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Experimental Investigation of Modified Solar system with Copper Box Substituting absorber.

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Abstract:

An experimental investigation into the performance and reliability of a newly constructed parallel plate solar collector is the goal for this paper. Many industrial and commercial applications that require fluid temperatures lower than 1000 degrees Celsius use Parallel Plate Collectors (PPCs). Traditionally, all parallel plate collector absorbers include straight copper or aluminium sheets. It does, however, limit how much heat can be transferred from the collector to the collector's surface. Traditional collectors have been commercialised in many forms, but their purchase costs are still high. To overcome this issue, a new low-cost solar collector is built, with a simple copper box substituting the absorber and copper tube combination. Varied parallel plate collectors are tested under various operating situations, and data is collected. New and old parallel plate collectors are compared in terms of temperature output variations in this paper.

Keywords: *Parallel Plate Collector (PPC), Solar Energy, solar water heater, Copper Sheets*

I.**INTRODUCTION:**

The sun is the most cost-effective power source available today. We refer to solar power as a renewable source of energy that is constantly replenished by sunlight. Plants use the sun's rays to produce food. Coal, oil, and natural gas were produced by the decomposition of plants millions of years ago. Because of the sun's magnetic field, a steady stream of solar energy is available all the time. Solar radiation intensity on Earth's orbit is 1367kw/m2. Assuming an equatorial orbit, we can calculate that the Earth receives 173,000 Terawatts of energy.

These systems are essential for low-temperature applications such as household hot water, central heating and drying as well as many other industrial uses. Solar water heating systems have been around for a long time because they are the most convenient method of taking advantage of direct solar radiation. Heat exchangers are used in solar water heating systems. In a solar hot water system, the collector field is one of the most critical and valuable components. Solar collectors have been at the heart of solar energy systems for the vast majority of their existence. As a result, the collector absorbs solar radiation from the sun, transforms it into thermal energy, and then transfers it to a fluid that flows through the collector. Figure 1 depicts the fundamental parts of a parallel plate. collector.

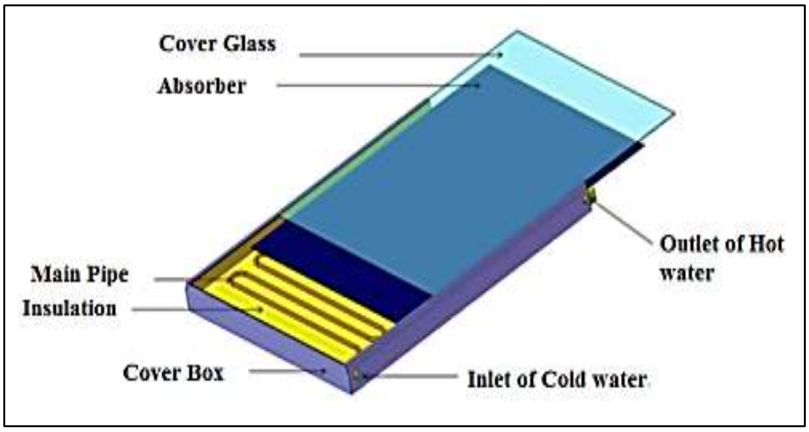


Fig.01- Principle layout of conventional parallel plate collector.

Insulation is used in the cover box shown in Fig. 1 to reduce losses [4]. The box used to conceal the opening is typically made of copper or aluminium. An absorber of dark-colored material and a cover glass are used to transfer the heat from the copper primary pipe to water. Material that quickly absorbs heat from the sun's rays and quickly transfers that heat to tubes or fins attached in some fashion, resulting in an excellent thermal bond is called an absorber plate Because of its high heat conductivity, copper is the most commonly used material for absorber plates. [5]

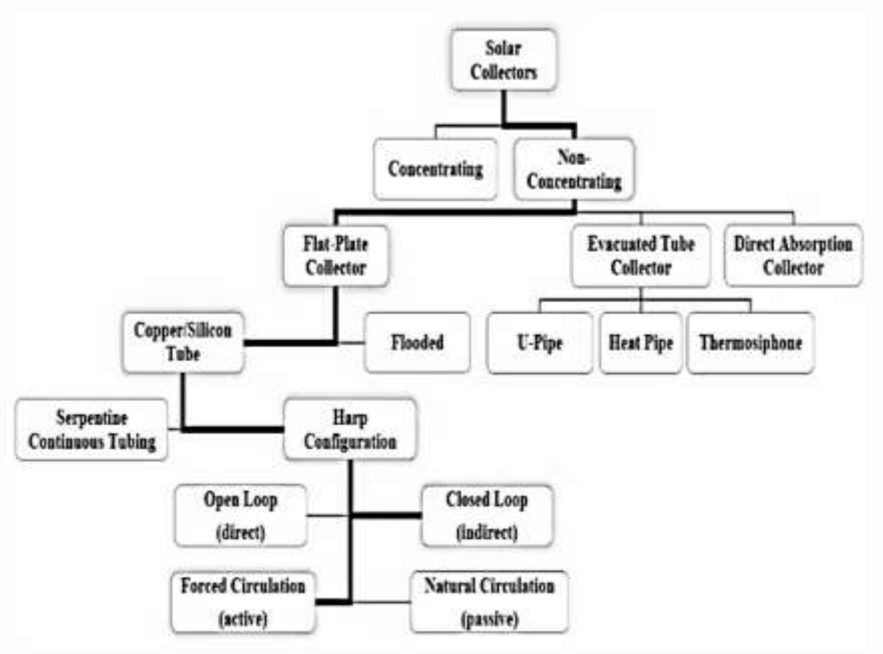


Table.01- Few Solar Energy Conversion Technologies

Solar radiation may be converted into a number of useful forms of energy via a wide range of technologies now under development. Solar energy conversion, application, and usage methods are shown in Table 1.1. In non-concentrating collectors, collector area is the same as absorber area. [6] [7] Low-temperature heating (1200C) is the most common application, but they may also be used for solar air heating in buildings to warm the air within. High reliability, the flexibility to use both diffuse and beam radiation, the absence of a tracking device, ease of operation, and outstanding dependability are all advantages of non-concentrating collectors over concentrating collectors. There are several reasons to avoid using a non-concentrating collector for applications requiring high temperatures, despite their ability to achieve such temperatures

i) The price of an absorber is more than the price of a mirror.

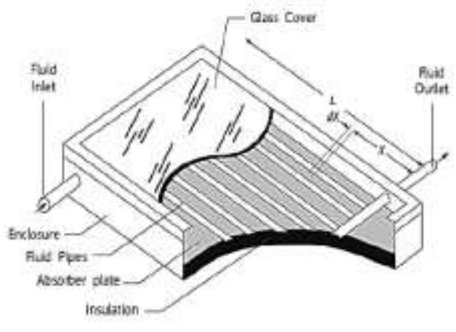
ii) The collector's heat losses are proportional to the absorber area.

iii) Because radiation losses are related to temperature, there is a significant increase in radiation loss as the temperature rises.

Concentrating collectors focus the sun's rays on a smaller area (collector) than they would otherwise (absorber). Consequently, more energy is lost per unit area on the concentrating surface compared to any other surface. Higher temperatures can be achieved because of a higher heat input rate per unit area. As a result, point focusing collectors are used in applications with much higher temperatures.. [8][9][10].

II.COMPONENT OF SOLAR WATER HEATING SYSTEM

There are three major parts to solar water heating systems.: a storage tank, a pipe and a solar collector.as shown in figure no 2



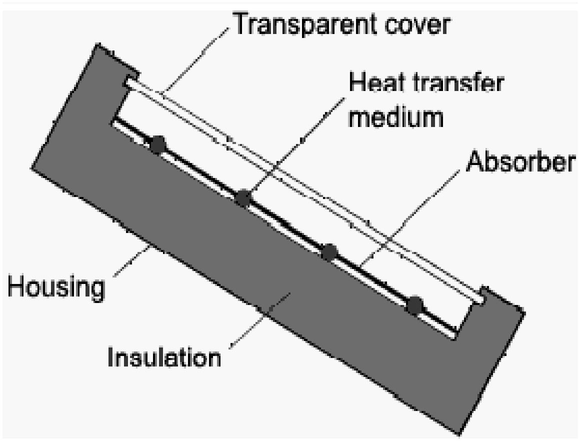


Fig.02- Component of Solar Water Heating System. [27]

A] Solar collector: Water heating systems rely on the use of a solar collector to convert solar energy into heat energy.. Solar collectors with associated absorbers capture and convert solar energy into heat energy that may be utilized in a variety of applications. Because of its great heat conductivity, copper is the ideal material for collectors, but it is also the most costly. The functioning principle of a solar collector is depicted in Figure 1.

B] Storage tank: The hot water storage tank is built of rolled galvanized steel. From the collection loop, heated water is delivered to the storage tank. Drainage can be accomplished through a tiny vent in the tank's bottom part.

C] Pipe: Galvanized steel pipes were chosen because of their stiffness and corrosion resistance. This is essential since they store water for both home and industrial usage.

III.NEW PARALLELPLATE SOLAR COLLECTOR

New flat-plate solar collectors require less tracking and less maintenance than their predecessors. types [3]. Figure 3 depicts the real-life use of a novel parallel plate collector.

Fig.03- New parallel plate Heating System

It was possible to alter the layout of the copper tubes in a new type of parallel plate collector by simply inserting a 1100x1100x15 mm copper box into the collector frame. Parallel plate collector's technical specifications are shown in Table 2. Face-centered cubic crystal structure: atomic weight 63.54, 29th-most abundant element on Earth.

Particular	Specification
Collector dimensions (Length x Width x Thickness)	1.25 m x 1.25 m x 0.080 m
Collector type	parallel plate
Number of glass covers	1
Cover material	Low iron glass
Cover thickness	4 mm
Cover transmission	94%
Box dimensions (Length x Width)	1.1 m x 1.1 m
Thermal conductivity of plate material	386 W/m °C

Copper sheet thickness	1 mm (22 gauge)
Collector heat absorber area	1.44m2
Insulation material	Rockwool
Thermal conductivity of insulating material	0.045 W/m °C
Insulation thickness	30 mm
Sheet Material of collector tray	Aluminum

Table.02- TECHNICAL SPECIFICATIONS OF NEW PARALLEL PLATE COLLECTOR

When it comes to noble metals like silver and gold, copper is a transitional element. When it comes to its properties, copper's elemental origins play a big role. The copper plate is 1 mm thick and 22 gauge. The copper box is placed in a collector's frame and covered with a transparent cover. On one side of the frame, the water tank's cold water exits into the copper box, while the hot water exits out the other. Solar radiation absorbed by the copper box collector causes the water temperature to rise, resulting in water movement into the storage tank. Figure 4 depicts a copper parallel plate collector in three dimensions. [12] [13] [14]

Fig.04- Actual Experimental setup

IV.EXPERIMENTATION

In addition to the collectors, the test setup includes a collector frame, flowmeter, and thermocouple, as well as a thermometer. Figure 5 shows a flowchart of the procedure for performing the test.

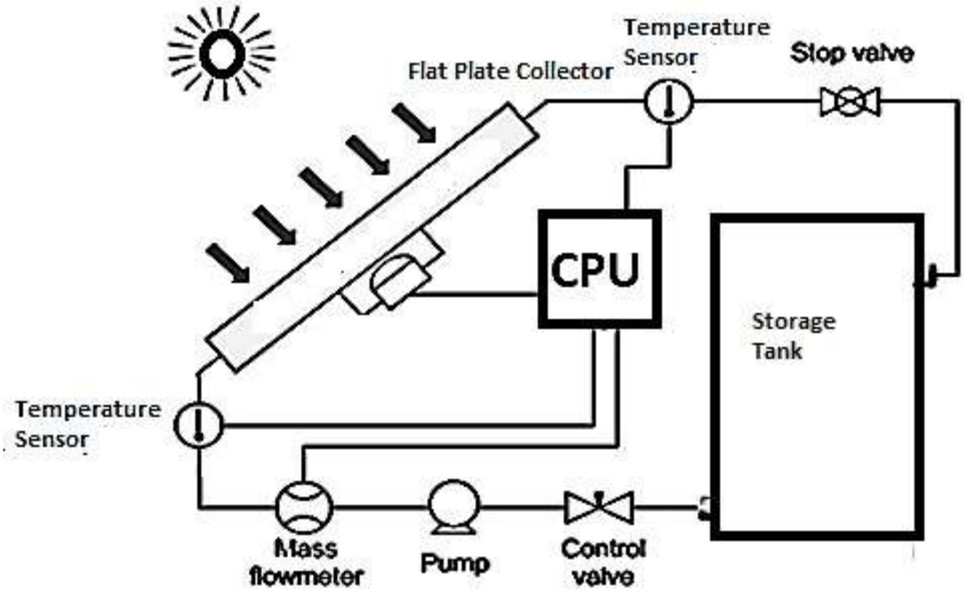


Fig.05- Schematic Diagram of Experimental Setup [16]

As depicted in Figure 5, two digital thermometers with a range of up to 150 degrees Celsius are required for the experiment. There are two digital thermometers: one in the collector's intake and one at its exit. Both are used to monitor temperature changes as water passes through the collectors. A flow metre is also installed on the system's input side to monitor the water flow before it enters the collector. Figure 5 depicts the experiment's set up.[16]

The cold water tank was filled after it had been sufficiently filtered. The valve was opened to allow water to flow into the circulating pipes. Water flows through the collection at a constant rate throughout the measurements. In order to start a flow, the absorber plate heats the copper box integrated underneath the absorber plate to a temperature that is lower than the water's density difference (i.e., the cold water flows down while hot water rises) (thermo-syphon or natural convection). [17] Storage tanks for hot water are equipped with a valve that allows them to be tapped when needed. Once critical operational parameters have been measured at a specific location, observations are taken following the established protocol. Throughout the trial, the sun shone brightly and there was no overcast sky. [18][19][20]

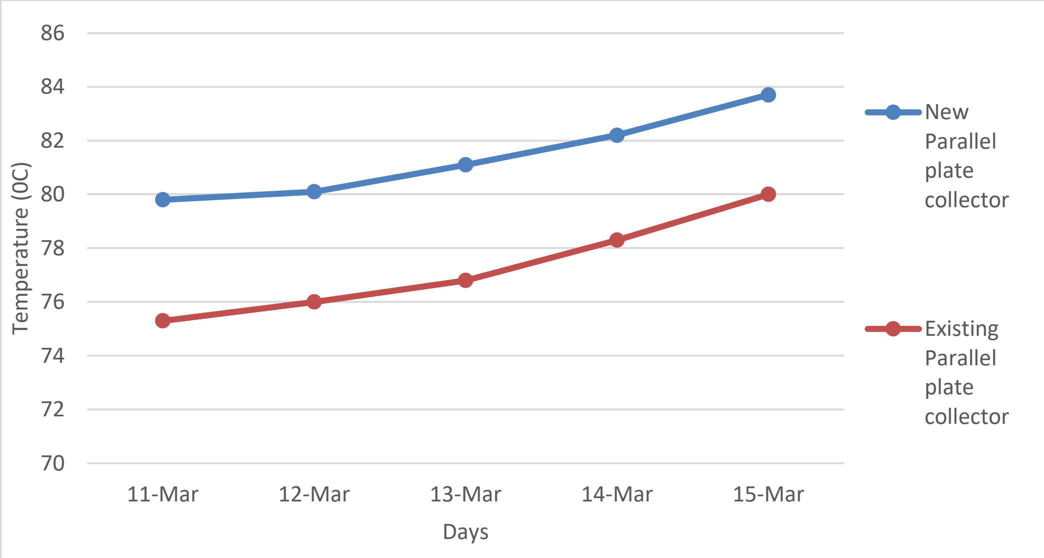


Fig.06- Temperature vs Days at 2 pm.

For five days in a row from March 11 to 15, 2017, an experiment was carried out at 2 p.m. This can be seen in the diagram in figure 6. Temperature rises 5% to 6% in the new parallel plate collector when compared to an old parallel plate collector when the water outflow temperature changes over time. [21] [22] [23] [24]

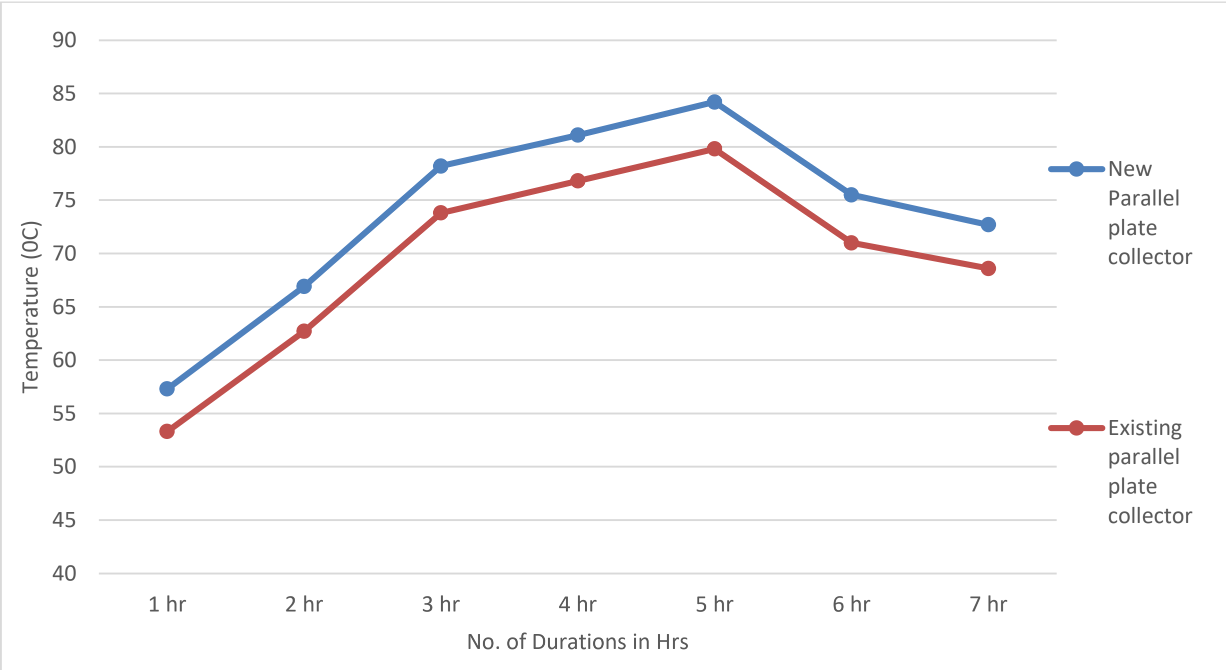


Fig.07- Variation in water outlet temperature vs. time 11pm to 5pm

Figure 7 depicts the change in water outlet temperature over a six-hour period, from 11 a.m. to 5 p.m., as a function of time. There is a 5%–7% increase in water temperature when comparing a new parallel plate collector to an old parallel plate collector. A new parallel plate collector shows the highest water exit temperature after a four-hour test period. The new parallel plate collector has a larger heat transfer area, which results in a higher water exit temperature..

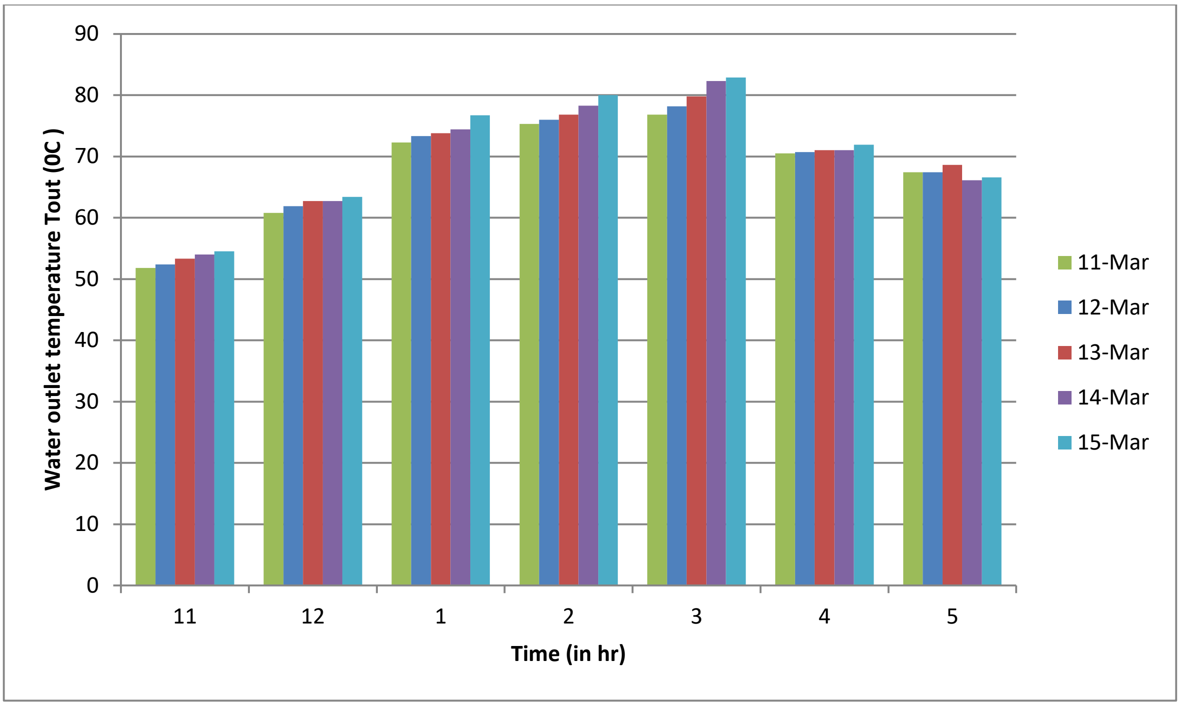


Fig.08- variation in water outlet temperature vs. time 11pm to 5pm for five days

Figure 8 depicts the change in water outlet temperature over the course of a 5-day period from March 11 to March 15. Temperature increases by 2 to 4% when new parallel plate collectors are used in place of older parallel plate collector models. After a six-hour test period, a new parallel plate collector shows the highest water exit temperature around 3:00 pm. [25] [26] [27]

V.CONCLUSIONS

The following conclusions can be made of the current research. The parallel plate solar water heater has been designed effectively, and experimental research has revealed that increasing the heat transfer area of the parallel plate solar water heater enhances the heat transfer rate.

1. According to testing data, the water output temperature from the collector rises linearly with the increase in daytime up to a certain limit..

2. Temperatures peak between 2:00 and 3:00 p.m., according to the data, with a maximum of 73 degrees Fahrenheit of 86^{o} C.

3. For the same collector area as the previous parallel plate collector, We found a high water outlet temperature in the new parallel plate collector..

4. According to the studies, the temperature rises linearly and then falls linearly as the number of days in the day increases.

5. Experiments show that when compared to conventional parallel plate solar water heaters, there is an increase in heat transfer rate with regard to time in water heating while keeping other parameters same.

REFERENCES:

[1] Tiwari G.N. ―Solar Energy. Fundamentals, Design, Modeling and Applications. – New Dehli: Alpha Science International Ltd, 2006.

[2] Nosa Andrew Ogie, Ikponmwosa Oghogho, Julius Jesumirewhe, ―Design and Construction of a Solar Water Heater Based on the Thermosyphon Principle. Ashdin Publishing Journal of Fundamentals of Renewable Energy and Application, Vol. 3, pp. 1-8.,2013

[3] Kreith F, Kreider JF. ―Principles of Solar Engineering‖. NewYork: McGraw-Hill; 1978.

[4] P. Sivakumar, W. Christraj, M. Sridharan and N. Jayamalathi,―Performance Improvement Study of Solar Water Heating System‖. Asian Research Publishing Network (ARPN) Journal of Engineering and Applied Sciences, Vol. 7, No. 1, ISSN 1819-6608, pp. 45-49, January 2012.

[5] Ziapour Behrooz M, Aghamiri Azad, ―Simulation of an Enhanced Integrated Collector – Storage Solar Water Heater‖. Energy Conversion Management, Vol.78, ISSN 0196-8904, pp. 193–203 Feb 2014

[6] Taheri Y, Ziapour Behrooz M, Alimardani K. ―Study of an Efficient Compact Solar Water Heater‖. Energy Conversion Management, Vol. 70, ISSN 0196-8904, pp.187–193, Jun 2013

[7] Kostic´ Ljiljana T, Pavlovic Zoran T. ―Optimal Position of Flat Plate Reflectors of Solar Thermal Collector‖. Energy and Buildings, Vol. 45, pp. 161–168, Feb 2012
[8] Cruz Jose MS, Hammond Geoffrey P, Reis Albino JPS. ―Thermal Performance of a Trapezoidal-Shaped Solar Collector/Energy Store. Applied Energy, Vol.73, pp. 195–212,2002
[9] Kumaresan Govindaraj, Sridhar Rahulram, Velraj Ramalingom, ―Performance Studies of a Solar Parabolic Trough Collector with a Thermal Energy Storage System‖. Energy, Vol.47(1), pp. 395–402, Nov 2012.
[10] S. Jaisankar, T.K. Radhakrishnan, and K.N. Sheeba, 2009, ―Experimental Studies on Heat Transfer and Friction Factor Characteristics of Thermosyphon Solar Water Heater System Fitted with Spacer At The Trailing Edge of Twisted Tapes‖. Applied Thermal Engineering, Vol. 29(5), pp. 1224–1231, April 2009
[11] P. Hernandez, P. Kenny, ―Net Energy Analysis of Domestic Solar Water Heating Installations in Operation. Renewable and Sustainable Energy Reviews, Vol.16, pp. 170–177, Jan 2012
[12] Benz N, Hasler W, Hetfleish J, Tratzky S, Klein B. ―Flat Plate Solar Collector with Glass T. Proceedings of Eurosun'98 Conference on CD-ROM, Portoroz, Slovenia, 1998.
[13] Kalogirou S. ―The Potential of Solar Industrial Process Heat Applications‖. Applied Energy, Vol.76, pp.337– 61,2003
[14] Sunil.K.Amrutkar, Satyshree Ghodke, Dr. K. N. Patil. ―Solar Flat Plate Collector Analysis, IOSR Journal of Engineering (IOSRJEN), Vol. 2 Issue 2, ISSN: 2250- 3021, pp.207-213, Feb.2012
[15] K. Maddilety swamy, P. Venugopal, M.Ravichandra. ―Modeling of a Bucket Air Cooler by Using Solar Energy‖. International journal of Modern Engineering Research (IJMER), Vol. 4, Iss.10, ISSN: 2249–6645, pp. 20-33, Oct. 2014
[16] Ashish Agrawal, Neelesh Soni, Amit Agrawal. ―Performance Analysis of Solar Flat Plate Collector Using Tubes of Different Materials‖, International Journal of Emerging Trends in Engineering and Development, Vol.5, Issue 4, ISSN 2249-6149, pp. 458-472, Aug.- Sep. 2014
[17] Rajesh Brahmankar, Prof. S.S Pawar. ―Solar Flat Plate Collector Analysis, Global Journal of Multidisciplinary Studies, Vol. 3, No. 3, ISSN: - 2348-0459, Feb.2014
[18] Kalogirou SA. ―Thermal Performance, Economic and Environmental Life Cycle Analysis of Thermosiphon Solar Water Heater. Solar Energy, Vol.83, pp. 39–48, Jan 2009
[19] Taherian H, Rezania A, Sadeghi S, Ganji DD.―Experimental Validation of Dynamic Simulation of the Flat Plate Collector in a Closed Thermo syphon Solar Water Heater‖. Energy Convers Manage, Vol.52, pp.301– 307, 2011
[20] Manjunath M S, K. Vasudeva Karanth , N Yagnesh Sharma , ―Three Dimensional Numerical Analysis of Conjugate Heat Transfer for Enhancement of Thermal Performance using Finned Tubes in an Economical Unglazed Solar Flat Plate Collector. Proceedings of the World Congress on Engineering,Vol. III WCE 2011, , London, U.K. ISSN: 2078-0958, July 6 - 8, 2011
[21] Selmi, M., Al-Khawaja, M.J., and Marafia, A., ―Validation Of CFD Simulation For Flat Plate Solar Energy Collector‖, Renewable Energy,Vol. 33, pp. 383- 387, 2008
[22] Raj Thundil Karuppa R., Pavan P. and Reddy Rajeev D., ―Experimental Investigation of a New Solar Flat Plate Collector‖. Research Journal of Engineering Sciences, Vol. 1(4),), ISSN 2278 – 9472, pp. 1-8, 1-8 October 2012
[23] Mustafa, Ismail.N.R. ―Collectors Innovation to Increase Performance Solar Water Heater‖ IJRET: International Journal of Research in Engineering and Technology, Vol. 02 Issue: 09, ISSN: 2321-7308, pp. 464-470, Sep 2013
[24] Ashish N. Sarode, Atul A. Patil, Vijay H. Patil, ''A Critical Review on Low Temperature Solar Water Heater Collectors'', PRATIBHA: International Journal of Science, Spirituality, Business and Technology (IJSSBT), Vol. 3, No. 1, ISSN (Print) 2277—7261, PP.67- 70, December 2014.
[25] Atul A. Patil, Ashish N. Sarode and D. S. Deshmukh, - Experimental Investigation of an Innovative Flat Plate Solar Collector", Pratibha International Journal of science, Spirituality, Business and Technology (IJSSBT), Vol. 4, No. 1, ISSN (print) 2277- 7261, November 2015, pp. 13-17.
[26] Ashish N. Sarode, Atul A. Patil and Vijay H. Patil, "Experimental and Computational Fluid Dynamics Analysis of a New Flat Plate Solar collector", International Journal of Engineering Trends and Technology (IJETT), ISSN 2231- 5381, DOI:10.14445/22315 381/ IJE TT-ICGTETM-N4, PP.455–460, January 2016.
[27] Jazlan, Ahmad. (2014). Time Weighted Model Reduction of Flat Plate Solar Collectors.
[28] Deshmukh, M. S., & Shinde, S. S. (2021). Technology Involving Absorption Refrigeration Run by Solar Energy: A Review. Design Engineering, 1970-1980.