ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 5, Special Issue 1, February 2024

Development of Hybrid Solar Thermal System With Dish Concentrators and Fresnel Lens for Hot Water Generation

[1]Arunesh Verma,[2] Vardan Singh, [3]Arun Kumar Patel, [4]Amit Vishwakarma
[1]MTech Scholar, VIST Bhopal, India
[2]Assistant Professor, VIST Bhopal, India

Abstract:- A single thermal energy-based approach that has seen widespread commercialization is sunlight for water heating, owing to its excellent dependability and affordability in comparison to alternative approaches. Solar buyers, a tank for holding water, pipelines, and an additional heating device are among the parts of a system to heat water using sunlight that are typically present. The collection device or receiver, which is the main part of a solar heating system, transforms ultraviolet light into heat afterwards transfers this heat to a medium that is moving around it. In previous project a 4foot diameter parabolic solar collector for experimental testing in order to create a commercial water heating system for residential usage is designed and fabricated. After three sets of studies, with the device being focused exposed to the atmosphere and a water flow rate at 600 ML per second, we have seen a mean rise in temperature of 35 degrees Celsius over atmospheric. Second, we observed a mean heat 45 degrees Celsius higher than atmospheric at an average flow velocity of 600 ML per hour with the receiver at concentration concealed by a black box. Third, in a pump-provided system for 20L water, we noticed an average 46-degree centigrade rise in temperature over the course of an hour when the receiver was covered with a black box. The average temperature found at the receiver part was around 150 degree centigrade but we have not received this amount of thermal energy in useful cause as indicated in the results above. In current project a Fresnel lens of 12*8 inches is fixed at optimum height near focus of the dish and the radiations are intensified with it. Thermal energy generated is further received on same receiver and found increment in it.

Key words: **- concentrated solar energy, dish collector, Fresnel lens, receiver material, solar thermal, thermal efficiency.**

I. INTRODUCTION

One type of power is thermal energy from the sun, and there are various methods available to capture solar radiation and produce heat for use in different uses. Solar heating enthusiasts, which are made up of a mirror and a receiver, are used to transform sunlight from sunlight into heat energy. There are three categories for solar energy receivers: low, medium, and higher heat detectors. Collections use lenses or reflectors to focus sunlight. The three forms of radiation collectors include the parabola dish, bottom, and tower devices. Due to its lower area need, higher system efficiency, and concentrate ratio, the parabola collector has drawn the greatest attention in the area of solar energy generating research when compared with troughs and tower collecting. This kind works well in small- and medium-sized applications where the resultant temperatures are high.

A. Classification of Solar Collectors

A device that gathers sunlight, transforms it into thermal energy, and then transmits that warmth into a gas that is travelling past its recipient is called a collector for the sun (reflector and reception). Solar panels are necessary for the use of solar energy. There are two varieties of solar catchers that are outlined below.

- Non-concentrating solar collector
- Concentrating solar collector

Non-concentration types have the same roofing (the glass covering plate) and collection areas (level ratio of 1), which transfer sunlight to the collection area (absorbent area). Conversely, the ratio of concentrations in focusing readers can be up to 100 times higher than in non-concentrating (flat plate) readers. Non-concentrating or static collector can reach temperatures between 30 and 80 degrees Celsius since they are continuously positioned and do not follow the light (Kalogirou 2004). Concentrate collects are better suited for temperature ranges than non-concentrating collects.

B. Concentrating Solar Collectors

In this type of collectors the solar radiation reflected by the reflector surface are focused on to the smaller surface (absorber) area of the receiver, only the direct radiation are reflected and indirect radiation are not reflected by reflector. The percentage of concentration of the collection system can be described as the proportion of the reflector area compared to the absorption surface (absorbent) of the receiver, which determines the range of temperatures that can be attained.

C. Types of Concentrating Solar Collectors

There Are Four Basic Types of Concentrating Collector

1. Collector for parabolic dishes
2. A collector for parabolic troughs
3. Reflector/linear Fresnel lens
4. Receiver for the central tower

D. Parabolic Dish Collector

These reflecting surfaces, that are dish-shaped parabola reflections, are used for focusing and focusing sunlight onto an antenna that is placed above the mirror. It functions by directing the sun's Directly Normal Radiation exposure (DNI) onto the receiver's hollow absorption region using a dish-shaped covering which transfer the absorbed heat to the heat transfer fluid. The possible temperature ranges of heat transfer fluid is100 to 1500^{o}C (BarIiv *et al.*2011), with the concentration ratio range of 100 to 1000. More number of setups is

ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 5, Special Issue 1, February 2024

connected in series when this type of collectors is used in larger power plants.

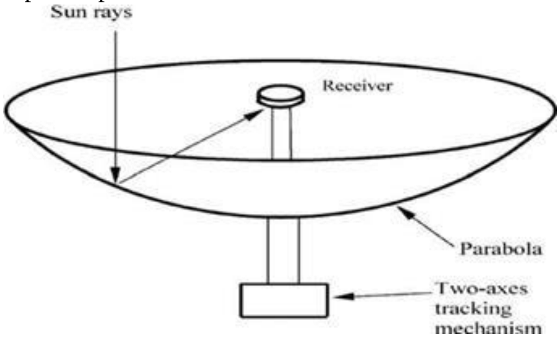


Fig.1. Parabolic Dish Collector

1. Components of Parabolic Dish Collector

A parabolic signal collectors resembles a big satellites dish in physical appearance, but it has absorbers at the centre of gravity and reflections that resemble mirrors. A double axis sun sensor is used. A computing device is used in an upside-down dish arrangement to monitor the sun and focus its rays onto an absorber, or absorption area, of the receiving device that is situated at the focal point, which is in the middle of the reflector's surface. The receiver absorbs the reflected solar energy and transfers it into the HTF, which is circulated inside the receiver. Collector system can attain a temperature of about 1500ºC. The main components of parabolic dish collector system are dish reflector, receiver, support structure and tracking system.

Fig.2. Parabolic dish collector system

2. DISH REFLECTOR

Sunlight is reflected and concentrated by a parabolic antenna reflectors towards the cavity reception situated at the reception's focus. The reflector is made upon by the parabolic dish shaped mirrors or polished metal sheets with optimum reflectivity. The glass mirrors with reflective silver layercoating on the back side of the glass is used as the reflector. A special multilayer paint coating below the silver layer protects the silver and to ensurethe better performance of the reflector.

3. Cavity Receiver

Cavity receivers are either single or multi cavity type. It absorbs or receives the solar radiations and transfers its energy into the heat transfer fluid. There are two types of receivers: tubular and volumetric. Tubular receivers are used when liquid HTF such as water, molten salt thermic oil and liquid sodium are used. The volumetric receiver's are used when air or super critical CO_2 are used as HTF. The type of receiver used is also depends upon power cycle (Rankine or Brayton) used in the system.

4. Supporting Structure

The reflecting mirror's steel-supported frame gives the collector part the rigidity that it needs for withstanding wind stresses. In order to guarantee precise and efficient concentration of sunlight into the absorbers the cavity, the primary focus will be on reducing the total weight of the supporting framework and limiting the bending of the framework.

5. Tracking Mechanism

A dish's monitoring system typically tracks the sun throughout the day by aligning it on an east-west plane. It also features a system that allows it to be adjusted to reflect the sun's periodic locations. The tracking mechanism operated mechanically and controlled by computer programming. The computer control tracking system gives high accuracy in tracking and give higher efficiency.

E. Domestic Hot Water and Its Need

Everywhere in the country, demand for hot bath water varies enormously. When it's cold outside, a medium-sized family needs 85 liters of hot water each day to accomplish things like wash dishes, soak grains, and cook. Hot water is typically utilized around 68 degrees centigrade, according to research. Greentech Knowledge Solutions (P) Ltd New Delhi conducted a survey to find out how often people use hot water. According to these statistics, households used hot water for an average of six months out of the year. Climate change and human behavior have an impact on hot water usage, according to the results of a main survey (which is influenced by culture and traditional practices).

According to the results of the survey, there is a large demand for hot bathing water outside of cold and mild climate regions (>8 months of the year). Maharashtra, Kerala and Tamil Nadu households report using hot water for more than eight months of the year, despite the warm temperature. The use of hot water is common in a wide range of businesses, from dairy processing to soap manufacture to chemical manufacturing to hotels.

There are several sources of heat generation, such as: There are several ways to heat fluid, but the most popular ones include electric eruptions, burning wood stoves, and fluid fuel. Consider the costs of keeping it running while selecting a mode. Moreover, the flue gases that are created damage the natural world.

As previously said, solar water heating can be an important approach to promote free energy systems while also operating at a low cost per unit of used energy. The study found that installing a solar water heater pays for itself in fuel savings within a year, even if the upfront cost is higher.

ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 5, Special Issue 1, February 2024

II. LITERATURE REVIEW

Anurag arpan, Vardan Singh have designed and fabricated a 4 foot diameter parabolic solar collector for experimental testing in order to create a commercial water heating system for residential usage. After three sets of studies, they've discovered an average temperature increase of 35 degrees centigrade above ambient while the receiver is focused open to the air and the incoming water flow rate is 600 ML per Minute. Furthermore, they discovered a typical heat 45 degrees Celsius higher than atmospheric at an average flow velocity of 600 ML every minute with an instrument at concentration covered by a black box. Third, they observed an average 46-degree Celsius temperature increase over a period of thirty minutes within a pump-provided system containing 20L of fluid when the transmitter was shielded with a black box.

***Nawar Saif* Al-Dohani et al** have created a prototype power home using Fresnel lenses that can produce energy. The vapour was produced by heating the melting salt in an exchanger that transfers heat using the concentrated heat from a Diffraction lens. The steam engine that was connected to the power source was rotated by the steam that was produced. Maximum output of 30 W could be produced during the work. Furthermore, a comparison analysis was conducted to comprehend the functioning of the Fresnel juggernaut with respect to both chemicals and heat exchanger composites. Ultimately, their research provided insightful information about the application of Fresnel prisms in Oman's energy generation process.

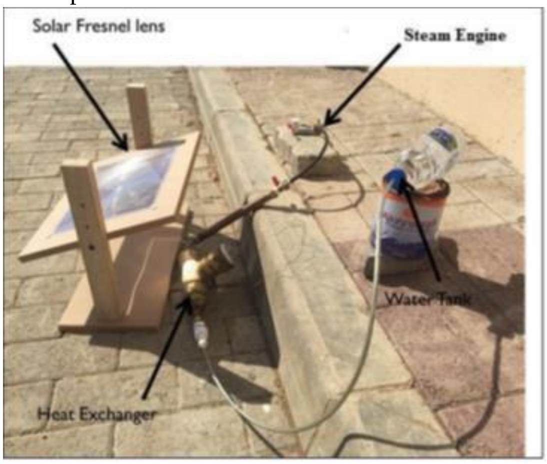


Fig.3. Example of Solar hater

Abdukkarim Hamza El-Ladan et al The initial data gathered indicates that the Fourier lens concentrate has a lot to offer as a compact independent device for producing energy and heating with high yields that is affordable for households and simple to manufacture. Changes are being made to create a simpler, more effective system with simpler optics that will lower total costs and consequently cut down on the use of fossil fuels, which lowers CO2 emissions. Given its higher stalemate the temperature subsequent generation's capability contrasted to a parabolic valley of the identical geometric scale, it is moments to give Freckle lens methods an opportunity for possible incorporation into a solar heat concentrating device system for electricity as well as heat generation. To date, no completely thermal facilities using Fresnel optics have been reported to be in functioning as commercially available electricity plants. According to the initial research results, the maximum plateau temperatures measured at the receiving surfaces of the 50 cm circumference 3 mm thick Schneider lens, the 50 cm opening parabola trough, and the 25 cm 3 mm solid Schneider lens under no load were around 170°C, 900°C, and 250°C, respectfully. This shows that the Fresco lens technological advances are very exciting. It is possible to actualize a tiny standalone unit with excellent performance for both preparing food and generating electricity, and it is simple to re-fabricate at less money. Modifications continue to make the system a reality that will lower overall costs and reduce the use of fossil fuels, which in turn reduces CO2 emissions as a demonstration prototype,

J.Macedo-Valencia et al outlined the phases involved in the design, development, and evaluation of a water warming device called the parabolic trough collector (PTC). In the design phase, the 0.5 m broad by 0.95 m tall conical window had been taken into consideration. Computer-aided design and manufacturing were used in the creation of the design. To determine the thermal performance of the parabolic trough collector, the results of the evaluation showed that at a flow rate of 0.200 L/min and a solar radiation of 783 W/m2, the maximum output temperature was 47.3 °C.

III. PROBLEM FORMULATION AND OBJECTIVE

In previous project (our base paper) a 4 foot diameter parabolic solar collector for experimental testing in order to create a commercial water heating system for residential usage was designed and fabricated. The sample water had been raised to 45°C above ambient after multiple sets of studies, and the total velocity was 600 ml/min. However, the average the climate at the receiving part was only 150°C, indicating that we had not actually received this much warmth for any useful purpose.

Fig.4. Previous experimental model of dish collector and receiver system.

ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 5, Special Issue 1, February 2024

In current project we shall place a Fresnel lens at optimum distance near focus so that the heat produced through solar radiations shall be more intensified and shall get better results, so that the existing water heating systems shall be replaced by this new commercial model.

IV. CONSTRUCTION OF MODEL

So as to satisfy the objective we have developed model in two stages.

A. The concentrator and receiver

Fig.5. Proposed construction of setup

The construction of setup is done in following steps and shown in figure. 5

The positional and the actual experimental setup is clearly shown in the Figure 5.

1. A 1200 mm diameter dish with depth of 240 mm is made of MS sheet.
2. Mirrors are pasted by adhesive on its surface
3. The parabolic dish is mounted on a structure so as to find necessary angular moment and able to be adjusted in different angles incident to sun.
4. Receiver coil of 300 * 240 mm is made by a copper tube of 12mm diameter and placed at the focus of dish.

B. The Fresnel lens

a) A rectangular Fresnel lens of glass

Fig.6. A Rectangular Fresnel lens of glass

A rectangular Fresnel lens of glass of 240*300 mm is used in this work as shown in the figure which itself is producing temperature of 107.5 C in just one minute time. Now the lens is kept at focus of the dish and receiver coil nearer to focus of lens. Water tank connected with the receiver is now allowed to pass and the results are viewed.

V. EXPERIMENTATION AND OBSERVATION

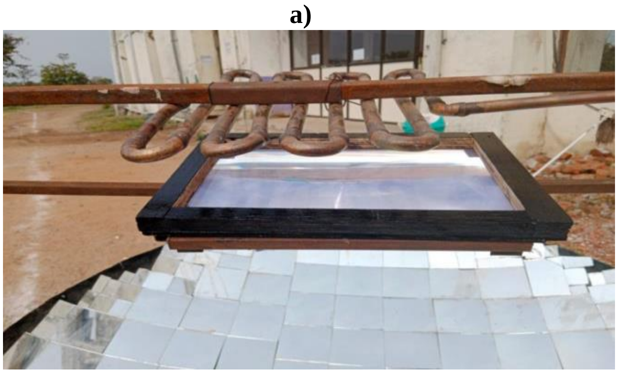
The experimentation shall be done in two set of events.

Event I: - Receiver at focus open in air (without lens)

Note: -

- *All temperature readings are taken in degree Celsius.*
- *For both events a submersible pump is put in tank of 10 L and water is circulated and readings are taken for half hour*

a)



b)

ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 5, Special Issue 1, February 2024

Event I Observation date 01.03.2022

S.NO.	TIME	AMBIENT TEMPRATURE	TEMPERATURE OF RECEIVER	INLET TEMPRATURE	OUT LET WATER TEMPERATURE	TEMPERATURE DIFFERENCE
1	10:00am	32	35	22	25	3
2	10:10am	32	38	25	31	6
3	10:15am	32	43	31	38	7
4	10:20am	32.5	49	38	44	6
5	10:25am	32.7	54	44	47	3
6	10:30pm	33	63	47	55	8

Event I Observation date 02.03.2022

S.NO.	TIME	AMBIENT TEMPRATURE	TEMPERATURE OF RECEIVER	INLET TEMPRATURE	OUT LET WATER TEMPERATURE	TEMPERATURE DIFFERENCE
1	10:00am	30	34	22	24	2
2	10:10am	30	40	24	30	6
3	10:15am	31	56	30	39	9
4	10:20am	32	58	39	43	4
5	10:25am	32.5	63	43	45	2
6	10:30pm	33	69	45	52	7

Event I Observation date 03.03.2022

S.NO.	TIME	AMBIENT TEMPRATURE	TEMPERATURE OF RECEIVER	INLET TEMPRATURE	OUT LET WATER TEMPERATURE	TEMPERATURE DIFFERENCE
1	10:00am	28	33	22	26	4
2	10:10am	28	38	26	28	2
3	10:15am	29	47	28	33	5
4	10:20am	31	51	33	36	3
5	10:25am	31.6	56	36	40	4
6	10:30pm	32.1	67	40	44	4

The average rise in temperature found is 28 degree centigrade in this event.

Event II :- Receiver at focus of lens and open in air

Event II Observation date 04.03.2022

S.NO.	TIME	AMBIENT TEMPRATURE	TEMPERATURE OF RECEIVER	INLET TEMPRATURE	OUT LET WATER TEMPERATURE	TEMPERATURE DIFFERENCE
1	10:00am	28	37	22	25	3
2	10:10am	28.7	41	25	33	8
3	10:15am	29.1	48	33	40	7
4	10:20am	30	52	40	48	8
5	10:25am	32	59	48	55	7
6	10:30pm	32.8	67	55	64	9

Event II Observation date 05.03.2022

S.NO.	TIME	AMBIENT TEMPRATURE	TEMPERATURE OF RECEIVER	INLET TEMPRATURE	OUT LET WATER TEMPERATURE	TEMPERATURE DIFFERENCE
1	10:00am	31	33	22	25	3
2	10:10am	31	39	25	31	6
3	10:15am	31.6	46	31	39	8
4	10:20am	32	53	39	45	6
5	10:25am	32.3	62	45	52	7
6	10:30pm	32.8	71	52	60	8

Event II Observation date 06.03.2022

S.NO.	TIME	AMBIENT TEMPRATURE	TEMPERATURE OF RECEIVER	INLET TEMPRATURE	OUT LET WATER TEMPERATURE	TEMPERATURE DIFFERENCE
1	10:00am	32	33	22	27	5
2	10:10am	32.2	40	27	31	4
3	10:15am	32.8	51	31	39	8
4	10:20am	33	59	39	48	9
5	10:25am	33.6	66	48	55	7
6	10:30pm	34	73	55	63	8

The average rise in temperature found is 40 degree centigrade in this event

VI. CONCLUSION

This work's research demonstrates how well conical solar panels operate. A four-foot-diameter hyperbolic solar array with a lens made of Fresnel is planned and built for testing purposes in order to create an industrial freshwater heat pump for residential usage.

The trials are divided into two sets of occurrences. In the first, we observed an average increase in temperature of 28 degrees Celsius in a half-hour when we used a pump-provided system for ten liters of drinking water at the focus. In thirty minutes, we saw a median increase in temperature of forty degrees Celsius when we used a pump-provided system containing 10L of fluid and a receiver at the focus on both the lens and the dish.

According to evaluation, the need for sun water and the amount of unusable roof space that can be used to put solar panels should be taken into consideration when designing a solar hot water systems. Economic evaluation shows that sunlight to heat water are far more appealing than gas and electrical heaters, hence this approach might be seen as an innovative business model that could replace the water warming methods that are now in use.

REFERENCES

[1]. Anurag Arpan, Arvind gupta, Vardan Singh “Development of Parabolic Disc Solar Thermal Collectors for Hot Water Generation” Irjet e-ISSN: 2395-0056 Volume: 08 Issue: 05 | May 2021.

[2]. Nawar Saif Al-Dohani1, Nagaraj S. Nayak1*, Anarghya A.2 and Abhishek V. N.3 “Development of Power house Using Fresnel lens” MATEC Web of Conferences 144, 04006 (2018).

[3]. J.Macedo-Valenciaa, J. Ramírez-Ávilaa, R. Acostaa, O.A. Jaramillob and J.OAguilara “Design, construction and evaluation of parabolic trough collector as demonstrative prototype”, 2013 ISES Solar World Congress.

[4]. Anan Ashrabi Anannob, Mahadi Hasan Masuda, Peter Dabnichkia, Asif Ahmedb “Design and numerical analysis of a hybrid geothermal PCM flat plate solar collector dryer for developing countries” Solar Energy 196 (2020) 270–286.

[5]. Aishwarya Sharma, Namish Mehta and Nilesh Diwakar “Study of Solar System with Possible Modification to Increase the Efficiency of PV Panel.” International Journal

of Engineering and Management Research, Page Number: 20-24 Volume-8, Issue-1 February 2018.

[6]. Soroush Dabiri, Mohammad Fazel Rahimi"Basic introduction of solar collectors and energy and exergy analysis of a heliostat plant" The 3rd International Conference and Exhibition on Solar Energy ICESE-2016 5-6 September, 2016, University of Tehran, Tehran, Iran.

[7]. I.Zeghib A, A.Chaker"Simulation of a solar domestic water heating system" Energy Procedia 6 (2011).

[8]. Fernández-García, Zarza. E, Valenzuela. L, Pérez. M. "Parabolic-trough solar collectors and their application" .Renewable and Sustainable Energy; 2009.

[9]. J.Macedo-Valenciaa J.Ramírez- Ávilaa "Design, Construction and Evaluation of Parabolic Trough Collector as Demonstrative Prototype Energy" Procedia Volume 57, 2014.

[10]. Kalogirou. S, parabolic trough collectors for industrial process heat in Cyprus. Energy; 2002.

[11]. Garg, H.P., Adhikari, R.S. "Conventional hybrid Photovoltaic/Thermal (PV/T) air heating collectors: steady state simulation". Renewable Energy, 1997.

[12]. Dubey, S., Sandhu, G.S., Tiwari, G.N. "Analytical expression for electrical efficiency of PV/T hybrid air collector". Applied Energy, 2009.

[13]. Tiwari, A., Sodha, M.S., Chandra A., Joshi J.C. "Performance evaluation of Photovoltaic Thermal solar air collector for composite climate of india". Solar Energy Materials and Solar Cells. 2006.

[14]. Joshi, A.S., Tiwari, A., Tiwari, G.N., Dincer, I., Reddy, B.V. "Performance evaluation of a hybrid photovoltaic thermal (PV/T) (glass-to-glass) system". International Journal of Thermal Science. 2009.

[15]. Touni, J.K., Tripanagnostopoulos, Y., "Air cooled PV/T solar collectors with low cost performance improvements". Solar energy.