FABRICATION AND PERFORMANCE EVALUATION OF A SOLAR AIR COOLER

By

LINDA. N. E.

SUNIL. A. P.

PROJECT REPORT

Submitted in partial fulfilment of the requirement for the degree of

Bachelor of Technology in Agricultural Engineering

Faculty of Agricultural Engineering & Technology
Kerala Agricultural University

Department of Farm Power Machinery and Energy
Kelappaji College of Agricultural Engineering and Technology
Tavanur - 679 573
Malappuram

1993

DECLARATION

We hereby declare that this project entitled "Fabrication and Performance Evaluation of a Solar Air Cooler" is a bonafiderecord of project work done by us during the course of project and the report 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.

Linda
LINDA.N.E

Sunil
SUNIL.A.P.

Place : Tavanur

Date : 30/10/93

CERTIFICATE

Certified that this project report entitled "**Fabrication and Performance Evaluation of a Solar Air Cooler**" is a record of project work done by **Miss. Linda.N.E** and **Mr. Sunil A.P** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowshhip or associateship to them.

OFFICE OF THE DEAN, KELAPPAJI COLLEGE OF AGRL. ENGG & TECH ★ KERALA AGRL. UNIVERSITY, 30 OCT 93 TAVANUR.

HAMZA MOLLAKADAVATH

Project Guide

Assistant Professor

Department of Farm Power

Machinery and Energy

K.C.A.E.T, Tavanur

Plae : Tavanur

Date : 30/10/93

ACKNOWLEDGEMENT

We avail this opportunity with great pleasure to express our profound and sincere sense of gratitude and affinity to our much respected guide Shri. Hamza Mollakadavath, Asst. Professor, Department of Farm Power Machinery and Energy, for his professional guidance, valuable advices, constructive criticism, critical suggestions and immense help throughout this project work.

We express our heartful thanks to Prof. John Thomas, Dean and Shri. Jippu Jacob, Assosiate Professor, Department of Farm Power Machinery and Energy for their constant encouragement and valuable advices.

We are greatly indebted to Mr. C.V. Mohan Das, Engineer, V.S.S.C Thiruvananthapuram, who inspired us with the idea and provided needed help in the completion of this work.

We are greatful to Dr. K.I. Koshy, Head, Dept. of SAC and Er. Samkunju M.G, Jr. Programmer, for their help to complete the project report well in time.

We are very thankful to the workshop staffs especially to Shri. C.S. Krishnan and Shri. K.K. Vijayan for the assistance and co-operation rendered by them.

We also acknowledge the help rendered by Shri.Satheesan.M.M. and Shri.Saji.K for their help to complete the project report well in time.

We express our greatfulness to all the staff members and our dear friends for their help and co-operation extended towards us for the completion of this work.

At this moment we also extend,sincere gratitude to our parents for their help and management.

Above still we bow our heads before God Almighty in enabling us to complete this work and for His blessings.

LINDA N.E.

SUNIL A.P.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

SYMBOLS AND ABBREVATIONS USED

am	-	antimeredian
C	-	Celcius
Cal	-	Calories
cm	-	centimetre
Cv	-	specific heat of air at constant volume
d	-	diameter of vertical pipe
Fig	-	Figure
G.I	-	Galvanised Iron
GJ/m2	-	Giga joule per metre square
gm	-	gram
h	-	heat of solution of NH_4NO_3
hr	-	hour
H_2O	-	water
kg	-	kilogram
kwh	-	kilo watt hour
LiBr	-	Lithium Bromide
l/day	-	litre(s) per day
ml	-	milli litre
MW/cm2	-	milli watt per centimetre square
MW	-	Mega Watt
NH_3	-	ammonia
NH_4NO_3	-	ammonium nitrate
o	-	degree

PVC	-	poly vinyl chloride
sec	-	second
temp	-	temperature
ta	-	ambient temperature
tb	-	temperature inside the barrel
w	-	mass of air
w/m2	-	watt per metre square
η	-	efficiency
%	-	percent

INTRODUCTION

Energy is required to sustain and improve the quality of life.It is defined as the capacity to do work.Energy is currently derived from different primary sources such as oil,natural gas,coal and wood.The reserve of fossil fuels are being consumed at a very fast rate. The supplies of most of the common energy sources are finite. So we may have to shift to renewable energy sources.

In India, major portion of domestic needs are met from non-renewable sources like fire wood, cow dung, sowdust, rice husk and other agricultural waste. Attempts are being made in different parts of the world to tap alternatives sources. One such attempt to the utilization of solar energy reaching the earth in the form of electromagnetic radiations. The need for harnessing renewable energy supplies is apparant as fossil fuels becomes expensive,as world population increses,and each individual desires for a higher standard of living .

Solar energy is clean ,non polluting,non depleting energy available almost everywhere .The power from the sun intercepted by the earth is 1.8×10^{11} MW,which is many thousands of times larger than the present consumption rate on the earth of all commercial enery sources.Thus in priciple 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 non-conventional energy sources.

The main problem associated with the use of solar energy is that it is a dilute source of energy.Even in the hottest region on earth ,the solar radiation flux available rarely exeeds $1KW/M^2$,which is a low value for technological utilization.Consequently,large collecting areas are required in many applications and these resulted in excessive costs.The second problem associated with the use of solar energy is that its availability varies widely with time. Thus the energy collected when the sun is shining must be stored for use during periods when it is not available.The need for storage increses the cost of the system.

The applications of solar energy are heating of buildings, ,cooling of buildings, solar water heating,salt prodution by evaporation of sea water, solar drying of agricultural products ,solar cookers, solar engines for water pumping ,bio conversion ,photo-voltaic conversion etc. Solar energy is directly converted to electricity using solar cells.

The heat from solar energy can be used to cool buildings using the absorption cooling principle. Presently available equipments require extremely high operating temperatures, causing efficient solar colletion.

The use of solar energy for cooling can be either to provide refregeration for food preservation or to provide comfort cooling .Solar cooling has some inherent advantages over solar heating. Cooling demand is more in phase with the shining of the sun, both annually and daily. Since the solar radiation is the most important factor in the determination of outdoor temperature, the hottest seasons of the year usually occur during periods of great solar intesity.

The two principle methods for lowering air temperature for space cooling are refrigeration (actually removing energy from the air) and evaporation cooling (the vaporization of moisture). Dehumidification is also used. Evaporative cooling occurs when water vapourizes; the evaporation of perspiration from the skin is one of the mechanism which our bodies use to remain cool. Evaporative cooling for building work best in dry climates. Removing moisture from the air (dehumidification) is a cooling method used in humid climates, often reffered to as absorption dehumidification.

The importance of solar refrigeration especially for the preservation of perishables in rural areas of developing countries needs no emphasis. Cooling for comfort and for the preservation of food and medicine has been supplied for most of the countries by the vapour compression cycle. Another refrigeration cycle operates using a binary solution is the absorption refrigeraion cycle. Absorption refrigeration cycle was the only cycle for cooling used earlier. The current lack of popularity of these machines is perhaps due to their low coefficient of performance (cop) per unit volume of the machine and the high refrigeration capacities obtained by vapour compression refrigeration cycle system.

Absorption refrigeration cycle run on low level energy sources such as solar energy. More over refrigeration and cooling are most needed in places where solar energy availability is the greatest. This is the primary reason for continued research in the solar refrigeration system.

Considering the importance of research in the solar refrigeration system, the project entitled "Fabrication and Performance Evaluation of Solar Air Cooler" was undertaken. The objectives of this project are,

(i) To fabricate a solar air cooler.

(ii) To evaluate its performance.

REVIEW OF LITERATURE

This chapter briefly describes the history, classification, the research and development activities done about solar cooling.

2.1 History

Solar powered absorption cooling was suggested more than 25 years ago as a solution to the refrigeration problem in remote locations.

Experiments on solar powered refrigeration at the Asian Institute of Technology were started in 1978. They have constructed and tested an intermittent ammonia water absorption refrigeration system with flat plate solar collector panels having a total area of 25 square meters.

2.2 Classification

A broad classification of various method of solar energy utilization is given below.

```
                      Solar energy Utilization
              /-----------------------------------\
   Direct methods                        Indirect methods
   /-----------\                 /-------------|-------------\
Thermal   Photovoltaic   Water   Wind   Biomas   Ocean   Temperature
                         power                           Difference
```

2.3 Thermal Applications of Solar Energy

The important fields of application of solar energy are as follows.

2.3.1 Solar water heating

Solar water heating happens to be one of the simplest and most wide spread exploits of solar energy. Solar water heaters are classified as,

(i) Unsheltered heaters
(ii) Sheltered heaters
(iii) Selective surfaces
(iv) Evacuated collectors
(v) System with seperate storage

2.3.2 Solar Distillation

The distillation of salt water to recover portable water is accomplished by exposing thin layers of the salt water to solar radiation, and condensing the water vapour produced on a transparent cover in such a way that it can be collected in receiving troughs.

2.3.3 Solar Pumping

Solar pumping consists basically in utilizing the power generated by solar energy by water pumping, useful for irrigation.

2.3.4 Solar Drying

A traditional and wide spread use of solar energy is for drying particularly of agricultural products.

2.3.5 Solar Cookers

Cooking with solar cookers is currently being promoted world-wide, especially in developing countries as a method to alleviate the need and cost for fuels.

2.3.6 Photo-Voltaic Power Generation

One way of utilizing the energy of the Sun is to generate electricity directly from sunlight by the photo-voltaic process.

2.3.7 Heating of buildings

The heat is directly used for warming the living spaces of a building in conventional way, e.g., through radiators and hot air resistors. When the building needs heat the air or water from its heating system passes through the storage, is warmed, and is then fed through the conventional heaters to warm the space.

2.3.8 Solar Cooling

The use of solar energy for cooling can be either to provide refrigeration for the preservation of food and medicine or to provide comfort cooling. There is less experience with solar cooling than solar heating. Several solar heated buildings have been designed, built, operated for extented period. But only a few short time experiments have been reported on solar cooling. However research work is expected to close the gap between the two, within few years.

Using solar energy in space cooling appears to be an attractive application due to the fact that the maximum amount of solar energy is avaiable when the demand is also at its maximum level. This is along with the necessities of providing comfort for people in hot areas of the world may be the motivating factor in continuing research and development in the field of solar cooling system.

In our country some means of cooling is necessary to maintain temeperatures inside building with either in the human comfort zone or within some other given range of temperatures for other applications (like 25 +_ 3 oC for rearing chambers for silk worms). Conventional methods of air conditioning however need electricity or fossil fuels, both of which are scarce and expensive. It is thus logical to consider the use of the abundant solar energy for space cooling.

2.4 Methods of Solar Cooling

Three main methods for achieving cooling from solar energy have been used in various applications. These methods are,

(i) Passive cooling

(ii) Compression refrigeration cooling

(iii) Absorption cooling

2.4.1 Passive Cooling

Passive cooling is quite reliable and economical. The main objective of this type of cooling is to achieve human comfort inside buildings by natural means as far as possible. This can be done by several means such as the building shape, window, orientation, shading, ventillation, evaporation and radio active cooling.

Although considerable work on active cooling systems has been done for the last two decades, due to its complexity, both in concept and in constructions, the utilization of solar cooling is not as wide-spread as other solar energy applications like solar water heating.

2.4.2 Compression Refrigeration Cooling

It is by using a vapour compression cycle driven by photo-voltaic pannels. Electrically driven vapour compression is most comonly used cooling system. It can be employed for conditioning air which enters under almost any condition, it can also provide a level of comfort higher than that of other systems.

2.4.3 Absorption Cooling

Absorption cooling is based on the principle that the refrigerant combines chemically with an absorbant to release heat during absorption while they absorb heat during evaporation. Extensive experiments on solar air conditioning of building using the absorption cycle have been constructed by many workers and the pioneers in this field.

2.5 Works done on Solar Cooling

Sheridan (1970) cooled a solar house with a floor area of 122 m2 using 3 ton H_2O-LiBr absorption refrigeration unit and flat plate collectors.

Alizadeh et al. (1979) presented a study on design and optimization of the H_2O-LiBr and NH_3-H_2O absorption cycle.

Mansoori *et al*. (1979) developed a technique for comparing differnt refrigerent absorbant combinations on the basis of the first and second laws of thermodynamics. This technique is applied for comparative evaluation of NH_3-H_2O and H_2O-LiBr.

Gomaz *et al*. (1983)developed another methodology for evaluation of working fluid combinations of absorption cycle based on the corresponding thermodynamic equations.

Hammoudeh *et al*. (1984) compared the economics of two conventional vapour compression systems and solar cooling systems (absorption and photo-voltaic) for different occupancies and capacities on the basis of respective life cycle costs per unit of refrigeration output. The absorption system and the water and air cooled photo-voltaic systems are assumed to resume equal amounts of conventional electricity. The study concludes that occupancy is a major factor in determining costs per ton-hour and cost per ton installed capacities. Among all the solar systems considered the absorption system is most promising and cost difference between that system and conventional system declines steadily as occupancy increases.

Kaushik *et al*. (1985) suggested a two stage absorption refrigeration system using H_2O-LiBr and NH_3-H_2O at the first and second stage respectively, for the purpose of producing very low temperatures. Both the stages are operated by hot water for seperated collectors and the evaporator of the first stage produces cooling water which is circulated in the absorber of the second stage.

Lenz (1986) assembled and tested a complete open cycle absorption cooling system. The sub system includes a packed bed regenerator and modified carrier corporation absorber/evaporator. Chilled water (10 oC) has been produced at a rate equivalent to 2% refrigeration tons.

Anand (1987) computed the properties of solution over the range of useful temperatures and concentrations and used to calculate individual irreversibilities for all the component of the H_2O-LiBr absorption cycle.

Bansal et al.(1987) presents the results of theoretical and experimental study of an underground tunnel system for space cooling. The experiments were carried out on a lage tunnel system located in the campus of St. Methodist Hospital at Madhura. The simple theoretical model developed for this system is based on the assumption that the temperature of the surface of the tunnel remains constant during the operation of the tunnel. The assumption was found to be justified by the measurements.

Clerx (1987) considered ice making by means of a NH_3-H_2O unit for which a computer aided thermodynamic analysis is performed for various ranges of operation parameters, climatic conditions and solar collector types.

Asha Iyer <u>et</u> <u>al</u>. (1988) presented comparative thermodynamic analysis of absorption cooling systems with H_2O-LiBr, NH_3-NaCN as working fluids. These systems were found to yield higher COP values at high heats of temperatures compared to other systems. H_2O-LiBr system stand out in terms of overall performance.

Bansal <u>et</u> <u>al</u>. (1988) presented passive cooling techniques for a building in a hot arid zones. A building has been designed, constructed and simulated for hot and dry zones of India using solar passive concepts like wind power, earth berm, evaporative cooling, etc, besides using the concepts of building science, viz, orientation and overhangs to efficiently keep the room temperature conditions within comfortable limits. The conclusions of study are as follows; (i) for dry months of the year it is desirable to evaporative cooling in the tower. The evaporative cooling in the wind tower provide a temperature difference of at least 8 oC between the outside air and air coming out of the wind tower, (ii) during the wet season the tower can be used as a ventillator during night.

Borda Diaz et al. (1989) designed a passive cooling strategies for a building proto type design in a warm humid tropic climate. The main design criteria is heat gain prevention by thermal optimization of the building.

Koushic et al. (1989) studied the feasibility of an open cycle absorption cooling system both theoretically and experimentally. Various investigations on heat and mass transfer process in solar regenerators, thermodynamic modelling and thermal design aspects of open absorption solar cooling system are summarised. A comparative study of open and closed cycle absorption cooling has also been presented, in which it was found that the former is better in performance, less expensive and simpler in technology. This review highlights the importance of open cycle absorption solar cooling system, possible applications, some innovative concepts relevant to open cycle absorption cooling.

Kishore (1988) developed a new method of acheiving cooling in buildings in hot climates, viz, roof sack-cloth cooling, relies on maintaining a thin film of water on the roof. Here a method of accessing the stability of given climatic conditions for natural cooling is prevented. This method is then applied to predict the performance of a roof sack-cloth cooling technique to certain hot-dry and hot-humid locations in India. It has been concluded that this method can be used to predict the average performance of sack-cloth roof cooling system.

Kumar et al. (1989) developed a mathematical model of a solar refrigerator which could be used in either an open cycle desicant-cooling system or an open cycle absorption cooling system. The regenerator concentrates weak salt solution, e.g., LiCl, by evaporating some of the water from the solution. The resultant strong salt solution is used to produce cooling. The effects of variation of the values of various parameters on the performance of the regenerator have also been analysed.

Lowrence et al. (1989) conducted studies on evaporative cooling for a typical house in Port Moreshy. It is observed that an evaporative cooling system having an efficiency of 50% has significant effect on room temperature of non air conditioned as well as shaded room.

Venkatesh et al (1989) had done experiments and explained the operations of a single stage and a two stage NH_3/H_2O intermittent solar refrigeration system. It is inferred that a single stage system is capable of producing the refrigeration with relatively high overall coefficient of performance at even low generation temperatures.

Al-Turki *et al*. (1990) analysed a solar operated two stage LiBr- H_2O cycle. The cycle can operate at higher ambient temperature and lower generator temperature than those required by a single stage cycle. Numerical correlations are developed to specify the minimum allowable generator temperature and the coefficient of performance of both single stage and two stage cycles.

Kouremenos D.A (1990) developed a solar driven compound NH_3/ H_2O - H_2O/LiBr absorption refrigeration system in Athens. The analysis shows that the cooling produced by a NH_3/ H_2O unit is 0.87 GJ/m2 year.

Kumar *et al*. (1990) conducted performance and cost evaluation of solid desicant solar cooling system. A fixed bed adiabatic dehumidifier model and a standard flat plate solar collector were choosen to investigate the overall desicant cooling performance as a function of regenaration temperature and the effectiveness of heat exchangers. The economics of solar regeneration dehumidifier based cooling system were evaluated for one ton of cooling capacity equivalent and comparative study using other energy sources was also made. It was found that the solar option should be the cheapest, which could make the solid desicant solar cooling system cost effective.

Maqsood Bajwa *et al*. (1992) carried out experiments on the effectiveness of natural ventillative passive cooling strategy in the maritime desert climate of the Arabian Gulf region. The experiments were structured to identify the comfort enhancement potential of direct and induced nocturnal convective cooling techniques.

MATERIALS AND METHODS

The materials used for the fabrication of solar air cooler and the methods employed to measure the various parameters are described in this chapter.

3.1. Materials Used

3.1.1. Vertical Pipe

A vertical pipe having 3 m height and 2.5 inch diameter was used. It consists of three sections , each having 1m length. The top and bottom parts were made of G.I to assist fast heat transfer. The middle portion was made of PVC inorder to reduce the heat conduction from the top of the vertical pipe. A conical hopper was fitted at the top of the vertical pipe to increase the heating surface area. The bottom end of the vertical pipe is closed. There is a provision for applying fresh water to the bottom of the vertical pipe.

3.1.2. Adapters

Suitable adapters were fixed at both ends of the PVC pipe.

3.1.3. Couplings

Two couplings of 2.5 inch diameter were used to connect the PVC and G.I pipes. M-seal was used in the joints to make it leak proof.

3.1.4. Ammonium NItrate

The vertical pipe was filled with saturated NH_4NO_3 Solution. NH_4NO_3 was selected for this experiment because its heat of solution is negative. The heat of solution is the quantity of heat absorbed or liberated when one mole of substance is dissolved. The heat of solution is negative because heat is absorbed during dissolution. Heat of solution of some of the substances are given in Appendix.2.

3.1.5. Reflectors.

18 reflectors- 9 trapezoidal and 9-triangular were mounted on an umbrella type structure, made of 24 guage galvanised iron sheet. The trapezoidal reflectors were kept at an angle of 55 degree to the horizontal. The reflector was mounted 30 cm below the hopper to concentrate the incident rays on the it.

3.1.6. Water Tank.

A water tank having capacity of 17 litres was used.

It was insulated inorder to prevent the heating of water during day time. The water was supplied from the tank to the bottom of the pipe by means of an hose having 0.5 inch diameter and 5 m length.

3.1.7. Insulated Barrel.

An insulated barrel of volume 350 litres was used for testing the cooling effect. The bottom end of the vertical pipe was inserted into the barrel. The temperature inside the barrel can be measured through the opening provided on the side of the barrel.

3.1.8. Thermocol.

Thermocol having 25 mm thickness was used as an insulating material to cover the barrel and the water tank. Thermocol is provided inorder to prevent the inside air of the barrel from getting heated,which will reduce the efficiency of cooling. .

3.1.9. Metallic Stand.

The barrel was mounted on a metallic stand of 1.5 m height which was fixed on the ground. The frame was made of G.I pipes having 0.5 inch diameter.

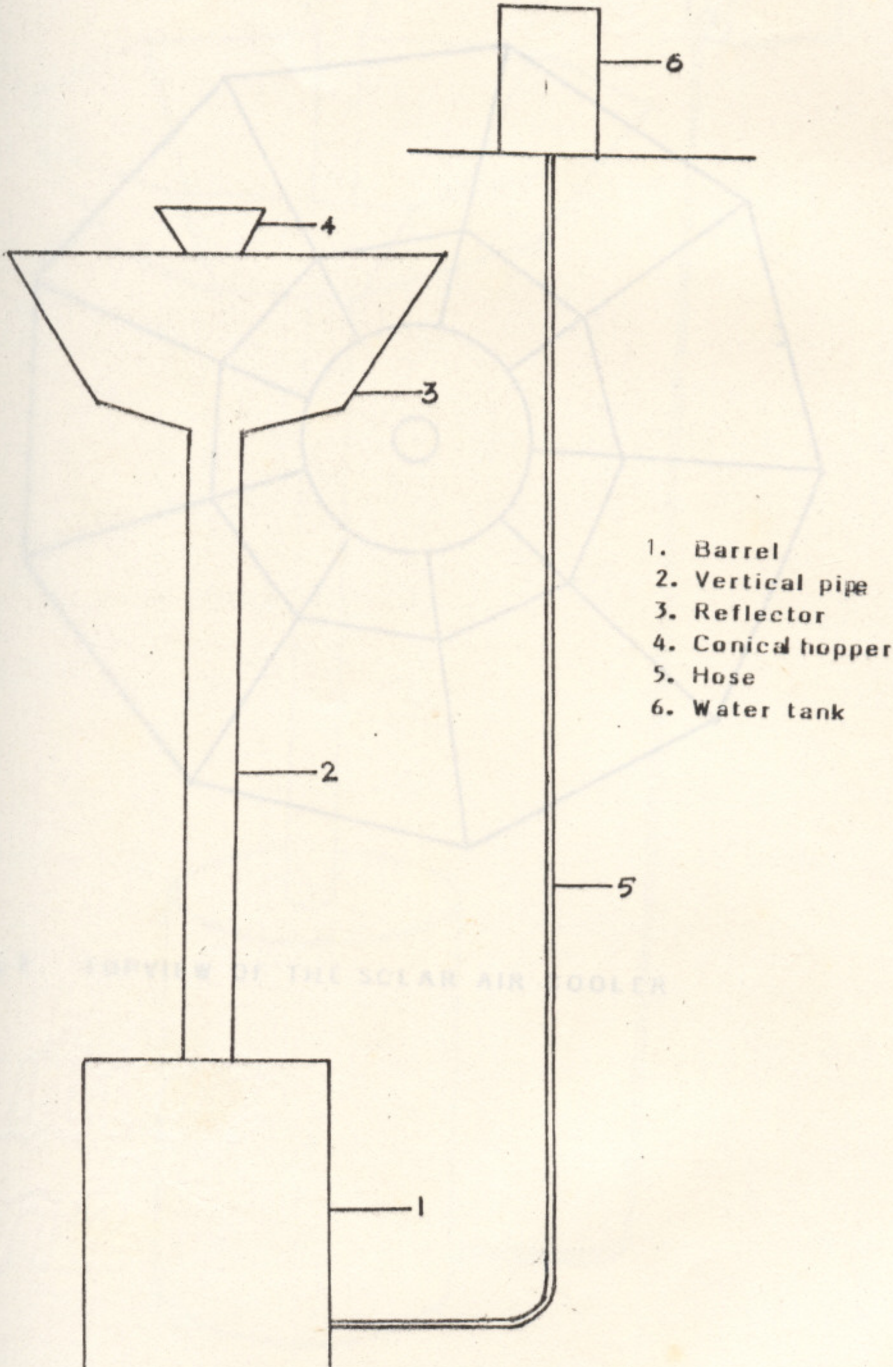

Fig. 1. ELEVATION OF THE SOLAR AIR COOLER

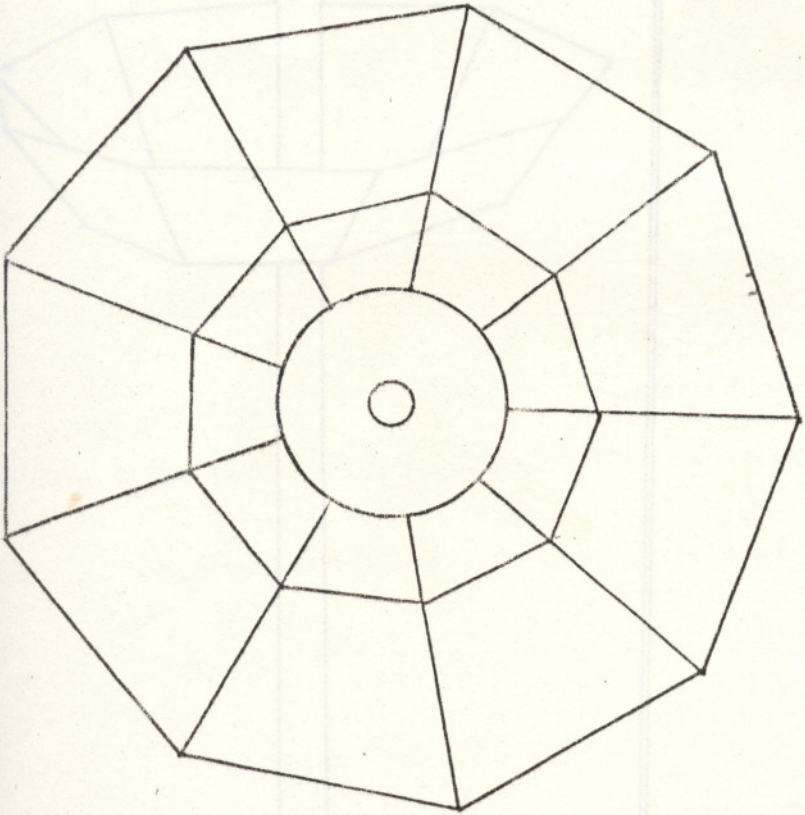

Fig. 2 TOPVIEW OF THE SCLAR AIR COOLER

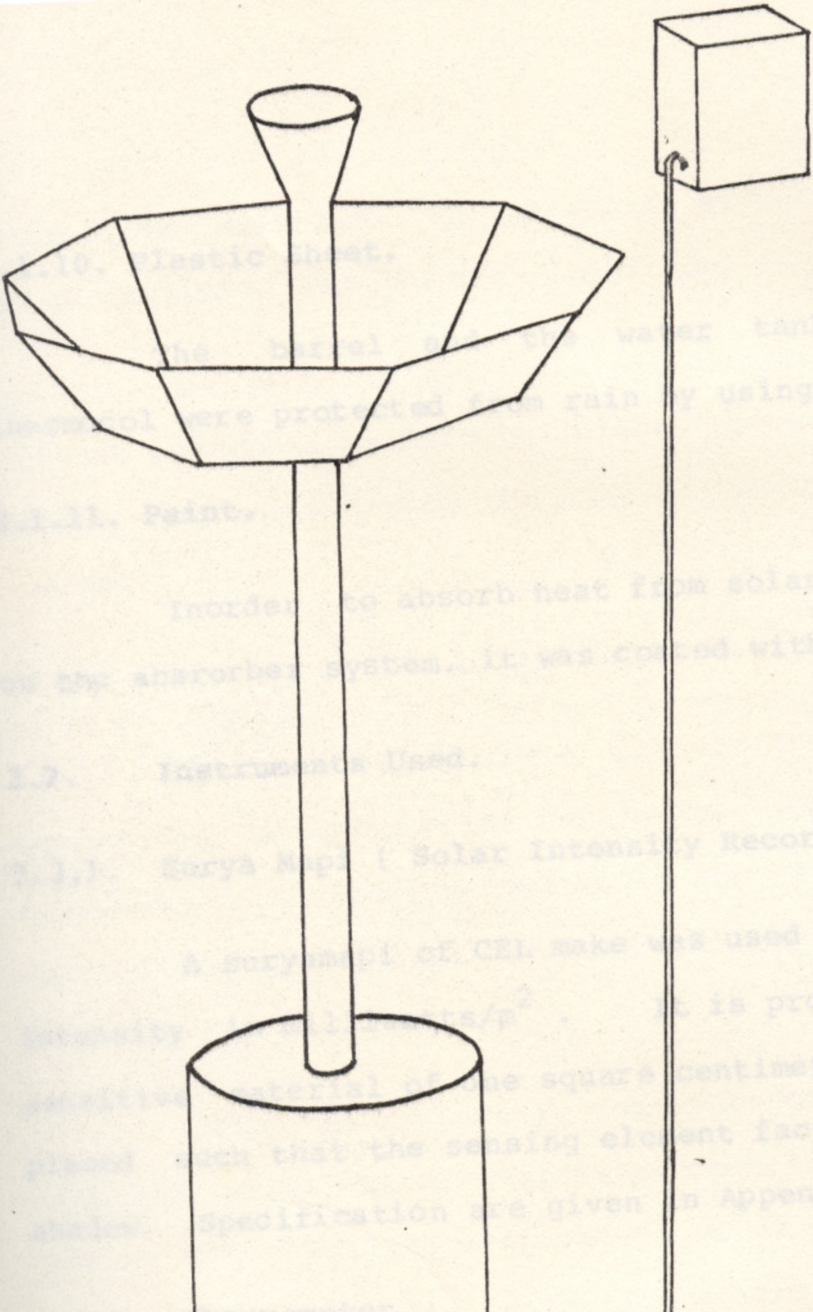

Fig. 3. ISOMETRIC VIEW OF THE SOLAR AIR COOLER

3.1.10. Plastic Sheet.

The barrel and the water tank insulated by thermocol were protected from rain by using plastic sheet.

3.1.11. Paint.

Inorder to absorb heat from solar radiation falling on the absrorber system, it was coated with black paint.

3.2. Instruments Used.

3.2.1. Surya Mapi (Solar Intensity Recorder).

A suryamapi of CEL make was used for measuring solar intensity in milliwatts/m^2. It is provided with a photo sensitive material of one square centimeter. Instrument was placed such that the sensing element faces the sun with out shadow. Specification are given in Appendix.1.

3.2.2. Thermometer

A centigrade thermometer was used for the measurement of temperature. It directly gives the temperature in degree celsius. Specifications are given in Appendix.1.

3.3 Installation of the solar air cooler

The study was conducted at K.C.A.E.T, Tavanur in

Malappuram district. This place is situated at 10o 52' 30" north lattitude and 76o east longitude.

The site for the installation was carefully selected without obstructions like buildings, trees etc. The solar air cooler was installed by the side of SAC building, inside the campus.

3.4. Working of the solar air cooler

When certain salts dissolved in water there is liberation or absorption of heat. The amount of heat liberated or absorbed depends on the nature of the salts. Salts which absorb heat on dissolution produce cooling and are suitable for this purpose.

When solar energy concentrates on the top of the vertical pipe, water evaporates from the saturated solution inside it. For the evaporation of each gram of water, (w) mass of the salt will be settled at the bottom of the pipe. The salt will be dissolving in the fresh water entering the bottom of pipe from the tank. The effect of cooling will depend upon the heat of solution as well as solubility of salt.

If h is the heat of solution of salt in cal/gm, then cooling will be w x h calories.

Plate 1   Overall view of the Solar air cooler.

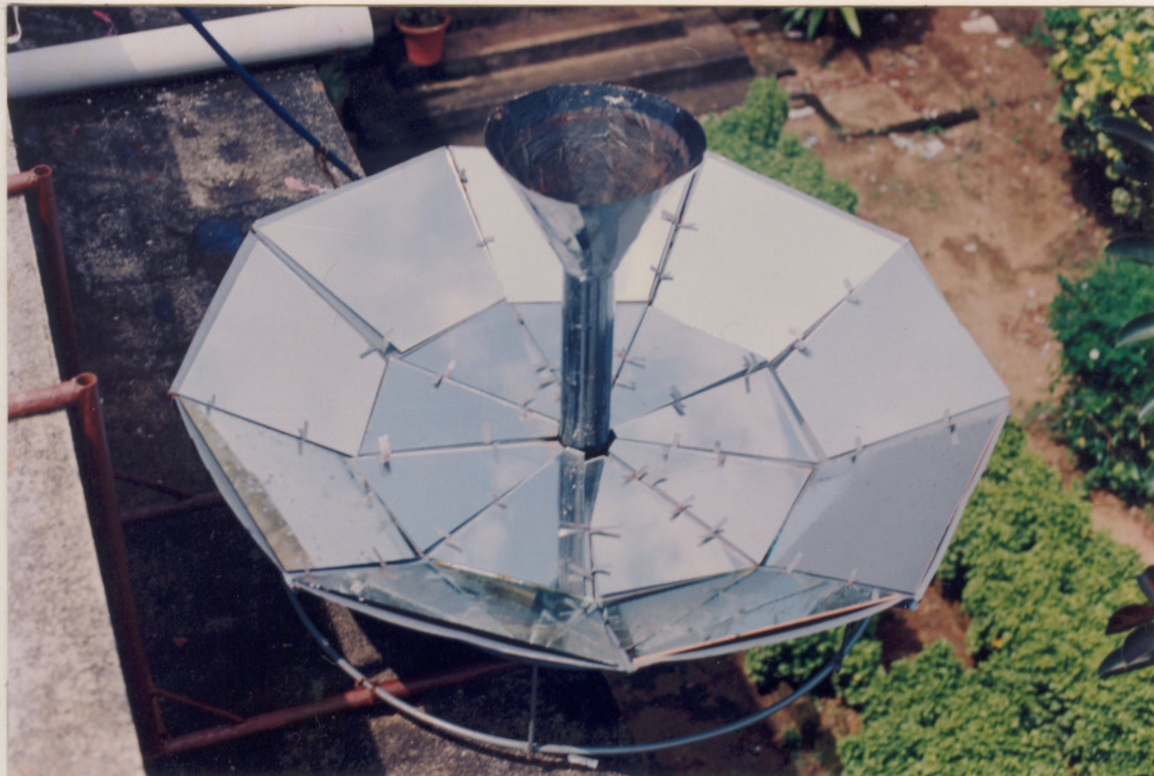

Plate 2   Top part of the Solar air cooler.

Plate 3 View of the connection between the hose and the vertical pipe.

3.5 Performance of solar air cooler

The experimental studies were conducted during the daytime from 10 am to 4 pm. The temperatures of the top surface of the saturated solution in the vertical pipe were taken at intervals of one hour at 10 am, 11 am, 12 am, 1 pm, 2 pm, 3 pm and 4 pm. At first the fresh water supply from the water tank to the bottom of the vertical pipe was closed. The initial level of the saturated solution in the vertical pipe was noted at 10 am and the final level was noted at 4 pm. From the difference between the two levels, total quantity of water evaporated was calculated. Then that much quantity of water was added to the bottom of the vertical pipe.The salt at the bottom of the pipe dissolved in this water .Some amount of heat energy was required for this process and this was obtained from the air inside the barrel. Thus the air inside the barrel gets cooled. The temperature of air inside the barrel was noted.

3.6. Efficiency of the solar air cooler.

Efficiency of the solar air cooler is obtained by taking the ratio of output energy to the input energy.

$$\text{Efficiency} = \frac{\text{Output}}{\text{Input}}$$

$$= \frac{\text{Amount of cooling obtained}}{\text{Heat energy used for evaporation of water}}$$

$$= \frac{W \times Cv\ (ta - tb)}{m \times s \times t + m \times L}$$

where,

W = mass of air, kg

Cv = specific heat of air at constant volume, Cal/ kg

ta = ambient temperature,oC

tb = temperature inside the barrel, oC

s = specific heat of water, cal/kgoC

t = maximum temperature obtained at the top of the pipe oC

L = latent heat of vapourization at toC cal/kg.

m = mass of water evaporated, kg.

RESULTS AND DISCUSSION

The results of the performance study of the solar air cooler is presented and discussed in this chapter.

4.1 Performance Results.

The performance study was carried out on 18 th,19th and 20th of October 1993. During these three days the temperatures of the top surface of saturated NH_4NO_3 solution was found to increase from 10 am to 1 pm and then started decreasing.

The intensities of solar radiations obtained during these days are given in Table 1.The temperatures obtained at the top surface of the saturated solution on these days are given in Table 2.A maximum temperature of 68oC was obtained on the top of the saturated NH_4NO_3 solution on 19 th October 1993. The evaporation of water from the saturated solution was more at higher temperatures.The total amount water evaporated from 10 am to 5 pm on each day are given in Table 3.The amount of salt regeneration is obtained by multiplying the amount of evaporation on each day by the solubility of NH_4 NO_3 solution.

The minimum temperatures obtained inside the barrel on each testing day is given in Table 5.The lowest temperature

Table 1. Intensity of solar radiation on 18 th, 19 th and 20 th of october 1993

Sl. No.	Date	Intensity of solar radiation (Watt/m^2)						
		10 AM	11 AM	12 PM	1 PM	2 PM	3 PM	4 PM
1	18 th	720	800	900	760	720	640	620
2	19 th	660	720	880	900	860	700	660
3	20 th	700	740	800	760	720	600	560

2. Maximum temperature obtained on the top of the saturated solution at a regualar interval of 1 hour

Date	Maximum temperature obtained at the top of the solution (° C)						
	10 AM	11 AM	12 PM	1 PM	2 PM	3 PM	4 PM
18 th	36	51	60	63	58	54	44
19 th	38	52	63	68	61	50	46
20 th	36	48	59	61	58	52	43

ble 3. Total evaporation of water from the top of the vertical pipe on on 18 th, 19 th and 20 th of october 1993

Sl. No.	Date	Total evaporation (ml/day)
1	18 th oct	237.5
2	19 th oct	239.0
3	20 th oct	220.0

able 4. Minium temperature obtained inside the barrel on 18 th, 19 th and 20 th of october 1993

Sl. No.	Date	Min. temp. obtained inside the barrel (° C)	Ambient Temperature (° C)
1	18 th oct	25	30.5
2	19 th oct	24	30.0
3	20 th oct	25	30.0

Table 5. Amount of cooling obtained and the efficiency of the solar air cooler

Sl. No.	Date	Heat energy used for the evaporation of water (cal)	Amount of cooling obtained (cal)	Efficiency of the system (%)
1	18 th oct 1993	140243.7	392.7	0.28
2	19 th oct 1993	142444.0	428.4	0.30
3	20 th oct 1993	129580.0	357.0	0.27

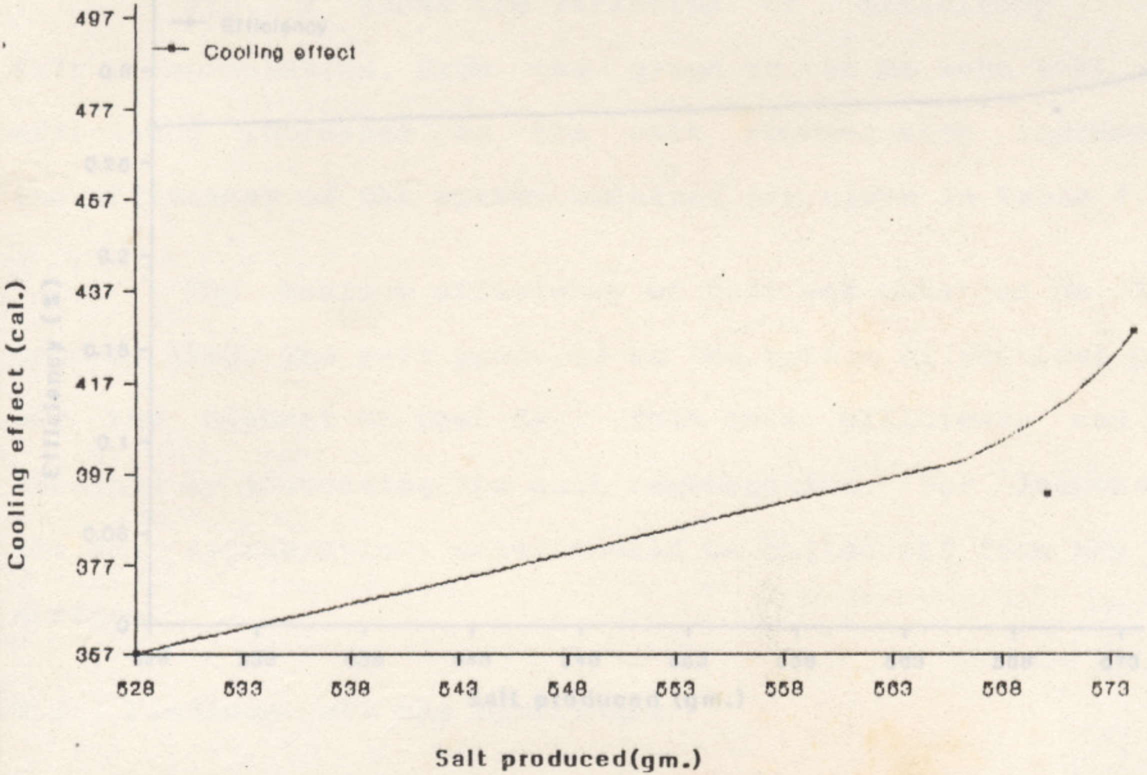

Fig. 4. Variation of cooling effect with salt regeneration

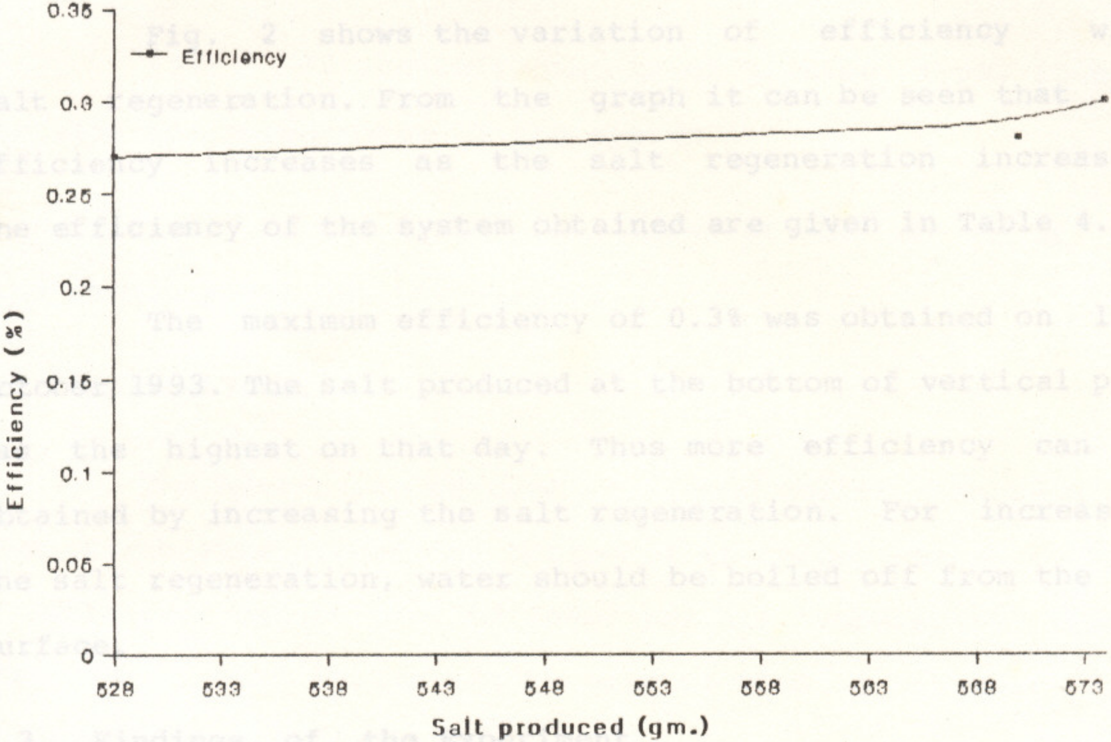

Fig. 5. Variation of efficiency with salt regeneration

obtained inside the barrel was 24o C.It was obtained on the day on which maximum salt regeneration occured.

4.2 Efficiency of the solar air cooler.

Fig. 2 shows the variation of efficiency with salt regeneration. From the graph it can be seen that the efficiency increases as the salt regeneration increases. The efficiency of the system obtained are given in Table 4.

The maximum efficiency of 0.3% was obtained on 19th October 1993. The salt produced at the bottom of vertical pipe was the highest on that day. Thus more efficiency can be obtained by increasing the salt regeneration. For increasing the salt regeneration, water should be boiled off from the top surface.

4.3 Findings of the Experiment

(i) The amount of cooling produced mainly depends on the evaporation rate. Higher cooling was obtained when the evaporation was more.

(ii) More cooling could be achieved if water is boiled off from the solution. For this a better reflector which can heat the solution above 100oC is required.

Following suggestions are made for further improvement of the solar air cooler.

(i) A better reflector should be made to evaporate water at higher temperature.

(ii) If the reflector is of tilting type, it will increase the performance of the system.

(iii) The fresh water added at the bottom of the pipe should be at low temperature.

4.4 Applications.

The system can be used as a room cooler. Ambient air when circulated around the bottom of the pipe, where cooling is obtained, can be used to lower the air temperature inside the room. This system can be used to cool a chamber, for storing perishable articles.

SUMMARY

An experimental study to fabricate a solar air cooler and to evaluate its performance was conducted at K C A E T, Tavanur during the month of October 1993. A vertical pipe of 2.5 inch diameter and 3 m length was made. It consists of three sections. The top and bottom parts were made of G.I and middle part was made of PVC. It was done to reduce the heat transfer from the top to the bottom. The vertical pipe was filled with saturated soltion of $NH_4 NO_3$. A concentrating type reflector was placed 30 cm below the top of the pipe. It was done to increase the evaporation from the top of the solution. Crystals of $NH_4 NO_3$ were formed due to evaporation and settled at the bottom of the pipe. The quantity of water equal to that evaporated was added to these crystals. The dissolution of the crystal in this water produced cooling at the bottom of the pipe. Since the bottom of the pipe was inserted in an insulated barrel a temperature drop was obtained inside the barrel. The minimum temperature obtained 24oC.

Findings of the experiment.

(i) The amount of cooling produced is mainly dependent on the evaporation rate. Higher cooling was obtained when the evaporation was more.

(ii) The maximum efficiency of the system obtained was 0.3%.

(iii) More cooling can be achieved if water is evaporated from the solution at higher temperature.

Following suggestions are made for further improvement of the solar air cooler.

(i) A better reflector should be made to evaporate water at higher temperature.

(ii) If the reflector is of tilting type, it will increase the performance of the system.

(iii) The fresh water added at the bottom of the pipe should be at low temperature.

References

Alizadeh,S., Bahar,F and Geoola,F.(1979). Design and optimization of an absorption refrigeration system operated by solar energy, Solar Energy, 2 2 , 483-491

Al-Turki,A.M, and Eslayed, M.M.(1990). Comparison of the solar operated two stage and single stage LiBr-H_2O absorption cycle, Solar and Wind Technology, 7 (3), 355-365

Anand,D.K and Kumar, B.(1987). Absorption machine irreversibility using new entropy calculation, Solar Energya, 3 9, 243-256

Asha Iyer,P.S., Srinivasa Murthy,S.,and Krishna Murthy, (1988). Advance in Solar Energy Technology, Proceedings of the Biennial Congress of the International Solar Energy Society

Bansal, N.K., Manfred Kleemann and Michael Meliss, (1990). Renewable Energy Sources and Conversion Technology, New-Delhi

Borda-Diaz, N, Moscony, P.I., and Vazquez, J.a., (1988). Passive Cooling Strategies for a building prototype design in a warm humid tropic climate, Solar and Wind Technology,6 (4), 389-400

Clerk, M.M., (1987). Performance of an aqua ammonia absorption solar refrigeration at sub freezing evaporator conditions, Solar Energy

Gomez, A.L., and Monsoori, G.A., Thermodynamic equation of state approach for the choice of working fluids of absorption cooling cycles, Solar Enmergy, 3 1, 557-566

Hammoudeh and Shawkat (1984).conventional and solar cooling system for Kuwait, Energy Economics, 6, 259-266

Jan, F., Kreidev, Charles,J., Hoogendoorn and Frank Kreith (1989). Solar Components Systems Economics, Newyork

John Twidell and Jonyweir (1986). Renewable Energy Resources, Newyork

Kaushi, S.C, and Kaundinya, J.V (1989). Open cycle Absorption Cooling, Energy Conversion and Management, 2 9 (2), 89-109

Kishor, (1988). Performance and cost evaluation solid desicant solar cooling system, The International Journal of Building Science and its Applications, 2 3, 215-230

Kaouremenos , D.A., Antonopoulous, K.A., and Rogdakise,E., Performance of a solar driven component NH_3/H_2O-H_2O/LiBr absorption refrigeration system in Athens, Solar and Wind Technology, 7 (6), 685-697

Kumar, P., and Devotta,S.(1989). Modelling of the thermal behaviour of a solar regenerator for open cycle cooling system, Applied Energy, 3 3, 287-295

Lawrence,S.A., and Tiwari,G.N.(1989).Performance study of an evaporative cooling system for a typical house in PortMoresby, Solar and Wind Technology, 6

Lenz, (1989). Proceedings of the nineth Bienial Congress of the International Solar Society, Canada

Mansoori,G.A., and Patel,V.(1979).Thermodynamic basis for the choice of working fluids for solar absorption cooling systems, Solar Energy, 2 2, 483-491

Prasad,C.R.(1981).Space heating and cooling by passive methods, National Solar Energy Conversion, Solar Energy Society of India, Bangalore

Rai,G.D(1991).Solar Energy Utilization, Khanna Publishers, Delhi

Sheridan,N.R., 1989, Performance of the Brasbone Solar house, International Solar Energy Society, Melbourne.

Sukhatme,S.P., (1991). Solar Energy Principles of Thermal Collection and Storage,Tata M C Grow-Hill, New-Delhi

Venkatesh,A., and Moni, A.(1989).Comparison of performance of single stage and two stage intermittent $NH_3 - H_2O$ solar refrigeration system, <u>Solar Wind Technology</u>,6, 75-78

APPENDIX- I

a   Specification of the solar intensity meter

Name	:	Suryamapi
Model number	:	SM 201
Range	:	0-120 mw/cm2
Supplied	:	Central Electricals Ltd.

b   Specification of thermometer

Make	:	Pensky Martens, England
Range	:	0 to 110oC

APPENDIX -II

HEAT OF SOLUTION OF CERTAIN SALTS

Name	Molecular weight	Heat of solution (Cal/gm)
Ammonium Bromide	098.0	44.90
Ammonium Chloride	053.5	72.52
Ammonium Iodide	145.0	24.48
Ammonium Nitrate	080.0	79.00
Calcium Nitrate	164.0	44.51
Cesuim Chloride	168.0	28.27
Cobalt Nitrate	291.0	17.04
Cupric Nitrate	296.0	36.51
Potasium Fluoride	130.0	07.69
Sodium Bromide	139.0	33.81
Sodium Nitrate	085.0	58.82
Zinc Nitrate	297.0	19.66

APPENDIX - III

Specifications of Solar Air Cooler

No	Item	Specifications
1.	Mirror Reflector	Material Glass
		Number 18
		Trapezoidal: Number 9
		Size base- 25 cm, 40 cm
		sides 30 cm, 30 cm
		Triangular
		Number 9
		Size base-25 cm
		sides-30 cm,30 cm,
2.	Vertical Pipe	(i) Material - G.I
		Number - 2
		Size:
		diameter - 2.5 inch
		length - 1 m
		(ii) Material - PVC
		Number - 1
		Size :
		diameter - 2.5 inch
		length - 1 m

3.	Water Tank	Material	: Aluminium
		Number	: 1
4.	Barrel	Material	: Mild steel
		Number	: 1
		Capacity	: 350 litres
5.	Hose	Material	Plastic
		diameter	0.5 inch
		length	5 m
6.	Thermocol	Number	10
		Size	1 m x 0.5 m
7.	Plastic cover	Material	Plastic
8.	Saturated $NH_4\ NO_3$ solution	Quantity	: 14 kg. 14 litres

FABRICATION AND PERFORMANCE EVALUATION OF A SOLAR AIR COOLER

By

LINDA. N. E.

SUNIL. A. P.

ABSTRACT OF THE PROJECT REPORT

Submitted in partial fulfilment of the requirement for the degree of

Bachelor of Technology in Agricultural Engineering

Faculty of Agricultural Engineering & Technology
Kerala Agricultural University

Department of Farm Power Machinery and Energy

Kelappaji College of Agricultural Engineering and Technology
Tavanur - 679 573
Malappuram

1993

ABSTRACT

The study was conducted with the objectives of developing and testing a solar air cooler.

Salt (NH_4NO_3) was dissolved in water for cooling and the solar energy is used for regenerating the salt crystals from the solution, thus forming a closed cycle.

The vertical column initially contained a saturated solution of the salt with excess salt at the bottom. When the reflector concentrates the solar radiation on to the top of the column, the water evaporated and the crystals formed fall downwards. Fresh water was admitted at the bottom to compensate evaporation. The newly formed crystals dissolved in fresh water, thereby producing cooling. Since the bottom of the pipe was inserted in an insulated barrel, the air inside the barrel was cooled. The minimum temperature inside the barrel was 24 C. The extent of cooling depends on the evaporation rate.