver so the fluid (a heat transfer oil: (Duratherm FG) within the receiver tube is heated and might carry the energy to the storage. The loop connecting the collector and also the storage is crammed with the warmth transfer oil that circulates by self-circulation. The primary storage in principally manufactured from metallic element and salts, whereas the second relies on the oil and salts. The system is heated unnaturally to simulate the Sun and make sure that we have a tendency to place a similar quantity of energy for the 2 experiments. The potency of the metallic element system is drastically affected around 200˚C, whereas the oil system continues it's charging at this temperature. The oil-based storage so desires one.5 times less time to be charged for a given temperature below two hundred ˚C. The metallic element storage cannot be charged over this temperature in a very affordable time.[3]

Y.B. Tao et al.[4], supported total heat methodology, numerical studies were performed for top temperature liquefied salt phase change thermal energy storage (PCTES) unit (figure 5) utilized in a dish solar thermal power generation system. Firstly, the consequences of the heat transfer fluid (HTF) recess temperature and speed on the PCTES performance were examined. The results show that though increasing the HTF recess speed or temperature will enhance the melting rate of the phase change material (PCM) and improve the performance of the PCTES unit, the two parameters can prohibit one another for the mounted solar dish heat output. Then 3 enhanced tubes were adopted to boost the PCTES performance, which are dimpled tube, cone-finned tube and helically-finned tube respectively. The consequences of the improved tubes on the PCM melting rate, solid–liquid interface, TES capability, TES potency and HTF outlet temperature were mentioned. The results show that compared with the sleek tube, all of the 3 enhanced tubes may improve the PCM melting rate.

Fig. 2.3 The schematic of the shell-and-tube PCTES unit.[4]

Chee WohFoong et al.

This paper reports on the testing of a little scale double-reflector star concentrating system with heat storage. The most advantage of thermal heat storage is that the thermal energy is on the market conjointly throughout times once there's very little or no sun shine. A well-insulated heat storage ought to keep the warmth for concerning twenty four hrs. Several solar heat assortment systems area unit supported transportation of warmth from the put concentration to the storage by a current heat transfer fluid. With a double-reflector arrangement, the storage is heated directly, and no heat transport fluid is required during this system. $NaNO_3$ and KNO_3 in 60:40 percent ratio (mol %) were used as heat energy medium. The melting temperature of concerning 220˚C is kind of appropriate for cooking and baking functions. Copper fin was accustomed increase the warmth transfer rate from the warmth prime plate into the heat medium. The experimental results incontestable that the melting of natural action material occurred inside a pair of to a pair of.5 hrs. And reached the temperature vary of 230 to 260 ˚C. The heat energy storage unit has been analyzed numerically employing a finite part model. Effective heat capability methodology was adopted to simulate the phase transition process. The charging temperature profiles of the check module at totally different positions were investigated. Solar chase system wasn't put in during this study, manual changes were administered concerning each ten min.

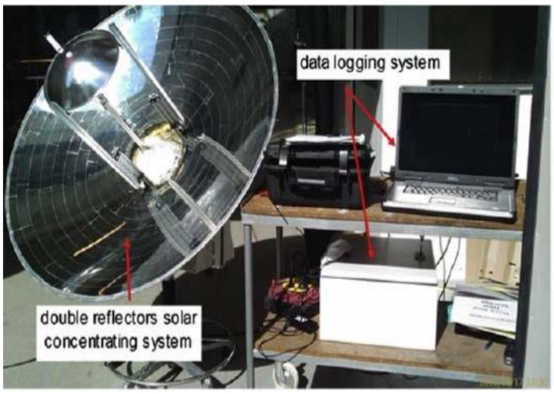

Fig. 2.4 Expt. setup for the double-reflector solar concentrating system. [1]

The present study investigates a little scale double-reflector star concentrating system with heat storage.$NaNO_3$-KNO_3 binary mixture was used because the natural action material (PCM) within the heat storage and also the thermal behavior of this salt was analyzed victimization differential scanning measuring system (DSC). With the given experimental setup, the direct illuminating system was ready to soften the PCM inside a pair of to a pair of.5 hrs. And reached the temperature vary of 230 to 260˚C.This temperature vary is kind of appropriate for cookery or baking functions. [1]

MaximeMussard et al.

Comparative experimental study of 2 solar cookers. The primary is that the widespread ISK14 (figure 2.5) cooker; the second could be a paradigm of a solar concentrator (parabolic trough) employing a storage unit. The ISK14 could be a direct solar cooker where the cookery pot is placed on the focal point of a parabolic dish; within the trough system heat is transported from associate degree absorbent to a storage unit by means that of a self- circulation loop crammed with thermal oil. Each boiling and frying tested to estimate the cookery potency of the warmth storage system. The paradigm storage unit gave twenty fifth longer cookery times than the SK14. Experiments with an electric sander heat transfer surface offers fifty fifth shorter times than the first surface. The warmth transfer issues are modelled and a standardization of warmth transfer coefficients offers smart correspondence with experiments for each some extent model.

Fig 2.5: 1SK 14 system [2]

V.Praveen Kumar (2014)

Analyzed different kinds of heat transfer fluids used in CSP technologies that include air, water, molten salts, glycol based, glycerol based and synthetic oils which can transfer heat effectively. He had listed out various properties of heat transfer fluids and formulated selection criteria which are to be followed for selecting a HTF for Concentrated Solar Power Technologies.[11]

Abhat.A. was first to identify latent heat storage materials and listed their thermodynamic, kinetic and chemical properties. Belen Zalba et al.listed out quantitatively enormous amount information regarding PCM used for Thermal Energy Storage spread widely in literature.[13]

M. Faizal et al.

For a solar thermal system, increasing the warmth transfer space will increase the output temperature of the system. However, this approach results in an even bigger and bulkier collector. It will then increase the price and energy required to manufacture the solar dish. This study is administered to estimate the potential to style a smaller solar dish that may turn out a similar desired output temperature. This is often attainable by victimization Nano fluid as operating fluid. By victimization numerical ways and knowledge from literatures, efficiency, size reduction, value and embodied energy savings area are calculated for various Nano fluids. From the study, it had been calculable that 10,239 kg, 8625 kg, 8857 kg and 8618 kg total weight for a thousand units of solar collectors are often saved for CuO, SiO2, TiO2 and Al2O3

Nano fluid severally. The typical worth of 220 MJ embodied energy are often saved for every collector, 2.4 years payback amount are often achieved and around 170 kilogram less carbon dioxide emissions in average are often offset for the Nano fluid based mostly solar dish compared to a standard solar dish. Finally, the environmental injury value may be reduced with the Nano fluid based mostly solar dish. it's been found that the, Higher density and lower heat of nanoparticles results in the next thermal potency and CuONano fluid have the best worth compared to alternative three Nano fluids, 25.6%, 21.6%, 22.1% and 21.5% solar dish space reduction area unit achieved for CuO, SiO2, TiO2 and Al2O3 respectively. Smaller and compact solar dish operated victimization Nano fluids are often factory-made. Hence, it will cut back the burden, energy and value to manufacture the collector. It had been calculable that 10,239 kg, 8625 kg, 8857 kg and 8618 kg total weight for a thousand units of star collectors are often saved for CuO, SiO2, TiO2 and Al2O3 Nano fluid respectively.[14]

GianlucaSeraleaet

In this research he investigated the performance of flat plate solar thermal collector for alternative energy conversion supported the exploitation of the heat energy of the heat carrier fluid. So as to assess this strategy, a antecedently developed numerical model of flat plate solar thermal collector with suspension PCM as heat carrier is hereby accustomed simulate the technology. The characterization and energy performance of such a system area unit hereby conferred, supported the end result of the numerical analysis. The results of the numerical characterization and performance analysis of the suspension PCM-based solar thermal collector demonstrates that this technique presents promising energy potency enhancements, a minimum of from the theoretical purpose of read. On average, the instant potency will increase up to +0.08 if compared to a standard, water based mostly technology. it's value mentioning that the system conjointly shows some limitations: it's not possible to figure with PCM concentrations higher than 50 %, pumping energy demand is maybe increased compared to a standard system and technological problems as so much because the suspension PCM is bothered (segregation, durability) ought to be any investigated.[12]

Hu¨seyinBenli et al. -

During this study, the thermal performance of a phase change thermal storage unit is analyzed and mentioned. The storage unit could be a part of 10 pieced star air collectors utility being developed for area heating of a greenhouse and charging of PCM. $CaCl_2.6H_2O$ was used as PCM in thermal energy storage with a melting temperature of 29˚C. Hot air delivered by 10 pieced star air collector is passed through the PCM to charge the storage unit. The stored heat is used to heat ambient air before being admitted to a greenhouse. This study relies on experimental results of the PCM utilized to analyzed the transient thermal behavior of the storage unit throughout the charge and discharge periods. The projected size of collectors integrated PCM provided concerning 18 to 23% of total daily thermal energy needs of the greenhouse for 3 to 4 hrs, as compared with the standard heating device. An in depth analytical and experimental study was conducted to evaluate the thermal performance of 5 types of 10 pieced solar air collectors and PCM, below a large vary of operational conditions. This technique was thought-about preponderantly helpful for heating applications considerably enhanced. The solar air collectors and PCM system created 6 to 9˚C temperature distinction between the inside and outside the greenhouse. The system worked a lot of expeditiously in day with high radiation air temperatures. The projected size of collectors integrated PCM provided concerning 18 to 23% of total daily thermal energy needs of the greenhouse for 3 to 4 hrs, as compared with the standard heating device. This technique proved that it might be used expeditiously for heating of the greenhouse within the dark of summer and within the winter days. Just in case of rainy days, this technique is unsuitable for heating of the greenhouse and charging of the PCM.[17]

E. Zambolin et al

New comparative tests on two differing types of solar collectors are conferred. A standard glazed flat plate collector and an evacuated tube collector are put in in parallel and tested at a similar operating conditions; the evacuated collector could be a direct flow through sort with external compound parabolic concentrator (CPC) reflectors. Efficiency in steady-state and quasi-dynamic conditions is measured following the standard EN12975-2 and it is compared with the input/output curves measured for the whole day. The primary purpose of the current work is that the comparison of ends up in steady- state and quasi-dynamic check ways each for flat plate and evacuated tube collectors. Beside this, the target is to characterize and to match the daily energy performance of those 2 types of collectors. An efficient mean for describing and analyzing the daily performance is that the thus known as input/output diagram, within which the collected solar energy is plotted against the daily incident solar radiation. Check runs are performed in many conditions to breed totally different typical uses (hot water, area heating, solar cooling). Results also are conferred in terms of daily efficiency versus daily average reduced temperature distinction. Experimental measurements taken on flat plate and evacuated tube collectors are conferred here. The efficiency curves are obtained following the steady-state and also the quasi-dynamic ways represented by the standard EN 12975-2.[6]

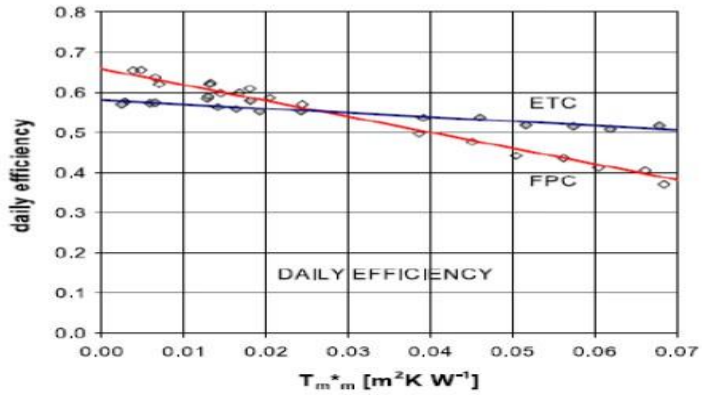

Fig. 2.6Efficiency of tested collectors: efficiency in steady-state conditions[6]

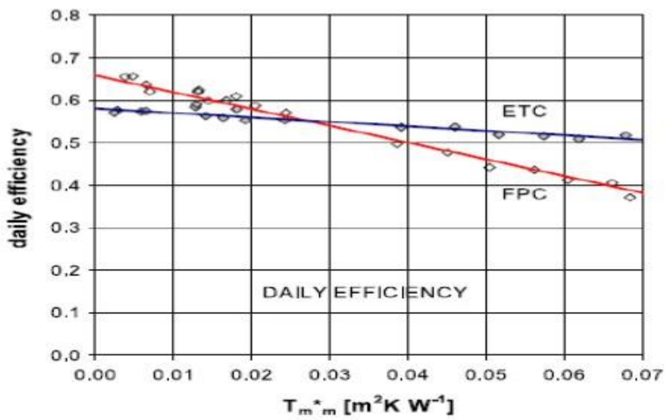

Fig. 2.7Efficiency of tested collectors: daily efficiency

1.1 Problem Statement

Performance and analysis of the Parabolic trough collector using phase change material.

Now a days the collectors used are simple in construction and without using PCM. In this project we are using PCM so that the performance of solar collector in which the latent heat is stored and will be useful whenever it is required.

1.2 Objectives

- Checking performance of solar collector using PCM
- Increasing the energy storage capacity through latent heat storage material.
- Maintaining low depths and utilization of various scrap materials for heat storage.

1.3 Scope

There is scope for further improvement in the systems by using PCM to enhance the heat storage capacity. Use of PCM has a great affect on the system. PCM reduces the thermal losses and enhances the heat storage value.

1.4 Proposed methodology

General survey

⇩

Material selection

⇩

List of components

⇩

Design of solar collector

⇩

Process chart

⇩

Cost Estimation

⇩

Fabrication of Parabolic trough collector

⇩

Testing & analysis

1.5 Organization of dissertation

Work activity	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Problem definition											
Literature review											
Study of existing system											
Design of project											
Fabrication											
Experimentation											
Verification of experimentation &design											
Report writing											
Final Presentation											

Table 1.5.1 Working Methodology per Month

CHAPTER 3

DESIGN AND DEVELOPMENT

3.1 Design of Components

3.1.1 Trough Reflector:

The cylindrical parabolic concentrating solar water heater made of a parabolic concentrating trough and copper absorber tube. Absorber tube is fitted along the focal axis of the concentrating reflector, in order to receive the radiations reflected from parabolic concentrating reflec- tor. Black paint painted around the outer surface of the copper absorber tube to enhance the absorptance and reduce the reflectance. The reflector is covered by the thin SOLARFLEX foil of reflectivity 0.974. The schematic view is shown in Figure 1. The present theoretical study is worked out using the theoretically calculated data of beam radiation, inclination, zenith angle and hour angle, on 21st April of 2016, at IIT (ISM) Dhanbad, Jhankhand (longitude 86.444 E, latitude 23.875o), India. On 21st April of 2016, the average wind velocity 0.5 m/s and ambient temperature varied from 27oC to 32oC as recorded. The theoretical study is worked out using the specifications of the experimental setup, which is under construction. The length and width of the parabolic concentrating reflector are 1.22 m and 1.69 m respectively. The length of Copper absorber tube is 1.22 m. Also the values of thermal prop- erties are absorptivity 0.9, emissivity 0.9, and thermal

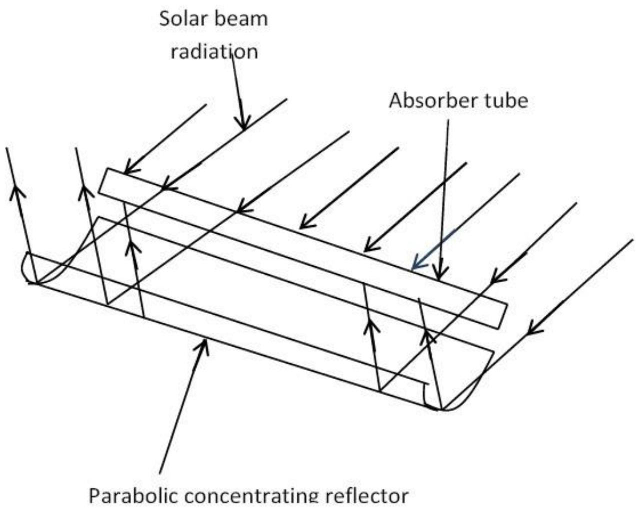

Figure 1. Schematic view of a parabolic concentrating reflector.

conductivity (k) 386 W/m-K etc. The specifications of the cylindrical parabolic concentrating solar water heater are detailed in Table 1. The theoretical study worked out using water as working fluid. The thermo-physical prop- erties of water at 20^o C.

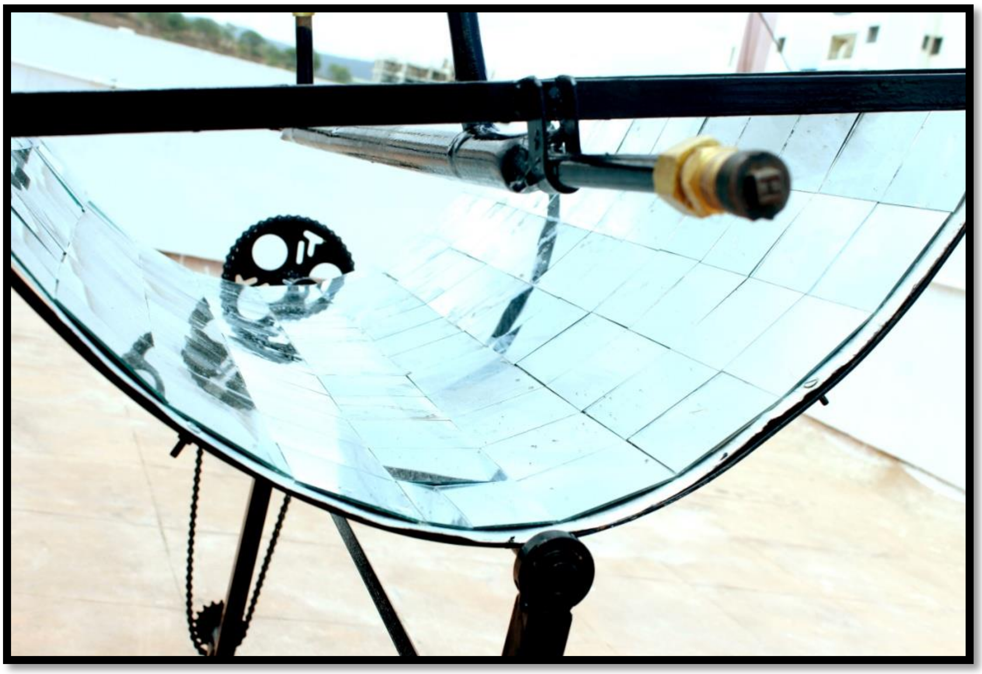

Fig.3.1.1 Trough Reflector

3.1.2 Heat Collecting Element:

The Heat Collecting Element is a concentric tube in which outer tube is Copper tube of diameter 1.4inch(29mm) and inner tube is copper tube of diameter 0.5 inch(15mm).Outer tube has given inlet port and outlet port on its surface which are used for feeding and discharging of PCM(paraffin wax).Inner tube having two openings for water flow.

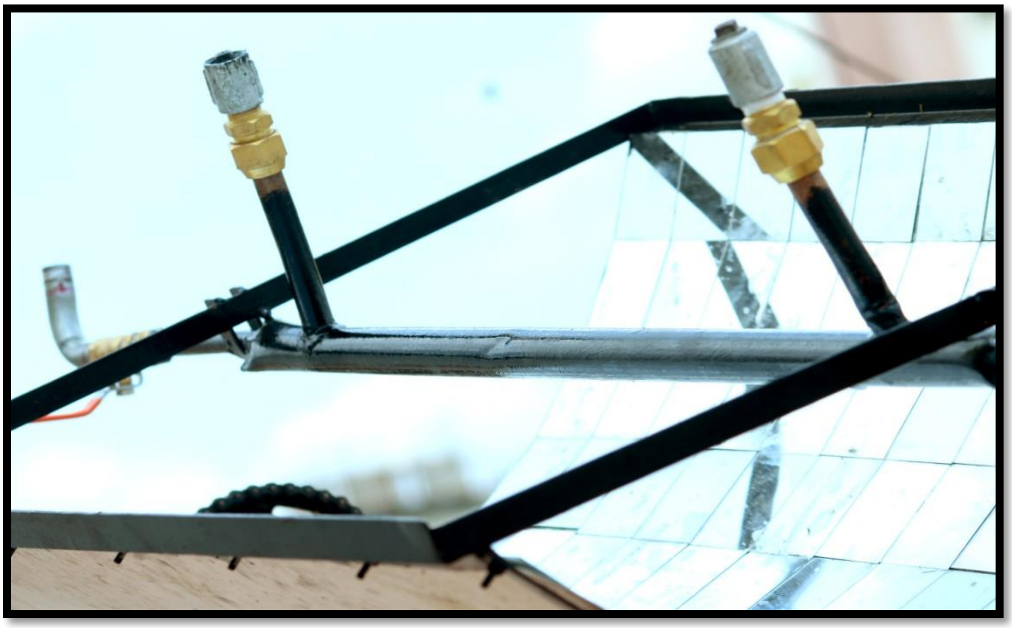

Fig. 3.1.2Heat Collecting Element

Selection of material for heat collecting element:

Material	Thermal Conductivity(W/mk)
Silver	406
Copper	385
Gold	314

Table 3.1.1Thermal conductivities of metals

Silver is selected as a material for heat collecting element because silver is having high thermal conductivity than copper and gold.

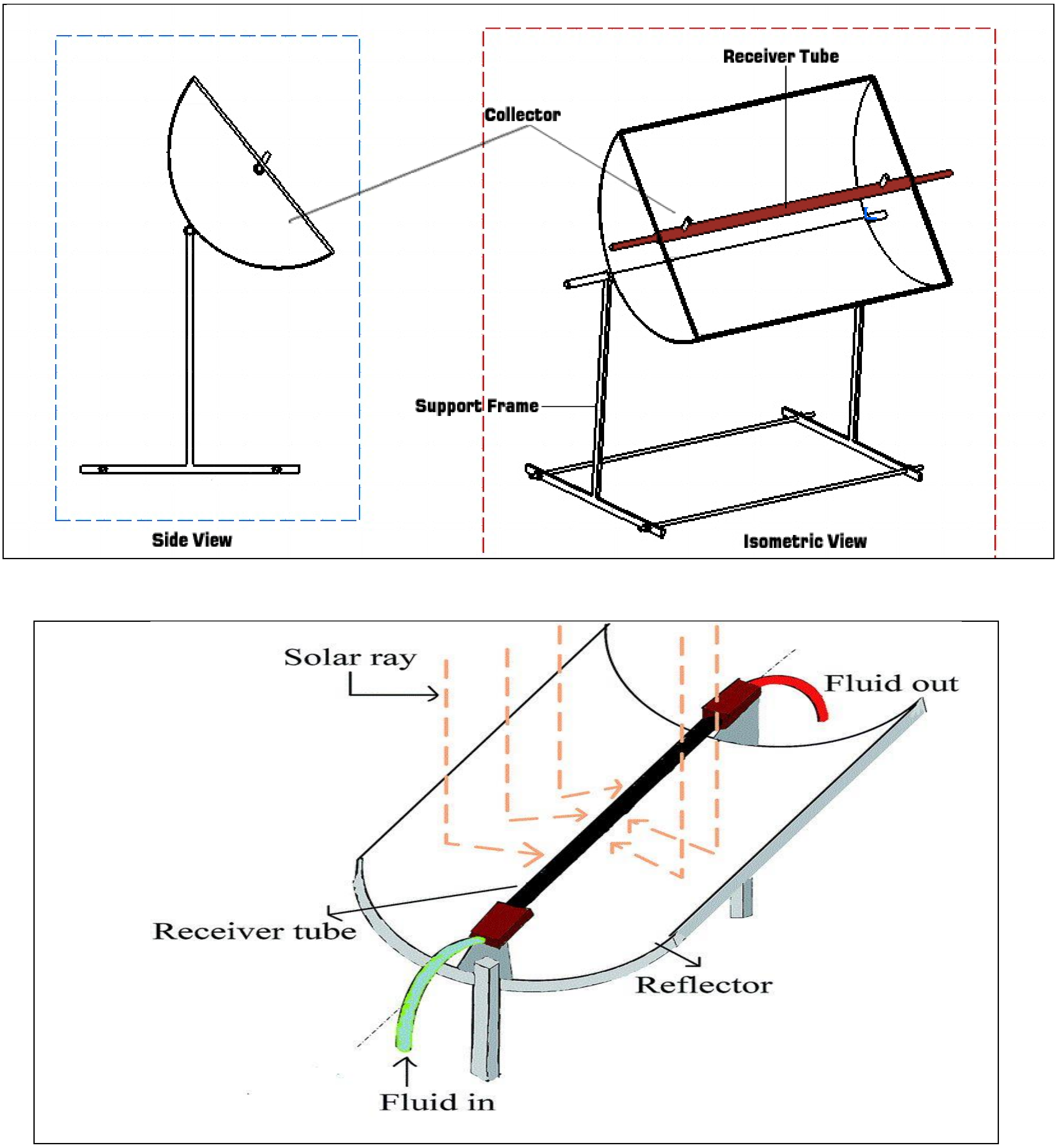

Fig 3.1.3 Schematic Diagram

3.1.3 calculations:

The declination has determined by Cooper13 simple relation as follow:

$$\delta = 23.45\sin[(360/365)(284+N)] \quad (1)$$

The expression of solar beam radiation over a clear day has formulated by ASHRAE14 as follow:

$$I_b = I_{bn}\cos\theta_z \quad (2)$$

REFLECTOR	APERTURE	AREA		(A_p)
2.07278 m2				(L)
Reflector		length		
1.22 m				
Reflector		width		(W)
1.699 m				
Focal		distance		(f)
0.606 m				
Concentration		Ratio		(C)
3.630				
Absorber	Tube			Material
Copper				
Absorber	Tube	inner	dia.	(Di)
0.037 m				
Absorber	Tube	outer	dia.	(Do)
0.042 m				

Table 2. Thermo-physical properties of water at 20o C

Property Value	
Density	998.2 kg/m3
Kinetic viscosity	1.006 x 10-6 m2 /s
Thermal conductivity	0.599 W/m-o C
Prandlt number	7.02
Specific heat, Cp	4.183 kJ/kg-o C

Whereas, solar beam radiation in the direction of the sun rays has postulated from ASHRAE model such as

$$I_{bn} = A\exp(-B/\cos\theta_z) \quad (3)$$

$\cos\theta_z=\sin\phi\sin\delta+\cos\phi\cos\delta\cos\omega$(4)

Where, A and B are constants whose values have been given by Threlkeld and Jordan. Tilt factor for beam radiation can be derived as follow:

$\tau_b = (1- \cos^2\delta \sin^2\omega)^{1/2} / (\sin\emptyset\sin\delta+\cos\emptyset\cos\delta\cos\omega)$ (5)

The expression of heat flux absorbed by the absorber tube can be derived as follow:

$$S=I_b r_b \rho\alpha\gamma \quad (6)$$

The rate of theoretical useful heat gain is the solar beam radiation absorbed by working fluid with time is given by16 and determined using equation (7) as follow:

$Q_{u,th}=L(W-D_o)F_R(S-U_1(T_{fi}-T_a)/C)$(7)

Where,F,F'andUaregivenby[16].Thesearecalculated usingequations(8),(9)and(10)asfollow:

$$F_R=\left(mC_p/\pi D_o LU_1\right)\left[1\text{-}\exp\left\{-\left(F'\pi LD_o U_1\right)/mC_p\right\}\right]$$

$$F'=(1/U_1)/\left[(1/U_1)+(D_o/D_i h_f)+\left\{D_o\ln(D_o/D_i)/2k_p\right\}\right]$$

$$U_1=h_w+h_{p\text{-}a}$$

Where,$h_w=Nu_a k_a/D_o$

$$Nu_a=0.3Re_a^{0.6} \quad \text{for} \quad 1{,}000<Re_a<50{,}000$$

$Re_a=\rho_a V_w D_o/\mu$

The radiation heat transfer coefficient on outside ofcopper absorber tube ($h_{p\text{-}a}$) is given by. It is evaluatedusingequation(11)asfollow:

$h_{p\text{-}a}=\varepsilon\sigma\left(T_p+T_a\right)\left(T_p^2+T_a^2\right)$(11)

While, heat transfer coefficient (h_f) based on insidediameter of the absorber tube is given byand evaluatedusingEquation(12)asfollow:

$h_f=(k_w/D_o)\left[3.6+\left\{0.0668(D_i/L)RePr\right\}/\left\{1+0.04((D_i/L)RePr)^{2/3}\right\}\right]$(12)

Reynolds number for average water velocity is deter-minedusingequation(13)asfollow:

$$Re=\rho_f V_m D_i/\mu_f \quad (13)$$

Where,$V_f=m/\rho_f A_0$

Thewateroutlettemperatureisdeterminedusingthe Equation(14)asfollow:

$$T_{fo}=T_{fi}+\left(Q_{u,th}/mC_p\right) \quad (14)$$

Theaveragetemperatureoftheabsorbertube(T_p)isgivenby[12]andevaluatedusingEquation(15)asfollow:

$T_p=T_{fm}+\left(mC_p\left(T_{fo}-T_{fi}\right)/h_f\pi D_o L\right)$(15)

Where, water bulk mean temperature is the half ofsumofwater temperatures at inlet and outlet and determinedusingEquation(16)asfollow:

$$T_{fm} = (T_{fi} + T_{fo})/2 \quad (16)$$

The instantaneouscollectorefficiency forsolarbeamradiationisevaluatedusingtheEquation(17)asfollow:

$$\eta_{th} = Q_{u,th} / I_b\, r_b\, WL \quad (17)$$

Theenergyquantityisdeterminedtocountthehourlycollection of the useful heat gain by water. The hourlyenergy collected is the solar radiation absorbed by waterduringonehourintervalasgivenbyanddetermined using equation (16) as follows:

$$E_c = \frac{\left[mC_p (T_{fo} - T_{fi})_{j+1} + mC_p (T_{fo} - T_{fi})_j \right]}{2} \times 3600 \quad (18)$$

Therateofheatlossisthedifferencebetweenthetotalsolarenergyincidentontheaperture oftheconcentratingreflectorandrateofsolarenergyabsorbedbywateranditiscalculatedusingtheEquation(19)asfollow:

$$Q_l = (W - D_o) LS - Q_{u,th} \quad (19)$$

3.1.4Pipe Fittings and Measuring Devices:

The connection between heat collecting element and tank is done by 0.5 inchGI pipes and fitting accessories. Brass control valves are placed where it necessary. Temperature is measured by thermocouples and temperature indicator.

i. Thermocouple

Thermocouple wires used for temperature measurement is of J-type.The two dissimilar metal wires used in this thermocouple are of iron and constantan.

ii. Temperature indicator

The temperature indicator consists of 8 channels. Each channel receives input from different thermocouples which are incorporated in the energy storage unit.

3.1.5Working Medium:

There are two working medium namely water and phase change material for thermal storage. (paraffin wax) is selected as PCM.

3.2 Manufacturing Process estimation

Part	Process/Machining	Time(Min)	Cost(Rs./min)	Total Cost(Rs.)
Outer Copper Tube(inlet & outlet ports)	Flaring	30	10	250/-
Copper To Copper joint	Brazing	30	5	230/-
Trough Collector to iron frame	Arc Welding	45	3	225/-

Table no.3.2.1 Manufacturing process cost

3.3 Cost Estimation

Material	Bought/Made	Quantity	Cost (in Rs.)
Aluminium Sheet	bought	(24gauge thickness)	800
Reflecting Mirrors	bought	(10 dozen)	950
Copper tube	made	1	4000
Bearing	bought	2	210
Flow Control valves	made	2	280
Thermocouples	bought	2	300
PCM()	bought	2 kg	450
Temperature indicator	bought	1	1450
Chain-Sprocket	bought	1	350
Support (Iron Frame)	made	-	500
Other Accessories	-	-	980
			Total= 10,270

Table no.3.3.1 Cost Estimation

3.4 System Operation

The parabolic-trough-shaped concentratorreflects direct solar radiation onto a receiver tubelocated in thefocal line of the parabola (linear-focusconcentration). Since the collector aperture area is bigger than the outer surface of the receiver tube, thedirect solarradiation is concentrated. Theconcentrated radiation reaching the receivertube heats the PCM stored in it's outer tube, thus transforming the solar radiation intothermal energyin the form of sensible heat of the PCM.During day time this heat is given to the water present in inner tube.

In the absence of sun's radiation this heat is stored in the form of latent heat of PCM .Thus, stored latent heat is given to the heat transfer fluid(Water).

The experiments are conducted in the bright day time in the months of March, April and May 2017. The data are recorded at an interval of 30 minutes from morning 10.00 AM to evening 08.00P.M. Experiment is conducted for four days each and values are averaged for a single day.

The experimental setup proposed mainly consists of two major sub systems. It is a combination of a parabolic trough solar collector, Copper Tubes as shown in figure;

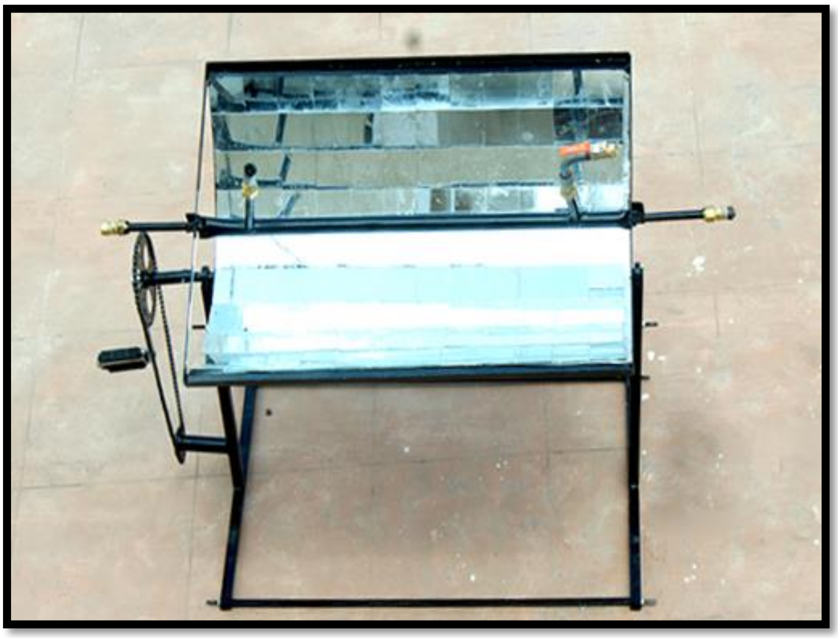

Fig3.4.1 Experimental Setup

CHAPTER 4

RESULT AND DISCCUSION

Aim of the experiment is to check the performance of the Parabolic troughCollector.Main tool of performance is Efficiency.

Two parameters are analyzed. First, the Thermal Response of the PCM and waterto the solarradiation is studied by recording the temperature change for every half hour. Secondly,the troughefficiency is calculated by,

$$\eta = \frac{mC_P(T_{Hf} - T_{Hi})}{I_o A_S}$$

Where,

m=mass of the fluid, i.e., Water(Kg) =Density×Volume

Here, Density of water can be taken as 1000 Kg/m3 and

Volume $= \frac{\pi}{4} \times Di^2 \times L$

$= \frac{\pi}{4} \times 0.015^2 \times 0.9$

$$= 1.59 \times 10^{-4} m^3$$

Cp =Specific heat capacityof Water=4.184 KJ/kg,

(Thf-Thi)=Change in Temperature of water(℃)

Io=Intensity of Solar Radiation(MJ/m2)

As=effective cross-section area of heat transfer(m^2) = 0.744m^2

CHAPTER 5

CONCLUDING REMARK AND FUTURE SCOPE

5.1 Concluding Remark

It is seen that efficiency of collector is maximum at 2:00 pm which is 14.30%.

Use of phase change material is an important aspect of energy management, by utilization of excess availableenergy.

Use of phase change material is an effective way of storing thermal energy and has advantages of high storage density and isothermal nature of energystorage.

5.2 Scope for future Work

- By using PCM in solar collector, the amount of thermal energy will be stored.
- Use of PCM enhances the thermal energy storage capacity of the system and increases its efficiency.
- In this project, only single copper tube is used with increase in number of tubes at focal points of collector the efficiency and performance can be improved.
- Use of phase change material is an important aspect of energy management, by utilization of excess availableenergy.