MENG 411 Capstone Team Project

Eastern Mediterranean University

Faculty of Engineering

Department of Mechanical Engineering

Design and construction of Heat Exchanger for a Solar Parabolic Dish Collector

Course Coordinator

Assist. Prof. Dr. Mostafa Ranjbar

Supervisor
Prof. Dr. Uğur Atikol

Team Members

Joel Ikechukwu David	**118305**
Mayowa Familade	**118648**
Abdullah Awad	**138942**

Group Name: Parabolas

CAPSTONE TEAM PROJECT FALL 2015-2016

JURY MEMBERS

Prof. Dr. Uğur Atikol (Supervisor)	
Assoc. Prof. Dr. Qasim Zeeshan	
Assist. Prof. Dr. Murat Özdenefe	

ABSTRACT

The present project is concerned with the design and construction for a heat exchanger to be used in the focal point of a solar parabolic dish collector. The main aim of the project is to use solar radiation that will shine on the solar parabolic dish to heat the working fluid (such as water) to generate hot water or steam. Among the many application this system can be used are heating processes, generating electricity and absorption chillers. The project utilized a solar parabolic dish which was covered with Aluminum foil which is a good reflective material and the heat exchanger is made up of copper because copper is a good conductor of heat. After the design and manufacturing of the system, the experiment was carried out during fall season on two separate days which had a solar intensity reaching a maximum of 1152.59 W/m^2 . Both the inlet and outlet of the heat exchanger was measured with a K-type thermocouple. The experiment was performed at a constant flow rate of 0.4L/min for the flowing water and it was checked at intervals of 5minutes and the temperature increases from 17 ℃ to about 69 ℃ in 30 minutes.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

NOMENCLATURE

A_a: *aperture area* (m^2)

$A_¿$ |¿| : absorber area m^2 ¿)

C: *concentration ratio*

C_{pw}: *specific heat capacity of water at constant pressure* (J/kg.k)

D_a: *aper ture diameter* (m)

F_R: *heat removal factor*

F : *focal length* (m)

I_b: *beam radiation* (W/ m^2)

$\acute{I}_D$: *long term average direct radiation* (W/ m^2)

h: *height of the dish* (m)

$\acute{m}_w$: *rate of heating water* (kg/s)

|¿|: *rate of energy absorbed by the absorber* $P_¿$ (W)

$\acute{Q}$: *useful thermal energy deliverd* (W)

T_1: *temperature of heat transfer fluid entering the collector* (℃)

T_2: *temperature of heat transfer fluid leaving the collector* (℃)

T_a: *ambient temperature* (℃)

T_w: *temperature of water* ($℃$)

t: *time is second* (s)

t_x: *thickness of absorber wall* (m)

U_L: *overall heat loss coefficient* (W/m²K)

V_w: *volume of water* (L)

η: *instaneous thermal efficiency* ( ) / η_o: *optical efficiency* ( ) /

Ψ_{rim}: *rim angle*

CHAPTER 1

INTRODUCTION

1.1 Background

Solar energy is for sure the most ancient source of energy since the beginning of time. It is the radiant light and heat energy emitted by the sun and harnessed using a wide range of new evolving technologies. It is of a truth an important source of renewable energy and its related technologies are widely characterized as either passive solar or active solar depending on the way the energy is being captured, distributed or converted into solar power. For the past centuries, solar energy has been increasingly used to either to produce electricity or to satisfy various human wants. The distance between the earth and the sun is about $1.496*10^{8} km$ yet the earth receives 175000 terawatts (TW) of incoming solar radiation at the upper part of the atmosphere despite the distance apart from the sun [2]. Roughly 30% of this radiation is reflected back to space while the remaining is absorbed by land masses, clouds and oceans [2]. The energy absorbed by land masses and oceans keeps the surface at a mean temperature of 17ºC. Through photosynthesis, green plants metamorphose solar energy into chemical energy which produces food, biomas from which fossils fuels are derived and woods. Without the energy from the sun all life on earth will end. A simple example of the power of the sun can be seen by using a magnifying glass to focus the sun rays on a small amount of water. Before long the water begins to heat. This is one way of using the suns energy but it is not efficient enough to boil water unless by applications of many numbers of magnifying glasses. A more practical and reliable way is by using a solar parabolic dish collector.

Solar parabolic dish collectors are the most powerful type of collectors because they are one of the concentrated solar thermal collectors used for energy conversion and power generation by concentrating sunlight radiation at a single point known as the Focal point. Parabolic dish systems comprises of a parabolic shaped point focus concentrator that is in the form of a dish that reflects sun rays onto a receiver (heat exchanger or generator) stationed on the focal point where all energy is concentrated. In order to avoid confusion of the phraseology, the term collector will be applied to the total system, including the receiver and the concentrator. The receiver is an element of the system where the heat radiation is absorbed and then converted to another form of energy; it includes the absorber, its associated covers and insulators. The concentrator, or optical system, is that part of the collector that directs radiation onto the receiver. The opening of the concentrator is the gap through which the solar radiation enters the concentrator.

1.2 Problem definition

As stated above, the aim of this project is to design a heat exchanger which will function as a medium to heat water into steam. However, there seems to be a problem in the design of this project. The related problem is to design and construct a small and light weight heat exchanger at the focus of the parabolic dish collector. This is because the total area of all the concentrated energy from the sun to the focus is not so large and as a result the concentrated energies at the focus will not completely encompass the heat exchanger.

1.3 Objective of project

The ultimate purpose of this research is to design and construct a small and concise heat exchanger for a solar parabolic dish concentrator that heats fluid (such as water) to a high temperature at a high flow rate

1.4 Limitations and span

In as much as solar energy is beneficial to this project there are also related limitations, notwithstanding the fact that they are not so plentiful. The initial cost of purchasing and installing solar parabolic dish collectors always become the first disadvantage. Despite the fact that allocation programs, tax initiatives and rebate incentives are given by the government to promote the use of parabolic collectors we are still way behind in making full and efficient use of solar energy. As new technologies show up, the cost of parabolic collectors is likely to decrease. Implementing this project on a full scale in rural areas will require more than just one parabolic dish collector. As a matter of fact, multiple parabolic dish collectors will bring about more electricity but at the same time it will require large land mass region to mount the dishes (installation area) which can be a bit costly. Location of parabolic collectors is of a major importance in generating electricity, areas which remains mostly cloudy and foggy will produce electricity but at a reduced rate and this may also be a reason to install more parabolic collectors to generate enough electricity.

Availability of the sun is usually not constant for 24hours here on earth therefore solar energy proves to be useless during the night and another limitation is the fact of tracking the sun during the day in order to get optimum heat radiation.

This project will deliberate about the topic of solar parabolic dish collector by first giving information of other research work done on the subject-literature review, afterwards explaining the methodology, design manufacturing, calculation and then ends with a conclusion and discussion.

1.5 Report organization

The Chapter 2 of this report will discuss the literature review of the previous studies done by the past scientist. The Chapter 3 will contain the design analysis of the system such as equations. The Chapter 4 and 5 will elaborate on the manufacturing, assembly, testing, results and discussion, and also the design improvement. Chapter 6 focuses on the conclusion and future work as regards to the project while the references and appendices comes after

CHAPTER 2
LITERATURE REVIEW

2.1 Information

The use of solar energy is not widely spread until the 18th century where it is been used for many applications like solar water heater, burning mirrors to light torches, renewable energy, generating electricity. A solar parabolic dish collector is used to gather together rays from the sunlight. The shape of the device is parabola because the sun rays falling on the dish are parallel to one another and the parabolic dish will reflect the rays back at a focal point. This will only happen if and only if there is a reflector on the dish, like glass or aluminum plate. Meanwhile, losses reflected sun rays in any solar parabolic dish collector are due to imperfections of the dish shape. The glass and aluminum are both materials that have the ability to reflect sun rays just because of the way they gloom. At the focal point where the light rays are been concentrated is been used for some things like putting a heat exchanger for boiling water, cooking pot for cooking food or a turbine for generating electricity.

2.2 Previous researches

The second research titled Heat Exchanger Market by Type (Shell & Tube, Plate & Frame, Air Cooled, Printed Circuit), by Application (Chemical, Petrochemical, Oil & Gas, HVACR, Food & Beverage, Pulp & Paper, Power Generation), Classifications (MoC, Temperature Range & Fluid Type) and Geography, Trends & Forecast to 2019 says European region is the biggest market of heat exchangers, accounting for more than one-third of the total heat exchangers demand [3]. Currently, Europe acquires more than 30.0% of the total global market. Heat exchanger consumption in the region is estimated to grow at a CAGR of around 4.81% from 2014 to 2019. There is a lot of scope in the Asia-Pacific heat_exchanger_market due to the surging demand for energy in the region. With the emerging technological developments and innovations in the region, the demand for heat exchangers may further augment at a higher pace. It is estimated to grow at a CAGR of 10.70% for the next five years [3].

2.3 Solar energy one power plant 1913

The Concentrated Solar Power (CSP) plant is the first documented Solar Engine [4]. In the year 1912 the building of the solar parabolic trough collector started for the irrigation pumping station. The location of the place for the construction of the concentrated solar power plant lies on the River Nile south of Cairo, a water mineral resort town. The Solar engine had a capacity of 100 brake HP. The solar engine one was developed by a USA inventor called Frank Shuman [5]. Five parabolic concentrating reflectors were builds then, each of these collectors was 62m long, 4m wide, with 7.6m spacing facing the sun from east to west. This project or construction was supported by a man called Lord Kitchener who offered 12000 hectares of land for cotton plantation in Sudan.

2.4 Augustin Bernard Muochot (1825- 1912) truncated one solar engine

Augustin Bernard is best known as a mathematics lecturer in France, Lychee de Tour to be precise [6]. He was the one that built a solar engine using a truncated cone dish. As a mathematician, he thinks about the future that coal which was an industrial fuel at that time would run out as time goes on. Is fear that time was that if there is no more coal, what would happen to all the industries. In the year 1860 he performed an experiment which was his first experiment with a solar cooking device. Initially he used Iron cauldron surrounded with a glass of which solar radiation goes through it and boil the water. However, the pressure and amount of steam were not that good. He realized that the addition of reflector could produce more steam to operate the steam engine. Later on he constructed a solar engine in the form of a truncated cone and he refined the reflector for a better the improvement in capacity. The steam engine powered a water pump and on a sunny day produced a power of half HP (1/2 HP).

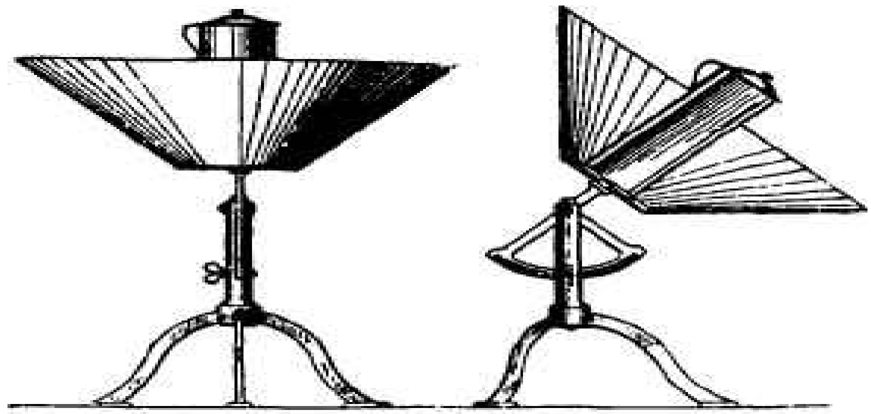


Figure 2.1 Mouchot design [6]

In figure 2.1 above shows the design of the great mathematician whose project was supported the French Government.

The Government (French) also share in the view that coal might finish anytime soon. They decided to sponsor Augustin's project by constructing a larger boiler seventy liters of water and thirty liters of steam boiler for a whole city called Constantine in Algeria. The project was improved with the use of multi-tube boiler which makes it for larger heat transfer water which yields a high amount of steam pressure and good performance.

Other countries and companies also built the solar parabolic dish collector for the help of the people and the nation at large. In table 2.1 below it shows the some other review on the past projects as far as solar parabolic dish collector is concerned. There are many others that are really efficient however few have been mentioned below.

Table 2.1 Countries company project

PROJECT	LOCATION (MWe)	CAPACITY (MWe)	TOTAL CAPACITY	COMPANY AGENCIES
Parabolic dish	Egypt	127	29	GEF grant
Parabolic dish	Greece	50	50	OADYK EU
Parabolic dish	Israel	100	100	Israel ministry of National Infrastructure
Parabolic dish	Italy	40	40	ENEA
Parabolic dish	India	140	35	GEF grant
Parabolic dish	Algeria	140	35	New Energy

In conclusion, there has been improvement in the solar parabolic dish collector compared to the old ways of doing it, improvement in the type of material to be used for the reflector and the dish itself, and improvement in the efficiency of the dish which gives better performance.

Figure 2.2 Solar parabolic dish [7]

In figure 2.2 above shows examples of solar parabolic dish collector used for cooking and heating metals respectively. This same invention could be used to generate electricity.

CHAPTER 3
DESIGN AND ANALYSIS

3.1 Overview of system

In order to victoriously design and develop a functional solar parabolic dish collector, certain major components must be made available. The major components of this system are the solar parabolic concentrator which is mainly used for the collection of sunlight from a large region by focusing it on a single point and the heat exchanger which is placed at the focus.

The reflective material used in reflecting the sun rays off the parabolic dish is the aluminum reflector. Aluminum appears to be a non-ferrous metal, it is quite easy to shape and suitably perfect for all types of machining. After bending, stamping, treatment of surface, process of machining and shaping, its performance can be better to meet the production of different aluminum products. Aluminum is recognized for its low density and ability to withstand corrosion. Aluminum reflector is one of the most reflective metals in the world due to the fact that it has a mirror like surface and is made from very high purity aluminum with photometric qualities to control light.

Heat exchangers are devices that enhances the transfer of heat between two fluids (gas or liquid) that are at separate temperatures while keeping them from contacting each other. Heat exchangers are usually used in practice in a vast range of applications, from air-conditioning systems and heating in a household, to power production in large plants and chemical processing. Majority of heat exchangers can either exists as parallel flow heat exchangers or counter-flow heat exchangers. In the case of the parallel flow heat exchangers, the two fluids move in the same direction while for the counter-flow heat exchangers the two fluids move opposite in direction.

3.2 Alternative design

An alternative design can be a solar parabolic trough collector. This is a type of solar thermal collector that is straight in one dimension and curved as a parabola in the other two, lined with a polished metal mirror. The energy of sunlight which enters the mirror parallel to its plane of symmetry is focused along the focal line, where objects are positioned that are intended to be heated. Parabolic trough concentrators have a simple geometry, but their concentration is about 1/3 of the theoretical maximum for the same acceptance angle, that is, for the same overall tolerances of the system to all kinds of errors [7]. The theoretical maximum is better achieved with more elaborate concentrators based on primary-secondary designs using non imaging optics which may nearly double the concentration of conventional parabolic troughs and are used to improve practical designs such as those with fixed receivers. An elaborate depiction of a parabolic trough is shown in the figure 3.1 below.

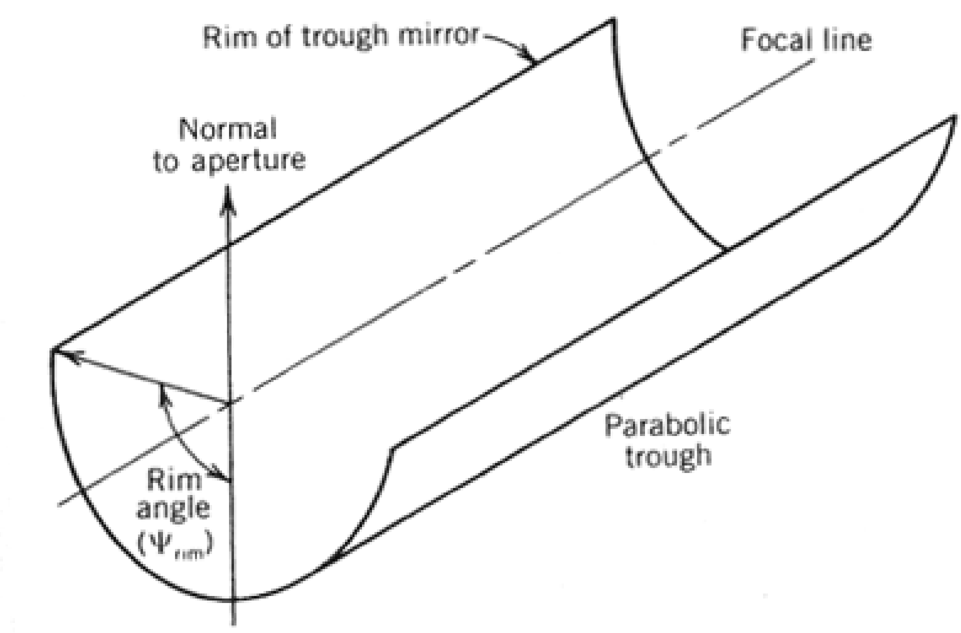


Figure 3.1 Parabolic trough collector [7]

3.3 Initial design consideration

Having chosen a parabolic collector over a trough collector was due to the fact that a parabolic collector is more powerful and it focuses all the energies from the sun at a single point. The initial design proposal of the heat exchanger that is designed for this system was neither a parallel nor counter flow heat exchanger. The design of the heat exchanger was based on having series of in-line copper tubes were both ends of the tubes will be connected to two semi-circular copper tubes. Water goes in through one of the semi-circle tube and flows through the straight tubing's then leaving out from the other semi-circle tube. This heat exchanger will be placed at the focus of the parabolic dish collector were all the heat energy is reflected to. Figure 3.2 below depicts the geometry and design.

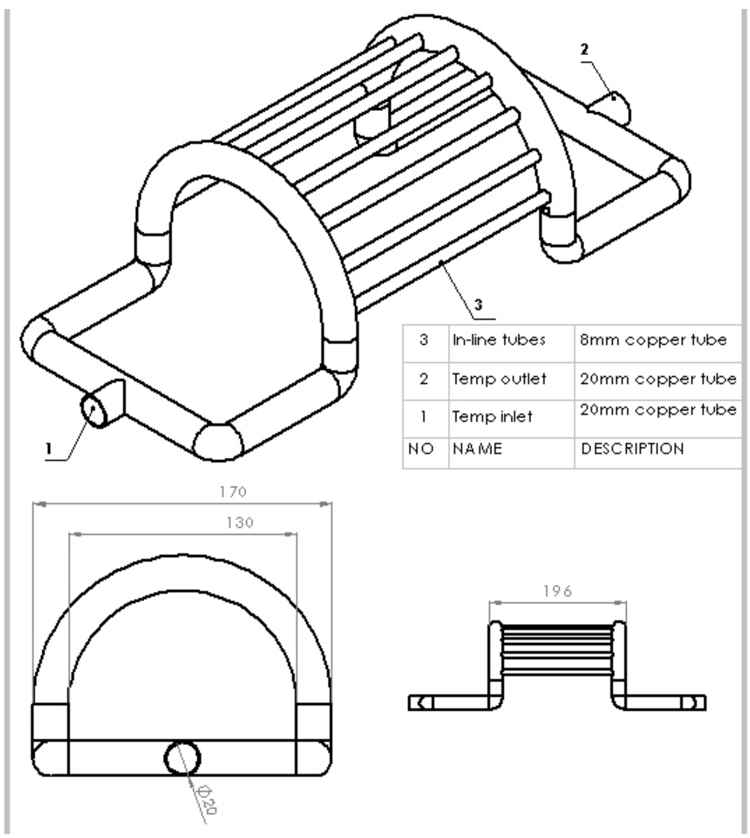


Figure 3.2 Initial heat exchanger design

3.4 New design development

The new design of the heat exchanger is based on having series of wound up spiral copper tubes as this is to increase the surface area compared to the previous design as well as increasing the time for the water to exit the system thereby giving room for a higher temperature of water at exit. Both ends of the spiral tubes will be connected to two semi-circle copper tubes. Water goes in through one the semi-circle tube and flows through the spiral tubing's then leaving out from the other semi-circle tube. This heat exchanger will be placed at the focus of the parabolic dish collector were all the heat energy is reflected to. The copper heat exchanger becomes hot quickly due to its high rate of conductivity which results to heating up cold water that flows in from the inlet of the system before exit.

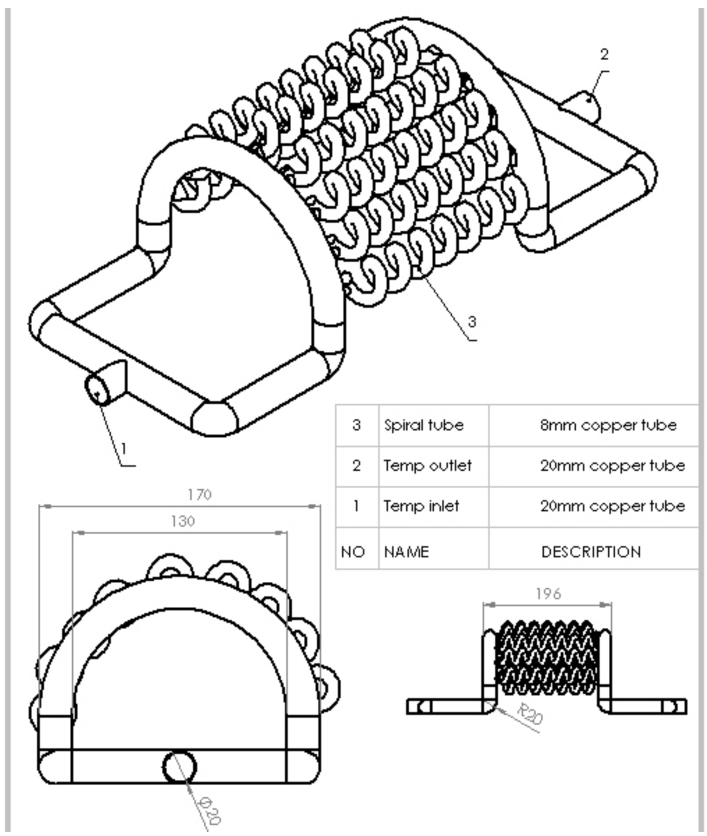
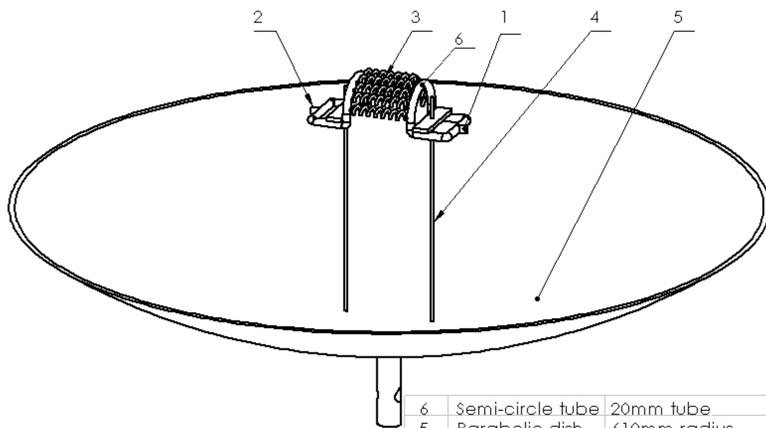


Figure 3.3 Heat exchanger

The above figure 3.3 illustrates a cylindrical heat exchanger and a water tubing that will be passed through it.

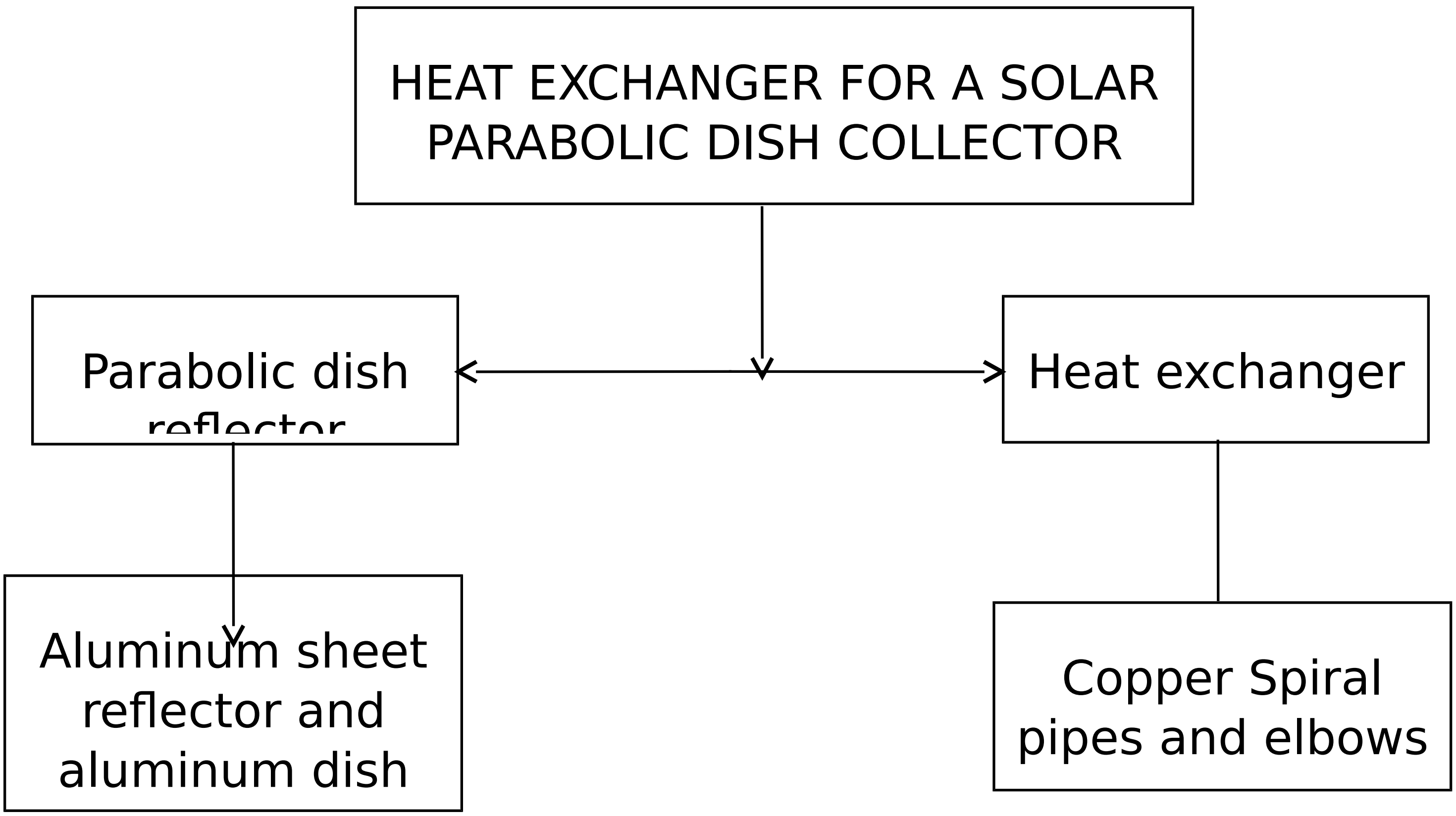


NO	NAME	DESCRIPTION
6	Semi-circle tube	20mm tube
5	Parabolic dish	610mm radius
4	Holder	12mm screw
3	Spiral tubee	8mm tube
2	Temp outlet	20mm tube
1	Temp inlet	20mm tube

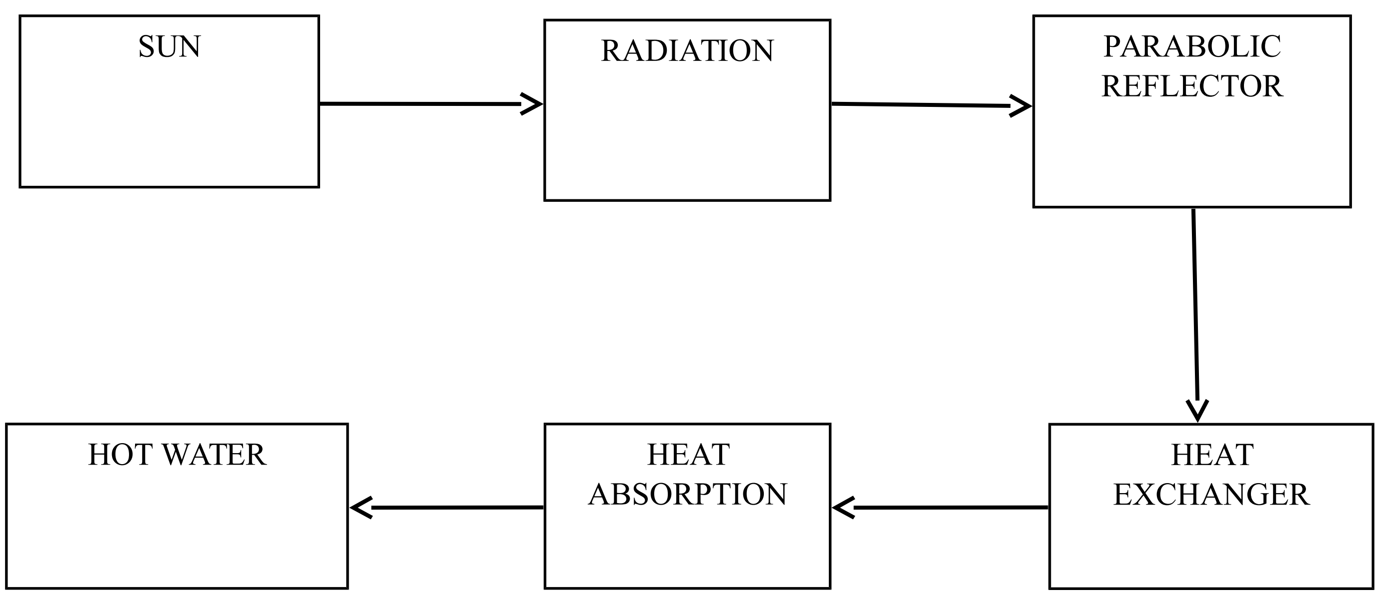
Figure 3.4 Heat exchanger of a parabolic collector

The above figure 3.4 illustrates how the system will be designed. As you can see, the heat exchanger is placed at the focus of the parabolic dish collector where all the incident rays from the sun is directed to.

3.5 System breakdown structures



3.6 Functional block diagram



3.6 Solar analysis of localization (Famagusta)

To adequately design our system to create the required output some basic factors have to be put in place. These factors include, the intensity of radiation of sunlight in our locality Famagusta, Turkish Republic of Northern Cyprus, materials to be used and their properties, these will all be discussed shortly.

First of all, Famagusta is situated at the longitude and latitude coordinates of 33.95 and 35.125 [8]. Famagusta has a typical Mediterranean climate- warm dry summers and mild winters. The typical Mediterranean climate has a temperature in excess of 22.0 °C average monthly to be the warmest period and an average in the coldest month between 18 to -3 °C. Since the sun's radiation on earth is a function of the geometry of the receiving surface relative to the sun, it is important therefore to notice several geometric angles that show the sun-earth surface relations.

The declination of the sun for any given day can be calculated approximately with the equation: $\delta = 23.45 \sin [(360/365)* (284+n)]$; Where n is the day of the year. In engineering calculations, this declination is considered to be constant for any given day [9].

3.7 Theoretical background

Several parameters are used to describe solar concentrating collectors. Given below are brief descriptions of some of these parameters: The *aperture area* Aa is the area of the collector that intercepts solar radiation. The *Acceptance angle* is defined as the angle through which a source of light can be moved and still converge at the receiver [10]. A concentrator with small acceptance angle is required to track the sun continuously while a concentrator with large acceptance angle needs only seasonal adjustment. The *absorber area* A*abs* is the total area of the absorber surface that receives the concentrated solar radiation. It is also the area from where useful energy can be gained. The *Concentration ratio* C is defined as the ratio of the aperture area to the absorber area i.e.

$A_{|¿|}$

$$C=\frac{A_a}{¿}$$ [13] 1

Where $A_a = \text{¿}$ Aperture area, $\overset{|\text{¿}|}{A_{\text{¿}}}$ = Absorber area

The *optical efficiency* is defined as the ratio of the energy absorbed by the absorber to the energy incident on the concentrator aperture (Garg and Prakash, 2000). It includes the effect of mirror/lens surface, shape and reflection/transmission losses, tracking accuracy, shading, receiver-cover transmittance, absorptance of the absorber and solar beam incidence effects. The optical efficiency is given as:

$$\frac{P_{|\text{¿}|}}{Aa . I_D} \quad \eta o = \text{¿} \qquad [13] \qquad 2$$

Where $\overset{|\text{¿}|}{P_{\text{¿}}}$ = rate of energy absorbed by the absorber (W), $I_D = \text{¿}$ direct radiation(W/ m^2)

The optical efficiency of most solar concentrators lies between 0.6 and 0.7. In a thermal conversion system a working fluid is used to extract energy from the absorber. The thermal performance of solar concentrator is determined by their thermal efficiency.

The *thermal efficiency* is defined as the ratio of the useful energy delivered to the energy incident at the concentrator aperture:

$$T_2 - T_1 \quad \text{¿} \quad \rho V C_{PF} \text{¿} \quad \eta = \text{¿} \qquad [13] \qquad 3$$

The incident solar radiation consists of beam (direct) and diffuse radiation. However, the majority of concentrating collectors can utilize only beam radiation. The *instantaneous thermal efficiency* of a solar concentrator may be calculated from an energy balance on the absorber. The useful thermal energy delivered by a concentrator is given by:

$$|\text{¿}| - T_a \quad T_{\text{¿}} \quad \text{¿} \quad |\text{¿}| \quad \dot{Q} = \eta o . I_b . A_a . - U_L \text{¿} \qquad [13] \qquad 4$$

Therefore, the instantaneous thermal efficiency may be written as:

$$\eta=\frac{q_u}{I_b . A_a}=\eta o-\text{¿} U_L \text{¿} \; \text{¿} \; T_{\text{¿}} \; |\text{¿}|-T_a \qquad [13] \qquad 5$$

At higher operating temperatures the radiation loss term dominates the convection losses and the energy balance equation may be written as:

$$\dot{Q} = \eta o. \; I_b \; . \; A_a-U_L \; \left(T^4_{|\text{¿}|\,\text{¿}} - T_a^{\;4} \right) \; A_{\text{¿}}^{|\text{¿}|} \qquad [13] \qquad 6$$

Instead of Eq. (4). In Eq. (6) U_L takes into account the accompanying convection and conduction losses also. The instantaneous thermal efficiency η is now given by:

$$\eta=\eta o-\text{¿} U_L \text{¿} \; \text{¿} \; \text{¿} \; T^4_{|\text{¿}|}-T_a^{\;4} \qquad [13] \qquad 7$$

Since the absorber surface temperature is difficult to determine, it is convenient to express the efficiency in terms of the inlet fluid temperature by means of heat removal factor F_R as:

$$\eta=F_{R\text{¿}} \; \text{¿} \; \eta_o-U_L \text{¿} \; \text{¿} \; T_{L\text{¿}} \; -\text{¿} T_a \qquad [13] \qquad 8$$

The instantaneous thermal efficiency is dependent on two types of quantities, namely the concentrator design parameters and the parameters characterizing the operating conditions. The optical efficiency, heat loss coefficient and heat removal factor are the design dependent parameters while the solar flux, inlet fluid temperature and the ambient temperature define the operating conditions.

3.8 Proposed design

Now we will count for area of the aperture: $A_a = \frac{\pi (D_a)^2}{4}$

We will take the diameter of the aperture: $D_a = 1.22\,m$; $A_a = \frac{\pi (D_a)^2}{4} = 1.2\,m^2$

Also we take the absorber to be a half cylinder with $\{r = 0.085\,m\}$; height (0.16m)

The effective surface area of the absorber is given by: $A_{¿}|¿| = \pi r h$

$A_{¿}|¿|$ = $\pi (0.085)(0.16)$ =0.04272 m^2

The half-acceptance angle is given by:

$C = \frac{1}{\sin^2 ø} \gg ø = \sin^{-1}\sqrt{\frac{1}{C}}$; Where C is concentration ratio?

Recall that $C = \frac{Aa}{Aabs} = 28$

$ø = \sin^{-1}\sqrt{\frac{1}{28}} = 10.8933^0$

The optimum rim angle is: $\Psi_{rim} = 90 - ø$

The focal length, *f*, of the dish is obtained from [12]: F= D_a^2 /16h ; h=height of dish

F=1.22^2/16(0.2) =0.46m

Expected or assumed thermodynamic performance of the system

The estimated useful energy of the designed heat exchanger of parabolic collector is given by:

$\dot{Q}$ =η $I_b A_a$; Where $I_b = ¿$ beam radiation, η =thermal efficiency

The efficiency range of most solar concentrators is 40% - 60% [13].

$I_b = I_D = 750\, W/m^2$ (Average of 400-2500 in Cyprus)

$\eta = 0.5$ (Average of 0.4 and 0.6)

$\acute{Q} = 0.6 \times 750 \times 1.2 = 540\, W$

The useful energy is also given by:

$$\acute{Q} = \acute{m}_w Cp_w (T_w - T_a) = \eta . I_D . A_a \qquad 9$$

Where $\acute{m}_w$ is the rate of heating the water and Cp_w is the specific heat capacity at constant pressure of the water is obtained from tables of properties of water 4185J/kgK (at 15^{o}C) [14]. We have (m= 0.4kg), also the estimated time for water to exit the heat exchanger is t =60s. The time was estimated by filling a bottle of water which is 0.4L, the same volume with the volume of the heat exchanger. When the time was turned on, it took 60s to fill the bottle up. The volume of the water can be easily calculated by dividing the mass which is measured above and divide it by the density of the water at given temperature.

The density of the water at 15 Celsius is 999.1 kg/ m^3 .

So, $V = \frac{m}{\rho_w} = \frac{0.4\, kg}{999.1} = 4 \times 10^{-4} m^3$ = 0.4 L

$\acute{V}$ =0.4L/min

$\acute{m}_w = \frac{m}{t} = \frac{0.4\, kg}{60\, s} = 0.006\, kg/s$

We have the equation to find the exit temperature as follow:

$\acute{Q} = \acute{m}_w Cp_w (T_{exit} - T_{inlet})$ $\quad 540 = 0.006 \frac{kg}{s} . 4185 \frac{j}{kgk} . (T_{exit} - 15)$ $\quad T_{exit} = 36.5$ ^{0}C

The energy, Pabs, absorbed by the absorber is obtained from Eq. (2):

$\eta_0 = 0.65$ (Is the average of 0.6 and 0.7) and the bracketed term is same as $\acute{q}_u$

$$|¿| = 0.65 \times 1.2 \times 750 = 585\,W$$
$$P_{¿}$$

3.9 Material selection

Material used for the body of dish:

Aluminum was chosen over steel due its low cost, energy effectiveness, lightness, and easy fabrication of material for the body of the dish. Due to its lightweight the overall weight of the system is reduced, and it also tends to reduce the degree of work to be done by the super-jack from west to east and vice versa.

Material used for the heat exchanger:

Copper was chosen due to its high level of thermal conductivity, energy effectiveness. This mean that by heating one end of a piece of copper, the other end will quickly reach the same temperature. Most metals are pretty good conductors; however, apart from silver, copper happens to be the best. It is used in many heating applications because it doesn't corrode and has a high melting point, therefore it is used in the application of a heat exchanger. Copper can be joined easily by soldering or brazing. This is important for pipework's and for making sealed copper vessels. The overall weight of the heat exchanger is reduced due to the light weight of copper and also the work done in turning the dish about its horizontal axis by the super-jack is reduced.

Surface coating material for the heat exchanger:

Black paint was picked out for the coating of the heat exchanger. It is chosen over other coating materials due to the fact that it has a higher level of absorptivity at angles other than normal incidence, constancy and durability when exposed to weathering, cost effectiveness and protection to the heat exchanger, sunlight and high stagnation temperature.

Material used for the base of the parabolic dish collector:

Angular and flat steel bars were selected for the base which support the whole solar parabolic dish system. Flat and angular bars were chosen to create solid and rigid supports for the rectangular, vertical axis steel bar which supports the parabolic dish.

TABLE 3.1 Properties of aluminum and copper

Property	**Copper(Cu-ETP)**	**Aluminum(1350)**	**Units**
Electrical-conductivity	101	61	%IACS
Electrical resistivity(annealed)	1.72	2.83	mOhm-cm
Thermal conductivity at 20°C	397	230	W/mK
Coefficient of expansion	17 x 10-6	23 x 10-6	/°C
Tensile strength (annealed)	200-250	50-60	N/mm2
Tensile strength (half-hard)	260-300	85-100	N/mm2
0.2% proof strength (annealed)	50-55	20-30	N/mm2
0.2% proof strength (half-hard)	170-200	60-65	N/mm2
Elastic modulus	116-130	70	N/mm2
Fatigue Strength (annealed)	62	35	N/mm2
Fatigue Strength (half hard)	117	50	N/mm2
Specific heat	385	900	J/kgK
Density	8.91	2.70	g/cm3
Melting Point	1083	660	°C

The table 3.1 illustrates the different physical or characteristics of both aluminum and copper.

CHAPTER 4

MANUFACTURING, ASSEMBLY and TESTING

4.1 Manufacturing Procedure

Different manufacturing processes were used in the production of our project. The processes includes winding, drilling, soldering, use of sandpaper, welding. Firstly, a hollow 13cm steel cylinder is being held stationary upward by the use of a bench vise to avoid movement. The straight 20mm copper tube is filled with dry beach sand and then closed at both ends as this is to prevent it from compressing during winding process. This tube is clamped to the hollow cylinder by the use of a G-clamp and then wounded round the cylinder severally to form spirals. As it is known that spirals are circular, a single circle was picked and then cut into to two semi-circles. After the accomplishment of this process, the sand was evacuated from the semi-circle tubes and a total of eight holes were drilled round the tube.

Figure 4.1 20mm copper winding

The above Figure 4.1 depicts the winding process of the 20mm copper tube done around the hollow cylinder with the use of a bench vice and G-clamp and also the drilling process.

Next step is winding the 8mm copper tube to also form series of spirals. A cylindrical steel rod of 22mm is placed immobile upward on a bench vice. The 8mm tube is filled with sand also in order to prevent compression during winding. The tube is clamped to the steel rod by the use of a smaller G-clamp and then wounded round the steel rod multiple times to form a spiral, after which the sand is removed by using compressed air and a total of five different spirals were made. Two tubes were wounded to form a single spiral having made three sets, and a single tube is wounded also to form a single spiral having made two sets making a total of five different spirals. This then amounts to having a total of eight passes of spirally wounded 8mm copper tube connected to the two 20mm semi-circle tube.

4.2 Method of assembly

The methods of assembly used for the project were done manually and also performed in the workshop of mechanical engineering department excluding the soldering which was done in another workshop located outside the department. The major processes involved here is screwing and soldering. For the assembly of the heat exchanger, both ends of the sets of copper spiral tubes were attached to the semi-circle tubes by mode of soldering as welding cannot be used for this kind of joining. Copper elbows were connected to the semi-circle copper tubes for the inlet an outlet of the fluid flow. The figure 4.2 shows how the soldering is carried out to for the connections of the spiral tubes and the elbows.

Figure 4.2 Soldering process for the heat exchanger

Next, surface cleaning of the parabolic dish is done with the use of sand paper to eliminate uneven surfaces before an adhesive aluminum reflector is placed on the parabolic dish. This process requires careful assembly in order to avoid air bubbles while installation is carried out. Furthermore, in order to keep the heat exchanger at the focus of the parabolic reflector, long screws were attached with nuts from the base of the dish up to the focus so as to hold the heat exchanger there.

4.3 Testing

The testing was done during mid-day and the weather conditions was quite favorable despite the fact that the experiments was done in fall season when there is little sunshine. Recording and data was collected for just one day as it was forecasted in the news that there is little sunshine. These data and results will be discussed in the following chapter. For the testing to be carried out, the heat exchanger was placed at the focus of the parabolic reflector as aforementioned before. The system was taken outside of the mechanical engineering department and was faced to the sun so as to get the incident rays of the sun. For the measurement of the inlet and outlet temperatures, a K-type thermocouple was used as shown in figure 4.4. The figure 4.3 below shows how the experiment was done during mid-day by facing the parabolic dish towards the sun.

Figure 4.3 Performance of experiment

Figure 4.4 Thermocouple testing

The above figure 4.4 shows the use of a k-type thermocouple to measure both the outlet and inlet temperature

4.4 Cost analysis

Our heat exchanger and parabolic reflector is designed having in mind the viable nature of the project, therefore cost effective measures were considered when selecting the materials to be used. This is notable from the pre-mentioned materials that is used in the project. Steel is readily available in our locality (Famagusta TRNC) at an affordable price rate, but copper is quite rear and expensive.

Getting an aluminum reflector was not so much of a big deal even if the price is high, while the parabolic dish was gotten at an expensive rate though fairly used. The table below illustrates the price rate of each material used in this project.

TABLE 4.1 Cost analysis

	ITEMS	AMOUNT	COST(TL)	SOURCES
1	Cylindrical steel bar	1	80	Ilkay Genc
2	Aluminum reflector	1	69	Deniz Plaza
3	8mm diameter copper tube	5	150	Ibo Can
4	20mm diameter copper tube & elbows	8	250	Ibo Can
5	Parabolic dish	1	250	Industrial workshop
6	Transportation		300	
	Total		**1099**	

CHAPTER 5

RESULTS AND DISCUSSION

5.1 Results

The temperatures important for the performance are the inlet temperatures and outlet temperatures. The k-type thermocouples was placed in two points within the system to obtain the necessary temperatures. The system was tested in a weather condition quite favorable for the experiment to produce increased heat radiation with a solar radiation intensity of ranging from 735W/m^2 to 1513W/m^2. The experiments was done on 9th and 10th January.

9th January:

$$\acute{Q}=\acute{m}_w Cp_w (T_w - T_a) = \eta . I_D . A_a$$

Where

$\acute{m}_w = \frac{mass}{time} = \frac{0.4}{60}$ = 0.006kg/s

$\acute{V}$ =0.4L/min

Temperature inlet= 17^{o}C

Temperature outlet= 45.6^{o}C

Temperature average= 31.3^{o}C

Cp_w average= 4178 (J/kgK)

$A_a = ¿$ 1.2 m^2

I_D @12:38pm= $\frac{920.5025}{\cos 37^o}$ =1152.59(W/m^2)

$\acute{Q}=\acute{m}_w Cp_w (T_w - T_a)$ = 0.006 $\times$ 4178 $\times$ (45.6-17)= 716.9W

$\acute{Q}$ = $\eta . I_D . A_a$

$\eta = \frac{\acute{Q}}{I_D . A_a}$ = 51.8(   )

The table below illustrates the results performed on the 9th of January 2016 during mid-day

Table 5.1 Results

Time	Temp inlet (^oC)	Temp outlet(^oC)	A_a $(m^2$	$Cp_{w\ average}$ (J/kgK)	θ $(°)$	I_D (W/m^2)	$\dot{Q}$ (W)	η ( )
12:13	17.0	31.7	1.2	4180.0	32	2128.5	368.7	14.4
12:18	17.0	36.0	1.2	4179.0	33	2152.3	476.4	18.5
12:23	17.0	39.2	1.2	4179.0	35	2203.5	556.6	21.1
12:28	17.0	42.3	1.2	4178.0	36	1137.8	634.2	47.1
12:33	17.0	43.0	1.2	4178.0	36.5	1145.1	651.8	47.4
12:38	17.0	45.6	1.2	4178.0	37	1152.5	716.9	51.8

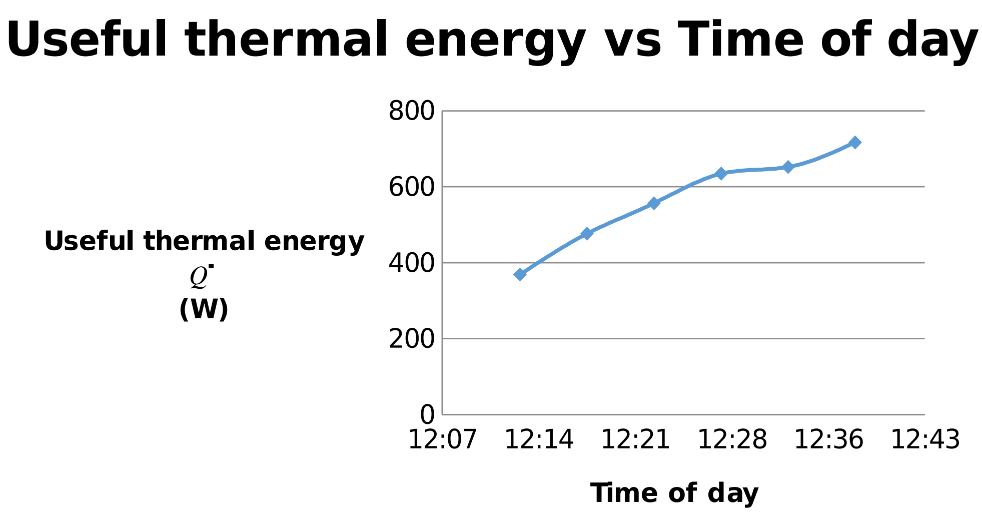


Figure 5.1 Graph of useful energy vs time

Figure above shows how the useful thermal energy increases with respect to time during the hours of the day.

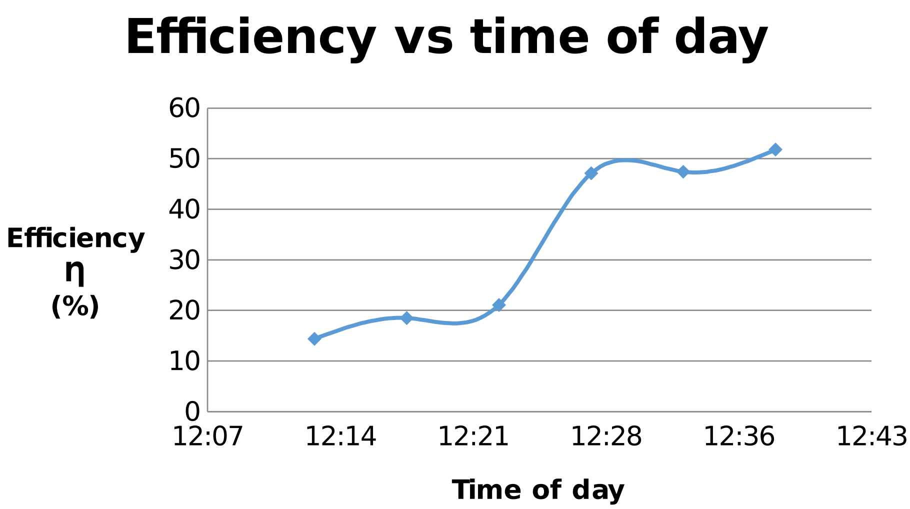


Figure 5.2 Graph of thermal efficiency vs time

In the figure above, it is observed that the efficiency of the system increases as time goes on during the day.

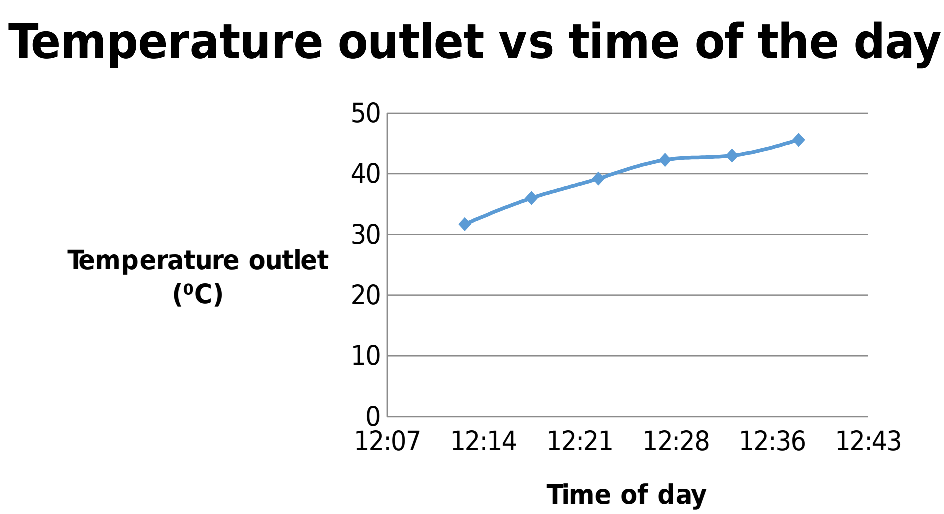


Figure 5.3 Graph of temperature vs time

The above graph shows the relation between temperature and time, as the time increases during the day with a constant flow rate, the temperature of the water increases as well.

10th January:

Calculations for the constant flow of water

$$\acute{Q}=\acute{m}_w Cp_w (T_w - T_a) = \eta . I_D . A_a$$

Where

$\acute{m}_w$ = 0.004kg/s

$\acute{V}$ =0.4L/min

Temperature inlet= 20^{0}C

Temperature outlet= 68.6^{0}C

Temperature average= 44.3^{0}C

Cp_w average= 4181 (J/kgK)

$A_a = ¿$ 1.2 m^2

I_D @12:20pm = $\frac{920.5025}{\cos 37^0}$ = 1145.1 W/m^2 ¿)

$\acute{Q}=\acute{m}_w Cp_w (T_w - T_a)$ = 0.004 × 4178 × (68.6-20)= 812.6W

$\acute{Q}$ = $\eta . I_D . A_a$

$\eta = \frac{\acute{Q}}{I_D . A_a}$ = 59.1( )

The table below illustrates the results performed on the 10th of January 2016 during mid-day

Table 5.2 Results

Time	Temp inlet (^{0}C)	Temp outlet(^{0}C)	A_a	Cp_w average	$\theta(°)$	I_D (	$\acute{Q}_u$ (W)	η ( )

			(m^2)	(J/kgK)		W/m^2)		
12:00	20	38.2	1.2	4179	32	2128.5	304.2	11.9
12:05	20	49.8	1.2	4179	33	2152.3	498.1	19.3
12:10	20	60.6	1.2	4179	35	2203.5	678.7	25.7
12:15	20	62.2	1.2	4179	36	1137.8	705.4	51.7
12:20	20	68.6	1.2	4180.0	36.5	1145.1	812.6	59.1

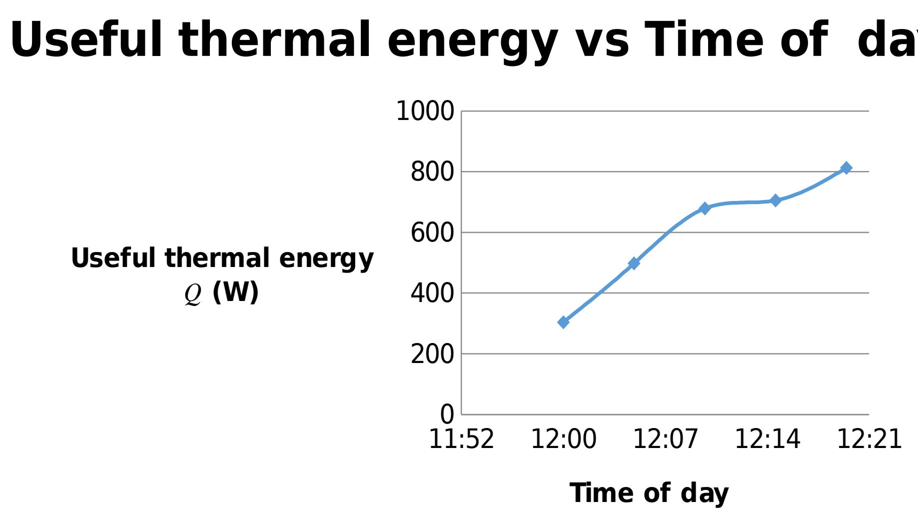


Figure 5.4 Useful energy vs time

Figure above depicts how the thermal energy increases with respect to time during the day as the sun shines..

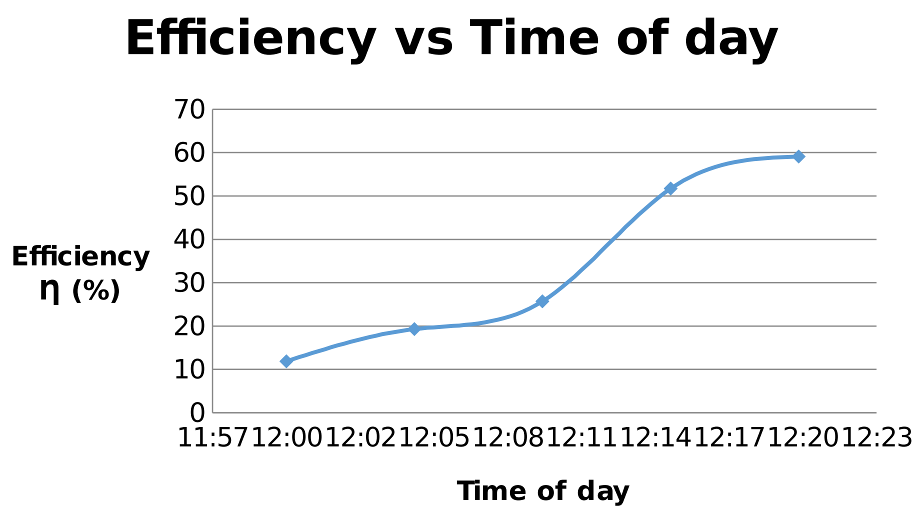


Figure 5.5 Thermal efficiency vs time

In the figure above, it is observed that the efficiency of the system increases as time goes on during the day.

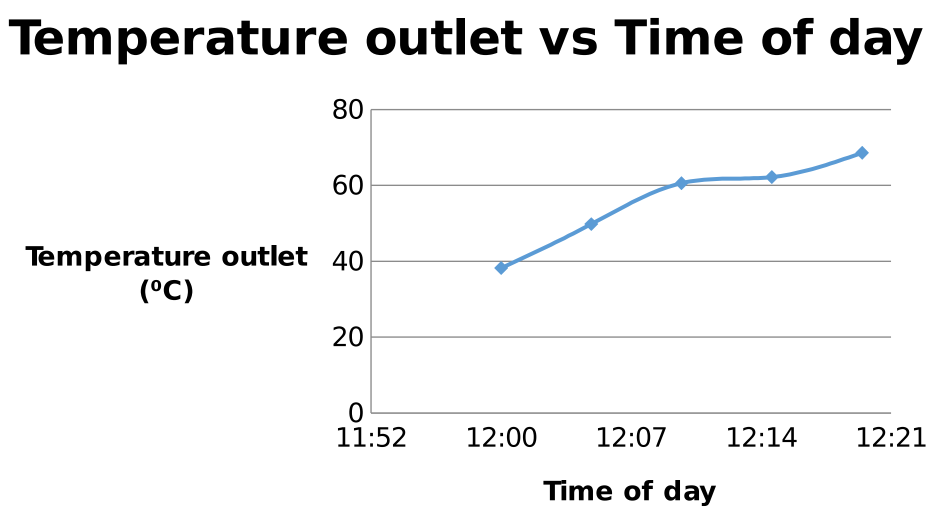


Figure 5.6 Temperature vs time

The above graph illustrates temperature vs time, the temperature increases with respect to time of the day.

5.4 Technical difficulties encountered

There were a few impediments to the effective conduct of the project, these included workshop machining and operations. Most times the workshop was not always available at our free periods but we managed to skip some classes and get the job done. Other difficulties includes the machining of the different work parts we had to work with, it was not so easy as we even got injured on some occasions but still the job had to be done. More so, during the testing/ experiment days we had difficulties in positioning the collector at the best possible point to maximize power radiation intensity. And because also this had to be done outside of the department with no shades provided we were sun-burnt most times but we are happy to have gotten the job done.

5.5 Design improvement

After series of experiments and observations, the project had some errors which led to not having good results at the end. Errors like reading the values, heat losses due to reflection on the heat exchanger and calculation errors. To improve the project, insulation can be made with an insulated cover on the heat exchanger so that when the sun rays reflects to the focal point where the heat exchanger located there will be less heat loss to the environment.

CHAPTER 6

CONCLUSION AND FUTURE WORK

In conclusion, the main purpose of the project is to concentrate solar radiations at the focus point of a parabolic dish reflector where the heat exchanger is located. To achieve this goal, it was essential to get a uniform concentration so as to get the desired outlet temperature of the water flowing through the heat exchanger. Written in this project is the mathematical modeling of the system as well as equations to aid one to know how heat is generated and dissipated through the system.

Nevertheless, this project can be modified in the future by applying some adjustments in the system. Flat mirrors can be installed to be in front of the parabolic reflector and this intention will aid the increase of concentration of solar radiation at the focus point. This is because the reflected sun rays coming to the parabolic reflector are parallel to the principal axis. This type of model is called on-axis model. The advantage of this system is that the absorber of the system will not shade the parabolic reflector.

The temperatures generated in this project is high enough to be used in solar cooking applications. Also, high water temperature from the heat exchanger can be used for heat systems as well as to produce electricity using the organic Rankine cycle. Since this is a moving trend around the globe in our today's world, and bearing in mind that Cyprus has a huge amount of sunlight radiation, these applications have to be reviewed in the nearest future to create a more renewable means of generating energy.

REFERENCES

[1]A.C.Yunus. Heat Transfer a Practical Approach International edition. New York: McGraw-Hill, 2002

[2]http://www.algebra.com/algebra/homework/word/travel/Travel_Word_Problems.faq.question.506661.html

[3]https://www.youtube.com/results?search_query=Roughly+30%25+of+this+radiation+is+reflected+back+to+space+

[4]http://www.egy.com/maadi/solar-energy.pdf

[5]https://en.wikipedia.org/wiki/Frank_Shuman

[6]https://en.wikipedia.org/wiki/Augustin_Mouchot

[7]https://www.google.com.tr/search?q=solar+parabolic+dish+collector&source=lnms&tbm=isch&sa=X&ved=0ahUKEwjbjtP8y6fKAhVlEXIKHaeDDoQQ_AUIBygB&biw=1517&bih=741&dpr=0.9#imgrc=VjX96g354k9FaM%3A

[8]http://www.newstrackindia.com/information/locations/Cyprus/518096-city-famagusta.htm

[9]http://www.pveducation.org/pvcdrom/properties-of-sunlight/declination-angle

[10]https://books.google.com.cy/books?id=R5slur_hdfEC&pg=PA132&lpg=PA132&dq=acceptance+angle+hsieh+1986&source=bl&ots=zX9mcEL0J1&sig=cuieaeiqOu-i-PLJHMJDcq9762Y&hl=en&sa=X&ved=0ahUKEwilgP3Hi6rKAhVD7XIKHaKVBxIQ6AEIjAB#v=onepage&q=acceptance%20angle%20hsieh%201986&f=false

[11]https://books.google.com.cy/books?id=v_LfcIdJxIC&pg=PA126&lpg=PA126&dq=optical+efficiency+garg+and+prakash&source=bl&ots=3SLvsMsmYK&sig=Vpyy79qRQYDmlcZl9zOAsCc-8-4&hl=en&sa=X&ved=0ahUKEwiyiNjPjKrKAhXivHIKHR8RD-kQ6AEIJzAB#v=onepage&q=optical%20efficiency%20garg%20and%20prakash&f=false

[12]http://www.satsig.net/focal-length-parabolic-dish.htm

[13]http://www.ijera.com/papers/Vol2_issue1/EF021822830.pdf

[14]http://www.slideshare.net/SGhallab/steam-tables-fifth-edition-by-rogers-and-mayhew

[15]"ISO 9806-1:1994 - Test methods for solar collectors -- Part 1: Thermal performance of glazed liquid heating collectors including pressure drop". *iso.org*. 2012. Retrieved September 17, 2012.

[16]ISO 9806-2:1995. Test methods for solar collectors -- Part 2: Qualification test procedures. International Organization for Standardization, Geneva, Switzerland

[17]Julio Chaves, *Introduction to Nonimaging Optics*, CRC Press, 2008 [ISBN 978-1420054293]

[18]J.S.Hsieh. Solar Energy Engineering. Prentice Hall, 1986

[19]J.P.Holman. Heat Transfer 10th edition. New York: McGraw-Hill, 2010

[20]Kalogirou S. Solar Energy Engineering. California: Elsevier Inc. 2009. P.31-32

[21]Mojiri, *Spectral beam splitting for efficient conversion of solar energy — A review*, Renewable and Sustainable Energy Reviews Volume 28, December 2013, Pages 654–663,http://www.sciencedirect.com/science/article/pii/S1364032113005662

[22]Pol Duwez (1998). The Caltech Solar furnace. Retrieved December 16, 2014 from the World

[23]Wide Web: caltechs.library.caltech.edu/1597/1/Duwez.pdf

[24]"Solar Thermal Collectors in Polymeric Materials: A Novel Approach towards Higher Operating Temperatures - Springer". Springerlink.com. Retrieved 2013-08-20.

[25]Sandia (2005). Solar furnace in United States of America. Retrieved November 10, 2014 From the World Wide Web: http://www.sandia.gov/renewable_energy

[25]Tom Lane, Solar Hot Water Systems, Lessons Learned 1977 to Today p7

[26]"The Solar Keymark, The main quality label for solar thermal". *estif.org*. 2012.

Retrieved September 17, 2012.

[27]Wikipedia (2014). Solar furnace. Retrieved October 5, 2014 from the World Wide Web:

http://en.wikipedia.org/wiki/solar_furnace

[28]Vijaypratap R Singh et al Int. Journal of Engineering Research and Applications ISSN: 2248-

9622, Vol. 4, Issue 1(Version 1), January 2014, pp.216-220

[29] Wikipedia (2014). Solar furnace. Retrieved October 5, 2014 from the World Wide Web: http://en.wikipedia.org/wiki/solar_furnace

APPENDICES

APPENDIX A- LOG BOOK

Name & Surname: Joel David's- LOG BOOK

Student Number: 118305

Accomplished Task	Dates
Project Proposal Request to **Prof. Dr. Uğur Atikol (Chair)** and Assist. Prof. Dr. Mostafa Ranjbar	17/3/2015
Discussing the nature of the project	23/3/2015
Discussing about the new idea that will be included in the project	31/3/2015

Conversing about the objective and scope of our project, learning more information's on parabolic dish collectors	17/4/2015
Exchanging views on the measurements of the project devices	22/4/2015
Explanation on the preliminary design and methods of production	23/4/2015
Talking about the different sources to gather information from	15/5/2015
Deliberating on material selections	21/5/2015
Completing design on solid works	18/6/2015
Finalizing thermal analysis and design calculations	20/6/2015
Selecting of dish and heat exchanger material	05/10/2015
Material analysis	10/10/2015
Manufacturing of first dish	17/10/2015
Manufacturing of the second dish	02/11/2015
Drawing of the heat exchanger with solid works	05/11/2015
Heat exchanger material selection and design	08/11/2015

Manufacturing of the heat exchanger	10/11/2015
Bending, drilling and soldering of copper pipes	05/12/2015
Putting aluminum foil on dish	08/12/2015
Joining heat exchanger to parabolic dish	23/12/2015
Writing of report	25/12/2015
Testing and result	06/01/2016
Reviewing all works	06/01/2016

MAYOWA'S LOG-BOOK

Student number: 118648

ACCOMPLISHED TASK	DATES
PROJECT PROPOSAL REQUEST TO ASSIST. PROF. DR. TAHIR ABDUL HUSSAIN AND ASSIST PROF. DR. NERIMAN OZADA (VICE CHAIR)	17/03/2015
MEETING WITH THE SUPERVISOR	18/03/2015
ANALYZING THE PROJECT WITH TEAM MEMBERS	23/03/2015
EXCHANGING VIEWS ON THE DIMENSION OF THE PROJECT PARTS	30/04/2015

LITERATURE REVIEW	30/04/2015
WORKING ON THE GANTT CHART	20/06/2015
PREPARING MY LOG BOOK	20/06/2015
Selecting of dish and heat exchanger material	05/10/2015
Material analysis	10/10/2015
Manufacturing of first dish	17/10/2015
Manufacturing of the second dish	02/11/2015
Drawing of the heat exchanger with solid works	05/11/2015
Heat exchanger material selection and design	08/11/2015
Manufacturing of the heat exchanger	10/11/2015
Bending, drilling and soldering of copper pipes	05/12/2015
Putting aluminum foil on dish	08/12/2015
Joining heat exchanger to parabolic dish	23/12/2015
Writing of report	25/12/2015
Testing and result	06/01/2016
Reviewing all works	06/01/2016

Abdullah Awad log book

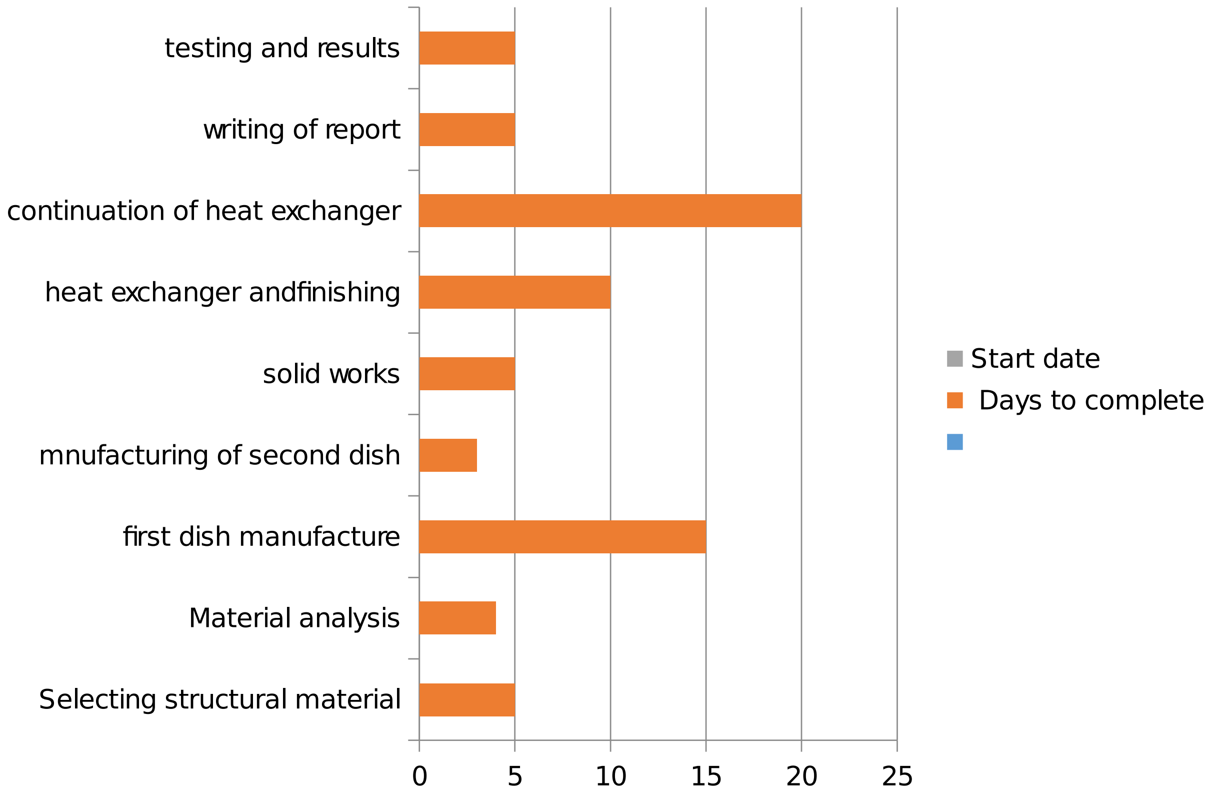
Student number: 138942

• **Choose the idea of the project with Assist.Prof. Dr. Tahir Abdul Hussain and Assist. Prof. Dr. Neriman Özada.**	**17/3/2015**
• **Studying the main idea of the project and it goals.**	20/3/2015
• **Get advises about how to work together to finish the project.**	23/3/2015
• **Get some useful resources to gather information to clear any confusing in our mind.**	25/3/2015
• **Asking some friends who are expert in solar power to start well and avoid mistakes.**	29/3/2015
• **Gathering what I got from all of previous resources and start work.**	1/4/2015
• **Meeting with my group mates and each of us took his own chapter to do, we decide for me to work with calculations.**	3/4/2015
• **I searched for useful equations and give them to my advisor to check them and took the acceptance.**	6/4/2015
• **I searched for different types of heat exchanger and put my assumption for designing the heat exchanger and the parabolic dish after that calculating the equations.**	7/4/2015
• **I checked my first part for designing with my advisor and he accepted them with some modification about liquids and mass flow rate.**	9\4\2015
• **I worked with second part of heat transfer and thermodynamic equations.**	10/4/2015
• **I checked them with my advisor and take the acceptance.**	13/4/2015
• **I met with my group mate to check what each of us has been done with his work.**	20/4/2015
• **I searched for some resources to help me with drawing on solidworks.**	7/5/2015
• **I draw the parabolic dish and check it with my group mate**	10/5/2015
• **I draw the heat exchanger and facing some problems and I took help with my solid works assistance.**	15/5/2015
• **I checked all previous drawing with my advisor**	18/5/2015

• **We met again with my group members to check or works and changing some of mistakes.**	20/5/2015
• **I get back to work with drawing to put two tanks which they will provide water to the heat exchanger.**	25/5/2015
• **Met with my advisor to give him my design and he gave me some advices for heat exchanger pipes to modify it.**	1/6/2015
• **I modified the design and check it again with my group members and our advisor.**	5/6/2015
• **We asked technician in our work shop if we can manufacture the parabolic dish with sand casting or not, and he gave us some places where we can make it.**	8/6/2015
• **I met my group again to calculate the exit temperature of the water from heat exchanger.**	10/6/2015
• **Put our design in 2d and put the dimension on it.**	12/6/2015
• **Gathering all chapters and reform it in our report.**	15/6/2015
• **Check all chapters again with our advisor.**	18/6/2015
• **Writing my log book.**	20/6/2015
• **Selecting of dish and heat exchanger material**	5/10/2015
• **Material analysis**	10/10/2015
• **Manufacturing of first dish**	17/10/2015
• **Manufacturing of the second dish**	2/11/2015
• **Drawing of the heat exchanger with solid works**	5/11/2015
• **Heat exchanger material selection and design**	8/11/2015
• **Manufacturing of the heat exchanger**	10/11/2015
• **Bending, drilling and soldering of copper pipes**	5/12/2015
• **Putting aluminum foil on dish**	8/12/2015
• **Joining heat exchanger to parabolic dish**	23/12/2015
• **Writing of report**	25/12/2015

• **Testing and result**	6/1/2016
• **Reviewing all works**	**6/1/2016**

APPENDIX B-GANTT CHART


testing and results
writing of report
continuation of heat exchanger
heat exchanger andfinishing
solid works
mnufacturing of second dish
first dish manufacture
Material analysis
Selecting structural material
0
5
10
15
20
25
Start date
Days to complete

APPENDIX C
ENGINEERING DRAWING

Appendix D

http://students.emu.edu.tr/118305/