SOLAR COOKER USING PARABOLIC REFLECTORS

A project report submitted in partial fulfillment of the requirements for the Award of the Degree of

BACHELOR OF ENGINEERING
IN
MECHANICAL ENGINEERING

by

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CERTIFICATE

This is to certify that the Project Report entitled **"SOLAR COOKER USING PARABOLIC REFLECTORS"** being submitted by DUMPALA DHARMELRACHIT (317126520075), LAGUDU DEVI VARA PRASAD (317126520094), GANDI RAHUL NARASIMHA SAI GANESH (317126520078), GARAPATI NAGA SURYA MOHAN UPENDRA (317126520080), KORRA JASHUVA PRASANTH (317126520091) in partial fulfillments for the award of degree of **BACHELOR OF TECHNOLOGY** in **MECHANICAL ENGINEERING**. It is the work of bona-fide, carried out under the guidance and supervision of **DR.K.SIVA PRASAD**, Professor, Department Of Mechanical Engineering, ANITS during the academic year of 2017-2021.

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ABSTRACT

For cooking we generally make use of gas which is a commercial source. Solar energy is a renewable and non-commercial source which is adequately available for usage. So the idea of making use of solar energy to cook brought the existence of solar cookers. But the main problem with the model with it is, it is not effective during day start and end because rays cannot incident completely over it. So it takes more time to cook. So to overcome this issue, usage of a parabolic reflector is the solution where the incident rays meet at the focus which generate more heat and results in faster cooking that saves time.

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NOMENCLATURE

Symbol	Description
f	Focal distance, m
h	Depth of the parabola, m
R	Radius of the parabola, m
d	The concentrator diameter, m

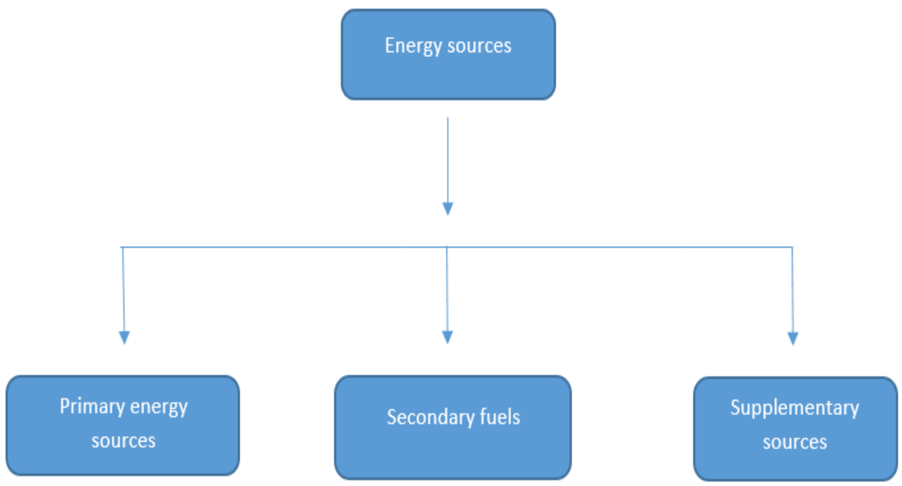
CHAPTER - I

INTRODUCTION

1.1 Energy

Energy is the primary and most universal measure of all kinds of work by human beings and nature. Everything what happens in the world is the expression of flow of energy in one of its form.

The energy sources available can be divided into three types:



Primary energy sources

Primary energy sources can be defined as sources which provide a net supply of energy. Coal, oil, uranium etc. are examples of this type.

Secondary fuels

Secondary fuels produce no net energy. Though it may be necessary for economy, these may not yield net energy. Secondary sources are like solar energy, wind energy, water energy etc.

Supplementary sources

Supplementary energy sources are defined as those whose net energy yield is zero and those requiring highest investment in terms of energy insulation is an example of this source.

Energy sources are further classified as:

i. Renewable energy sources : This energy is inexhaustible
ii. Non-renewable energy sources: This energy is exhaustible

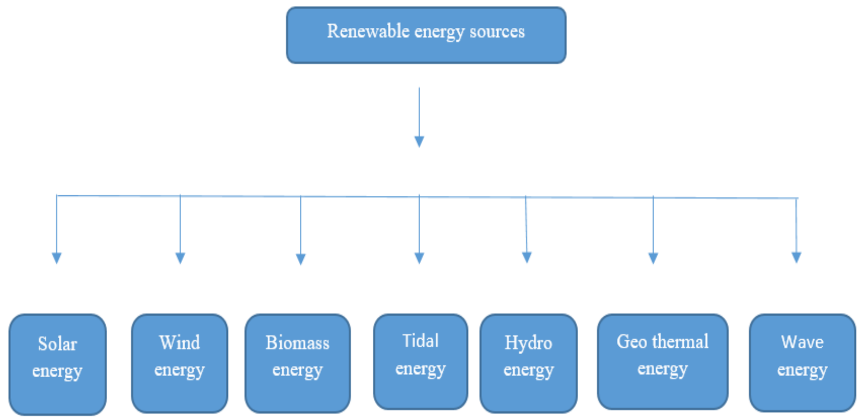
1.2 Introduction to renewable energy

Renewable energy is useful energy that is collected from renewable resources, which are naturally replenished on a human timescale, including carbon neutral sources like sunlight, wind, rain, tides, waves, and geothermal heat.

This form of energy can also be represented as energy that is sustainable - something that can't run out, or is endless, like the sun. When you hear the term 'alternative energy' it's usually referring to renewable energy sources too. It means sources of energy that are alternative to the most commonly used non-sustainable sources - like coal.

Renewable energy often displaces conventional fuels in four areas: electricity generation, hot water/space heating, transportation, and rural (off-grid) energy services.

1.3 Types of renewable energy sources



Solar energy: Solar energy comes from the light of the sun, which means it is a renewable source of energy. We can use the sunlight to create pollution free electricity. The solar cell is the system used to convert the sunlight energy into electrical energy.

Wind energy: Wind energy is the kinetic energy associated with the movement of atmospheric air. Wind energy systems convert kinetic energy into more useful forms of power. Wind energy systems for irrigation and milling have been in use since ancient times. From beginning of the 20th century it is being used to generate electric power.

Biomass energy: Biomass energy is stored in non-fossil organic materials such as wood, vegetable oils and wastes from the forest, agricultural and industrial sectors. Burn Fuel → heat water to make steam → steam turns turbines → turbines turn generators → electrical power sent around the country.

Tidal energy: Tidal energy is the energy due to the water waves created in the ocean. The tidal energy is also called hydropower. The hydropower is due to rise and fall of water waves in the ocean. The rise and fall of water wave are due to the gravitational forces of the moon and the sun as well as the revolution of the earth. The rising and falling waves are used to rotate the turbines and hence the electricity is produced.

Hydro energy: Hydro energy is derived from flowing water in rivers, water streams in the mountains, or from man-made installations where water flows from a high-level reservoir down through a tunnel and away from the dam. A dam is built to trap water, usually in a valley where there is an existing lake. Water is allowed to flow through tunnels in the dam, to turn turbines and thus drive generators and the electricity is produced.

Geothermal energy: Geothermal energy is energy derived by tapping the heat of the earth itself like volcano, geysers, hot springs (etc.). These volcanic features are called geothermal hotspots. Basically a hotspot is an area of reduced thickness in the mantle which expects excess internal heat from the interior of the earth to the outer crust. The heat from these geothermal hotspots is altered in the form of steam which is used to run a steam turbine that can generate electricity.

Wave energy: It is an irregular and oscillating low frequency energy source that can be converted to a 50 Hertz frequency and can then be added to the electric utility grid. Waves get their energy from the wind, which comes from solar energy. Waves gather, store, and transmit this energy thousands of kilometres with very little loss. Though it varies in intensity, it is available twenty four hours a day all-round the year. Wave power is renewable, pollution free and environment friendly. Its net potential is better than wind, solar, small hydro or biomass power. Wave energy technologies rely on the up-and-down motion of waves to generate electricity.

1.4 Solar Energy

It has been estimated that the sun provides as much energy in 15 minutes as humans use in a year. By taking advantage of that with heating and electrical generation, we can work to end our dependence on fossil fuels.

Solar energy is the energy obtained by capturing heat and light from the Sun. Energy from the Sun is referred to as solar energy. Technology has provided a number of ways to utilize this abundant resource. It is considered a green technology because it does not emit greenhouse gases. Solar energy is abundantly available and has been utilized since long both as electricity and as a source of heat.

1.5 Solar technology classification

Active solar: Active solar techniques include the use of photo-voltaic systems, concentrated solar power and solar water heating to harness the energy. Active solar is directly consumed in activities such as drying clothes and warming of air.

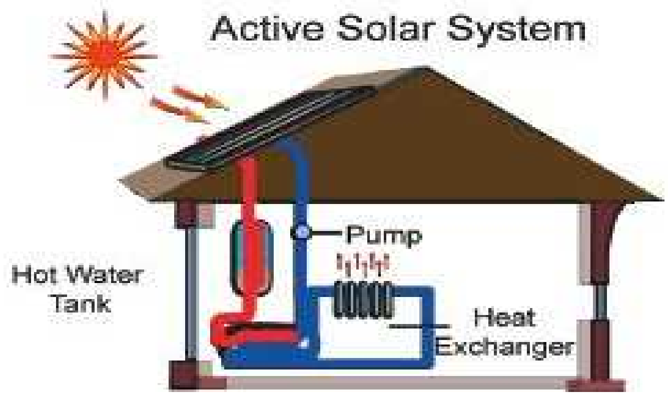


Fig 1.1 Active solar system

Passive solar: Passive solar techniques include orienting a building to the Sun, selecting materials with favourable thermal mass or light-dispersing properties, and designing spaces that naturally circulate air.

Fig 1.2: Passive solar system

1.6 Effects of earth position

The earth rotation and its inclined position will cause days and nights of varied magnitude/lengths depending up on geographical location and varied seasons. Solar energy is intermittent energy source available abundantly in nature .It is not like continuous fuel LPG/wood. It varies with respect to geographical location wise .As distance from equator increases the availabilityof solar energy varies. It also varies with respect to season also. Its intensity varies with respect to morning, noon and evening. It is of lower calorific value fuel and is expressed in W/m2hr or K Cal/m2s. Solar energy is expressed as solar constant 1000W/m2hr. The total incident radiation per day is expressed as insolation. For example 5KW insolation means total radiation received per day at square meter area is 5 KW.

1.7 Heat energy generation from solar power

Solar energy is converted in to thermal energy or directly into electricalenergy. Thermal energyform conversion by absorption (black bodies) or concentrating by reflectors in reflection or refraction phenomenon.

In absorption mode the temperature developed depends uponintensity of incident light and it is used for temperature less than 150 degrees Celsius application.

In this form of energy cooking, drying/frying pasteurizing can be easily done. Roasting application requires more temperature.

High Concentration of light generates higher temperature more than 150 degrees Celsius and useful for high temperature application. The concentrators are used for roasting and for steam generation and other industrial applications.

In electricityconversion photovoltaic panels are used. Theelectricpowergeneratedis of direct current.

In solar energy utilization the reflector or lenses used energy collection size/ area is more to get the required heat quantity and the designed equipment occupies higher space in comparison with LPG stoves or electrical stoves/heaters. More over the designs should be robust to with stand wind loads andreflectors or lenses are to be placed in open areas where sun rays are falling. The frequentdustfalling on the equipment is a criteria which reduces efficiency.

In electricity conversion photovoltaic panels are also occupy more space and placed in open areas where sun rays are falling.

The sun movementisof diurnal. Thereflectors or Photovoltaic panels are to be aligned with respect to sun position is called tracking. Tracking is of uni-direction or bidirectional type.

In heat conversionequipment likereflectors/lenses concentrators or other type non imaging concentrators and PV panels areto be aligned to sun in unidirectional or bidirectional for better utilization in extraction of solar energy. If theyare keptstationerythe energy collection willbeless. Trackingiscostlierand adds moving parts and maintenance issuesare to be addressedas and when required.

Thesolar energy isintermittentresource but abundantly availablethroughout the year. Solarenergy is oflowercalorificvaluefuel expressed as solarcconstant1000W/m^{2}hr. Thetotalincident radiation per dayis expressed as Insolation. It is to beusedas supportive energy source in parallel withLPG and electricity. In thisway reductionof useof LPG, electricityfor presentsociety needs ispossible andleads tolessening ofenvironmental damage.

To increase the usage of solar energy the new design of box type solar equipment was worked out from concept, design, manufacture, assembly, testing was done for guaranteed performance. In this design in normal sky morethan one time boiling is ensured and frying/drying is done. The design procedure/technology is simple and easily adoptable for common man knowhow. This cooker reflector tracks the sun and to be rotated once in aday only at noon to take care of sun movement towards west. The utensilsand the materials are normally available in local market.

1.8 Introduction to parabolic surface

Consider the one-parameter family of parabolas, with vertex at the origin and the*y*-axis as its axis of symmetry. The Cartesian equation of such a “canonical parabola”is $x^2 = 2py$, or $2y = 1/px^2$, withp, the semilatusrectum, being the parameter. If several parabolasare graphedona common chart, one noticesthat as$|p|$ is increased, the “flatness” of the parabola at its vertex increases, while its “curvature” decreases.

It is well known that a beam of light, coming from infinity parallel to the axis of symmetry and reflected by a paraboloid mirror, converges at the focus of the mirror.

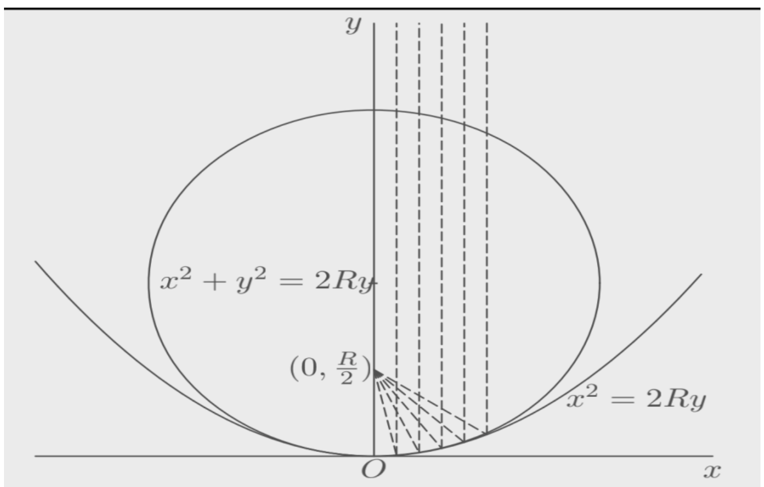


Fig 1.3Parabolic mirror

1.9 Study of parabolic surfaces as reflectors

As per Physics parabola formula: Square Y=4aX. The light rays when fall on parabolic surface all the rays concentrated at focal point. In parabolic surface rays falling surface below focal point rays deflected/reflected upwards. In parabolic surface rays falling surface above focal point rays deflected/reflected downwards.

The curves plotted on graph paper are attached in below figure with 4aX replaced with perfect squares like 1.21X

If 4aX is replaced with perfect squares like 1.96X& 3.24X curve plotting is curves are indicating that the shape is less access to scatter/diffusion radiation of light.

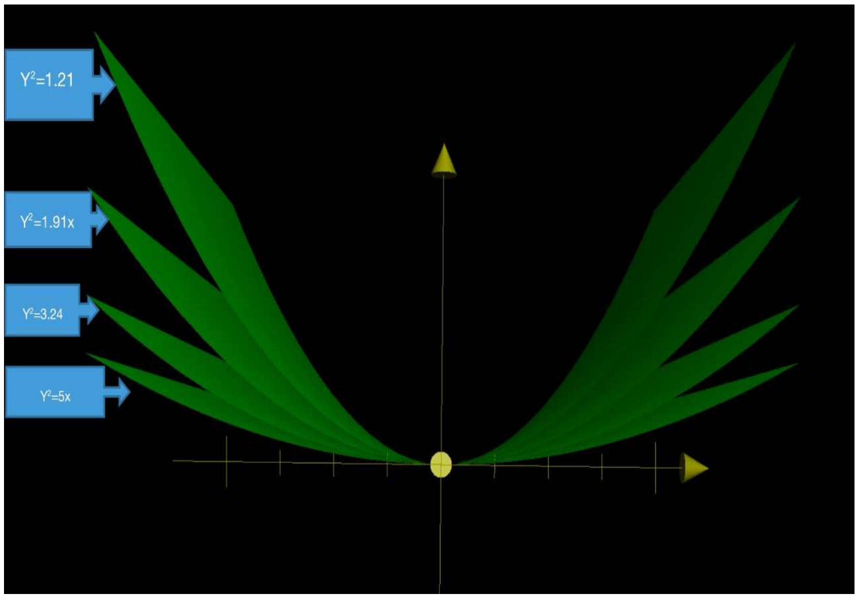


Fig 1.4 Access to scatter light

The above figure indicates different parabolas generated4aX isreplaced with perfect squares like 1.21X, 1.96X&3.24X.

As the focal point increases parabola widens and accessibility forreception of radiation increases.

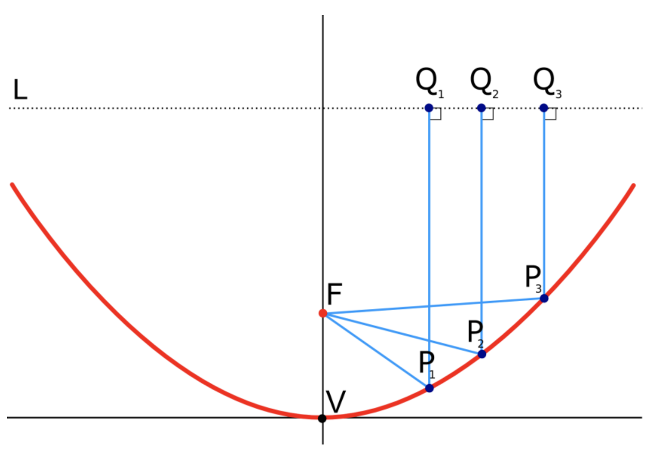


Fig 1.5 Parabolic reflector

In the above drawing at point P_1 (X1,Y1) ordinates At point P_2 (X2,Y2) at P_3(X3,Y3) For making good profile the difference of straight line length and curve length should be bare minimum. Straight line length of points A&C is equal to arc length of points A&C. This can be achieved by fixing the intervals of Y ordinates (difference in between Y2 & Y1, Y2 & Y3). The length of curve at B&C, B&A of curve and straight line lengths of points B&C and B&A difference will be bare minimum. The minimum interval (difference of Y2-Y1&Y3-Y2) is key factor and also decides the shape deviation with respect to mathematical equation to actually fabricated model. Paraboloid can be considered into number of frustum cones of radius as follows:

The top cone radius is (y) r at height x, next immediate bottom cone radius is r delta r(r minus delta r) and the height of cone is x-delta x (x minus delta x).

In this way all frustum cone radii and heights can be nomenclature up to x=0 and y=0(The length of arc is square root of sums of difference square of x ordinate and y ordinates-slant height of frustum cone).

In this way if cross section is changed into square shape the length of top square side is 2r and height is x, next immediate bottom square side at delta x height is 2(r- delta r) [(r minus delta r)].In this square sides and heights can be nomenclature up to x=0 and y=0

If cross section is changed into rectangle l (length), b(breadth) at height x and immediate bottom rectangle length will be (l- delta l) [(l minus delta l)] and breadth will be (b- delta b).In this way nomenclature can be done up to x=0&y=0.

In this way by changing the cross section from circle to rectangle paraboloid becomes parabolic surface. In the same way spherical surfaces also can be explained.

By changing from circle cross section to square section the compound parabolic surface (as shown in fig-1 the surface area of the shape will increase and useful for designing the absorber type solar heat conversion equipment. In this way without tracking, the solar household appliance can be designed. In this model effect of shade factor is bare minimum, acceptance angle is high .Incident area to surface area ratio is higher which increases thermal efficiency and higher temperature generation. In this type without tracking time duration of receiving the sun will increase when compared with box type cooker. By applying high absorptive and low emissive coating like black chrome, aluminum oxide and copper oxides the temperature generated can be increased still further. By placing a mirror facing towards south the efficiency will increase in comparison to box shape as used in box type cookers. In this way solar energy can be utilized for house-hold purposes/application.

1.10 Tracking

Paraboloid/parabolic surface is to be tracked for suitably for solar energy concentration. The parabolic surfaces are used for communication antennas and for solar energy equipments.

1.11 Advantages

Parabolic profile/shape can focus direct beam of light at focal point as per application of physics.

- The dish antenna used for receiving/transmitting signals can be manufactured in this method for better accuracy of profile and size can be reduced for communication industries.
- It is useful in lighting industries for better illumination for area covered. This is useful for fabricate process perfect parabolic surfaces.
- This can be used for concentrating photovoltaic systems generation for achieving maximum electrical energy generation with tracking facilities. By implanting photovoltaic cells on the surface (trial could not take.)
- High performance solar cookers can attain temperature above 290°c .They can be used to grill meat, bake bread boil water etc.
- Solar cookers use no fuel .This saves cost as well as reduce environmental damage caused by fuel usage. Since billions of people cook on open fire using

biomass fuels, solar cookers could have large economic and environmental benefits by reducing deforestation.

1.12 Disadvantages

- Parabolic solar cookers are less useful in cloud weather and near poles. So, there is a necessary to go with alternate source for cooking in these conditions.
- Parabolic solar cookers take long time to cook than conventional stove or oven. Using solar cookers may require food preparation start hours before meal. However it takes less hands on time during cooking. So, this is often considered a reasonable trade off.
- Cooks may need to learn special cooking techniques to fry common foods, such as fried eggs or flatbread like chapattis.
- Parabolic solar cooker designs are affected by strong winds, which can slow the cooking process, cool the food due to convective losses and disturb the reflector. It may be necessary to anchor the reflector, such as with string and weighted objects like bricks.

1.13 Limitations

- Requires periodic adjustment to refocus is as sun moves or a mechanical solar tracking apparatus.
- Generally more expensive than panel and box type solar cookers.

1.14 Solar cooker

A solar cooker is a device which utilizes solar energy to cook food. Solar cookers also enable some significant processes such as pasteurization and sterilization. It is a clear fact that there are countless styles of solar cookers that are continuously improved by researchers and manufacturers. Therefore, classification of solar cookers is a hard work.However, it may be asserted that most of the solar cookers today fall within three main categories called solar panel cookers, solar box cookers and solar parabolic cookers.

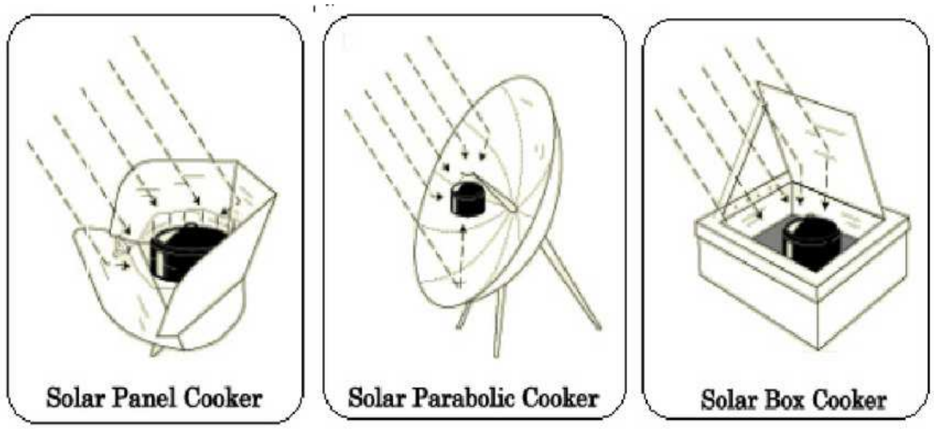


Fig 1.6 Basic solar cooker types

significant processes such as pasteurization and sterilization. It is a clear fact that there are countless.

1.15 Different types of solar cookers

A. Parabolic Solar Cooker Using Stainless Steel as a Reflective Material

Stainless steel is a steel alloy that contains minimum 10.5% of chromium content by mass. There are five types of stainless steel. They are Austenitic, Ferritic, Martensitic, Duplex and Precipitation Hardening. For this design, Austenitic stainless steel had used. It is mainly made by molybdenum, Nickel, Manganese and chromium alloy. It has a high combination of weld-ability and formability. These steels are vulnerable to stress corrosion cracking. It is totally nonmagnetic steel. During the construction period, first of all, two stainless steel pipes of square shape were wielding to make the horizontal stand. By applying hydraulic pressure in the stainless steel sheet, the appropriate parabolic shape was found. The main advantage of this steel is corrosion resistance and a good reflector. It is also poor conductivity of electricity. This structure has some problems. Firstly, due to extreme hydraulic pressure it is not ideally parabolic shape. Secondly, the exact focal point had not found because of this shape. Finally, its cost is too much high. Finally, it is difficult to carry because of its size and weight.

B. Parabolic Solar Cooker Using Aluminum Foil as a Reflective Material

Aluminum has been used commercially for over 100 years. Aluminum foil paper is made by the thin aluminum metal leaves with a thickness less than 0.2 mm. It is also called misnomer tin foil. Aluminum foil has a shiny side and a matte side. The reflectivity of bright aluminum foil is approximately 88%. Aluminum foil is widely used for radiation shield and heat exchangers. First of all, a dish antenna had needed for this cooker. Afterwards, the aluminum foil was cut down into small pieces. When the aluminum foil had cut in appropriate size then by using glue or two-sided tape for setting those aluminum foils in parabolic dish antenna. After that, three different pipes welded with that bending pipe to get a tripod. From the middle of the tripod another slightly curved pipe was welded. The Parabolic dish was perfectly attached with this curved pipe's head according to the required position. The overall cost of this cooker is lower to compare than other types of parabolic solar cooker. Aluminum foil is locally available material. This paper works like a good concentrator and delivered a maximum amount of heat to the focal point. The main Disadvantage of this aluminum foil is that it will be damaged or dammed within ninety days. Another drawback is that the available highest temperature of this cooker (used aluminum Foil as reflective material) is not enough to boil rice. Parabolic Solar Cooker Using aluminum Foil as a Reflective Material.

C. Parabolic Solar Cooker Using Mylar Tape as a Reflective Material

Mylar tape is made from Bi-axially Oriented Polyethylene Terephthalate Polyester film and Acrylic adhesive. The most important use of Mylar tape is a radiation shield and sensing. The main advantage of this tape is corrosion resistance, good reflector and poor conductivity of electricity. The reflectivity of this tape is approximately 98%. Mylar tape is widely used for high-temperature applications and heat exchangers. The main disadvantage of Mylar tape is not a locally available material. Another disadvantage of Mylar Tape has a higher cost than Aluminum foil

CHAPTER - II

LITERATURE REVIEW

The literature review is carried out on the various fields of research on parabolic solar dish collector which is aiming to improve the performance of parabolic solar dish collector. In this, following literature,

2.1 Analysis of parabolic dish collector

C Z M Kimambo[1]in their paper optimized various parameters and concluded that results obtained from this study show that under various conditions of insolation and wind, different types of solar cookers are superior to others. However, under best respective operating conditions, box solar cookers have lower performance compared to the reflector cookers. The reflector cooker with glass reflector achieved highest temperatures and accordingly shortest cooking times than any other cookers tested under sunny days with no cloud cover. It is recommended as being the most suitable type of cooker in areas with long durations of strong solar radiation with no cloud cover and low wind interference. However, special attention should be paid to protect the users from possible burns or eye damage that may occur due to the reflected radiation of the cooker. The reflector cooker with polished aluminium reflectors has significantly lower performance than that of the reflector cooker glass mirror reflectors, under clear sky conditions. The reflector cooker with unpolished aluminium reflectors has the poorest performance of all the solar cookers even the box solar cookers under clear sky conditions. The ordinary unpolished aluminium should therefore never be used as reflector for solar cookers. Dissemination of such cookers would definitely end up in failure as the cookers would not be able to meet the cooking expectations of the intended users. The 'Sun Stove' box cooker was able to cook 2 kg of rice, which is sufficient for a moderate family in Tanzania. Both the 'Sun Stove' and the wooden box cooker can be used for cooking where the global insolation is high and wind effects are not pronounced. This work had shed some light on the status of solar cooking worldwide and provided a detailed account of activities taking place in Tanzania, in relation to solar cooking. Results obtained indicate that many of the cookers could be used to cook food for households in areas with medium and high insolation with appropriate selection of the type and specification of the cookers. The specification should be based on the measured insolation data of the location indicating the direct and diffuse components. This should go hand in hand with proper instruction and training of the users for successful dissemination. As a guiding tool, reflector cookers offer best comparative performance in areas with longest durations of clear sky (greatest direct beam), panel and collector cookers under moderate cloudy conditions and box cookers under very cloudy conditions. It should be noted here that all types of cookers offer best performance under clear sky conditions.

Prof. Viral K Pandya, Prof. Shailesh N Chaudhary, Prof. Bakul T Patel[2]started their study with the objective to analyzed the performance of Box Type Solar Cookers under Gujarat Climate Condition in Mid-Summer to improve the workability of cooker a small review on the box type solar cooker applications and its designs given here. Two designs of cookers were tested. The first type has a painted black base and second type has a pained black with coal. These designs were examined under two modes of operations: at fixed position and on tracking system. The cooker at a fixed position had recorded thermal efficiencies ranging from 25.2 % to a sharp peak of 53.8% at the maximum solar intensity of the day around 12-13 pm with an average overall efficiency around 32.3%. Whereas, cooker with black coal pained installed on a sun tracking system gave higher water and pot temperatures, and thermal efficiency ranged from 28% to 62.1% with an average overall efficiency around 43.8 %. Cookers installed on sun tracking system had the advantage of maintaining a higher as well as closer range of thermal efficiencies through the daylight than the ones at fixed positions.

S. D. Pohekar [3]paper discusses cooking energy dissemination in the country with an objective of understanding the underlying socioeconomic factors governing the utilization of various fuels/energy carries in cooking. The diffusion of renewable energy devices is observed to be far better their estimated potential. Policy intervention required for better dissemination of renewable energy based devices is also discussed. In view of the above, it is necessary to follow certain principles which are true for any household energy technology in general and cooking devices in particular. The suggested that dissemination programmers should have an objective of assuring adequate supply of energy in environment friendly and socially acceptable manner. The benefits should occur at user level and not necessarily at national or regional level which are assured anyway by the effective implementation of the programme. It has been proved in many cases that wherever subsidies are offered, quality suffers as the main accent is to minimize the cost. Technology has to compete with conventional cooking energy technologies. Development and dissemination of cooking energy devices should address technical requirements and support, needs orientation, integration into socio-cultural setting, participatory approach by masses, social and environmental sustainability as a goal, training and learning from experience and intensive follow up.

B. Ahmad [4] in their paper interviewed twenty-eight families in three urban sites in Gujarat, India. Direct discussions with families, who were using practical solar cooking, brought forward the practical issues. The study showed that many disusers of solar cookers do not have a suitable place for their solar cookers. Other disusers could not adjust their daily routines with what solar cooking requires, and some disused their solar cookers because they were not interested in using them. User want practical and objective technology, most of the user have problem in using the solar cooker, and have maintenance problem, price issue and production problem. The paper stressed on the need of close understanding between the user and the developer of technology so that it becomes user friendly ad there is no missing link.

Nivay Ananda rajah [5]discusses the study on different types of solar cooker the main goal of their study was to help build the tools necessary to compare the performance and cost of solar box cooker (SBC) designs, which will then inform future prototypes. The models were based on a commercially produced solar box cooker manufactured by Fair Fabricators. Scenarios were chosen, altering only one major solar box component at a time to determine both performance and cost benefits of the changes. After reviewing the results, combination scenarios were created to test the performance and cost of altering multiple solar box components concurrently. This assessment focused on material costs and the following efficiency parameters: peak temperature, rise time for the temperature inside the SBC to reach pasteurization temperature (176 ºF), and length of time above the pasteurization point.

S. Mahaver [6]presents the design development and, thermal and cooking performance studies of a novel solar cooker; it is named as Single Family Solar Cooker (SFSC). Small size, convenient design, inexpensive lightweight hybrid insulation and specially designed lightweight polymeric glaze are the main features of this cooker. A complete theoretical consideration for the fabrication of SFSC had been presented. The thermal profiles of various components of SFSC on different days under different conditions have been measured. During testing, the highest plate stagnation temperature, under no-load condition, approached 144 _C. The two figures of merits F1 and F2 are found to be 0.116Cm2/W and 0.466, respectively, which are according to the Bureau of Indian Standards. The cooking power regression curve is fairly linear with the regression coefficient R2 =0.948. Initial cooking power 103.5Wand the heat loss level 1.474 W/_C, place it in the region of small cooker with good insulation, as per International Standard. The thermal and cooking performance of SFSC (which is small in size and has been fabricated by using new efficient materials for glaze, insulation and casing) are found to satisfy Bureau of Indian Standards and International Standard. Calculated F1 and F2 values indicate that the cooker can be used for consecutive cooking on a sunny day. The values of the initial adjusted cooking power, heat loss coefficient and adjusted cooking power at a temperature difference of 50C are within the range of these parameters obtained by Funk (2000) for small size good insulation solar cookers. The cooking of different items ascertains its good cooking performance for cooking requirement of two persons for two meals. The stagnation temperature achieved by SFSC was 144C.

Ouederni[7]developed parabolic solar concentrator. Experimental measurements of solar flux and temperature distribution on the receiver have been carried out. The solar flux concentrated on receiver has been experimentally determined. The obtained results describe correctly the awaited physical phenomenon. The temperature in the centre of the disc reaches a value which is about 400 °C. So that, a good quality of industrial high temperature equipment's, can be obtained using this technology of solar energy concentration. The second result was the good efficiency of the studied solar concentrator which can be increased by different interventions. In another term, using this solar equipment we can extract eventually 27 % of direct solar energy and convert it into thermal energy that can be used directly for several applications such as water heating, electricity generation using Stirling engine, vapour production, etc.

LifangLi[8]developed a new concept for designing and fabricating large parabolic dish. The dish mirror was formed from several optimal-shaped thin flat metal petals with highly reflective surfaces. Attached to the rear surface of the mirror petals were several thin layers whose shapes optimized to reflective petals form into a parabola when their ends were pulled toward each other by cables or rods.

Ibrahim[9] reported the design and development of a parabolic dish solar water heater for domestic hot water application. He found that the heater is providing 40 litres of hot water a day for a family of four members, assuming that each member of the family requires 10 litres of hot water per day. Initially he expected the thermal efficiencies of 50% by the design but he obtained thermal efficiencies of 52% - 56% and this range of efficiencies is higher than the expected designed value.

Fareed. M. Mohamed[10] studied Portable Solar Dish Concentrator and reported design and fabrication of solar dish concentration with diameters 1.6 meters for water heating application and solar steam was achieved .The dish was fabricated using metal of galvanized steel, and its interior surface is covered by a reflecting layer with reflectivity up to (76 %), and equipped with a receiver (boiler) located in the focal position. The dish equipped with tracking system and measurement of the temperature and solar power .Water temperature increased up to 80 0C, and the system efficiency increased by30% at mid noon time.

Eswaramoorthy[11] conducted an experiment on small scale solar parabolic dish thermoelectric generator. They fabricated solar parabolic dish collector using an unused satellite dish antenna fitted with polished aluminium sheet as concentrator surface. The concentrated solar radiation and water cooled heat sink was the driving potential to generate electricity; they studied various operating parameters like receiver plate temperature, power output and conversion efficiency with respect to solar radiation. From the experiment it was found that the receiver plate temperature was significantly affecting the power output.

Ibrahim LadanMohammed[12]designed and constructed parabolic dish solar thermal cooker. The cooker was designed to cook food equivalent of 12 kg of dry rice per day, for a relatively medium size family. For effective performance, the design required that the solar cooker track the sun frequently and a linear actuator (super jack) were adopted for this purpose. Preliminary test results show that the overall performance of the solar thermal cooker was satisfactory. The cooker was capable of cooking 3.0 kg of rice within 90 – 100 minutes, and this strongly agrees with the predicted time of 91minutes.

Yadav[13] investigated a solar powered air heating system using parabolic trough collector using different reflectors. In this experiment, the reflected solar radiations were focused on absorber tube which was placed at focal length of the parabolic trough. In this setup, air was used as working fluid which collects the heat from absorber tube. He used three different reflectors for analysis and they observed that performance of Aluminium sheet is excellent as compare to steel sheet and Aluminium foil as reflector.

Vardhan[14] studied efficiency of parabolic dish collector under different seasons in Bhopal (M.P) India. They also reported the influence of meteorological parameters (such as Direct Normal Irradiance (DNI), wind, ambient air temperature and humidity etc.) on the performance of parabolic dish collector. The concentrated solar thermal power system constructed for this system follows that of conventional design of a parabolic concentrator with the receiver placed along the line between the center of the concentrator and the sun. For that system the concentrator is theoretically capable of producing temperature upwards to 658 degrees centigrade. This study investigates the potential for our intervention to accelerate the deployment of small-scale concentrated solar power (CSP) in various parts of Bhopal (M.P.)

Sakhare[15]used line focus concentrator with a unique receiver (copper tube in the form of helical coil) mounted at focal point. They investigated the performance of the concentrator experimentally with the water circulated as heat transfer fluid. This system was fabricated with highly reflective aluminium foil sheet (0.8 reflectance factor). They placed experimental setup in open, and the tests were carried out. The collector's efficiency was noted. The results were encouraging to provide the data for developing steam generation for rural application. The concentrated heat was absorbed by a copper tube which was made up of coil in a curved shape (22cm diameter and length with 15 no of turns) and it was fixed on solar trace path in which, it eliminates tracking the sun in the east west direction and optimal tracking of the sun in the north-south to obtain maximum solar energy. The experimental results were taken on summer and cloud free days. The test results were measured 215oC with solar steam conversion efficiency is 60-70%measured.

Sonal C Yogi[16] developed a model of the two axis parabolic dish which works on the automatic circuit that is by readymade parabolic solar dish is taken and fabricated. The circular iron ring provides the two axis motion of the dish. A compound chain drive system was developed for the smooth movement of the dish. An electromechanical system which tracks the sun on both axes and which is controlled via a programmable logic control (PLC) was designed and implemented. In this theoretical study was done. A C program was made which gave the required result for the graphical representation of the recorded radiation. Programmable Logic Controls (PLC) was used instead of photo sensors, which are widely used for tracking the sun. The azimuthal angle of the sun from sunrise to sunset times was calculated for each day of the year at 23.59 Latitude& 72.38Longitude in the Northern hemisphere, the location of the city Mehsana. According to this azimuth angle, the required analog signal was taken from the PLC analog module and sent to the power window motor, which controlled the position of the panel to ensure that the rays fall vertically on the panel. After the mechanical control of the system was started, the performance measurements of the solar panel were carried out. The values obtained from the measurements were compared and the necessary evaluations were conducted.

Arunachala U. C.[17] reported the performance analysis of Solar Cooker for Night Cooking. They used CPC based solar cooker. The setup is tested for six consecutive days. The maximum oil temperature is noted to be 110˚C. During off-sunshine hours, the oil temperature drop was around 35˚C. Due to the increment weather and inherent limitations, the system couldn't attain maximum efficiency. It is observed that during afternoon, oil temperature rise is sufficient to cook rice and the oil temperature during late evening is sufficient for food warming.

Parthipan[18]described Design of solar parabolic dish concentrator for low cost solar water heating system was proposed in this model. In this project a small scale Aluminium cylindrical solar receiver with spherical cavity was installed at the focal point of the dish. There were various factors played in the model which increases the water temperature running through such receiver. Receiver efficiencies were shown in terms of mass flow rate, receiver spherical diameter, maximum receiver surface temperature and inlet temperature of the working fluid. An overall solar to heat efficiency of between 45 % and 70 % is attainable for the solar collector using the open cavity receiver.

VanitaThakkar[19] studied the performance Analysis of Parabolic Dish Solar Concentrators for Process Heating Using Thermic Fluid. They present a performance assessment model for PDSC for process heating application, using Thermic fluid. Considering the effect of various system parameters, the expected and actual efficiencies are worked out. This can help in assessing the performance as well as detecting possible faults. It also gives an idea about losses or errors which have remained unaccounted, also providing a scope of their detection and tracing remedies for their removal / prevention. The suggestion and calculation of providing a glass cover on the receiver to minimize convective heat losses, which contribute maximum to the tally of heat losses from the receiver, can be implemented and experimented on, especially for systems working in high wind velocity terrains.

Himanshu Agrawal and AvadheshYadav[20]studied Solar Cooker with Sensible Heat Storage unit. They reported the thermal analysis of sensible heat storage units (sand, stone pebbles, iron grits and iron balls) in a solar cooker based on parabolic dish type solar collector for late evening cooking is theoretically investigated. In the theoretical analysis the heat input and output to the system was calculated using the thermodynamics equations. The various losses in the system were measured. The theoretical data obtained were compared to the experimental data and relative error was calculated. The efficiency of the system for different cases was calculated theoretically and experimentally and was found to be in range of 4 to 9%.

ManavSharma[21] presented Design, fabrication and analysis of helical coil receiver with varying pitch for solar parabolic dish concentrator. In his study they reported that the parabolic dish of opening diameter 1.4 m was fabricated using galvanized steel and its interior Surface covered with reflective surface of ionized aluminium with a reflectivity of 92.5%. The system is equipped with a receiver fabricated using copper metal positioned at the focal point. The working fluid is water. The research was focused on the temperature variations achieved from changes in the geometry of the helical receiver. This paper reveals the temperature variations achieved with a bare tube helical receiver with zero pitch and with black coated helical receiver with non-zero pitch and capped. The maximum attainable temperature with non-zero pitch helical receiver coated with black paint and capped was approximately 43% higher than that of bare tube helical receiver with zero pitch.

Gavisiddesha[22]built& tested a parabolic cooker and experimental results showed that the low efficiency of the parabolic cooker was attributed to the optical and thermal losses from the reflector and the pot. The exergy efficiency of the solar cooker is varying because input solar radiation is rich in exergy and being utilized in the form of heat at low temperature. The exergy efficiency can be increased only marginally by increasing the reflectivity of reflectors, proper designing of cooking place and by using a suitable cooking pot. Cylindrical shaped cooking vessels made of aluminium or copper and painted black should be preferred for a higher cooking efficiency. The parabolic cooker presents encouraging results while being compared to other types of solar cooker. Solar cooking technology is a key item in order to deal with deforestation.

Soteris A. Kalogirou[23] Performed a study of the different models of solar thermal collectors covering flat-plate, compound parabolic, evacuated tube, parabolic trough, Fresnel lens, parabolic dish and heliostat field collectors, and the applications. Based on the comparisons of each type with the different uses of space heating and cooling, industrial heating process, refrigeration, steam generation and water desalination.

Ahmed Yassen[24]an experimental and theoretical study has been performed to define the thermal efficiencyof the (PTSC). Through using program FORTRAN90, the experiments have been conducted during winter and summer at Tikrit-Iraq.

The result of the experimental thermal efficiency of the collector was less than the theoretical method in percentage between (7-15). So the increase in the water mass flow rate leads to an increase in the thermal efficiency, and there was no significant change in thermal efficiency when the water mass flow rate becomes more than forty kilograms per hour. He found the thermal effectiveness of the collector in the winter was more than the thermal efficiency in the summer by (2-5) percent.

2.2 Solar cooker using Mylar tape

Ali A. Badran[25] and his team had implemented a design entitled "Portable solar cooker and water heater". In this research portable solar cooker had specially designed for the Bedouin community for continuously available in the desert. Moreover, during the operation of the cooker, 7 kg of water at 20 ^{o} C was a need to a boil in 1 hour. However, the efficiency of this cooker was 77% and the slope of the efficiency curve was 10.63 W/m2 ^{o} C.

E. Cuce and P. M. Cuce[26] did research entitled "A comprehensive review on solar cookers". This analysis paper covered the historical evolution of solar cooking technology, an explanation of different types of solar cookers, glazing, absorber plate, cooking pots, materials for heat storage and insulation. Ultimately, the research also takes into account feasibility analysis, environmental effects and the future potential of solar cookers.

I. Berryman and N. Jelley [27] had analyzed "Novel solar concentrator geometry for point focus, low-cost applications". The geometry for a novel Solar Concentrator was presented in this study. This paper discusses the novel geometry of a mirror system. The developable surfaces allow mirrors to be made from flat reflective hardwearing sheets. Compared with parabolic dishes, the focusing capabilities and tolerances for monitoring errors of this novel device will be discussed. The simplicity of the design will simply enable the high performance of the proposed system to be obtained and allow applications at high temperatures.

A. Harmim[28] and his team did research entitled "Experimental study of a double exposure solar cooker with the finned cooking vessel". For this analysis, a box-style solar cooker was performed with two separate cooking vessels, the first being a conventional one. Besides, the second was the same in form and volume as the first but fitted with fins on its external lateral surface. This greatly decreases the time needed to cook. This greatly decreases the time needed to cook. The experiments were carried out on the Renewable Energies Research Unit's experimental platform in Adrar's Saharan Medium.

2.3 Adjustment in tracking time

Mirunalini [29], researchers performed intensive efforts; in recent years, on study, design and development of solar cookers. Kumar presented simple thermal analysis to evaluate the natural convective heat transfer coefficient for an absorber plate-inner glass trapezoidal enclosure of a double-glazed box type solar cooker.

Kumar [30] presented the performance results of experimental study conducted on solar pressure cooker and developed a simulation model for predicting the cooker performance under a variety of operating and climatic conditions.

Hussein [31]designed, constructed and tested a novel indirect solar cooker with outdoor elliptical cross section, wickless heat-pipes, flat-plate solar collector and integrated indoor PCM thermal storage and cooking unit under actual meteorological conditions of Giza, Egypt.

Sharaf [32] revealed the concept of the conical focus and explained and tested the design of an economical, highly efficient, conical solar cooker.

2.4 Summary of Literature Review

From the above literature review it is concluded that many researchers have worked on different types of solar collector. From the above literature review it is concluded that some of researchers worked on design and performance of parabolic solar dish collector. Each shape have some advantage in then in terms of cost, difficulty in manufacturing, thermal absorptivity etc. From the above literature review it is concluded that very few Researchers have been reported that the use of different design of absorber and multiple reflectors enhances the total solar gain in many applications.

CHAPTER - III

CALCULATIONS

f Focal distance

h Depth of the parabola

R Radius of the parabola

d the concentrator diameter

The equation giving the focal distance (f) is given by:

$$f=h^2/(4*R)$$

The parabola surface is:

$$A=8*\pi*f^2\left[\left(\left(\frac{d}{4*f}\right)^2+1\right)^{3/2}-1\right]$$

3.1 Effective heat utilised:

Total area of light: Area of reflector (RA) + Direct incident rays received by black trough area (Tr A)

Due to variation in Sun, hourly angle the reflector reflections will be varying and varying heat inputs will be given to boil the food.

Effective heat generated (ideal situation where total light falls in to box)=incident light of the total area. The maximum heat = (RA +Tr A)

Quantity of food boiled = Q (heat used for boiling water& food material-for boiling .For frying quantity kept in the utensil for frying).

Considering solar constant 1000W/Square meter/Hour 860Kcals/hour/Square meter. Effective heat input=860(RA+ TrA) Kilo calories

Finding the Critical Angle: Because the position of the sun in the sky is constantly changing, we are interested in determining the focal height and radius that will collect the most reflected rays with the most angle tolerance. If a solar cooker has a large angle tolerance, it means that it is able to reflect light onto the absorbing surface at extreme or smaller incoming angles. For a generic model the aperture length of the solar cooker is held constant at 1 while the radius (r) and focal height (f) are interpreted as ratios of the diameter.

All the reflected light rays are hitting the pot. But at what angle Θ do the light rays start missing the pot? Geometry Expressions calculates the critical incoming angle that light starts missing the pot as

$$\arctan\left(\frac{1}{16}\,\frac{\sqrt{1+32f^2+256f^4-256r^2f^2}}{r\,f}\right)$$

This critical angle is the widest incoming angle for a given r and f and an aperture length of 1 that concentrates all the reflected rays to the pot with radius r.

To judge the performance the cooker is to be tested in different sky conditions& at different seasons of a year period and for time of boiling with respect to quantity. In normal box type cooker, with single reflector, in the place where sun rays does not fall temperature is less in comparison to place sun rays fall. Even in this design temperature gradient from one corner to other corner& top to bottom were observed. The temperature gradient is very less in comparison to single reflector box type cooker.

In solar cooker cooking starts from top to bottom along with sides to central portion.

In the present model reflector area (mirror area) = 0.585 Square Meter. Trough incident area = 0.1764 Square meter.

For boiling 450 grams rice water used is 1000to 1100 ml depending upon the rice.

In normal sky conditions in 2 hours period 450 grams of rice is boiled in the model. All types of vegetables green leafy & roots are tested for boiling. Chick pea (gram dal-chana, mung etc), peas, peanuts were tested for boiling. All gram dals including peanuts/groundnuts were tested for frying.

CHAPTER - IV

EXPERIMENTATION

4.1 Sun rays analysis

As earth rotates, Sun rays travels East to West, East to noon the rising sun-shade length decreases- reduces the reflected light length the intensity of sun rays increases from morning to noon and reaches peak value at noon. Noon to west lowering sunshade length increases- increase the reflected light length. The intensity of sun rays reduces from peak value to minimum. In spite of this the shade rotates. The rotation of sun rays varies with respect to season wise.

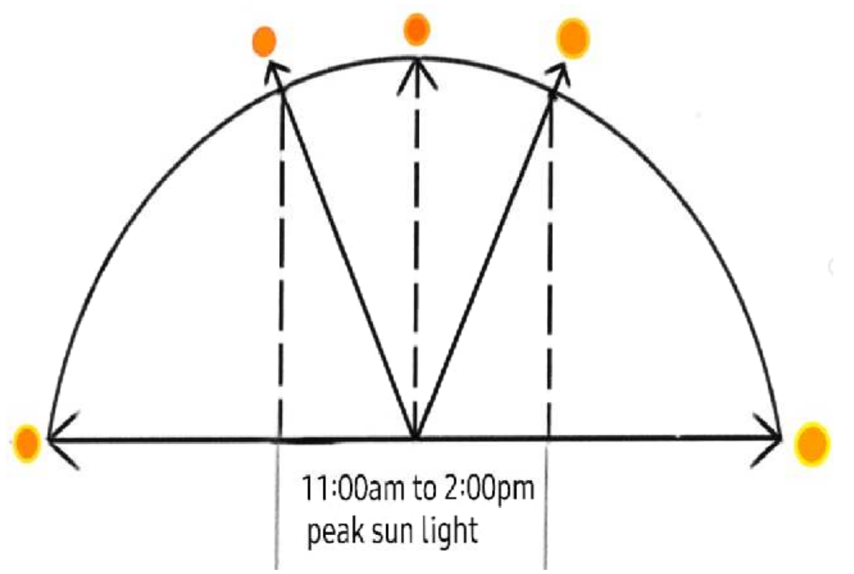


Fig 4.1:Sun tracking

In this way, from fig 4.1 rays can be classified into inclined portion& vertical type. The sun rays usage in inclined zone will increase the operating period of solar cooker. This is done with the help of tracking system using one direction& two direction using electrical/mechanical aids manually automatically.

In the present design the tracking part is eliminated to maximum extent and incorporated in reflector design.

In general the direction sun raising position varies season wise. The sun rises in east. Due to variation in east the directions west, north and south positions varies.

In fig 4.2 ,at position E2 with respect to India peak summer. At position E1it is peak winter in India. If we observe the above figure the sun crosses 2 times position E where the day and night timing are equal. With this figure we can understand differences summer, rainy and winter seasons in the geographical locations above and below equator .Below equator it is opposite to above equator conditions that means peak summer at E1 and peak winter at E2. Rainy season will be at March month and at E position where days & nights are equal.

In the following fig-4.2 we can observe the sun rays falling on a box.

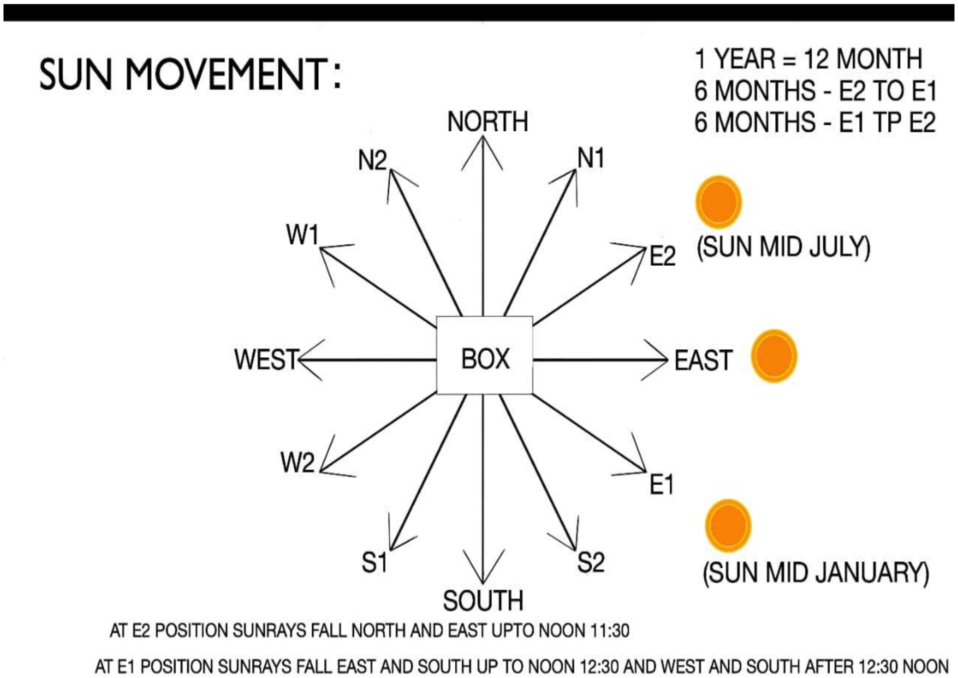


Fig 4.2 Sun movement

The sun rays when falls on a square box (Fig 4.2) it can be observed that rays falls on two sides of the block& top side /surface at any time. At position E1 the sun rays fall on East & south side of box. At noon rays falls on South side for some period (This is observed practically at Visakhapatnam in 4 week of March month). Afternoon rays fall on South and West side of box. At position E2 sun rays fall on east and north of box. At noon the rays are vertical for some period. Afternoon rays fall on South & west side of box. At position E the rays falling is similar to E1.

If the same rays fall on a cylindrical surface it can be seen that at any point of time 180 degrees of perimeter will be exposed to sun rays and top surface of cylinder exposed to sun rays. But the change in the position of direction east is understandable causes due to rotation of shade.

Keeping this observation into consideration reflector has been designed to cover 2 sides of box and or 180 degrees perimeter of box only. It is mounted / positioned in sides (directions where radiation does not falls).

4.2 Reflector & reflection patterns

If rays falling on an inclined mirror depending upon the incident angle reflected rays position will be varying as shown in the sketch. At Q1 the rays reflected length will be up to X1 on the ground. For more than Q1 up to Q2 the reflected ray length is X2 on ground. If reflected ray angle increase further reflected ray will not fall on ground& falls in air. As the sun raises from early hours to noon the length of reflected ray on the ground will decreases. From noon to sun set the length of reflected ray on the ground will increases. If the ray is parallel to mirror (at noon) reflected length will be slit as shown in sketch- for different positions of sun. As the sun lowers from noon hours to West the length of reflected ray on the ground will increases. In this present design the reflected ray part (X1, X2) will be transferred to black trough of solar cooker to generate heat.

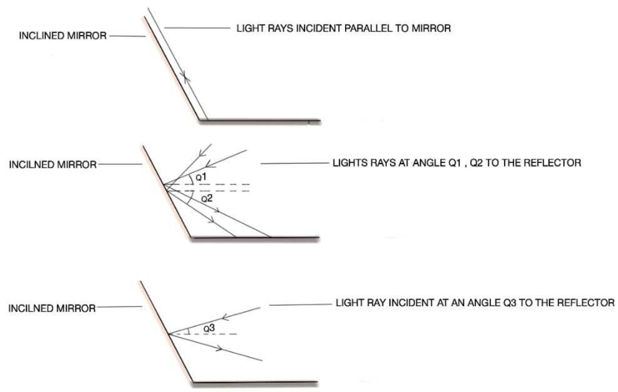


Fig 4.3Incidence of light rays

Reflector design is based on the reflection pattern and temperature raise is based on reflections intensity and retention time of reflections in parabolic trough. The reflections varies w.r.t. to sun position

4.3 Parabolic trough design

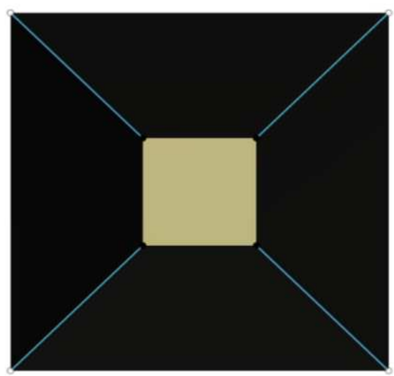


Fig 4.4Trough

Since parabolic profile will deflect/reflect the incident rays to focal point. The parabolic surface (parabola : Square Y=4aX-where a is focal point) incident light rays falling on parabolic surface below focal point rays will be deflected/reflected to upwards& incident rays above focal point rays will be reflected/deflected to downwards.

Paraboloid cross section is circle in shape. If the circles are replaced with squares then compound paraboloid forms& the shape formed is two parabolas focal axes of which perpendicular to each other In this way the compound parabolic surface type absorber is designed to take care of vertical rays. At noon the reflector reflections are nil and only compound parabolic surface take care of heating of the food and food utensil. This shape can be observed in Indian Temples-architecture.

The Sun rays falling on parabolic trough as mentioned above from reflector through double cover glasses it is seen clearly with necked eye. This shape will take care of inclined sun rays which are reflected by mirror. As the experiment is carried out at residence due to lack of sophisticated cameras the photos could not be taken. Though shade is formed in the trough due to rays of different directions the effect of shade in reduced to large extent and improved performance observed in the form of sustenance of higher temperature for higher periods. Due to sustenance of higher temperatures increasing the number of times boiling increases.

More over the depth/thickness of food layer will affect the cooking period. By selecting parabolic surface suitably with respect to utensils used the height of utensil can be reduced in turn lessen the food layer thickness.

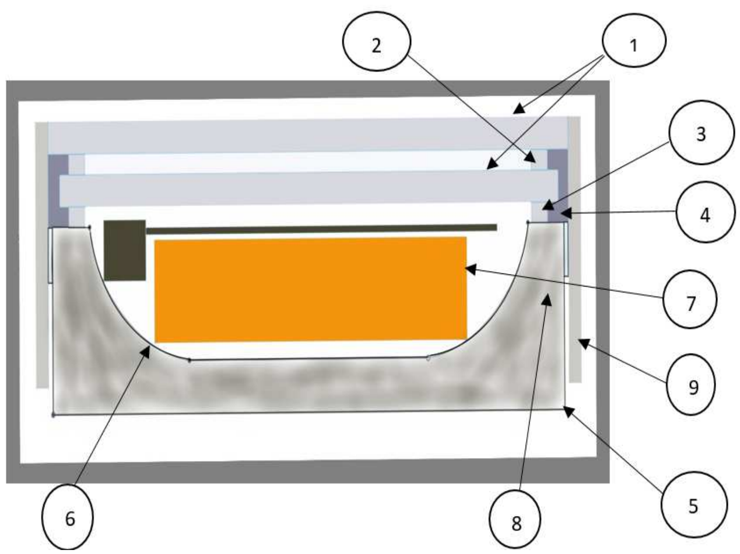


Fig 4.5 Sectional view of the box

1-Cover glass (toughened)

2-Packing (for maintaining gap)

3-Sealing packing

4-Box lid

5-Box

6-Compound parabolic trough (Aluminium made)

7-Utensil (S.S made and brass coated with black non selective coating)

8-Thermal insulation (Hot)

9-Aluminium angles

Fig 4.5 indicates the cross sectional view of insulated box fixed with rubber sealing and cover glasses. In the insulated box food containers black coated outside and lids coated with black outside with food material are placed in black coated compound parabolic trough as mentioned above. The insulation mineral wool to withstand more than 200° C. Sealing rubber is fixed on the insulated box. The sealing should be of rubber material to withstand more than 200 degrees Celsius. Cover glasses are of toughened glasses .One toughened glass is directly placed on rubber packing. The toughened glasses are placed at 10 mm apart. The total load on the ceiling is weight of toughened glass and reflector material weight plus reflector template weight and in turn transferred on to insulated box.

From fig 4.6, the setup is made with mirror reflectors which are joined as segments. All of them were combined together in the form of a parabola. A box is designed which has a black coating in it that is capable of absorbing heat energy where the utensils are placed for cooking. The reflectors arrangement is placed on the box and sun rays are made to focus on to the box. Concentrating all the sunrays at a point produces too much heat energy at the focus point there by aiding cooking process.

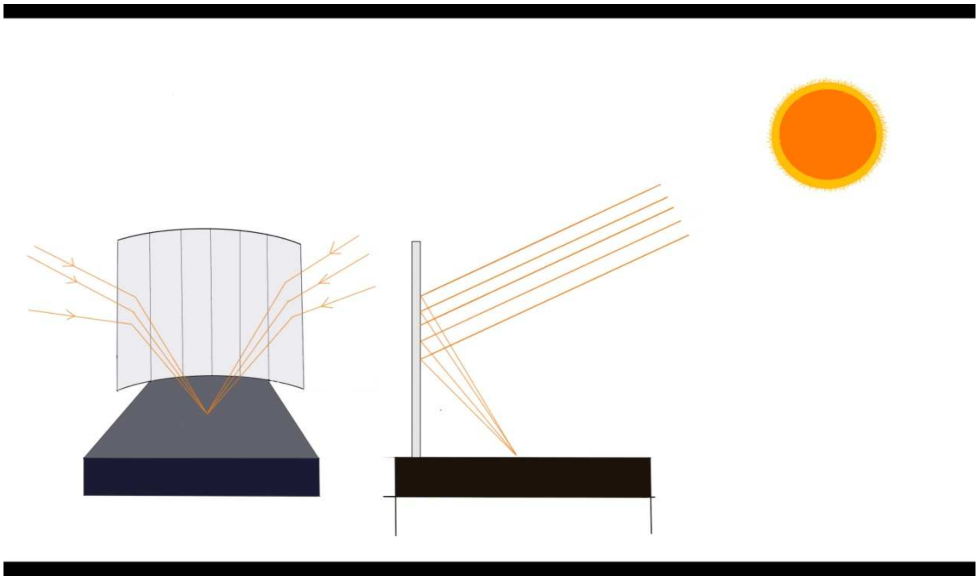


Fig 4.6 Illustration of sun rays falling on cooker

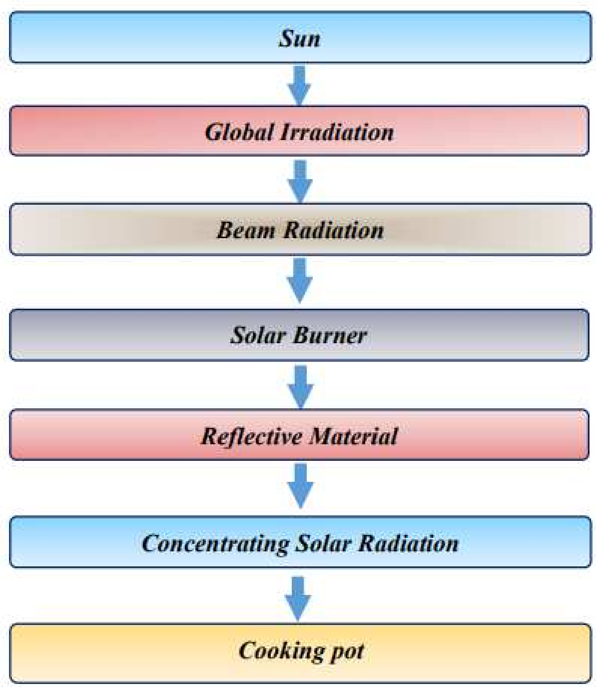


Fig 4.7 Block diagram of Parabolic Solar cooking

4.4 Advanced reflector design

5 segment reflector function well in clear sky in inclined and rotary portion of sun rays. Boiling is also ensured without fail. But slight cloudy sky in winter boiling time increasing and sometimes boiling is incomplete due to

intermittent sun. To increase the uniform distribution of reflections of reflector in compound parabolic trough and to reduce the boiling time further reflector design was changed. The aim of change in reflector is to equalize the boiling time and to complete boiling in slight cloudy sky of winter at Visakhapatnam. A reflector of seven segments was fabricated. The same was tested and it was found that marginal improvement in performance. But moisture accumulation in winter part cloudy sky is remaining.

Fig 4.8 - 9 Segment reflector

9 segment reflector assembly was made to improve the performance in winter slight whitish cloudy sky. In the above figure the distribution of reflected light is differing with 7 segments&5 segments. The over lapping are more and temperature gradients at corners less in comparison to5 & 7segments In this sky slight cloudy condition boiling ensured but time is 2hrs 30 mts. But there is less wastage of food material due to non-boiling of food in comparison to 5segments & 7 segments reflectors. Still moisture formation on bottom cover inside surface and drop lets are prevailing in lesser quantity. The insulated box, trough, utensils etc., are of same size of previous models 5 &7 segments one. This is of new template. In this also at normal sky performing well. A permanent flexible fixture is used to template back side to adjust the inclination (tilt) of the reflector assembly to match or advance the sun position

winter sky (the sun rays minimum insolation is available continuously). This is tested for different sky conditions of a year. The wastage of light reduced. The size of insulated box used is of same as 5 segment one.

Fig 4.9 - 11 Segment reflector

The reflector area is slightly less than 9 segment reflector. In comparison to 9 segment reflector the template design is slight complicated. The specific advantage is the spreading of overlap reflections over the black trough area is more in comparison to 9 segments is more. There is a reduction of time 15 minutes in ½ kg food boiling occurred in comparison to reflector 5 segment, 7 segments, 9 segments. For frying or drying, 15 minutes reduction observed. The experiment was carried out at residence, Visakhapatnam, Andhra Pradesh, India. The size of black trough and insulated box are of same size of 5 segment reflector. Moisture formation in part cloudy slightly reduced in comparison to 9 segment reflector.

4.5 Experimental set up

Fig 4.10-5 segment parabolic solar cooker

In pilot model Rice 370 grams& leafy vegetable with dal 75 grams boiled. The reflector is taken out and cover glasses are taken out in the fig-4.11 thermometers 3 no's are placed to monitor the temperature.They are used to measure temperature at different time periods.19 months temperatures were monitored continuously to rectify the problems arise during this experimentation This has led to ensuring guaranteed performance in normal sky conditions at different seasons.

Fig 4.11: Utensils in the trough

If we closely observe fig -4.12 we can find moisture accumulation. Due to moisture accumulation in winter slight cloudy sky there is increase in cooking period. In pilot model sealing material used is papers.

Fig 4.12:Accumulation of moisture

The black trough in which leafy vegetable boiled in brass utensil& rice boiled in stainless steel utensil of standard pressure cooker 12 lts (smaller one). The lids are in open condition. Utensils outside black coated and lids outside black coated. In Fig 4.12 slight increased load with 2nd cup. Moisture accumulation is observed.

In bigger size model Fig 4.13 boils 1 kg rice. (The reflector used is 5 segments model used for ½ kg boiling). Reflector is mounted on box.

Fig 4.13:Cooking rice using solar energy

In this position in normal sky in 3 hours one kg of rice boiled. This indicates if reflector is mounted on box there is increased boiling quantity and reflection losses reduction (falling out side box) reduced.

Fig 4.14: Cooked food

CHAPTER V

ANALYSIS

5.1Geographic analysis

With respect to Visakhapatnam geographical location the following is the sun rays position tentatively. To track the sun the reflector is to be rotated once in a day at noon when Sun moves towards west at noon, the amount of rotation 90 degrees w.r.t. vertical circle from early September to Middle April. In this period sun rays falls on East & rotates to south of box up to noon. After noon sun rays falls on south& west sides of box. In the remaining period mid-April to early September early hours to noon rays fall East& North and after noon South & West. In this period sun rays falls east& North during morning to noon11:30 hrs & at noon sun rays are vertical. After noon beyond 12:30 hrs the rays falls on South & West faces of box. The reflector is to be rotated 180 degrees at noon with respect vertical circle. To cater the winter rays inclination (during December& January months) a semi-permanent lever attachment is provided with reflector template to adjust tilt of reflector for better usage of cooker in this period. The temperature generated is 110 to 120 degrees Celsius which suitable for normal household cooking needs .More over in this design more than one time boiling& frying was done in clear sunny days even in winter months also. In this cooker time of operation from 0900 hrs to 1500hrs IST. The utensil used is of stainless steel make standard pressure cooker 12 lts smaller one coated with non-selective black coating outside. Lid is black coated outside like utensil.

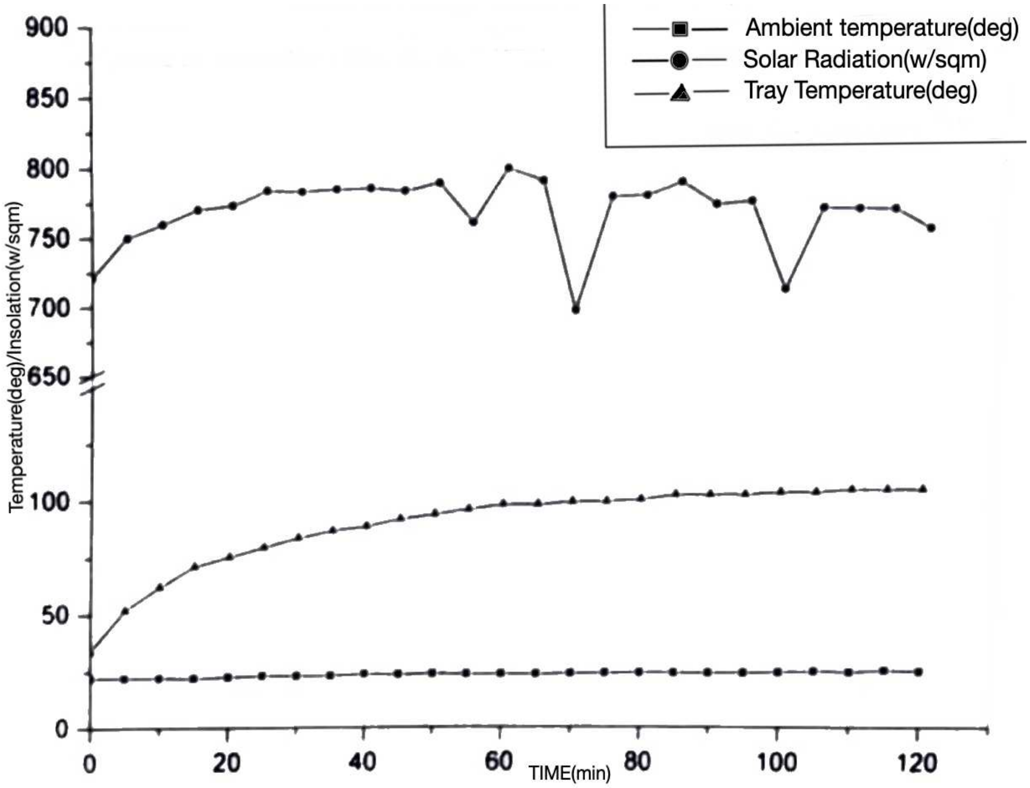
After the experimental setup is done, the parabolic solar cooker is subjected to different weather conditions that impact the cooking time. A pyrometer is used to find the temperature that is obtained at different time intervals in different climatic conditions. By performing the entire experiment throughout the day, the required data will be tabulated in the following way.

5.2 Testing of solar cooker

Wind speed = 2 m/s

Table 5.1:Analysis in working condition

S.No	Time(hrs)	Air temperature(°C)	Average Global Solar Radiation(W/m^2)	Tray temperature(°C)
1	10:30	22.3	721.9	34
2	10:35	22.1	750.2	52
3	10:40	22.1	759.7	62
4	10:45	22.0	770.4	71
5	10:50	22.3	773.4	75
6	10:55	22.8	783.8	79
7	11:00	22.6	782.9	83
8	11:05	22.7	784.8	86
9	11:10	23.3	785.2	88
10	11:15	23.1	783.2	91
11	11:20	23.4	788.8	93
12	11:25	23.2	760.2	95
13	11:30	23.1	798.6	97
14	11:35	23.1	789.6	97
15	11:40	23.3	695.5	98
16	11:45	23.5	777.6	98
17	11:50	23.6	778	99
18	11:55	23.7	787.0	101
19	12:00	23.6	770.8	101
20	12:05	23.6	772.5	101
21	12:10	23.8	708.9	102
22	12:15	24.3	766.7	102
23	12:20	24.0	765.7	103
24	12:25	24.8	764.9	103
25	12:30	24.4	750.7	103



5.3 Loadtest:sensible heating of water

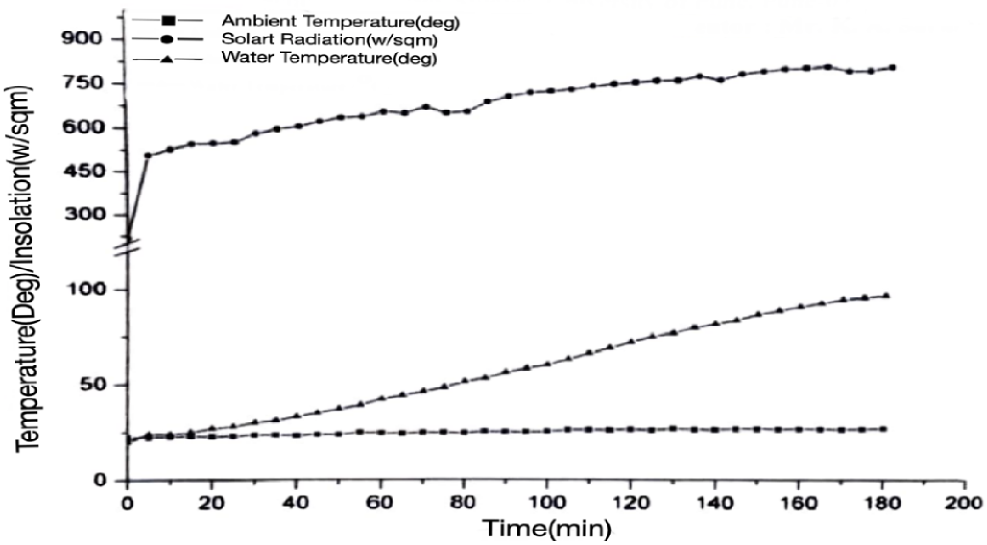
Average wind speed=2.2m/s

Table 5.2:Sensible heating of water

S.no	Time(hrs)	Air Temperature(^oC)	Average Global Solar Radiation (W/m^2)	Water Temetrature (^oC)
1	10:00	22	218.7	20
2	10:05	22.3	506.9	24
3	10:10	22.5	527.1	24
4	10:15	22.7	545.7	25
5	10:20	22.6	584.3	27
6	10:25	22.8	553.3	28
7	10:30	23.4	584.0	30
8	10:35	23.3	600.4	31
9	10:40	23.2	609.6	33
10	10:45	23.7	627.5	35
11	10:50	23.7	641.9	37

12	10:55	24.7	645.7	39
13	11:00	24.4	662.7	42
14	11:05	24.2	657.7	44
15	11:10	24.6	679.7	46
16	11:15	24.5	659.8	48
17	11:20	24.4	664.3	51
18	11:25	25.3	698.7	53
19	11:30	24.9	717.5	56
20	11:35	25	729.0	58
21	11:40	25.3	734.3	60
22	11:45	26.1	741.3	63
23	11:50	26.1	751.7	66
24	11:55	25.9	759.1	69
25	12:00	26.4	763.4	72
26	12:05	25.9	769.5	75
27	12:10	26.9	769.6	77
28	12:15	26.5	784.2	80
29	12:20	26.3	768.9	82
30	12:25	26.8	790.0	84
31	12:30	26.8	799.1	87
32	12:35	26.6	805.6	89
33	12:40	26.8	808.3	91
34	12:45	26.8	813.7	93
35	12:50	26.6	798.4	95
36	12:55	26.7	789.2	96
37	13:00	27.1	810.7	97

Graphical illustrations of above presented data



Graph:Time Vs Temperature/Insolation

5.4 Conclusion of temperature readings

1. The place where light is not falling temperature is less and place where light falls temperature is more by 20 Deg Celsius. This indicates temperature differential in black trough is to be reduced.

2. Thermal leaks are to be arrested with better sealing. This reduces condensation.

3. Uniform distribution of light and overlapping are increasing temperature and reduces boiling time. 4. Reduction in loss of light and light unexposed area during operation of cooker.

5. There is difference of temperatures of 3 corners observed. This corners temperature difference to be reduced for reducing boiling period. The above observations are to be eliminated to promote solar cooking.

CHAPTER - VI

CONCLUSION AND FUTURE SCOPE

6.1 Conclusions

Cooking with solar energy remains a fuel-saving technique, which can provide definite help in situations of fuel scarcity. Solar cookers and especially cooking boxes can be successfully locally made .By performing the experiment we can come to an assumption that the parabolic reflector solar cooker perform far better than a box type solar cooker when it comes to subjecting more heat into the box. As the number of segments increases the effectiveness also increases. Continuously tracking of sun automatically increases the manufacturing cost as it involves sensors and moving objects.Parabolic Solar Cooker helps in avoiding crores of tonne of biomass and wood fuel can be saved.

6.2 Future Scope

There is a great deal of work that can still be done in this area. Several advanced models can be designed and fabricated in such a way that most of the solar energy can be made use of by concentrating the accumulated sunrays on to the working zone. Usage of different materials as collectors can help in improvement of the model. By making use of solar cookers depletion of non-renewable energy sources can be controlled.

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