PERFORMANCE EVALUATION OF SOLAR FLAT PLATE COLLECTOR

A THESIS SUBMITTED TO THE DEPARTMENT OF "MECHANICAL ENGINEERING" IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF BACHELOR OF SCIENCE IN MECHANICAL ENGINEERING

Submitted By

Capt. Alija Alam	**Student No. 201318002**
Minhaz Uddin	**Student No. 201318037**
Md. Nazmul Haque	**Student No. 201318056**

Supervised By

Maj. Dr. Faisal Kader

Associate professor,

Department of Mechanical Engineering, MIST

DEPARTMENT OF MECHANICAL ENGINEERING

MILITARY INSTITUTE OF SCIENCE AND TECHNOLOGY (MIST)

MIRPUR CANTONMENT, DHAKA

January 2017

Acknowledgement

We would like to thank my supervisor Major.Dr. Faisal Kader for all his supports throughout the duration of this thesis at MIST.We would also like to thank many technicians who have provided their advice and knowledge during the experimental part of this research. It has been a great pleasure and honor that he has gracious willing to encounter plenty of challenges with us from the beginning until the end of the project.

We express our heartiest indebtedness to Mechanical Engineering Department, MIST, for providing us with full financial support and workshop facilities with appropriate working people throughout the whole research work.

Authors

January, 2017

Abstract

The analysis of thermal performance of the flat-plate collector includes parameters such as solar intensity, ambient temperature and configuration of flat-plate collectors etc. In this paper, the effect of the parameter $(T_i - T_a)/IT$ on thermal performance of glazed flat-plate solar collector was experimentally analyzed for water heating application in winter climatic condition. The flat-plate collector consists of the total surface area 0.6656 m^2 and the copper tubes are integrated beneath the absorber plate. The plate has a selective coating with high absorptivity of 92% and the heat transfer fluid flowing in the tubes is water. In the paper, evaluation of useful heat gain or collector efficiency has been done. It is based on steady state analysis and by calculating the thermal performance of liquid flat-plate collector. Results show that the flat-plate collector gives good performance and provide a desire quantity of hot water.

CERTIFICATION

This thesis entitled as "PERFORMANCE EVALUATION OF SOLAR FLATE PLATE COLLECTOR" submitted by the group as mentioned below has been accepted as satisfactory as a part of the requirements in order to complete the B.Sc. degree at the Department of Mechanical Engineering, Military Institute of Science and Technology, Bangladesh. This paper embodies the original work done under my super vision.

GROUP MEMBERS

Capt. Alija Alam	Student No: 201318002
Minhaz Uddin	Student No: 201318037
Md. Nazmul Haque	Student No: 201318056

SUPERVISOR

Maj. Dr. Faisal Kader

Associate Professor,

Department of Mechanical Engineering

Military Institute of Science and Technology

Dhaka, Bangladesh

DECLARATION

We the authors hereby declare that, thesis entitled as “PERFORMANCE EVALUATION OF SOLAR FLAT PLATE COLLECTOR” is submitted to Department of Mechanical Engineering, Military Institute of Science and Technology as a part of the requirement in order to complete the B.Sc. degree in Mechanical Engineering. This is our original work and was not submitted elsewhere for the award of any other degree or any other publication.

AUTHORS

Capt. Alija Alam

Student No: 201318002

Minhaz Uddin

Student No: 201318037

Md. Nazmul Haque

Student No: 201318056

Contents

CHAPTER 4

CHAPTER 5

CHAPTER 6

Keywords –

Flat-plate collector, solar energy, thermal performance, collector efficiency.

Nomenclature

R, The absorbed energy for one hour is calculated. Solar radiation received by earth in 1 hours in terms of energy

A,Area of flat plate collector

T1,Temperature of water inlet in ºC

T2,Temperature of water outlet in ºC

Cp,Specific heat of water

List of Figures

List of Tables

List of Graphs

CHAPTER 1

Introduction

• Over the past decades, the increasing environmental concerns and energy needs, it is necessary to explore alternatives to the use of non-renewable and polluting fossil fuels. One such option is solar energy. Solar energy is very large, inexhaustible and clean source of energy. Solar energy is the radiation resulted by nuclear fusion reactions in the sun. This energy radiates outwards in all the directions.

• The solar thermal energy is collected by a device called solar collector. A flat plate collector is such type of solar thermal collector which is using in such place where moderate heat is require. It can increase the temperature of the fluid up to 1000oC above ambient temperature. It is also simple in design, have no moving parts and require little maintenance. They are also relatively cheap and can be used in variety of application.

• A simple flat plate consists of four components absorber plate, tubes fixed to the absorber plate, the transparent cover, the collector box. The collector plates absorb the maximum possible amount of solar irradiance and transfer this heat to the working fluid which is flowing in absorber tube. The fluid used for heat transfer generally flows through a metallic tube, which is connected to the absorber plate.

• The absorber is usually made of metallic materials such as copper, steel or aluminium and surface is generally black. The collector box can be made of plastic, metal or wood type insulator to prevent heat loss and the transparent front cover must be sealed so that heat does not escape, and the collector itself is protected from dirt and humidity.

• The heat transfer fluid may be either water or water with antifreeze liquid. Still the heat losses due to the temperature difference between the absorber and ambient air result in convection and radiation losses. The main advantage of a flat plate collector is that it utilizes both beam and diffuse components of solar radiation.

- Efficiency of flat plate collector depends on the temperature of the plate, ambient temperature, solar isolation, toploss coefficient emissivity of plate; transmittance of cover sheet, number of glass covers etc. The efficiency improvement for flat-plate solar collector can reduce its size and obtain higher temperature fluid at outlet for wider application.

- In response to these demands, different highly-effective techniques have been used in the past to enhance the thermal performance of solar collectors including the methods of reducing the heat loss from the top surface or increasing the energy gain inside the solar converter.

1.2 History and Utilisation of Solar Energy

- Humans have always used the rays of the sun to gather their energy needs. In the energy needs of today with increasing environmental concern, alternatives to the use of nonrenewable and polluting fossil fuels have to be investigated. One such possibility is solar energy, which has become increasingly popular in recent years.

- Solar energy is the radiation produced by nuclear fusion reactions in the core of the sun. This radiation travels to Earth through space in the form of energy called photons. Even though only 30% of the solar power actually reaches the Earth, every 20 minutes the sun produces enough power to supply the Earth with its needs for an entire year.

- Unfortunately the atmosphere and clouds absorb a large amount of this sunlight. So the amount of light that reaches any point on the ground depends on the time of day, the day of the year, the amount of cloud cover, and the latitude at that point, with the solar focus directly dependent on three of these factors.

- The history of using the sun for energy goes way back to the Ancient Greeks and Romans as their buildings were constructed such that the rays of the sun provided light
and heat for indoor spaces. The Greek philosopher Socrates wrote, "In houses that look toward the south, the sun penetrates the entrance in winter."

- Romans advanced this art by covering the openings to south facing building with glass, in order to retain the heat of the winter sun. The history of utilising solar energy in recent times dates from 1861 when Mouchout developed a steam engine powered entirely by the sun and in 1883 American inventor Charles Fritts described the first solar cells made of selenium wafers.

- Throughout the 20th century, scientists developed large cone-shaped collectors that could boil ammonia for refrigeration. In the United States, John Ericsson designed the "parabolic trough collector" a technology which functions more than a hundred years later on the same basic design . Albert Einstein was awarded the 1921 Nobel Prize in physics for his research on the photoelectric effect; a phenomenon central to the generation of electricity through solar cells .

- In 1953 AT&T laboratory scientists developed the first silicon solar cell capable of generating an electric current. In 1956, solar photovoltaic (PV) cells were very expensive and electricity from solar cells cost about $300 per watt. The Arab oil embargo in 1973 confirmed the degree to which the western economy depended upon there, being a cheap and reliable flow of oil.

- In the 1970s it was thought that through massive investment in funding and research, solar photovoltaic costs could drastically reduced, such that eventually solar cells could become competitive with fossil fuels.

• By the 1990s, the reality was that the costs of solar energy had dropped as predicted and the huge PV market growth in Germany and Japan from the 1990s to the present has boosted the solar industry. Furthermore, such large PV productions are creating steadily lowering costs. Meanwhile, the heating of water by solar energy is an increasingly costeffective means of lowering gas and electricity demand.

• Due to the nature of solar energy, two components are required in order to have a functional solar energy generator. These two components are a collector and a storage unit. The collector collects the radiation that falls on it and converts it to other forms of energy (electricity, heat). Whilst the storage unit is required because of the non-constant nature of solar energy, as during cloudy days the amount of energy produced by the collector will be quite small.

• The storage unit can hold the energy produced during the periods of maximum radiation and release it when it is needed or the productivity drop. Methods of collecting and storing solar energy vary depending on the use of the solar generator. In general, there are three types of collectors (flat -plate collectors, focusing collectors, and passive collectors) and many forms of storage units.

1.3 The Structure of the Thesis

• The thesis consists of six Chapters, dedicated to research and to the examination of flat plate solar water collectors and their features. The current Chapter contains information regarding the utilization of solar energy over the years, as well as analyses of how each chapter is formed and an outline of the research undertaken within that chapter

• *Chapter 2* contains a literature review; an overview of solar water heating and different solar water heaters and collectors. An extensive description of absorber coatings and glazing for flat plate solar collectors. Various designs and improvements in Solar Water Systems are also included in this chapter.

• *Chapter 3* is concerned with the experimental work; explains the design and construction of the experimental test rig and the various experimental setups. The techniques used for temperature, fluid flow and pressure measurements are also described in detail. Various graphs created from the numerical data recorded during the experiments are illustrated and analyzed.

• *Chapter 4 contains result and discussion about the experiment.*

• *Chapter 5* contains the conclusions and recommendations of the research conducted; the evaluation of the design, manufacturing, and tests of the sections of the solar collectors.

• *Chapter 6* lists all the references used in the thesis.

• Appendices contain supplementary information such as types of solar water systems, tables with experimental results and charts that can be used to predict the performance of the collector when utilized in conjunction with the experimental data and the lumped parameters model. Furthermore there are information concerning the apparatus and components used in the experiments.

CHAPTER 2

Literature Review

2.1 Overview of Solar Water Heating

Solar energy can be utilised as a form of heat, such as solar water heating and as electricity, such as solar photovoltaic. Solar water heating systems are commonly referred to in industry as Solar Domestic Hot Water (SDHW) systems and it is a technology that is not entirely new. In the 19th century, people used a stove to heat water by burning pieces of wood or coal. In cities, the wealthier heated their water with gas manufactured from coal.

In many areas, wood, coal or gas could not be easily obtained and hence such fuels were often expensive. problems, a much easier and safer way to heat water was created. This was achieved by placing outside a black painted metal tank full of waterto absorb solar energy. The disadvantage was that even on clear hot days it usually took from morning to early afternoon for the water to get hot. As the sun went down, the tank rapidly lost its heat because it had no insulation.

In 1891, Clarence Kemp patented the old design of metal tanks exposed to the sun by adding a metal panel to the tank, shown below in Figure 2.1a, in order to increase the efficiency of the solar tank .

In the beginning of the 20th century, inventors designed improved systems, but still the heating and the storage unit were one, and both were exposed to the weather and the cold nights.

2.2 Solar Water Heaters and Collectors

The solar collector is the key element in solar energy systems. It absorbs the solar radiation and converts it into a useable form of energy that can be applied to meet a specific demand. More sophisticated systems have also been developed for higher temperatures.

There are a number of different design models for collectors but generally they are either stationary or concentrating. The stationary type includes: Flat Plate Collectors, Evacuated Tube Collectors and Compound Parabolic Collectors. The Concentrating type includes: Parabolic and Cylindrical Trough Collectors, Parabolic Dish Reflector and Heliostat Field Collector .

2.3 Flat Plate Collectors

Flat-plate collectors are the most common for residential water-heating and spaceheating installations. A typical flat-plate collector consists of an absorber, transparent cover sheets and an insulated box. The absorber is usually a sheet of high-thermalconductivity metal with tubes or ducts either integral or attached. Its surface is painted.

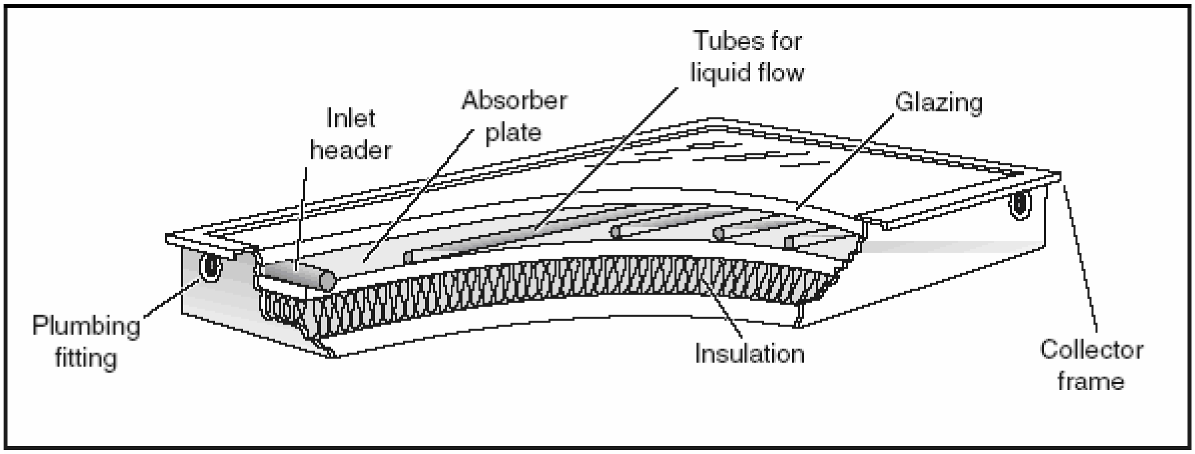


Figure 2.1 Flat plate solar water collector .

The heat pipe as shown in Figure 2.4c3 is similar to the direct flow tube type. In this case there is a change of the state of the liquid. Inside the heat pipe there is a small quantity of purified water and some special additives. Due to the vacuum of the tube, the water boils at a lower temperature, typically 30 ºC, so when the heat pipe is heated above 30ºC the water vaporises. This vapour rapidly rises to the top of the heat pipe transferring heat into the condenser.

As the heat is lost at the condenser, the vapour condenses to form a liquid and returns to the bottom of the heat pipe and the process starts again.

2.4 Solar Air Collectors

Solar air collectors operate similarly to liquid collectors at the difference that air is circulated through the collector to cause of heat transfer. Air collectors are simple flatplate collectors used primarily for space heating

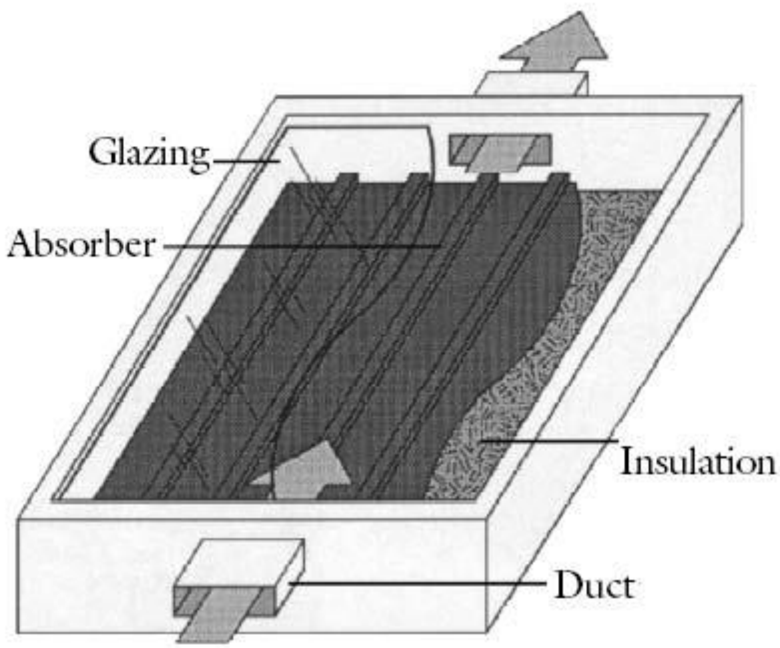


Figure 2.2 Flat Plate Air Collector.

The absorber plates in air collectors can be metal sheets, layers of screen, or non-metallic materials. Air collector absorber plates can be unfilled or wavy to create air turbulence that helps the heat to pass from the plate. The air flows through the absorber by natural convection or it is forced by a fan.

As air conducts heat slower than liquid does, less heat is transferred between the air and the absorber than in a liquid collector. The disadvantage of this design is that it can also increase the amount of power needed for fans and hence increase the costs of operating the system .

2.5 Evacuated Tube –Heat Pipe Collectors

The Evacuated Tube Collector as shown in Figure consists of rows of parallel transparent glass tubes, each of which contains an absorber tube covered with a selective coating. When evacuated tubes are manufactured, air is evacuated from the space between the two tubes so forming a vacuum.

Conductive and convective heat losses are eliminated because there is no air to conduct heat or to cause convective losses. There can still be some radiant heat loss (heat energy will move through a space from a warmer to a cooler surface, even across a vacuum); but this loss is small and of little consequence compared with thevamount of heat transferred to the liquid in the absorber tube.

Evacuated tube collectors can be classified in two main groups:

1. Direct flow tubes: the heat transfer fluid flows through the absorber,
2. Heat pipe tubes: tubes with heat transfer between the absorber and heat transfer fluid of the collector.

The direct flow collectors as shown in Figure 2.3 consist of a group of glass tubes. Inside each tube there is a flat or curved aluminium plate which is attached to a metal (usually copper) or glass pipe depending on the configuration.

The aluminium plate is generally coated with a selective coating. The heat transfer fluid is water and circulates through the pipes, one for the inlet fluid and one for the outlet fluid. In an evacuated-tube collector, sunlight enters through the outer glass tube, strikes the absorber tube and is transformed into heat. The heat is transferred to the liquid flowing through the absorber tube.

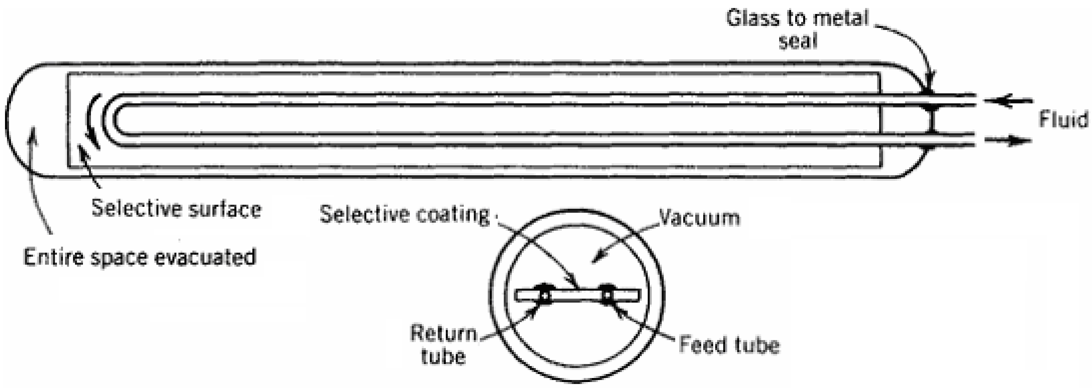


Figure 2.3 Direct evacuated tube Flow collector.

The heat pipe as shown in Figure 2.3 is similar to the direct flow tube type. In this case there is a change of the state of the liquid. Inside the heat pipe there is a small quantity of purified water and some special additives. Due to the vacuum of the tube, the water boils at a lower temperature, typically 30 ºC, so when the heat pipe is heated above 30ºC the water vaporises. This vapour rapidly rises to the top of the heat pipe transferring heat into the condenser.

As the heat is lost at the condenser, the vapour condenses to form a liquid and returns to the bottom of the heat pipe and the process starts again.

Figure 2.4 An Evacuted Tube Collector.

2.6 Concentrating Solar Collectors

Concentrating solar collectors are used when higher temperatures are required. Solar energy which is falling onto a large reflective surface is reflected onto a much smaller area before it is converted into heat. Most concentrating collectors can only concentrate the parallel insolation coming directly from the sun's beam and hence must follow (track) the sun's direction across the sky. Three types of solar concentrators are in common use; central receivers, parabolic dishes and parabolic troughs .

2.7 Water Storage Drum

The water storage drum are shown in figure. The top pipe was used to fill up the drum with cold water and the bottom pipe was used to tap the hot water from the drum. The original capacity of the storage drum was 90 litre of water.

Figure 2.5 Drum (capacity 90 litre)

2.8 Selection of Working Fluid

The working medium for the flat plate collector was selected based on the following desirable properties:

i. Low boiling point

ii. High specific heat

lll. High latent heat

iv. Non-corrosiveness for most of the fabrication materials

v. Wide useful range

VI.Easily available in the market and low in cost

vii. Excellent stability in the working range

viii. Low temperature

ix. Should not form scales in the tubes

x. High thermal conductivity

CHAPTER 3

EXPERIMETAL SETUP

APPARATUS:

1. Copper tube
2. Ms plate
3. Glass wool
4. Wood box
5. Pipe
6. Drum
7. Frame
8. Thermometer
9. Water working fluid.

Table 1. The specifications of flat plate solar collector components

Component	Dimensions	Remarks
Collector Absorber plate Transparent cover header Pipes	1.04mx0.64mx0.12m 0.95mx0.526mx0.003m 3mm thick 8mm inner diameter , 10mm outer	Gross area=0.6656 Material: black painted stainless Steel Material: window glass Material: copper

	diameter, 0.08m tube center to center distance 0.75m length	Number of tubes: six
Bottom insulation	0.045m thick	Material: glass wool
edges insulation	0.03m thick	Material: glass wool

For current experimental study, a setup of flat plate collector was made in workshop and then erected at the roof top of the hall. The collector was oriented due south (using a compass) with a tilt angle of 45°. Photograph of experimental set up show flat plate collector, tank and instruments used along Experiments.

The frame where the box set up its 23º angle with the sun. which figure show in below.

Figure 2.6 The frame where the box set up .

Specifications of the collector components used in Table 1. It simply consists of an absorber plate (0.95m long, 0.64m wide, 0.003m thick), mounted on a wooden box and insulated from bottom and edges of the box with a glass wool insulation to minimize conduction losses. Finley, the box closed from top with a sheet of glass to transmit about 90% of the incoming shortwave solar irradiation and transmitting none of the long wave radiation emitted outward by the absorber plate and to prevent convection losses with the environment.

Experimental test set up involves a solar collector, closed working fluid system and measurement devices. The working fluid system has a tank, a paypass pipes system and simple manual valves used to control flow rate of working fluid. The flow rate is measured with the help of flow meter. A thermometer was installed to measure collector inlet and outlet fluid temperatures. The readings were collected and stored in a table.

Figure 2.7 Flat plate solar collector .

We continue our experiment in four month.Each month we take data from 11.00 am to 03.00 pm. The following graphs show the variation of output temperature with time on different days. This data has been taken only first 10 days of each month.

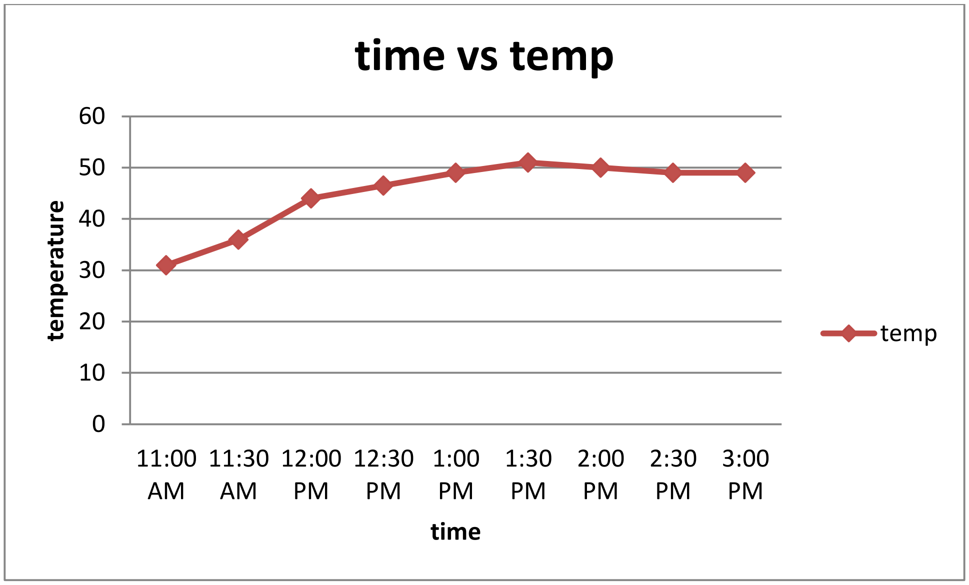
EXPERIMENTAL DATA :

May 1 :

Table : 1

Time	Temp (◦C)
11:00	36◦
11:15	38◦
11:30	40◦
11:45	43◦
12:00	47◦
12:15	50◦
12:30	54◦
12:45	55◦
01:00	57◦
01:15	57◦
01:30	57◦
01:45	57◦
02:00	56◦
02:30	55◦
03:00	53◦

Graph 1:

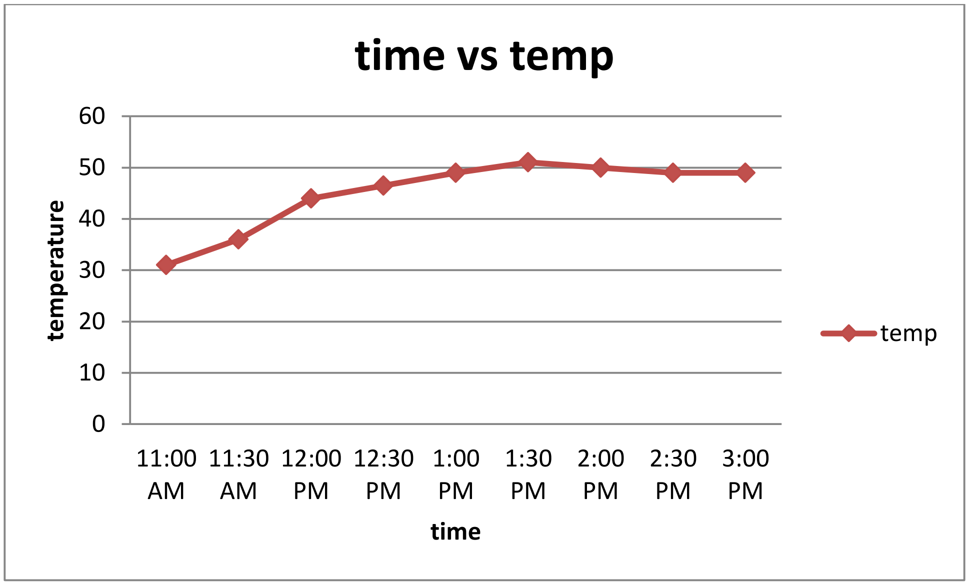

time vs temp
temperature
60
50
40
30
20
10
0
11:00 AM
11:30 AM
12:00 PM
12:30 PM
1:00 PM
1:30 PM
2:00 PM
2:30 PM
3:00 PM
time
temp

May 2

Table : 2

Time	Temp(◦C)
11:00	32◦
11:15	34.5◦
11:30	36◦
11:45	39◦
12:00	45◦
12:15	47◦
12:30	49◦
12:45	51◦
01:00	51◦
01:15	51◦
01:30	51.5◦
01:45	52◦
02:00	52◦
02:30	50◦
03:00	49◦

Graph 2 :

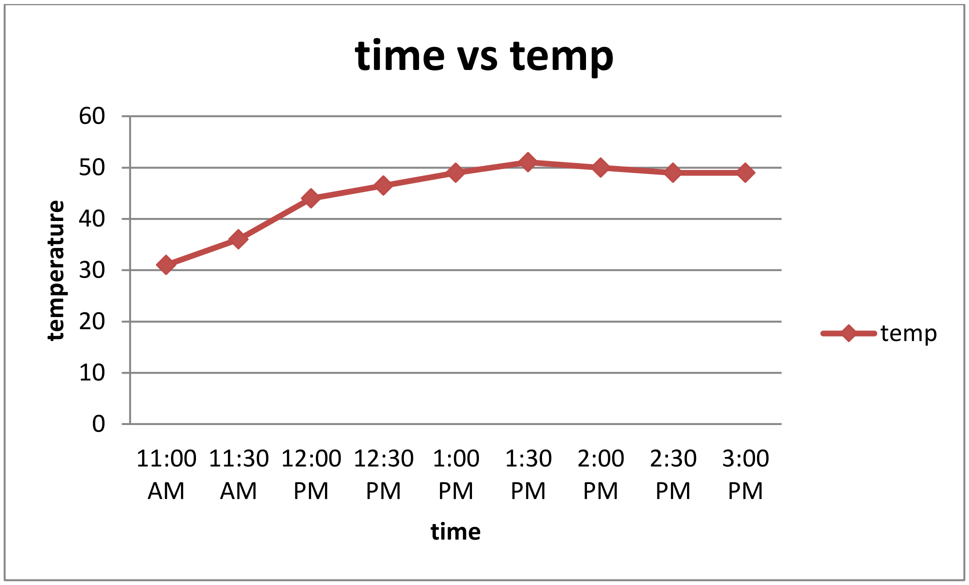


May 3:

Table 3 :

Time	Temp(◦C)
11:00	31◦
11:15	33◦
11:30	36◦
11:45	40◦
12:00	44◦
12:15	45◦
12:30	46.5◦
12:45	47◦
01:00	49◦
01:15	50◦
01:30	51◦
01:45	51◦
02:00	50◦
02:30	49◦
03:00	49◦

Graph 3 :

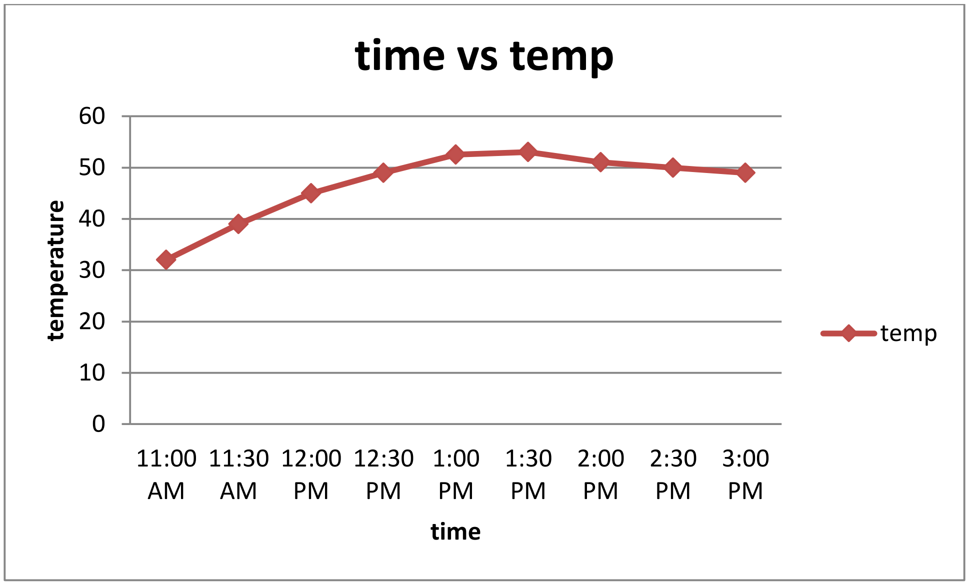


May 4:

Table 4 :

Time	Temp(◦C)
11:00	32◦
11:15	35◦
11:30	39◦
11:45	42◦
12:00	45◦
12:15	47◦
12:30	49◦
12:45	51◦
01:00	52.5◦
01:15	53◦
01:30	53◦
01:45	52◦
02:00	51◦
02:30	50◦
03:00	49◦

Graph 4 :

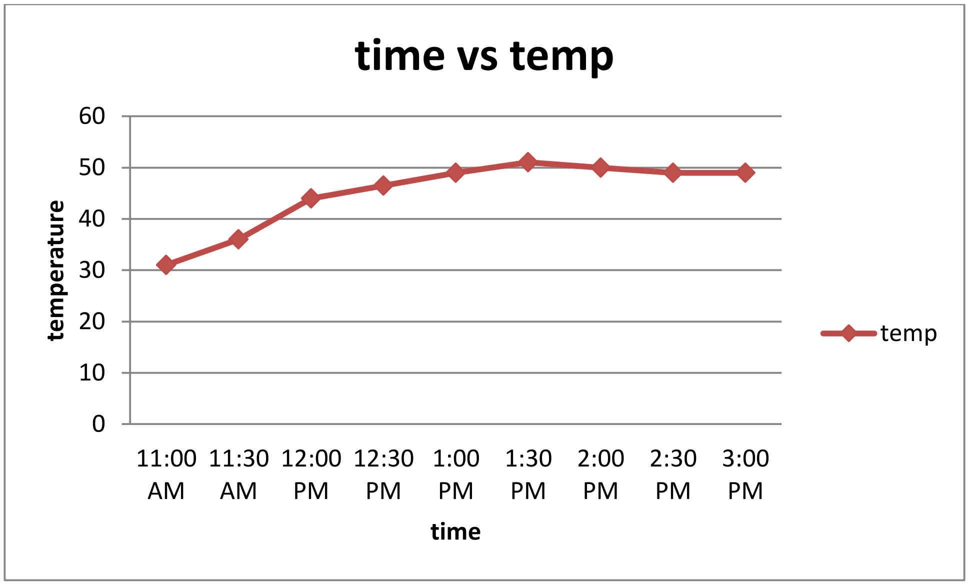


May 5 :

Table 5 :

Time	Temp(◦C)
11:00	34◦
11:15	37◦
11:30	41◦
11:45	43◦
12:00	45◦
12:15	46◦
12:30	46◦
12:45	48◦
01:00	50◦
01:15	51◦
01:30	53.5◦
01:45	55◦
02:00	54◦
02:30	54◦
03:00	52◦

Graph 5:

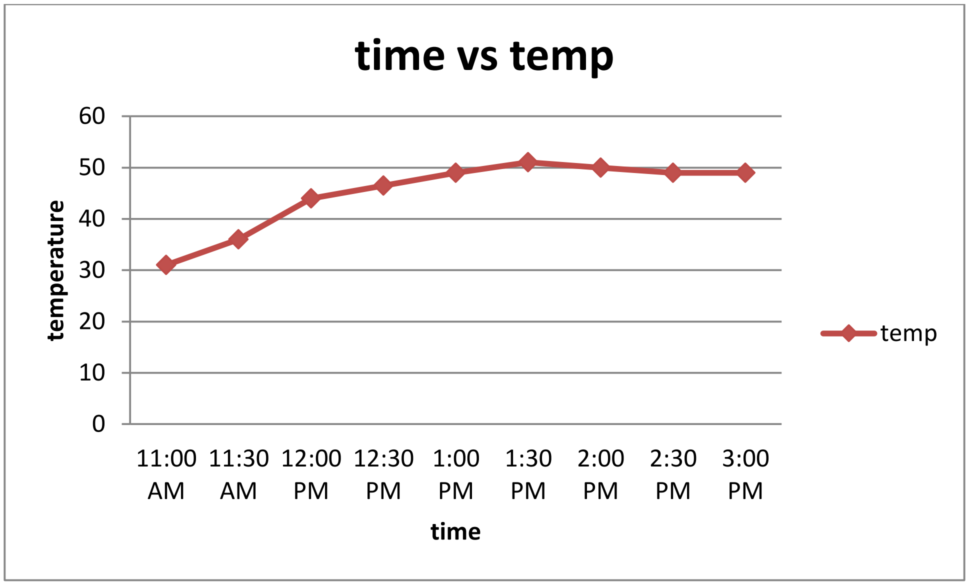


May 6:

Table 6 :

Time	Temp(◦C)
11:00	34◦
11:15	37.5◦
11:30	41.5◦
11:45	45◦
12:00	47◦
12:15	50◦
12:30	51◦
12:45	52.5◦
01:00	53◦
01:15	54◦
01:30	55◦
01:45	55◦
02:00	53◦
02:30	52◦
03:00	52◦

Graph 6 :

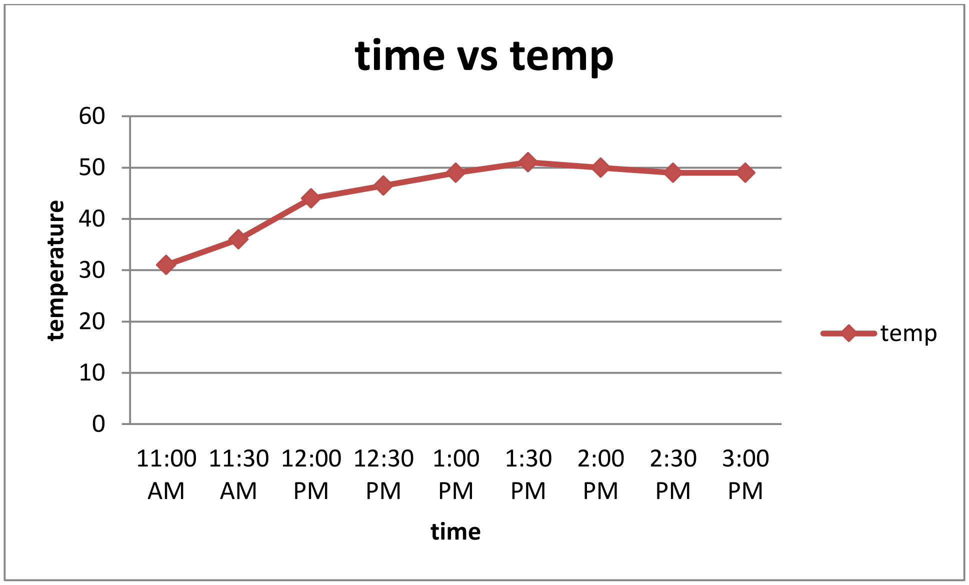


May 7 :

Table 7 :

Time	Temp(◦C)
11:00	30◦
11:15	32◦
11:30	34◦
11:45	37◦
12:00	41◦
12:15	45◦
12:30	47◦
12:45	48◦
01:00	48.5◦
01:15	50◦
01:30	51◦
01:45	51◦
02:00	49◦
02:30	48◦
03:00	47◦

Graph 7 :

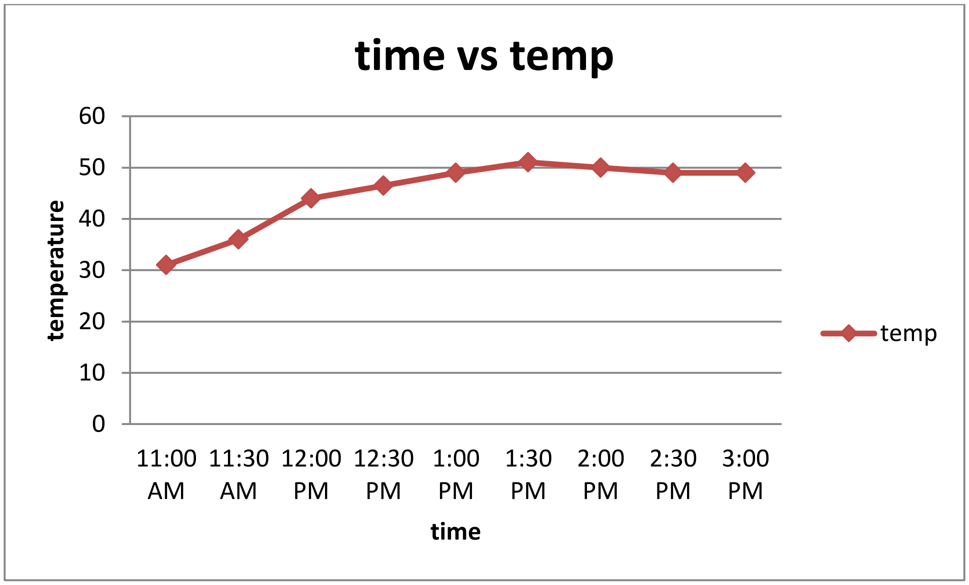


May 8 :

Table 8 :

Time	Temp(◦C)
11:00	33.5◦
11:15	35◦
11:30	37◦
11:45	40◦
12:00	45◦
12:15	47◦
12:30	50◦
12:45	51◦
01:00	52.5◦
01:15	53.5◦
01:30	54◦
01:45	54◦
02:00	53◦
02:30	52◦
03:00	51.5◦

Graph 8 :

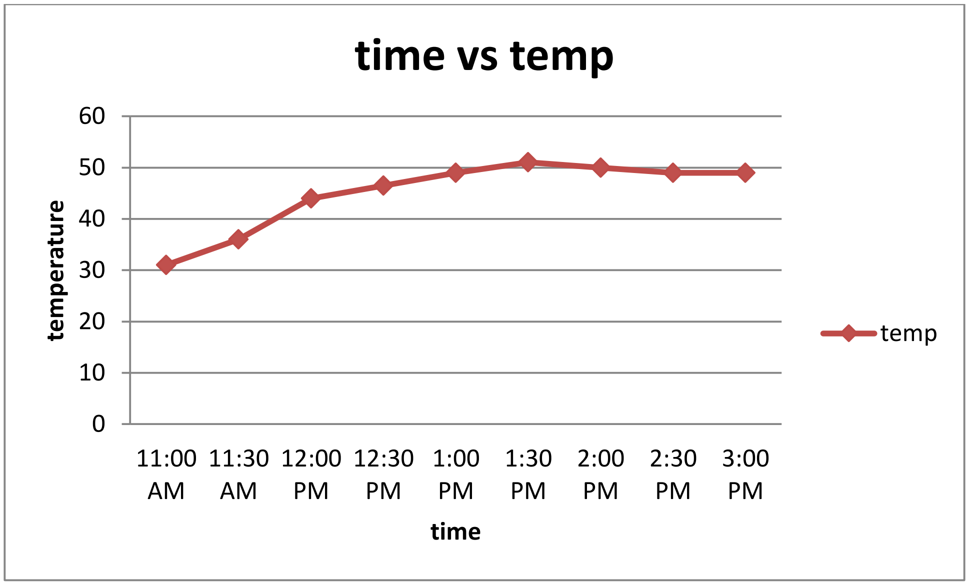


May 9 :

Table 9 :

Time	Temp(◦C)
11:00	35◦
11:15	36◦
11:30	38◦
11:45	39◦
12:00	40◦
12:15	43◦
12:30	47◦
12:45	50◦
01:00	53◦
01:15	55.5◦
01:30	56◦
01:45	55.5◦
02:00	54◦
02:30	53.5◦
03:00	52.5◦

Graph 9 :

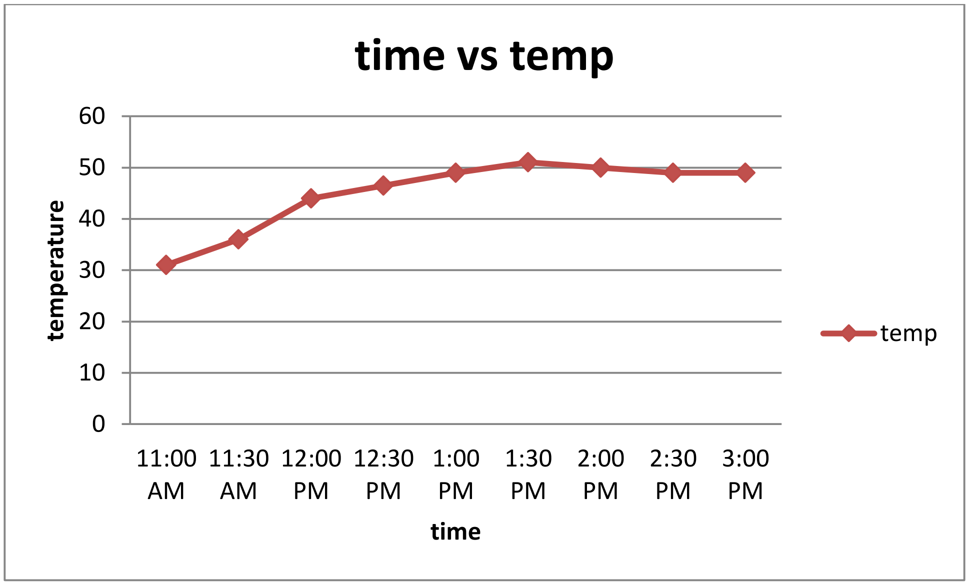


May 10 :

Table 10 :

Time	Temp(◦C)
11:00	35◦
11:15	38◦
11:30	40◦
11:45	43◦
12:00	45◦
12:15	47◦
12:30	49◦
12:45	50◦
01:00	53◦
01:15	56◦
01:30	56◦
01:45	54.5◦
02:00	53◦
02:30	52◦
03:00	51◦

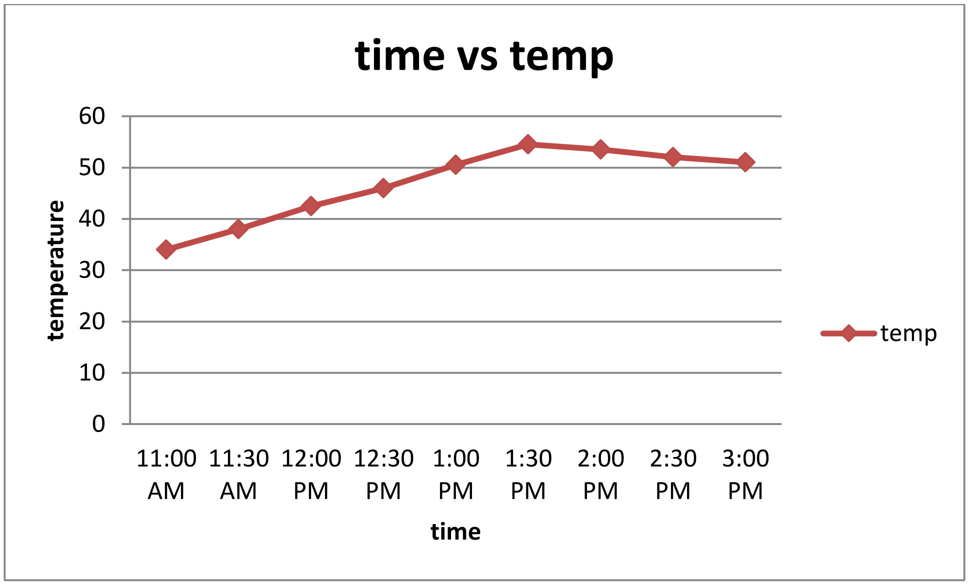
Graph 10 :



June 1 :

Time	Temp(◦C)
11:00	32◦
11:15	34◦
11:30	36◦
11:45	38◦
12:00	40◦
12:15	41◦
12:30	43.5◦
12:45	47◦
01:00	49◦
01:15	51.5◦
01:30	53◦
02:00	52.5◦
02:30	51◦
03:00	50◦

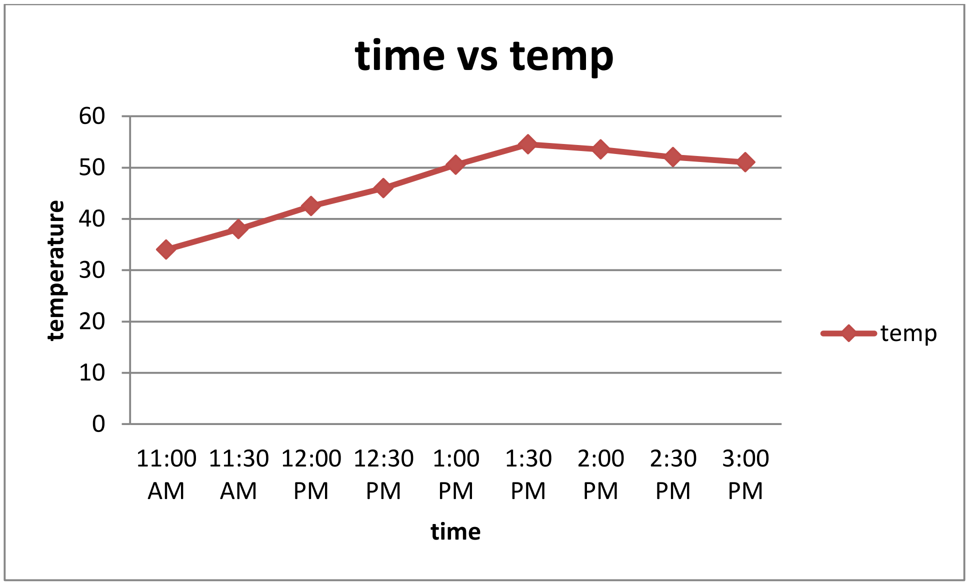
Graph 1 :



June 2 :

Time	Temp(◦C)
11:00	35◦
11:15	38◦
11:30	40◦
11:45	43◦
12:00	47◦
12:15	49◦
12:30	51◦
12:45	52◦
01:00	53◦
01:15	55◦
01:30	55◦
02:00	54.5◦
02:30	53◦
03:00	52◦

Graph 2:



June 3 :

Time	Temp(◦C)
11:00	36◦
11:15	39◦
11:30	40◦
11:45	42◦
12:00	43◦
12:15	45◦
12:30	47.5◦
12:45	50◦
01:00	52◦
01:15	54◦
01:30	56◦
02:00	56◦
02:30	55◦
03:00	54.5◦

Graph 3:

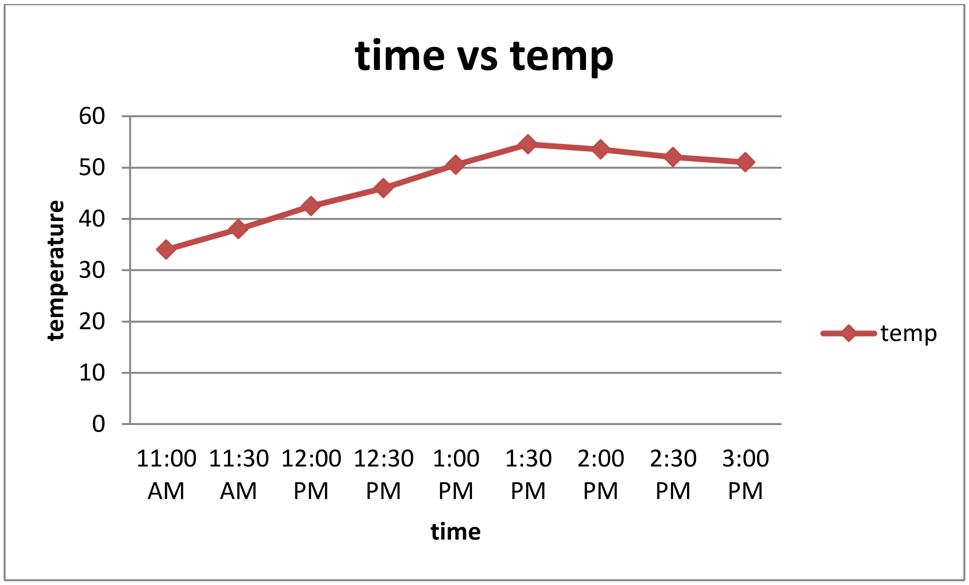


Table 4:

Time	Temp(◦C)
11:00	34◦
11:15	37◦
11:30	39◦
11:45	42◦
12:00	45◦
12:15	49◦
12:30	51◦
12:45	52◦
01:00	53.5◦
01:15	55◦
01:30	54.5◦
02:00	53◦
02:30	52.5◦
03:00	52◦

Graph 4:

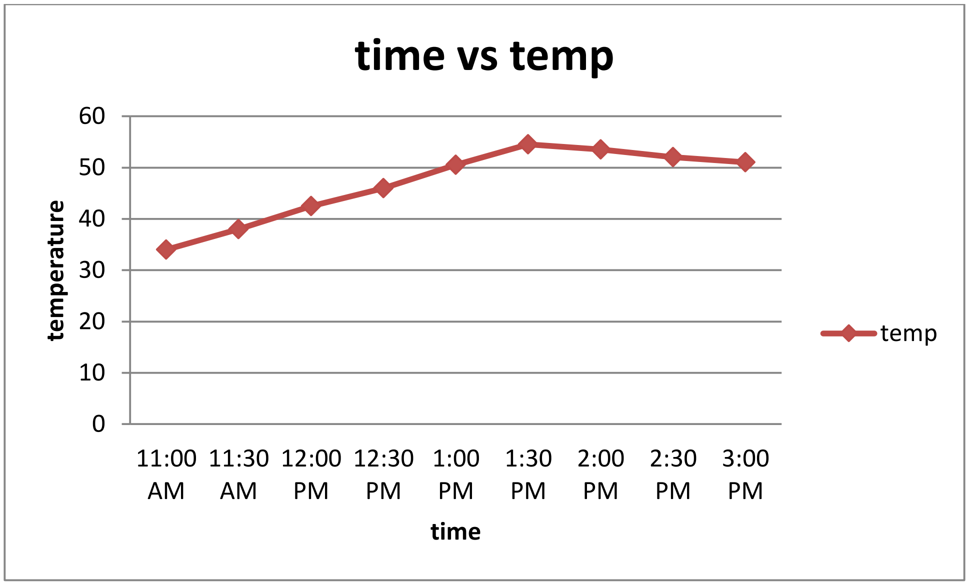


Table 5:

Time	Temp(◦C)
11:00	34◦
11:15	36◦
11:30	38◦
11:45	41◦
12:00	42.5◦
12:15	44.5◦
12:30	46◦
12:45	49◦
01:00	50.5◦
01:15	52◦
01:30	54.5◦
02:00	53.5◦
02:30	52◦
03:00	51◦

Graph 5 :

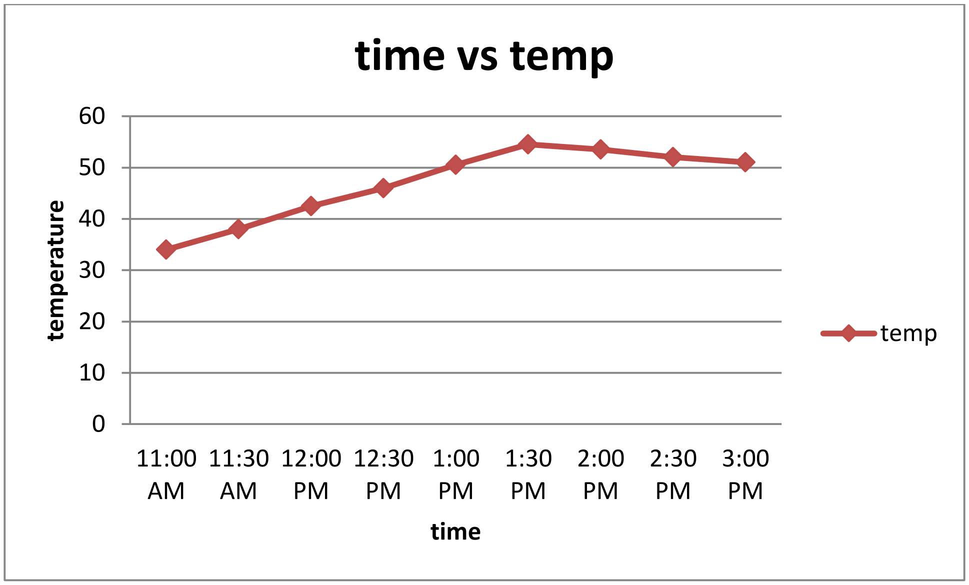


Table 6 :

Time	Temp(◦C)
11:00	31◦
11:15	33◦
11:30	36◦
11:45	39.5◦
12:00	42.5◦
12:15	45◦
12:30	47◦
12:45	49◦
01:00	51◦
01:15	53◦
01:30	54◦
02:00	53◦
02:30	52◦
03:00	51.5◦

Graph 6 :

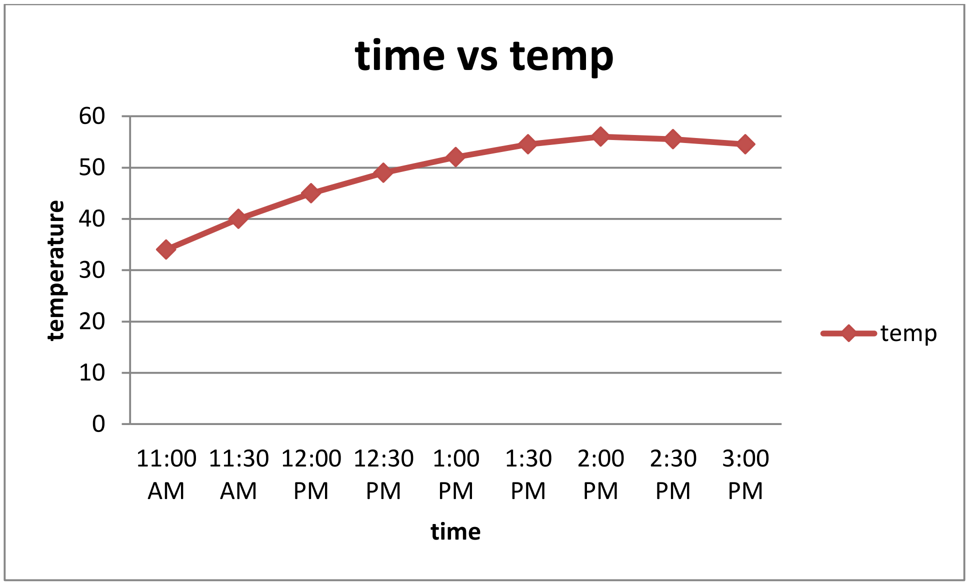


Table 7 :

Time	Temp(◦C)
11:00	32◦
11:15	34◦
11:30	37◦
11:45	39◦
12:00	41◦
12:15	44◦
12:30	47.5◦
12:45	50◦
01:00	52.5◦
01:15	53◦
01:30	53.5◦
02:00	53◦
02:30	52◦
03:00	51◦

Graph 7 :

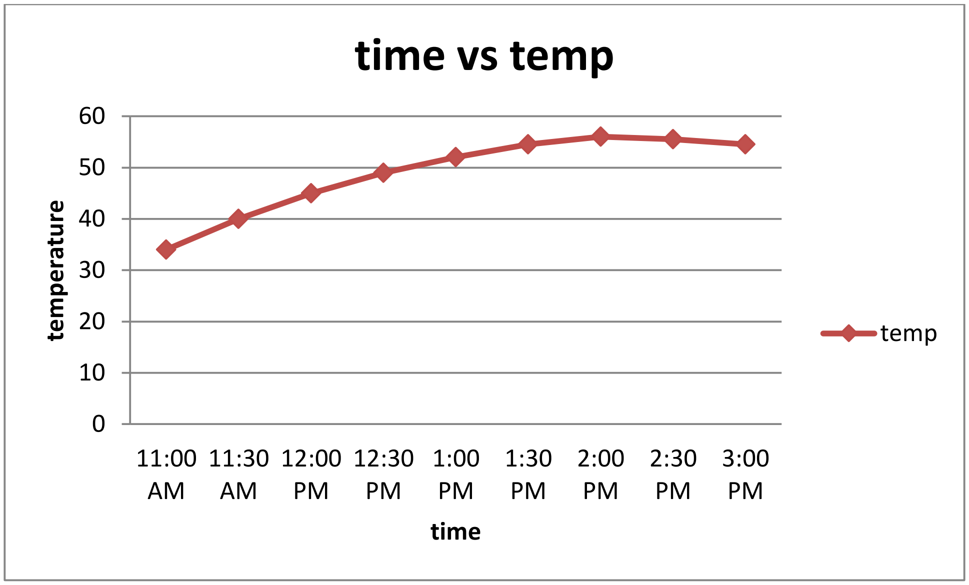


Table 8 :

Time	Temp(◦C)
11:00	33◦
11:15	36◦
11:30	38◦
11:45	43◦
12:00	45◦
12:15	47◦
12:30	50◦
12:45	51◦
01:00	52◦
01:15	53.5◦
01:30	53.5◦
02:00	54◦
02:30	53.5◦
03:00	53◦

Graph 8 :

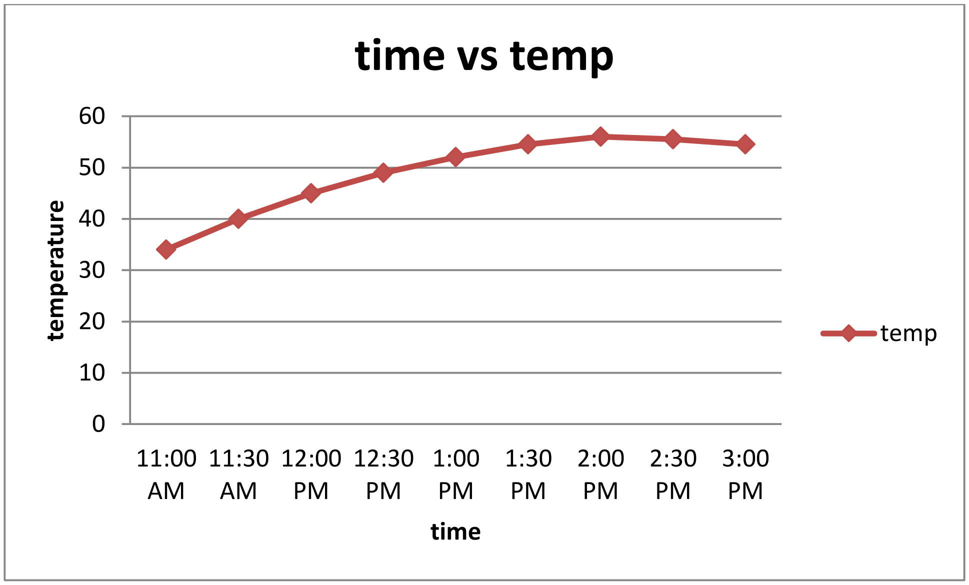


Table 9 :

Time	Temp(◦C)
11:00	31◦
11:15	33◦
11:30	35◦
11:45	37◦
12:00	39◦
12:15	41◦
12:30	43.5◦
12:45	47◦
01:00	49◦
01:15	51.5◦
01:30	51.5◦
02:00	52◦
02:30	51.5◦
03:00	50.5◦

Graph 9 :

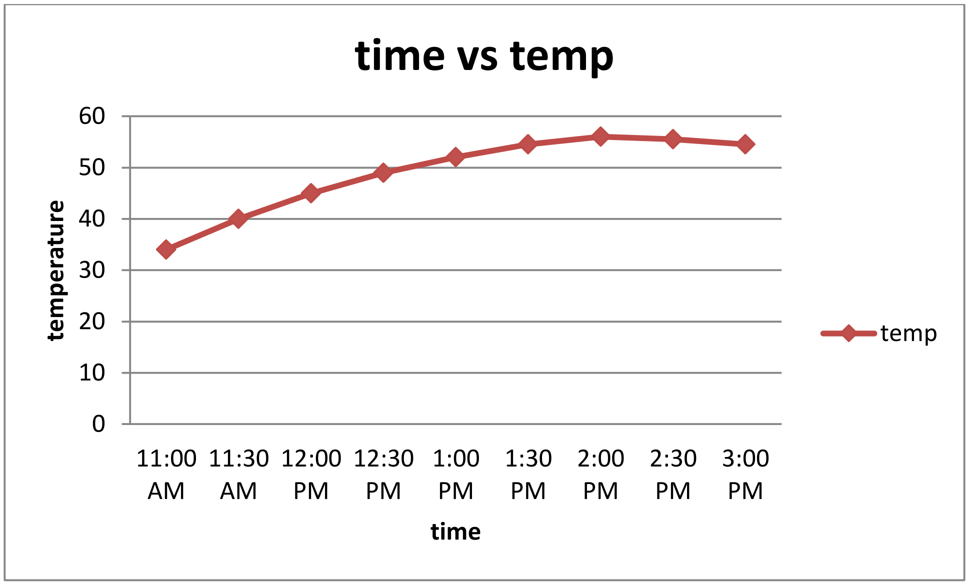
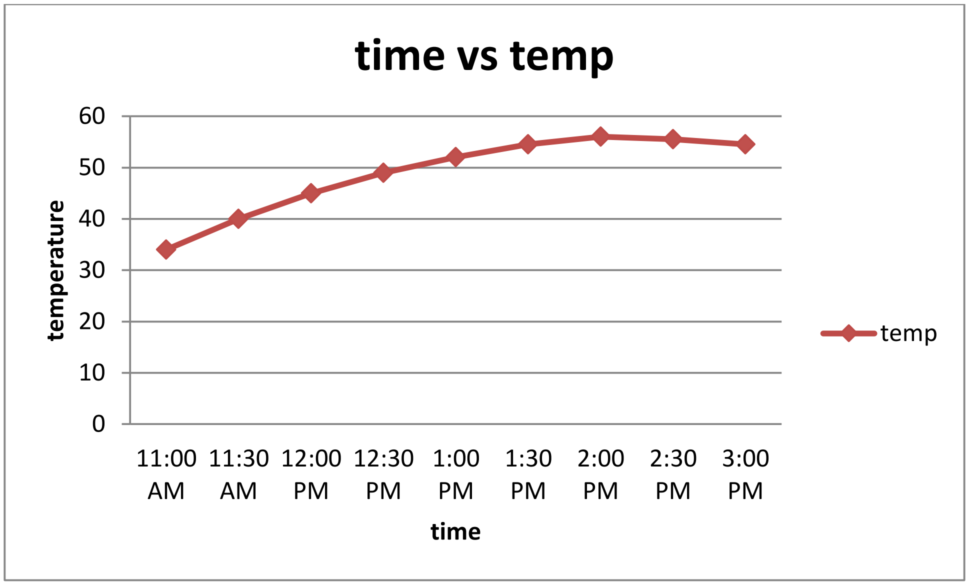


Table 10 :

Time	Temp(◦C)
11:00	34◦
11:15	37◦
11:30	40◦
11:45	42◦
12:00	45◦
12:15	47◦
12:30	49◦
12:45	51◦
01:00	52◦
01:15	53.5◦
01:30	54.5◦
02:00	56◦
02:30	55.5◦
03:00	54.5◦

Graph 10 :

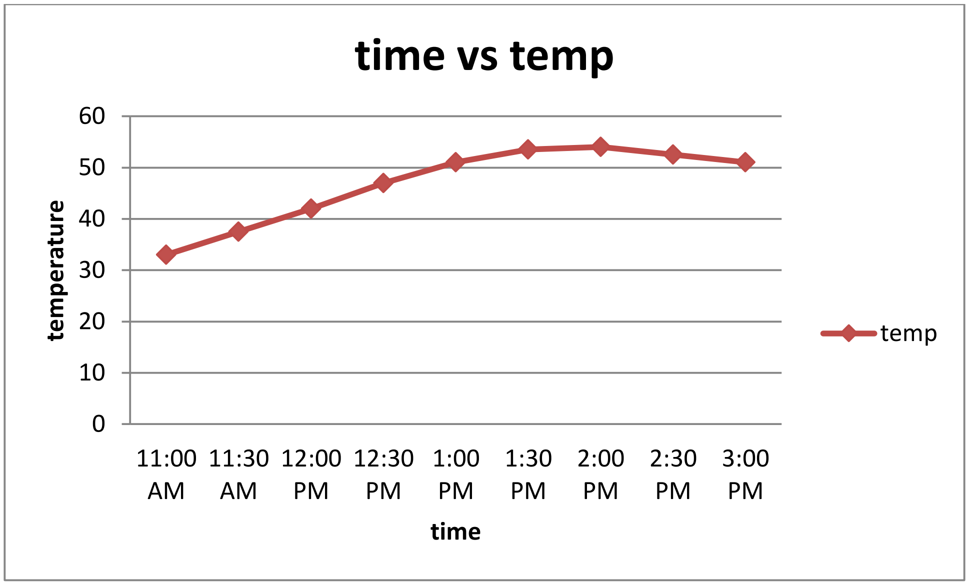


July 1:

Table 1:

Time	Temperature(◦C)
11:00	33◦C
11:15	35.5◦C
11:30	37◦C
11:45	39.5◦C
12:00	42◦C
12:15	45.5◦C
12:30	47◦C
12:45	48.5◦C
01:00	50.5◦C
01:15	52◦C
01:30	53◦C
01:45	53◦C
02:00	52.5◦C
02:30	51.5◦C
03:00	50◦C

Graph 1:

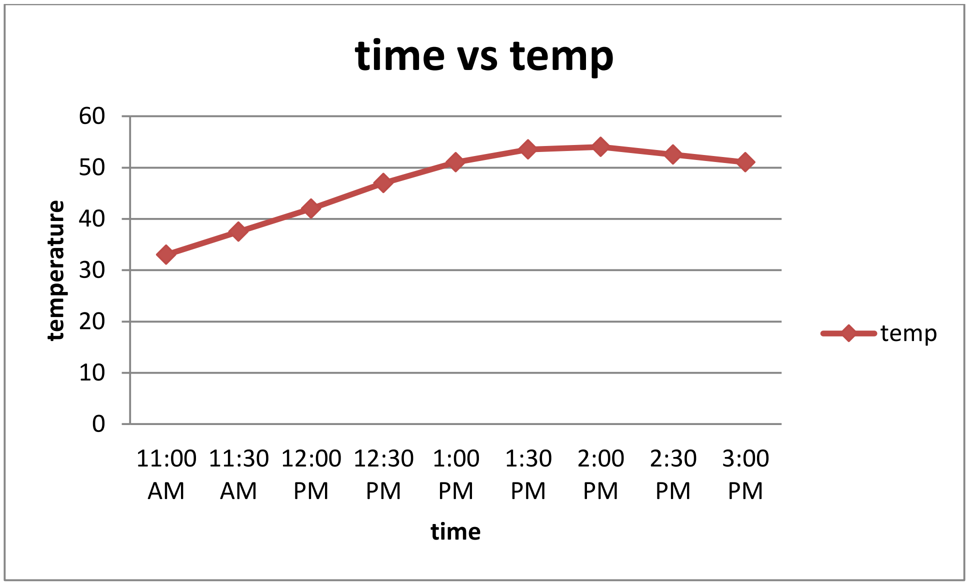


July 2:

Table 2:

Time	Temperature(◦C)
11:00	32◦C
11:15	33.5◦C
11:30	36◦C
11:45	38◦C
12:00	41◦C
12:15	43.5◦C
12:30	45◦C
12:45	47◦C
01:00	49.5◦C
01:15	51◦C
01:30	52◦C
01:45	52.5◦C
02:00	52◦C
02:30	51◦C
03:00	50◦C

Graph 2 :

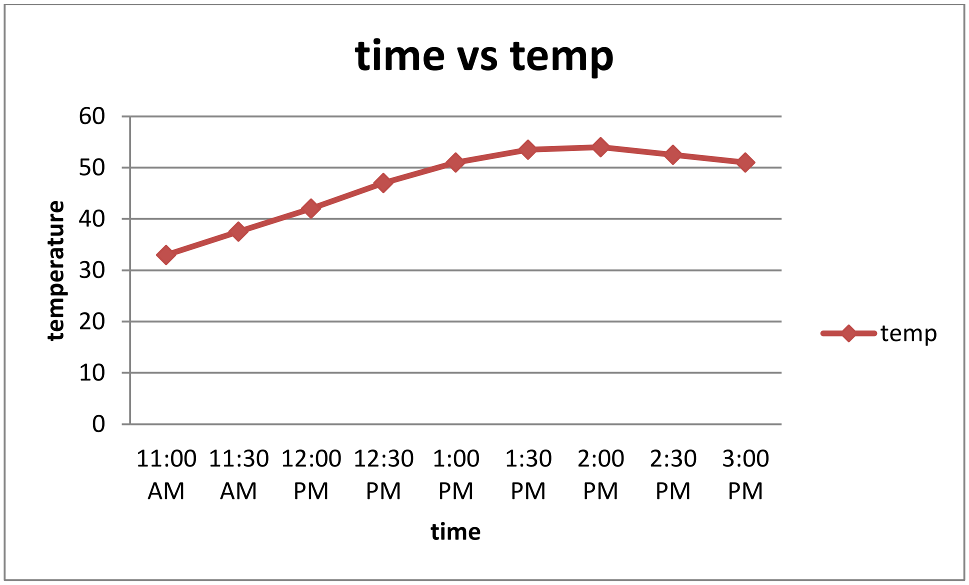


July 3 :

Table 3 :

Time	Temperature(◦C)
11:00	33◦C
11:15	35◦C
11:30	37.5◦C
11:45	39◦C
12:00	42◦C
12:15	44.5◦C
12:30	47◦C
12:45	49.5◦C
01:00	51◦C
01:15	53◦C
01:30	53.5◦C
01:45	54◦C
02:00	54◦C
02:30	52.5◦C
03:00	52◦C

Graph 3 :


time vs temp
60
50
40
30
20
10
0
temperature
11:00 AM
11:30 AM
12:00 PM
12:30 PM
1:00 PM
1:30 PM
2:00 PM
2:30 PM
3:00 PM
time
temp

CHAPTER 4

Results and Discussion

Efficiency Calculation: The steady state efficiency is calculated. All the heat loss coefficients are irrelevant because of the smaller size of the collector area. The actual mathematical modeling is done and the instantaneous efficiency is found to be almost same as that of the steady state value. The experiment has been conducted three different times on both the collectors and the average values have been taken into account for the following calculations.

Average Solar radiation received by earth in terms of energy R= 722 W/m^2/Hr. So, the absorbed energy for one hour is calculated. Solar radiation received by earth in 1 hours in terms of energy R = 722*1 W/m^2 /day.

R = 722 Wh/m^2, R = 10396800 W Sec/m^2, where,

A = Area of Flat plate collector in m^2 ,

T1 = Temperature of water at inlet inºC,

T2 = Temperature of water at outlet in ºC,

Mass of water taken in the storage tank = 35 liters,

Specific heat of water, Cp =4.182 kJ/kg K

Area of the flat plate collector,A = L*W m^2, = 1.04*0.64, = 0.6656 m^2 Radiation received by collector,

R1 = R*A, = 10396800*0.6656, =6920110.08 Joules

Output of the Stationary Collector,Q = 35*4.187*(32 – 58), = 35*4.187*10^3*(26), =3810170

Efficiency of Conventional flat plate collector, = Output of the collector / Input Radiation, = M*Cp*(T2 – T1) / R*A, = 3810170 Joules / 6920110.08 Joules, =55%

In our experiment we have seen that at the initial position the water temperature was low.When we continue heat this by the evacuated tube this temperature rise up, and measure this temperature after 15 min later.we see that this temperature conitiniously rise up at a definite time after that it continuosly decreases.From this time vs temperature graph we have got a peak point at approximately 01.45 pm. Then after that its temperature continuously decreases.

CHAPTER 5

Conclusions

Research has been conducted with the aim of enhancing the heat transfer in a passive flat plate solar water collector using a cost effective technique that could be easily applied in a typical (conventional) flat plate collector without changing or redesigning its shape. The literature review performed in this work suggested that previously designed models as described in Chapter 2 achieved the increase in the efficiency of the collectors by using relatively expensive design solutions which in some cases made the product bulky, heavier and therefore difficult to install and exploit. This could result in putting off customers from buying solar collectors and use renewable energy technologies especially in the current economic crisis conditions. Furthermore the highest efficiency was achieved in the cases where the convection heat transfer was enhanced by the means of fins within the pipes.

We continue our experiment in four month.Each month we take data from 11.00 am to 03.00 pm. The following graphs show the variation of output temperature with time on different days. This data has been taken only first 10 days of each month.

The efficiency can be increased if we increase the area of the solar collector.

CHAPTER 6

References

1. Duffie, J. A., and W. A. Beckman, Solar Engineering of Thermal Processes, John Wiley and Sons, New York, 1991.
2. United States, Department of Energy, Solar energy technologies Program http://www1.eere.energy.gov/solar/solar_time_1767-1800.html
3. California solar centre, http://www.californiasolarcenter.org/history_pv.html
4. Ken Butti, John Perlin A Golden Thread, Published by Van Nostrand Reinhold Company, 1980.
5. Charles Smith, History of Solar Energy Revisiting, Past Solar Power Technology Review, 1995.
6. The Kentucky Solar Partnership, http://www.kysolar.org/
7. International Energy Agency of Solar Heating and Cooling Programme, Data-Annual Report 2001.
8. S. Kalogirou, Solar thermal collectors and applications, Progress in Energy and Combustion Science 30, 231–295, 2004.
9. U.S. Department of Energy - Energy Efficiency and Renewable Energy Solar Energy Technologies Program. http://www1.eere.energy.gov/solar/
10. International Standard, ISO 9806-1, Test methods for Solar Collector's Thermal performance of glazed liquid heating collectors, 1996.
11. Mahjouri F, Stiteler R, Walker A, Evacuated-Tube Heat-Pipe Solar Collectors National Renewable Energy Laboratory, 2004.
12. Innovators in Solar, INS-SOLAR, http://www.ins-solar.com/index.html
13. George Simons, Joe McCabe, California Research and Development, Energy Research and Development Division, 2005.
14. Solar Thermal Technology Department Sandia National Laboratories Albuquerque. http://solstice.crest.org/renewables.
15. G. W. Treadwell, Low-Temperature Performance Comparisons of Parabolic -Trough and Flat-Plate Collectors Based on Typical Meteorological Year Data, Sandia National Labs,Report 1979.
16. Hans Muller, Franz Tried, Institute Of Technical Thermodynamics, (DLR), power point presentation, Stuttgart, Germany.
17. L F. Caslake, D J. Connolly, V Menon, CM. Duncanson, R Rojas and J Tavakoli, Disinfection of Contaminated Water by Using Solar Irradiation, Appl. Environ Microbiol.70, 1145–1150, 2004.
18. Amnon Einav, Solar Energy Research and Development Achievements in Israel and Their Practical Significance Sol. Energy Eng. Volume 126, 92, 2004.
19. P.Konttinen, R.Kilpib, P.D.Lund, Micro structural analysis of selective CyAl2O3yAl solar absorber surfaces, Thin Solid Films 425, 24–30, 2002.
20. P. Konttinen, P.D. Lund, Mechanically manufactured selective solar Absorber surfaces Solar Energy Materials & Solar Cells 79, 273–283, 2003.

21**.** Iordanou, Grigorios Flat-Plate Solar Collectors for Water

Heating with Improved Heat Transfer for Application in Climatic Conditions of the Mediterranean Region, Doctoral thesis, Durham University. Available at Durham E-Theses Online: http://etheses.dur.ac.uk/174/ **(2009)**

22**.** Rhushi Prasad P., Byregowda H.V. and Gangavati P.B. Experiment Analysis of Flat Plate Collector and Comparison of Performance with Tracking Collector, *European Journal of Scientific Research*, **40(1)**, 144 -155, **(2010)**

23**.**Sukhatme SP Solar energy, McGraw–Hill, NY, 83-139, **(1993)**

24. Norton B., Anatomy of a solar collector: Developments in Materials, Components and Efficiency Improvements in Solar Thermal Collector Systems, **7,** 32-35 **(2006)**

25**.** Fabio Struckmann, Analysis of a Flat plate Solar

Collector, Renewable Energy Technology **(2008).**

26.KISHORE, V.v. ., M.R. GANDHI and K.S. RAo. 1984. Analysis of flat plate collectors charged

with phase changing fluids. *Applied Energy* 17(2): 113-149.

27.MAHAR, .M. 1985. Performance and testing of an improved solar water heater cum

steam cooker. *Energy Research* 9: 113-116.

28.NORTON, B. and S.D. PROBERT. 1984. Achieving thermal rectification in natural circulation

solar water heaters. *Applied Energy* 14(3): 211-225.

29.PRAKASH,]., H.P. GARG and G. DATTA. 1985. A solar water heater with a built in latent heat

storage. *Energy Conversion Management* 25(1): 51-56.

30.QUDAlS, M.A., T. TAMlMl and F. AI MOMANI. 2002. Experimental study of a tubeless convex

type solar collector. *Energy Conversion and Management* 43: 791-797.

31.REDDY, B.S. 1995. Electrical vs solar water heater: A case study. *Energy Conversion and*

Management 36(11): 1097-1106.

32.RUDI CH, A., Y. KAPLAN, A.I. KUDISH and D. WOLY. 1986. A study of solar collector-aging,

installation and materials problem. *Solar Energy* 36(3): 227-240.

33.SAIFUL-BARI. 2001. Optimum orientation of domestic solar water heaters for the low

latitude countries. *Energy Conversion and Management* 42: 1205-1214.

34.SOROUR, M.M. 1985. Developments in solar water heaters. *Energy Conversion Management*

25(3): 365-372.

35.YADAV, Y.P. and G.N. TIWARI. 1987. Transient analysis of double pipe heat exchanger

coupled to flat plate solar collector. *Energy Conversion Management* 27: 15-19.

36.YILMAZ, T. and R.T. OGULATA. 1990. Influence of the tank height on the efficiency