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Design and Fabrication of Vacuum Tube Solar Cooker and Dryer

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***Abstract:** This project aims to develop a water distillation device that can purify water from almost any source, a system that is relatively cheap, compact and relies on renewable solar energy only. The impetus for this project is the limited availability of clean water supplies and the abundance of unclean water available for conversion into potable water.*
Furthermore, there are many coastal locations where plentiful seawater is available but there is no potable water. Solar cooking and water heating are widely accepted as clean and green energy technologies at both the domestic and commercial levels.
Referring to the different collector designs, it was concluded that the cost wise box type cooker is better and that the Compound Parabolic Collector (CPC) is better when considering the cooking time. Therefore, developing, manufacturing and analyzing a form of cooker that is not monitored but can absorb full solar energy throughout the day was scheduled.
The energy produced from the analytical and experimental tests is far above the energy needed to cook 500 gm of rice. Owing to variability in the degree of analytical and measured solar radiation, there is a noticeable difference between analytical and expe rimental oil temperature values.

I. INTRODUCTION

A solar thermal power generating device also known as a solar thermal power plant is an emerging renewable energy technology where we produce thermal energy by concentrating and converting direct solar radiation at medium / high temperature. By absorbing light as heat, all solar thermal systems catch the sun's energy. Solar thermal power systems rely on sunlight to heat a fluid to high temperatures and drive an engine, usually with mirrors. Particularly the technologically mature parabolic trough power plants have excellent prospects for the future, with their high efficiency and the lowest energy production costs of all solar technologies. Photovoltaic technology has many benefits, such as unattended operation and small-scale viability, but remains significantly more expensive than solar thermal technologies as a source of large-scale electricity.

II. DESIGN OF LATENT HEAT POWER GENERATION SYSTEM

A. Design of parabolic Reflector

Parabolic Trough Solar Collector, which is a cylindrical parabolic collector, uses the concentration of linear images. Such collectors consist of a cylindrical parabolic cross concentrater – sectional form, and a circular cylindrical receiver situated along the parabola's focal line. The cylindrical parabolic reflector focuses all the incident sunlight onto a metallic tubular receiver placed along its length in the focal plane. The heat transfer fluid is allowed to flow through the receiver. Parabolic troughs have a focal line, which consists of the focal points of the parabolic cross-sections. Radiation entering a plane parallel to the optical plane is mirrored so as to pass through the focal line.

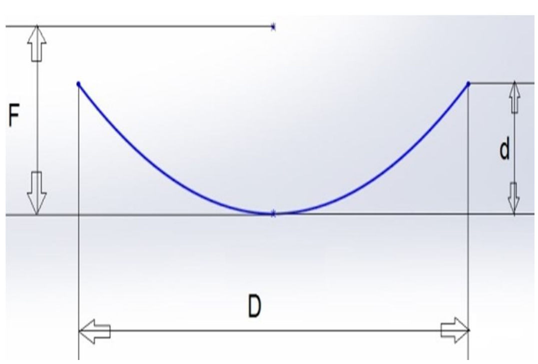

Figure 1. Design of parabolic Reflector

The following four parameters are widely used to describe a parabolic trough's shape and size: trough length, focal length, aperture width, i.e., distance between one rim and the other, and rim angle, i.e., angle between the optical axis and line between the focal point and the mirror surface. The focal length, i.e. the distance between the focal point and a parabolic pole, is a parameter that fully defines the parabola.

The angle of the rim, i.e. the angle between the optical axis and the line between the focal point and the mirror surface, has the interesting features that it defines the form of the cross-section of a parabolic trough by itself. This means the cross-sections of parabolic troughs with the same rim angle are identical in geometric terms. A uniform scaling (enlarging or shrinking) will make the cross-sections of one parabolic trough at a given rim angle congruent to the cross-section of another parabolic trough with the same rim angle. If only the shape of a collector cross-section is of concern but not the absolute thickness, then indicating the angle of the rim is appropriate. Two of the three rim angle parameters, aperture width, and focal length are necessary to completely evaluate the cross-section of a parabolic trough, i.e. shape and size. That also means two of them are enough to determine the third.

We see the angle of the rim should be neither too small, nor too high. The angle of the rim is related to the distance between the various parts of the mirrors and the focal line. The angle of the rim is a very significant collectors building feature. This influences for example the concentration ratio and the overall irradiance per meter of the absorber tube [W/m]. In qualitative terms, we can understand that there has to be some ideal rim angle range and that it should be neither too small nor too wide. If the angle of the rim is very high, then the mirror is very narrow and it is clear that a larger mirror (with a wider angle of rim) will increase the power projected onto the absorber tube. If the angle of the rim is very high, the way the reflected radiation from the outer parts of the mirror is very long and the width of the beam is very large, thereby reducing the ratio of concentration. A mirror with a smaller angle of the rim and the same width of the aperture would allow a greater concentration ratio. Last but not least there is an economic aspect restricting the fair angle of the rim: At high rim angles the outer parts of the mirror area have a low contribution to the energy yield. That means there is a need for a high investment which contributes little to the energy yield. So, there are several criteria that together determine the angle of the rim.

The formula for a parabola is

$$f = \frac{D^2}{16d}$$

To find the focal point of a parabola,

D- Aperture width = 600mm

d –a depth of reflector = 125mm

Focal length

$$f = \frac{600^2}{16X125} = 180mm$$

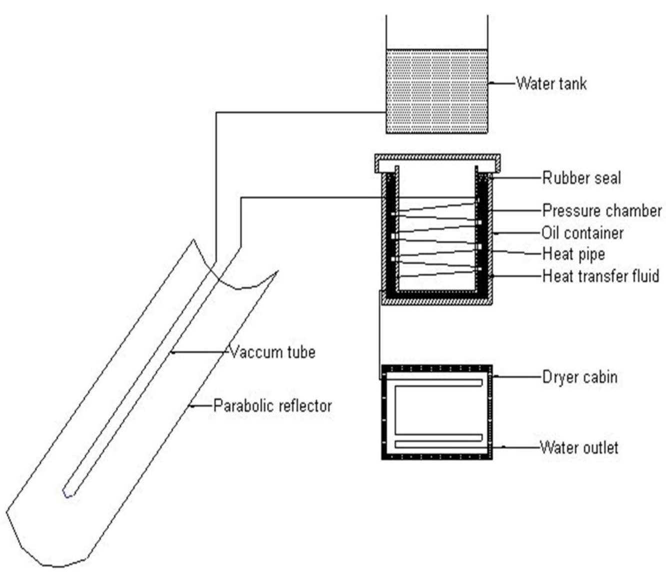

Figure. 2 Schematic view of system

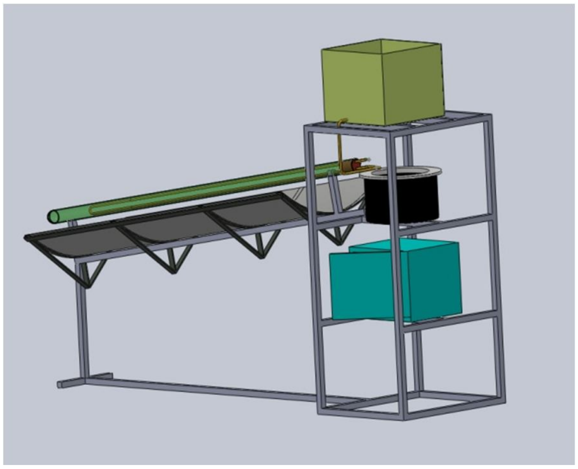

Figure 3 Design of solar thermal power generator

Figure 4 Assembly Of System

III. DESCRIPTION OF EQUIPMENTS

A. *Parabolic Sheet Metal*

Sheet metal is metal which is molded into small, flat pieces by an industrial process. It is one of the basic forms used in metalworking, and can be cut and bent into a variety of forms. The sheet metal fabricates countless everyday objects. Extremely thin thicknesses are considered foil or leaf, and sections thicker than 6 mm (0.25 in.) are considered plate.

The sheet metal is available in coiled strips or flat pieces. The coils are formed by a continuous sheet of metal running through a roller slitter.

In the USA, sheet metal thickness is commonly specified by a traditional, non-linear measure called its gauge. The greater the number of gauges, the more thin the metal. Commonly used sheet metal ranges from 30 gauge to approximately 7 gauge. Gauge differs between ferrous (iron based) metals and nonferrous metals such as aluminum or copper; copper thickness, for example is measured in ounces, which represents the weight of copper contained in an area of one square foot. In the rest of the world, the sheet metal thickness is given in millimeters.

B. *Vacuum tube*

The vacuum tubes are constructed from borosilicate glass and are insulated from vacuum pressure. In the outer area of the inner tube there is insulation, which has a property of high absorption, low emission and good temperature retention. Vacuum tubes have a greater isolating advantage. Therefore the use of a vacuum tube in place of a GI pipe was beneficial to the design. Within 15 minutes the water in the tube begins to boil and large amount of steam is produced. The only drawbacks are that one side of the vacuum tubes are exposed, are very fragile and expensive compared to a GI pipe.

C. Heat Pipe

A heat pipe (HP) has high thermal conductance tubes and inside the heat pipe there is small amount of working fluid. Working fluid evaporates in a heating zone of the heat pipe by absorbing a latent heat from evaporation. The evaporated vapor then moves to the cooling zone and condenses through the rejection of heat to fluid flowing through the multiplier. The condensate then returns to heating zone and completes the process. The condensate returns by capillary action, gravity or wick structure to the evaporative portion. The tubes are mounted onto a heat exchanger (manifold) containing flowing water or water / glycol with the metal tips projecting. Heat is transferred into the manifold and through circulation pipe work to be used in heating and/or hot water applications.

IV. WORKING OF SOLAR COOKING SYSTEM

A typical heat pipe is nothing but a sealed pipe or tube which is made with compatible material with working fluid such as for water heat pipe copper is suitable and for ammonia heat pipes aluminium is suitable. When heat pipes are empty at that time for maintaining vacuum inside it a vacuum pump is used. Upon generating vacuum within the heat pipes it partially fills with working fluid and then sealed. The working fluid mass is selected so that over the operating temperature spectrum the heat pipe incorporates both vapour and liquid. The liquid is too cold under the operating temperature and can not vaporize into a gas. All the liquid has converted to gas above operating temperature, and the ambient temperature is too high to condense any of the material. Thermal conduction is still possible through the heat pipe walls, whether too high or too low, but at a considerably reduced rate of thermal transfer. Working fluids are chosen according to the temperatures the heat pipe has to operate at. Sometimes water heat pipes are filled by partially filling them with water, heating them up until the water boils and displaces the air, and then sealing them while it is hot.

For a certain period of time, the water from a tank capacity of 5 liters is admitted into the vacuum tube and then turned off. The tube generates high temperature due to the sun's radiation and it increases water temperature at constant volume. According to Gay Lussac law the pressure inside the tube also increased. Steam then transformed into steam that was overheated. The stored in the enclosed tank will then steam. It is admitted into reaction turbine after filling of the tank. In turbine the steam expands to give it reaction force. High velocity steam rotates turbine shaft.

Solar assisted steam cooking is put in front of the department of the automobile inside campus MAHENDRA COLLEGE facing east west. A large number of parameters have different impacts on system performance. Each day before the reading starts, the parabolic collector is manually controlled so that the solar radiations fall on the aperture region. The major determinant of the yield is the availability of solar radiation. A comparative research on parabolic trough collector with different reflectors is also performed to find more effective reflective surface for cooking purposes. And also the nutritional quality of steam-cooked food has been analyzed as compared to conventionally cooked food. Experiments are conducted from 9:00 am to 5:00 pm.

The variation in solar intensity for aluminum sheet and galvanized sheet as a reflector is plotted at different times of the day. The collector was exposed to solar radiation for half an hour before the start of reading, and experimental data were recorded during the daytime after regular intervals of one hour. From the graph shown in Fig-4 it is obvious that during the noontime the solar intensity is highest.

A. Heating oil with steam

Steam is supplied to heat exchanger in a gaseous state. Saturated steam heat transfer utilizes latent steam heat, releasing a large amount of energy as it condenses (changes to liquid state). Liquid condensate leaves the exchanger at temperatures similar to saturated vapour. .The amount of energy released per steam unit is high (up to 539 kcal / kg or 970 kg, and higher with vacuum vapour).

The amount of heat needed to increase a substance's temperature may be expressed as: The liquid or fluid flow is heated continuously in heat exchangers. Homogeneous heat surface temperatures are again with steam, because temperatures on heat surfaces depend on steam pressure.

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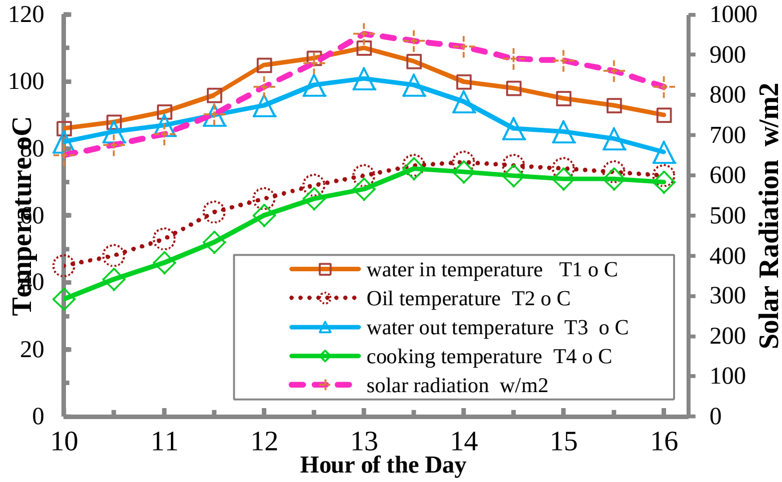

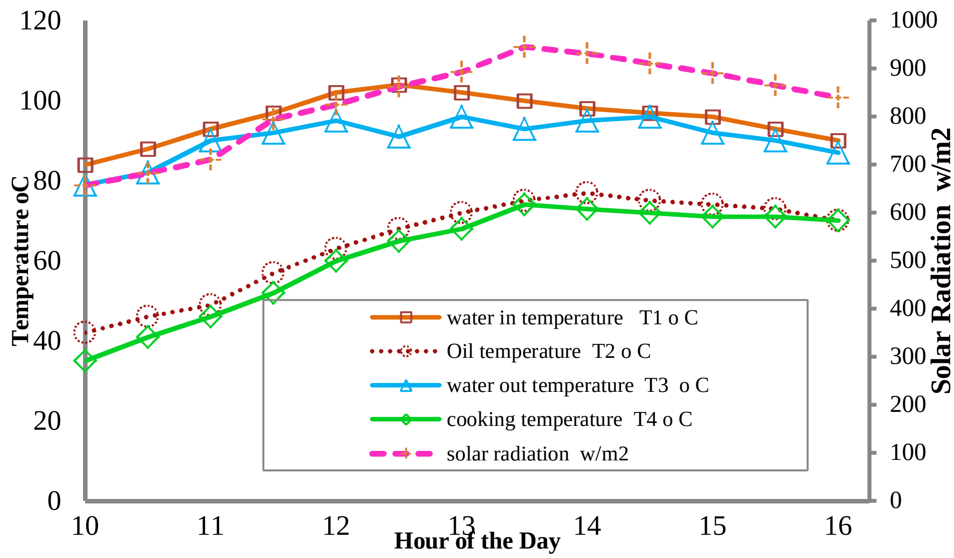

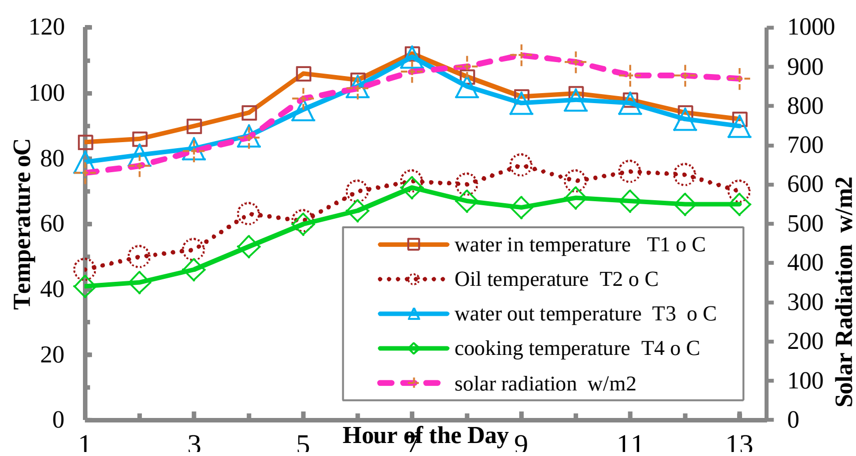

Average Value of steam in Temperature. steam out Temperature, oil Temperature, Cooker temperature and Solar Radiation Temperature with time a: Test at 04 March 2020, b: Test at 05 March 2020, c: Test at 06 March 2020

The mean heat transfer can be expressed as

$$q = C_p dT \frac{m}{t}$$

where

q = mean heat transfer rate, kW

m / t = mass flow rate of the product, kg/s

cp = specific heat of the product, kJ/kg ^{o} C

dT = change in fluid temperature , ^{o} C

Example - Continuously Heating by Steam

Water flowing at a constant rate of 3 l/s is heated from 10 ^{0}C to 60 ^{o} C w

The heat flow rate can be expressed as:

q = 4.19 x (60 - 10) x 3 x 1

= 628.5 kW

B. Calculating the Amount of Steam

If we know the heat transfer rate - the amount of steam can be calculated:

$$m_s = \frac{q}{h_e}$$

where

m_s = mass of steam kg/s

q = calculated heat transfer kW

h_e = evaporation energy of the steam kJ/kg

The steam flow rate can be expressed as

m_s = 628.5 / 2030

= 0.31 kg/s

= 1115 kg/h

C. Heating Water With Oil

Heat transfer from a liquid medium such as hot water or oil allows use of active heat of the medium. The liquid is supplied to the heat exchanger at elevated temperatures. As the liquid releases thermal energy, its temperature decreases and the exchanger exits at a lower temperature. The amount of energy released per unit of heat transfer medium is relatively low In non-flow style applications the process fluid is stored in a tank or vessel as a single batch. A steam coil or vapor jacket heats the fluid from low to high. The mean rate of heat transfer for such applications can be expressed as:

$$q = C_p dT \frac{m}{t}$$

where

q = mean heat transfer rate kW kJ/s

m = mass of the product kg

cp = specific heat of the product (kJ/kg.^{o}C) –

dT = Change in temperature of the fluid (^{o}C)

t = total time over which the heating process occurs (seconds)

A quantity of water is heated with steam of 5 bar (6 bar abs) from a temperature of 35 ^{o}C to 100 ^{o}C over a period of 20 minutes (1200 seconds). The mass of water is 50 kg and the specific heat of water is 4.19 kJ/kg.^{o}C.

Heat transfer rate:

Amount of steam:

ms = 11.35 / 2085

= 19.6 kg/h

D. Heat Loss From Oil Filled Tanks

The amount of energy released per unit of heat transfer medium is relatively low In non-flow style applications the process fluid is stored in a tank or vessel as a single batch. A steam coil or vapor jacket heats the fluid from low to high. The total heat loss from an application can in general (in SI-units) be expressed as:

Q = α A dt

where

Q = heat loss W

α = heat transfer rate W/m2 ^{o}C

A = area m^2

dt = temperature difference ^{o}C

Heat Loss from an Exposed Insulated Oil Tank

The total heat loss from an insulated tank with 1000 m2 exposed surface, filled with heated oil at 38^{o}C, surrounding temperature of 0^{o}C and a heat transfer rate of 2.27 W/m^2 ^{o}C - can be calculated as:

Q= 86.3 kW

V. CONCLUSION

Because solar cookers are fireless appliances, it has been shown that successful implementation of this technology can dramatically reduce the risk of indoor and outdoor cooking fires, thereby alleviating their destructive health, forest and safety effects. Finally, these tools may tackle a number of other problems, such as water contamination, biomass and fossil fuel rivalry, deforestation and indoor / outdoor air pollution. Distillation is a process for removing water from the contaminations rather than removing pollutants from the atmosphere. Solar energy is a potential source for that. The Solar distillation involves zero maintenance cost and no energy costs as it involves only solar energy which is free of cost.

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