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

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***Abstract:-* - The only solar energy-based method that has found broad commercialization is solar-powered water heating because of its great dependability and cost in comparison to other options. Among other components, a solar water heater usually includes pipes, an auxiliary heating unit, a water storage tank, and solar collectors. The main component of a solar heating system, a collector or receiver, converts sunlight into heat and distributes that heat to a fluid passing through it. In a prior effort, a 4 foot circular parabolic solar collector was built and constructed for testing purposes in order to develop an industrial water-based heating system for domestic use. Following three sets of tests, we discovered that the average temperature increases by 35 degrees Celsius above ambient when the receiver is left open to the air and the incoming water flow is 600 ML per minute. Second, we observed an average temperature 45 degrees Celsius higher than ambient at a mass flow rate of 600 ML per minute with a receiver at focus covered with a black box. Third, when the receiver was enclosed in a black box, we observed an average rise in temperature of 46 degree Celsius over a period of an hour in a pump-provided system that contained 20L of water. The average temperature at the receiver portion was roughly 150 degrees Celsius, but the results above demonstrate that we have not benefited from this amount of thermal energy. In the current project, a 12-by-8-inch Fresnel lens is mounted at the ideal height close to the dish's focus, intensifying the radiation. The same receiver receives the additional thermal energy produced and detects an increase in it.**

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

1 Introduction

Solar thermal energy is one form of energy, and there are a number of devices that can absorb solar radiation and convert it into thermal energy for a variety of applications. Solar thermal collectors convert solar energy from sunlight into thermal energy. They are composed of a reflector and a receiver. Solar thermal collectors fall into three different categories: low, medium, and high temperature collectors. The collectors focus sunlight using mirrors or lenses.

The parabolic dish, trough and tower systems are the types ofhigh temperature collectors. The parabolic dish collector attracted the greatest attention in the area of solar thermal power generating research because it required less space and had a greater concentration ratio and system efficiency than trough and tower collectors. This kind works best in small to medium-sized applications with high heat output.

A. Classification of Solar Collectors

The solar collector (reflector and receiver) is a device that gathers solar radiation, transforms it into thermal energy, and then transfers that energy to a fluid passing through the receiver. Utilizing solar energy requires solar collectors. Solar collectors come in two kinds, which are explained below.

- Non-concentrating solar collector
- Concentrating solar collector

The glazing (glass cover plate) area in the non-concentration type transmits solar energy to the collected surface (absorber area), and the collecting area is the same (concentration ratio equals 1). Conversely, the concentration ratio in concentrating collectors can be hundreds of times higher than in non-concentrating (flat plate) collectors. Temperatures between 30 and 80 degrees Celsius can be achieved using stationary or non-concentrating collectors that are firmly fixed in place and do not follow the sun (Kalogirou 2004). Compared to non-concentrating collectors, concentrating collectors perform better in greater temperature ranges.

B. Concentrating Solar Collectors

The indirect radiation is not reflected by the reflector; only direct radiation is. The solar energy mirrored on the reflector surface is concentrated by this type of collector onto the absorber, which is the recipient's smaller surface area. The temperature range attained is determined by the concentration ratio of the collector system, which is the ratio of the reflector area to the receiver's absorbing surface (absorber).

Types Of Concentrating Solar Collectors

There Are Four Basic Types of Concentrating Collector

1. .Parabolic dish collector
2. Parabolic trough collector
3. Linear Fresnel lens/ reflector
4. Central tower receiver

C. Parabolic Dish Collector

The sun's rays are focused and concentrated onto a receiver that is positioned above the reflector using these dish-shaped parabolic mirrors. It transfers the heat that is absorbed to the heat transfer fluid by directing the sun's Direct Normal Irradiations (DNI) onto a cavity absorber area of the receiver using a dish-shaped surface. The possible temperature ranges of heat transfer fluid is100 to 1500ºC (BarIiv *et al.*2011), with the concentration ratiorange of 100 to 1000. When this type of collector is employed in larger power plants, more installations are connected in series.

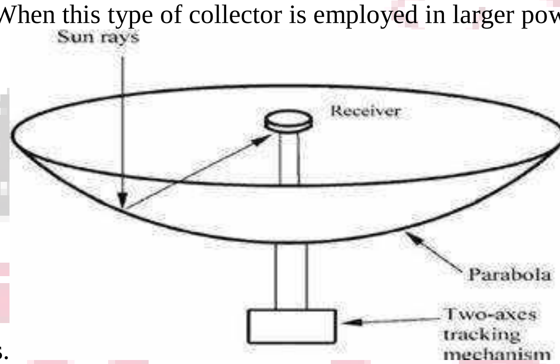

Figure 1. Parabolic Dish Collector

Components Of Parabolic Dish Collector

Similar in appearance to a big satellite dish, a parabolic dish collector features an absorber at the focus point and reflectors that resemble mirrors. A dual axis sun tracker is used. Using a computer to track the sun, a parabolic dish system directs the sun's rays onto the receiver's absorber, which is situated at its center in front of the reflector. The reflecting solar energy enters the HTF and circulates throughout the receiver after being taken in by it. A temperature of roughly 1500ºC can be reached with the collector system. The tracking system, supporting structure, receiver, and dish reflector are the primary parts of the parabolic dish collection system.

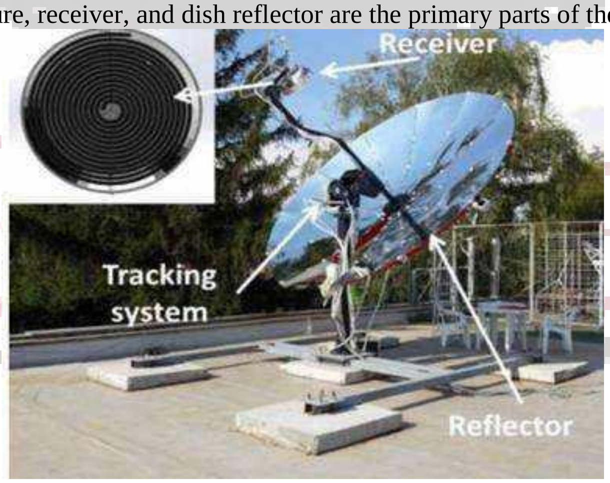

Figure 2 Parabolic dish collector system

1. Dish Reflector

The sun's rays are reflected and focused onto the cavity receiver, which is situated at the receiver's focal point, by a parabolic dish reflector. Mirrors in the shape of a parabolic dish or sheets of polished metal with the highest reflectivity are used to make the reflector. Glass mirrors that have a layer of reflective silver applied to the rear of the glass serve as reflectors. Below the silver layer, a unique layered paint coating preserves the silver and guarantees improved reflector performance.

2. Cavity Receiver

There are two types of cavity receivers: single and multi-cavity. It transmits the energy of the solar radiation into the heat transmission fluid after absorbing or receiving it. Receivers come in two varieties: volumetric and tubular. Tubular receivers are used when using liquid HTF, such as water, molten salt thermic oil, or liquid sodium. When using air or supercritical CO2 as HTF, volumetric receivers are employed. The type of receiver used is also depends upon power cycle (Rankine or Brayton) used in the system.

3. Supporting Structure

The collector is mechanically strengthened to withstand wind loads by the steel-supported structure in the rear of the reflector mirror. The main goal is to reduce the weight of the support structure and the distortion of the structure in order to provide accurate and effective focus of the solar radiation to the absorbers cavity.

4. Tracking Mechanism

In order to monitor the sun during the day, a dish's tracking mechanism is often oriented on an east-west axis. It also features a device to adjust the track for the sun's seasonal locations. Computer programming was used to regulate the mechanical tracking mechanism. The computer-controlled tracking system provides increased efficiency and tracking precision.

D. Domestic Hot Water and Its Need:

The collector system can reach a temperature of about 1500ºC. The main components in the parabolic dish collecting system are the tracking system, receiver, dish reflector, and supporting structure. Research indicates that hot water is usually used at 68 degrees Celsius. To find out how frequently people use hot water, Greentech Knowledge Solutions (P) Ltd New Delhi performed a survey. These figures show that families utilized hot water for six months of the year on average. A major survey found that human behavior and climate change affect the amount of hot water used (which is impacted by cultural and traditional customs).

The survey's findings indicate that, outside of areas with cold and moderate climates (more than eight months of the year), there is an immense need for hot bathing water. Despite the warm weather, households in Tamil Nadu, Kerala, and Maharashtra claim to utilize hot water for approximately eight months of the year. Hot water is frequently used in a variety of industries, including hotels, soap production, chemical manufacturing, and dairy processing.

Heat comes from a variety of sources, including: Although there are other methods for heating water, electric geysers, wood combustion, and liquid fuel are the most widely used. When deciding on a mode, keep in mind the costs of both operation and maintenance. Furthermore, the ecosystem is harmed by the produced flue gases.

Solar water heating, as mentioned before, can be a significant strategy to support free energy systems and run at an affordable cost per unit of energy used. According to the study, even though the initial cost is higher, installing a solar-powered water heater compensates for its own savings on fuel within a year.

2 LITERATURE REVIEW

Anurag arpan, Vardan Singh have created a commercial water heating system for home use by designing and building a 4 foot diameter parabolic solar collector for trial testing. After conducting three sets of experiments, they found that when the receiver is aimed at the air and the incoming water flow rate is 600 ML per minute, the average temperature rises by 35 degrees Celsius over ambient. Second, they discovered an average temperature 45 degrees Celsius greater than ambient at a mass flow rate of 600 ML a minute with a receiver at center enclosed with a black box. Third, while the receiver was enclosed with a black box, they observed an average temperature increase of 46 degrees Celsius over a period of an hour in a pump-provided system that contained 20L of water.

***Nawar Saif* Al-Dohani et al** have created an early Fresnel lens power house designed to produce electricity. The concentrated heat via a Fresnel lens was used to heat the molten salt in a heat exchanger, producing the steam. The steam generated powered a steam engine that was connected to a generator. A maximum of 30 W of power was generated during the work. In order to comprehend the functioning of the Fresnel powerhouse, a comparative analysis of heat exchanger materials and solar salts was also conducted. Overall, their study provided insightful information about Oman's use of Fresnel lenses to generate power.

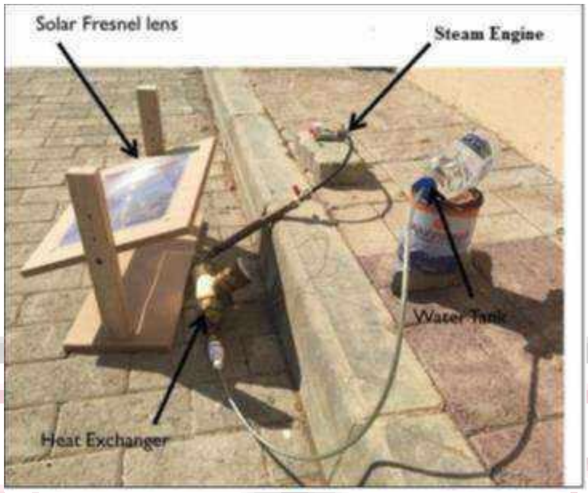

Figure 3 example of Solar heater

Abdukkarim Hamza El-Ladan et al According to preliminary data, the Fresnel lens concentrator offers a lot of potential as a compact, standalone device that can be manufactured at a low cost and distributed to local populations. It can be utilized for both cooking and highly efficient energy generation. A superior and more effective system with simple optics is being developed through ongoing changes. This will reduce the overall cost and, as a result, the use of fossil fuels, ultimately helping to reduce CO2 emissions. There are currently no known full-scale Fresnel lens thermal systems operating as commercial power plants. Given that Fresnel lens technologies have a higher capacity to generate stagnation temperature than a parabolic channel of the same geometrical magnitude, it is time to consider their potential integration into solar thermal concentrator systems for the production of both heat and electricity. The early experimental findings showed that the highest stagnation temperature without any load was roughly 170°C, 900°C, and 250°C at the receivers of the 50cm diameter 3mm thick Fresnel lens, the 50cm aperture parabolic trough, and the 25cm 3mm thick Fresnel lens. This demonstrates how promising Fresnel lens technology is. It is possible to realize a small standalone system that is highly efficient for both cooking and generating electricity. Changes are being made in order to make this structure a reality, and it is also possible to re-fabricate at a reduced cost. By doing this, the overall cost will be decreased, which will decrease the use of fossil fuels and, consequently, CO2 emissions.
As a demonstration prototype,

J.Macedo-Valencia etal described the steps needed to design, model, and assess a water heating parabolic trough collector (PTC). The design process took into consideration the parabolic aperture, which measures 0.5 m in width and 0.95 m in length. The design was created using computer-aided design and manufacturing. The evaluation's findings demonstrated that the highest output temperature of the parabolic trough collector was 47.3 °C at a flow rate of 0.200 L/min and a solar radiation of 783 W/m2.

3. Problem Formulation And Objective: -Problem:-

A 4 foot diameter parabolic solar collector was designed and built for experimental testing in a prior project (our basis paper) to develop a commercial water heating system for residential use. The average temperature at the receiver portion was about 150 degrees Celsius, but after multiple sets of experiments, the water was heated to 45 degrees Celsius above room temperature and the mass flow rate was 600 milliliters per minute. However, as the results above show, we are not getting that much of thermal energy in a useful way.

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

Objective:-

In order to improve the heat generated by solar radiation and replace the current water heating systems with this new commercial model, we will position a Fresnel lens at the ideal distance close to focus in the current project.

4. Construction of Model

We have created the model in two steps in order to meet the goal.

The concentrator and receiver

Figure 5 Proposed construction of setup

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

1. A 240 mm deep dish with a 1200 mm diameter is constructed from MS sheet.
2. Mirrors are adhered to its surface using glue.
3. The parabolic dish can be adjusted at various angles incident to the sun and is fixed to a structure to determine the required angular moment.
4. A copper tube with a 12 mm diameter is used to create a 300 * 240 mm receiver coil, which is positioned at the dish's center.

The Fresnel lens

As can be seen in the picture, this piece uses a rectangular Fresnel lens constructed of glass that measures 240 by 300 mm. It produces a temperature of 107.5 C in less than a minute. The lens is now maintained at the dish's focus, while the receiver coil is brought closer to the lens's focus. The receiver-connected water tank is now free to pass, and the outcomes are seen.

a) A rectangular Fresnel lens of glass

Figure 6 A rectangular Fresnel lens of glass

1. EXPERIMENTATION AND OBSERVATION

Two sets of occurrences will be used for the experiment.

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

- *Degree Celsius is used for all temperature readings.*
- *For both occasions, a submersible pump is inserted into a 10-liter tank, water is pumped, and measurements are made for 30 minutes.*

a)

b)

Event I Observation date 01.03.2022

Event I Observation date 02.03.2022

S.NO.	TIME	AMBIENT TEMPRATUR E	TEMPERATUR E OF RECEIVER	INLET TEMPRATUR E	OUT LET WATER TEMPERATUR E	TEMPERATUR E 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 TEMPRATUR E	TEMPERATUR E OF RECEIVER	INLET TEMPRATUR E	OUT LET WATER TEMPERATUR E	TEMPERATUR E 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 temperature rose by 28 degrees Celsius during this event.

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

Event II Observation date 04.03.2022

S.NO.	TIME	AMBIENT TEMPRATUR E	TEMPERATUR E OF RECEIVER	INLET TEMPRATUR E	OUT LET WATER TEMPERATUR E	TEMPERATUR E 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 TEMPRATUR E	TEMPERATUR E OF RECEIVER	INLET TEMPRATUR E	OUT LET WATER TEMPERATUR E	TEMPERATUR E 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 temperature rose by an average of 40 degrees Celsius during this event.

Conclusion

This work's experiments demonstrate the effectiveness of parabolic solar collectors. To build an industrial water heating system for domestic use, a four-foot-diameter parabolic collector for solar energy with a Fresnel lens is conceived and built for experimental testing.

Two sets of experiments are conducted. The first involves a receiver at focus that provides a pump system for 10L of water. Over the course of 30 minutes, we observed an average temperature increase of 28 degrees Celsius. Second, we observed an average temperature increase of 40 degrees Celsius over the course of 30 minutes when the receiver was placed at the focus of both the lens and the dish, and a pump was supplied for 10L of water.

Analysis indicates that while constructing a solar water heating system, consideration should be given to the total amount of roof area that may be utilized for the installation of solar collectors as well as the need for sun water. This model might be considered as an innovative business model to replace current water heating systems because economic analysis shows that solar heating systems for water are considerably more appealing than electric and gas heaters.

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