PERFORMANCE EVALUATION OF FLAT PLATE COLLECTOR SOLAR WATER HEATING SYSTEM

By

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Project Report

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the requirement for the degree

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DECLARATION

I hereby declare that this project report entitled **PERFORMANCE EVALUATION OF FLAT-PLATE-COLLECTOR SOLAR WATER HEATING SYSTEM** is a bonafide record of project work done by me during the course of project and that the project work has not previously formed the basis for the award to me any degree, diploma, associateship, fellowship or other similar title of any other University or society.

Tavanur

JIGIMON.T.

CERTIFICATE

Certified that this project report entitled PERFORMANCE EVALUATION OF FLAT-PLATE-COLLECTOR SOLAR WATER HEATING SYSTEM **is a record of project work done independently byMr.Jigimon.T.under my guidance and supervision and it has not previously formed the basis for the award of any degree, fellowship or associateship to him.**

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ACKNOWLEDGEMENT

I avail this opportunity to express my profound and sincere sense of gratitude to **Smt. Santhi Mary mathew**,Assistant professor of APS Department for her professional guidence, constructive criticism, prolific encouragement and help at each and every stage of this study.

I am grateful to **Sri. T. P. George**,Dean i/c, K C A E T, Tavanur; **Sri. Jippu Jacob**,Head of the Dpartment of Farm Power Machinery & Energy; **Sri. K. I. Koshy**,Head of the Department of SAC;**Sri. Sathyajith Mathew, Sri.Ajith Kumar.O.** - Department of FPM & E ; for their constant encouragement and valuable suggestions and sustain interest at every stage of investigation and preparation of this project report.

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JIGIMON.T.

CONTENTS

LIST OF FIGURES

Figure No.

LIST OF PLATES

SYMBOLS AND ABBREVIATIONS USED

Agrl.	-	Agricultural
am	-	anti meridian
C	-	Celsius
cm	-	centi metre
Dept.	-	Department
DNES	-	Department of Non-Conventional Energy sources
<u>et.al</u>	-	and others
Fig.	-	Figure
FPME	-	Farm Power Machinery and Energy
G.I.	-	Galvanised Iron
K C A E T	-	Kelappaji College of Agricultural Engineering and Technology
kWh	-	kilo watt hour
kW/m	-	kilo watt per square meter
LPM	-	Litres per minute
m	-	metre
mm	-	milli metre
pm	-	post meridian
temp.	-	temperature

W/sq.m	-	Watt per square metre
%	-	per centage
η	-	efficiency
τ	-	transmittance
α	-	absorptance

INTRODUCTION

Energy can be defined as the capacity to do work, and it is the basic ingredient for all industrialized societies. Oil, natural gas, coal and wood are the primary sources of energy. As these sources are using continuously their supplies are finite. Life time estimated for these supplies are limited. Availability of wood is also limited by deforestation and climate. Thus an energy gap will develop by the effects of population growth and dependence of energy. After nonrenewable energy sources are consumed, people will turn to permanent energy sources, of which nuclear energy and solar energy are important. Nuclear energy requires high techniques and costly means for its proper utilization. But solar energy is a dependable energy source and it is having wide-spread utilization. More over it is having no polluting effects from its use.

The solar energy could supply all the present and future 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, are it can not be stored and it is a dilute form of energy.

The application of solar energy are many, such as solar water heaters, solar air heaters, solar refrigeraters, air conditioners, space heaters, grain driers, etc.

Solar energy is a clean, non-depliting energy available almost everywhere. At ground level the energy ranges from 10 to 1000 watts/sq.m. Solar energy reaching the earth in an year is equivalent to the energy from burning 120 million tonnes of coal which is about 25 times the total coal supply. The intensity of electromagnetic radiation is 1.94 cal/sq.cm./min. or 1.353 kw/sq.m. on a surface normal to the solar beam. This average value of solar radiation outside the atmosphere is known as solar constant. The peak clear sky intensity available at a horizontal surface is 1 kw/sq.m. The integrated daily average could be as high as 6 to 8 kw/sq.m. This would give an idea of tremendous amount of energy incident on the surface of the earth.

The three approaches for utilization of solar energy are low grade solar heating, high grade solar heating and direct conversion to electricity.

India consumes energy from nuclear fuel to animal waste. 20 percentage of the energy is used for domestic purpose of water heating. This can be saved if we use solar water heaters. Solar water heaters employing flat plate collectors can be devided into three types,

(i) Domestic solar water heaters in which the storage tank and absorber plate are seperate and water is circulated by natural circulation.

(ii) Large size solar water heater with forced pumping designed for community use such as in hostels, hotels, hospitals etc.

(iii) Built - in - storage type solar water heaters designed with a view toward reducing cost.

Flat plate collectors have been and may remain the most popular type of solar collectors for general or residential use. They are simple in design, operate at medium to low temperatures and have few mechanical parts.

Advantages of flat-plate collector system is higher efficiency due to direct contact of water with the absorber plate. In the present work there is a solenoid valve to control the flow, a monoblock pump for timely pumping and a thermostat for adjusting the required outlet temperature of water. Among these there is an insulated tank for collecting water. As a result whatever get heated will be collected inthe tank and there will be sufficient hot water.So it can be conveniently recommended to the people for their day to day life. Following are the objectives of this work

(i) To check and rectify the existing system.

(ii) To study the performance of the system by adjusting the thermostat for various efficiency.

(iii) To test the system as thermosyphon system.

(iv) To study the performance of the storage tank.

REVIEW OF LITERATURE

2.1 HISTORY

The solar water heater was invented during the second half of seventeenth century.Even in earlier times the people of Africa, the Arab countries, Australia, China, India and Pakistan used their ingenuity in heating water by placing a specially shaped copper pot filled with water, in the sun during the winter.

The first scientific work on solar heating began in 1940., at Masachuseets Institute of Technology, when a team of Engineers under the direction of Dr:Hottel, with financial support from Godfrey L.Cabot began to study the performance of solar collectors and fliud heating system. The first definite paper on flat plate colloctors was published by Dr: Hottel and Wortz (1942).

In the later half of 18th century and during the first half of 19th century, progress in the field solar energy research was slow. This was mainly due to avialability of cheap fossil fuels.

In fact there is no home which does not make use of solar energy in a passive way. This was only when liquid fuels become abundant and readily available. Man ignore the significance of such passive system to make a dwelling comfortable and resorted to active devices.

But recently, a resurrection of solar energy application had occured, due to the energy crisis facing the world.

2.2 CLASSIFICATION.

Basically there are two approaches of application of solar energy viz:

(i) Active system

(ii) Passive system.

2.2.1 ACTIVE SYSTEM.

The active system uses, solar collecting panels, storage units, energy transfer mechanism and energy distribution system. This type of heating system always use one or more working fluids which collects, transfer, store and distribute the collected solar energy. The working fluids are circulated by means of fans and pumps.

2.2.2 PASSIVE SYSTEM.

It is a system in which thermal energy flows by natural means without a need to utilize outside power. In passive system all the functions of collection, storage and distribution are carried out by the materials of construction themselves.

Passive solar system can be placed into three basic catogories termed,

1. Direct gain
2. Indirect gain
3. Insolate gain

All refers how radiation is intercepted or collected by the nature of the design of the system.

Emittance

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

Hour angle

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

Infra-red

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

Irradiance

The irradiance at a surface is the ratio of the radiant flux incident on the surface to the area of that surface. Irradiance is measured in W/sq.m.

Latitude

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

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.

Net radiation

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

Radiant flux

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

Reflectance

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

Solar azimuth

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

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 * 10 km. Solar constant is 1.353 kW/sq.m. on earth's surface perpendicular to the sun.

Solar hour angle

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

Solar noon

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

2.4. SOLAR WATER HEATING.

Different types of solar water heaters were designed and constructed during the course of solar water heater history. Solar water heaters are classified as follows,

A. Unsheltered heaters

(i) Bare trough on the ground

(ii) Bare trough off the ground

(iii) The black bag

(iv) Black sack with bottom insulation

B. Sheltered heaters

(i) Sheltered black sack

(ii) Metal plate collector with moving fluid

(iii) Collector- cum - storage type

C. Selective surfaces

D. Evacuated collectors

E. System with seperate storage

(i) Thermosyphon circulation

(ii) Forced circulation

2.4.1 Bare trough on the ground

This is the simplest possible water heater fig. a. A trough of water resting on the ground is exposed to the sun. An out door swimming pool is an example. On a hot sunny day the water is warmed, but the temperature rise is limited by the ease with which the heat is conducted to the ground.

2.4.2 Bare Trough off the Ground

Supporting the trough off the ground de couples that heat sink fig b, but the heating is still severly by low absoptance, of water. Moreover much of the heat that is absorbed goes into increased evaporation, thus lessening the temperature increase.

2.4.3The black bag

Here the water is enclosed in a shallow matt- black bag, usually place on a roof fig c. So no heat is lost by evaporation. The black outer surface absorbs radiation much better than transparent water. Some of this absorbed heat is then passed to the water inside by conduction.

This type of heater is cheap, easy to make, and gives moderately hot water, (45°C). It is widely used in Japan to provide hot water for the evening bath.

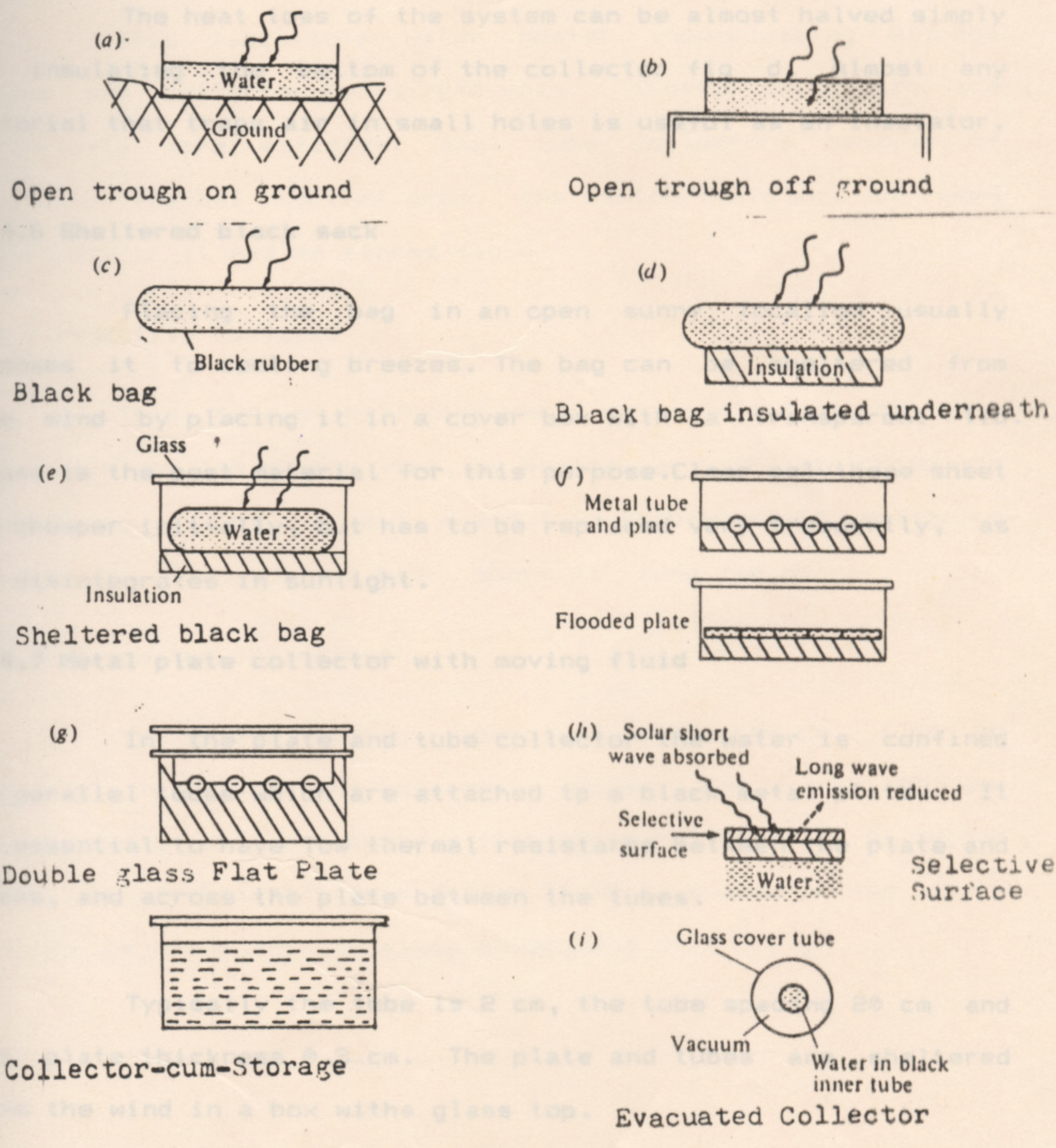


Fig. 1 Classification of Solar water heaters

2.4.5 Black sack with bottom insulation

The heat loss of the system can be almost halved simply by insulating the bottom of the collector fig d. Almost any material that traps air in small holes is useful as an insulator.

2.4.6 Sheltered black sack

Placing the bag in an open sunny location usually exposes it to cooling breezes. The bag can be sheltered from the wind by placing it in a cover box with a transparent lid. Glass is the best material for this purpose.Clear polythene sheet is cheaper initially, but has to be replaced very frequently, as it disintegrates in sunlight.

2.4.7 Metal plate collector with moving fluid

In the plate and tube collector the water is confined in parallel tubes which are attached tp a black metal plate. It is essential to have low thermal resistance between the plate and tubes, and across the plate between the tubes.

Typically the tube is 2 cm, the tube spacing 20 cm and the plate thickness 0.3.cm. The plate and tubes are sheltered from the wind in a box witha glass top.

2.4.8 Collector-cum-storage type

This type solar water heater incorporating storage volume and collector iun single unit. TRhese collectors are potentially more efficient that tube collectors because of increased thermal contact area. The heated fluid may be used immediatly or it may be stored fig g.

2.4.9 Selective surfaces

This type of collector would maximize its energy gain and minimize its energy loss, by having a high monochromatic absorptance at 0.5 m and low monochromatic emittance at 10 m. Such surface has short >> long fig h.

2.4.10 Evacuated collectors

To obtain higher temperature (above 100 C) , it is necessary to reduce the convective losses. One way is to use extra layers of glass above a flat plate collector. A method better but technically more difficult is to evacuate the space between the plate and its glass cover, fig (i).

2.4.11 THERMOSYPHON CIRCULATION

The water circulation in a thermosyphon system is driven by the density difference between hot and cold wateer.When water in the collector is heated by the sun, it expands and rises up the collector through a pipe and into the top of the tank. This forces cooler water at the bottom of the tankout another pipe leading to the bottom of the collector.

2.4.12 FORCED CIRCULATION

For domestic system, this type is used. Only a small pump is needed for forced circulation. It is common to set the pumping rate so that the water temperature rises about 4 C in each passage through the collector. Single speed pumps are used as they are the cheapest. Since the temperature rise depends on the solar irradiance and the inlet temperature, the 4 C rise will be achieved only for one set of conditions.

2.5 SOLAR ENGINES FOR WATER PUMPING

A few solar engines and water pumps have been developed in US, France, Israel, USSR and recently in India.

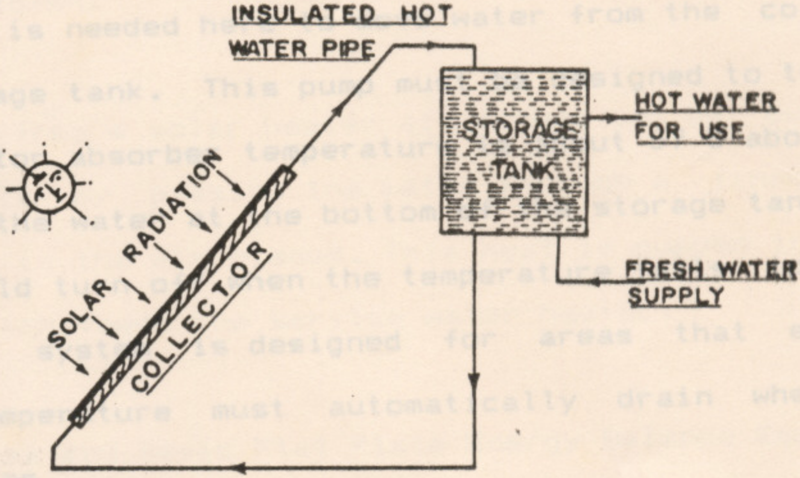


Fig.1(J) SCHEMATIC OF A THERMOSYPHON SOLAR WATER HEATER

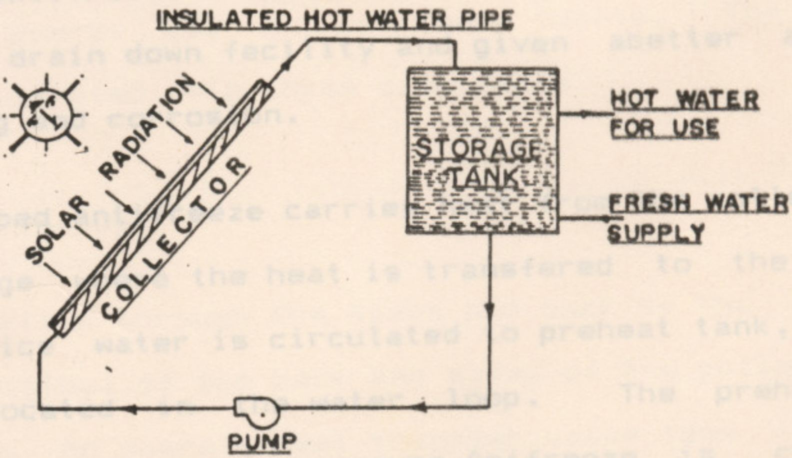


Fig.1(K) SCHEMATIC OF A FORCED FLOW SOLAR WATER HEATER

Fig. 2 Heater with separate storage

2.6 PUMPED WATER HEATERS

A pump is needed here to move water from the collector down to the storage tank. This pump must be designed to turn on when the collector absorber temperature is about 57 C above the temperature of the water at the bottom of the storage tank, and the system should turn off when the temperature falls to about 5.4 C. This system is designed for areas that exhibits freezing. Temperature must automatically drain when the freezing threatens.

2.7. DUAL - FLUID - ANTIFREEZE SYSTEM

An antifreeze system eliminates the cost of constructing a drain down fecility and given abetter assurance against freezing and corrosion.

A pumped antifreeze carries heat from the collector to a heat exchange where the heat is transfered to the service water.The service water is circulated to preheat tank, with a second pump located in the water loop. The preheat tank operates at service water pressure.Anifreeze is circulated through the collector heat exchanger loop in an unpressurized state, and an expansion tank with bend is installed at the highest part of this loop.

2.8. AIR-WATER SYSTEM.

Energy from a solar heater air stream can be extracted for heating water by passing the water through a finned tube assembly located in the air plenum. This heat is pumped into the pre heat tank which feeds the service water heater.

2.9 Thermal losses and Basic Flat Plate Energy Balance Equation

The performance of a solar collector is described by an energy balance that indicates the distribution of incident solar energy useful energy gain and various losses. The thermal losses can be separated into three components.

(i) Conductive losses

Conduction through the sides and back of the collector is usually negligibel if the back and sides of the collector are well insulated. An overall heat transfer value less than 0.69 W/sq.m K is suggested to minimise back losses.

(ii) Convective losses

Convective losses occur from the absorber plate to the environment through intermediate convection exchanges between the air enclosed in each insulating zone and the boundaries of each zone - the collector covers. Sizing the air gap between collector covers at 1.25 to 2.5 cm reduces internal convective losses to the minimum possible level.

(iii) Radiative losses

Radiative losses from the absorber can be reduced by the use of spectrally selective absorber coatings. Such coatings have a high absorptance of about 0.9 in the solar spectrum, and a low emittance usually on the order of 0.1, in the infra red spectrum in which absorber radiates to the environment. Selective absorber coatings therefore decreases heat losses and increases efficiency.

2.10 HEAT BALANCE EQUATION

The useful heat delivered = heat absorbed by the solar
~~by the solar collector~~ collector + heat lost to the
surroundings

$$Q = A\,[Ht - Ul\,(Ta - TA)]$$

But,

$$Q = Ww\,(dTw/dt) + Wa\,(dTA/dt)$$

$$Ww\,(dTw/dt) + Wa\,(dTa/dt) = HTA - UlA\,(Ta - TA)$$

At ideal conditions,

$$Tw = Ta$$

$$dTw/dt = dTa/dt$$

$$(Ww + Wa)\,dTw = [\,HTA - Ul\,A\,(Ta - TA)]\,dt$$

$$dTw = [HTA - UlA\,(Ta - TA)]\,dt/N$$

On integrating,

$$Tw = Tw + P\,(t - t\,)\,/\,N$$

where,

A = Absorber area.

Ht = Total solar radiation falls on the absorber surface.

Wa = Water equivalent of collectors.

Ww = Weight of water heater - Absorbance of absorber area

dtw = Rate of rise of average water temp C

dta/dt = Rate of rise of average temperature C/hour

TA = Ambient temperature C

Tw = Temperature of hot water heated C

Ta = Absorber surface temperature C

Ul = Heat transfer coefficient

P = HtA - Ul (Ta - TA)

N = Ww + Wa

2.11 STATUS OF SOLAR ENERGY IN INDIA.

Only a few places in India, do we have the solar water heating units. Solar cells (photo volataic) generate electricity directly when sunlight falls on them. A 10 kw solar power station has been constructed by Indian Institute of Technology, Madras and Bharat Heavy Electricals, Bhopal.

Solar energy is potentially very important for India which has a large number of villages. The use of solar energy for air-conditioning and pumping may become economical soon. The large scale use of solar pumps has the potential to lower the demand for electricity by 5000 mw. Recently, a high performance solar hot water system using UTR 371 ETC (Evacuated Tubular Collector) has been installed at Madras. The efficiency of the

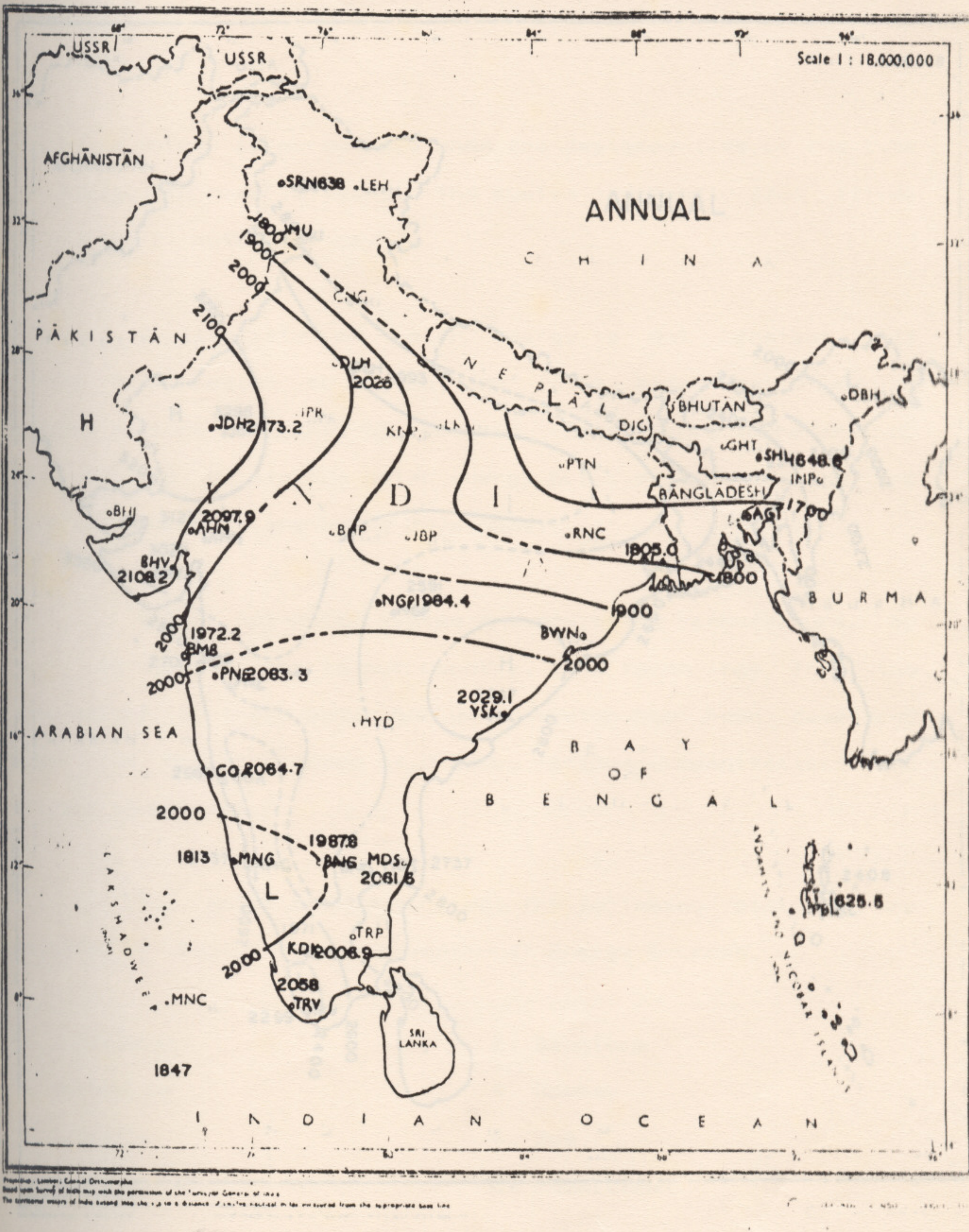


Fig. 3 · Distribution of global solar radiation – Annual Unit : $Kwh.m^{-2}.year^{-1}$

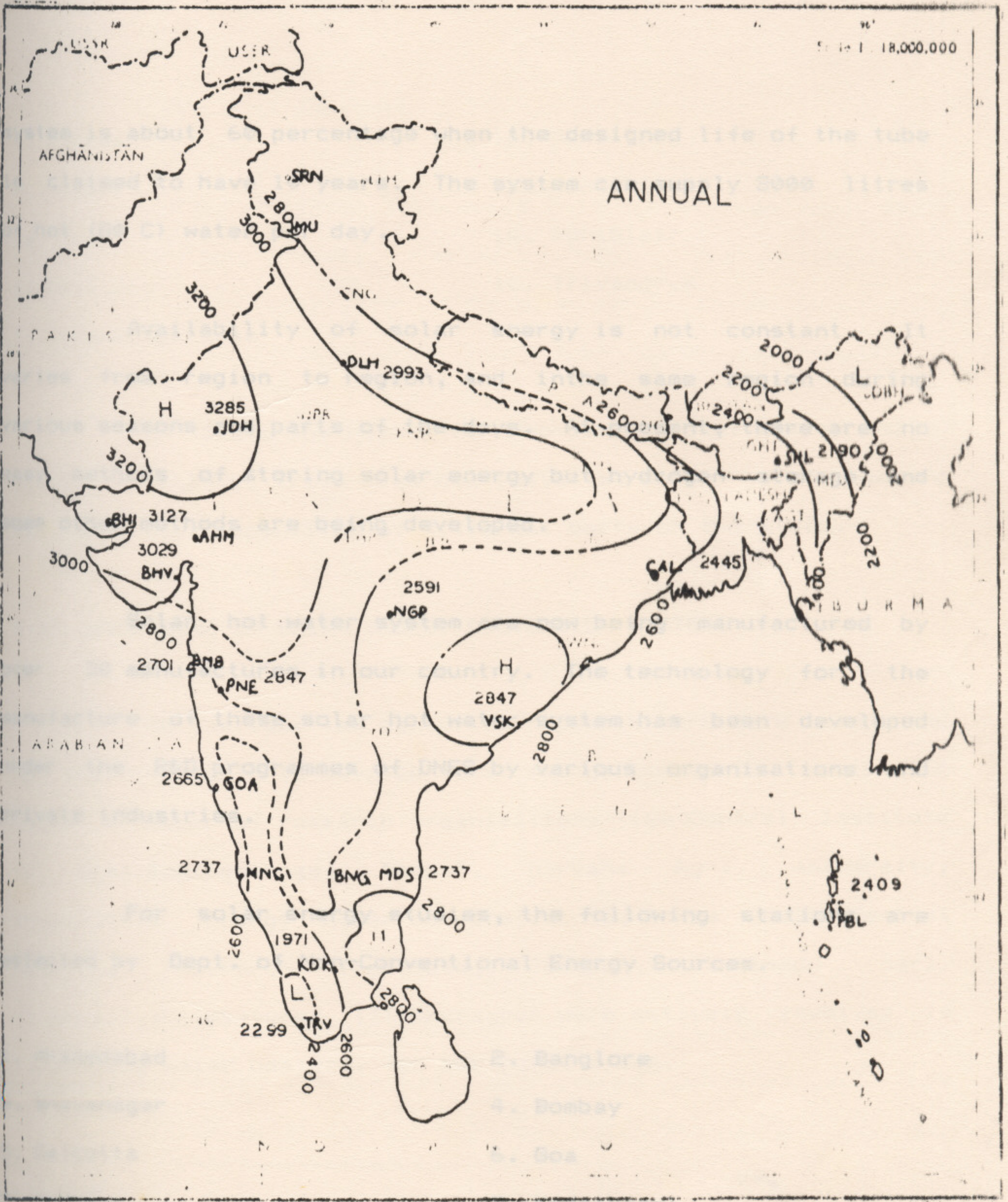


Fig. 4 Distribution of hours of sunshine Annual

system is about 60 percentage when the designed life of the tube is claimed to have 10 years. The system can supply 3000 litres of hot (80 C) water per day.

Availability of solar energy is not constant. It varies from region to region, and inthe same region during various seasons and parts of the days. At present, there are no easy methods of storing solar energy but hydrogen storage and some other methods are being developed.

Solar hot water system are now being manufactured by over 30 manufactures in our country. The technology for the manufacture of these solar hot water system has been developed under the R&D programmes of DNES by various organisations and private industries.

For solar energy studies, the following stations are selected by Dept. of Non-Conventional Energy Sources.

1. Ahamedabad
2. Banglore
3. Bhavanagar
4. Bombay
5. Calcutta
6. Goa
7. Jodhpur
8. Kodaikanal

9. Madras 10. Mangalore

11. Nagpur 12. NandiHills

13. Puna 14. PortBlair

15. Shillong 16. Trivandrum

17. Vishakhapatanam

In Kerala the Agency for Non-Conventional Energy and Rural Technology, Trivandrum had installed Solar water heaters having various capacities at different parts of the state.

2.12 WORK DONE ON SOLAR ENERGY CONVERSION SYSTEMS

As the last few centuries research work were conducted all over the world to develop solar energy conversion systems. In India a number of research organisations like Central Institute of Agrl. Engineerings; Bhopal, Haryana Agrl. university, Hissaritata Energy Research Instistute; New Delhi, Central Aridzone Research Institute; Jodhpur, Tamilnadu Agrl. University; Coimbatore; IIT Kharagpur were actively involved in developing water heaters, for our rural areas.

2.13 WORKS DONE IN INDIA.

Garg H.P (1975) designed a built-in storage type solar water heater and prototype tested in Jodhpur. He claimed that this heater could supply 90 litres of water at a mean temperature of 50-60 C in winter and 50-70 C in summer and monsoon seasons.

Venugopal (1978) designed a solar milk heater to heat milk or hot milk drinks like tea and coffee. The mobile unit could heat 1.25 litres of water 0.75 litres of milk per hour of sunshine from 11 am to 3 pm.

Pradeep Kumar Bansal (1981) conducted studies on collector cum-storage solar water heaters and concluded that these water heaters hold promise to meet the hot water requirements for a variety of applications.

Garg(1982) had developed a built in storage solar water heater of new design.

Nahar (1983) designed an improved collector-cum-storage type solar water heater for year round performance. This improved solar water could supply hot water throughout the day and night.

Herpal Singh (1985) developed a built-in-storage solar water heater having a work capacity of 100-200 litres of hot water at 55-60 C temperature per day. The efficiency of the system was found to be 40-42 percentage. The hot water was being made available at an installed cost of about Rs. 7/- per litre.

Techchandani et al (1986) developed a low cast solar water heater of 350 litre capacity and operated with average temperature rise of 16-17 C.

Prakash et al (1990) studied the effect of transparent insulation on the performance of a 100 dm capacity built-in-storage type solar water heater. Performance of the material was compared with glass cover with and without night insulation cover. The system with honey comb PC presented the best performance, but it was inferior to the system with night insulation cover.

Lizzy Kirian (1990) had conducted tests on a low cost flat plate collector-cum-storage type solar water heater; at KCAET, Tavanur. The water heater was found to attain a temperature of 52 C at 3 pm; with an efficiency of 51 percentage.

CAZRI Jodhpur (1991) designed a domestic hot water heater.

Ananda Bose D et al (1991) had conducted studies on low cost passive water heating at KCAET, Tavanur. They had tested the effect of black board painting (dull black) over the natural surface fo enhancing the water heating and found that it gives hot water having a temperature of 60 C.

2.14 WORK DONE IN ABROAD.

Solar hot water heaters were commonly available in California and Florida during the first half of this century. In 1897 10 percentage of the homes in Pasadena and California were having solar water heating. In U.S as a whole over 3 lakhs solar collectors were manufactured in 1978.

Kenna (1983) conducted studies on multiple layer solar collector designed by Caouris. He concluded that the multiple layer collector was not a viable design.

Vaxman and Sokolov (1985) designed an integral compact solar water heater.A total of 24 iron constant thermocouples were placed at various location to indicate the temperature of an equal volume. the collector stood at a slope of 40 with the zenith facing south and had an initial uniform temperature of 27

Tariq Muneer (1985) had constructed and tested a built-in-storage solar water heater. He concluded that storage heater having 8cm depth with with double glazing seems a good design.

Fanny and kalin (1986) had done experiments and calculated performance of integral collector storage solar water heater. They had measured total irradiance, effective black body, sky temperature, wind speed etc.

Ecevite <u>et al</u> (1989) conducted studies on triangular built-in-storage type solar water heater of different volumes.They concluded that the built - in storage triangular collector showed a higher daily efficiency as aresult of better heat transfer to the fluid.

Yu.K.Rashidov (1989) had reported about the plan, principles of operation, design peculiarities and technical indices of seasonal systems of solar hot water supply of the modulart type for individual residential homes.

Williams *et al* (1990) of pacific north west laboratory have conducted a study on various solar thermal power concepts.

Y.M.Dakhoul *et al* (1990) had reported about the design of a space based solar water heater.

R.Schaefer *et al* (1991) had reported about the design of honey comb solar ponds for water heating.

M.G.Parent *et al* (1991) had reported that natural convection heat exchangers can be used in solar hot water systems to replace the pump on the tankside of the exchanger.

MATERIALS AND METHODS.

The materials that were used for the fabrication of the flat plate collector water heating system and the methods employed to measure the various parameters are described in this chapter.

The various components of the water heating system is discussed below with their materials of construction.

3.1.1 THE INLET PIPE

The inlet pipe is 3.2 m long and 1 inch in diameter which is of galvanised iron material. It consists of a gate valve for controlling the flow.

3.1.2. SOLENOID VALVE

The solenoid valve is located at the end of the inlet pipe and prior to the monoblock pump. The solenoid valve is winded with 30 gauge copper wire . The number of turns of the coil is 750. Electric supply is given to the coil for producing magnetic effect around the coil.

3.1.3. MONOBLOCK PUMP

Two monoblock pump units are installed on a rectangular concrete base with a spacing of 0.25 m between the units. Each of them consists of a centrifugal pump connected to an electric motor. The speed of the motor at no load condition is 2890 rpm; and it varies as the load changes. Gate valve is also provided for both units.

3.1.4 ROTAMETER

A rotameter is included in the system to measure the discharge to the flat plate collectors in litres per minute. Its range is 0 to 11 LPM. A gate valve is also associated with the rotameter to controle the flow.

3.1.5 FLAT PLATE COLLECTORS

The flat plate collectors are the most important part of the solar water heating system. There are 14 number of collectors arranged in two rows with 7 number in each row. Each collector is a solar panel which is 2m long, 1m broad and 0.06 m. wide It is made of GI and is rectangular in shape. A transparent

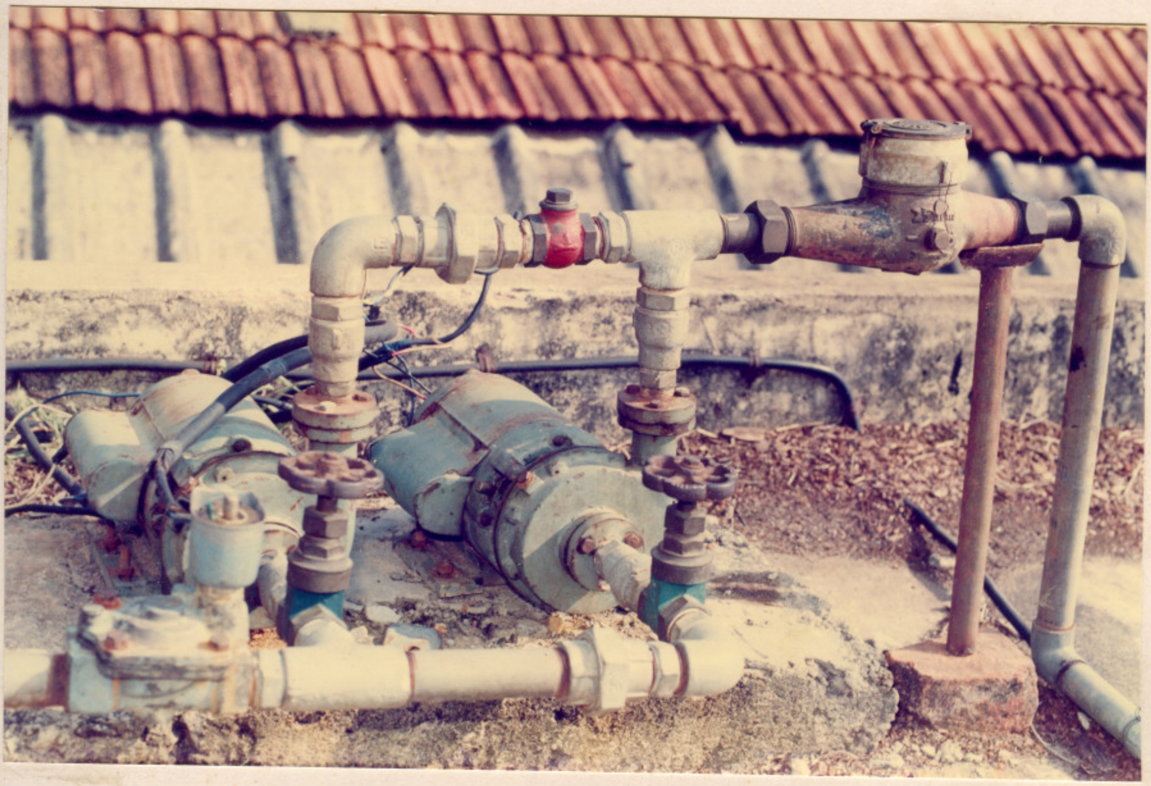


Plate I   Monoblock pump units with solenoid valve.

Plate II   Solar panel array

cover is provided on the top of the panel. The function of the transparent cover is to allow the solar radiation to pass through it and act as an opaque curtain to the radiation emitted by the hot absorber. It also avoids or reduces the convective heat losses from the absorber.

Glass is most favoured material for the transparent covers.Ordinary glass of 4mm thickness is used for cover in this system.

Inside the panel there are two main pipes at top and bottom and eight laterals located lengthwise. These pipes are used to carry the cold water for heating up in the solar panel.The diameter of the main pipe is 18 mm and lateral is 8 mm. All the panels are connected by the main pipe in a zig - zag manner.The capacity of each panel is 0.95 liters.

A black absorber plate is provided over the pipes to absorb the solar energy and to convert it into heat energy.Aluminium sheet is used as absorber plate because of its high thermal conductivity, lower cost and lighter weight.

The panel is installed at an angle of 30° to the horizontal surface.

3.1.6 THERMOSTAT

Thermostat is located at outlet end of the collector array. Bellow type thermostat is being used. The function of the thermostat is to adjust the outlet temperature of the hot water . A knob is provided to adjust the thermostat valve and it reads from 0 to 110 C. Two indicating lamps are provided, in which one lightens up at the time of pumping and other lightens for the rest of the time. A covering is also used for the thermostat in order to protect it properly. It also consists of a 3A fuse in its system.

3.1.7. STORAGE TANK

The storage tank is a mild steel tank having a capacity of 1000 litres and insulated on all sides with 10 cm thick glass wool. A glass tube connected to the tank with its same height and 1 cm dia. indicates the water level inside the tank. A dial gauge thermometer attached to the tank reads the temperature of the hot water inside the tank ranging from 0 C to 110 C.

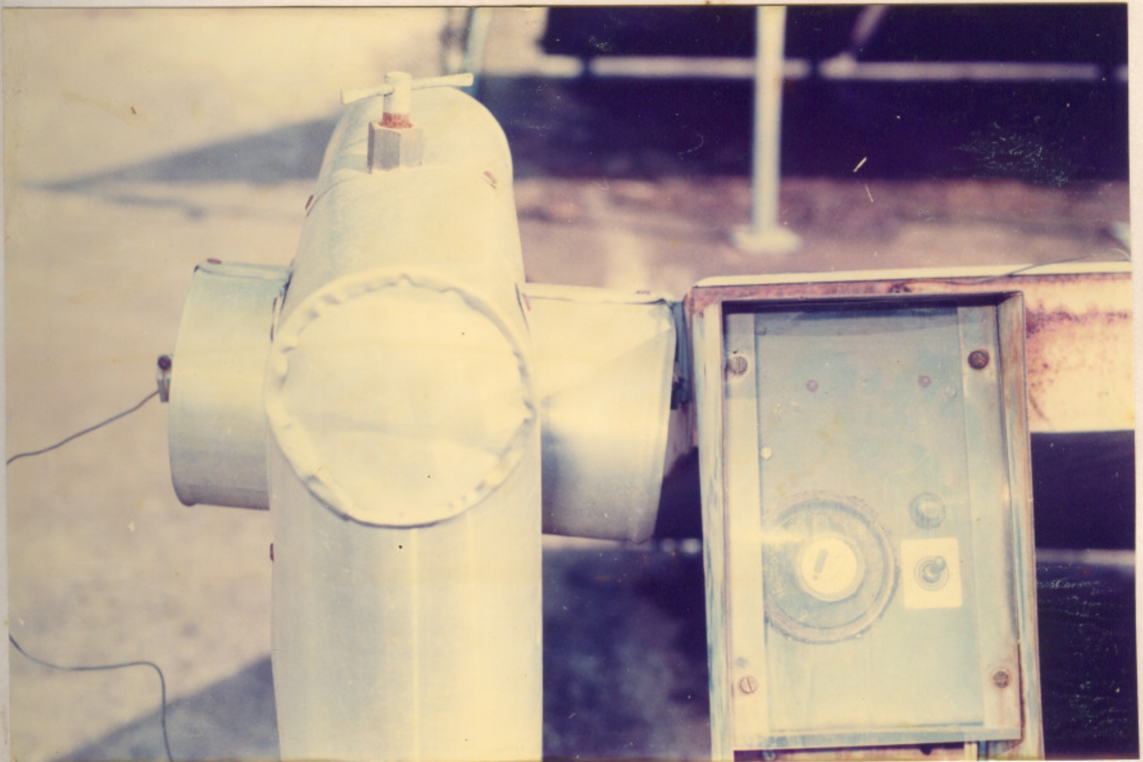


Plate III Thermostat

Plate IV   Storage tank with dial guage thermometer

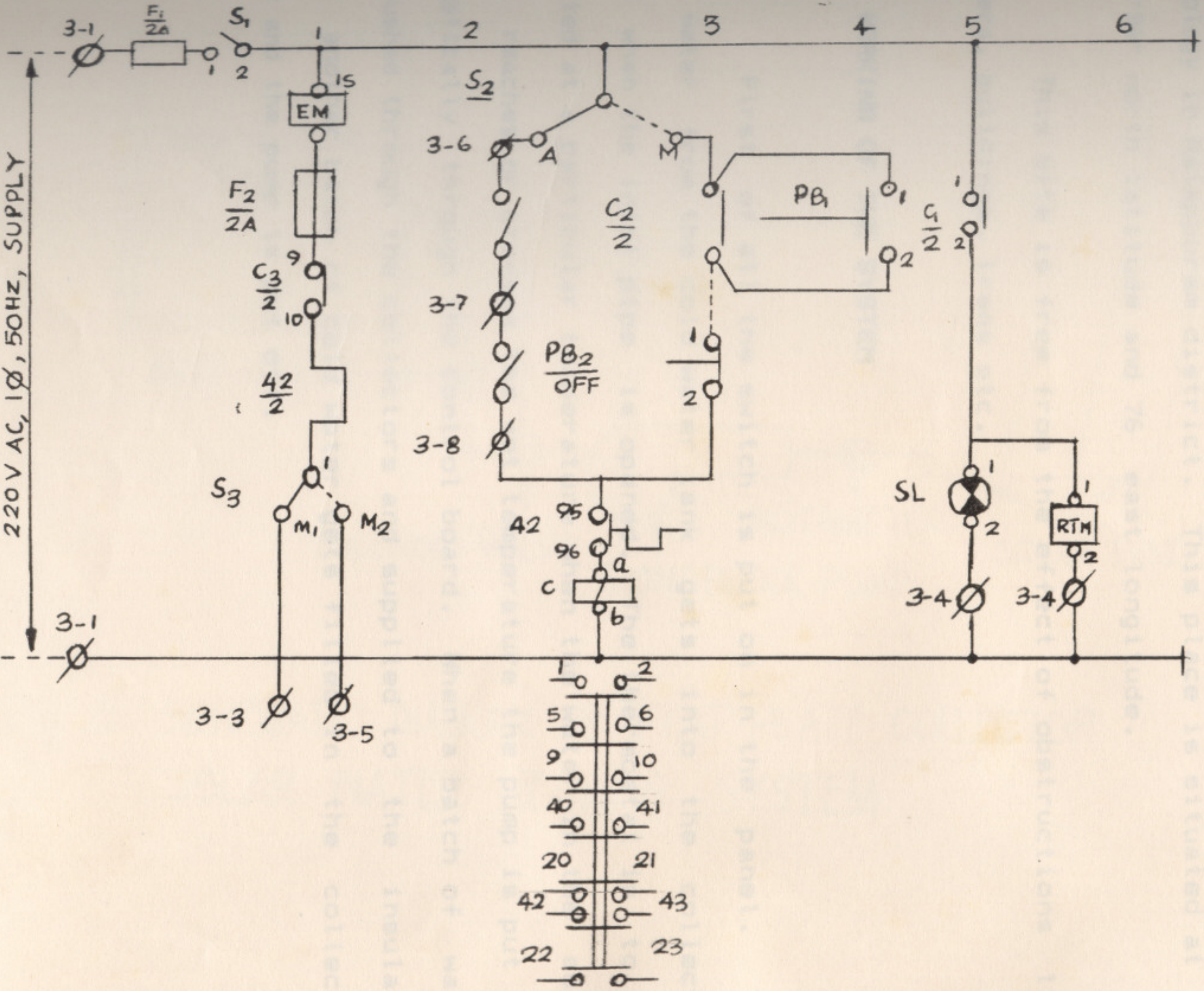
An open GI pipe is also provided at the top of the tank to permit overflow.

3.1.8. THE OUTLET PIPE

The outlet pipe is a GI pipe insulated with glass wool in circular manner of 10 cm dia. and covered with M.S sheet. It consists of two outlet points of which one is located inside the canteen and other to the ladies hostel. Ordinary tap is used at the user points.

3.1.9 PUMP CONTROL PANEL

It controls the overall working of the system and is installed inside the canteen. The connection diagram of the pump control panel is shown in the fig.5 . Mainly three switches are there, first is to put on and put off; second is to adjust the working of the system automatically or mannually. The third switch is to give supply to either motor I or motor II at a time. The pump control panel is connected to the main supply.



LEGENDS

RTM	Running time meter
SL	Indicating Lamp
PB1	On push button
PB2	Off push button
F1	Control fuse
F2	Power fuse
EM	Energy Meter
S1	On or off Switch
S2	A/M Switch
S3	MTR Select Switch
C	Contactor
42	TH O/L Relay.

Fig 5 Pump Control Panel

3.2. LOCATION OF THE WATER HEATER

Present model under study is being located on the top of the canteen at Kelappaji College of Agricultural Engineering & Technology in Malappuram district. This place is situated at 10 52'30" north latitude and 76 east longitude.

This site is free from the effect of obstructions like barriers, buildings, trees etc.

3.3. WORKING OF THE SYSTEM

First of all the switch is put on in the panel. The cold water from the cold water tank gets into the collector array when the inlet pipe is opened. The thermostat is to be adjusted at a particular temperature when the water in the solar panel reaches or crosses the set temperature the pump is put on automatically through the control board. When a batch of water is pushed through the collectors and supplied to the insulated tank, another batch of cold water gets filled in the collector array and the pump is put off.

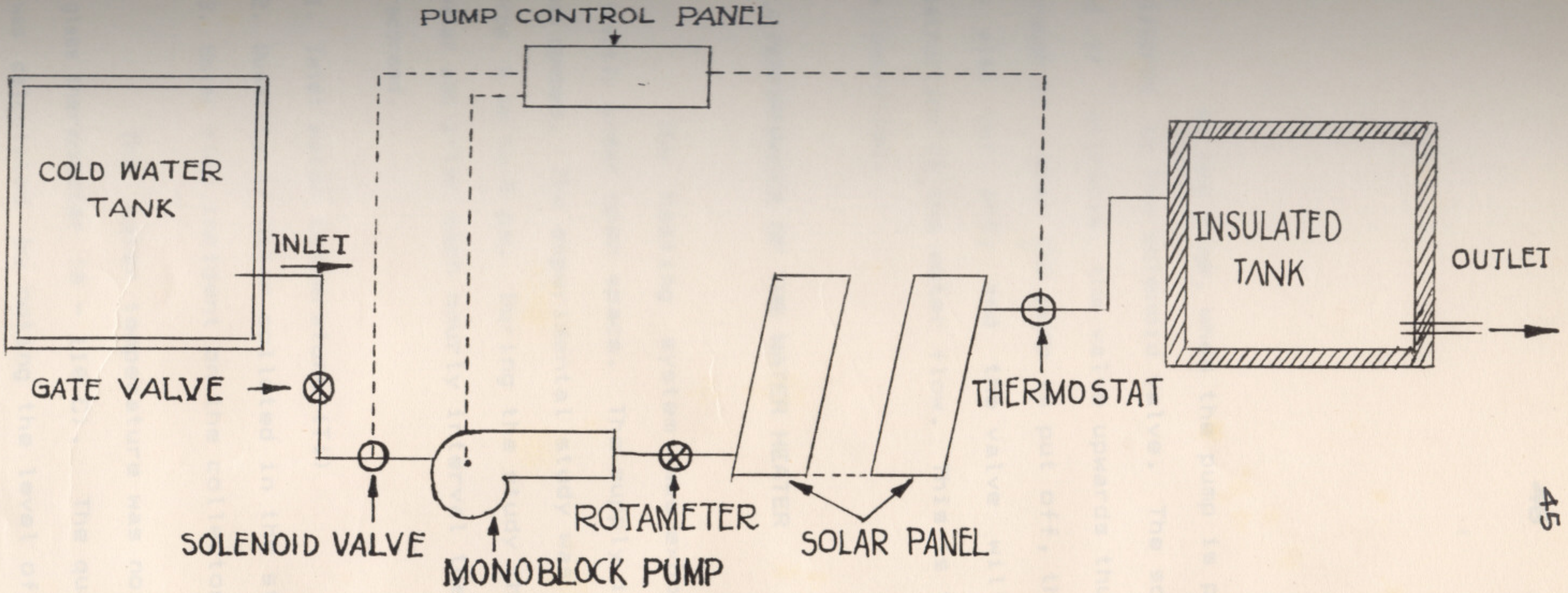


Fig:6 SCHEMATIC DIAGRAM OF FLAT PLATE COLLECTOR SOLAR WATER HEATING SYSTEM

At the time, when the pump is put on the supply is also delivered to the solenoid valve. The solenoid gets magnetised and it attracts the valve upwards thus causing water flow through it. When the pump is put off, the supply to the solenoid is also cut off, and the valve will be closed making an obstruction to the water flow. This is the way in which the flow is controlled.

3.4 PERFORMANCCE OF THE WATER HEATER

The heating system was exposed to solar radiation directly under open space. The supply is put on. The inlet pipe was opened. The experimental study was conducted during day time from 9 am to 4 pm. During the study the panel was filled with water and after each hourly interval the following readings were recorded.

1. Inlet water temperature (Ti)
2. Quantity of water colleted in the storage tank (M)
3. Solar flux incident on the collector plane (H)

The water temperature was noted with a mercury - in - glass thermometer (0 - 110 C). The quantity of water collected was calculated by noting the level of water collected in the

Plate V Solar intensity meter for measuring solar radiation.

tank. Total solar radiation received on the horizontal surface was measured by solar intensity meter. All the readings were taken at a discharge of 6 LPM.

The system was also analysed as thermosyphon system. For that the supply was cut off, the coil around the solenoid valve was removed. The inlet pipe was opened at 9 am and the readings were taken upto 4 pm. In this case the out let water temperature (To) was also noted. It was recorded from the dial gauge thermometer attached to the storage tank.

3.5 PERFORMANCE OF THE STORAGE TANK

To study of the performance of the storage tank, water was collected in the storage tank by adjusting the thermostat at 60 C. By noting the readings in the dial guage thermometer the decrease in temperature of the hot water was observed.

3.6 EFFICIENCY OF THE WATER HEATER.

Hourly efficiency of the water heating system is calculated. It is defined as the ratio of the useful gain over any time period to the incident solar energy over the same time period.

= Useful heat gained / Radiation incident on the collector

$$= MS\ (To - Ti)\ /\ HA$$

where,

M = Mass of water heated up (Kg)

S = Specific heat of water (J/Kg)

To = Outlet temperature of hot water C

T_i = Initial temperature of cold water C

H = Solar radiation on unit area on horizontal surface (W/sq.m)

A = Absorbing area of the water heating system (sq.m.)

RESULTS AND DISCUSSION

The results of the performance study of the flat plate collector water heating system is discussed in this chapter.

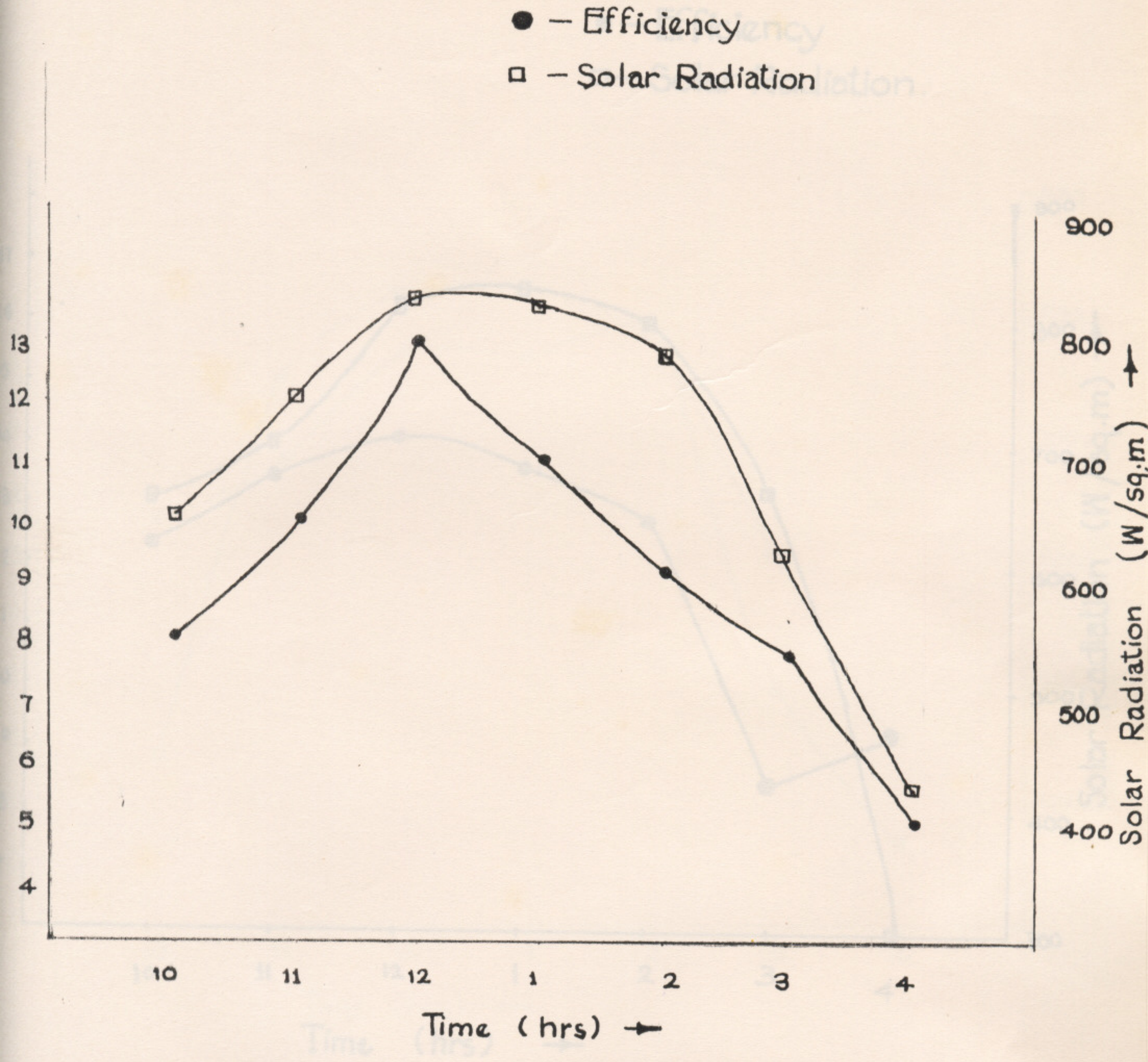
4.1 Maintenance of the system

The system was checked and defects were noted. The motor of the monoblock pump units which were not working were repaired and made to working condition. The solenoid valve had no winding. It was winded. The thermostat was out of order as there was no fuse. A 3 A fuse was replaced.

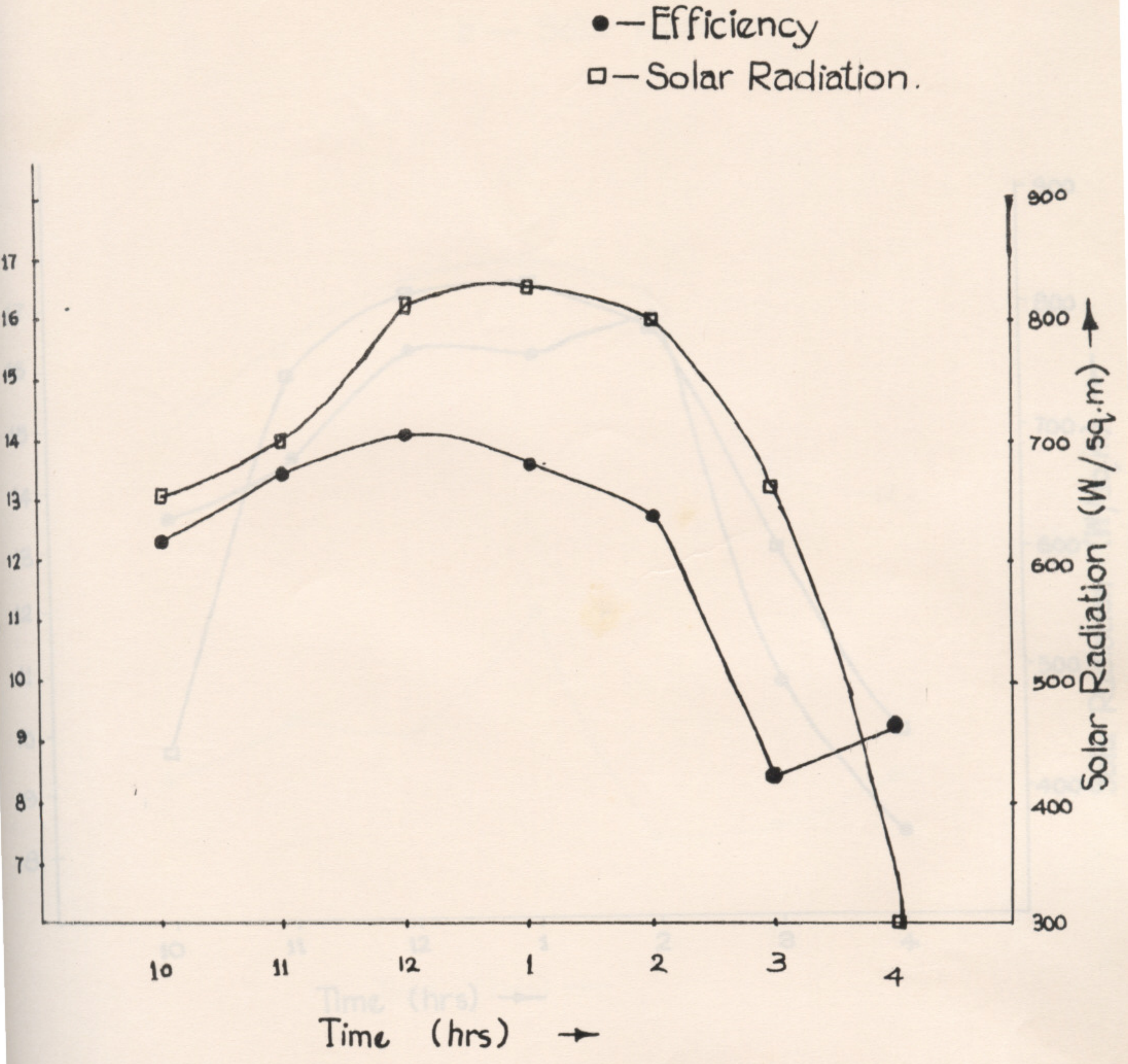
4.2 PERFORMANCE RESULTS

4.2.1 Performance at different constant outlet temperatures.

Fig. 7-11 shows the graphical representation of the test results for various temperatures from 50 C to 70 C at same time interval. From the graph it was found that the maximum efficiency was obtained at 60 C. In this case the quantity of water collected as well as the solar intensity were more. Upto 60 C the quantity of water collected was more but the efficiency was less. At 65 C & 70 C the quantity of water collected per hour were lesser than the peak temp of 60 C . So it is concluded that the system is more efficient when the valve is adjusted at 60 C.



Efficiency of the System (At 50°C)



g: 8 Efficiency of the System (At 55°C)

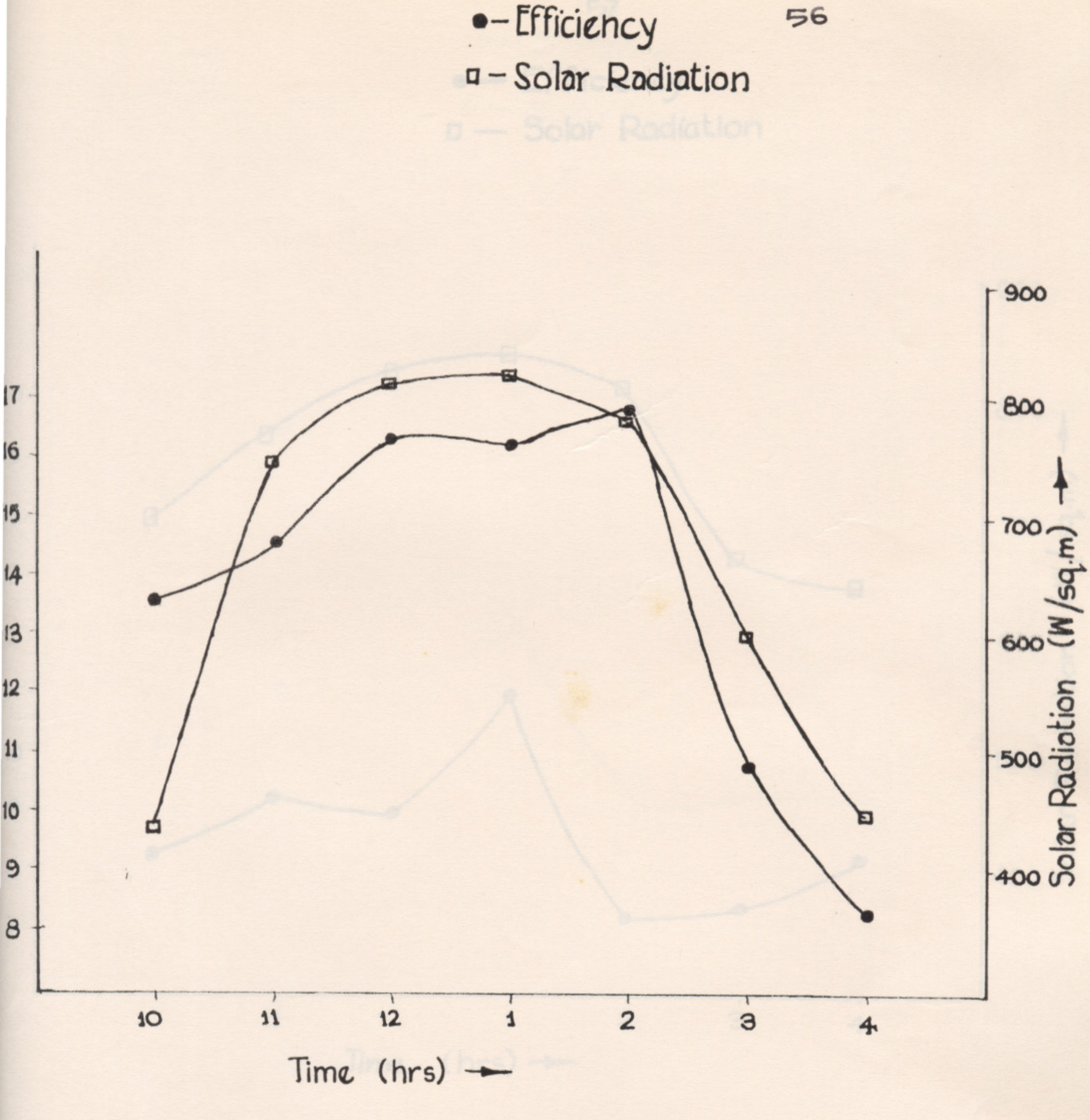


Fig: 9 Efficiency of the System (At 60°C).

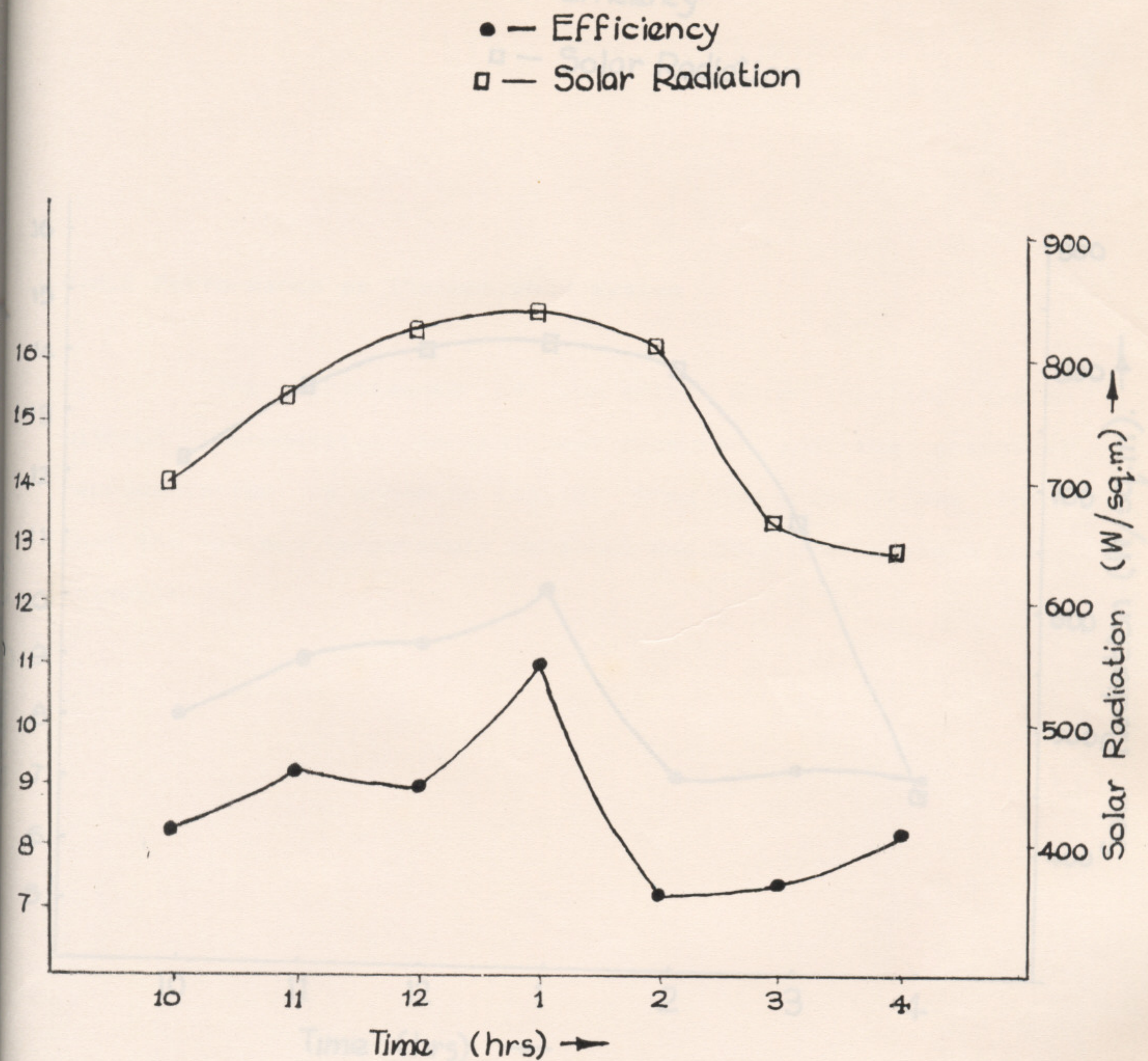


Fig : 10 Efficiency of the System (At 65°C)

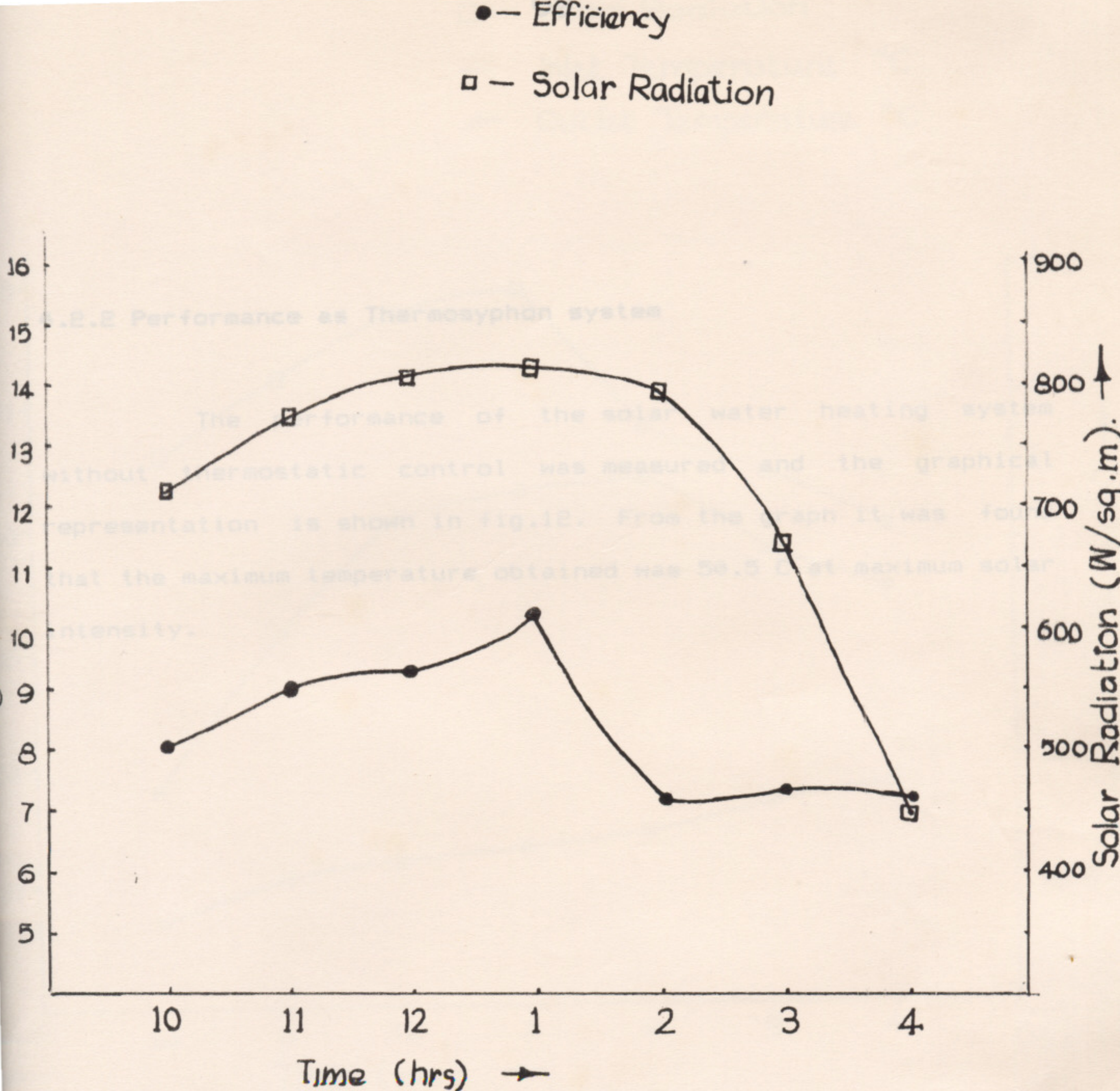
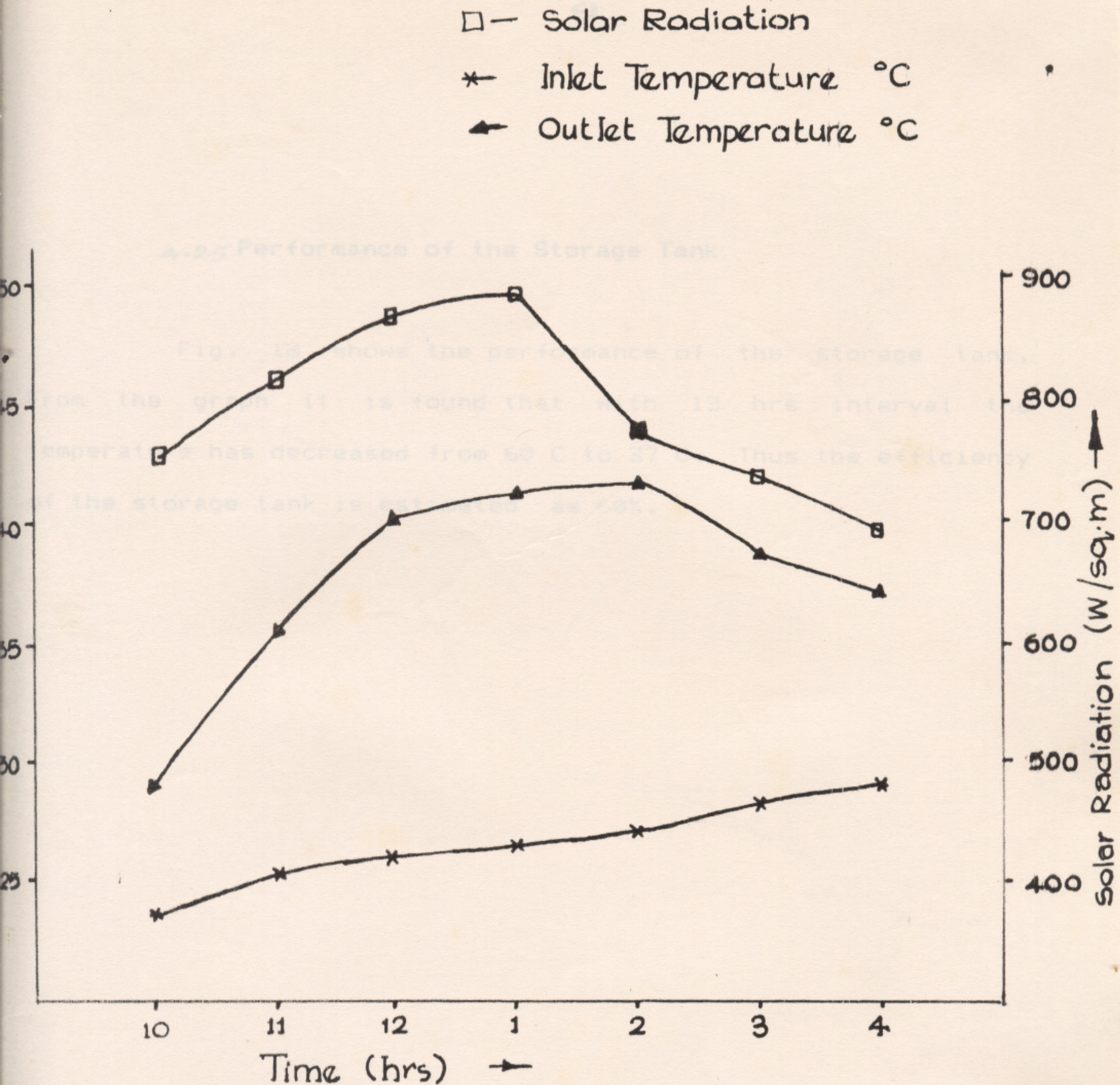


Fig-11 Efficiency of the System (At 70°C)

4.2.2 Performance as Thermosyphon system

The performance of the solar water heating system without thermostatic control was measured and the graphical representation is shown in fig.12. From the graph it was found that the maximum temperature obtained was 50.5 C at maximum solar intensity.



12 Performance As Thermosyphon System.

4.2.5 Performance of the Storage Tank

Fig. 13 shows the performance of the storage tank. From the graph it is found that with 13 hrs interval the temperature has decreased from 60 C to 37 C. Thus the efficiency of the storage tank is estimated as 60%.

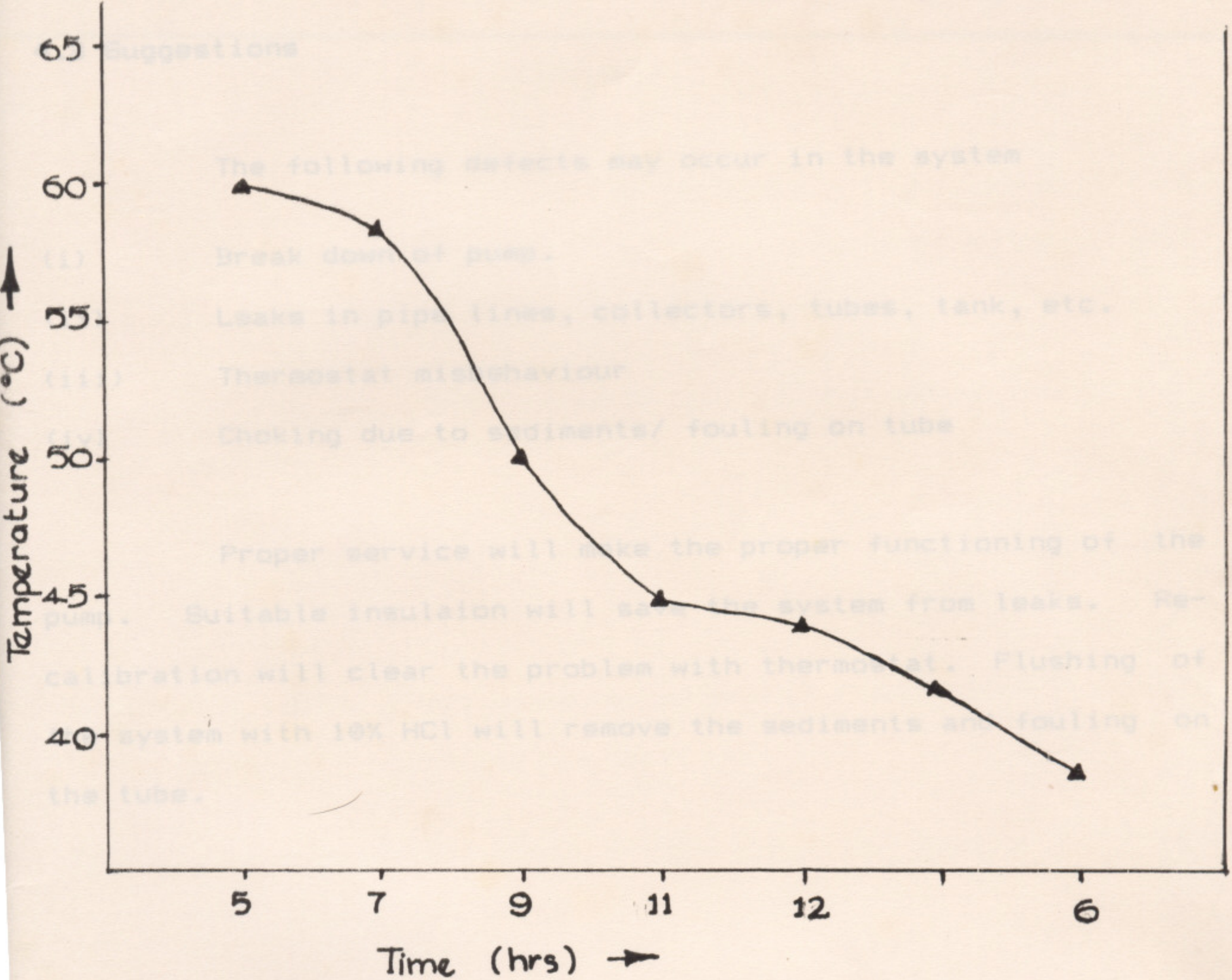


Fig : 13 Performance of Storage Tank

4.3 Suggestions

The following defects may occur in the system

(i) Break down of pump.

(ii) Leaks in pipe lines, collectors, tubes, tank, etc.

(iii) Thermostat misbehaviour

(iv) Choking due to sediments/ fouling on tube

Proper service will make the proper functioning of the pump. Suitable insulaion will save the system from leaks. Re-calibration will clear the problem with thermostat. Flushing of the system with 10% HCl will remove the sediments and fouling on the tube.

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APPENDIX- I

Material	Coefficient of thermal conductivity (Cal/hr,cm, C)
Aluminum sheet	117.000
Glass	0.440
Air	0.014
GI	79.450
MS	46.100

APPENDIX-II

INSTRUMENTATION

Specification of solar intensity meter.

Name	:	Surya Mapi
Model No.	:	SM 201
Range	:	0 - 120 MW/sq.cm. AMI radiation
Supplied	:	Central Electronics Limited

APPENDIX-III

Table 1. Solar water heating, when outlet temperature was 50 C., Dated 25th April 1993.

Sl.No.	Time	Inlet Temp (C)	Quantity of Water Collected (Kg)	Solar Radiation (W/Min)	Efficiency (%)
1	10 am	25	50	650	8.01
2	11 am	26	75	750	10.00
3	12 noon	27.5	110	830	12.97
4	1 pm	28.5	100	820	10.92
5	2 pm	30	85	790	8.90
6	3 pm	30.5	60	620	7.86
7	4 pm	30.5	25	400	5.33

APPENDIX-IV

Table 2. Solar water heating, when outlet temperature was 55 C., Dated 26th April 1993.

Sl.No.	Time	Inlet Temp (C)	Quantity of Water Collected (Kg)	Solar Radiation (W/Min)	Efficiency (%)
1	10 am	25	65	660	12.31
2	11 am	26.5	80	700	13.57
3	12 noon	27	98	810	14.11
4	1 pm	29	105	825	13.78
5	2 pm	30	99	800	12.89
6	3 pm	30.5	55	660	8.50
7	4 pm	30	27	300	9.37

APPENDIX-V

Table 3: Solar water heating, when outlet temperature was 60 C., Dated 27th April 1993.

Sl.No.	Time	Inlet Temp (C)	Quantity of Water Collected (Kg)	Solar Radiation (W/sq.m)	Efficiency (%)
1	10 am	25	40	430	13.56
2	11 am	26.5	77	740	14.52
3	12 noon	27	96	810	16.29
4	1 pm	28.5	100	815	16.17
5	2 pm	30	94	780	16.78
6	3 pm	30.5	53	600	10.85
7	4 pm	30.5	30	450	8.2

APPENDIX-VI

Table 4: Solar water heating, when outlet temperature was 65 C., Dated 28th April 1993.

Sl.No.	Time	Inlet Temp (C)	Quantity of Water Collected (Kg)	Solar Radiation (W/sq.m)	Efficiency (%)
1	10 am	25	35	700	8.30
2	11 am	25.5	45	780	9.50
3	12 noon	27.5	47	820	8.96
4	1 pm	28.5	60	830	11.00
5	2 pm	29.5	40	810	7.30
6	3 pm	30.5	36	660	7.84
7	4 pm	30.5	28	640	8.2

APPENDIX-VII

Table 5. Solar water heating, when outlet temperature was 70 C., Dated 29th April 1993.

Sl.No.	Time	Inlet Temp (C)	Quantity of Water Collected (Kg)	Solar Radiation (W/Min)	Efficiency (%)
1	10 am	25	32	720	8.33
2	11 am	25.5	38	770	9.15
3	12 noon	27.5	43	810	9.40
4	1 pm	28.5	50	820	10.50
5	2 pm	29.5	34	800	7.17
6	3 pm	30	30	680	7.35
7	4 pm	30.5	20	450	7.31

APPENDIX-VIII

Table 6. Solar water heating as thermosyphon system, Dated 30th April 1993.

Sl.No.	Time	Solar radiation (W / sq.m)	Inlet temp. (C)	Outlet temp. (C)
1	10 am	740	24.5	29.50
2	11 am	801	25.5	37.00
3	12 noon	851	26.0	42.00
4	1 pm	860	27.5	50.50
5	2 pm	762	28.0	43.50
6	3 pm	721	29.5	39.50
7	4 pm	690	30.0	38.50

APPENDIX-IX

Performance of the storage tank

Sl.No:	Time	Reduction in temperature (C)
1	5 pm	60
2	6 pm	60
3	7 pm	58
4	8 pm	55
5	9 pm	50
6	10 pm	47
7	11 pm	45
8	12 pm	44
9	6 am	37

PERFORMANCE EVALUATION OF FLAT PLATE COLLECTOR SOLAR WATER HEATING SYSTEM

By

JIGIMON. T.

Abstract of a Project Report

Submitted in partial fulfilment of the requirement for the degree

Bachelor of Technology in Agricultural Engineering

Faculty of Agricultural Engineering
Kerala Agricultural University

Department of Agricultural Processing and Structures

Kelappaji College of Agricultural Engineering and Technology

Tavanur - Malappuram

1993

ABSTRACT

The study was conducted with the objective of making the exising system in working condition and evaluate its performace.

The system consists of a solenoid valve with copper winding, monoblock pump units, and a thermostat valve, all connected to the pump control panel. There are 14 number of solar collectors (solar panel). An insulated storage tank is also provided for the system to store the heated water. The tank is having a capacity of 1000 litres. The heater was inclined to the latitude of Tavanur and was oriented to south for collecting maximum solar radiation.

The solar water heater was filled daily at 9 am with fresh water. The performance of the water heater was observed from 25th April 1993 to 30th April 1993.

The water heater was tested for a maximum outlet temperature of 70 C. The efficiency of the heater was calculated to be 16.78%. Solar intensity meter read a maximum solar flux of 860 w/sq.m at 1 pm on 30th April 1993.The performance of the storage tank was also analysed.