DOUBLE EXPOSURE EVACUATED FLAT PLATE SOLAR COLLECTOR WITH TRACKING SYSTEM

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ABSTRACT

The objective is to design & develop the high efficient solar energy collector. Passive system is used in which the water flows naturally in tubes due to density difference. Aluminum material is used for solar flat plate collector. Double exposure system is implemented so that the flat plate solar collector is exposed to the sun from both the side with the help of mirrors. This double exposing system helps to increase the heating rate of water in tubes. Due to that, the flow rate of water in tubes also increases. The tracking system is used to track the sun's movement and reflect the solar radiation on another side of the solar plate with the help of mirror. Evacuated flat plate solar collector is implemented because of its high efficiency. The overall efficiency of the solar water heater increases due to double exposure system so the time required to heat water is decreases to some extent. The maximum temperature of water in the storage tank found to be 72^{o}C at 30^o tilt angle with vacuum and tracking system.

Keyword: - *Solar Energy1, Solar collector2, Double exposure system3, Evacuated system4 and Tracking system5 etc.*

1. INTRODUCTION

It is well known that the burning of coal has enormous effects on the environment that is environmental degradation that impact is visible in the form of pollution, acid rain, global warming etc. Tons of coal is burned in the world daily only to heat water for domestic purpose. Instead of coal, the whole world is blessed with Solar Energy in abundance at no cost. Using the sun's energy to heat water is not a new idea. In addition to the energy cost savings on water heating, there are several other benefits derived from using the sun's energy to heat water.

One of the popular devices that harness the solar energy is solar water heater system (SWHS), while solar water heater device has been around for even 100 years. The solar water heater system is further classified as passive and active system. Passive system do not require external pumping agency and the flow takes place due to thermo-syphon action and active system require pumping agency to circulate fluid through flat plate solar collector. SWH systems are generally very simple using only sunlight to heat water. A working fluid is brought into contact with a dark surface exposed to sunlight which causes the temperature of the fluid to rise. This fluid may be the water being heated directly, also called a direct system, or it may be a heat transfer fluid such as a glycol/water mixture that is passed through some form of heat exchanger called an indirect system. Now a day's Evacuated Tube Collector (ETC) has been used instead of Flat Plate Collector (FPC). Due to evacuated system the convection loss is minimized, so the ETC is more efficient than FPC. The position of the sun needs to be tracked for the maximum utilization of the incoming solar radiation. The intensity of solar radiation varies during the day as well as with seasons.

Mr. Kishan Patel et al. reviewed that, now a days, plenty of hot water is used for domestic, commercial and industrial purposes. Solar energy is the main alternative to replace the conventional energy sources. The solar thermal water heating system is the technology to harness the plenty amount of free available solar thermal energy. The solar thermal system is designed to meet the energy demands. The size of the systems depends on availability of solar radiation, temperature requirement of customer, geographical condition and arrangement of the solar system, etc. Therefore, it is necessary to design the solar water heating system as per above parameters. [1]

M. A. Sabiha et al. says that, the solar energy is the most available, environmental friendly energy source and renewable to sustain the growing energy demand. Solar energy is captured by solar collectors and an evacuated solar collector is the most efficient and convenient collector among various kinds of solar collectors. An evacuated tube collector is also very efficient to be used at higher operating temperature. [3]

Johane Bracamonte et al. address the issue by analyzing the impact of the slope on thermal behavior of the device at low tilt angles, of particular interest for sub-tropical regions. It was found that the tilt angle has significant effect on daily solar energy gain, flow patterns inside the storage tank and stratification. Nevertheless, it was found little impact on the thermal efficiency due to the low magnitude of the heat losses through the vacuum tubes. A non-dimensional number to quantify the stratification effect is proposed and it was found an exponential dependence on the tilt angle. [4]

Hossein Mousazadeh et al. reviewed that, the sun trackers are such devices for efficiency improvement. The diurnal and seasonal movement of earth affects the radiation intensity on the solar systems. Sun trackers move the solar systems to compensate for these motions, keeping the best orientation relative to the sun. Although using sun-tracker is not essential, its use can boost the collected energy 10-100% in different periods of time and geographical condition. It is found that the power consumption by tracking device is 2-3% of the increased energy. [5]

2. DESIGN AND FABRICATION

Creo Parametric V2.0 software is used for designing and modeling of different component which has been used in tracking and concentrating system.

2.1 Flat Plate Solar Collector with Glass Assembly

Flat plate collector has been designed and fabricated of aluminum sheet of 400mm×800mm×2mm and tubes of inner diameter 6 mm and length 900mm. Five longitudinal U-shaped grooved are made by pressing operation on the aluminium sheet. The tubes are then fitted in those U-shaped grooves. And this whole assembly of aluminium plate and tube is then enclosed in the glass box. The glass box is then evacuated to minimize the thermal loss. Thermocouples are mounted on each input and output of the tubes to measure the temperature of the water flowing in the tubes. A vacuum gauge is mounted on a pipe which is attached to the glass box, to measure the vacuum inside the glass box.

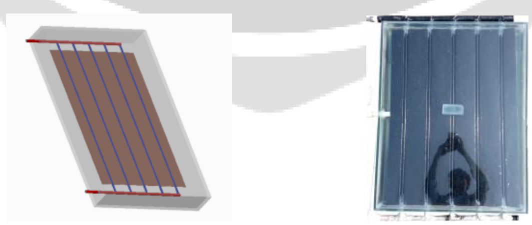


Fig -1: Designed & Fabricated Flat Plate Solar Collector with Glass Assembly

2.2 Storage Tank:

Two tanks are used here, the smaller tank is enclosed in the bigger tank having some gap in between them. Vacuum is created in between them to minimize the convectional heat loss. Input and output water pipeline assembly is mounted on one side of the tank. A vacuum gauge is mounted on pipe which is attached to the outer tank, to measure the vacuum between the two tanks. The main tank is of 275mm diameter and the other tank is of 375 mm diameter. The capacity of the main tank is 25 liters.

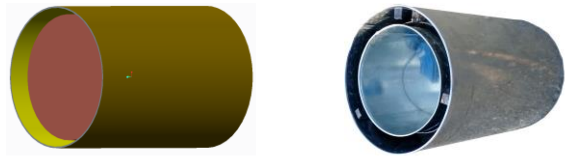


Fig -2: Designed & Fabricated Storage Tank

2.3 Frame:

The frame is designed in such a way that the tilt angle of the mounted plate assembly can be change from 0^o to 45^o. This is provided to find at what degree of tilt angle the solar water heater is more efficient. Frame is fabricated of L-type MS angles. Frame is so fabricated that the tilt angle of the solar plate can be change in three different angles that are 20^o, 30^o & 45^o.

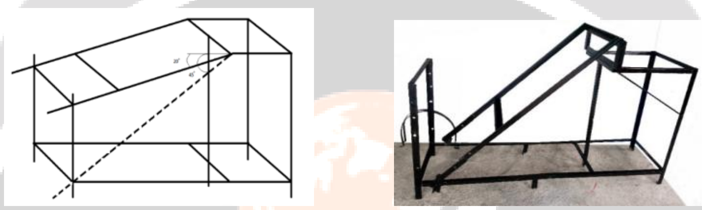


Fig -3: Designed & Fabricated Frame

2.4 Tracking System:

The tracking system has been designed in such a way that the solar collector can be exposes to sun from both the sides. On tracking system mirrors are mounted so that the solar radiation can be reflected towards the flat plate from back side.

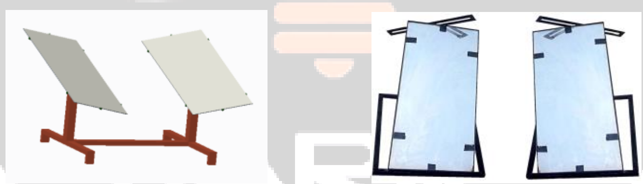


Fig -4: Designed & Fabricated Tracking System with Mirrors

3. EXPERIMENTAL SETUP

Double exposure evacuated solar flat plate collector system mainly consist of 5 important parts and they are solar collector, evacuated glass box, adjustable frame, evacuated tank and the tracking system with mirrors. Here solar collector is made up of the aluminium plate of cross section 400mm×800mm. By pressing operation 5 U-shaped grooves are made longitudinally and aluminium tubes are fitted in each tube. Thermocouples are attached to measure the temperature of water in each tube at inlet and outlet. The whole assembly is placed inside a glass box. The glass box has a hole on one side through which air is removed to evacuate it. A vacuum gauge and a ball valve are mounted on the pipe which is fitted in the hole of glass box. The vacuum gauge and ball valve is used to measure and hold vacuum inside the glass box. The vacuum is maintained at 3 mm of Hg. The purpose of evacuation of glass box is to minimize the convectional thermal loss created over the solar collector. This assembly of solar collector and the glass box is mounted on the adjustable frame. The adjustable frame is so made that the tilt angle of solar collector can be changes from 20^o to 45^o. The adjustment is given to analyze the better flow rate on different tilt angles that are 20^o, 30^o & 45^o. The cold water input and hot water output of the solar collector is connected to a single storage tank. The storage tank is made up of two tanks. The main tank is of diameter 275mm and the other tank is of diameter 375mm. The main tank is enclosed in the other tank. 12 mm of gap is maintained in between the two tanks from all the directions. The gap is provided to evacuate the storage tank due to which the convective thermal losses get minimized. Here the main component of the overall setup is the tracking system because of which the heating rate of water and flow rate of water increases. The tracking system is placed below the solar collector plate in such a way that the reflected solar radiations from the mirrors placed over the tracking system will incident on the solar collector plate. The tracking system is manually adjustable.

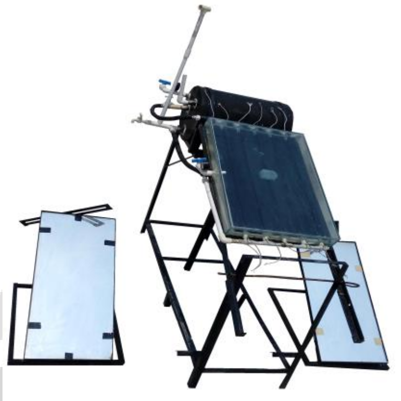


Fig -5: Experimental Setup

4. PERFORMANCE

For better evaluation, readings are performed on 20°, 30° & 45° tilt angles. Seven readings are taken for a day at the interval time of 1 hour, from 10:00 am to 5:00 pm. Without vacuum and without tracking system readings are taken on 25, 27 and 28 February, 2016 for 20°, 30° & 45° tilt angles respectively. With vacuum and without tracking system readings are taken on 19, 20 and 21 March, 2016 for 20°, 30° & 45° tilt angles respectively. With vacuum and with tracking system readings are taken on 31 March, 1 and 2 April, 2016 for 20°, 30° & 45° tilt angles respectively. The water temperature of storage tank and atmospheric temperature are taken at the interval of 1 hour. The temperature is measured by the thermocouples mounted on the solar collector tubes and tank, through digital thermometer. The performance readings are shown below through Table and Graph of Time and Temperature for each tilt angle with respect to date and time.

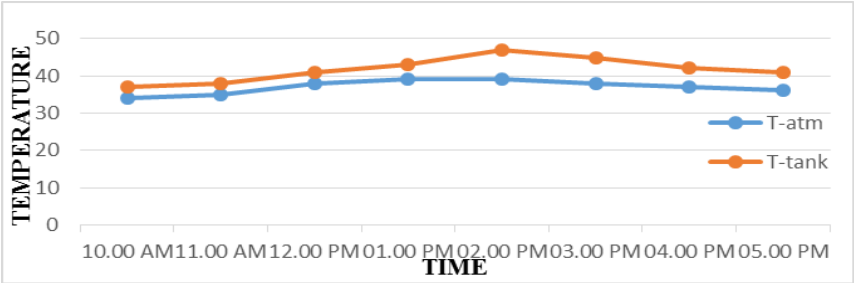
Abbreviations: **T-atm**. – Thermocouple reading of Atmospheric temperature.
T-tank – Thermocouple reading of Tank.

4.1 Without Vacuum and Tracking System:

4.1.1 Readings taken on 25 Feb. 2016 from 10:00 am to 5:00pm for 20° tilt angle.

Table -4.1.1: Water Temperature in Tank

		TIME							
		10.00 AM	11.00 AM	12.00 PM	01.00 PM	02.00 PM	03.00 PM	04.00 PM	05.00 PM
THERMOCOUPLE	T-atm	34	35	38	39	39	38	37	36
	T-tank	37	38	41	43	47	45	42	41

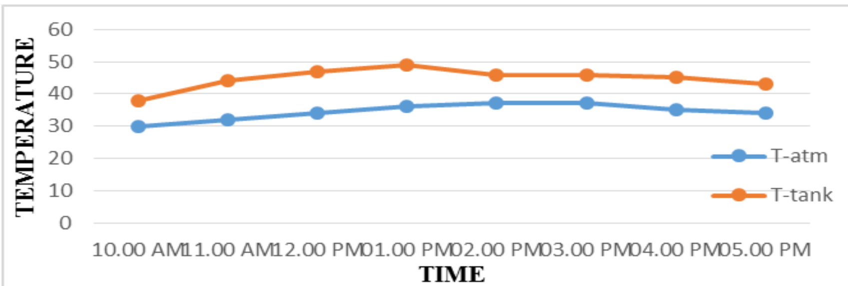


Graph -4.1.1: Time vs. Temperature

4.1.2 Readings taken on 27 Feb. 2016 from 10:00 am to 5:00pm for 30^{o} tilt angle.

Table -4.1.2: Water Temperature in Tank

		TIME							
		10.00 AM	11.00 AM	12.00 PM	01.00 PM	02.00 PM	03.00 PM	04.00 PM	05.00 PM
THERMOCOUPLE	T-atm	30	32	34	36	37	37	35	34
	T-tank	38	44	47	49	46	46	45	43

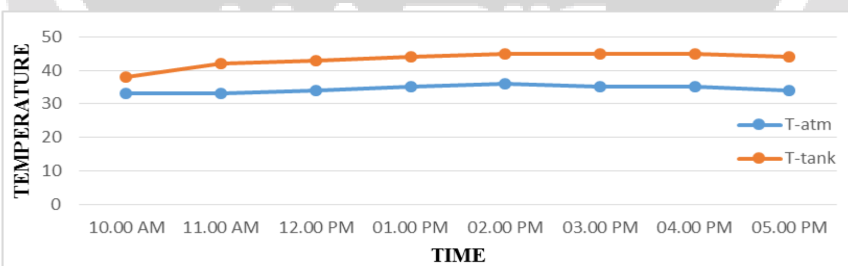


Graph -4.1.2: Time vs. Temperature

4.1.3 Readings taken on 28 Feb. 2016 from 10:00am to 5:00pm for 45^{o} tilt angle.

Table -4.1.3: Water Temperature in Tank

		TIME							
		10.00 AM	11.00 AM	12.00 PM	01.00 PM	02.00 PM	03.00 PM	04.00 PM	05.00 PM
THERMOCOUPLE	T-atm	33	33	34	35	36	35	35	34
	T-tank	38	42	43	44	45	45	45	44



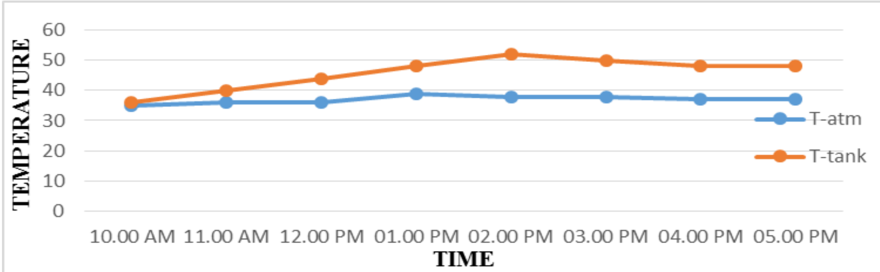
Graph -4.1.3: Time vs. Temperature

4.2 Readings with Vacuum and without Tracking System:

4.2.1 Readings taken on 19 March 2016 from 10:00 am to 5:00pm for 20^{o} tilt angle.

Table -4.2.1: Water Temperature in Tank

		TIME							
		10.00 AM	11.00 AM	12.00 PM	01.00 PM	02.00 PM	03.00 PM	04.00 PM	05.00 PM
THERMOCOUPLE	T-atm	35	36	36	39	38	38	37	37
	T-tank	36	40	44	48	52	50	48	48

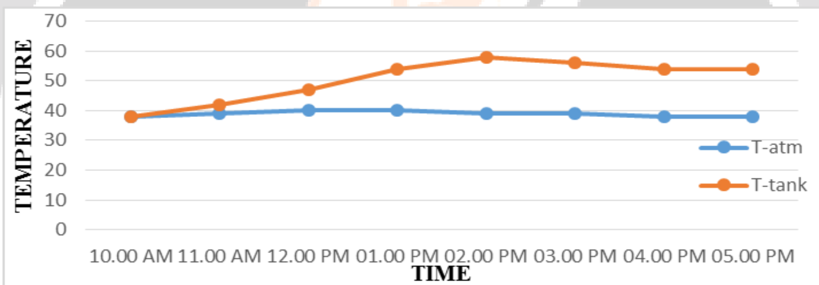


Graph -4.2.1: Time vs. Temperature

4.2.2 Readings taken on 20 March 2016 from 10:00 am to 5:00pm for 30° tilt angle.

Table -4.2.2: Water Temperature in Tank

		TIME							
		10.00 AM	11.00 AM	12.00 PM	01.00 PM	02.00 PM	03.00 PM	04.00 PM	05.00 PM
TERMOCOUPLE	T-atm	38	39	40	40	39	39	38	38
	T-tank	38	42	47	54	58	56	54	54

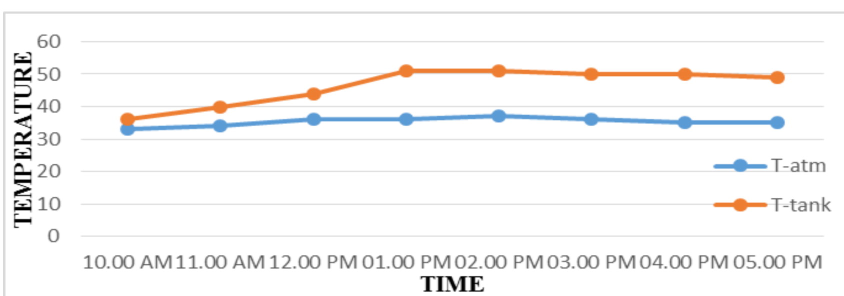


Graph -4.2.2: Time vs. Temperature

4.2.3 Readings taken on 21 March 2016 from 10:00am to 5:00pm for 45° tilt angle.

Table -4.2.3: Water Temperature in Tank

		TIME							
		10.00 AM	11.00 AM	12.00 PM	01.00 PM	02.00 PM	03.00 PM	04.00 PM	05.00 PM
THERMOCOUPLE	T-atm	33	34	36	36	37	36	35	35
	T-tank	36	40	44	51	51	50	50	49



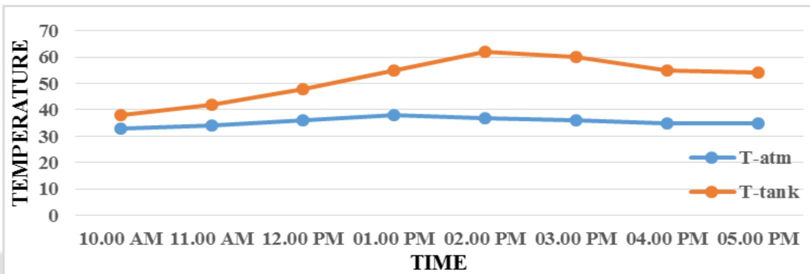
Graph -4.2.3: Time vs. Temperature

4.3 Readings with Vacuum and Tracking System:

4.3.1 Readings taken on 31 March 2016 from 10:00 am to 5:00pm for 20^{o} tilt angle.

Table -4.3.1: Water Temperature in Tank

		TIME							
		10.00 AM	11.00 AM	12.00 PM	01.00 PM	02.00 PM	03.00 PM	04.00 PM	05.00 PM
THERMOCOUPLE	T-atm	33	34	36	38	37	36	35	35
	T-tank	38	42	48	55	62	60	55	54

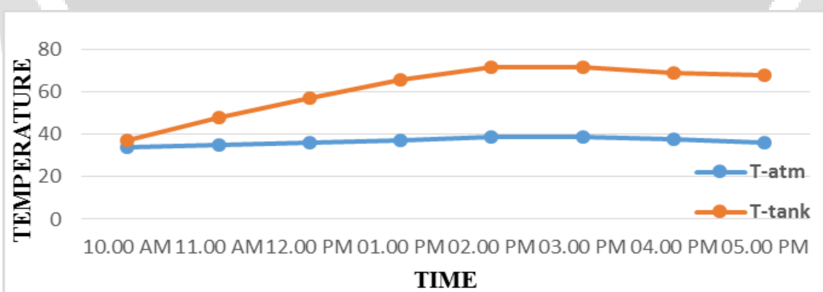


Graph -4.3.1: Time vs. Temperature

4.3.2 Readings taken on 1 April 2016 from 10:00am to 5:00pm for 30^{o} tilt angle.

Table -4.3.2: Water Temperature in Tank

		TIME							
		10.00 AM	11.00 AM	12.00 PM	01.00 PM	02.00 PM	03.00 PM	04.00 PM	05.00 PM
THERMOCOUPLE	T-atm	34	35	36	37	39	39	38	36
	T-tank	37	48	57	66	72	72	69	68

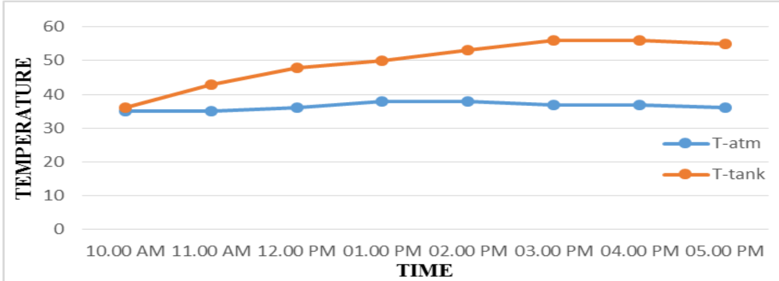


Graph -4.3.2: Time vs. Temperature

4.3.3 Readings taken on 2 April 2016 from 10:00am to 5:00pm for 45^{o} tilt angle.

Table -4.3.3: Water Temperature in Tank

		TIME							
		10.00 AM	11.00 AM	12.00 PM	01.00 PM	02.00 PM	03.00 PM	04.00 PM	05.00 PM
THERMOCOUPLE	T-atm	35	35	36	38	38	37	37	36
	T-tank	36	43	48	50	53	56	56	55



Graph -4.3.3: Time vs. Temperature

5. RESULT

The temperature of water in the tank found while performing on different tilt angles that are 20°, 30° & 45° for respective dates shown above in the performance are:

Table -5: Analysis Result

Type of System	Tilt Angles		
	20°	**30°**	**45°**
Without Vacuum and Without Tracking	47° C	49° C	45° C
With Vacuum and Without Tracking	52° C	58° C	51° C
With Vacuum and With Tracking	62° C	**72°** C	56° C

6. CONCLUSIONS

- It is found that the **30°** tilt angle is more efficient than the other two tilt angles that are **20° & 45°**.
- It is observed that the highest temperature of water in the storage tank that is **72°C** gain at **30°** tilt angle with vacuum and tracking system.
- It is found that, with new implemented double exposing system, the heating rate and flow rate of water is increases by 8° C in one hour than existing solar water heater (i.e. **5°C).** The heating rate increases by **37.50%** .
- Due to the evacuated storage tank, the heat loss is decreases by **4°C** and hot water has been stored for longer time.
- The ultimate aim is to raise the temperature of water in minimum time has been successfully obtained.

7. REFERENCES

[1]. Mr. Kishan Patel, Mrs. Pragna Patel, Mr. Jatin Patel, Patel et al., "Review of Solar Water Heating System", *International Journal of Advanced Engineering Technology E-ISSN 0976-3945*.
[2]. A. E. Kabeel, A. Khalil, S. S. Elsayed, A. M. Alatyar, "Modified Mathematical Model for Evaluating the Performance of Water-in-Glass Evacuated Tube Solar Collector Considering Tube Shading Effect", *Journal of Research in Energy 89 (2015) 24-34".*
[3]. M. A. Sabiha, R. Saidur, Saad Mekhilef, Omid Mahian, "Progress and Latest Developments of Evacuated Tube Solar Collectors", *Journal of Research in Renewable and Sustainable Energy Reviews 51 (2015) 1038-1054.*
[4]. Johane Bracamonte, Jose Parada, Jesus Dimas, Miguel Baritto, "Effect of the Collector Tilt Angle on Thermal Efficiency and Stratification of Passive Water in Glass Evacuated Tube Solar Water Heater", *Journal of Research in Applied Energy 155 (2015) 648-659.*
[5]. Hossein Mousazadeh, Alireza Keyhani, Arzhang Javadi, Hossein Mobli, Karen Abrinia, Ahmad Sharifi, "A Review of Principle and Sun-Tracking Methods for Maximizing Solar Systems Output", *Journal of Research in Renewable and Sustainable Energy Reviews 13 (2009) 1800–1818.*
[6]. Siddharth Suman, Mohd. Kaleem Khan, Manabendra Pathak, "Performance Enhancement of Solar Collectors - A Review", *Journal of Research in Renewable and Sustainable Energy Reviews 49(2015) 192-210.*

[7]. Hamid Moghadam, Saeed Moghadam Deymeh, “Determination of Optimum Location and Tilt Angle of Solar Collector on the Roof of Buildings with Regard to Shadow of Adjacent Neighbors”, *Journal of Research in Sustainable Cities and Society 14 (2015) 215–222*.