(Research Article)

Investigation of Different HTF in Indirect Solar Water Heater

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Abstract

Energy usage and energy conservation are greatly inter related and corresponds to a main concern in the world. Renewable energy sources are an inevitable in the sustainable development technologies in which the needs of this generation and for next generation for need of energy. Nowadays increasing energy demand and environmental issues have inspired many researchers for searching an alternative option to fulfill the energy demand. In such a case, solar energy appears as the most attractive option due to its abundance and clean feature. Today solar thermal technologies are the popular advanced techniques. The performance of solar thermal technology is dependent on certain factors. Among these factors, heat transfer fluids like water, air, antifreezes like ethylene glycol, propylene glycol, hydrocarbon oils etc. have a very crucial role in heat transfer through the effective utilization of solar thermal energy in solar water heater. The phase changing material (PCM) are latest development in the solar water heater. The system efficiency depends on temperature of the different heat transfer fluids used. Hence their performance analysis, also holds greater importance in this area. In this thesis work, a performance analysis on the solar collector of solar water heater system with different heat transfer fluids is being illustrated. The experiment is conducted using varying concentrations of heat transfer fluid mixture.

The time period of experiment was 22 April to 26 April, 2019. Starting from 08:00 am to 06:00 pm with observation was taken every one and half hour from data logger attached to J type thermocouples connected to different collectors and different water tanks.

Keywords: solar water heater, heat transfer fluid, refrigerant, nanofluid.

1. Introduction

The use of solar energy for water heating process is widely used for domestic purpose as well as industrial purpose. There are many factors that affect the performance of solar water heater. In those factors one of the important factors is heat transfer fluid (HTF) of the indirect solar water heating system.

1.1 Types of heat transfer fluid: Heat transfer fluid or solar thermal fluid are categorized as follow;

1. Water based
2. Oil based
3. Air
4. Molten salts
5. Silicones
6. Refrigerant

All these HTF have their advantages and disadvantages for application of solar water heating.

1.2 Key Properties of HTF: Here explained properties of HTF are very important for selecting the HTF for the water heating system. Different HTF have different properties for heating processes, in which some are very crucial for the requirement of the heating process.

1. Specific heat
2. Boiling point
3. Freezing point
4. Density
5. Viscosity

After studying all required properties best HTF should be selected. For use in water heating system the desired properties are; High specific heat, low viscosity, high boiling point, low freezing point etc.

1.3 Purpose of thesis: In this thesis work I have investigated three HTF in indirect solar water heater with flat plate collector. The design of model is referenced from the research paper proposed by M. Esen and H. Esen.^[3] There are some modification done for the use of different HTF then them.

The observation of temperature hourly during the day done and then calculate the efficiency of overall system with

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Figure 1. Design Proposed by M. Esen and H. Esen^[3]

known amount of water heated and initial temperature of water with required properties of HTF.

2. Experimental setup and Methodology

A setup is fabricated for the experiment with some changes in design of the referred research paper because in that paper they investigated only refrigerant. Here I am using three different HTF as Water-EG mixture, Al_2O_3 Nanofluid and Refrigerant R410A. The solar collector used in setup is class 2 flat plate collector with one glass cover.

The experiment of three different HTF was carried out in the same collector but separate and under the same condition side by side. For data collection three system names used as in System 1 for Water-EG system, System 2 for Al_2O_3 Nanofluid system and System 3 for refrigerant R410A system.

2.1 Experimental Setup: The dimensions of the components of the setup are as follow.

1. Aluminum Collector case
Length: 1150 mm
Width: 800 mm
Height: 150 mm
2. Rockwool Insulation
Thickness: 50 mm
3. Copper absorber plate (*3)
Length: 1000 mm
Width: 200 mm
Thickness: 0.8 mm
4. Copper Heat pipe (*6)
OD: 9.525 mm (3/8 inch)
Length: 1050 mm
U-shaped for each system consist of two pipes for each system.
5. Copper Pipe Coil (*3)
OD: 9.525 mm (3/8 inch)

- Length: 900 mm
Four rounds in each coil.
6. Glass Cover
Thickness: 4 mm
Air Gap: 30 mm

The fabricated setup photos are presented here in figure 2 below. There are two thermocouples attached with each absorber plate and one thermocouple is attached in each water tank. Thus total nine thermocouples are attached in system.

2.2 Information of HTF: The three different HTF used are Water-Ethylene Glycol mixture, Al_2O_3 blend in Ethylene Glycol with water based nanofluid and R410A refrigerant.

- Water and Ethylene glycol is mixed 50-50 by % volume and total of 125 ml is filled in first system of collector.
- Al_2O_3 nanoparticles of size ~50nm is blended in 25 ml Ethylene glycol and then mixed well with stirrer in 100 ml water to prepare total 125 ml of nanofluid and filled in second system of collector.
- The standard refrigerant R410A of 100 gm is filled in third system of collector checked for the leakage.

The Experiment is carried out at Surat (Latitude-21.1702 N, 72.8311 E) during 22nd April to 26th April from 08:00 am to 06:00 pm.

Figure 2. Actual Setup

2.3 Experiment Method: The experiment was carried out as given above for 5 days from 22nd April to 26th April. To measure the temperature J type thermocouples are used. The global radiation for the location is taken average 400 W/m². The temperature is read on the digital reader with relay system to note all different temperature at same time by pressing switch of each thermocouple.

Steps of experiment:

1. Uncover the system and fill all tanks with 15 liter of water, take the measurement of temperature of all three collectors and three water tanks and also ambient temperature.
2. After that in every one and half hour take the measurements of collectors and waters in tank.
3. This process is done at 09:30 am, 11:00 am, 12:30 pm, 03:00 pm, 04:30 pm and 06:00 pm.
4. Measurement of all nine temperatures is done for each system at a time.
5. For calculation of efficiency the area of each collector and average global radiation at location is used with measured temperatures.
6. This procedure is carried out for 5 days in a row and information collected from experiment is discussed in result.

3.Result and Discussion

The temperature measurement for system 1 with Water-EG, system 2 with nanofluid and system 3 with refrigerant is used as HTF. The different measurement at different time for collector of system 1,2 and 3 is as follows.

Table 1.System 1 collector temperatures

Date	22/04		23/04		24/04		25/04		26/04	
Sensor	1	2	1	2	1	2	1	2	1	2
Time	Temperature °C									
08:00	30	29	31	30	31	31	33	32	30	29
09:30	60	59	63	61	62	62	64	62	61	60
11:00	76	75	77	76	75	75	78	76	76	73
12:30	89	88	91	90	90	90	88	87	90	88
03:00	88	87	88	88	87	86	86	85	88	86
04:30	65	63	66	65	65	62	64	63	66	65
06:00	43	42	45	44	44	44	46	45	45	42

Table 2.System 1 collector maximum temperature

Date	22/04	23/04	24/04	25/04	26/04
Temp.	89	91	90	88	90

The daily maximum temperature is plotted with daily temperature in graph below. This detail is used for calculation of collector heat gain and overall efficiency of the system.

Figure 3.Daily temperature of collector 1

Table 3.System 2 collector temperatures

Date	22/04		23/04		24/04		25/04		26/04	
Sensor	1	2	1	2	1	2	1	2	1	2
Time	Temperature °C									
08:00	28	28	30	29	29	29	28	27	29	28
09:30	61	60	63	62	61	60	60	60	63	62
11:00	75	74	78	77	77	76	76	76	75	74
12:30	87	87	90	90	88	88	89	88	88	88
03:00	81	80	82	82	80	79	81	80	82	81
04:30	63	62	65	64	64	64	63	62	63	62
06:00	44	42	45	44	44	43	43	42	44	44

Table 4.System 2 collector maximum temperature

Date	22/04	23/04	24/04	25/04	26/04
Temp.	87	90	88	89	88

Figure 4.Daily temperature of collector 2

Table 5.System 3 collector temperatures

Date	22/04		23/04		24/04		25/04		26/04	
Sensor	1	2	1	2	1	2	1	2	1	2
Time	Temperature °C									
08:00	30	29	30	29	29	28	28	28	29	29
09:30	60	59	62	61	60	59	60	59	61	60
11:00	77	75	79	78	78	76	77	76	78	77
12:30	82	81	84	83	84	84	83	82	85	84
03:00	71	71	72	71	71	70	73	72	73	73
04:30	62	62	61	61	62	61	63	62	64	62
06:00	42	41	43	43	42	42	44	43	44	43

Table 6.System 3 maximum temperature

Date	22/04	23/04	24/04	25/04	26/04
Temp.	82	84	84	83	85

Figure 5. Daily temperature of collector 3

The temperature of water tanks are measured for each system and noted in table below.

Table 7. Water tank temperature system 1

Date	22/04	23/04	24/04	25/04	26/04
Time	Temperature °C				
08:00	25	26	25	27	26
09:30	39	40	40	41	39
11:00	48	50	49	52	49
12:30	51	53	52	54	51
03:00	58	60	59	59	57
04:30	55	57	57	56	55
06:00	49	48	48	49	47

Table 8. Water tank temperature system 2

Date	22/04	23/04	24/04	25/04	26/04
Time	Temperature °C				
08:00	25	26	25	27	26
09:30	38	40	38	39	41
11:00	46	48	47	49	50
12:30	53	51	50	52	53
03:00	56	55	54	55	56
04:30	52	53	51	51	52
06:00	45	44	42	43	45

Table 9. Water tank temperature system 3

Date	22/04	23/04	24/04	25/04	26/04
Time	Temperature °C				
08:00	25	26	25	27	26
09:30	37	39	38	40	41
11:00	48	49	47	51	52
12:30	52	55	51	54	55
03:00	60	61	59	59	61
04:30	58	59	55	55	57
06:00	50	52	51	53	52

Table 10. Daily maximum water temperature

Date	22/04	23/04	24/04	25/04	26/04
System	Temperature °C				
Tank 1	58	60	59	59	57
Tank 2	56	55	54	55	56
Tank 3	60	61	59	59	61

Figure 6. Daily maximum water temperature

To calculate overall system efficiency consider the equation used for the closed cycle solar water heater with fixed amount of water to be heated.

$$\eta = \frac{mw C_{p,w}(Tw2 - Tw1)}{A I_g}$$

Where, mw is mass of water in tank, Cp,w is specific heat related to water, (Tw2-Tw1) is temperature rise, A is collector area and Ig is average global radiation.

Mass of water of 15 liter water mw= 15 kg and specific heat of water Cp,w= 4.2 kJ/kg °C, Area of each collector A= 0.2 m² and Average Global radiation Ig = 299 W/m².

From **Table 10** average maximum temperature of water in tank 1 is Tw2=58.6 °C and from **Table 7** average of initial temperature of water in tank 1 is Tw1=25.8 °C.

Overall efficiency of system 1 with Water-EG as HTF is,

$$\eta_1 = 34.55 \%$$

From **Table 10** average maximum temperature of water in tank 2 is Tw2=55.2 °C and from **Table 8** average of initial temperature of water in tank 2 is Tw1=25.8 °C.

Overall efficiency of system 2 with nanofluid as HTF is,

$$\eta_2 = 30.97 \%$$

From **Table 10** average maximum temperature of water in tank 3 is Tw2=60 °C and from **Table 9** average of initial temperature of water in tank 3 is Tw1=25.8 °C.

$$\eta_3 = 36.03 \%$$

4. Conclusions

- Experiments have been carried out on a solar water heater containing three different collector system under one condition to investigate the performance of different heat transfer fluid for water heating and this all three systems of different heat transfer fluid were cascaded in on collector box.
- The system containing refrigerant R410A as HTF gave the highest hot water temperature, 61 °C. For other two systems containing water-EG mixture gave maximum hot temperature of 60 °C and Nanofluid system gave the minimum hot water temperature of 56 °C.
- As in concern of collector temperature, the highest collector temperature was 91 °C for water-EG system.

- For daily observation of temperature from the morning to evening, we can say that the maximum output of system was at the time period of 12 pm to 3 pm. After that the temperature is starting to getting down from the maximum of it.
- The overall efficiency of three systems are from high to low as system 3 has 36.03 % , system 1 has 34.55 % and system 2 has 30.97 %.
- So we can see that the system with refrigerant has the highest efficiency of all and can be further more improved by using full working model of refrigerant closed cycle solar water heater with more heat pipes as per water requirement.

Nomenclature

HTF – Heat Transfer Fluid
EG – Ethylene Glycol
Mw – Mass of Water
Cp,w – Specific heat of Water
Tw1 – Initial Water Temperature
Tw2 – Hot Water Temperature at Time
A – Area of Collector
Ig – Average Global Radiation
η – Overall Efficiency

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