FABRICATION AND TESTING OF A MULTI-REFLECTOR TYPE SOLAR OVEN

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PROJECT REPORT

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1992

DECLARATION

We hereby declare that this project report entitled **"Fabrication and Testing of a Multireflector Type Solar Oven"** is a bonafide record of project work done by us and this work has not previously formed the basis for the award to us of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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CERTIFICATE

Certified that this project report, entitled **"Fabrication and Testing of a Multireflector Type Solar Oven"** is a record of project work done jointly by **Kum. Beena Thomas, Kum. Helen Alex, Sri. Jayarajan, R. and Sri. Rajeev, M.** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to them.

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19-12-1992.

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SYMBOLS AND ABBREVIATIONS USED

ANERT	Agency for Non-Conventional Energy and Rural Technology
am	anti meridian
CEL	Central Electronics Limited
cm	centimetre
°C	degree centrigade
etc.	et cetera
et al.	and others
Fig.	Figure
GI	Galvanised iron
g	gram(s)
hr	hour(s)
KCAET	Kelappaji College of Agricultural Engineering and Technology
kg	kilogram(s)
km/hr	kilometre per hour
lit.	litre
m	metre
MRSO	Multireflector type solar oven
min	minutes
mm	millimetre
m.s	mild steel
mW	milliwatt
pm	post meridian
qty.	quantity
Sl.No.	Serial number

sq cm	square centimetre
sq m	square metre
temp.	temperature
w/m^2	watt per square metre
%	percentage
μm	micro metre

INTRODUCTION

Energy is defined in classical thermo dynamics as the capacity to do work. From a practical point of view, it is the basic ingredient for all industrialized societies. Energy is currently derived from different primary sources such as oil, natural gas, coal and wood. The supplies of most of these common energy sources are finite. Life times estimated for fossil fuels range from 35 years for oil to atmost 200 years for coal and natural gas. Availability of wood is limited by deforestation and climate. As current energy sources become exhausted, an energy gap will develop, exacerbated by the synergistic effects of population growth and increased dependence on energy. After non renewable energy sources are consumed, in what some authors call this "fossil fuel age", humanity must turn to longer-term, permanent energy sources. The two most significant of these are nuclear and solar energy. Nuclear energy requires highly technical and costly means for its safe and reliable utilization and may have undesirable side effects. Solar energy, on the other hand, shows promise of becoming a dependable energy source without new requirements of a highly technical and specialized nature for its wide-spread utilization. In addition, there appear to be no significant polluting effects from its use.

Solar energy is a clean, non-polluting non-depleting energy available almost everywhere. The power from sun intercepted by the earth is approximately 1.8 x 10" MW, which is many thousands of times larger than the present consumption rate on the earth of all commercial energy sources. Thus, the principle, solar energy could supply all the present and future energy needs of the world on a continuing basis. This makes it one of the most promising of the unconventional energy sources. The drawbacks in using solar radiation as energy, as has been pointed out are that it cannot be stored and it is a dilute form of energy.

The intensity of electromagnetic radiation is 1.94 calories/cm^2/minute or 1.353 KW/m^2 on the surface normal to the solar beam. The energy can be concentrated in solar furnaces, which can achieve temperatures in the region of 5000°C. A system used to convert it to heat on a practical scale must be relatively large. Solar energy collectors are the devices used to convert the sun's radiation to heat, usually have a surface that efficiently absorbs radiation and converts this incident flux to heat, which rises the temperature of absorbing material. Part of the energy is then removed from the absorbing surface by means of a heat transfer device fluid, which may be either liquid or gaseous.

The application of solar energy are many such as solar heaters, solar coolers, solar refrigeration, air condition, space heating, grain driers.

Cooking accounts for the major share of energy consumption in developing countries. Fifty per cent of the total energy consumed in India is for cooking. Most of the cooking requirement is met by non-commercial fuels such as firewood, agricultural waste and cowdung cake. The total consumption of firewood, cowdung cake and agricultural waste are 150, 75 and 50 million tonnes per year in India. One third of India's fertilizer consumption can be met if cowdung is not burnt for cooking and instead is used as a manure. The cutting of firewood causes deforestation which leads to desertification.

Cooking consumes a major portion of the total time and energy of an India house wife. They spent fairly a good amount of time and energy on this activity. The time and energy spent on cooking depends upon type of fuel consumed, efficiency of cooking equipment used, food consumption habits and style of cooking. The stock of conventional fuels used for cooking are not going to last long and is polluting also. By the end of this century it has been predicted that there will be a great shortage of firewood if a suitable alternative is not provided to the rural people. Fortunately, India is blessed with abundant solar radiation. The arid parts of India receive maximum radiation i.e., 7600-8000 MJ/m^2 per annum, followed by semi arid parts, 7200-7600 MJ/m^2 per annum and least on hilly areas where solar radiation is still appreciable i.e., 6000 MJ/m^2

per annum. Therefore, solar cookers seem to be good substitute for cooking with firewood.

Generally solar cooker falls in two category - Box type and Concentrating type. Cooking with solar box cookers is currently being promoted world-wide, especially in developing countries, as a method to alleviate the need and cost for fuels. The box type cooker essentially consists of a rectangular enclosure insulated on the bottom and sides and having two glass covers on the top. It can be made either with single reflector or multireflectors. A thorough understanding of energy collector with concentrating mirrors is essential for evolving better designs of solar cookers. The fact that the increase in stagnation temperature and reduction in cooking time can be achieved by using concentrating mirrors has been well recognised. More uniform rate of energy collection throughout the day can also be obtained. The above mentioned effects ultimately result in better performance of the cookers and collection of more energy for a marginal increase in investment.

The performance of the hot box solar cooker is very good during summer, but it is very poor during winter in the northern parts of India because its absorbing surface is horizontal, and solar radiation received by a horizontal surface is 33 per cent less as compared to a tilted surface in the winter season. Therefore, we believe that a new solar cooker should be designed which is better in performance than the hot box solar cooker. Considering the importance of developing a cooking device using solar energy the project entitled "Fabrication and testing of a multireflector type solar oven" was undertaken. The objectives are:

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REVIEW OF LITERATURE

This chapter briefly describes the research and development activities done in the past few years about solar cookers and the important terminology related to solar energy.

Research and developments on solar cookers

A solar cooker was developed by Ghai and manufactured in large scale in the 1950's, but it did not become popular due to its defects viz., it requires 10 min tracking; performance of the solar cooker was affected by dust and wind since cooking utensils were kept outside; there was danger of getting burnt, cooking must be done in direct sun only one had to be near the cooker for cooking and it was complicated. Therefore, it has slowed down the progress of solar energy utilization in the 1960's in India.

Solar cookers are either a reflector type as developed by Ghai, Duffie and Lof or a hot box type developed by Telker, Ghosh and Garg. Different models of solar cookers have been tested by Garg (1987) and the solar oven which was improved by Malhotra _et al_. and Nahar was found best.

The multireflector type solar oven was first designed and studied by Dr. Maria Telkes in 1951. Dr. Telkes attached plane reflectors to the cooker box at an angle of 60° with the plane of the glass cover provided on the cooker box. This oven needs to be adjusted towards the sun after every half to one hour. Researchers reported that solar oven showed greater promise due particularly to higher efficiency, ease of operation and ease of construction with locally available skills and materials.

Bhattacharya et al. (1978) made the first attempt to use a two-phase thermosiphon in a solar cooker. They proposed the use of one thermosiphon leg in out-door collectors.

Garg et al. (1978) did a trial to see the wind effects on the performance of a solar cooker. He found that when wind speed exceeds about 10 km/hr, the pot temperature does not exceed 80°C under Delhi conditions. The same pot containing one litre of water comes to a boil in less than half an hour in calm weather.

Von Oppen (1978) reported the development of a very simple and cheap automatic sun tracking device that greatly enhances the utility and efficiency of the solar cooker. The sun basket is an efficient low cost solar cooker which concentrates the heat with the help of a parabolic mirror when aimed towards the sun. As the sun moves, the sun basket requires readjustment. This tracking of the sun can be done by hand and the basket must be refocussed about every 20 minutes.

Bhim Sen Bhola (1979) described a human made solar cooker. It can cook porridge, pulses, gram, rice, potatoes, carrots etc. in 2-3 hours in summer and 3-4 hours in winter, depending on the intensity of solar radiation.

Manjunath (1981) developed a solar collector model of 135 litre capacity. This solar collector could be used during seven months in a year. The saving of fuel was reported to be Rs.150-175 per year.

Mishra et al. (1984) conducted a study on the effects of insulation of solar cookers. This research was undertaken with a view of finding out the effective, rural, cheap, thermally insulating materials used in ordinary box type solar cookers available in the Indian market. The performance of cookers with four different insulators were reported in terms of stagnation temperature, cooker temperature with load and thermal load efficiency. The four rural thermal insulators used were wheat chaff, rice husk, groundnut husk and wood shavings. From an economic point of view and insulating, they concluded that use of dried wheat chaff is most suitable. The change of wheat chaff should be done after every rainy season. They also found that solar cookers made of clay eventhough they attained slightly lower stagnation temperature they could store food materials for a longer period with minimum fall of temperature compared to ordinary solar cookers.

Khalifa *et al*. (1986) has designed two different solar cookers utilizing the heat pipe principle. A cooker utilising an east west line focussing collector, designated Mecca-1, was developed for this purpose. The second cooker was a flat plate heat pipe cooker, Mecca-2. A single heat pipe in each cooker absorbed the energy at the collector, transported it into the kitchen and delivered it to an insulating oven at the condenser end. It was found that Mecca-2 cooker with triple glazing has a utilization efficiency of upto 19 per cent and could boil one litre of water in 27 min for a solar insulation of 900 W/m^2.

Tiwari *et al*. (1986) introduced a new box type solar cooker design with a single reflector at the hood. In this design, the base of the oven act as the lid, unlike the conventional box type solar cooker, thus the problem of preheating as faced in the conventional box type solar cooker is solved.

Khalifa *et al*. (1987) developed a new oven that permitted heating from the bottom and sides. This oven consists of a spiral concentrator and glazed oven placed at the focus. Simulation studies were conducted for predicting the thermal behaviour of this cooker for which concentrated solar energy would be supplied via a spiral concentrator.

Mullick *et al*. (1987) has provided some guidelines for thermal evaluation of box-type solar cookers. Suitable thermal tests has been proposed and appropriate parameters are identified, which pertain to the solar cooker and are relatively independent of climatic variables as well as the cooked product.

Shrestha (1987) reported the theoretical analysis for the simple model of solar cooker. The effect of the conventional box type cooker is modified slightly and three versions are analysed mathematically to see the effect on the stagnant temperature of the cooker under simulation conditions. It was found that the stagnant temperature is much enhanced in all modified models.

Bhaskara Rama Rao (1988) fabricated a solar cooker. It was tested for several types of foods and found that the food could be cooked when the water temperature was between 85° and 90°C. The cooker is suitable for a family of four. With the use of reflectors, the time taken for cooking may be reduced but the cooker's cost and maintenance will increase.

Ghambir <u>et al</u>. (1988) conducted a study to find out the reasons for slow diffusion of solar cookers. They attempted to find out the reasons for slow diffusion and suggested some remedial measures. They found that slow diffusion of solar cookers are due to the fact that existing model of solar cookers are incompactible with cooking habits of households, the technical quality of solar cooker available in the market is very poor, tracking of sun is not easy, after sales services are poor and the drawback of non-storing of solar energy. They suggested development of a new model of solar cooker which can cater to the demands of different people with different food habits. Development of auto track solar cooker models which can store solar energy, development of different sizes of solar cookers so that solar cookers can be adopted for small families and even for restaurents, hospitals, hotels etc.

Jayaraman et al. (1988) had developed a compound conical concentrator for a a spherical absorber of diameter 10 cm and focal length 25 cm. it was fabricated with self adhesive aluminized polyester foil over MS sheet as reflecting surface. Its performance as a concentrating type solar cooker was studied, with black pointed aluminium spherical vessel as absorber.

Mamman (1988) had developed a folding two step asymmetric reflector solar cooker, which was capable of cooking two meals a day in sunny winter days in North Indian states. The performance of folding two step cookers in a fixed mode was superior to the performance of a tracking single reflector box cooker.

Narasimha Rao et al. (1988) conducted experiments on mirror boosters for solar cookers. An analysis of the effect of providing a single adjustable mirror booster, hinged on one side and points toward the south. The total energy falling on the cooker aperture is calculated for a latitude of 18° North (Warangal City) and for five different declinations of the sun. The effects of mirror adjustment are analysed under three categories to determine the energy boost. The calculations clearly demonstrate the choice among intermittent adjustment, continuous adjustment and fixed orientation of the mirror. Only beam radiation is considered in calculations.

Shyam Nandwani (1988) designed and farbicated an electric cum solar oven. This oven can be used for cooking and baking almost all types of meals at any time during the year employing solar and or electric energy and consuming the minimum quantity of electric energy when it is required.

Daniel et al. (1989) conducted a comparative study of box type solar cookers in Nicaragua. In this experiment two box type solar ovens were used for performance tests, under various measured solar intensity conditions. One oven was the 'Kerr-Cole-Eco' cooker assembled from a prefabricated cardboard kit. The second model was made of plywood. They adopted a simple parameter, free index to aid the comparison of oven performance. This index emphasises the dynamic cooking capability of ovens. They found that the cardboard oven exhibited a maximum temperature and sufficient thermal stability for cooking similar quantities of food to that of plywood model.

Al-Saad et al. (1990) conducted an experimental investigation to study the performance of two versions of a portable double glazing box type solar cooker manufactured from local materials. The results obtained were very encouraging, especially when reflectors were used, giving a maximum water temperature of 100°C in the cooker. The temperature was maintained for more than 3.5 hours, which means it can permit cooking in the late afternoon.

Balasubramanian (1990) conducted experiments to determine quantitative performance parameters and their dependence on constructional details of box type solar cookers. Stagnation and water heating tests were done a plane-mirror-boosted, double glazed, box type solar cooker with vessels of same size but of different types (stainless steel, aluminium, plain or black coated and so on). Total irradiance on the cooker and solar irradiance on horizontal plane during the tests were measured by a suitably placed pyranometer. Results indicate the unsuitability of using the second figure of merit as a practical indicator of performance. The advantage of using water heating efficiency as a performance indicator are discussed.

El-Kassaby (1990) developed a new solar cooker of parabolic square dish. The cooker can be used for water distillation as well as cooking in an isolated area. A simulation model for transient state was introduced to predict the pot, fluid, air gap and cover temperatures. Satisfactory agreement are obtained by comparing experimental and theoretical results.

Mathur *et al*. (1990) conducted an experiment on cooking utilising solar energy. The feasibility study of solar cookers, thermal performance study, analysis of cooking method and nutrient contents were also done in this study. The experiments with reflector type solar cooker showed that when solar intensity of 900 to 1200 Watts per square metre was available, cooking time for Omlette and rice were 15 and 45 minutes. They found that cooking time depends on solar intensity, initial temperature and pre-roasting of food. It was also observed that cooking time reduced at a faster rate when solar radiation intensity was between 750 to 800 Watts per square metre.

Nahar (1990) conducted a study on the performance of an improved hot box solar cooker. The performance and testing of a novel solar cooker has been described and compared with a solar oven and a hot box solar cooker. The uniqueness of the device is that it has a tilted absorbing surface so that more radiation can be obtained even during winter, therefore, two meals can be prepared in winter, while only one meal is possible in the hot box solar cooker because it has a horizontal absorbing surface. Simultaneously, there is no need of frequent tracking as compared to one hour tracking for the hot box solar cooker and 30 min tracking for the solar oven. The overall efficiency of this improve hot box solar cooker is 24.6 per cent. The payback period shows that use of solar cooker is economical.

Perumal et al. (1990) reported about the construction of a compound parabolic solar cooker. In their study a three dimensional parabolic concentrator having half acceptance angle 23.5° and absorber radius 7.5 cm was designed. The profile was truncated at a height of 70 cm from the absorber. An aluminium spherical was fixed at the focus. The system could collect solar radiation for 3 hours without any adjustments. They found that optical efficiency of cooker may be improved by having good reflector and absorber. The absorber may be glass enveloped to reduce convection loss. The concentrator may be truncated still more for easy fabrication.

Philip et al. (1990) conducted a study to develop a better model of box type solar cooker. In their study various parameters that could affect the performance of a box type solar cooker have been studied experimentally with a view of developing a better model. They found that the peeling of paint in the tray of cooker can be avoided if the tray is made of sheet with built in grooves. The black painting of cooker tray was not of much importance when cooker was loaded with vessels fully.

Ranjeet Singh et al. (1990) reported the design and testing of a paraboloid surface concentrated type of cooker. He stated that solar cooker available in market is box type and is taken 2 to 3 hours for cooking. To cut the cooking time a paraboloid surface concentrted type solar cooker would be more suitable. They also found that the paraboloid surface concentrated type solar cookers are suitable for cooking as well as frying. Moreover, it takes less time for cooking than box type solar cooker for same value of radiation. But it is costly and continuous tracking along the sun is required which restricts its utility.

Shukla et al. (1990) conducted a study about convective heat losses in solar cookers. An analytical study was undertaken to obtain heat losses due to free convection currents in it. From the study it was found that the convective heat losses in solar cookers are aspect ratio dependent and that these losses can be eliminated by selecting suitable gap height.

Suboth Kumar et al. (1990) have studied the optical efficiency and stagnation tests on a paraboloid solar cooker. The tests were carried out with a specially designed absorber arrangement normal to the optical axis of concentrator as well as in the horizontal position. They obtained optical efficiencies of 39.5 per cent and 36.5 per cent respectively and a stagnation temperature of 350°C has been obtained from a beam radiation inensity of 715 Watts per square metre.

Yusaf Ali et al. (1990) conducted a study about masonry solar cookers for cooking animal feed. They developed three different types of masonry solar cookers. The hot box of each was made from Madras stone, Aluminium sheet painted black and cement. A comparative study of all three along with commercial solar cooker at no load and full load with animal feed consisting of groundnut cake, cotton seed, churry of gram and barley was done. They reached to a conclusion that all cookers could attain stagnation temperature at 13.00 hours and the cooker made from Madras blackstone, aluminium sheet painted black and cement could attain a maximum temperature of 110°C, 130°C and 78°C respectively whereas commercially available solar with tracking along sun could attain a stagnation temperature of 148°C and one which is not tracked along sun could attain a stagnation temperature of 154°C. By conducting a water boiling test they also observed 2° to 4°C temperature drop when the number of containers increased from one to four.

Michael Grupp et al. (1991) presented a novel advanced box type solar cooker. A fixed cooking vessel in good thermal contact with a conductive absorber plate is set into the glazing the results are improved thermal performance, easier access to the cooking vessel and less frequent maintenance due to protection of all absorbing and reflecting surfaces. Out-door tests shows that 5 L of water per sq m of opening surface can be brought to full boiling in less than one hour.. A finite element simulation model of the advanced box cooker is presented. It is shown that the most decisive parameters are absorber to pot heat transfer an absorber conductivity. Field tests in Ethiopia and India are under way, local production in India has started.

Mullick et al. (1991) conducted a thermal test procedure for a paraboloid concentrator solar cooker. Suitable thermal tests have been identified for performance evaluation of a concentrating solar cooker. These tests provide parameters that characterise the performance of the solar cooker, and are more or less independent of the climatic variables. The overall heat loss factor is obtained from the cooking curve and the optical efficiency factor is determined from the heating curve - both under full load conditions. The performance characteristic curve for the solar cooker is obtained and discussed. The study indicate that, the no load test, which is useful in the case of a box type solar cooker, is not appropriate in the case of concentrator type cookers.

Veena Mann et al. (1992) did the evaluation of two models of solar cookers in terms of cooking time. The observation in terms of time taken in cooking in the two types of solar cooker revealed that the oven type was more efficient than the box type solar cooker.

Terminologies

1. Absorption

The process in which radiation is converted within a material into excitation energy. Most of the radiant energy falling or incident upon a mat black surface is absorbed.

2. Altitude

The angle which the rays of sun makes with the horizontal plane at any given point.

3. Angle of incidence of direct solar radiation

Angle of incidence of direct solar radiation is the angle between the direct solar radiation beam and outward drawn normal from the plane of collector aparture.

4. Black body

This describes an ideal substance which absorbs all the radiation falling upon it and emits nothing.

5. Diffused solar radiation

Diffused solar radiation is the solar radiation received at a surface from a solid angle of 2° with exception of the solid angle substended by the suns disk.

6. Diffused radiation

The scattered radiation falling on a plane of stated orientation over a stated period from the sky and in the case of an inclined surface, reflected from the ground as well.

7. Direct radiation

The scattered radiation falling on a plane of stated orientation over a stated period received from a narrow solid angle centred on the sun's direction is known as direct radiation.

8. Direct solar radiation

Direct solar radiation is the solar radiation received at a surface from a solid angle substended by the suns disk.

9. Emittance

The ratio of the radiant energy emitted from a given plane surface at a given temperature, to the radiant energy that would be emitted by a perfect black body at the same temperature.

10. Equinox

The moment at which the sun apparently crosses the celestial equator, the point of intersection of the ecliptic and the celestial equator when the declination is sero is known as equinox.

11. Global solar radiation

Global solar radiation is the sum of the direct and diffused solar radiation incident on a surface from a solid angle of 2°.

12. Green house effect

The air temperature under a glass or a transparent cover increases when subjected to heat radiation. This effect is caused by the absorption of radiation by the surface under the transparent cover and by the ready absorption of radiation in the long wave lengths, or infra-red, band being unable to re-radiate through the transparent cover.

13. Hour angle

Hour angle is the angular distance of the sun from its position at noon.

14. Infra-red

Infra-red radiations are invisible long wave radiations. Their wave length ranges from 0.78 μ m to 100 μ m.

15. Insolation

Insolation is the solar energy incident on a unit area of surface over a period of time.

16. Insulation

Insulation is the thermal wrapping or lagging applied to a heat store or pipe to reduce heat loss or to protect against frost.

17. Inclined radiation

It is the combined diffuse and direct radiation components calculated proportionately to the fraction of sky hemisphere to which the plane is exposed and also calculated vectorially.

18. Irradiance

The irradiance at a surface is the ratio of radiant flux incident on the surface to the area of that surface irradiance is measured in watts per metre square.

19. Irradiation

The irradiation at a surface is the time integral of the irradiance at that surface measured in Joules per square metre.

20. Latitude

The latitude of a point on the earth surface is its angular distance from the equator.

21. Longitude

Longitude is the angle which terrestrial meridian through the geographic poles and a point on the earth's surface makes with a standard meridian.

22. Net radiation

The difference between total incoming and total outgoing radiation is known was net radiation.

23. Radiant flux

Radiant flux is the power emitted, transferred or received in the form of radiation.

24. Reflectance

The ratio of the radiant energy reflected from the surface, to the radiant energy incident upon that surface.

25. Sky temperature

The terrestrial radiation received at a surface may be expressed in terms of an equivalent black body radiation temperature which is called sky temperature.

26. Solar altitude

It is the angle between the direction of the sun and the horizontal at the point of observation.

27. Solar azimuth

It is the angular position of the sun due south at the point of observation. It is measured clock-wise.

28. Solar constant

Solar constant is the solar irradiance at the outer edge of the earth's atmosphere, when the earth sun distance is at the average value of 150 x 10 kilometres. Solar constant is 1.353 kw per square metre on earth's surface perpendicular to the sun.

29. Solar collector (Concentrator)

A reflector system to increase sunlight intensity on a given area.

30. Solar collector (Flat plate)

Any non-focussing, flat surfaced solar heat collecting device.

31. Solar collector (Parabolic)

A focussing type of solar collector usually arranged in trough form, having a line focus.

32. Solar collector (Paraboloid)

A focussing type of solar collector produced from the rotation of a parabola around its axis. The concentration ratio will be the square of that for the parabola.

33. Solar collector (Tracking)

A mechanised solar collector arranged to follow or track the path of the sun and normalise the angle of incident radiation falling upon the collector surface.

34. Solar declination

It is the angular position of the sun at solar noon with respect to plane of equator.

35. Solar hour angle

It is the equivalent angle (0° to 360°) for the time obtained with each hour equal in 15 of the longitude and solar noon being zero.

36. Solar noon

For any given location solar noon is the local time at which the sun is at its highest altitude.

37. Solar radiation

Solar radiation is the radiation emitted by the sun. Approximately all of the solar energy incident at the earth's surface is at a wave length less than 4 m.

38. Terrestrial radiation

Terrestrial radiation is the radiation emitted by gases and particles in the atmosphere and by the ground at wave lengths greater than 4.

39. Visible radiation

It is the radiation with wave lengths that simulate the optic nerves. Visible radiation lies approximately within a wave length of 0.38 to 0.76.

MATERIALS AND METHODS

This chapter gives a brief description of equipments, materials used, cooking techniques with solar cooker and the methods used for determining various objectives.

Functional requirement of a solar cooker

The functional requirement of a good solar cooker are as follows:

1. No fuel, maintenance or recurring cost.
2. Simple to use and easy to manufacture.
3. No pollution of utensils, house or atmosphere.
4. Long durability and reliability.
5. Nutritive delicious food with natural taste.
6. Reasonable capacity.
7. Working of the cooker must be noiseless.
8. Cooking time must be reasonable.
9. Price must be affordable to the consumer.
10. Solar cooker should lend itself to standardization.
11. It should function as a heat insulating box.
12. Necessity for tracking should be minimum.
13. It should be easily transportable.
14. It must not infringe with solar rights of the neighbour.
15. No attention needed for cooking, no charring, no overflowing.

Instruments used

1. **Suryamapi (Solar intensity recorder)**

A suryamapi of CEL make was used for measuring solar insolation in milliwatts/cm^2. It is provided with a photo-sensitive material of one sq cm. Instrument is placed such that the sensing element faces the sun without shadow. The specification of the instrument are given in Appendix-I.

2. **Thermometer**

Thermometer is the instrument used for the measurement of temperature. It directly gives the temperature in degree celcious. The specification of the instrument are given in Appendix-I.

Materials used

1. **Reflectors**

Eight reflectors - four rectangular and four triangular - are mounted on the top of semi-cylindrical drum each making an angle of 60° to the horizontal. This is to provide maximum reflection of light rays into the collector area. The inclination of this reflector with vertical can be changed with a guide arrangement so that at all incident angles of sun light, maximum reflection is obtained to the cooking vessel. The

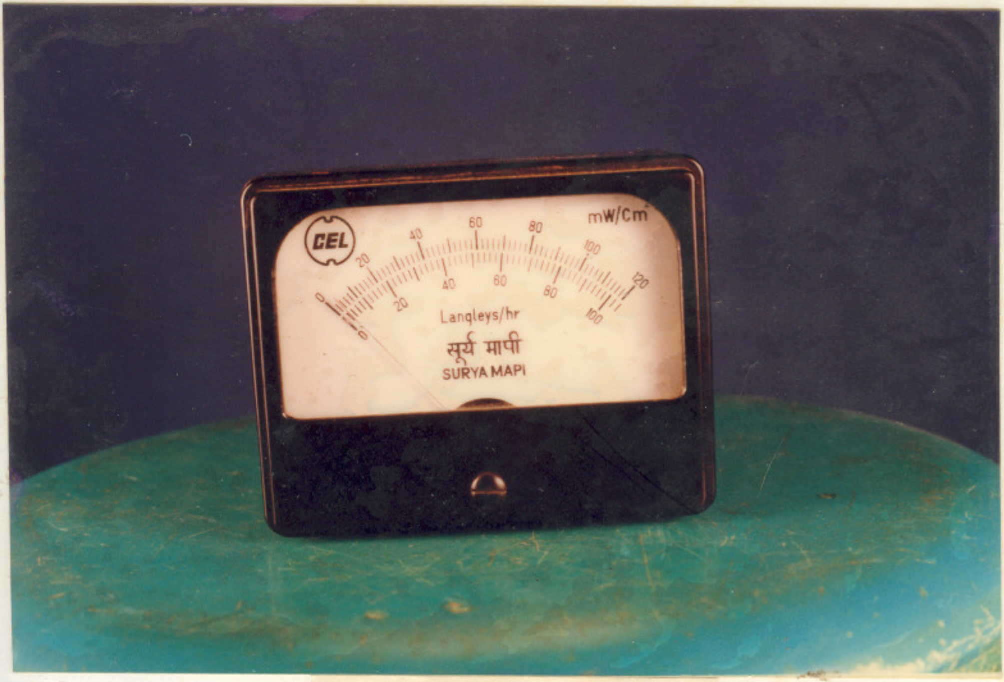


Plate 1 Suryamapi

images of the sun formed by the reflectors give the effect of 6 sun for cooking.

2. Plain glass plates

Two glass plates of size 31 cm x 36 x 3 mm are separated by 3 mm and fixed inside a frame made of wood. These glass plates form an air-tight chamber. Two glass plates are used so as to reduce chances of escape of longwaves which are formed when incident radiations are converted into heat.

3. Collector plate

A galvanised iron sheet which is of semi-cylindrical shape is used as the collector surface. The surface is coated with good quality black board paint. Two hooks are fixed at the sides. The tray for placing cooking vessels is kept hanging from the hooks.

The collector area has great importance as power of a solar cooker is proportional to the total receiving area.

4. Vessels for cooking

An aluminium vessel of 2 litre capacity was used for cooking the food stuff. The vessel is also painted black on its outer surface and placed in the tray while cooking.

5. Aluminium tray

The tray, which is kept hanging from the two hinges at the sides of the inside drum, is used for placing the vessels containing the cooking materials.

6. Glass wool

It is used as an insulating material. The gap between the inner drum and outer drum is filled with glass wool for a thickness of 8 cm. It reduces the conduction losses during cooking. The glass wool also makes the oven as a heat insulated box so that the cooked food can be stored inside the cooker with minimum fall of temperature.

7. G.I. cover

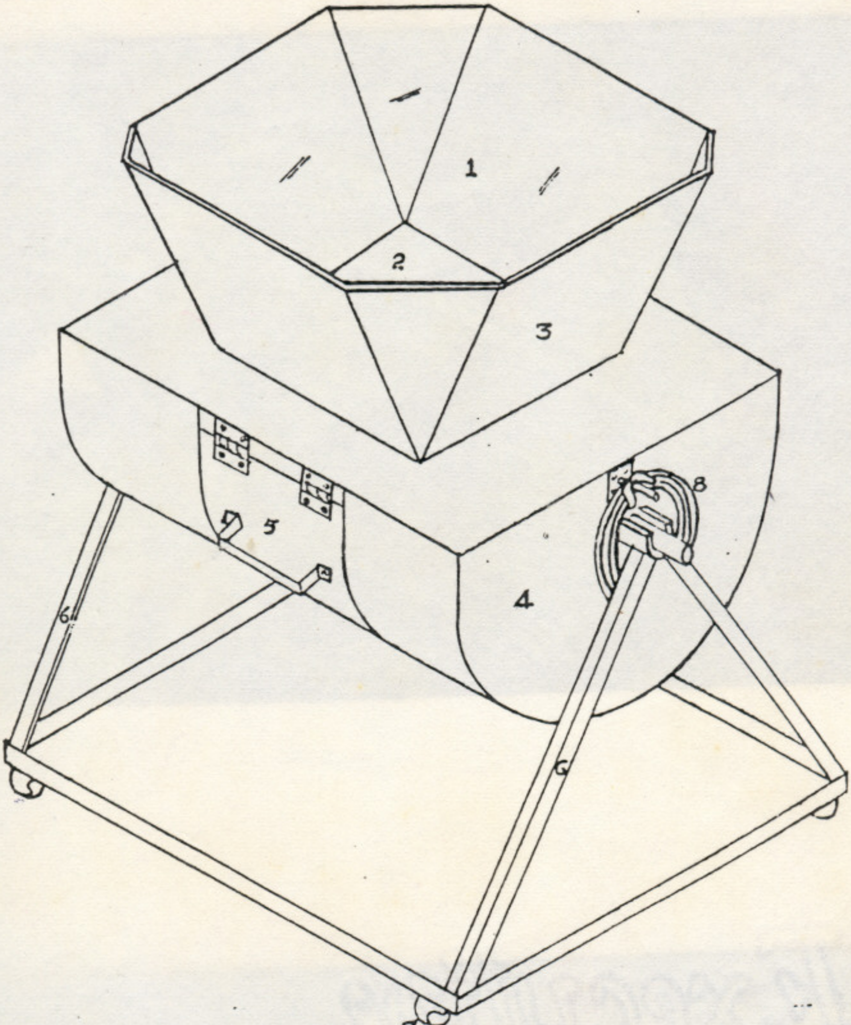
The overall unit is covered with 26 gauge galvanised iron sheet to protect from damages due to bad weather conditions.

8. Plywood casing

The glass wool is covered with plywood casing over which G.I. sheet is provided.

9. Metallic frame

The whole cooker is suspended on a stand so that it can be tilted to a wide range of angle easily. The frame is made of angle iron.



1. Mirror
2. Glass plate
3. G.I. sheet
4. Drum
5. Door
6. Iron stand
7. Roller wheel
8. Guide

Fig.1 Isometric view

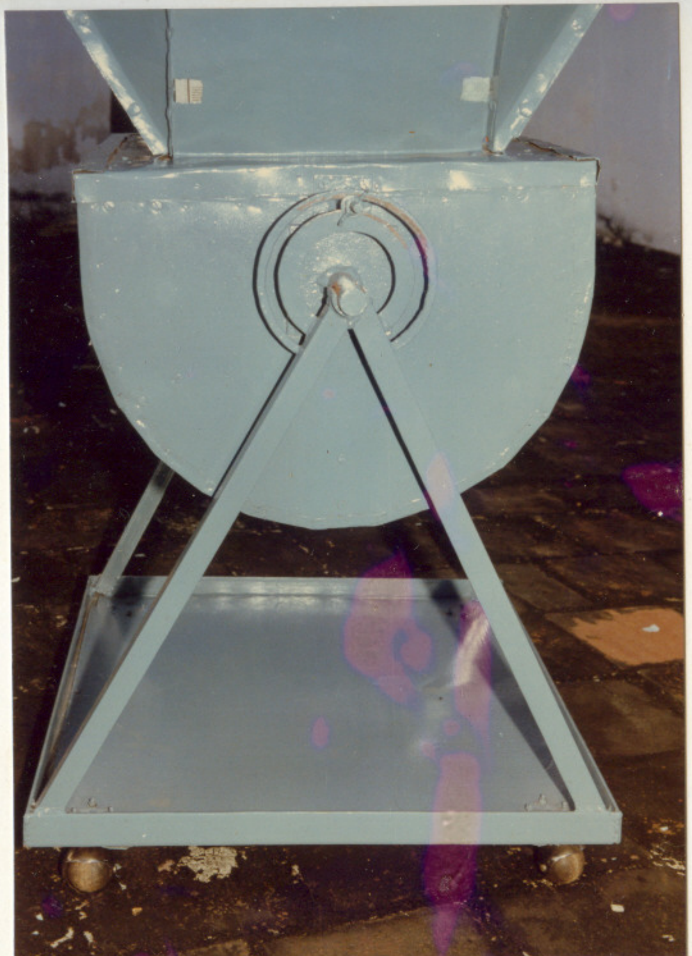
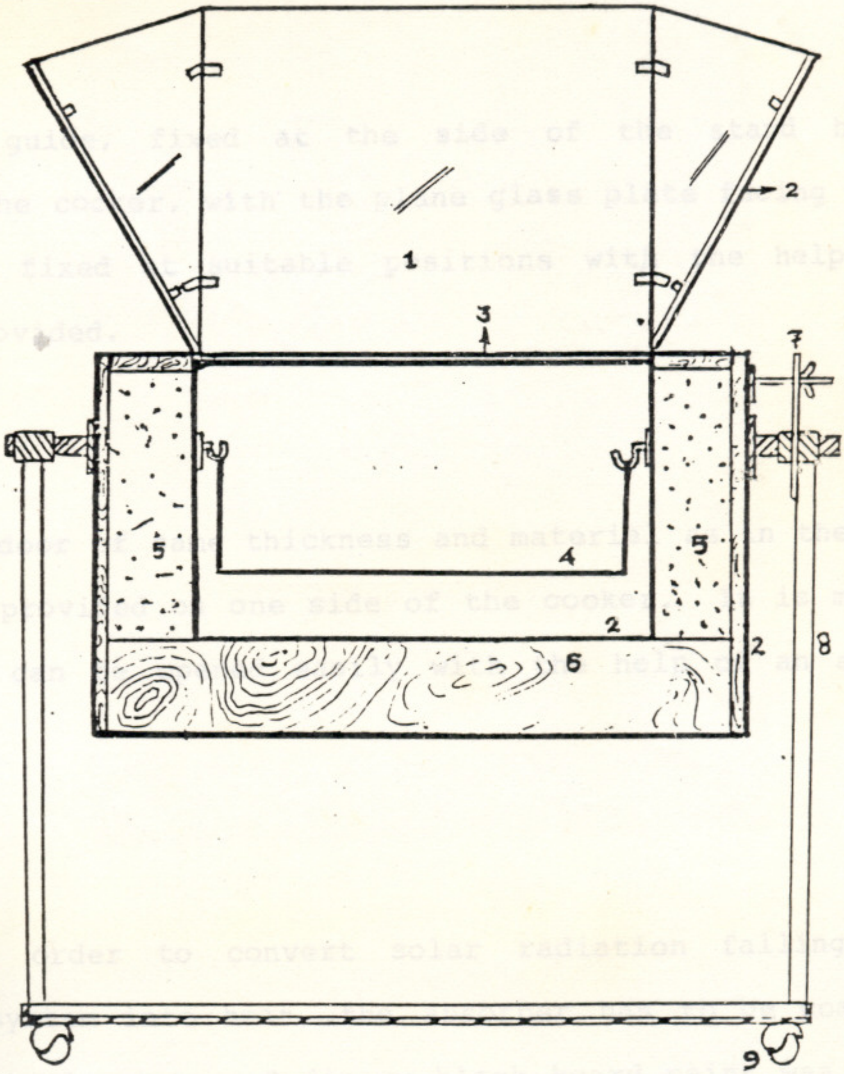


Plate 3 MRSO - Guide arrangement

Plate 2 Multireflector type solar oven



1. Mirror
2. G.I. sheet
3. Glass plate
4. Aluminium tray
5. Glass wool
6. Wood
7. Guide
8. Iron stand
9. Roller wheel

Fig.2 Longitudinal section

10. **Guide**

A guide, fixed at the side of the stand helps in rotating the cooker, with the plane glass plate facing the sun. It can be fixed at suitable positions with the help of the wingnut provided.

11. **Door**

A door of same thickness and material as in the plywood casing is provided on one side of the cooker. It is made air-tight and can be opened easily with the help of an aluminium handle.

12. **Paint**

In order to convert solar radiation falling on the absorber system into heat, the absorber has to be coated with black coloured paints. Ordinary black board paint was used for painting the absorber, so that the heat was absorbed to the maximum level and the reflection losses can be minimised.

The whole equipment is painted 'smoke grey' in order to protect it from atmospheric effects as well as for good appearance.

13. **Roller wheels**

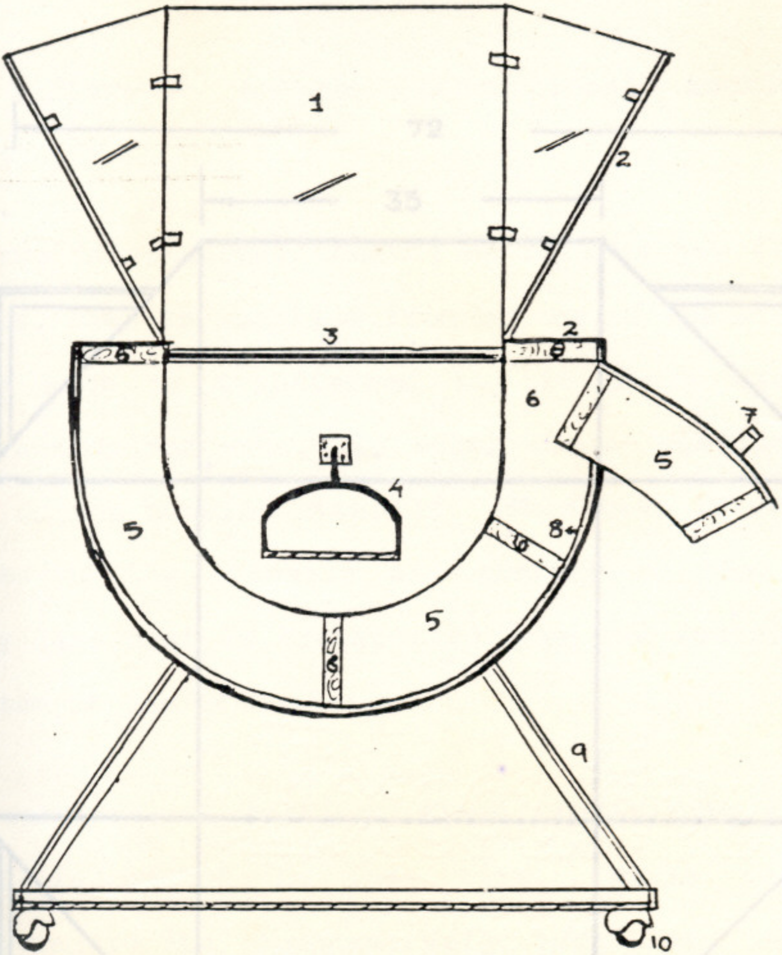
Four roller wheels are provided at the bottom of the cooker so that it can be easily transported.

Plate 4   MRSO - Door opened

Plate 5   MRSO - Tray suspended on hinges

Plate 4 MRSO - Door opened

Plate 5 MRSO - Tray suspended on hinges



1. Mirror
2. G.I. sheet
3. Glass plate
4. Aluminium tray
5. Glass wool
6. Wood
7. Handle
8. Plywood
9. Iron stand
10. Roller wheel

Fig.3 Cross Section

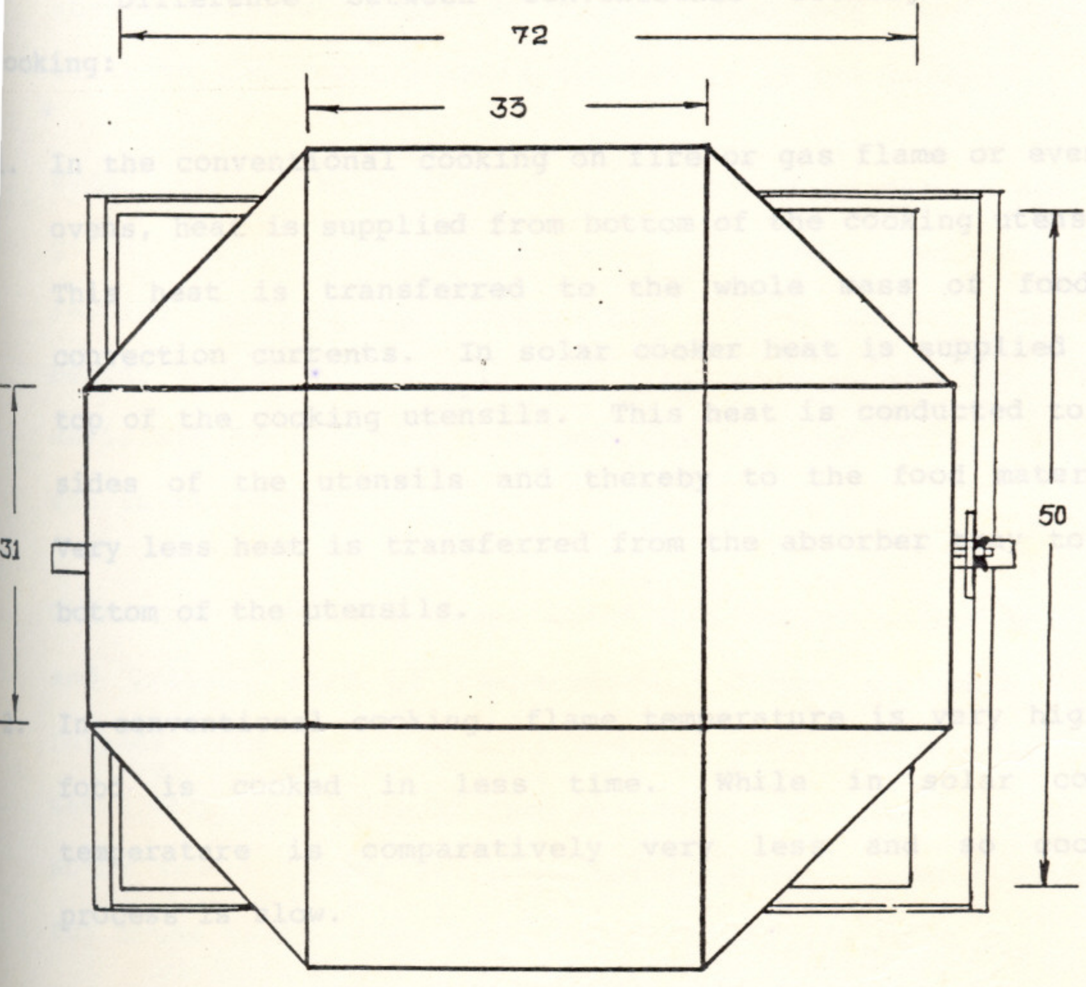


Fig.4 Plan

Cooking technology

Difference between conventional cooking and solar cooking:

1. In the conventional cooking on fire or gas flame or even in ovens, heat is supplied from bottom of the cooking utensils. This heat is transferred to the whole mass of food by convection currents. In solar cooker heat is supplied from top of the cooking utensils. This heat is conducted to the sides of the utensils and thereby to the food material. Very less heat is transferred from the absorber tray to the bottom of the utensils.

2. In conventional cooking, flame temperature is very high so food is cooked in less time. While in solar cooker temperature is comparatively very less and so cooking process is slow.

Cooking techniques with solar cooker can be classified in the following four categories:

1. In solar cooker as supply of heat is from top, convection currents are not set up. Hence the process of boiling food will be very slow when amount of water with the food is comparatively large, say 1 inch of water layer above food material. Amount of water with food is very critical in case of food like some pulses which are hard to cook. Hence

the solution is to soak the hard food for 2 to 3 hours in water, prior to putting it in the solar cooker. Food will absorb certain amount of water. Then put less amount of water in the utensil while putting it in the cooker.

Bread, cake, biscuits which are prepared by baking and some green vegetables like pumpkin, brinjals, tomatoes etc. require instant high temperature (100°C above). They are better cooked during peak intensity hours of the day. It is advisable to put such food material in the cooker when the sun is at zenith.

There are some food items which are better cooked with low and gradual rise of temperature. These are milk preparations like khir, pudding and all root vegetables. They taste very delicious if they are cooked by simmering (80° to 90°C) for a longer period. Solar cooker is most suitable for these items.

Food items prepared by the process of roasting are also very well cooked in the solar cooker. All the roots, tomatoes, groundnut etc. can be nicely roasted in the solar cooker without any water. Groundnut kernel are evenly roasted in the cooker without charring the skin of the kernel. Eggs can also be cooked without water. In roasting food items can be put in open utensils or even directly on the absorber tray.

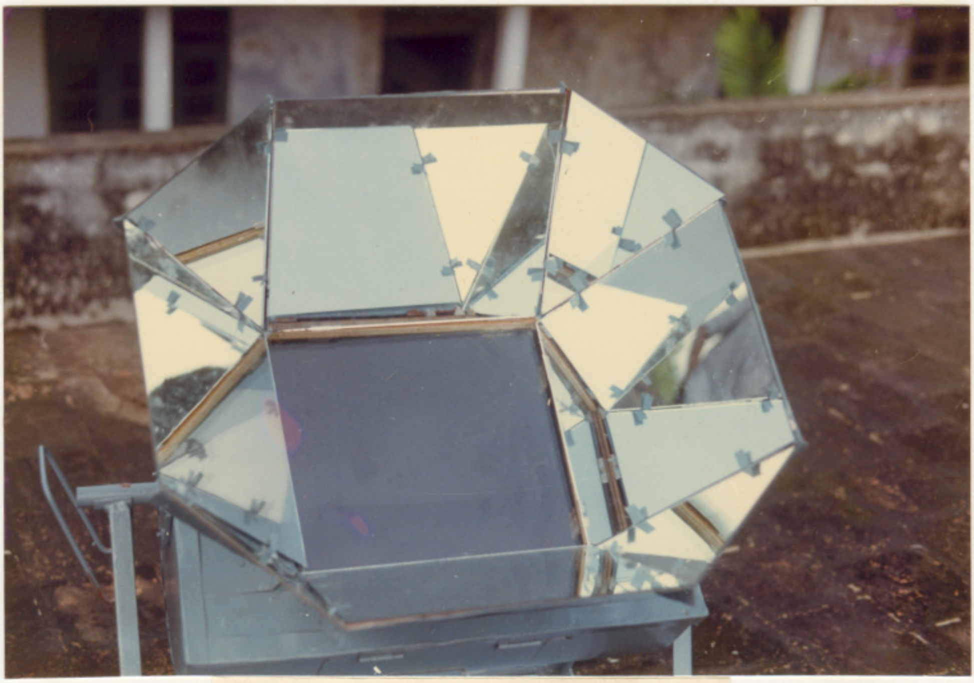


Plate 6   MRSO - Top view

Plate 7   MRSO & ANERT model - Experimental set up

In short all the food items cooked in pressure cooker and baked in oven can be prepared in solar cooker. In all the above methods of cooking spices, as per the taste, are to be added before or after cooking. Indian house-wives prepare many pickles in open sun where they need to be protected from dirt or dust. Many of them can be prepared in the solar cooker in less time.

Test procedure for MRSO

A place in KCAET, Tavanur was selected to conduct the experiments where direct sunlight during 8 to 5 pm was available. The oven is cleaned properly before starting the experiment. It is mounted on a stand on wheels for the facility of moving it towards the sun. The items to be cooked are kept in aluminium utensils. The utensils are recommended to be painted black and should have tight fitting covers. The utensils are placed in the tray inside the drum which always keep it in horizontal position. The door, which is a part of the drum is provided to facilitate putting and taking out the utensils. The solar radiation reaching mirrors get reflected and concentrated into the drum through the plain glass plates. The inside surface is painted black so that it can absorb the heat reaching inside the drum. The oven needs to be adjusted towards the sun after every half to one hour. The food can be cooked in 30 min to 90 min in this oven.

Thermal performance of MRSO

After the fabrication of the oven, preliminary trials were made for its performance. The oven was operated without loading to see the extend upto which air temperature could be raised. The experimental studies were conducted in November, 1992.

The inside, outside and room temperatures were measured using thermometers. The solar flux intensity is measured using a suryamapi by keeping the sensor in such a way that the sun rays falls directly to the sensor. The thermal performance curves for the MRSO were plotted.

Determination of cooking time

All food dishes cooked in pressure cooker and baked in oven can be prepared in solar cooker. Cereals, pulses, vegetables, roots (like potato), eggs, soups and porridges as well as other special Indian dishes are all deliciously cooked in the cooker. Bread and cake can also be baked in the cooker. The potato, sweet potato, tomato, brinjal etc. can be roasted. For office goers and other workers who eat from lunch boxes can have warm food if their lunch boxes are put inside the solar cooker one hour prior to lunch.

Materials to be cooked were well mixed with required quantity of water and spices and placed in cooking utensils with close fitting lids. These utensils are then placed in the cooker at a suitable time. The inside, outside and room temperatures were noted at regular intervals. Solar radiation was measured using suryamapi and the time for cooking each item were noted.

Comparison of MRSO with ANERT model solar cooker

ANERT model solar cooker is a box type solar cooker with mirror reflector. The MRSO is fabricated and is compare with the ANERT model. The experimental set up is shown in Plate No.7

The experiment is conducted by placing both MRSO and ANERT model box type solar oven in sun without any load. The mirror is adjusted so that solar insolation is reflected to the collector area. The temperature of the air inside both the oven is measured in regular intervals by placing thermometers inside the chamber. Intensity during the same interval is also taken. Thermal performance curves are plotted for both the ovens.

The chambers of both the cookers are then loaded with some amount of water inside the vessel. The temperature of water inside the ovens were then continuously measured at 10 min interval. The solar insolation data is also measured, during the experiment. Thermal performance curves were plotted for both the ovens.

RESULTS AND DISCUSSION

This chapter highlights the results of the tests conducted and the economics of operation of MRSO.

Evaluation of functional requirement of MRSO

No fuel is required and maintenance or recurring cost is less except the painting charge of collector area. It is noiseless, its capacity is reasonable and it is easily transportable. The cooking time is reasonable. It tooks about 75 min (maximum) for cooking the food items. There is no need for attention during cooking. It acts as a good insulating box.

The experiment is conducted on 24.11.1992. The results of no load testing of MRSO are shown in Tabel 1 and the thermal performance is plotted in a graph (Fig.5). It is observed from the figure that, this oven could attain the stagnation temperature of 162°C which means that the equipment is efficient in working. It could attain the stagnation temperature at 12.00 hours.

Determination of cooking time

The observations in terms of time taken for cooking different recipes in MRSO are given below. The different recipes cooked are given in the Table below.

Test Results

Thermal performance of MRSO (no load)

Time (00.00 hrs)	Temp. inside MRSO °C	Ambient temp. °C	Room temp °C	Solar intensity (mW/cm^2)
7.30	35	31	31	15
8.00	68	31	30	30
8.30	90	31	30	45
9.00	115	31	30	50
9.30	124	32	30	56
10.00	135	32	30	66
10.30	150	32	31	72
11.00	155	32	32	76
11.30	160	32	31	80
12.00	162	33	32	82
12.30	160	33	32	70
1.00	160	34	33	79
1.30	158	35	33	75
2.00	158	33	33	72
2.30	161	34	32	64
3.00	153	33	32	54
3.30	155	33	32	38
4.00	138	33	32	24
4.30	120	33	32	14
5.00	107	32	31	12

Table 1

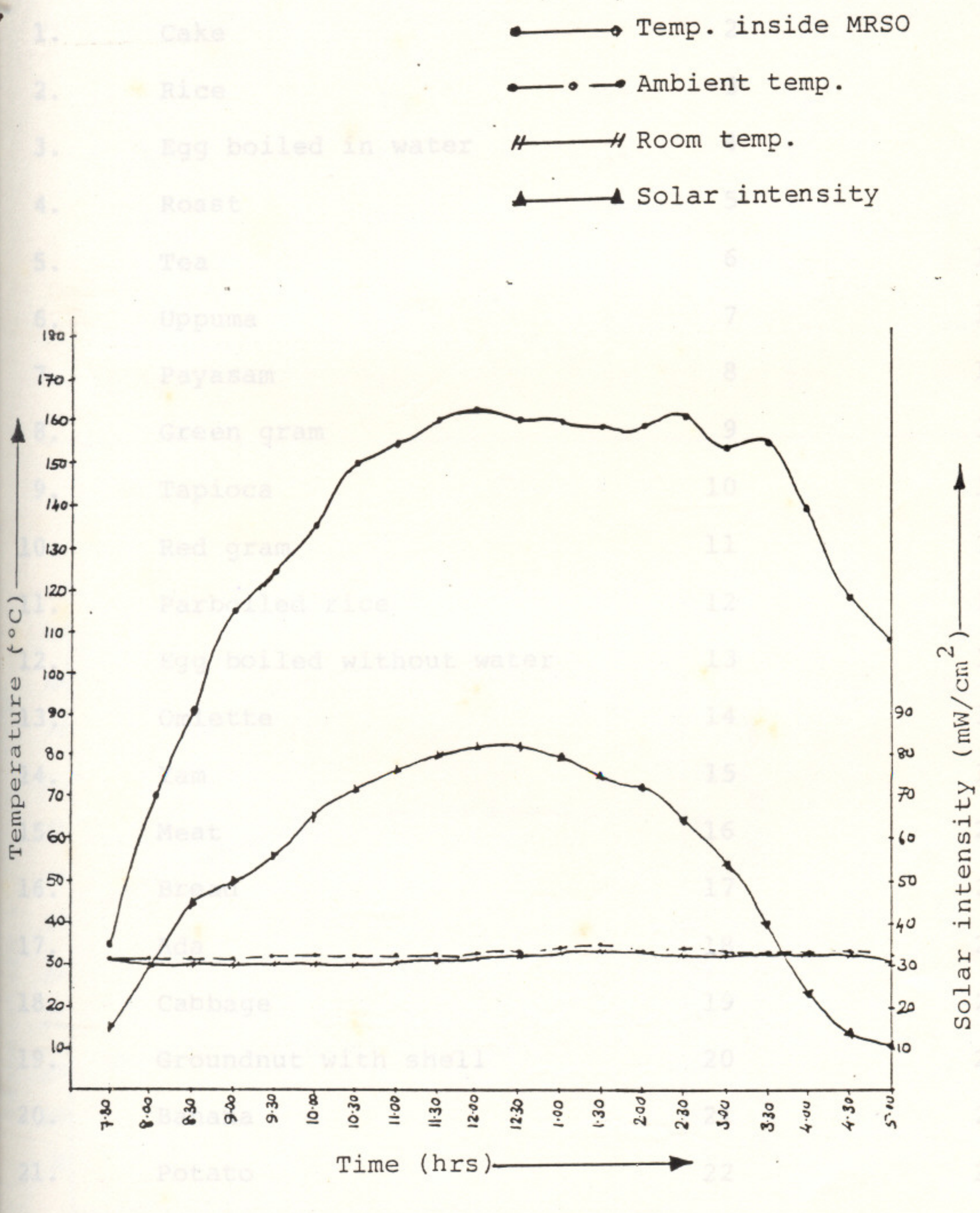

Temp. inside MRSO
Ambient temp.
Room temp.
Solar intensity
Temperature (°C)
Solar intensity (mW/cm²)
Time (hrs)
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
7·30
8·00
8·30
9·00
9·30
10·00
10·30
11·00
11·30
12·00
12·30
1·00
1·30
2·00
2·30
3·00
3·30
4·00
4·30
5·00

Fig.5

Sl.No.	Item	Table No.	Figure No.
1.	Cake	2	6
2.	Rice	3	7
3.	Egg boiled in water	4	8
4.	Roast	5	9
5.	Tea	6	10
6.	Uppuma	7	11
7.	Payasam	8	12
8.	Green gram	9	13
9.	Tapioca	10	14
10.	Red gram	11	15
11.	Parboiled rice	12	16
12.	Egg boiled without water	13	17
13.	Omlette	14	18
14.	Yam	15	19
15.	Meat	16	20
16.	Bread	17	21
17.	Ada	18	22
18.	Cabbage	19	23
19.	Groundnut with shell	20	24
20.	Banana	21	25
21.	Potato	22	26
22.	Sambar	23	27

Time (00.00 hrs)	Temp. inside MRSO °C	Ambient temp. °C	Room temp. °C	Solar intensity (mW/cm^2)
1.30	115	34	32	70
1.45	115	34	32	70
2.00	120	33	32	69

Table 3

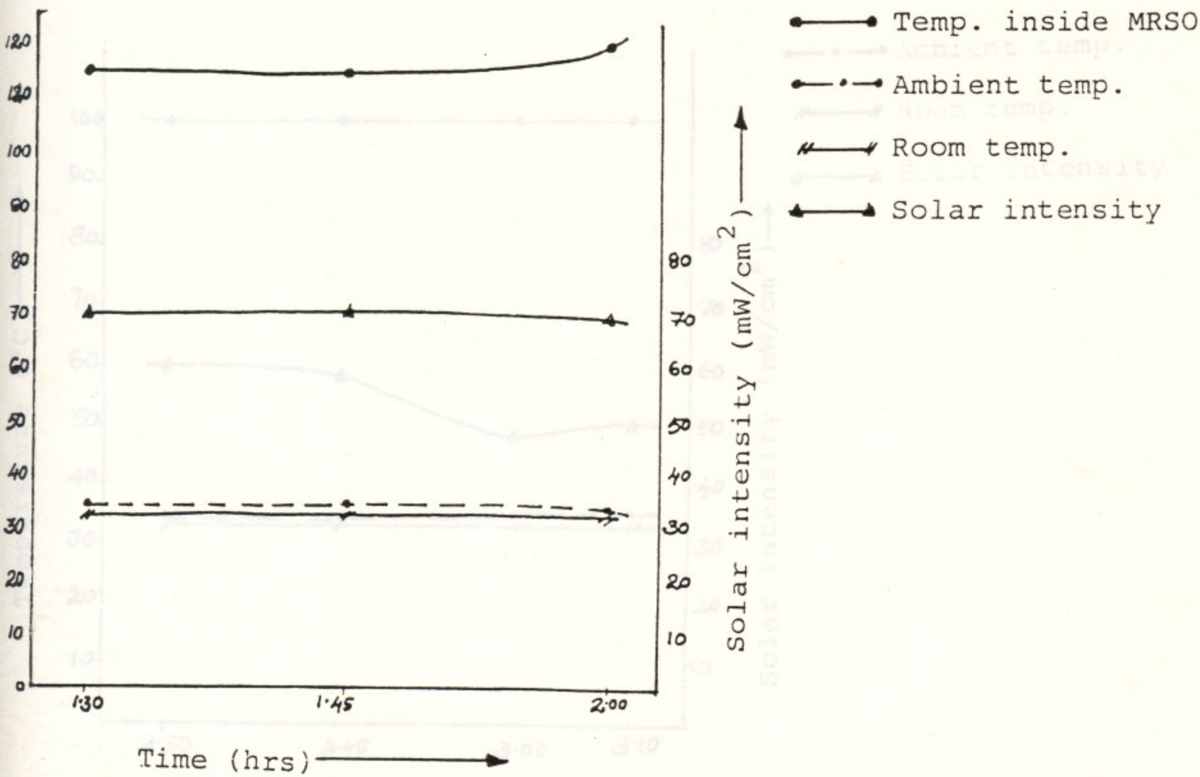


Fig.7

Time (00.00 hrs)	Temp. inside MRSO °C	Ambient temp. °C	Room temp. °C	Solar intensity (mW/cm2)
2.30	100	34	33	60
2.45	100	34	33	58
3.00	100	35	33	48
3.10	100	35	33	50

Table 4

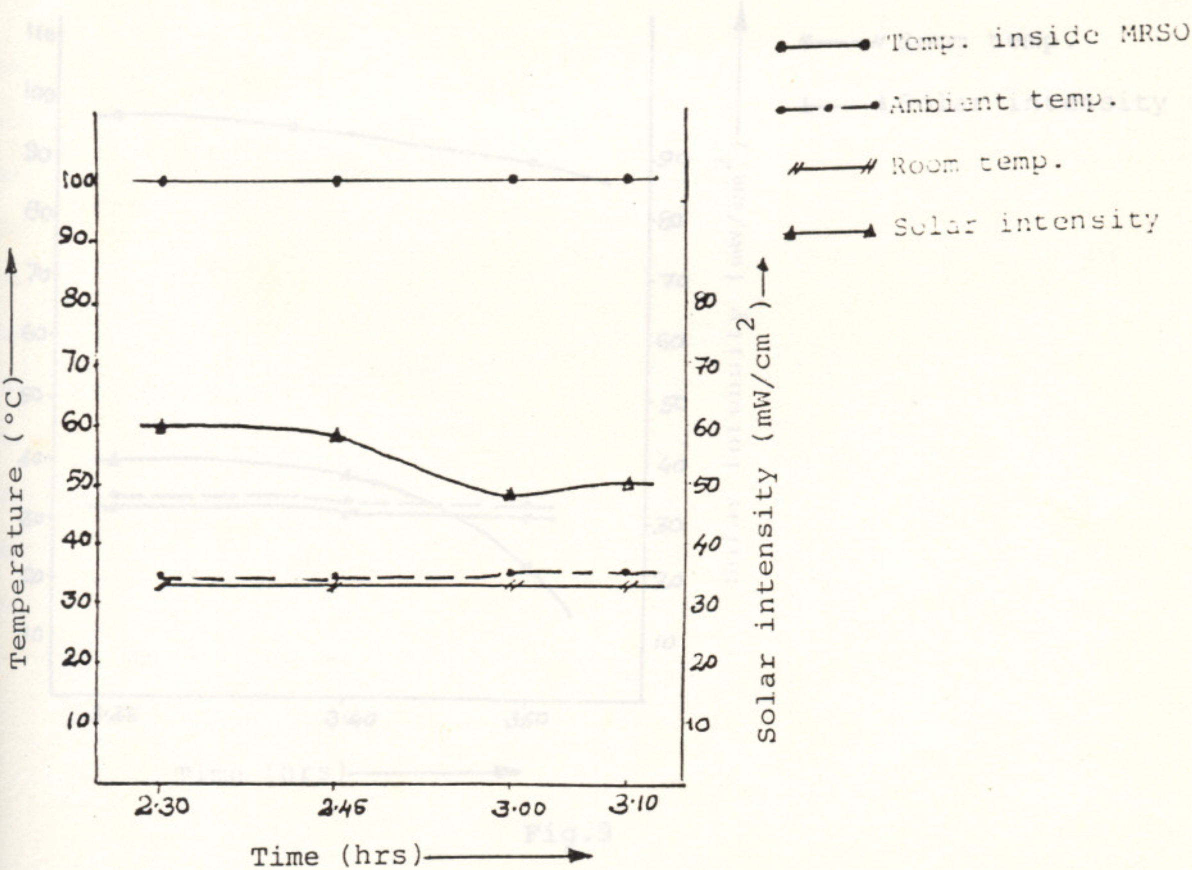


Fig.8

Time (00.00 hrs)	Temp. inside MRSO °C	Ambient temp. °C	Room temp. °C	Solar intensity (mW/cm^2)
3.25	97	34	32	40
3.40	95	33	31	38
3.50	90	33	32	22

Table 5

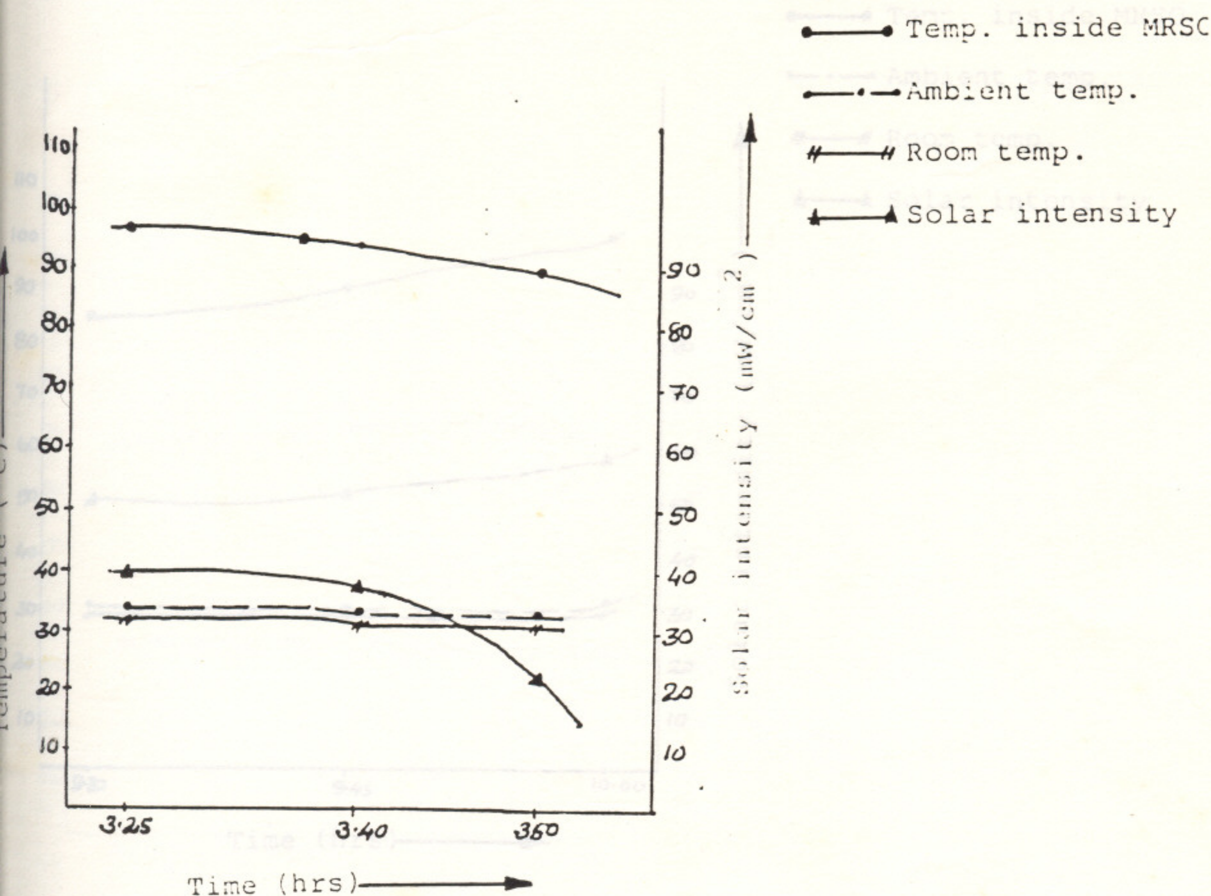


Fig.9

Time (00.00 hrs)	Temp. inside MRSO °C	Ambient temp. °C	Room temp. °C	Solar intensity (mW/cm2)
9.30	85	30	29	50
9.45	91	30	29	52
10.00	100	31	30	58

Table 6

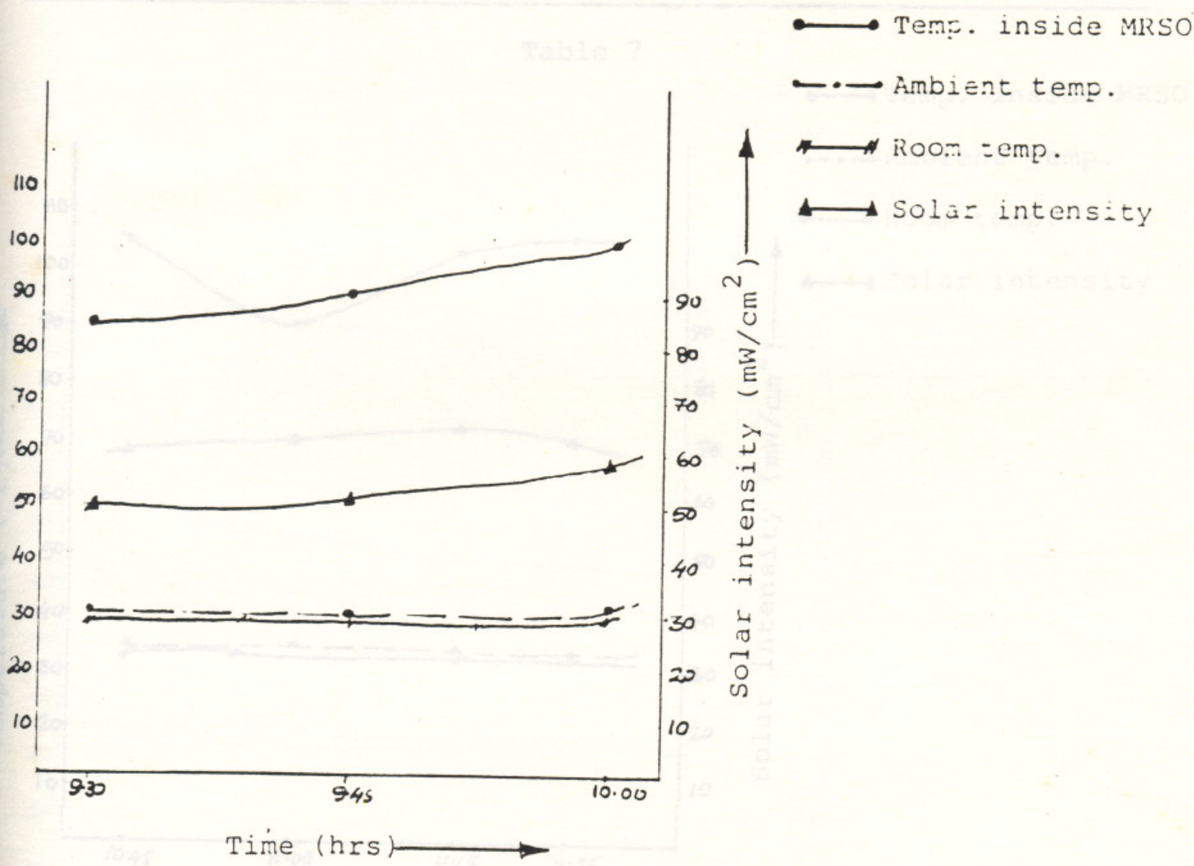


Fig.10

Time (00.00 hrs)	Temp. inside MRSO °C	Ambient temp. °C	Room temp. °C	Solar intensity (mW/cm^2)
10.45	105	34	33	68
11.00	90	34	32	70
11.15	103	33	32	72
11.25	105	33	32	70

Table 7

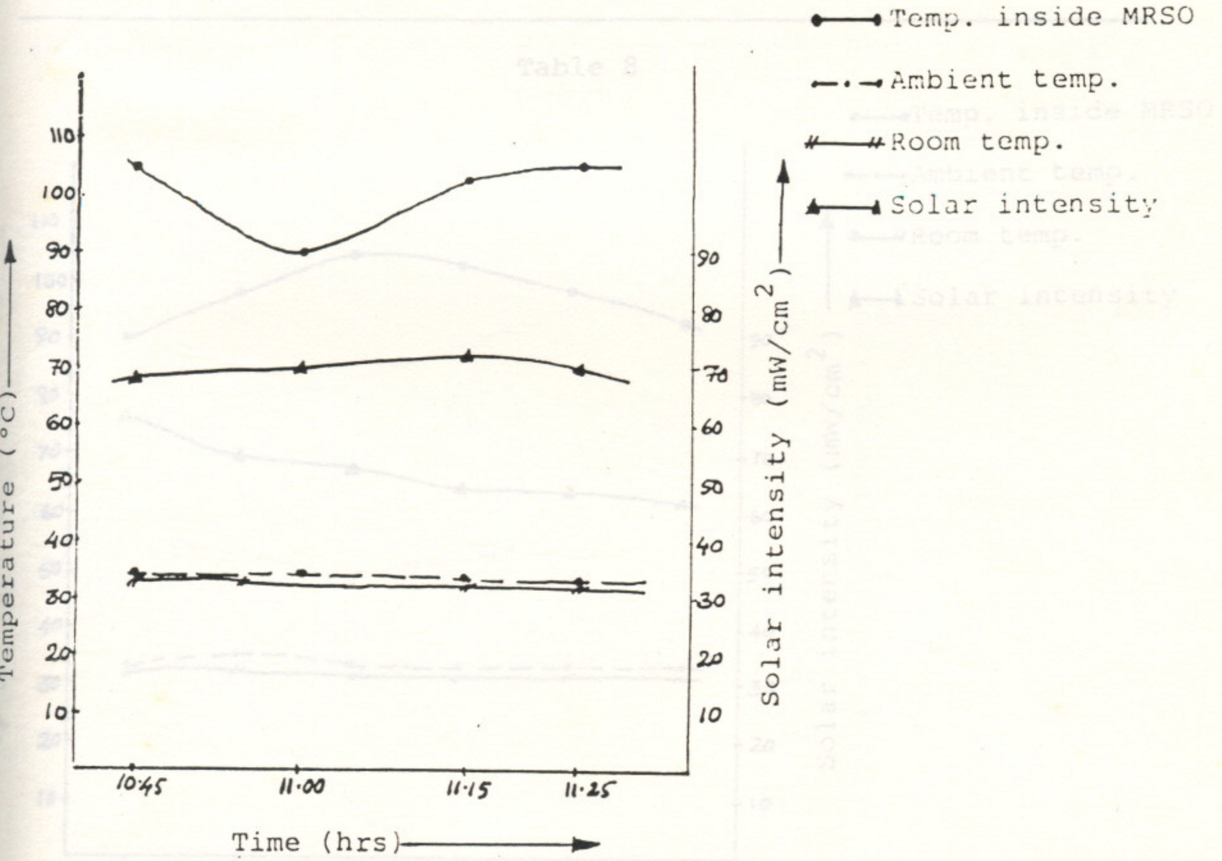


Fig.11

Time (00.00 hrs)	Temp. inside MRSO °C	Ambient temp. °C	Room temp. °C	Solar intensity (mW/cm^2)
12.30	90	33	32	77
12.45	98	35	32	70
1.00	105	33	31	68
1.15	103	33	32	64
1.30	98	33	31	64
1.45	93	33	31	62

Table 8

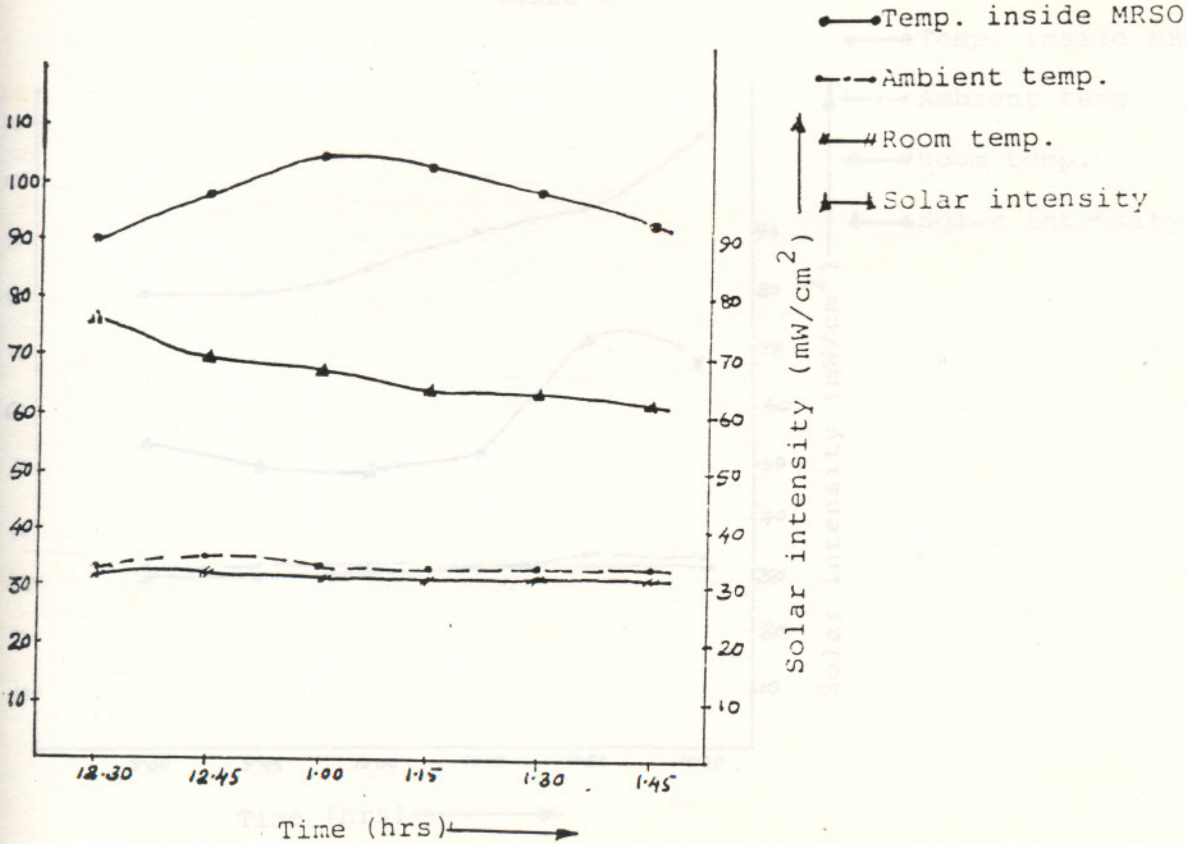


Fig.12

Time (00.00 hrs)	Temp. inside MRSO °C	Ambient temp. °C	Room temp. °C	Solar intensity (mW/cm^2)
9.30	80	32	30	54
9.45	80	32	30	50
10.00	85	32	31	49
10.15	91	32	32	52
10.30	95	34	32	72
10.45	108	33	32	68

Table 9

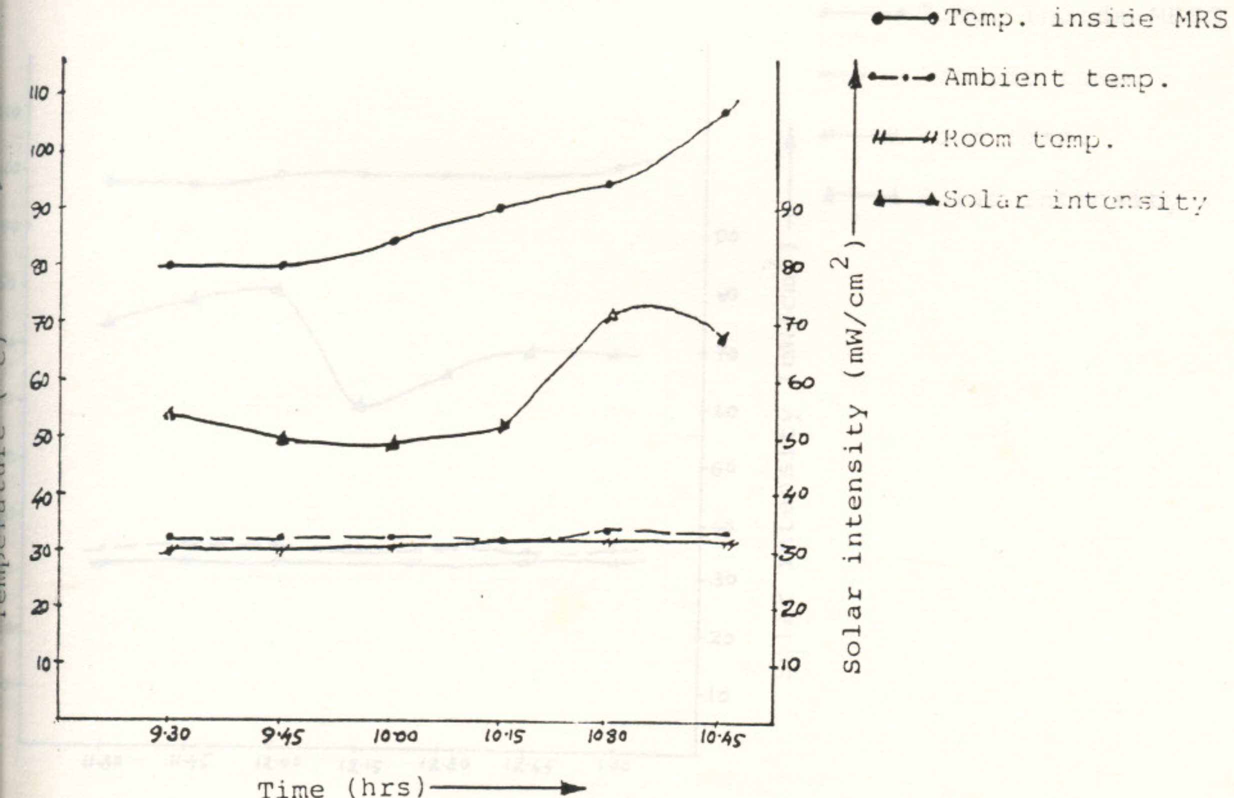


Fig.13

Time (00.00 hrs)	Temp. inside MRSO °C	Ambient temp. °C	Room temp. °C	Solar intensity (mW/cm^2)
11.30	98	34	32	74
11.45	98	35	32	78
12.00	100	35	32	80
12.15	100	34	32	60
12.30	100	35	32	66
12.45	100	34	33	70
1.00	102	35	33	70

Table 10

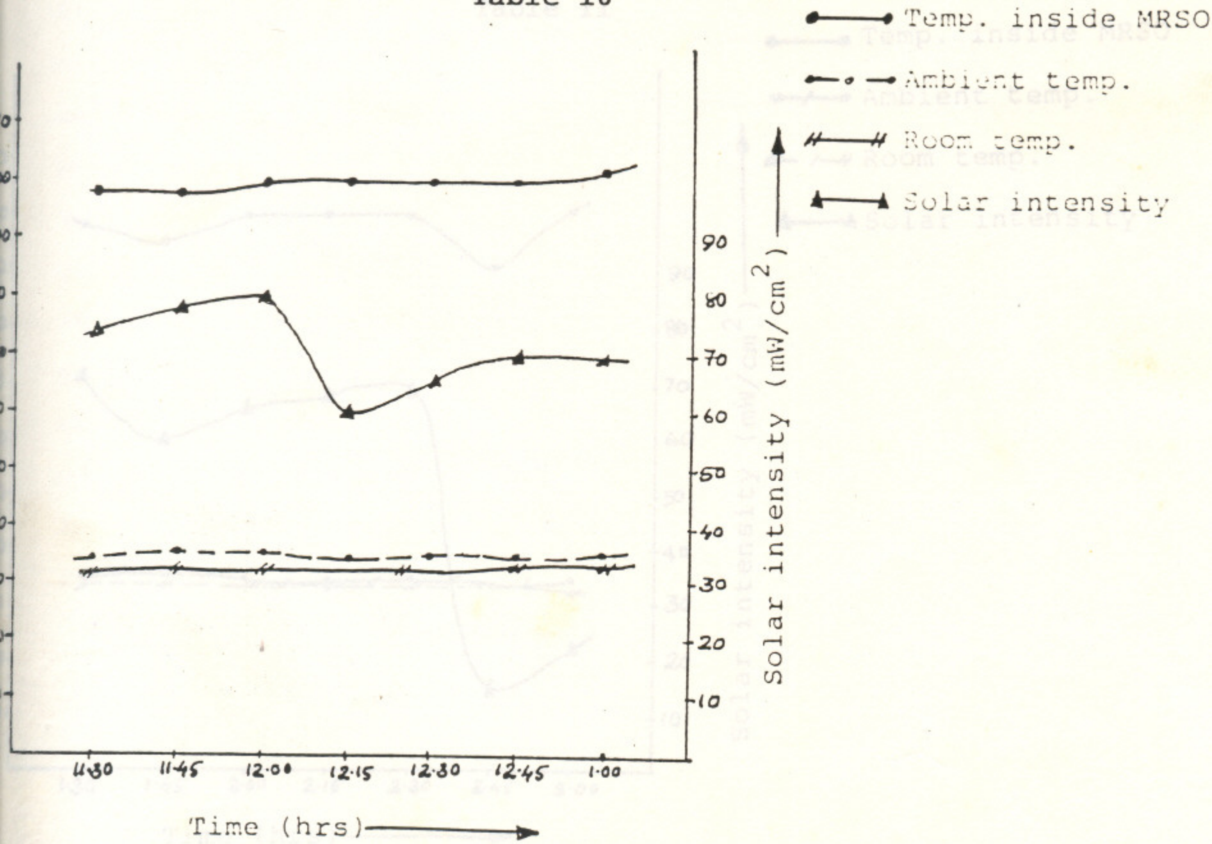


Fig.14

Time (00.00 hrs)	Temp. inside MRSO °C	Ambient temp. °C	Room temp. °C	Solar intensity (mW/cm^2)
1.30	98	34	33	72
1.45	95	35	33	60
2.00	100	34	33	66
2.15	100	34	33	68
2.30	100	34	33	70
2.45	90	33	33	14
3.00	101	34	32	22

Table 11

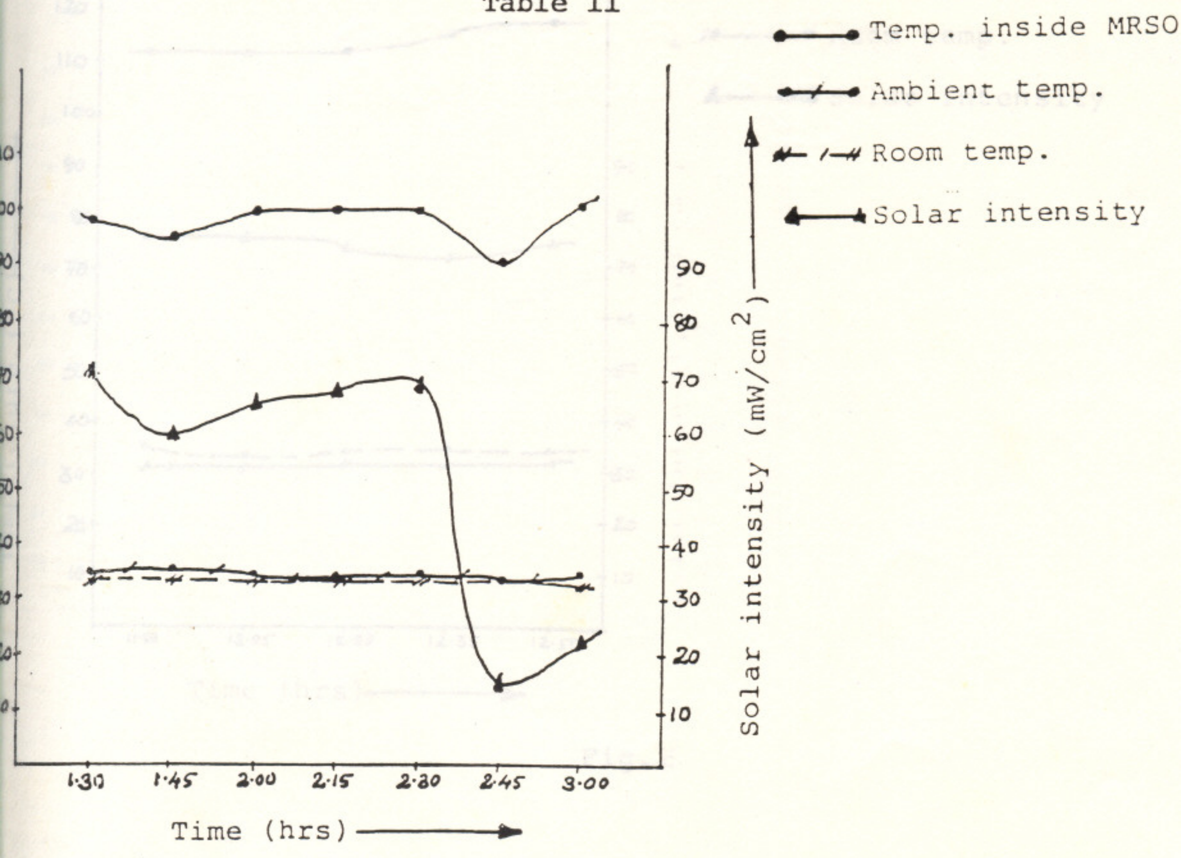


Fig.15

Time (00.00 hrs)	Temp. inside MRSO °C	Ambient temp. °C	Room temp. °C	Solar intensity (mW/cm^2)
11.50	112	[illegible]	31	76
12.05	112	[illegible]	31	76
12.20	112	[illegible]	31	74
12.35	116	[illegible]	31	72
12.50	118	[illegible]	32	74

Table [illegible]

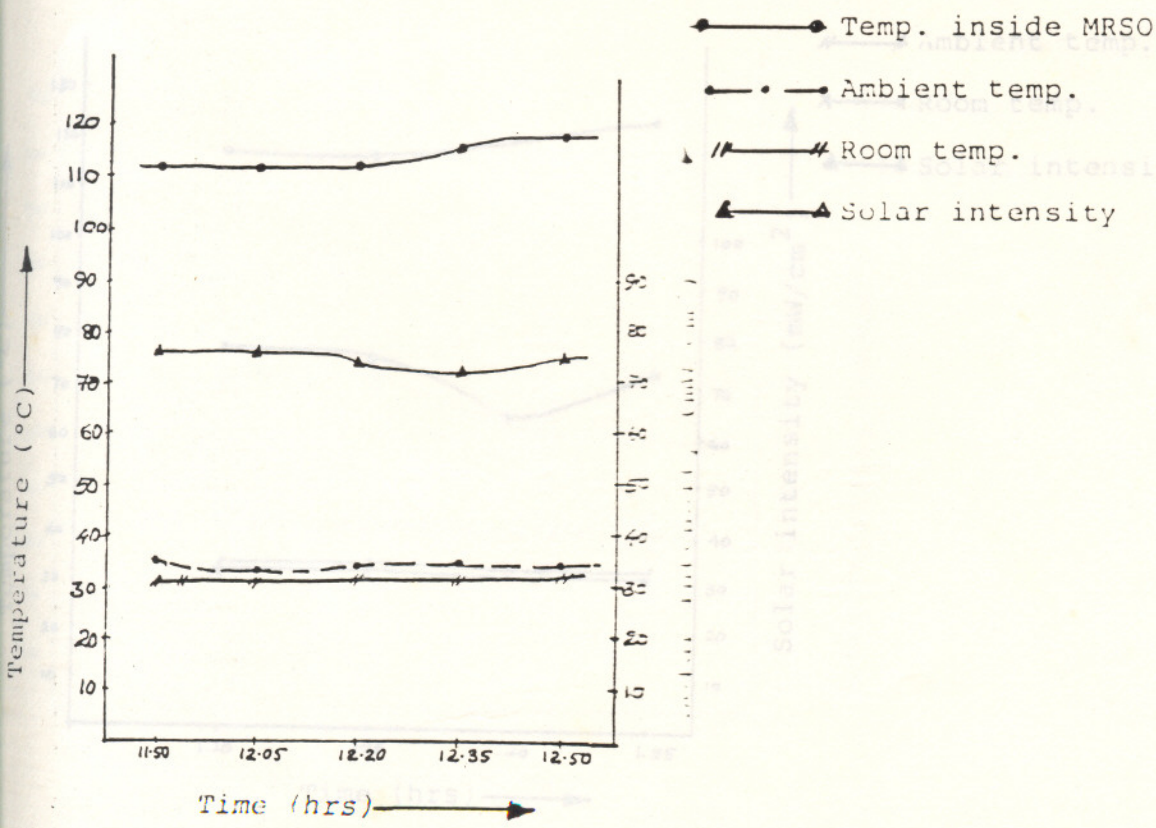


Fig.[illegible]

Time (00.00 hrs)	Temp. inside MRSO °C	Ambient temp. °C	Room temp. °C	Solar intensity (mW/cm2)
1.10	117	34	33	78
1.25	117	34	33	76
1.40	120	33	32	64
1.45	124	33	32	74

Table 13

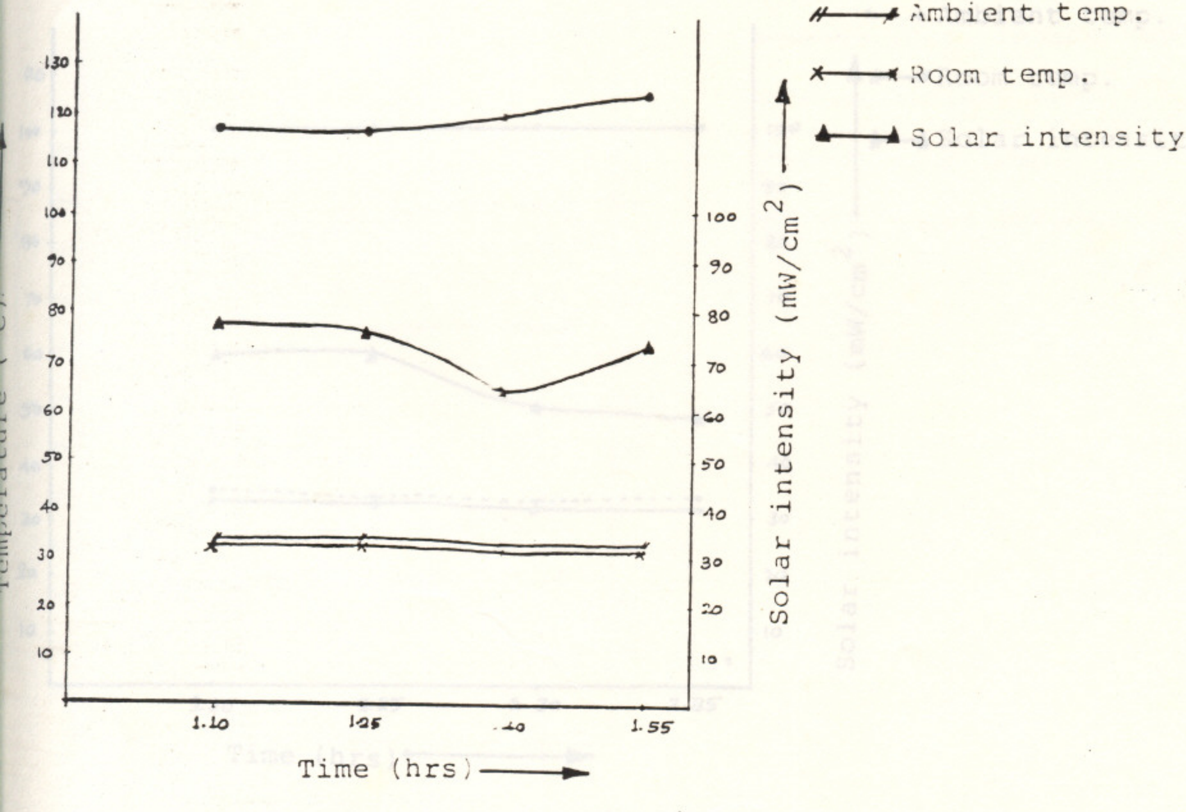


Fig.17

Time (00.00 hrs)	Temp. inside MRSO °C	Ambient temp. °C	Room temp. °C	Solar intensity (mW/cm^2)
2.20	100	35	33	60
2.25	100	34	33	60
2.30	100	33	32	50
2.35	100	33	32	48

Table 14

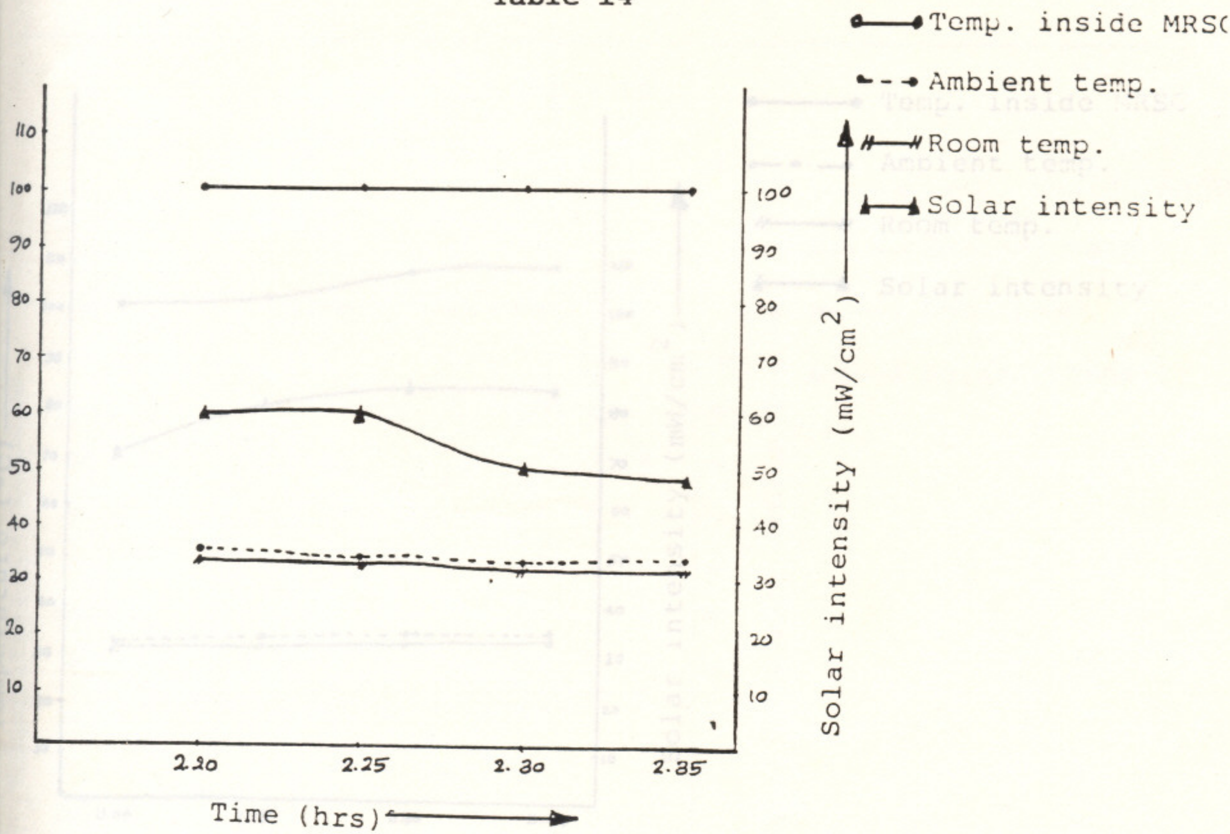


Fig.18

Time (00.00 hrs)	Temp. inside MRSO °C	Ambient temp. °C	Room temp. °C	Solar intensity (mW/cm^2)
11.00	100	32	32	70
11.15	102	33	31	80
11.30	108	34	32	84
11.45	109	34	33	84

Table 15

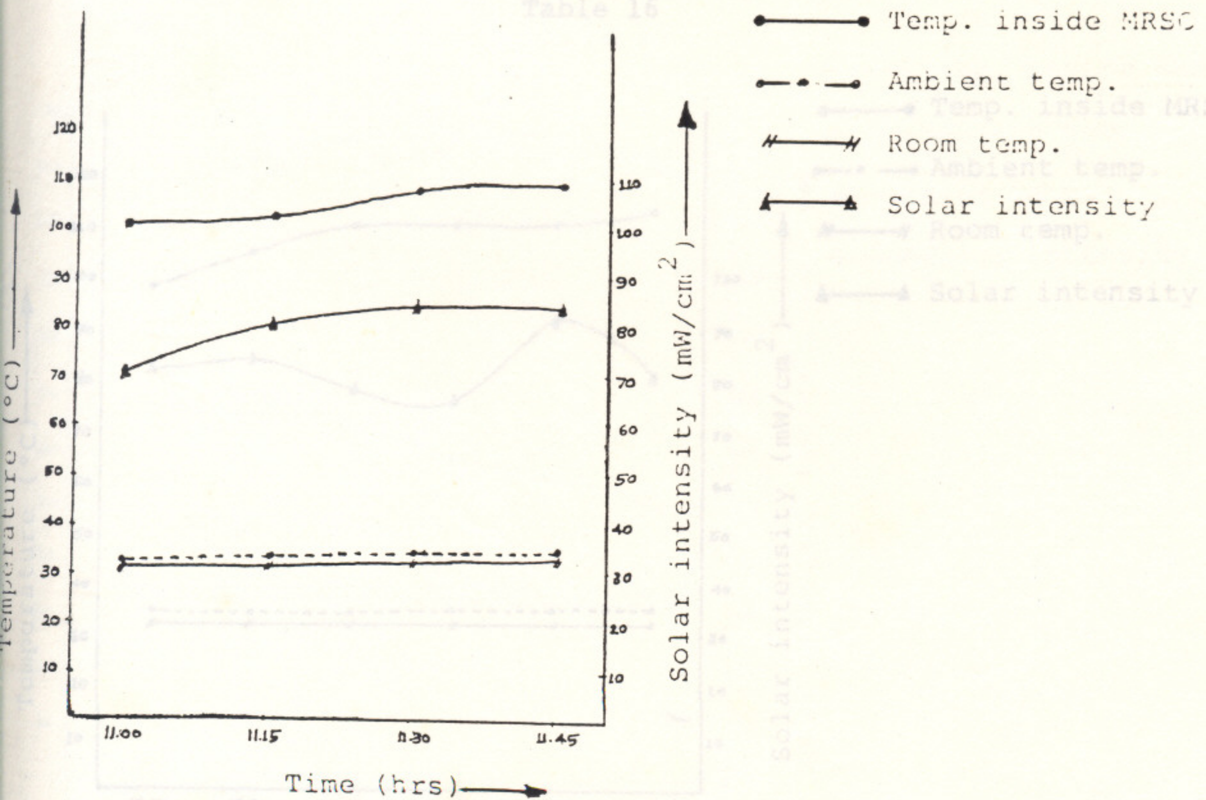


Fig.19

Time (00.00 hrs)	Temp. inside MRSO °C	Ambient temp. °C	Room temp. °C	Solar intensity (mW/cm^2)
12.05	98	34	32	82
12.20	105	34	32	84
12.35	110	34	32	78
12.50	110	35	32	76
1.05	110	35	32	92
1.20	113	35	32	80

Table 16

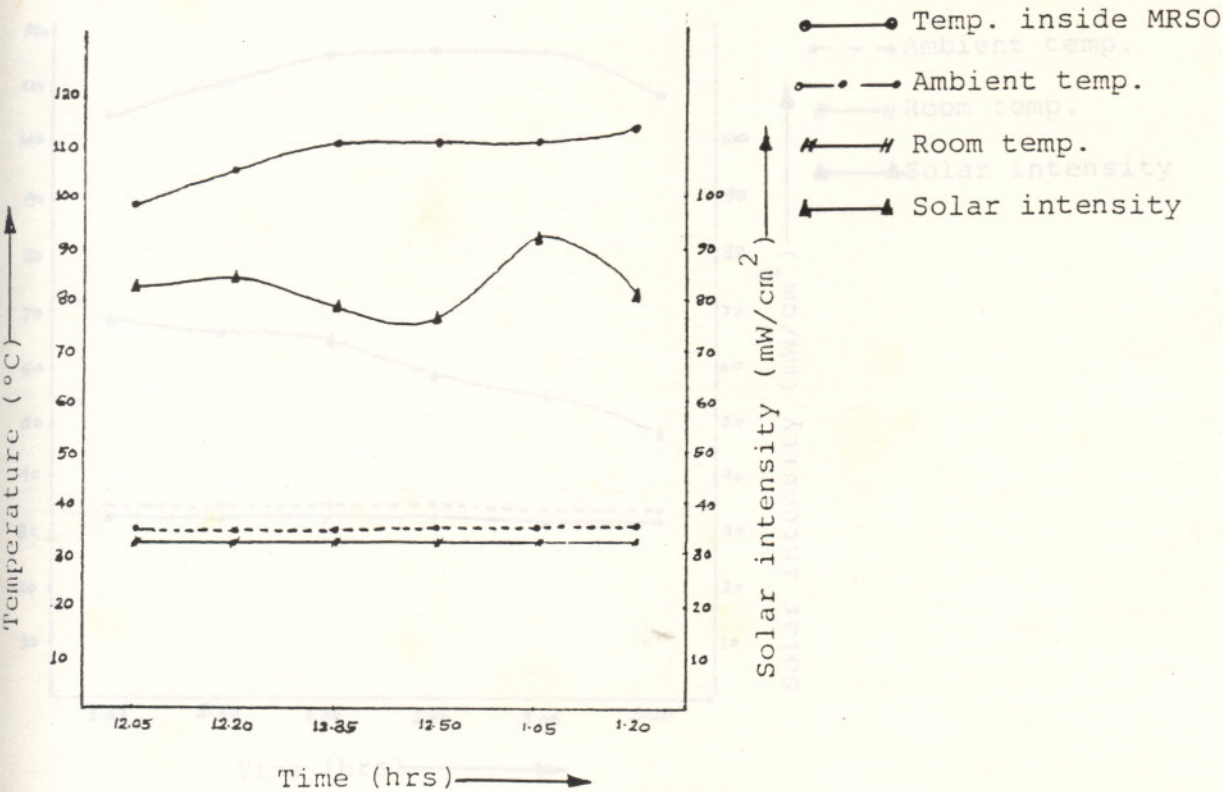


Fig.20

Time (00.00 hrs)	Temp. inside MRSO °C	Ambient temp. °C	Room temp. °C	Solar intensity (mW/cm^2)
2.05	104	34	32	68
2.20	110	34	32	66
2.35	115	34	32	64
2.50	115	33	31	58
3.05	115	33	31	54
3.20	107	33	31	47

Table 17

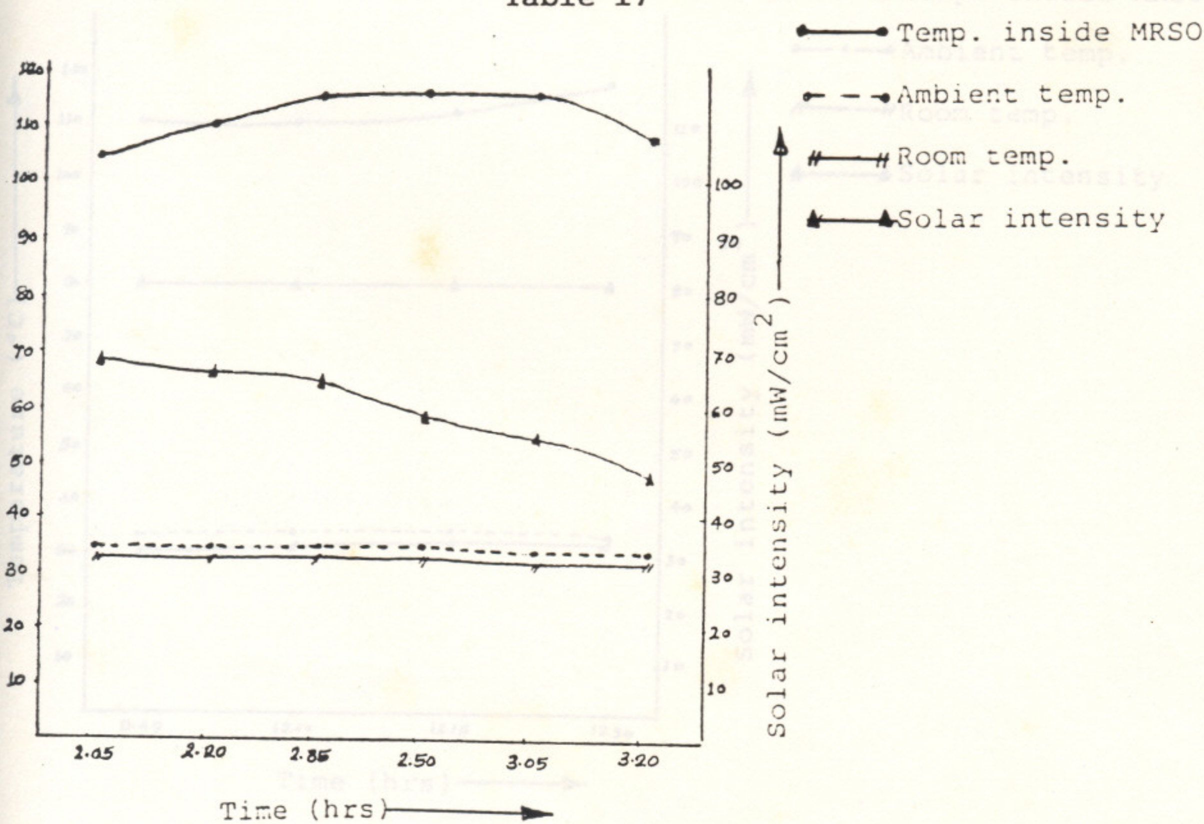


Fig.21

Time (00.00 hrs)	Temp. inside MRSO °C	Ambient temp. °C	Room temp. °C	Solar intensity (mW/cm^2)
11.45	110	33	30	80
12.00	110	34	31	80
12.15	112	34	32	80
12.30	117	33	32	80

Table 18

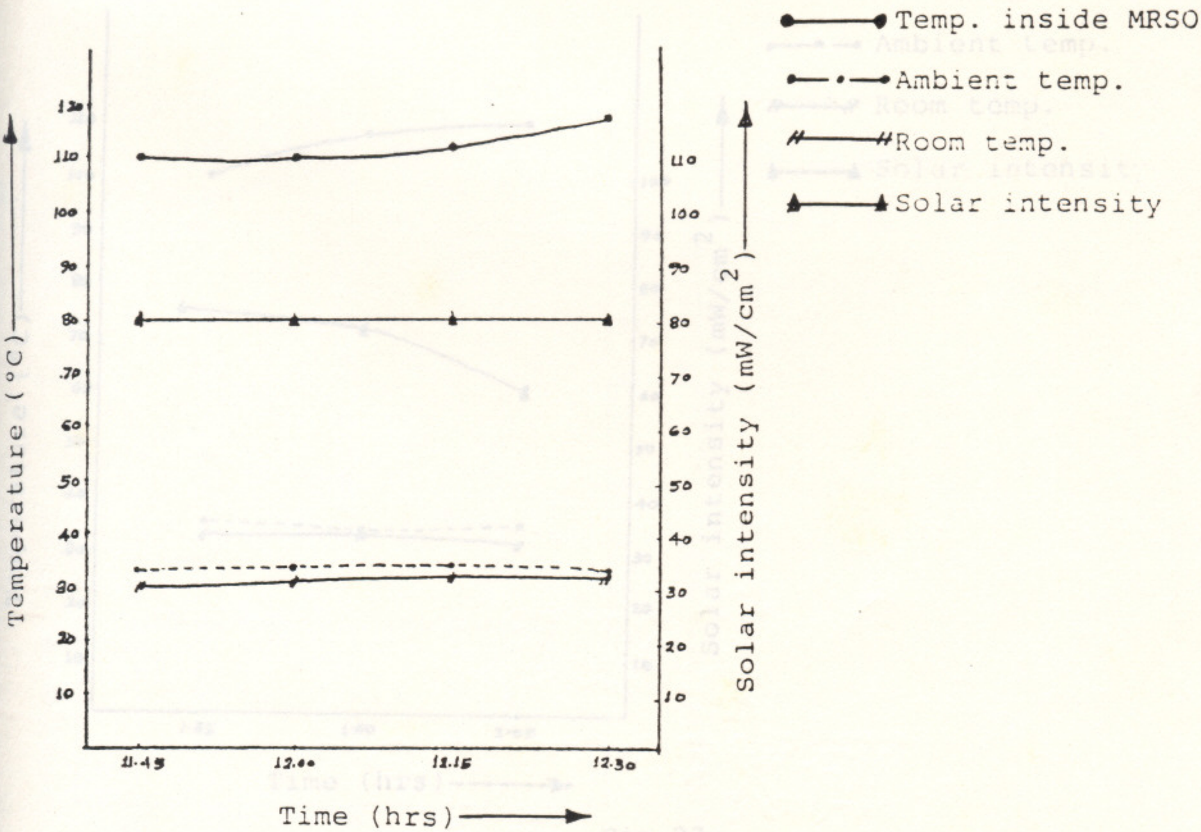


Fig.22

Time (00.00 hrs)	Temp. inside MRSO °C	Ambient temp. °C	Room temp. °C	Solar intensity (mW/cm^2)
1.35	100	35	33	75
1.50	108	34	33	72
2.05	110	35	32	60

Table 19

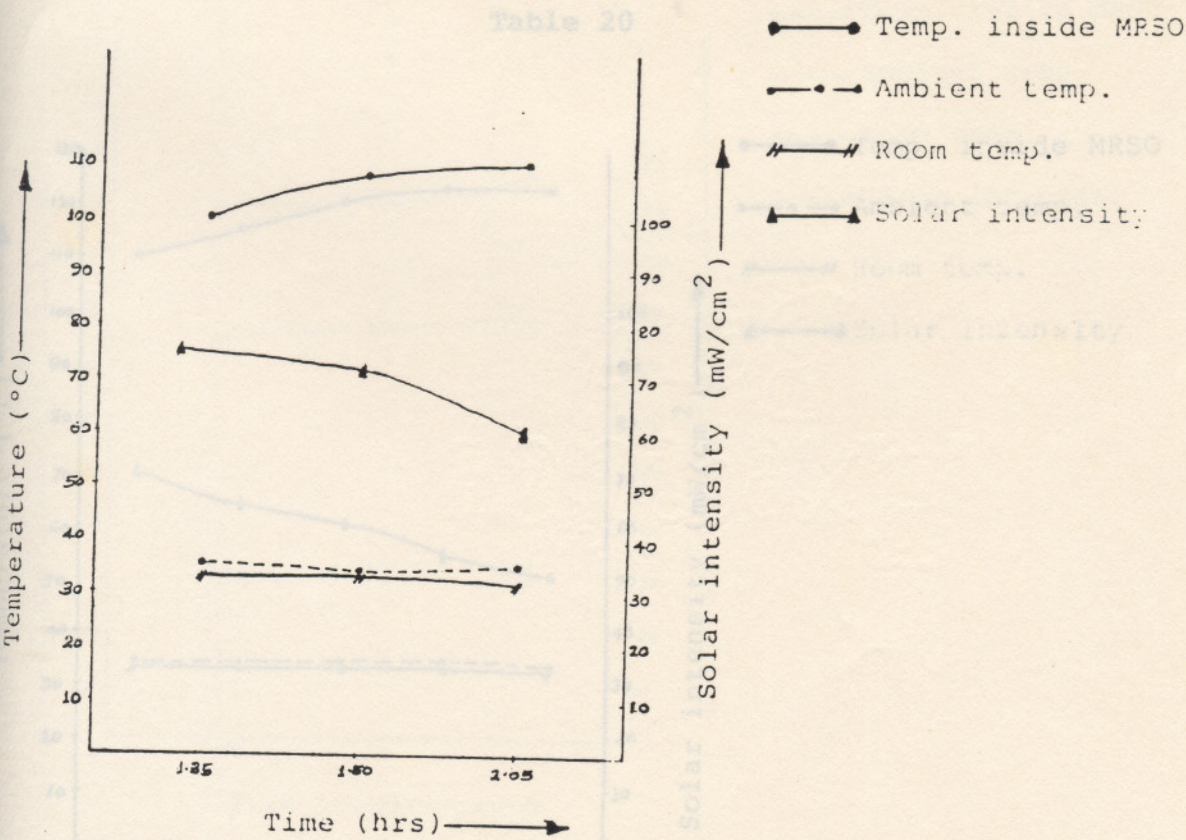


Fig.23

Time (00.00 hrs)	Temp. inside MRSO °C	Ambient temp. °C	Room temp. °C	Solar intensity (mW/cm^2)
2.15	110	34	33	70
2.30	115	34	33	64
2.45	120	34	33	60
3.00	122	34	33	54
3.15	122	33	32	50

Table 20

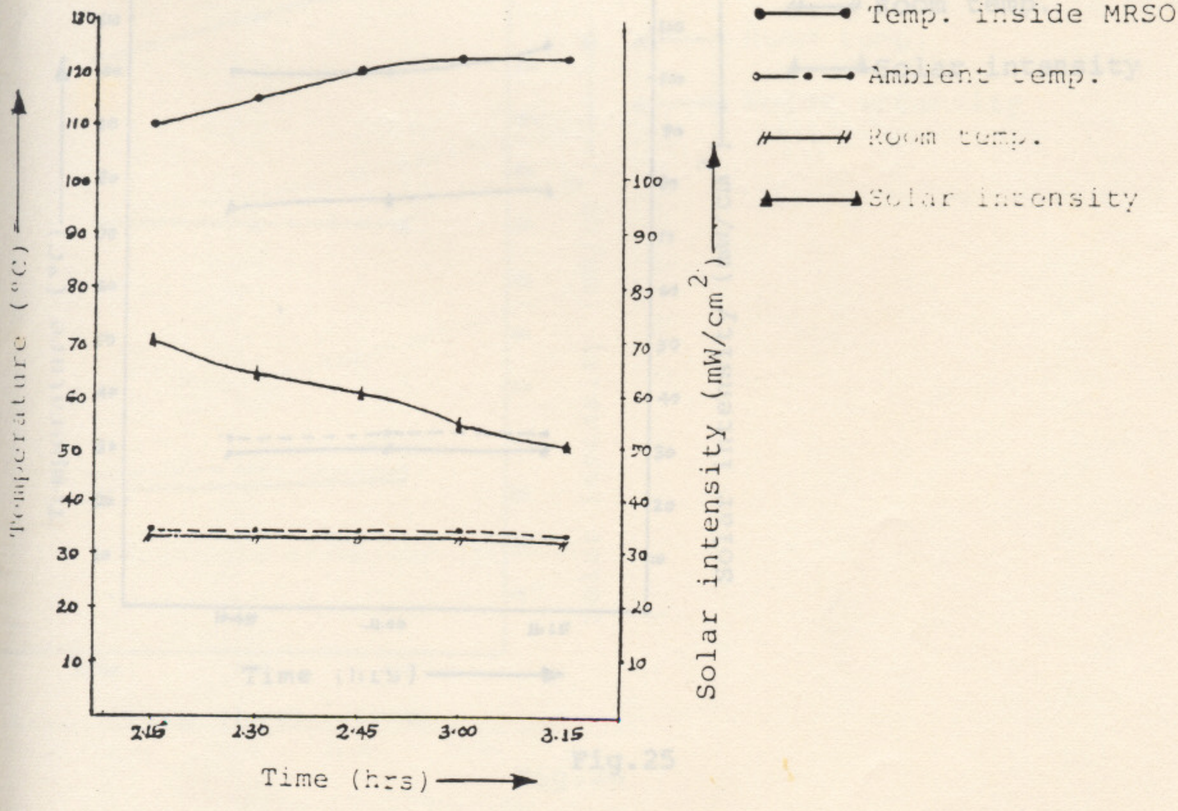


Fig.24

Time (00.00 hrs)	Temp. inside MRSO °C	Ambient temp. °C	Room temp. °C	Solar intensity (mW/cm^2)
10.45	100	32	29	74
11.00	100	33	30	76
11.15	105	33	30	78

Table 21

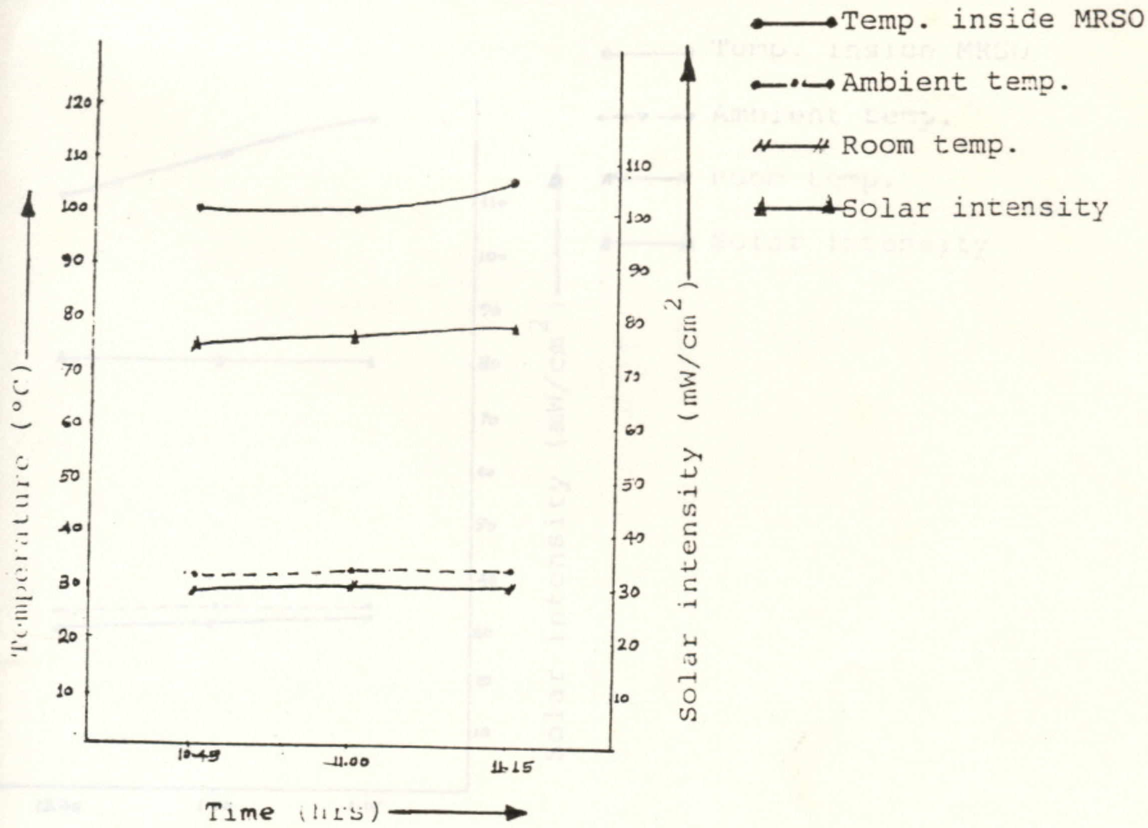


Fig.25

Time (00.00 hrs)	Temp. inside MRSO °C	Ambient temp. °C	Room temp. °C	Solar intensity (mW/cm^2)
12.45	110	33	30	80
1.00	118	34	31	80
1.15	125	34	32	80

Table 22

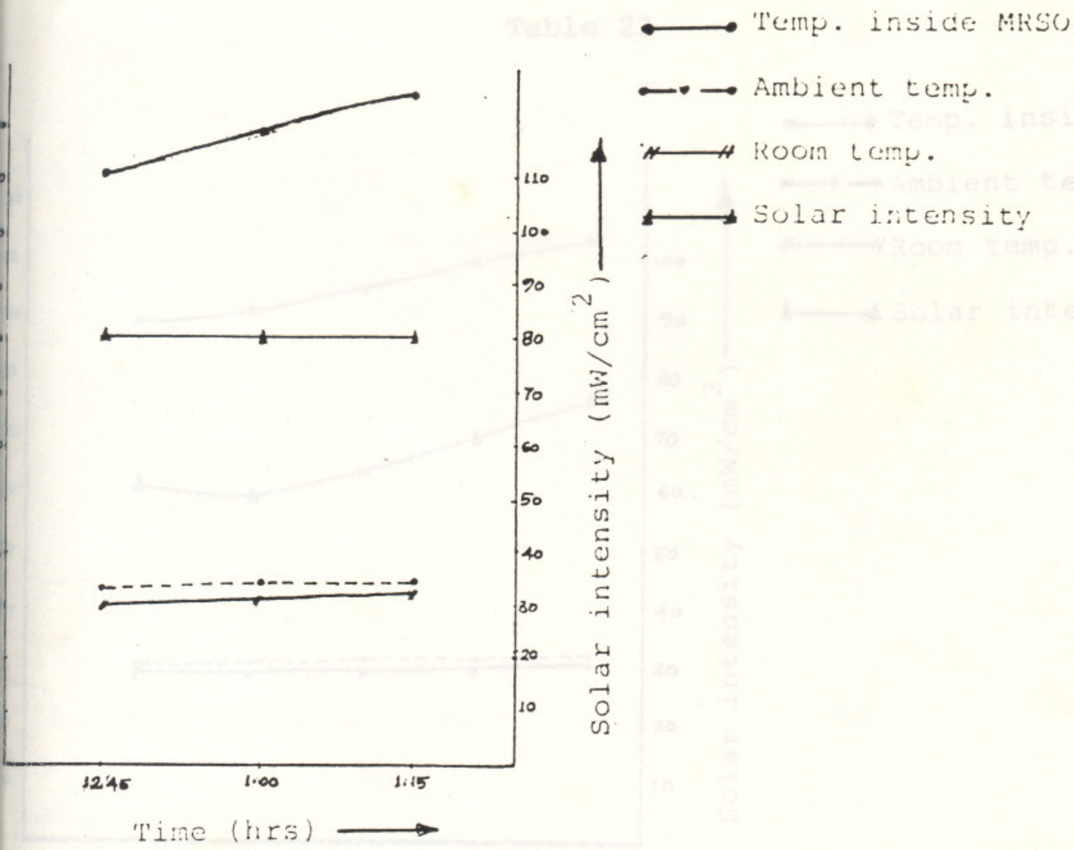


Fig.26

Time (00.00 hrs)	Temp. inside MRSO °C	Ambient temp. °C	Room temp. °C	Solar intensity (mW/cm^2)
10.00	90	31	30	62
10.15	92	31	30	60
10.30	96	32	30	64
10.45	100	32	31	70
11.00	104	33	31	76

Table 23

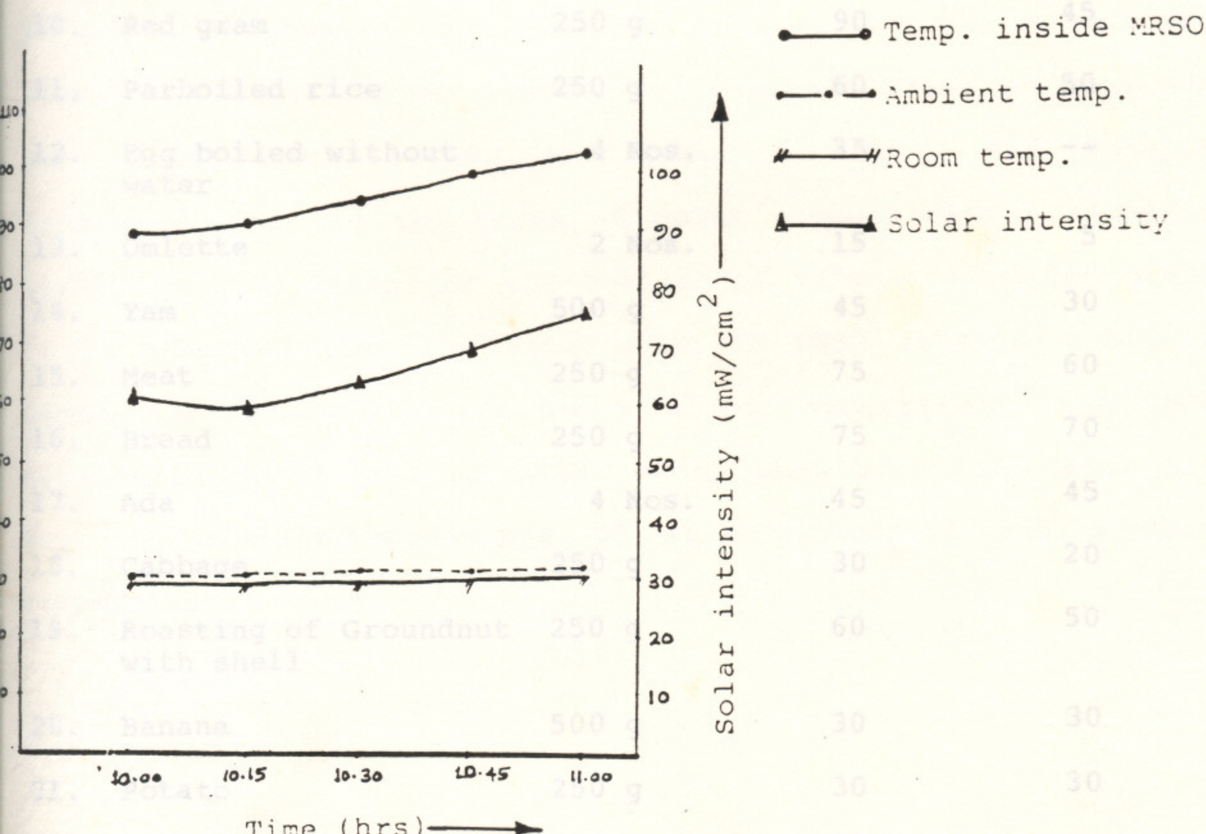


Fig.27

Comparison of cooking times of MRSO and conventional cooking

Sl. No.	Item	Quantity	Time taken in MRSO (min)	Conventional time (min)
1.	Cake	1 kg	75	45
2.	Rice	250 g	30	30
3.	Egg boiled in water	4 Nos.	40	15
4.	Roast	250 g	25	20
5.	Tea	4 cup	30	15
6.	Uppuma	250 g	40	25
7.	Payasam	1 kg	75	60
8.	Green gram	250 g	75	50
9.	Tapioca	1 kg	90	45
10.	Red gram	250 g	90	45
11.	Parboiled rice	250 g	60	50
12.	Egg boiled without water	4 Nos.	35	--
13.	Omlette	2 Nos.	15	5
14.	Yam	500 g	45	30
15.	Meat	250 g	75	60
16.	Bread	250 g	75	70
17.	Ada	4 Nos.	45	45
18.	Cabbage	250 g	30	20
19.	Roasting of Groundnut with shell	250 g	60	50
20.	Banana	500 g	30	30
21.	Potato	250 g	30	30
22.	Sambar	500 g	60	50

Table 24

Comparison of MRSO with ANERT model solar cooker

No load testing of MRSO and ANERT model were carried out to find out the stagnation temperature.

The experimental results of no load testing are shown in Table 25 and the thermal performance is plotted in the graph (Fig.28). From the graph, it is observed that the temperature inside the oven increases with time but at a faster rate in the case of MRSO. Thus, it may be inferred that the MRSO is more efficient than the ANERT model solar cooker.

The experimental results of water boiling test conducted in both the cookers are given in Table 26 and the curves are plotted in Fig.29. The cookers are exposed to sun at 12 noon and were loaded with water containers at 1 pm. The results indicates that the two types of solar cookers differ significantly in time taken for the boiling of water. From the graph it is observed that the water kept in MRSO attains a higher temperature than that attains a higher temperature than that attains by water kept in ANERT model when both the ovens are kept in similar conditions of solar intensity and ambient temperature.

Comparison of MRSO with ANERT model solar cooker - no load

Time (00.00 hrs)	Temp. inside MRSO °C	Temp. inside ANERT °C	Ambient temp. °C	Room temp. °C	Solar intensity (mW/cm^2)
9.30	90	75	31	30	54
10.00	117	85	31	30	60
10.30	120	98	35	30	70
11.00	135	110	33	30	70
11.30	147	116	35	30	74
12.00	153	120	35	31	78
12.30	157	120	34	31	80
1.00	161	120	34	31	80
1.30	161	118	33	30	78
2.00	158	115	33	30	74
2.30	155	107	33	30	62
3.00	153	100	33	30	54
3.30	150	85	33	30	42

Table 25

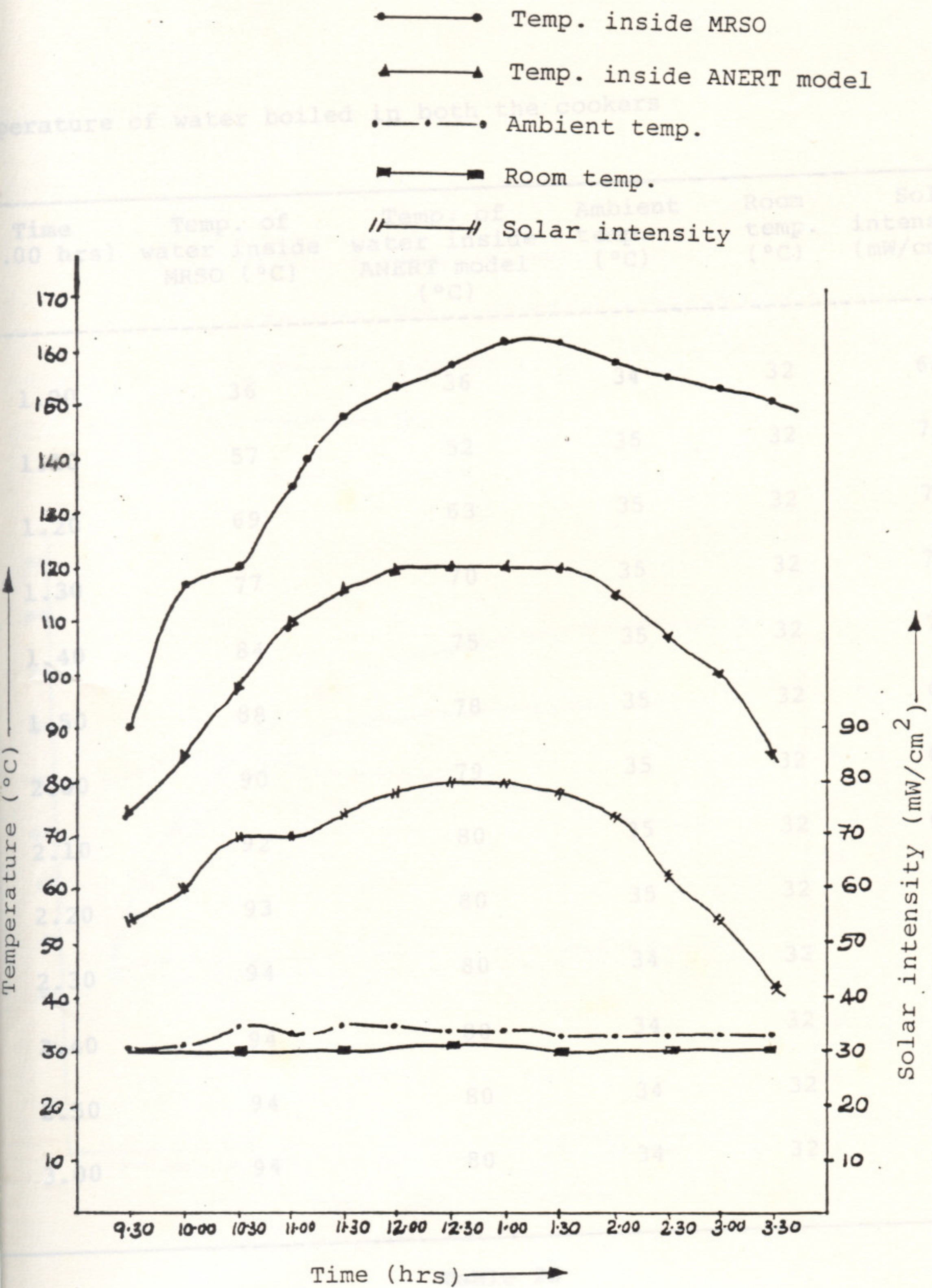

Temp. inside MRSO
Temp. inside ANERT model
Ambient temp.
Room temp.
Solar intensity
Temperature (°C)
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
Solar intensity (mW/cm2)
90
80
70
60
50
40
30
20
10
9·30
10·00
10·30
11·00
11·30
12·00
12·30
1·00
1·30
2·00
2·30
3·00
3·30
Time (hrs)

FIg.28

mperature of water boiled in both the cookers

• Time 0.00 hrs)	Temp. of water inside MRSO (°C)	Temp. of water inside ANERT model (°C)	Ambient temp. (°C)	Room temp. (°C)	Solar intensity (mW/cm^2)
1.00	36	36	34	32	68
1.10	57	52	35	32	72
1.20	69	63	35	32	74
1.30	77	70	35	32	72
1.40	84	75	35	32	70
1.50	88	78	35	32	68
2.00	90	79	35	32	68
2.10	92	80	35	32	66
2.20	93	80	35	32	64
2.30	94	80	34	32	60
2.40	94	80	34	32	58
2.50	94	80	34	32	56
3.00	94	80	34	32	52

Table 26

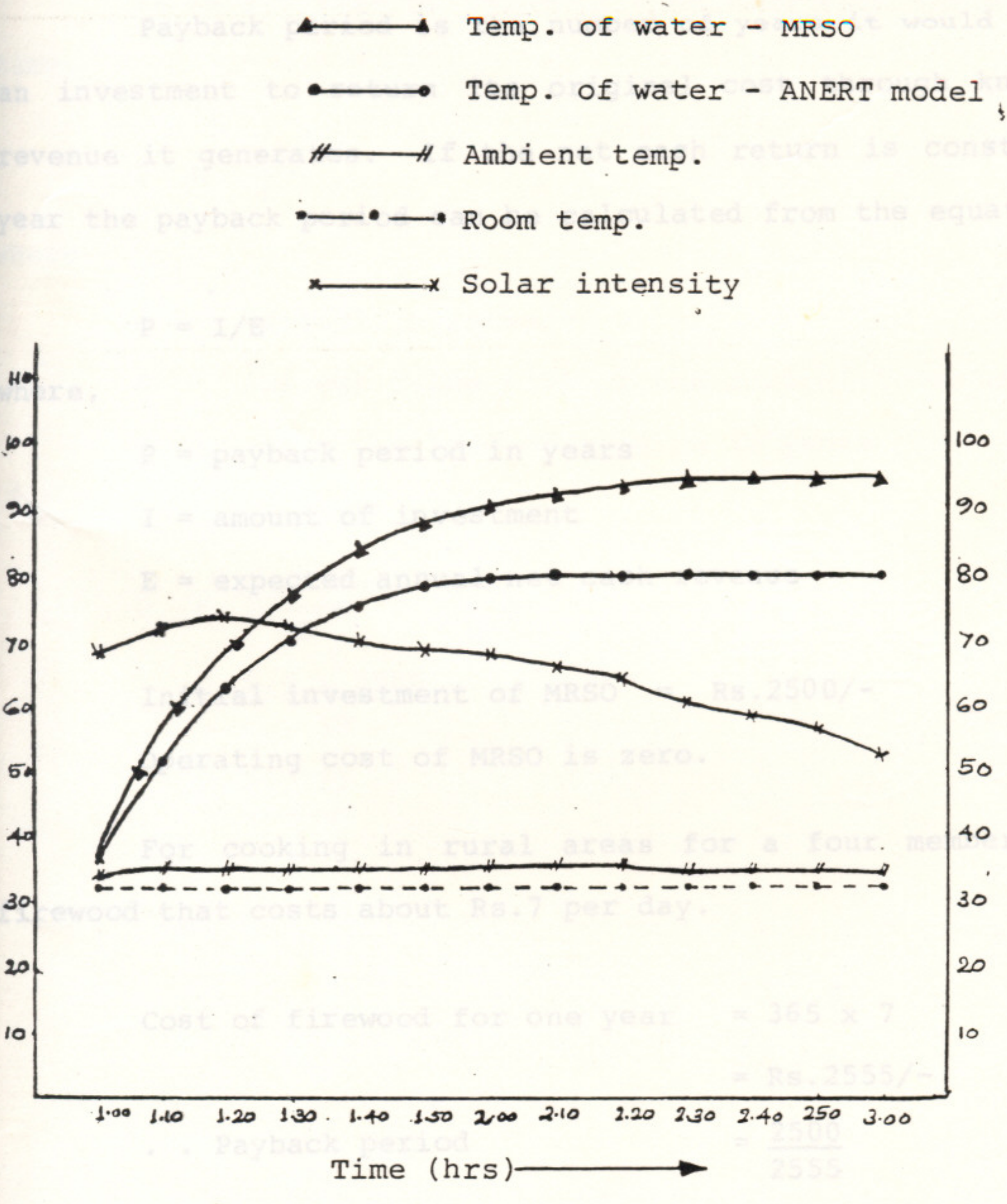

Temp. of water - MRSO
Temp. of water - ANERT model
Ambient temp.
Room temp.
Solar intensity
Solar intensity (mW/cm2)
Time (hrs)
1.00
1.10
1.20
1.30
1.40
1.50
2.00
2.10
2.20
2.30
2.40
250
3.00
10
20
30
40
50
60
70
80
90
100

Fig.29

conomic aspects

ayback period

Payback period is the number of years it would take for an investment to return its original cost through known cash revenue it generates. If the net cash return is constant each year the payback period can be calculated from the equation

$$P = I/E$$

where,

P = payback period in years

I = amount of investment

E = expected annual net cash revenue

Initial investment of MRSO = Rs.2500/-

Operating cost of MRSO is zero.

For cooking in rural areas for a four member family, firewood that costs about Rs.7 per day.

Cost of firewood for one year = 365 x 7

= Rs.2555/-

$\therefore$ Payback period $= \frac{2500}{2555}$

= 1 year

That is, the payback period of MRSO is one year, which means that the owner can get full profit of his investment in the very first year itself.

Depreciation

It is the loss of value of a machine with the passing of time.

$$D = \frac{C-S}{L}$$

where,

C - capital investment

S - Salvage value (10% of the capital investment)

L - estimated life of machine in years

10 years

$$D = \frac{C-0.1C}{L} = \frac{0.9C}{L}$$

$$= \frac{0.9 \times 2500}{10}$$

= Rs.225

Depreciation calculation

Sl.No.	Years of operation	Depreciated value at the end of year (Rs)
1.	1	2275
2.	2	2050
3.	3	1825
4.	4	1600
5.	5	1375
6.	6	1150
7.	7	925
8.	8	700
9.	9	475
10.	10	250

Table 27

The depreciation is plotted in a graph (Fig.30).

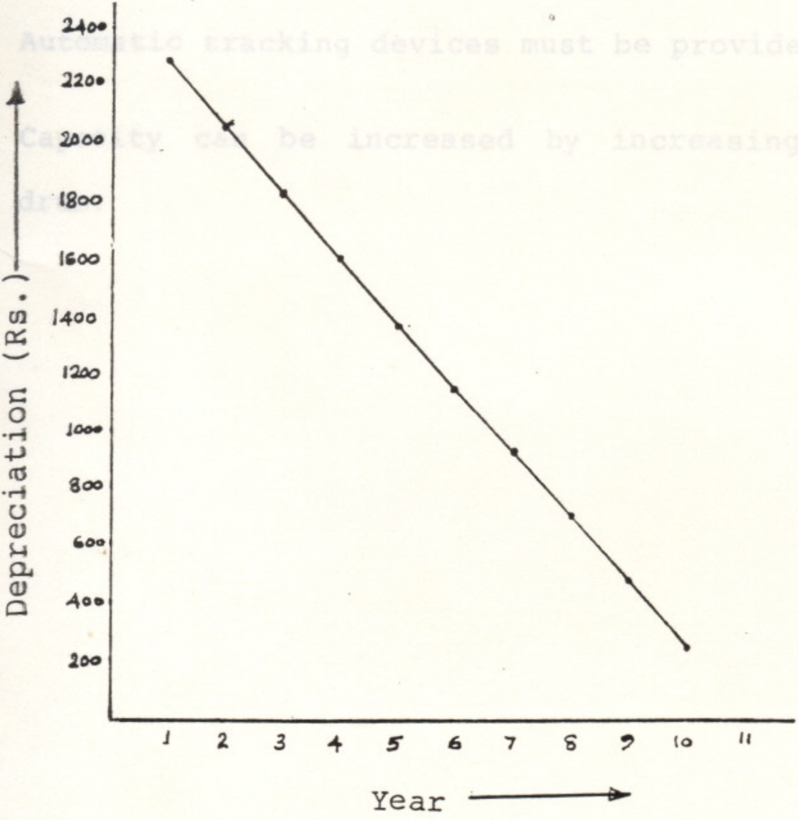

Depreciation (Rs.)
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
1
2
3
4
5
6
7
8
9
10
11
Year

Fig.30

Scope for further research

1. Life of the black paint on absorber tray and cooking utensils should be increased.

2. A cheaper substitute of glass mirror has to be found out for plane reflector used in solar oven.

3. Automatic tracking devices must be provided.

4. Capacity can be increased by increasing the size of the drum.

SUMMARY AND CONCLUSION

Energy is defined in classical thermodynamics as the capacity to do work. From a practical point of view it is the basic ingredient for all industrialised societies. Energy is currently derived from different primary sources such as oil, natural gas, coal and wood. The shortage of fossil fuels and their high prices in the international market has affected the development activities of third world countries. After non-renewable energy sources are consumed, the humanity must turn to permanent energy sources like nuclear and solar energy.

Cooking consumes a major portion of the total time and energy of an Indian house wife. The time and energy spent on cooking depends upon type of fuel consumed, efficiency of cooking equipments used, food consumption habits and style of cooking. Solar cooker is a promising technology for cooking food. It is a new kind of cooking device and does not require any conventional fuel for operation as it works with solar energy. It gives no smoke and there appears to be no significant polluting effect from its use and keeps the environment clean. It also preserves the nutritive value of food. Considering the importance of developing a cooking device using solar energy the project entitled "Fabrication and Testing of a Multireflector type solar oven was undertaken.

also done. The performance curves in each case were drawn and it was found that MRSO was more effective and efficient than the ANERT model.

The main advantages of MRSO are the higher temperature it can produce, its ability to maintain the temperature for a long time and less cooking time. From the performance of solar oven we could conclude that

1. It can be used for preparing all food dishes.

2. The cooking time depends upon the temperature and intensity of solar radiation.

3. Food items prepared by the process of roasting is also possible with this oven.

4. Eggs can also be boiled without water.

5. The best time of the day for cooking is between 11 am and 3 pm.

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Appendix - I

Instrumentation

a. Specification of the solar intensity meter

Name	:	Suryamapi
Model Number	:	SM 201
Range	:	0-120 mW/cm^2
Supplied	:	Central Electronics Ltd.

b. Specification of thermometer

Make	:	Pensky Martens, England
Range	:	0 to 300°C

Appendix - II

Material	Coefficient of thermal conductivity [kcal per (hr m°C)]
Aluminium sheet	174
Air	0.0014
Glass	0.64
Glass wool	0.032
G.I.	160
Mild steel	39
Plywood	0.12
Wood	0.15

pendix-III(Contd.)

.No.	Item	Specification		
.	G.I. Cover	Material	-	G.I.
.	Guide	Material	-	M.S.
		Number	-	1
		Thickness	-	3 mm
.	Roller wheels	Material	-	Plastic
		Number	-	4
.	Metallic frame	Material	-	Angle iron

FABRICATION AND TESTING OF A MULTI-REFLECTOR TYPE SOLAR OVEN

By

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HELEN ALEX
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ABSTRACT OF THE PROJECT REPORT

Submitted in partial fulfilment of the requirement for the degree

Bachelor of Technology in Agricultural Engineering

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Malappuram

1992

ABSTRACT

The study was conducted with the objectives of fabrication and testing of a multireflector type solar oven to evaluate its performance.

The MRSO mainly consists of a semi-cylindrical collector, plane glass plates and reflectors. A tray made of aluminium is kept hanging from the two hinges at the sides of the inside drum for placing the vessel. The solar radiation reaching the mirrors got reflected and concentrated into the drum through the plane glass plates. The inside surface of the drum is painted black so that it can absorb the heat reaching inside it. Aluminium vessel of 2 lit capacity can be placed inside the drum.

Intensive testings were conducted for the MRSO and comparative evaluation of the oven was done with the ANERT model. The MRSO was found to be more efficient than the existing ANERT model box type solar cooker.

The main advantages observed from the MRSO are as follows:

1. higher temperature
2. ability to maintain the temperature for a long time
3. less cooking time