Performance Evaluation and Utilization on a Thermal Storage Type Solar Cooker for High-Temperature Cooking in Composite Climate

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Abstract

This paper presents a Solar thermal storage type cooker in composite climate in and its utilization of high-temperature cooking process like frying, roasting, and baking using solar energy. In this paper, an experimental setup is fabricated a solar thermal storage cooker using a parabolic type solar concentrator. It works as a thermal energy storage container with the help of solar energy and the use of Phase Changing Material (PCM). This PCM material is known as a Nanofluid and this Nanofluid increases the temperature. On this setup, a parabolic dish concentrator is used as a reflector and it reflects the solar radiation on the cupper cylinder bottom surface. It is used as a boiler. It is fill up the water with the PCM material and it is fitted with a Thermal storage type cooking vessel. When the solar radiation collects on the solar collector and focuses on the receiver then the receiver increases the water temperature than the hot water supply in the surrounding cooking vessel. This vessel heats up and use various type high-temperature cooking process. At current Nanofluids are predictable to excellent heat transmission properties as relate to the conventional heat transmission fluids. Nanofluids are deferments of metallic or non-metallic Nanoparticles like copper, aluminium-silicon, alumina (Al_2O_3) in a base fluid. On this Setup it uses alumina (Al_2O_3) as a Nanofluid. The thermal storage type cooker is made puff insulated MS container. And it is use in indoor Kitchen. It is also properly stored in 268^{o}Cin approx. 90 min. Potato chips frying 160^o C -180^{o}C temperature is easy and rice cooked with fry 140^o C -150^{o}C taking 15min in one time.

Keywords: Solar cooker, parabolic dish concentrator, High temperature cooking Thermal energy storage, Phase change material.

- ## Introduction

It is a major part of the total energy consumed in cooking. Current scenario in village, 95% energy consumed for cooking. They are used as coal, kerosene, cooking gas, firewood, and dung for the cooking process. Approx. half of the world's population burn wood or dried dung to cook food. Woodcut for cooking purposes and these results contribute to the 16 million hectares (approx.) of forest destroyed annually. People are not safe to indoor air pollution as a result of burning solid fuels for cooking and heating. About 1.4 billion people do not have access to clean drinking water. So, on a year 1.5 million children die because of un-boiled drinking water. Cooking is an important part of every household women in this world. So, need of us a large amount of cooking energy. They fulfil their need for energy by burn solid fuel and cooking gas. But these are sort amount available in India. But above all cooking fuel is increasing smoke and harmful gases in the kitchen. So, the air pollution is increasing. This result health problem is increase. Now days mostly they are move to LPG for cooking process in rural areas. And know that LPG is a fossil fuel and it contributes to global warming. It is an essential source of renewable energy. It is also a saving of firewood and fossil fuels for the cooking process. It is another good advantage of solar cooking it is not any smoke problem in the kitchen. So, no any health effect and no energy cost. Solar cooker cannot burn cooking food so does not have to be stirred or watched. Various types solar cooker available in India like Figure 1 are shown its.

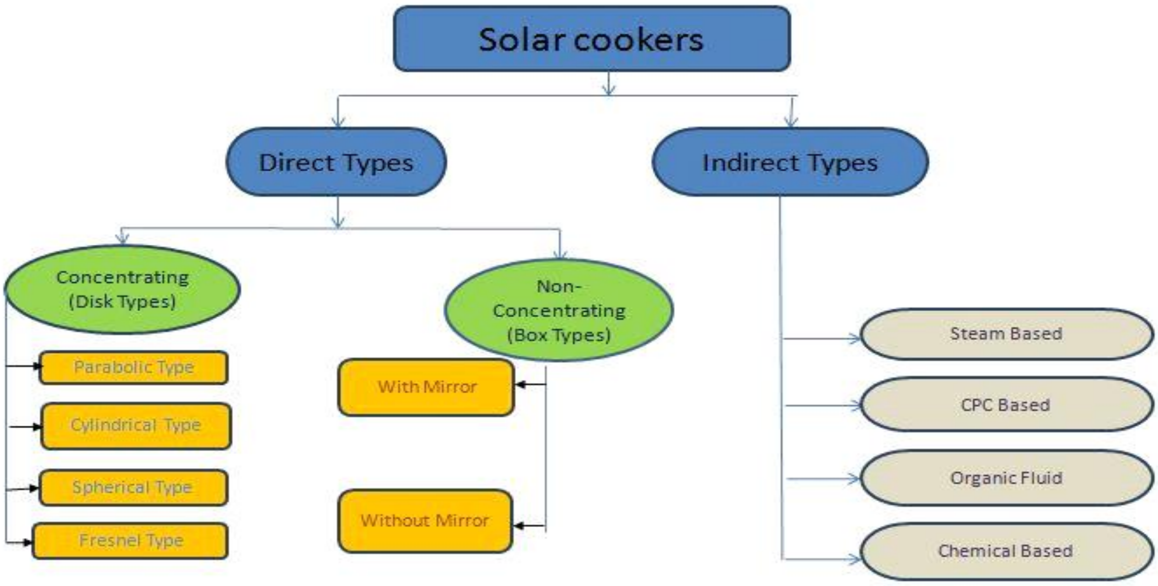

Figure 1: Types of Solar Cookers

Now day's high temperature solar thermal storage is mostly used in hot water storage. But in this setup, it's used as a high-temperature cooking application.

- **Nano Fluids in Solar Energy**

In this paper a solar thermal storage use as a solar thermal storage cooker. Also, discuss the Nanofluid are used as a PCM. So, a small discus about the Nano Fluid and its important role in solar energy the usage of Nanofluids for the devices like solar collectors as an operational medium is a relatively an innovative idea. To recover the physical properties for improving direct solar Collectors, various studies have to be approved out. As solar power is willingly available, researchers are emerging the various means to make effective use of this vitality. Nanofluids are transfer the latent heat on fluids with enhanced thermophysical properties and heat transmission performance can be applied in many devices for healthier performances (i.e., energy, heat Transfer, and other performances).

Nanoparticles deliver the following possible benefits in solar power plants

- The very minor size of the particles preferably lets them to permit through pumps without adverse effects. Nanofluids can engross energy directly--- hopping intermediate heat transmission steps.
- The Nanofluids have great preoccupation in the solar range and low emittance in the infrared).

A more unchanging receiver temperature can be reached inside the collector.

Enhanced heat transfer via better convection and thermal conductivity which may enhance the performance of a receiver. Preoccupation efficiency may be enhanced by modifying the Nanoparticle size and shape to the application.

One of the most actual methods to raise the solar collector efficiency is to replace the working fluid, water, with great thermal conductivity fluids. At current Nanofluids are predictable to excellent heat transmission properties as relate to the conventional heat transmission fluids.

Nanofluids are deferments of metallic or non-metallic Nanoparticles like copper, aluminium-silicon, alumina (Al_2O_3) in a base fluid such as water, ethylene glycol. Common fluids such as water, ethylene glycol, and heat transfer oil play a vital role in numerous industrial processes such as the generation of power, heating or cooling processes, chemical processes, and microelectronics.

However, the thermal conductivity of these fluids is moderately low and thus cannot able to reach high heat exchange rates in thermal engineering devices. A method to solve this obstacle is using extreme fine solid particles adjourned in common fluids so that their thermal conductivity will be upgraded.

Experiments have exposed that Nanofluids have large higher thermal conductivities compared to the base fluids. These suspended Nanoparticles can variation the transport and thermal properties of the base. Nanofluids show healthier stability, rheological properties, and significantly higher thermal conductivity.

For various industrial and automotive submissions, Nanofluids are the original generation heat transfer fluids because they exhibit excellent thermal performance. Newly, many researchers have inspected the effects of Nanofluids on the upgrading of heat transfer in thermal engineering devices, both experimentally and theoretically.

The excellent features of Nanofluids are an upsurge in liquid thermal conductivity, liquid viscosity, and heat transfer coefficient. Consuming Nanofluids as a (Direct Absorption Solar Collector) DASC lead to the following advantages:

Eroticisms of the shape, size, material, and volume fraction of the Nanoparticles allows for tuning to get the chemical most out of spectral absorption of solar energy throughout the fluid volume.

Improvement in the thermal conductivity can lead to proficiency improvements, although small, by more effective fluid heat transfer; and, finally.

Huge progresses in surface area due to the very minor particle size, which makes Nanofluid-, based solar systems attractive for thermal and photo-catalytic procedures.

- **Applications of Solar Thermal Energy Generators:**

Working in the direction of sustainable development and greener technology the Solar operated steam generators or SWH have stood the test of time and have proved their proficiency in the market due to their cost-effectiveness, feasibility to generate solar power abundantly in hot climates, and efficiency over others like solar photovoltaic cells or solar air conditioners. Steam, thus, harnessed from steam generators can be widely used in various institutional frames and spheres of life:

- Industries, large scale as well as small scale
- Hospitals
- Cooking (In form of solar cookers)
- Domestic applications or household purposes.

- **Research Objective**

Considering different aspects in mind transitive of solar energy for cooking applications and its usage of optimization to be 65% of sum energy generation is becoming low day by day in India and if there is no any optional path for the energy making is introduced widely at India. So, in the coming future days, coal will be the future generation of energy in India, at the world level.

Now, by designing solar storage Cooker (SSC) using parabolic disc collector with Nano Fluid for Jaipur atmosphere by performing such study, we can calculate about parameter and installing a solar water heater (SWHs) its constructive results and future advantages & scope.

- **Development of Experimental Setup**

A high-temperature solar cooker comprises the technology that converts heat concentrated from the parabolic thermal collector at an optical focal point utilized into heating the water inside the copper cylindrical tank kept at the focus, where all radiations are absorbed. Copper is an eminent component of solar thermal heating systems used in both primary circuits and receives in heat exchangers and pipes for water tanks, because of its high heat conductivity, high resistance to corrosion by water and atmospheric exposure, mechanical strength, and sealing and joining by soldering.

Further, the setup heats up to the maximum temperature of 268-degree centigrade on Nanofluid along with water to enhance the efficiency, which is further utilized for several purposes like radiant space heating in this setup. Here is the specification listed down:

S. No.	Components	Specifications

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1.	Parabolic concentrating collector.	Major Axis – 2a = 70.86 Inch Focal Point – 27.16 Inch
2.	Cu cylinder	Useful Volume 5litre Water Volume 3Litre
3.	Infrared thermometer	Range – 58 to 932^{o}F
4.	General thermometer.	00C to 1000C
5.	Thermocouple	Range 200^{o}C
6.	Circulating pump	Voltage 12v to 24v AC
7.	No of Reflector Sheet	12 pieces
8.	Sheet Angle	30^0

Wiper Motor for tracking
Cooking Vassal with puff Insulted

Table No 1. Specification of Experimental Setup

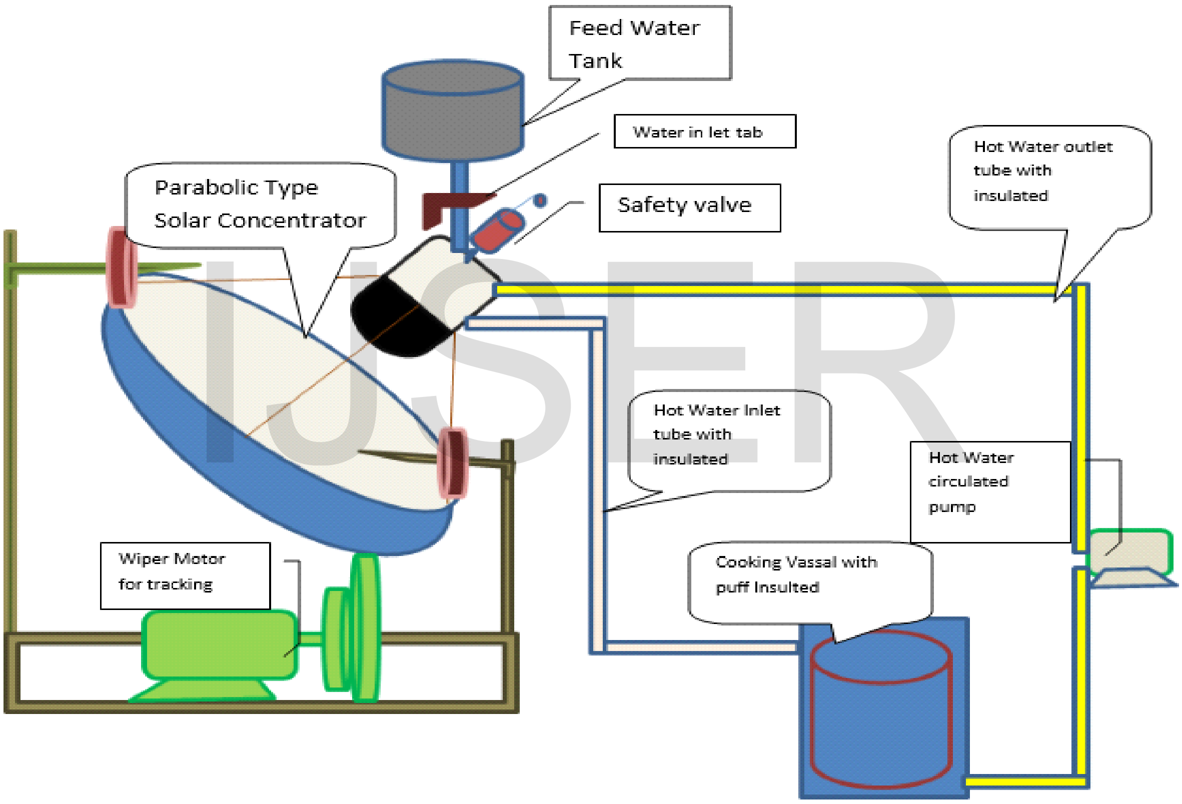


Figure 2: Parabolic Dish Type Solar Thermal storage Cooker

Construction and design of solar parabolic disc concentrator:
It comprises of following components in the making:

- Frame of parabola shape.
- Structural frame to support the parabola.
- Reflector sheet.
- Concentrator (Copper cylinder as boiler)
- Wiper motor.
- Fluid inlet or outlet pipes.
- Motor (for pumping fluid).
- Time-based solar tracker.

- Insulated cooking vessels


Figure3 Parabolic Dish Type solar concentrator Figure 4 solar receiver cylinder

- **Operating Principle**

Farther discretion develops parabolic solar dish were positioned in south-facing at the angle of 26°. The receiver fit on the middle top of solar dish and cooking vessel with the outlet hot water tube and this water again return into the receiver tank some measuring and safety equipment place different position they are also sown in figure.

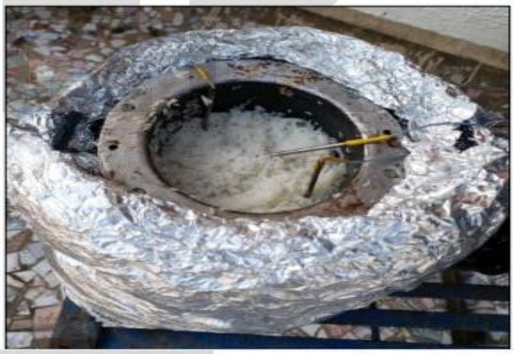


Figure 5 Cooking French fry Figure 6 Boiling Rice

The entire setup starts the system and it was left for the readings under the weather conditions. The thermocouple was attached at the bottom of the cylinder for the calculation of the outer surface temperature and another thermocouple is placed to take the reading of the water tank. Its limitations are that it requires good weather with relatively steady sunshine, and the person doing the cooking has to stay out in the sun and risks being dazzled or burned. The dish is tracked manually every 10- 20 min so that the beam of the sun is perpendicular to its aperture. Cooking by boiling, frying and baking, cooking in pressure cookers and production of distilled water are possible, as temperatures of 260 °C -270°CAll the readings are taken in the clear days of May -June on the top floor of the ISBM building in the energy lab of Suresh Gyan Vihar University. It found some data and graphs topically days data are sown.

- **Reading of Solar Parabolic Dish Type Thermal Storage Cooker Day 1**

South Facing-26⁰ **Humidity 16%**

Time of	Water inlet	Water outlet	Cylinder	Flow Rate	Global

Day (Hours)	Temperature (°C)	Temperature (°C)	Outer Surface Temp (°C)	(kg/min)	Radiation (W/m²)
10:00	39.8	46.6	99.8	1.32	750
10:30	76.5	100.9	145.9	1.36	780
11:00	87.8	136.8	160.4	1.4	850
11:30	101.9	150.9	168.3	1.46	870
12:00	129.1	188.9	194.3	1.36	835
12:30	163.1	167.1	156.3	1.4	350
13:00	174.9	214.9	232.8	1.33	860
13:30	189.1	209.6	230.3	1.35	850
14:00	174.4	182.4	185.3	1.37	730
14:30	148.7	165.4	172.6	1.5	700
15:00	132.3	145.3	157.3	1.48	340
15:30	108.6	125.1	142.8	1.45	300
16:00	83.1	86.1	115.6	1.4	450

Table No. 4 Reading of Solar Parabolic Dish Type Thermal Storage Cooker Day 1

- **Reading of Solar Parabolic Dish Type Thermal Storage Cooker Day 2**

South Facing-26^0 **Humidity 19%**

Time of Day (Hours)	Water inlet Temperature (°C)	Water outlet Temperature (°C)	Cylinder Outer Surface Temp (°C)	Flow Rate(kg/min)	Global Radiation (w/m²)
10:00	40.9	47.6	140.2	1.5	745
10:30	109.9	152.9	171.4	1.4	820
11:00	128.6	159.3	180.4	1.3	885
11:30	194.1	224.7	235.6	1.36	900
12:00	209.3	268.7	279.9	1.38	830
12:30	263.5	275.2	282.6	1.46	1020
13:00	259.1	266.3	270.3	1.44	720
13:30	211.3	249.6	252.4	1.4	800
14:00	195.6	231.2	242	1.37	720
14:30	177.8	181.9	202.6	1.36	320
15:00	138.3	140.3	175.3	1.4	250
15:30	119.4	128.3	152.8	1.39	320
16:00	80.5	81.2	145.6	1.3	300

Table No. 3 Reading of Solar Parabolic Dish Type Thermal Storage Cooker Day 2

- **Reading of Solar Parabolic Dish Type Thermal Storage Cooker Day 3**

South Facing-26^0 **Humidity22%**

Table No. 4 Reading of Solar Parabolic Dish Type Thermal Storage Cooker Day 3

Time of Day (Hours)	Water inlet Temperature (°C)	Water outlet Temperature (°C)	Cylinder Outer Surface Temp (°C)	Flow Rate (kg/min)	Global Radiation (W/m²)
10:00	39.8	76.6	111.8	1.32	725
10:30	53.5	90.9	145.9	1.36	770
11:00	77.8	126.8	160.9	1.4	840

11:30	111.9	161.2	198.3	1.46	870
12:00	159.1	198.9	218.3	1.36	885
12:30	183.1	214.1	226	1.4	700
13:00	204.9	244.9	262.8	1.33	860
13:30	239.1	259.6	270.3	1.35	860
14:00	244.4	261.1	265.3	1.37	730
14:30	198.7	203.4	202.6	1.5	710
15:00	150.1	154.1	175.3	1.48	600
15:30	91.3	106.9	142.8	1.45	700
16:00	83.1	86.1	145.6	1.4	450

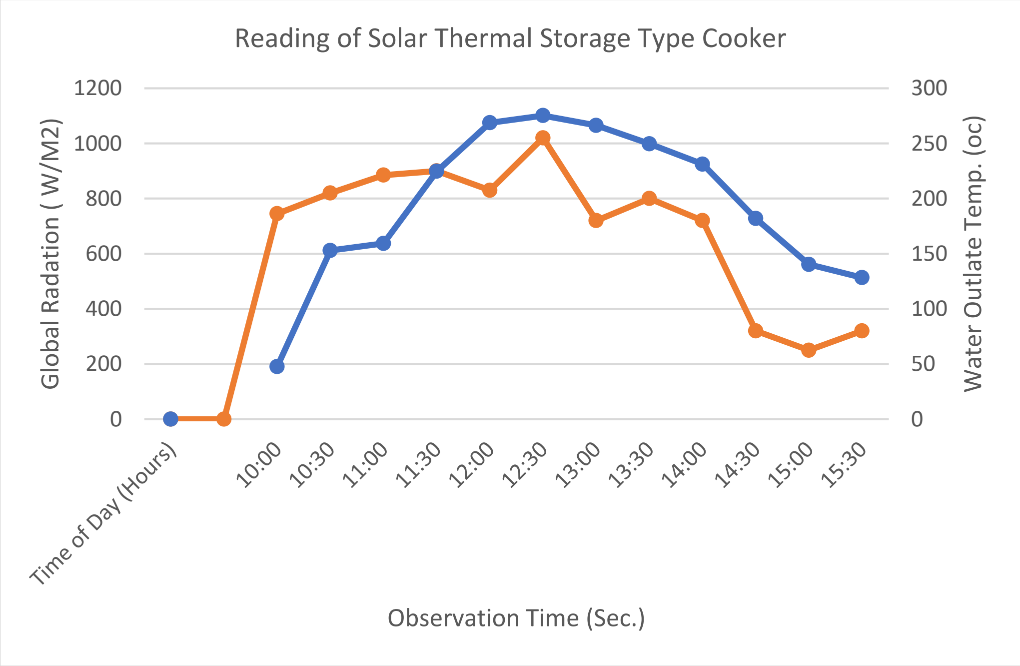
- **Reading of Solar Parabolic Dish Type Solar Cooker Day 4**

South Facing-26^0 **Humidity 17%**

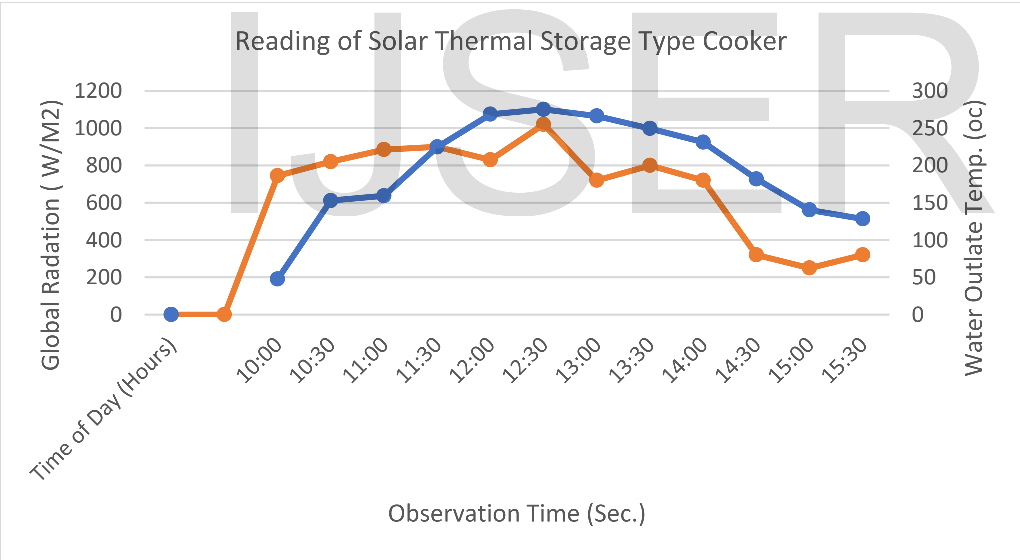
Time of Day	Water inlet Temperature (°C)	Water outlet Temperature (°C)	Cylinder Outer Surface Temp (°C)	Flow Rate(kg/min)	Global Radiation (W/m^2)
10:00	41.1	72.6	89.7	1.63	822
10:30	86.9	109.3	155.2	1.48	890
11:00	97.2	136.8	161.8	1.46	918
11:30	111.7	168.1	188.6	1.53	962
12:00	139.1	191.3	204.1	1.33	1002
12:30	166.6	207.8	216.3	1.36	1009
13:00	186.9	234.2	245.4	1.3	990
13:30	209.1	249.9	260.1	1.41	520
14:00	194.6	222.6	225.3	1.45	740
14:30	156.7	168.7	182.0	1.43	760
15:00	122.7	146.4	167.4	1.46	600
15:30	112.6	115.1	132.2	1.41	490
16:00	79.1	86.1	115.6	1.39	522

Table No. 5 Reading of Solar Parabolic Dish Type Thermal Storage Cooker Day 4

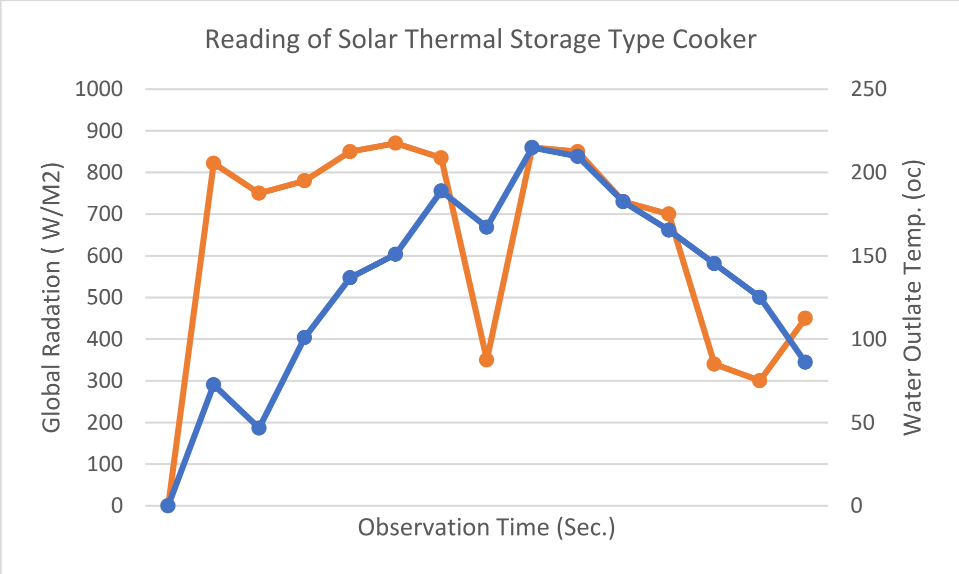
- **Graph of Solar Parabolic Dish Type Thermal Storage Cooker Day 1**



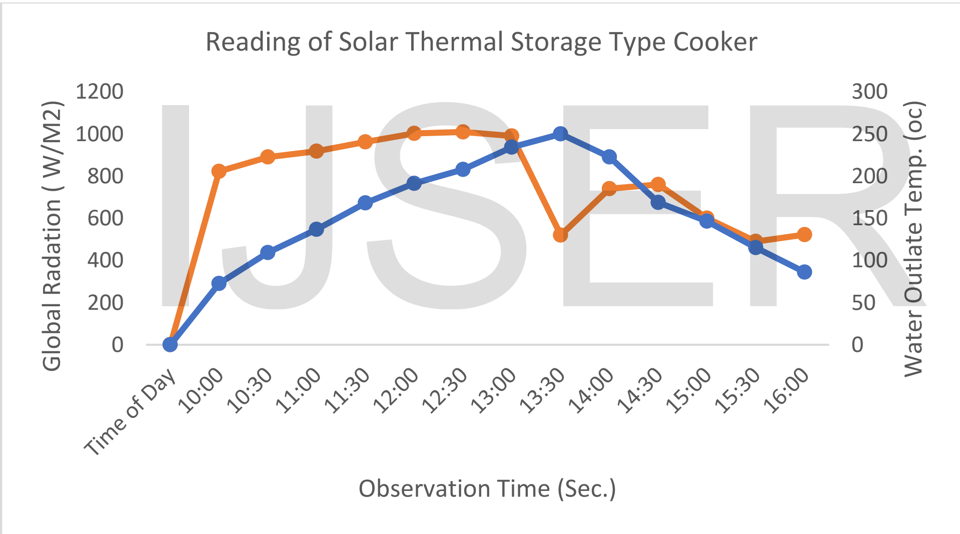
- **Graph of Solar Parabolic Dish Type Thermal Storage Cooker Day 2**



- **Graph of Solar Parabolic Dish Type Thermal Storage Cooker Day 3**



- **Graph of Solar Parabolic Dish Type Thermal Storage Cooker Day 4**



- **Results & Discussion**

This Setup deals with the results in the form of graphs. The graphs are obtained by the experimental work on the parabolic dish in a ray concentrator by using the water as a working fluid. This paper mainly deals with, the increasing or decreasing in the solar radiation, the whole day increasing and decreasing of the temperature is been recorded. Then this thermal storage cooker is using cooking process in high-temperature cooking like fry any vegetable, cooking rice in fry and boiling preparation also perform in the cooking process it is also used in indoor cooking process. it is clean technology and also time-saving.

In the graph, the left-hand side shows the temperature scale in (^{0}c), and on the right-hand side shows the global radiation in (w/m^2), and on the bottom side of the graph, shows the time.

(A)Calculations for the heat balance & the efficiency

1. Convective heat transfer coefficient

$$h_a=2.5(\Delta T)^{0.25}$$

Where h_a is the convective heat transfer coefficient and (ΔT) b_e the temperature difference.

$$U= [1/h_a+dx_1/kx_1]$$

2. Over all heat transfer

Where U is the overall heat transfer coefficient, dx_1 be the thickness of the insulation and kx_1 be the thermal conductivity of the insulating material.

$$Q=m\ C_p(\Delta T)$$

3. Useful energy

Q is the useful energy, (m) be the mass flow rate, and Cp is the specific heat of water whose value is 4.18 kJ/kg k, (ΔT) be the temperature difference.

$$Q = U\ A\ (\Delta T)$$

4. Loss for the receiver and the water tank

Here Q is the total loss from the receiver and the water tank, U be the overall heat transfer coefficient, (A) be the area of receiver and the area of water tank, and (ΔT) be the temperature difference.

$$S = A_c * I$$

5. Total energy input from the sun

Where (S) be the total input from the sun, the (Ac) be the area of collector in m^2, and (I) be the solar radiation in (w/m^2).

- **Frying Preparation of**
  - French fry
  - Dal Fry
  - Rice Fry
  - Idly fry

- **Boiling Preparation of**
  - Dal
  - Sambhar

- Rajma
- Vegetables
- Milk
- Tea

- **Steaming Preparation of**
  - Idle
  - Rice
  - Misc.
  - Hot Water For Cleaning

• Conclusion

In this paper, the study of a portable parabolic dish type solar thermal storage cooker for domestic use has been done. Also, an explanation has been given about the working and construction of a portable parabolic dish type solar thermal storage cooker and its advantages and disadvantages. There are many aspects of solar thermal storage cooker require development and that should be subject for working in the future. Any other solar cooker not any work at night. But thermal storage cookers are working at night by using thermal storage will be possible in the future.

• Future Scope

It will help to reduce the use of firewood as fuel and reduce petroleum fuel. This will also help to reduce the percentages of pollutants, which will be liberating during cooking.

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