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# Experimental Analysis of Evacuated Tube Solar Collector Using Adjustable Reflection Sheet with Fuzzy Logic Approach

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***Abstract*: Water heaters are widely used for heating water for both domestic as well as industrial purpose. In this paper, performance of evacuated solar collector using adjustable reflection sheet with fully covered so that heat loss through convection is minimized. It has been found that temperature of water increases by 5 degrees when the whole setup is covered with transparent cover and the peak temperature achieved with the single evacuated solar collector is 47 ºC.**

***Keywords*: ETC (Evacuated Tube Collector), solar, fuzzy logic, energy, FPC (flat plate collector), temperature.**

## 1. Introduction

In today's climate, environmental degradation and the energy shortage are very significant sustainability problems. Therefore, the energy from the sun is used for cooking, generation of power, field drying, etc. The world's overall demand for heated water is growing rapidly because of population and industrialization. Consumption of heated water in the residential sector is about 18 percent and 14 percent of overall energy production, respectively. The solar energy collector is then chosen for the purpose of ETC parameters and solar devices of a collector are configured.

In this study, two coaxial borosilicate glass cylinders are made of evacuated cylinders, joined at the top and enclosed at the bottom, containing a vacuum. The outer cylinder is a translucent cylinder, called a cover cylinder, which is 47 mm in diameter and 1800 mm in length. The inner cylinder, which is called the Absorber Cylinder, is 37 mm in diameter. The width is 1.6 and 2.00 mm respectively for the Inner Cylinder and Outer Cylinder.

Many researchers have performed various study for better performance of solar collector, some works are listed here. A. Fadhel et al. (2005) the goal of this research is to examine three solar processes in the drying phase of the grape variety. In a natural convection solar drier, under a tunnel greenhouse and in the open sun, three drying kinetics were developed respectively. Experiments indicate that the greenhouse drying of the solar tunnel is adequate and compatible with the solar drying phase of natural convection. [1]. A. Sundari Umayal et al. (2013), presented the study of a dryer based on solar energy with emptied pipe collectors without and with heat storing material (gravel) design &production. In the meteorological state of Thanjavur, Tamilnadu, India, the act of dryer based on solar energy for drying chilli was looked over. In comparison with traditional sun based drying, the designed dryer. Chilies drying in a built dryer decreased the average starting moisture level from 87.36 percent to 3.4 percent final moisture content in 10 hours with heat storage material, compared to twelve hours without material of heat storage in the dryer and thirty-two hours with drying in natural sun. The built dryer decreased the drying time length by up to 66 percent. A productivity of a dryer with heat storing material is observed to be 34.23, 22.03 and 9.32 percent, respectively, without heat storing material &traditional sun based drying. [02] A. B. Ubale et al. (2015) has designed and investigated the solar collector with evacuated tubes of diameter 55mm having length of 1.8m. Evacuated tubes are installed at 45-degree inclination in steel frame with insulation using polyethylene foam sheet to avoid contact with frame. Output of the evacuated tubes is supplied to dryer chamber using fans. Dryer chamber is fabricated with aluminium alloy sheets having thickness of 0.6 mm, three trays with stainless steel mesh and coated along with 12mm polyethylene foam sheet for avoiding heat conduction. Seedless grapes are used for drying purpose and kept in trays. Each tray is monitored for relative humidity, ambient temperature and air temperature with weigh balance. RTD sensors are also installed to check the temperature. Anemometer and solar pyranometer are installed to monitor air velocity and solar radiation respectively. Analysis of drying food product has been done using various mathematical models. Analytical and experimental has been compared for designed evacuated tube collector. Heat transfer by using forced convection system has given good results to reduce moisture content from the food product in uncontrolled environment. Market acceptable value was found also more than products dried in conventional drier. [3] A. E. Atabani al. (2013) the demand of energy is increasing in the world due to urbanization and change in living standards. Also, the fossil fuel getting shortage day by day due to increasing its demand and uses. So, it has become to search new

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fuel option for fulfilling requirement of society. In view of this the author has suggested non edible oil for production of biodiesel and fulfilling demand of fuel. He has studied various properties of non-edible oil along with its production/extraction methods. As a result, it is found that there is more chance for producing biodiesel with the help of non-edible oil. [4] A. H. Abdullah et al. (2003) This Research transcript presents the findings of a test analysis of the effectiveness with a honeycomb with various configurations equipped with a collector of solar energy. For this reason, a full collector research plant fitted with an acquisition system of data has been put together and tested. “A flat plate collector of solar energy with an area of 2 $m^2$ and an air gap of 60 mm has been planned and installed. The modified honeycomb device is structured out of a 16 mm thick polycarbonate sheet comprising two rows of 0.4 longitudinal aspect ratio honeycomb cells. Using single or double honeycomb units, the effect of gap thickness above, below or within the honeycomb units is studied. Six structures are being evaluated with the single honeycomb unit (SHU) with bottom gaps of 0, 3, 8, 14, 22 and 36 mm. Six other double honeycomb unit configurations with distinct top, middle and bottom holes are being studied”. [5] A. K. Pandey et al. (2018) stated that Materials for Phase Change can be applicable to various types of systems of solar power for increased thermal energy storage that is more important as energy from sun is isolated by inaccessible and default during the night time. At all time, except when the natural solar radiation is not present, a solar energy device needs solar energy to be used with the assistance of PCMs. “PCMs thus play an essential role in systems of solar energy in order to meet the supply and demand gaps of electrical service standard. The Research transcript presented the latest developments for integrating PCMs in various systems of solar energy and presented almost all of the new areas in which PCM implementations in systems of solar energy are anticipated. In solar thermal energy systems, like solar based cookers, water heaters, thermal power plants and air heaters and, recent and previous PCM developments have been explored”. The study revealed that PCMs have been used in nearly all systems of solar energy, but because of a variety of economic and environmental restrictions, their use is still limited and not commercially feasible. [6] Abdelhamid Farhat et al. (2004) the test data is presented with correlations obtained by linear regression. With respect to a heat loss coefficient, an effect of gap thickness for the collector fitted with SHU indicates that the bottom gap is crucial. The single honeycomb arrangement with a bottom gap of 3 mm is the optimal, since it has the maximum effectiveness of all the arrangements and the lowest heat loss coefficient among the other arrangements of the honeycomb. “The findings indicate less vulnerability of the heat loss coefficients to deviations of the top or middle gaps for the collector fitted with two honeycomb modules. A comparison of the outcomes obtained for single and double honeycomb units depicted that the collector effectiveness is substantially increased by a compound honeycomb collector of solar energy with air gaps of the proper thickness above and below the SHU. It also offers significant honeycomb material protection since its thickness is around 25 percent of the overall air difference”. [7] Aed Ibrahim Owaid et al. (2014) the thermal losses in water heaters based on solar energy with (32) emptied pipes and tank volume (263 litres) that have been used in the construction of a solar energy device for heating a meeting hall of the specified area have been tested in this article, where the research was in the evening and during the night, heat loss that induces the hot water temperature in the storage tank of the solar heater in the night. Where, during the winter season and for three consecutive days in February, the space heating system failed to function under environmental conditions in Baghdad, Iraq, the test used a data logger with the use of two thermal pairs (type k) to calculate the water temperature in the centre of the storage tank in the solar water heater and the ambient temperature. [8] Ahmet Z. Sahin et al. (2020) there are different strategies used to improve the transformation of solar energy into useful structures. The utilization of Nano fluids is one of the correct methods in the investigation of improving energy use. In this paper, a recent survey is done for different later investigations that show the utilization of Nano fluids in various sorts of solar powered collectors for development of their performance. Likewise, a few proposals are made corresponding to the future examination bearings taking into account the overarching difficulties utilizing Nano fluids in solar based energy system. It has been seen that appropriate scattering of nanoparticles is a main point of contention for sufficient solar absorption. Improvement of solar based collector execution concurs until certain restriction of Nano fluid volume portion above which it can wind up with unfriendly outcomes. Legitimate blend of molecule size, pH value and sufficient scattering of nanoparticles brings about proficiency increase. Among all conceivable nanoparticles carbon nanotubes bring about bigger upgrade when contrasted with rest, all in all. It is additionally noticed that the nanoparticles having optical properties assume a key function in the ingestion, annihilation coefficient and the entrance depth. [9]

## 2. Experimental Set Up and Data Collection

Iron rod is cut to the desired size and then weld into the desired shape. With the help of arc welding the desired frame is made. After completing the frame, the next target is to put the metal sheet into the frame such that the sheet can be easily adjusted according to the direction of sun hence the extra radiation coming from the sun is transferred towards the evacuated tube collector and the maximum output can be attend with help of this adjustable sheet for more reflection this sheet is coated with silver colour because silver colour reflects more radiation as compare to others. The next step is fitting the evacuated tube in the water tank. The experimental setup for improving efficiency of the system the sheet with ETC is fully covered with the help of transparent cover and tapping is around the sheet so that radiation loss to the environment should be minimised.

## 3. Fuzzy Logic Approach

Fuzzy logic works on degree of truth rather than the usual true or false (0 or 1) Boolean logic on which modern computer is based.

Steps to solve:

- Step 1: Identify input and output variables and decide descriptor for the same. Convert crisp value to fuzzy value.
- Step 2: Define membership functions for each of the input and output variables.
- Step 3: Form a rule base.
- Step 4: Rule Evaluation.
- Step 5: Defuzzification

Here input is time and output is water temperature. Now we have to check the variation of temperature with respect to time. Due to evacuated tube collector the temperature of water changes drastically and experimentally we have already taken the reading in every hour i.e., 9am to 5pm. Now with the help of fuzzy logic we can get the changes in water temperature in every minute hence experimentally we have only 9 reading in a day but with the help of fuzzy logic we have infinite number of readings.

Membership functions:

1. Triangular
2. Trapezoidal
3. Gaussian
4. Generalized bell

Fuzzy logic operator:

1. OR - max(A,B)
2. AND - min(A,B)
3. NOT - (1-A)

Defuzzification methods

1. Lambda cut method
2. Maxima method
3. Weighted sum method
4. Centroid method

*Input:* time 9 to 17 (24hr)

Morning from 9 to 12

Noon from 10 to 16

Evening from 14 to 17

*Output:* water temperature

Low – below 40

Medium – 29 to 56

High- above 46

*Rules:*

1. If time is morning then water temperature is low
2. If time is noon then water temperature is medium
3. If time is noon then water temperature is high
4. If time is evening then water temperature is high

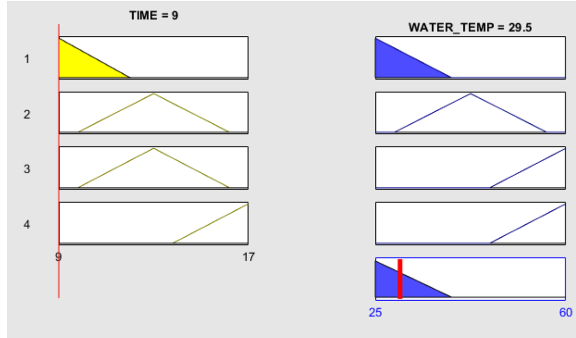
Membership function used- triangular

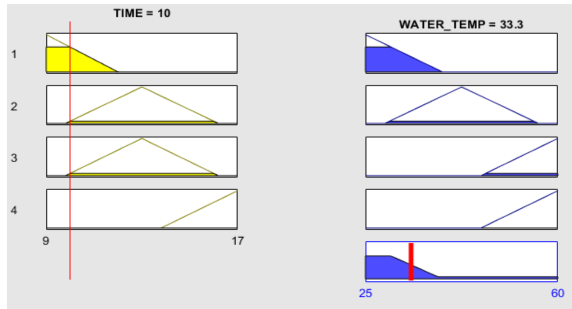
Operator- OR

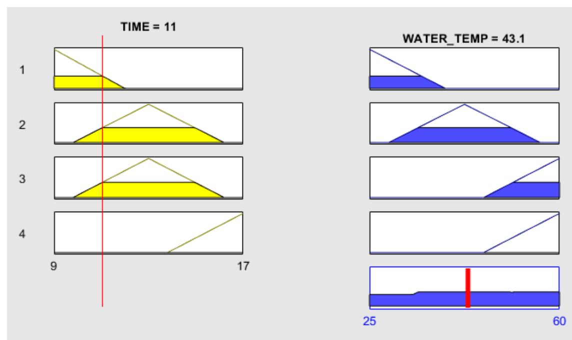
Defuzzification method: Centroid method

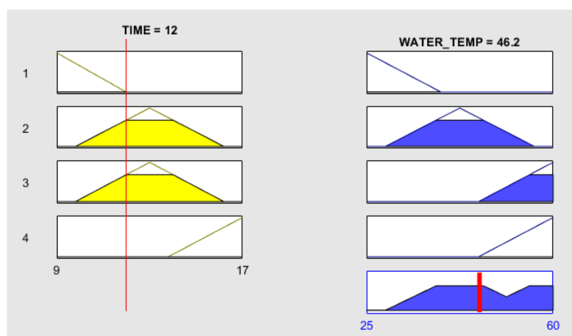
## 4. Result

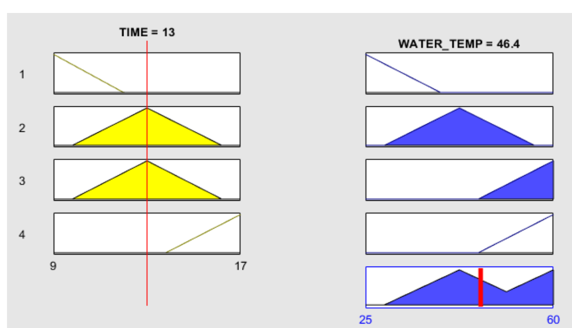
The maximum temperature which can be achieve through a single ETC is 47 $^{o}$ C and with the fuzzy logic approach 55.5 $^{o}$ C.

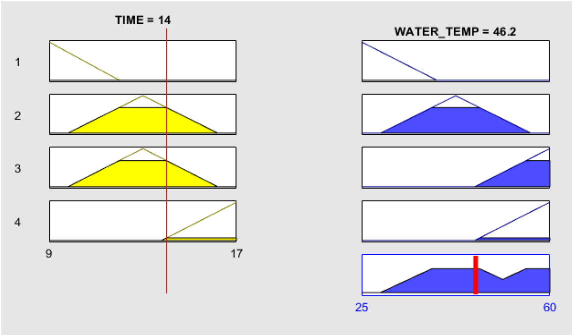


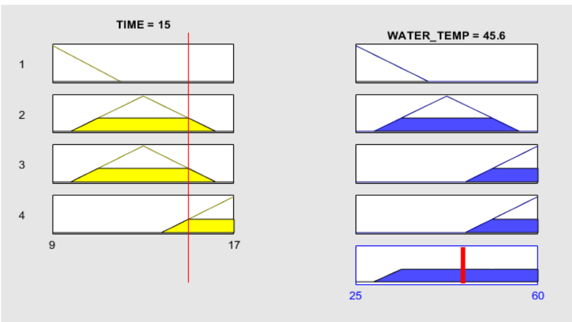



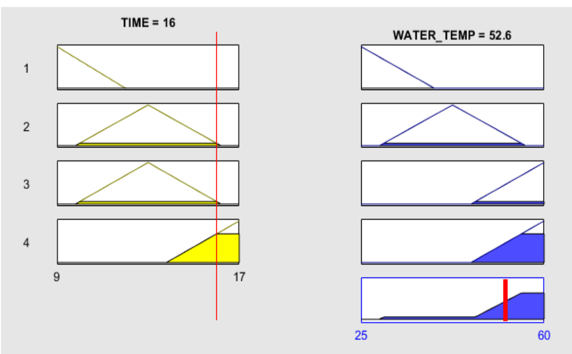



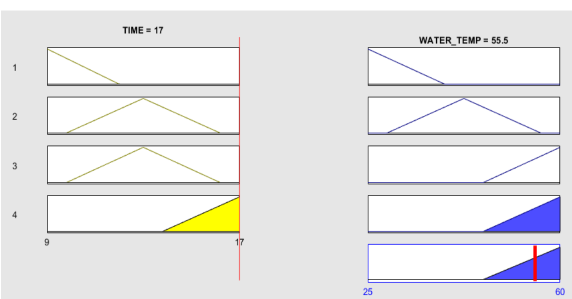



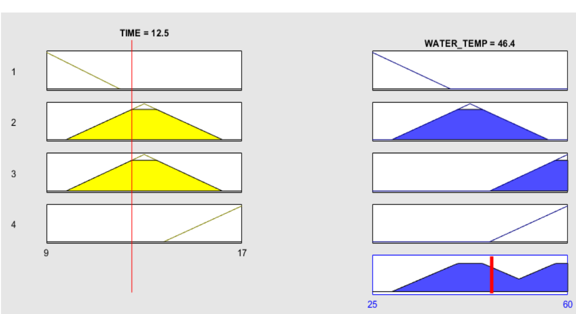





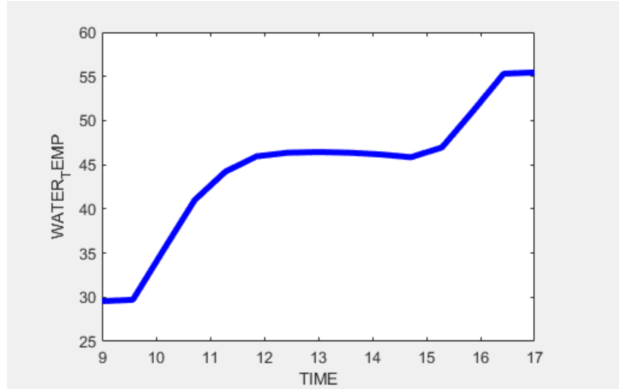




Fig. 1. Experimental data and graph

And the temperature at different point of time can also be determine with the help of fuzzy logic for example temperature at 12.30 pm is 46.4 ° C.

And the variation of temperature with respect to time can be explained through the graph.

Table 1
Without cover data 05-april-22

| Time | Ambient Temp. | Sheet Temp. | Reflection Temp. | Water temp. |
|---|---|---|---|---|
| 9 AM | 33.8 | 40 | 36 | 25.5 |
| 10 AM | 37.2 | 46.9 | 40.1 | 30.5 |
| 11 AM | 38.3 | 53.7 | 40.9 | 34.1 |
| 12 NOON | 39.6 | 56.9 | 41.3 | 38.3 |
| 1 PM | 39.6 | 49.7 | 40.3 | 41.3 |
| 2 PM | 39.3 | 49.6 | 40.1 | 42.6 |
| 3 PM | 37.2 | 48.6 | 41.3 | 43.4 |
| 4 PM | 36 | 47.5 | 41.3 | 43.7 |
| 5 PM | 35.1 | 46.1 | 40.5 | 43.8 |

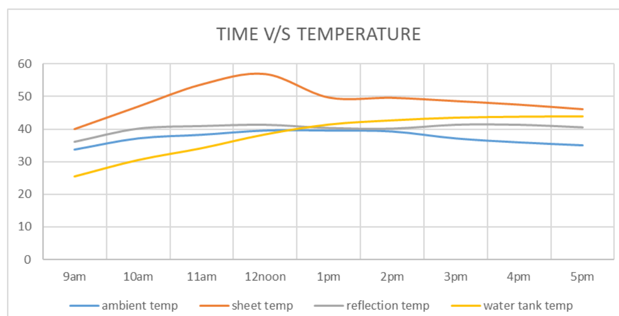



Fig. 2. Time vs. Temperature (Without cover)

Table 2
With cover data 02-May-22

| Time | Ambient Temp. | Sheet Temp. | Reflection Temp. | Water Tank Temp |
|---|---|---|---|---|
| 9 AM | 37.2 | 46.1 | 47.2 | 27.2 |
| 10 AM | 40.6 | 55 | 49.7 | 34.6 |
| 11 AM | 41 | 59.1 | 54.6 | 38.4 |
| 12 NOON | 41 | 57 | 53.9 | 43.9 |
| 1 PM | 42.3 | 53.5 | 56.4 | 45.1 |
| 2 PM | 42.6 | 55.1 | 55 | 46 |
| 3 PM | 41.2 | 51.8 | 49 | 47 |
| 4 PM | 40 | 46.2 | 46.4 | 46.8 |
| 5 PM | 39.2 | 46.1 | 45.7 | 46.2 |

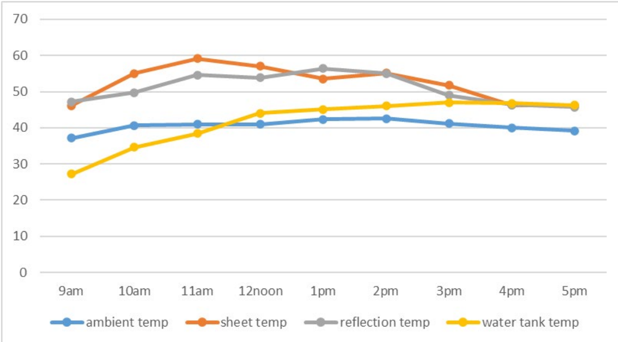



Fig. 3. Time vs. Temperature (With cover)

Table 3
Result validation

| S.No. | Time | Experimental Result of Water | Fuzzy Result | Percentage Error |
|---|---|---|---|---|
| 1 | 9 AM | 27.2 | 29.5 | 7.79 |
| 2 | 10 AM | 34.6 | 33.3 | -3.9 |
| 3 | 11 AM | 38.4 | 43.1 | 10.9 |
| 4 | 12 PM | 43.9 | 46.2 | 4.97 |
| 5 | 1 PM | 45.1 | 46.4 | 2.8 |
| 6 | 2 PM | 46 | 46.2 | 0.43 |
| 7 | 3 PM | 47 | 45.6 | -3.07 |
| 8 | 4 PM | 46.8 | 52.6 | 11.02 |
| 9 | 5 PM | 46.2 | 55.5 | 16.75 |

## 5. Conclusion

It has been found that evacuated tube in close system result is much better then open system, because due to covering the setup heat loss through convection is minimized. It has been found that maximum water temperature has been found 47 $^{o}$C, when ambient temperature is 42 $^{o}$C. the experiment has been performed with open system at the same temperature means 42 $^{o}$ C at this temperature 40 $^{o}$ C has been achieved. In overall experiment it has been found 5 $^{o}$ C temperature enhancing.

In this research work fuzzy based mathematical model has been developed and result has been validated from this model. From this model we achieved very close result in terms of experiment. The maximum percentage of error is 16.75% and minimum is -3.9% that is very close with experimental result.

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