DESIGN DEVELOPMENT OF SOLAR BOX COOKER ASSISTEDD WITH THERMAL ENERGY STORAGE SYSTEM FOR COOKING APPLICATIONS IN NON-SOLAR HOURS

A Project Report Submitted in partial fulfillment

of the requirements for the award of the degree of

BACHELOR OF TECHNOLOGY
IN
MECHANICAL ENGINEERING

Submitted by

B.NAGALAKSHMI (14091A0377)

A. RAJESH KUMAR (14091A03A3)

P.NARESH KUMAR (14091A0382)

K N C SAI PRATHAP (14091A0376)

D. SRI KANTH (14091A03E0)

D. NAVEEN KUMAR (14091A0384)

Under the esteemed guidance of

Dr.V.SIVA REDDY M.Tech, Ph.D(IITD)

Professor, Department of Mechanical Engineering

(ESTD-1995)

SCHOOL OF MECHANICAL ENGINEERING

RAJEEV GANDHI MEMORIAL COLLEGE OF ENGINEERING AND TECHNOLOGY

(AUTONOMUS)

(Affiliated to J.N.T. University, Anantapur, A.P, INDIA) (Approved by A.I.C.T.E, Accredited by N.B.A, & NAAC of UGC,New Delhi, with „A"Grade, & Participating in TEQIP-II)

YEAR (2017-2018)

Dr. K. THIRUPATHI REDDY
Professor & Head of M.E and ...
Department of Mechanical Engineering
R.G.M. College of Engg. & Tech., (Autonomous)
NANDYAL-518 501, Kurnool (Dist.), A.P.

Dr. T. JAYACHANDRA PRASAD
M.E,Ph.D,PE,FIETE,MWAPER,MISTE,MIEEE
PRINCIPAL
R G M College of Engg. & Tech.,
(Autonomous)
NANDYAL-518 501, Kurnool (Dt), A.P.

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(AUTONOMOUS)

Approved by AICTE New Delhi, Accredited by NAAC-A+ Grade, Accredited by NBA, Affiliated to J.N.T. University Ananthapuramu)Nandyal-518501, Kurnool Dist., A.P

Dr K. THIRUPATHI REDDY
B.E(Mech), M.Tech, Ph.D, MISTE, ASME
Professor & Head of M.E and SIEMENS
Department of Mechanical Engineering
R.G.M College of Engg. & Tech., (Autonomous)
NANDYAL 518 501, Kurnool (Dist), A.P

Dr. T. JAYACHANDRA PRASAD
M.E,Ph.D.,FIE,FIETE,MNAFEN,MISTE,MIEEE
PRINCIPAL
R G M College of Engg. & Tech.,
(Autonomous)
NANDYAL-518 501, Kurnool (Dt), A.P.

RAJEEV GANDHI MEMORIAL COLLEGE OF ENGINEERING & TECHNOLOGY

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(Approved by AICTE New Delhi, Accredited by NAAC-A+ Grade, Accredited by NBA, Affiliated to J.N.T. University Ananthapuramu)

Nandyal-518501, Kurnool Dist., A.P

(ESTD-1995)

DEPARTMENT OF MECHANICAL ENGINEERING

CERTIFICATE

This is to certify that the thesis entitled **"DESIN DEVELOPMENT OF SOLAR BOX COOKER ASSISTED WITH THERMAL ENERGY STORAGE SYSTEM FOR COOKING APPLICATIONS IN NON SOLAR HOURS"** that is being submitted by B.NAGALAKSHMI (14091A0377),A.RAJESH KUMAR(14091A03A3),P.NARESHKUMAR(14091A0382),KNCSAIPRATHAP(14091A0376),D.SRIKANTH(14091A03E0),D.NAVEEN KUMAR (14091A0384) have carried out the project for the fulfillment of the award of Bachelor of Technology in Mechanical Engineering in Rajeev Gandhi Memorial college of Engineering & technology (Autonomous) and thisis a record of bonafidework carried out by them under our guidance and supervision.The results embodied in this project work have not been submitted to any other university or institute for the award of any degree.

Signature of Guide

Dr.V.SIVA REDDY M.Tech,Ph.D(IITD)
Professor,
Dept. of ME, RGMCET.

Signature of HOD ME

Dr.SYED ALTAF HUSSIAN M.Tech,Ph.D,MISTE,FIE
Professor&Head of ME,
Dept. of ME, RGMCET.

Examiner:

Date:

Dr. K. THIRUPATHI REDDY
B.E(Mech), M.Tech.,Ph.D MISTE,ASME
Professor & Head of M.E and SIEMENS
Department of Mechanical Engineering
R.G.M College of Engg. & Tech., (Autonomous)
NANDYAL 518 501, Kurnool (Dist), A.P

Dr. T. JAYACHANDRA PRASAD
M.E,Ph.D.,FIE,FIETE,MNAFEN,MISTE,MIEEE
PRINCIPAL
R G M College of Engg. & Tech.,
(Autonomous)
NANDYAL-518 501, Kurnool (Dt), A.P.

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PROJECT ASSOCIATES

B.NAGALAKSHMI	**(14091A0377)**
A.RAJESH KUMAR	**(14091A03A3)**
P.NARESH KUMAR	**(14091A0382)**
KNC SAI PRATHAP	**(14091A0376)**
D.SRIKANTH	**(14091A03E0)**
D.NAVEEN KUMAR	**(14091A0384)**

Dr K. THIRUPATHI REDDY
Professor & Head of M.E and SIEMENS
Department of Mechanical Engineering
R.G.M College of Engg. & Tech., (Autonomous)
NANDYAL - 518 501, Kurnool (Dist), A.P

Dr. T. JAYACHANDRA PRASAD
M.E,Ph.D.,FIE,FIETE,MNAFEN,MISTE,MIEEE
PRINCIPAL
R G M College of Engg. & Tech.,
(Autonomous)
NANDYAL-518 501, Kurnool (Dt), A.P.

ABSTRACT

Solar cooking is one of the most promising techniques to meet the cooking needs in remote areas where electricity and fuel supplies are insufficient. Solar box cooker is an efficient device used in solar cooking as it is simple to fabricate, easy to operate and hazard-free. A latent heat energy storage system was designed and fabricated to cook the food at o-peak hours of solar radiation. The estimated dimension of the box cooker area is around 0.28 m^2, for the energy requirements of 2859 KJ/day for cooking. This latent heat energy storage system is combined with the solar box cooker. The selection of phase change material is based on high specific enthalpy and its melting point lying close to the cooking temperature.

A solar cooking box has been constructed with wood and for storing the thermal energy we have chosen the unrefined cotton seed oil as thermal storage medium in the aluminum duct. For being thermal resistance for the box the materials used are toughen glass and wood, and for increasing the maximum input energy we have increased the solar radiation incident area by providing the another reflective mirror and for absorbing more heat we have coated with black paint considering the absorptivity.

Dr K. THIRUPATHI REDDY
B.E(Mech), M.Tech, Ph.D, MISTE, ASME
Professor & Head of M.E and SIEMENS
Department of Mechanical Engineering
R.G.M College of Engg. & Tech., (Autonomous)
NANDYAL 518 501, Kurnool (Dist), A.P

Dr. T. JAYACHANDRA PRASAD
M.E, Ph.D., FIE, FIETE, MNAFEN, MISTE, MIEEE
PRINCIPAL
R G M College of Engg. & Tech.,
(Autonomous)
NANDYAL-518 501, Kurnool (Dt), A.P.

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Dr K. THIRUPATHI REDDY
B.E(Mech), M.Tech.,Ph.D MISTE,ASME
Professor & Head of M.E and SIEMENS
Department of Mechanical Engineering
R.G.M College of Engg. & Tech., (Autonomous)
NANDYAL 518 501, Kurnool (Dist), A.P

Dr. T. JAYACHANDRA PRASAD
M.E,Ph.D.,FIE,FIETE,MNAFEN,MISTE,MIEEE
PRINCIPAL
R G M College of Engg. & Tech.,
(Autonomous)
NANDYAL-518 501, Kurnool (Dt), A.P.

CHAPTER 1

INTRODUCTION

The potential of renewable energy sources is enormous as they can in principle meet many times the worlds energy demand. Renewable energy sources such as biomass, wind, solar, hydropower, and geothermal can provide sustainable energy services, based on the use of routinely available, indigenous resources. A transition to renewables-based energy systems is looking increasingly likely as their costs decline while the price of oil and gas continue to fluctuate. In the past 30 years solar and wind power systems have experienced rapid sales growth, declining capital costs and costs of electricity generated, and have continued to improve their performance characteristics. In fact, fossil fuel and renewable energy prices, and social and environmental costs are heading in opposite directions and the economic and policy mechanisms needed to support the widespread dissemination and sustainable markets for renewable energy systems are rapidly evolving. It is becoming clear that future growth in the energy sector will be primarily in the new regime of renewable energy, and to some extent natural gas-based systems, not in conventional oil and coal sources. Because of these developments market opportunity now exists to both innovate and to take advantage of emerging markets to promote renewable energy technologies, with the additional assistance of governmental and popular sentiment. The development and use of renewable energy sources can enhance diversity in energy supply markets, contribute to securing long term sustainable energy supplies, help reduce local and global atmospheric emissions, and provide commercially attractive options to meet specific energy service needs, particularly in developing countries and rural areas helping to create new employment opportunities there. In this project we use solar energy as the main energy supplier for the project. Solar thermal energy refers to the technologies that utilize the sun energy for cooking, for heating water and other heat transfer fluids for a variety of residential, industrial and utility applications.

CHAPTER 2

WAYS TO STORE THERMAL ENERGY

Thermal energy storage involves the storage of heat in one of three forms; Sensible heat, Latent heat and thermo-chemical heat storage. Sensible heat storage is the most common method and has been employed for hundreds of years as hot water tanks. Sensible heat storage simply means changing the temperature of storage medium. The storage medium is most commonly water but rock, sand, clay and earth can also all be used.

Latent heat energy storage involves the storage of energy in Phase-Change Materials (PCMs). Thermal energy is stored and released with changes in the materials phase. The most common phase change to exploit is the solid-liquid transition, as the liquid gas transition is impractical and solid-solid (crystalline structure) transitions usually have too low an energy density to be useful. When a PCM is heated initially it behaves like sensible heat energy storage and the materials temperature is increased. However, once the transition temperature is reached the material will continue to absorb heat at a constant temperature while it changes state. This heat absorbed at constant temperature is known as the latent heat of the transition. To retrieve the energy the PCM can be changed back from the liquid to the solid phase and the energy stored as latent heat is released.

Thermo-chemical heat energy storage involves storing heat energy in chemical bonds. A reversible chemical reaction which absorbs heat is used to absorb the heat energy that is to be stored. This reaction can then be reversed to release the stored heat. The most common reactions used for this process is the hydration of salts. The energy storage is based on the release of the heat of hydration. Hence, a salt hydrate storage system is charged by the endothermic thermal dehydration of the respective higher hydrated salt.

Table 1 - Typical Parameters of Thermal Energy Storage Systems [1]

TES System	Capacity (kWh/t)	Power (MW)	Efficiency (%)	Storage period (h, d, m)	Cost (€/kWh)
Sensible (hot water)	10-50	0.001-10	50-90	d/m	0.1-10
PCM	50-150	0.001-1	75-90	h/m	10-50
Chemical reactions	120-250	0.01-1	75-100	h/d	8-100

Figure 1 - Large Hot Water Storage (construction and final state) combined with Solar Thermal District Heating "Am Ackermann-bogen" in Munich, Germany

Figure 2.1: Under ground storage system

2.8 Aquifer storage

Aquifer storage uses a natural underground water-permeable layer as a storage medium. The transfer of thermal energy is achieved by mass transfer (i.e. extracting/re-injecting water from/into the underground layer). Most applications deal with the storage of winter cold to be used for the cooling of large office buildings and industrial processes in the summer (Figure 2). A major prerequisite for this technology is the availability of suitable geological formations.

2.9 Cavern storage and pit storage

Cavern storage and pit storage are based on large underground water reservoirs created in the subsoil to serve as thermal energy storage systems. These storage options are technically feasible, but applications are limited because of the high investment costs. For high-temperature (i.e. above 100 C) sensible heat storage, the technology of choice is based on the use of liquids (e.g. oil or molten salts, the latter for temperatures up to 550C. See

(ETSAP E10). For very high temperatures, solid materials (e.g. ceramics, concrete) are also taken into consideration. However, most of such high-temperature-sensible TES options are still under development or demonstration.

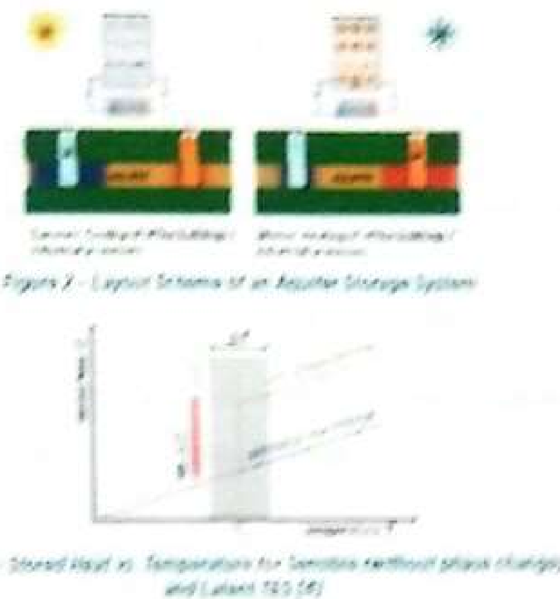

Figure 2.2: Aquier storage system

2.10 Phase Change Materials for TES

Sensible heat storage is relatively inexpensive, but its drawbacks are its low energy density and its variable discharging temperature . These issues can be overcome by phase change materials (PCM)-based TES, which enables higher storage capacities and target oriented discharging temperatures. The change of phase could be either a solid/liquid or a solid/solid process. Melting processes involve energy densities on the order of 100 kWh/m3 (e.g. ice) compared to a typical 25 kWh/m3 for sensible heat storage options. Figure 3 compares the achievable storage capacity at a given temperature difference for a storage medium with and without phase change. Phase change materials can be used for both short-term (daily) and long term (seasonal) energy storage, using a variety of techniques and materials. Table shows some of the most relevant PCMs in different temperature ranges with their melting temperature, enthalpy and density. For example, the incorporation of microencapsulated PCM materials (e.g. paraffin wax) into gypsum walls or plaster can

CHAPTER 3

LITERATURE REVIEW OF SOLAR COOKER

The standard proposed by Mullick is more complicated and less universal than the one being evaluated, though the characteristic curve they developed is a good predictive tool. Grupp employ a test procedure that presents much useful information especially for Europe. In recent years several authors have investigated methodologies for the evaluation and comparison of solar cookers . Traditional methods of characterizing the performance of solar cookers are based on energy analysis as they are based on the first law of thermodynamics and provide information about the total quantity of energy without investigating the quality and the avail- ability of energy. The exergetic analysis of low cost parabolic type and box type solar cooker was conducted by Ozturk for the first time in 2004. Inspired from the study of Ozturk, Petela in 2005 carried out the performance evaluation of a cylindrical trough shape solar cooker based on the exergetic analysis. Comparative study on energy and exergy efficiency for Box type and parabolic type solar cookers was conducted by Oztruk under the climatic conditions of Turkey. Buddhi and Sahoo designed a box-type solar cooker having latent heat storage and showed that it is possible to cook the food, even in the evening hours with latent heat storage. Nahar designed, developed and tested a novel solar cooker that does not require any tracking and its performance was compared with a hot-box type solar cooker. The overall efficiency of the novel solar cooker was found to be 29.5 percentage and the payback period was found to be between 1.30 and 3.29 years depending upon the fuel it replaces. made a performance study of the box-type solar cooker with special emphasis on the shape of lid of the utensils used. The study revealed that the performance of a solar cooker could be improved if a utensil with a concave shape lid is used instead of a plain lid [illegible] [illegible] the solar cookers also analyzed the thermal performance of a box [illegible] [illegible] second figure of merit with and without load [illegible]

CHAPTER 4

DESIGN CONSIDERATIONS OF SOLAR COOKER

4.1 WORKING

Essentially, reflectors in the solar cooker focus sunlight on a dark pot within the solar cooker, which has a tight-fitting lid to contain heat and moisture. A dark pot is used as it absorbs the maximum amount of heat, and allows higher cooking temperatures In order to trap heat, isolating the air inside the cooker from the surrounding atmosphere makes an important difference. Using a clear solid, like a plastic bag or a glass cover, will allow light to enter, but once the light is absorbed and converted to heat, a plastic bag or glass cover will trap the heat inside. This allows temperature to reach similar levels on cold and windy days as on hot days. These plastic sheets have an added benefit of blocking any leakages that could potentially seep through and damage the cooker. Cooking containers and the inside bottom of the cooker should be dark-colored or black. Inside walls should be reflective to reduce radiative heat loss and bounce the light towards the pots and the dark bottom, which is in contact with the dark pots.

A solar cooker can be advisably used when the length of one's shadow on the ground is shorter than that individual's height. This indicates that the sun is high enough in the sky to allow for efficient cooking.

4.2 Regional Considerations

Approximately 600,000 cookers are being used in the Andes, Tibet, Nepal, Mongolia and parts of China. However, the biggest recent success story has been in villages in India. If most of the following conditions apply, this region may be suitable for solar cooking Mostly-sunny days throughout several months of the year. Outdoor space available that remains sunlit for several hours and sheltered from high winds. If local cooking fuels are

Figure 4.3: Solar Box Cooker

Dr K. THIRUPATHI REDDY
B.E(Mech), M.Tech, Ph.D, MISTE, ASME
Professor & Head of M.E and SIEMENS
Department of Mechanical Engineering
R.G.M College of Engg. & Tech., (Autonomous)
NANDYAL 518 501, Kurnool (Dist), A.P

Dr. T. JAYACHANDRA PRASAD
M.E, Ph.D., FIE, FIETE, MNAFEN, MISTE, MIEEE
PRINCIPAL
R G M College of Engg. & Tech.,
(Autonomous)
NANDYAL-518 501, Kurnool (Dt), A.P.

CHAPTER 5

CONSTRUCTION AND PERFORMANCE OF SOLAR BOX COOKER

5.1 Design calculation of solar cooker

1. Sensible heat of water = m Cp (T2-T1)

= 1*4.2*((100+273)-(30+273))

=294 KJ

2. Latent heat of water at 100 degrees centigrade = 2250 KJ/Kg

3. Sensible heat of steam = m Cp (T2-T1)

= 1*2*((120+273)-(100+273))

= 42 KJ

4. Sensible heat of milk = m Cp (T2-T1)

=1*3.8*(80-8)

=273 KJ

* Energy required for heating of 1Kg of water and 1Kg of milk

= (S.H+L.H) of water+(S.H)of steam+(S.H)of milk

= (294+2250)+(42)+273

= 2859 KJ/day

* Solar radiations /day/m^2area= 5.5 KWhr (NREL-National Renewable laboratory)

= 5.5*3600 KJ

= 19800 KJ

* Efficiency of the box cooker = 50percent (Assumption)

Dr K. THIRUPATHI REDDY
B.E(Mech), M.Tech, Ph.D, MISTE, ASME
Professor & Head of M.E and SEIMENS
Department of Mechanical Engineering
R.G.M College of Engg. & Tech., (Autonomous)
NANDYAL 518 501, Kurnool (Dist), A.P

Dr. T. JAYACHANDRA PRASAD
M.E,Ph.D.,FIE,FIETE,MNAFEN,MISTE,MIEEE
PRINCIPAL
R G M College of Engg. & Tech.,
(Autonomous)
NANDYAL-518 501, Kurnool (Dt), A.P.

=19800*0.5

= 9900KJ/day/m^2 area

* Box cooker collection area =2859/9900

= 0.28 m^2 areaLet us consider the solar cooker is a square type:

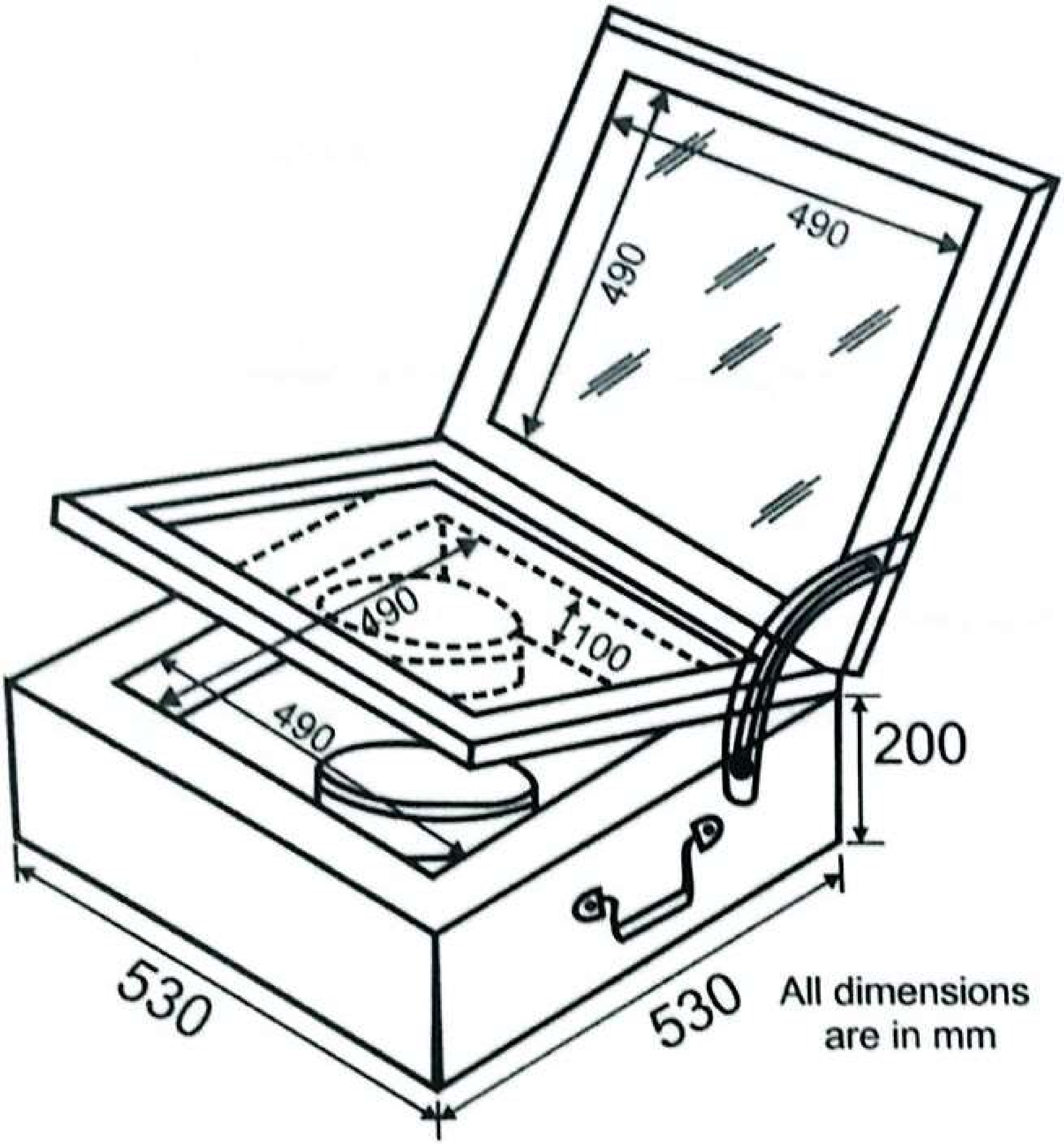

Figure 5.1: Box dimensions

CHAPTER 6

RESULT

* Experiments carried out show that the highest temperature gotten both on the ground floor and at the top of the roof was more than 180 0C.It means that temperature gotten at the top of the roof is same with that at the ground floor.
* Efficiency (n) is not a function of temperature of the collector but a function of the temperature difference between the collector temperature and the ambient temperature (Tc-Ta) 0C.
* Efficiency increased with decreasing temperature difference between collector temperature and ambient temperature. Increase in temperature does not necessarily mean an increase in efficiency. Efficiency decreased with decreasing solar radiation. Energy (E) per second radiated by the absorber plate is dependent on the Collector Temperature Tc (0C).
* Energy increased as collector temperature increased. For the cooking experiment that was carried out, 70 grams pack of indomie which takes about 15 minutes to cook using a conventional cooker was cooked in 25 minutes. This shows that a solar cooking might not be as fast as a conventional cooker but solar cooking is simple, safe and it is a very convenient way of cooking and it works.
* In this case the reflectors increased the amount of solar radiations getting into the box. The Maximum temperature of the absorber plate was more than 180 0C.
* The reflectors helped to concentrate more sunlight thereby increase the temperature of the Absorber plate.

CHAPTER 8

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Dr K. THIRUPATHI REDDY
B.E(Mech), M.Tech, Ph.D, MISTE, ASME
Professor & Head of M.E and SIEMENS
Department of Mechanical Engineering
R.G.M College of Engg. & Tech., (Autonomous)
NANDYAL 518 501, Kurnool (Dist), A.P

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M.E, Ph.D., FIE, FIETE, MNAFEN, MISTE, MIEEE
PRINCIPAL
R G M College of Engg. & Tech.,
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NANDYAL-518 501, Kurnool (Dt), A.P.