UNIVERSITY OF TURKISH AERNAUTICAL ASSOCIATION
INSTITUTE OF SCIENCE AND TECHNOLOGY

ASSESSMENT OF REFRIGERATION CYCLE BY USING SOLAR ENERGY AS HEAT SOURCE

MASTER THESIS

Osamah Ali Abd ALWAEED

INSTITUTE OF SCIENCE AND TECHNOLOGY
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Supervisor: Assist. Prof. Dr. Habib Ghanbarpour Asl

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I hereby declare that all the information in this study I presented as my Master's Thesis, called: Assessment of Refrigeration cycle by using solar Energy as heat source. I also declare and certify with my honor that I have fully cited and referenced all the sources I made use of in this present study.

17.01.2019
Osamah Ali Abd ALWAEED

بسم الله الرحمن الرحيم

((اقْرَأْ بِاسْمِ رَبِّكَ الَّذِي خَلَقَ (1) خَلَقَ الْإِنسَانَ مِنْ عَلَقٍ (2) اقْرَأْ وَرَبُّكَ الْأَكْرَمُ (3) الَّذِي عَلَّمَ بِالْقَلَمِ (4) عَلَّمَ الْإِنسَانَ مَا لَمْ يَعْلَمْ (5)))

صدق الله العلي العظيم

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In the name of Allah the Merciful

Praise be to Allah

With feelings full of love and hope, my fingers write the letters mixed with the letters of my thesis to….

- ❖ My parents, who gave me the path of knowledge and tasted the bitterness of life for me,.
- ❖ To which she bore thorny road, reassures all the plight and Life-long companion. She is my wife.
- ❖ To the fruit of my children Mohammed, Fatima, Ali, Mujtaba.
- ❖ To my dear brother Zaid and all sisters.
- ❖ To my professors, the supervisors of Dr. Habib Ghanbarpour Asl and the Committee of the respected discussion.
- ❖ To all the brothers, friends who supported me during this march and they are opening of the help to bring out this work in the best image

Give my product feed.

Thanks God first and last

January, 2019 Osamah Ali ABDALWAHID

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A	Area, $\boldsymbol{m^2}$
m	Mass of the water, Kg
$\dot{m}$	Mass flow rate, kg/s
T	Temperature, c°
t	Time, sec
h	Specific enthalpy, kJ/kg
Q	Amount of heat, KJ
q_{gain}	Amount of heat generated, kJ/sec
q_e	Amount of heat for the ton evaporator, Ton
q_c	Amount of heat rejected on condenser, Ton
q_a	Heat rejected from absorbent, Ton
q_{add}	Total Amount of heat added to the cycle, Ton
q_{rej}	Total Amount of heat rejected from the cycle, Ton
$q_{copper\ coil\ and\ iron\ pipe}$	Amount of heat gain from sun per meter, W/ m^2
Ib	Intensity radiation, W/ m^2
η	Collector efficiency, %
P	Pressure, Kpa
x	Solution concentration, %
PTSC	Parabolic Trough Solar Collector
EES	engineering equation solve program

ABSTRACT

ASSESSMENT OF ABSORPTION COOLING SYSTEM BY USING A SOLAR COLLECTOR SUCH AS A SOURCE OF HEAT

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The need to reduce electricity consumption and reduce pollution and international agreements to stop the use of cooling media that affect the ozone layer led us to resort to the use of an absorption refrigeration system. The main objective of this study is to design and equip a parabolic trough solar collector (PTSC) by utilizing accessible local materials in Iraq at low cost, although the use of these materials does not give us high efficiency, but we must bear in mind that solar energy is available free 100% and Iraq has large area not exploited and there are no indicators of losses or damages for using this technology. Two types of absorption tube were adopted for the solar collector, one of which is a regular galvanized iron tube and the second is a copper tube in the form of a coil to compare them in terms of time needed to obtain the desired temperature, efficiency and cost. The results of the study were based on the galvanized iron pipe because the time that needed to raise the required temperature by using galvanized iron pipe was less than by using the copper tube. In addition, the efficiency of the iron pipe is higher than the efficiency of the copper coil pipe, where the efficiency of the iron pipe 19.29%, while the efficiency of the copper tube with a file 10.5% Moreover, the cost of the iron pipe is much less than the cost of copper coil tube. The second aim is to simulate a single absorption cooling system using the EES program to evaluate the area required for the operation 2 ton refrigeration according to the results obtained from the solar collector. The results obtained from the simulation show that the area required to operate a cooling capacity of 123.7 square meters each 2TR and this area is available to a country such as Iraq.

Keywords: Renewable energy, Solar Energy, parabolic trough solar collector, absorption Refrigeration system.

ÖZET

AVUÇİÇİ DAMAR YAPISI İLE KİŞİ TANIMLAMA VE EŞLEŞTİRME

Osamah Ali Abd ALWAEED
Yüksek Lisans, Makine ve Havacılık Mühendisliği Bölümü
Tez Danışmanı: Assist. Prof. Dr. Habib Ghanbarpour Asl
Ocak 2019, 71 sayfa

Ozon tabakasını etkileyen soğutma araçlarının kullanımını durdurmak için elektrik tüketimini azaltma ve kirliliği ve uluslararası anlaşmaları azaltma ihtiyacı, yenilenebilir enerjinin en önemli uygulamalarından biri olarak kabul edilen soğutma sistemi emiliminin kullanılmasına başvurmamızı sağladı. Soğutma döngüsünü tamamlamak için ısının kullanılması. Bu çalışmanın temel amacı, bu malzemelerin kullanımı bize yüksek verim vermese de, parabolik oluklu güneş kollektörünün (PTSC) Irak'taki düşük maliyetli yerel malzemelerden yararlanarak tasarlanması ve donatılmasıdır. Güneş enerjisi %100 ücretsiz olarak kullanılabilir ve Irak'ın büyük bir alanı sömürülmemiş, bu teknolojiyi kullanmak için herhangi bir kayıp ya da hasar göstergesi yoktur, aksine birçok açıdan faydalıdır. Solar kompleksi için iki tip absorpsiyon tüpü benimsenmiştir, bunlardan biri düzenli bir galvanizli demir borudur ve ikincisi, istenilen sıcaklık, verim ve verimi elde etmek için gereken zaman açısından karşılaştırmak için bir bobin şeklinde bir bakır borudur. maliyet. Çalışma sonuçları galvanizli demir boruya dayanıyordu, çünkü galvanizli demir boru kullanılarak istenilen sıcaklığın yükseltilmesi için gereken süre, bakır borunun, bakır borunun gerekli sıcaklıklara ulaşması için 11 dakika sürdüğü bakır borudan daha azdı. Bakır boru aynı sıcaklığa ulaşmak için 20 dakikaya ihtiyaç duydu. Buna ek olarak, demir boru verimi, bakır borunun %19,29'luk verimine sahip bakır bobin borusunun verimliliğinden daha yüksek, bakır borunun %10,5'lik bir verimle verimliliği de, demir borunun maliyeti de daha yüksektir. bakır bobin borusunun

maliyetinden çok daha azdır. İkinci amaç, güneş kollektöründen elde edilen sonuçlara göre işlem 2 soğutma tonu için gerekli alanı değerlendirmek için EES programını kullanarak tek bir soğurma soğutma sistemini simüle etmektir. Simülasyondan elde edilen sonuçlar, her bir 2TR'nin 123,7 metrekarelik bir soğutma kapasitesini işletmek için gerekli alanın ve bu alanın Irak gibi bir ülkeye ulaşabileceğini göstermektedir.

Ayrıca, fosil yakıtlara dayanan karbon emisyonlarına kıyasla kWh başına 0.149 karbon emisyonunda azalma sağladık. Ayrıca, elektrik şebekesine dayalı bir kompresör soğutma sistemi için 1 tonluk buzdolabının (3.5) kW'lık işletme maliyeti (0.2975) dolar Irak tarifesine göre ve işimizle aynı maliyette tasarruf sağladık elektrik enerjisi gerektirir. Son olarak, elde edilen sonuçlara göre, güneş enerjisine dayanan, ucuz ve inşa edilmesi kolay ve yenilenebilir enerji uygulamasının önemli bir dayanağı olan soğutma sistemlerinin vaat ettiği bu çalışmadan istifade ediyoruz.

Anahtar Kelimeler: Yenilenebilir enerji, Güneş enerjisi ve soğurma soğutma Sistemi.

CHAPTER ONE

INTRODUCTION AND LITERATURE REVIEW

1.1 Preface

Solar energy is the main source of energy. It is environmentally friendly because it does not use materials that corrode the ozone layer or multiply global warming also it does not gas emissions from burning fuel. The Sun is the main source of energy for the earth's energy needs. The sun takes energy to the earth nearly five thousand times when compared to other sources [1]. The sun provides us with two things: solar energy is a thermal energy that can be converted into several types of energy process (mechanical, electrical, chemical, etc.). Secondly, the light is directly used by the plant through the process of photosynthesis and indirect production of electric energy through photovoltaic cells. Thermal energy can be directly applied for heating, air conditioning, and cooling by absorption or converting it into kinetic energy to rotate power output engines [2]. At present, the use of refrigeration and air conditioning systems in most areas is essential for multiple uses both for home conditioning, health use, industrial use, drying of food, etc. Due to the high power consumption of air conditioners, it is necessary to think of alternative cooling systems that do not depend on the electrical grid, but on other sources such as solar energy that provide us with the necessary heat to operate the absorption cooling system. Thus, we have avoided the use of electricity and the subsequent costs and pollution. Iraq's weather conditions according to statistics and studies allow it to implement alternative energy applications where the rate of solar radiation falling around (500-700)W/m^2 [3]. These parameters give us a good indicator of the use of solar energy in several areas, including cooling and air conditioning, especially at present as Iraq complains from a lack of electricity. Iraq suffered both after the war in 1990 for two things. The first when it targeted the infrastructure of electricity networks, resulting in heavy losses, as well as the product of the war of chemical contamination. The other is the huge increase in the demand for electricity after entering the thousands of electrical devices to the country after the lifting of the economic siege, especially air conditioning, cooling, and heating appliances, which require high power. These and other challenges have drawn attention to finding alternatives through which energy dependence is replaced by electricity and is consistent with use free from environmental pollution [4].

1.2 Refrigeration System

Refrigeration is defined as removing the heat from the space to be cooled and reaching the temperature of comfort or degree required., and then act to set the value of it, no matter how the temperature outside, it should be noted that the cooling feature applied to create the air conducive to effectiveness, food storage, and industrial processes [5].

1.3 Components of mechanical refrigeration cycle

Components of the basic cooling circuit can be represented from the following parts:

Compressor: The cooling process needs disparity in pressurized for the purpose of transferring the heat from inside the radiator space to the outside. This task is carried out by the important part of the cycle is the compressor.

Condenser: It is one of the basic cooling cycles parts.it is a heat exchanger which take the task of removes the heat outside the boundary where it is converted from vapor to liquid.

Expansion valve: The mission of this part is to controls the flow rate by reduce condensate pressure to evaporator pressure and results in a surprising reduction in the pressure of the cooling medium from a saturated liquid to a mixture of vapor.

Evaporator: the purpose from evaporator it is to reception the coolant which coming from the expansion valve and it has low temperature and pressure. And make it in thermal contact with the adjacent pregnancy. To enable the cooling medium to derives its inherent heat from the evaporation of the load. Any amount of heat absorbed in the evaporator turns part of the liquid at the saturation temperature to the vapor at the same pressure and temperature [6]. The figure (1) shows the basic component of refrigeration cycle.

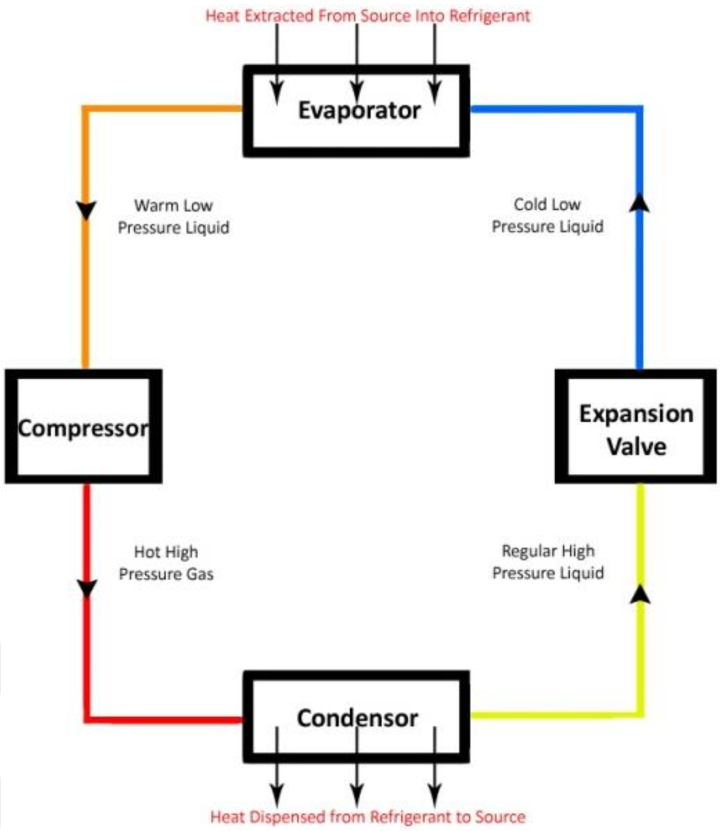

Figure 1.1: The basic component of refrigeration cycle.

1.4 Classify refrigeration systems

Refrigeration systems are based on one basic cooling cycle but vary depending on the nature of their operation and the refrigerant used and the method of working as described below:

1. Vapor compression systems.
2. Absorption systems.
3. Air or gas expansion systems.

1.4.1 Vapor compression systems

In this cycle, the compressors take upon themselves to raise the temperature of the cooling medium and compress it to a higher level by pressing. Then move it to the sink and condense into a liquid. The cooling medium then enters the expansion valve and the throttle of the carrier medium is obtained, resulting in a decrease in pressure and temperature and turning into steam. This course is considered the basic course for most applications of air conditioning and refrigeration.................

1.4.2 Absorption systems

In this cycle, the compressors are replaced by a part called the generator which is mainly based on heat two substances, one is absorbent and the other is a coolant. After the generator is supplied with heat, cooling is performed after heat dissipation during evaporation from the cooling medium. The generator is supplied with heat by fuel, solar energy, waste heat, etc. The process continues by evaporating the coolant and then intensifying it and so on.

1.4.3 Air or gas expansion systems

In this type of cooling circuit, mechanical energy is used to raise the pressure of the air or gas, after which the pressure is reduced and expanded through cooling. Where the gas and air are characterized by a drop in their hooves during expansion [5]. This thesis focuses on the second type Absorption systems by using the solar energy as heat source.

1.5 Absorption refrigeration systems

Cooling absorber systems that can be obtain cooling by adding thermal energy not mechanical energy as in the compression cooling system. This system is suitable for places where thermal energy is available without electrical power. We can gain large cooling capacities by this system. The operation of the cooling cycle by absorption requires the addition of heat in the generator part and the operator of the pump instead of the work needed by the compressor in compression cycle. Because the work pump is small relative for the generator heat, it is neglected and the energy required for operation is thermal energy and so called cooling by absorption (thermal cooling).

1.5.1 The generator and Absorber

This part consists of two materials that ability to form a homogeneous solution at a certain temperature and can be separated at another temperature. One of the substances acts as a cooling medium and other material as an absorbent substance. The cooling cycle absorbs system work at two different pressures. The high pressure is representing the condenser pressure and equals the generator pressure and the low pressure is representing the evaporator pressure and equal absorber container pressure. The pump works to increase the pressure of the solution from low pressure to high pressure and by heating the solution in the generator. The cooling fluid vapor starts by separating from the solution. The cooling fluid vapor condenses in the condenser and the pressure of the fluid is reduced by a drop in the expansion valve to the evaporator. In the Absorption container, the solution which returns from the heat generator after the pressure is reduced through an expansion valve that absorbs the cooling fluid vapor from the evaporator [7].

1.5.2 Work of the cycle

The absorption vessel and the generator together are positioned in this system as the compressor in the compression cycle. Where they draw vapor from the cryogenic fluid from the evaporator at low pressure and then release to the condenser with pressure and a higher temperature. The other parts of the cycle condenser, the instrument extend and evaporator is working the same in both cycles. When the absorbent material of the cooling fluid vapor is absorbed in the Absorption container, the ratio of the cooling fluid in the solution increases and becomes concentrated. The solution is called a strong solution because it is rich in cooling fluid. The result of the absorption process produces a quantity of heat called the heat of the solution, causing the high temperature of the concentrated solution in the Absorption container. The pump pumps the concentrated solution from the absorption container to the generator, where it increases the pressure of the solution to a higher pressure, the pressure of the generator and the condenser, thus providing the pressure difference between the high pressure and low pressure. The addition of heat in the generator increases the temperature of the concentrated solution as most of the cooling fluid evaporates and leaves the generator at high pressure and high temperature to the condenser leaving behind a weak solution in the generator. The poor weak solution returns to the cooling fluid through a valve or narrowing, causing its pressure to drop back to the Absorption container where it is ready to absorb the cooling fluid vapor again Thus, the cycle between the Absorption container and the generator to pull the cooling fluid vapor from the evaporator and pump it into the condenser at a higher pressure [8]. The figure (1.2) shows absorber refrigeration basic cycle. It is clear from the above that the main advantage of the absorption cooling cycle is that it does not need mechanical work. Instead of the large mechanical work needed by the Compression cooling cycle, the absorption cooling cycle is equipped with a thermal energy in the generator. Thermal energy can be generated from exhaust water vapor after use in industrial processes, for example, hot water, solar energy ….etc. As we mentioned earlier that Iraq's weather is characterized by high solar radiation throughout the year, and we can be exploited in this cycle instead of relying on electrical sources.

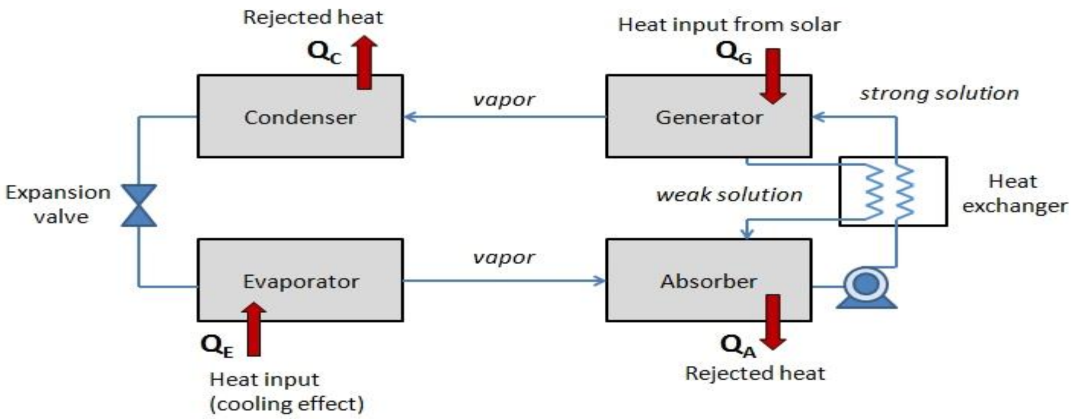

Figure 1.2: The absorber refrigeration basic cycle.

1.6 Problem Statement

due to of the hot weather in Iraq in the summer, in addition to the decrease in electricity, which in turn lead to increased demand for electricity for the convenience of people or for industrial or government use and high cost of electricity production by traditional methods, we have sought in this research to provide solutions to this problem At lower cost and clean and renewable energy.

1.7 Thesis Objective

The financial costs of air conditioning systems without the use of conventional electricity, in addition, the goal of this thesis is to promote the development and use of renewable energy sources of life to reduce and rationalize electricity consumption also to support the government by reducing to provide an enabling environment to attract investment in renewable energy sources. This study reports on estimation the area of the solar collector that is needed to satisfy the amount of desired energy for air conditioning. The major idea is to take advantage of solar refrigeration systems that are easy to construct, low cost, do not contain gas emissions furthermore it can be obtained by village or remote populations.

1.8 Organization of the Thesis

Chapter two: This chapter deals with previous research and studies related to cooling absorption and the resulting analysis and theory of practical and theoretical studies as well as studies on thermal gain from solar energy.

Chapter three: This chapter presents the thesis methodology for calculating the cooling load of the solar system which feeding the absorption refrigeration system by adding heat and evaluating the total area of the solar collector surface to provide us with 2 tons of cooling for the period eight hour.

Chapter 4&5: This chapter presents the results of the absorption system cycle by using a solar as a source of heat, estimating the economic cost process, and dissecting the results. Furthermore, debating the results obtained from non-use of pollutants that promoting a clean environment.

Chapter six: This chapter is consists of Conclusion of the thesis, the future work.

1.9 Literature Review

For thousands of years, the sun has been the main source of drying and maintenance of human food. They also benefited from the phenomenon of evaporation of seawater to extract salt. From here they have become clear that the sun is the main instrument of every natural phenomenon. The Greek historian Xenophon in his “memorabilia” mention some of the doctrine of the Greek philosopher Socrates (470–399 BC) regarding the correct direction of houses to have homes that were hot in winter and cool in summer [9]. Historically they have discovered that the sun's waves at their concentration can ignite a fire. The Greek scientist Archimedes of Syracuse (≈287 BC - ≈212 BC) l illuminated the wooden ships of the Roman enemy by concentrating the rays of the sun.it is one of the great historical discussions. He was building the system from the concentrated mirror. It has six angles. It was called a heat radiator or a ray of death [10]. Attempts to capture solar energy for the purpose of producing power began in 1771 as it is recorded in records [11]. The first solar collector was built in 1767 by the Swiss polymath Horace-Bénédict de Saussure (1740-1799). The collector was made of wood in the form of a rectangular box insulated with black material and covered with glass. It also included a smaller container covered with glass and inside the box contains water. When the box was exposed to the sun, he was found that the water could boil inside the inner box [12].

The Frenchman Antoine Lavoisier (1743-1794), achieved the best results at the time when he succeeded in designing a thermal furnace that reached 1750 degrees Celsius. The furnace has two lenses made from curved sheets of glass. The diameter for lenses is 1.32m and 0.2m interspersed with an internal area filled with a diluted solution of acetic acid (vinegar) [13].

The first patent in the heating system obtained by "the company "the metal manufacturer Clarence M. Kemp" in 1891 from Baltimore. The invention was not complex, it was a collector used to store and heat the water. In 1909, improvements added to the thermal system by William Jay Bailey of California. The development process was to separate the solar heat collector from the water storage cylinder [14].

A variety of solar energy devices were developed by The French mathematics professor and inventor August Monchot (1825-1911) such as ovens, stills, pumps and eventually, the first solar steam engines in this path [15].

In 1912, the world's first solar thermal power station built by Frank Shuman (1862-1918), who was major, an American solar energy researcher. The purpose of the constructed station, for pumping water from the Nile River in Meadi, Egypt.it is consist of Five parabolic concentrating reflectors, Each collector has (62m) in length, (4m) in width, with a spacing of 7.6 m, oriented in a north-south direction. The collectors provided by a mechanical tracker mechanism which give them automatically tilted to face the sun from east to west. Its feature gives at first produced the equivalent power of it being over 50hp and were qualified for of pumping 27,260 liters/ min. It was closed through WWI [13, 16].

G.Lof 1962 [17] made a study to develop schemes of solar collectors to promote the high concentration of the solar collectors. The studies illustrated the energy balances meant for a parabolic-cylindrical reflector with tubular receivers of various diameters. The conclusion of this inspection shows that the increase of the size of the receiver leads to an increase of the thermal losses and of the intercept factor, illustrated as "the fraction of radiation reflected from the reflector intercepted by the receiver”.

Then in 1963, the same researcher presented a study to discuss the method and factors affecting design improvement. He introduced a set of graphics relationships that chart a path to obtain the highest possible efficiency of the concentrated power system based on the ratio of the width "the fraction of width of the receiver to the parabolic cylinder reflector aperture" [18].

Edward and Cherng gave theoretically studies in1976, that refers to the target geometry maximum energy delivery and the intercept factor where the width ratio is (0.02-0.025) [19].

Parmpal and Cheema’s in 1976 [20] gave us an analytical study on solar energy. This study aims analysis for the collected energy quantity from a cylindrical-parabola collector and knows the performance and the advantage of its different parameters. This result appears to be more logical to use the aperture of a cylindrical-parabola collector as a characteristics’ dimension than the use of the focal length.

Study had done by Ramsey and Gupta 1977 [21] by means of the employment of three absorbers that vary from each other and heat pipe has a selective solar absorber layer applied to its surface, for assessing the performance of the PTSC; additionally, a black dyed tube prepared for operating close to the ambient temperature and a heat pipe which had its surface enveloped in a nonselective black paint.

Absorber refrigeration system which depends on solar energy as a heat source is still rare but steadily growing associated with concentrating solar collection technic. In 1878, the first exhibit of solar assisted absorption cooling machine was made through the Paris World Exhibition by Augustin Mouchot. He is depending on a technique enhanced by Edmond Carré. This technique has contained an ammonia/water absorption chiller and a parabolic reflector to generate ice [22].

In the records, and in 1956, announced in Montlouis in France and in Flordia in the US two systems of the solar cooling by the absorber. They are consisting of parabolic trough collectors related to prototype single stage water-ammonia absorption chillers [23].

In 1964 [24] a solar-cooling system was established by the East Pakistan University of Engineering consisted for ammonia/water absorber system coupled by the solar collector. The quantity that is equal (8,970) million Btu/yr of heat provided for absorption cooling, space heating, and domestic hot water, abstract of extracted energy by the solar cooling system established in 1979 for the US. Army Yuma, Arizona [25].

In 1984, M. G. OSMAN published a study on performance and analysis H2O/LiBr absorption cooling system with concentrating arrays collector installed in a Kuwaiti house [26].

The researchers H. Raheman & C. R Gupta in1989 conducted a research study by changing the design of an electric refrigerator (A vapor-absorption-type Himalux) has power 250Wand converting its work from electric to solar energy by linking it to a solar collector system (parabolic cylindrical collector) [27]. Because of the variation of heat equipping and the decreased intensity of solar radiation, the heat supplied to the generator and the refrigerating effect was less in the latter case. This considers the result of studies.

Analytical study and simulation employed a solar cooling system for a residential usage in Beirut. the Resulting of this simulation which gave the researchers possibility of using a solar collector with a minimum area of 23.3 square meters with a storage an ideal capacity ranging from 1000 to 1500 liters to achieve the task for about seven hours of work. This work accomplished by. K. GHADDAR, M. SHIHAB, and F. BDEIR in 1996 [28].

In small rural Madrid / Spain, the development and experiment a model of a water/ammonia absorption cooling system were designed. The design is for 2 kW refrigeration supply for Remote areas with a high of solar radiation to boost refrigeration requirements. The results are not as it is required; this is because of the equipment having low efficiency. But, the suggested objectives have been met, De Francisco A, R. Illanes, M. Castillo in 2001 [29].

In 2009 [30], introduced assessment studies, it was the technical benefit is estimated using solar cooling in the southern direction of the Mediterranean and specifically the use of the solar cooling system in the processed food industries. Concentration collectors, Ammonia/water absorption system, and refrigerated storage, they are the main part of the system. The work results obtained by this system were satisfactory and consistent with the initial planning with some improvements recommended. This research was presented by Osama. Ayadi, M. Aprile and M. Motta.

A design study by Tanmay Agrawal, Varun, and Anoop Kumar discussed the planned building in India using the solar cooling system. The first steps were to calculate the total cooling load of the building, the efficiency of the cooling system and the design of the solar collector. This simulation was done by MATLAB. The results were multiple according to the values of the strong and weak solutions. A design study by Ahmad discussed the planned building in India using the solar cooling system. The first steps were to calculate the total cooling load of the building, the efficiency of the cooling system and the design of the solar collector. This simulation was done by MATLAB. Results were obtained for several special values of the strong and weak solution as well as an economic analysis of costs [31].

The present work, it is an assessment of the absorption cooling system with a capacity of 2 TR utilized lithium bromide/water as absorbent and refrigerant. The system is related to trough concentrated solar collector, Compatible with air conditions in an establishment that works eight hours per day. The studies based on the weather data of Iraq.

CHAPTER TWO

PRINCIPLES OF SOLAR ENERGY AND ABSORBER REFRIGERATION SYSTEM

2.1 Introduction

The energy of the sun is the main source of energy on the planet, and distributed and turned to other sources of energy, whether it was stored in wind power and heat energy in the ground and energy generated from waterfalls and solar energy and other sources of energy, such as coal and wood, and since solar energy is The most important sources of renewable energy during the next century, the efforts of many countries are directed to them in various forms and monitor the amounts necessary to develop products and research on the exploitation of solar energy as one of the most important sources of alternative energy for oil and gas, and solar energy friend of the environment And does not contain environmental pollutants or gas emissions affect the health or the ozone layer, and as a result took the largest share in research and applications of the field of conversion of solar energy to electricity, which is known as photovoltaic and this source of energy is the hope of developing countries in the development where the availability of electric power from The most important factors for the creation of infrastructure in it does not require the production of electricity from solar energy to the centralization of generation, but produce energy and use the same region or place and this will save much of the cost of transportation and communication and rely mainly on this method to convert sunlight to And there are in nature many materials used in the manufacture of solar cells, which combines electrical system and engineering specifications to form a so-called solar panel, which displays the sun at a certain angle to produce the greatest amount of electricity. In this paper, investment a heat gained from the sun and connected to absorber cooling system requires a thermal generator to act as an alternative to the mechanical compressor, the heat that we get from the sun will be by manufacturing a trough parabolic solar collector of the parabola.

2.2 Solar Potential in Iraq

Several factors depend on available solar performance for investment in Iraq such as:

2.2.1 The Intensity of Solar Radiation

In view of Iraq's exposure to solar radiation in abundant quantities, it makes Iraq an attractive environment for the use of solar energy. Between 416 watt / m^2 in January and 833 watts / m^2 in June, the intensity of solar radiation in Iraq per hour, so it has protracted hours of sunlight that exceed 3000 hours of solar radiation per year figure (2.1) and table (2.1) show that [32].

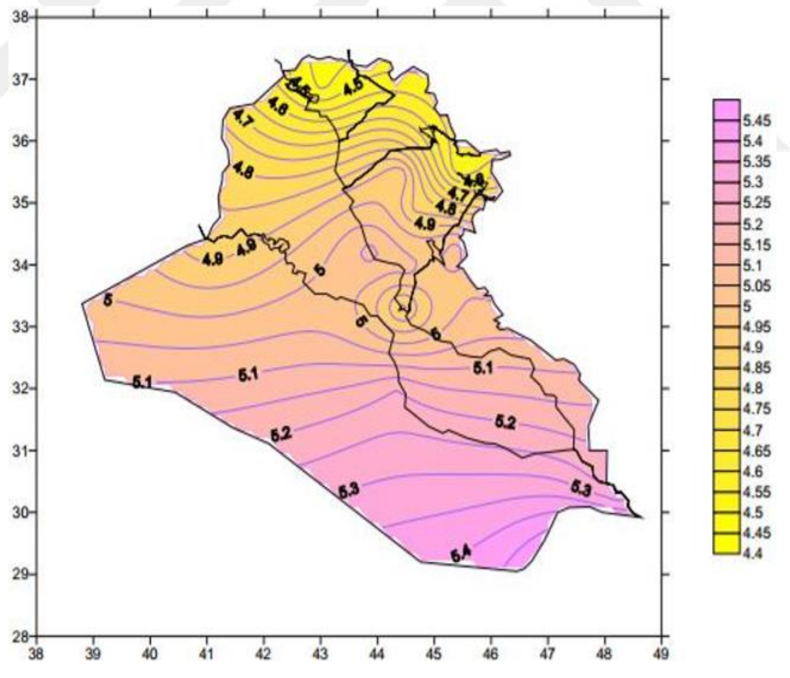

Figure 2.1: Daily averaged solar insolation for different locations in Iraq [33].

Table 2.1: Solar exposure period in Iraq [33].

Quantity	Solar exposure period
Sunny hours	4100 hours
Sunny days	333.6 days
Sunny cloudy	31.4 days

2.2.2 Solar Energy Exposure

In terms of exposure to solar radiation, almost all regions of Iraq have the possibility of exposure to the sun, and also have very high temperatures of more than 50 degrees Celsius in the summer and be fairly moderate in the winter, which qualify the potential areas for the construction of solar collectors on the wide rang In terms of exposure to solar radiation, almost all regions of Iraq have the possibility of exposure to the sun, and also have very high temperatures of more than 50 degrees Celsius in the summer and be fairly moderate in the winter, which qualify the potential areas for the construction of solar collectors on the wide range [34].

2.2.3 Solar Energy Applications in Iraq

The weather in Iraq is suitable for all solar applications technically, but economically there are some effects that must be focused on when choosing the application. First, the impact of dust, the weather in Iraq is characterized by a climate of dust for periods not short each year. According to this type of environment, the choice of solar thermal energy is the least affected by the same as the light energy to produce electricity directly because light energy absorbs the visible part and a little of the solar spectrum. The solar thermal system operates on long-wavelength infrared radiation, which is less affected by dust. Second: Refrigeration and air-conditioning equipment in Iraq takes about 60-70% per year of energy sources and the rest for lighting purposes and other needs. Fourth: Energy storage in the solar thermal system is better in terms of quantity, cost and age of the photovoltaic system. As the system option is offered, Solar thermal is likely to be the Iraqi weather conditions.

2.3 Fundamentals of Solar Radiation

2.3.1 The sun

The Sun is the star at the center of the Solar System. It is almost perfectly spherical and consists of hot plasma combine with magnetic fields [35, 36]. From nuclear fusion we draw the radioactive energy of the sun. The mass is converted into radioactive energy. Each square meter of the earth's surface gives a radiation power of 63.1 megawatts. The sun loses 4.3 million tons of mass per second. In other words, five square kilometers of the surface of the sun feeds an amount of energy equal to the global demand for primary energy on Earth [37]. The figure (2.2) Show the Sun photographed by the Atmospheric of NASA's Solar Dynamics Observatory (SDO).

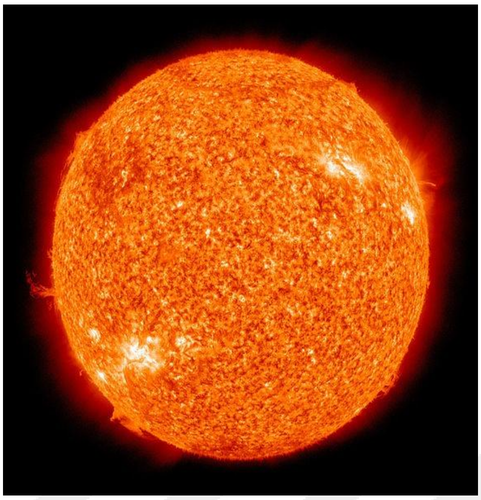

Figure 2.2: The Sun Photographed For NASA's Dynamics Observatory (SDO) [38].

2.3.2 Solar constant

Thermal energy received by a vertical surface on the sun, outside the Earth's atmosphere. It is assumed to be a relatively fixed amount of about 1,372 watts per square meter. This is called the solar constant [39]. Insolation refers to incoming solar radiation. The total daily insolation at a place on earth's surface is depending on:

1- Angle of the sun's rays.

2- The amount of time a place is exposed to the sun's rays.

3- The amount of clouds, dust and water vapor in the atmosphere.

Fortunately, only a teeny part of this energy reaches the earth's surface. solar irradiance lowering with the square of the distance to the sun. As the distance between the earth and the sun variations during the year, solar irradiance outside the earth's atmosphere also modifies between 1325 W/m² and 1420 W/m². The annual mean solar irradiance is recognized as the solar constant and is 1367±2 W/m².

2.3.3 Solar constant calculation

Firstly, let's calculate the flux density energy per unit area of the sun. The sun puts out an almost constant flux of energy that we name the solar luminosity, $L_o =$

3.9×10^{26} Watts and the radius of the sun equal 6.96$\times$ 10^8. Furthermore, we can write the equation as explain [40].

$$S_{photo} = \frac{flux}{area} = \frac{Lo}{4\pi r^2}$$

Substituting

$$S_{photo} = \frac{3.9 \times 10^{26}}{4\pi(6.96 \times 10^8)^2} = 6.4 \times 10^7 Wm^2$$

We assume that all energy emitted from the sun will pass into any area at any distance from the sun that does not contain any energy loss.

2.3.4 Emission Temperature

The emission of energy from a blackbody depends on temperature. The overall radiation emitted from the surface of a body rising rapidly as the temperature of the surface is increased.it is given by the Stefan-Boltzmann law and has the form [41].

$$E = \sigma T^4 \quad (2.1)$$

Where

E: surface Irradiance of the sun = 6.4× 107 W/m^2 .

σ: the Stefan-Boltzmann constant = $5.67 \times 10^{-8} \frac{W}{m^2}/k^4$

T: Emission Temperature (k)

2.3.5 Emissivity

The ratio of actual emission to emission from a blackbody at the selfsame temperature and take form [42].

$$E = \varepsilon\sigma T^4 \text{ Then } \varepsilon = \frac{E}{\sigma T^4} \quad (2.2)$$

2.4 Environmental characteristics

The suns total energy output is 3.8$\times 10^{20} MW$ which is equal to 63 MW/m^2 of the sun's surface. In all directions to external, we find the radiation of this energy [43]. The earth extradites only a teeny portion of the whole radiation emitted, equal to 1.7 $\times 10^{14}$ kW; however, even with this tiny part, it is evaluated that 84 min of solar radiation climb down on earth is equal to the world energy request for 1 year (about 900 EJ).

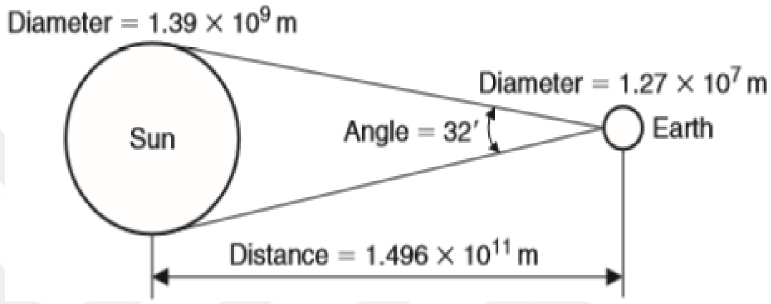

Figure 2.3: Sun-earth relationship.

When calculating solar radiation leaking on the surface of the sun must be briefed and know the path of the sun through the sky.it is important to describe the movements of the sun relative to the earth that gives to the sun its east–west path across the sky. The difference in solar incidence angle and the amount of solar energy received are anatomizing for a number of fixed and track surfaces. at all events, the solar system applies when the environment content an on solar energy availability. The generic weather of place is in demand in several energy calculations. One of the big benefits factors that must be taken into account in the calculations of solar energy is the apparent solar time (AST), which indicates the time of day. The apparent solar time depends on the angular movement of the sun across the sky. The local solar noon is the time when the sun passes the meridian of the observer. There is no correlation at 12 o'clock time of position. The equation of time (ET) and longitude corrections are used to modify the local standard time (LST) to AST [9].

2.4.1 Equation time

Because of the factors related to orbiting the Earth, the orbital velocity changes the course of the year. Thus, the apparent solar time is a bit different from the average time and therefore does not give a precise measurement of time. This situation is called equation time (ET) [44].

The day of the year (N) plays an important role to determine the value of the time equation. The following approximate equation can be used to calculate the time equation:

$$ET = 9.87\sin(2B) - 7.53\cos(B) - 1.5\sin(B)\ [\,min] \qquad (2.3)$$

$$B = (N - 81)\ 360/364 \qquad (2.4)$$

A graphical imaging of Equation (2.3) is explained in Figure (6), what is the ET can be gained immediately.

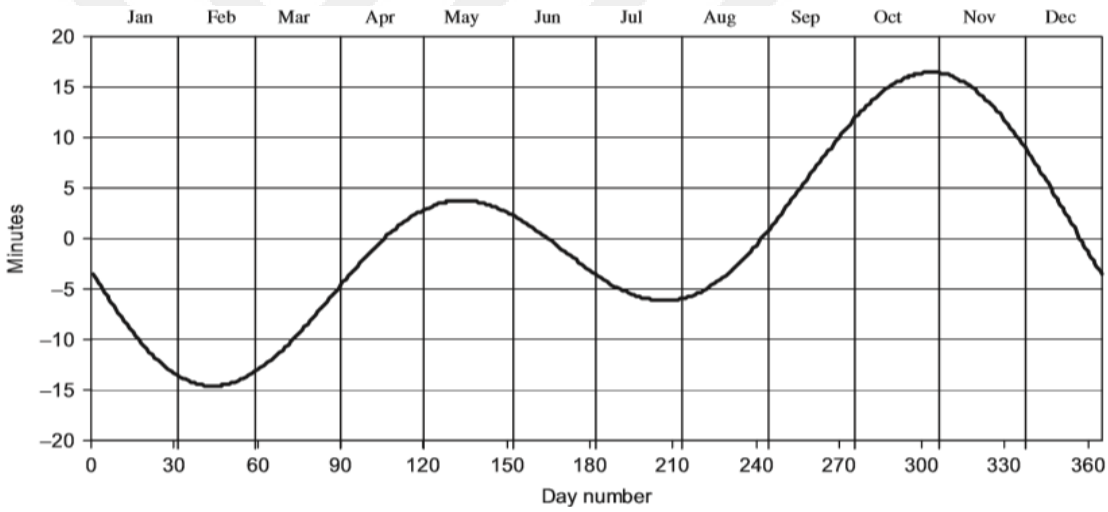

Figure 2.4: The Equation of time.

2.4.2 Longitude Correction

The center of a time zone or from the standard meridian is which the standard clock time is considered. Since the sun takes 4 minutes to pass one degree of longitude. We need a correction factor multiply by 4, and subtracted or added to the standard clock time in the local area. Accordingly, the term correction is as follows:

4× (Standard longitude [SL]-Local longitude [LL])

In case the location is east of the standard meridian, the correction is added to the clock time and in the case of a westward direction, it is subtracted

We can calculate the AST from this equation:

$$ASTN = LST + ET \pm 4(SL - LL) - DS \quad (2.5)$$

Hence

LST: local standard time.

ET: equation of time.

SL: standard longitude.

LL: local longitude.

DS = daylight saving (it is either 0 or 60 min). The term DS is using (Usually from the end of March to end of October) respect to whether daylight saving time is in the procedure.in other words, this term is mention if the assessment is within the period of the daylight saving.

Must be taken into account if a daylight saving time depends , this must be subtracted from the LST and If a position is west of Greenwich, the mark of Equation (2.5) is plus (+), and if it is east, the mark is minus (-) [45].

2.4.3 Solar angles

Generally, there are two principal motions of the earth: firstly, the revolution of the earth around the sun. Secondly, rotation about its axis every 24 h and completes a revolution about the sun in an interval of approximately 365.25 days. The earth is imagining an ellipse around the sun, with the latter at one of the loci. The apparent path of the sun as seen from the earth is known as the ecliptic. The eccentricity, e, of the earth's orbit is tiny, equal to 0.01673. The orbit of the earth around the sun is in truth closely circular. Moreover, the distance between the earth and the sun (R) is in two cases: the first when the perihelion is the shortest distance on 3 January and the second when aphelion longest distance, at July 4 is given by:

$$R = a(1 \pm e) \quad (2.6)$$

Where

a=mean (sun–earth) distance

$a = 149.5985 \times 10^6$ km

The plus sign when the earth is at the aphelion place

The minus sign for the perihelion place

When we applied the equation (2.6) we gets the magnitude of the farthest distance reaches to 152.1×10^6 km and for the minimum distance reaches to 147.1×10^6 km. Figure (2.5) show that.

The variation between the two distances is only 3.3%, The earth's axis of rotation is tilted 23.5° with relative to its orbit about the sun [46].

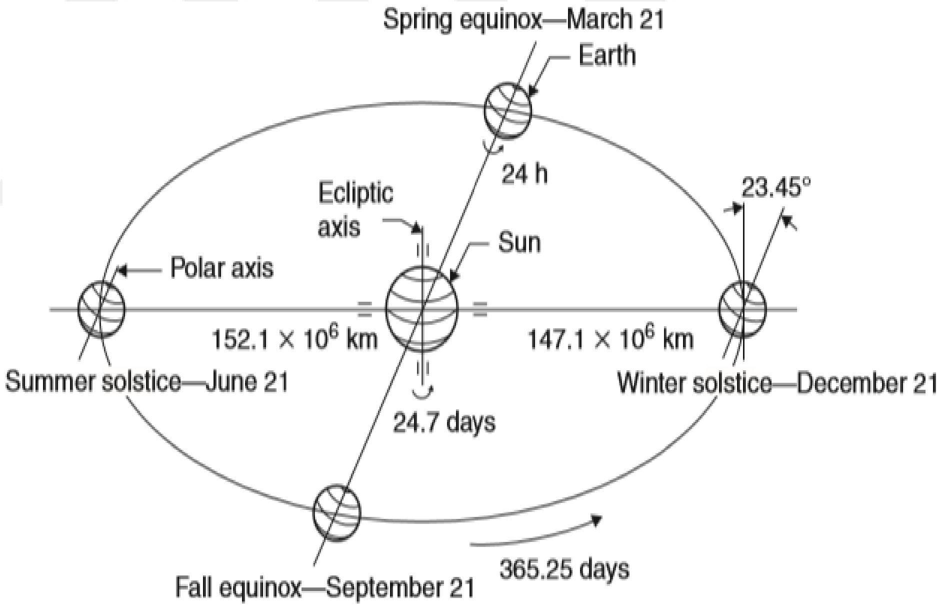

Figure 2.5: Annual motion of the earth about the sun [9].

2.4.3.1 Declination (δ)

The angular distance from the solar ray to the north or south of the equator is known as solar declination. Angle declination it is the angle between the projection of this line on the equatorial plane and the sun–earth centerline. So declinations north of the equator are positive, In the case of the south, it is negative. As shown in figure

(2.6) the ranges of Declination to be at the spring equinox and the summer solstice from (0° to +23.45°), at the fall equinox and the winter solstice from (0° -23.45°). We can calculation of declination in degrees for any day of the year by equation (ASHRAE, 2007) [47]:

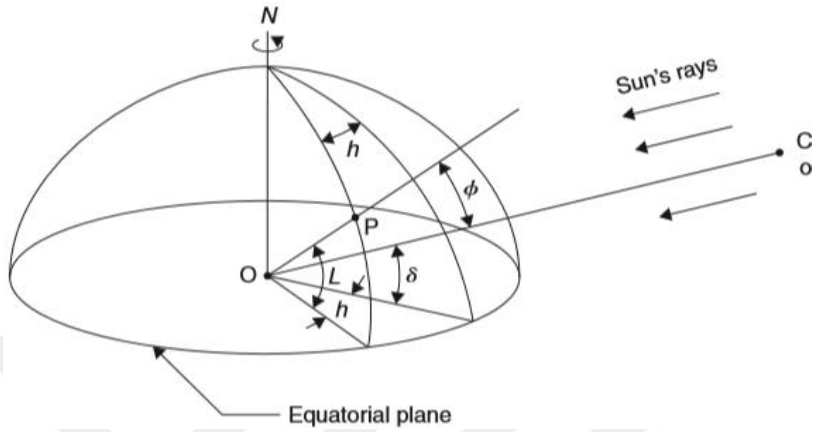

Figure 2.6: The definition of latitude, hour angle, and solar declination.

$$\delta = 23.45\sin\left[\frac{360}{365}(284 + N)\right] \quad (2.7)$$

2.4.3.2 Hour angle, (h)

Because of the rotation of the earth on its axis at 15◦ per hour, angular displacement is formed of the sun east or west of the local meridian; this is called the hour angle and to be negative in the morning, positive in the afternoon. The hour angle at local solar noon is zero [47].

h = 0.25$\pm$ (Number of minutes from local solar noon) (2.8)

Hence

The plus sign refers to afternoon hours and the minus sign to morning hours.

The hour angle can also be taken from the AST; that is, the corrected local solar time:

$$h = (AST - 12)15 \quad (2.9)$$

At local solar noon, AST =12 and h = 0°.

2.4.3.3 Solar altitude angle, (α)

The angle between the horizontal and the line to the sun called solar altitude angle, (α). It is linked to the solar zenith angle Φ which is the angle between the vertical and the sun's rays as shown in Figure (2.7).

$$\Phi + \alpha = \frac{\pi}{2} = 90^{\circ} \quad (2.10)$$

$$\sin(\alpha) = \cos(\Phi) = \sin(L)\sin(\delta) + \cos(L)\cos(\delta)\cos(h) \quad (2.11)$$

Hence

L = local latitude (the angle between the equatorial plane and a line from the center of the earth to the site of interest. Note that :the sign (+) is from the equator to the north and the sign (-) to the south [48].

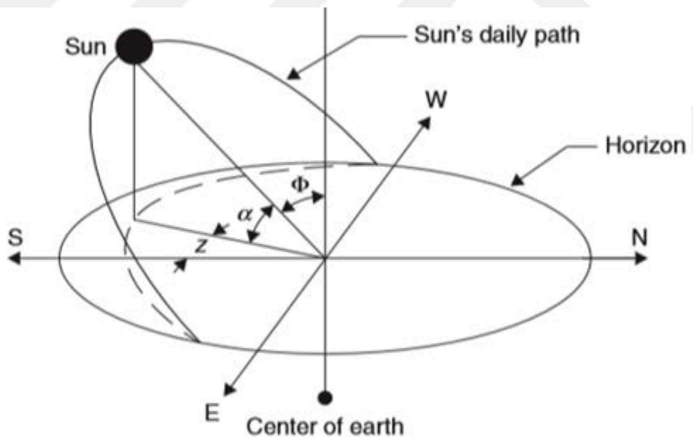

Figure 2.7: The daily path of the sun across the sky from sunrise to sunset.

2.4.3.4 Solar azimuth angle, (z)

The angle which measured between the horizontal plane and of the sun's rays is named Solar azimuth angle, (z). We can be considered of as the azimuth angle between the critical point of the Sun (s) and the origin point at 0° [49]. The expression for the solar azimuth angle is:

$$\sin(z) = \frac{\cos(\delta)\sin(h)}{\cos(\alpha)} \quad (2.13)$$

2.5 The solar radiation outside the earth's and Terrestrial Solar Radiation

Earth's atmosphere is in the situation a continuously changing that works on extraterrestrial direct beam, or direct normal [50]. In the case of absence of the earth's atmosphere, the amount of total radiant energy received from the sun per unit time per unit area apparent normal to the sun's rays at the mean sun-earth distance is called the solar constant, G_{sc} [51]. Many studies were conducted on the solar constant from 1838 to 1957 about the value of the solar constant using different methods and devices and The really direct solar irradiance at the top of the atmosphere oscillate by about 6.9% during a year from 1.412 kW/m² on 3 January (the sun is closest to the earth) to 1.321 kW/m² on 4 July (the sun is farthest away to the earth) this is due to the Earth's differ distance from the Sun, and typically by much less than 0.1% from day to day [52]. During the one year radiation outside the Earth is measured on the plane normal to the radiation on the Nth day of the year, the term G_{on} differ between these value, Vary between this value; as shown in Fig(2.8) in the domain of 3.3% and can be calculated by (Duffie and Beckman, 1991; Hsieh, 1986):

$$G_{on} = G_{SC}\left[1 + 0.033\, COS\left[\frac{360N}{365}\right]\right] \qquad (2.14)$$

Hence

G_{on}= extraterrestrial radiation (W/m2).

G_{sc} = solar constant (W/m2).

N = nth day of the year with 1st January

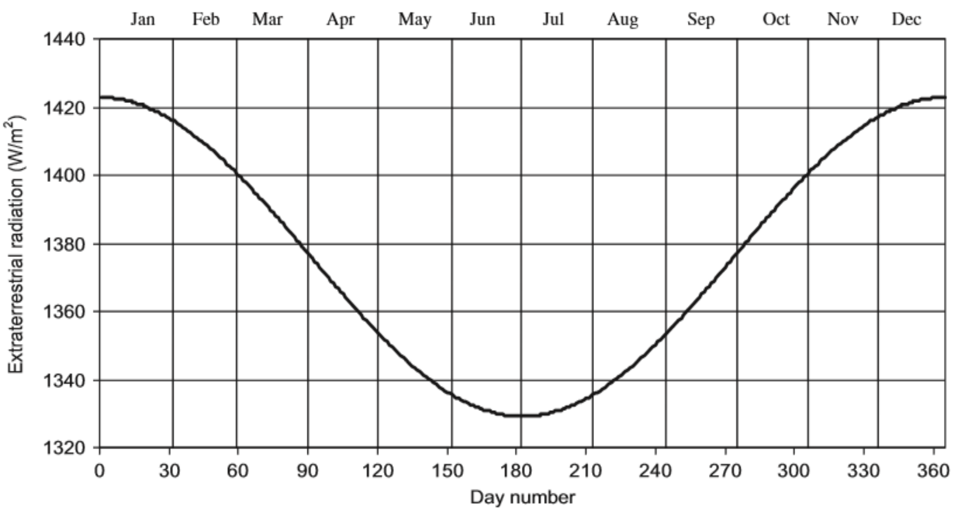

Figure 2.82: The differed of extraterrestrial solar radiation with the time of year.

In 2000 American Society for Testing and Materials (ASTM) was adopted the latest value of solar constant is 1366.1 W/m2. Which it is developed an AM0 reference spectrum (ASTM E-490). Figure (2.9) shown that the spectrum curve is based on a set of data included in ASTM E-490 (Solar Spectra, 2007).

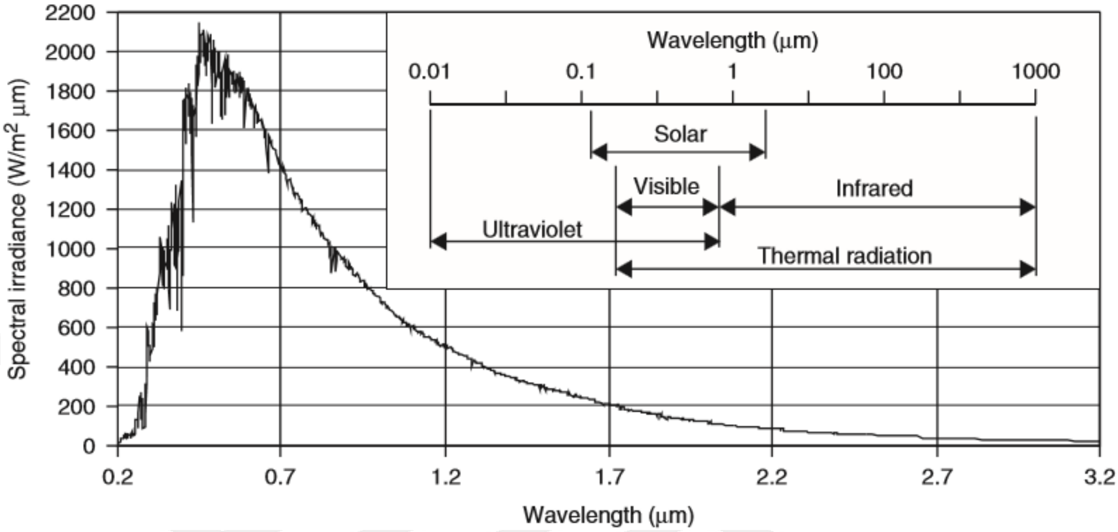

Figure 2.93: The standard curve giving a solar constant of 1366.1 W/m2 and its position in the electromagnetic radiation spectrum.

When a surface is placed horizontal to the ground, the term of value of solar radiation, becameGoH.

GoH = extraterrestrial horizontal surface and the equation

$G_{oH} = G_{on}\cos(\Phi)$

$$G_{oH} = G_{sc}\left[1 + 0.033COS\left(\frac{360N}{365}\right)\right][COS(L)COS(\delta)COS(h) + \sin(\text{L})\sin(\delta)] \quad (2.15)$$

The total radiation Ho incident on an extraterrestrial horizontal surface during a day can be obtained by the integration of Equation (2.15) [53]:

$$H_o = \frac{24\times3600G_{sc}}{\pi}\left[1 + 0.033\cos\left(\frac{360N}{365}\right)\right] \times \left[\cos(L)\cos(\delta)\sin(h_{ss}) + \left(\frac{\pi h_{ss}}{180}\right)\sin(L)\sin(\delta)\right] \quad (2.16)$$

Hence

hss = the sunset hour in degrees.

The units of Eq. (2.16) are joules per square meter (J/m2).

2.6 Spectral distribution of Solar Radiation

Entry into the field of solar energy research requires knowledge of the spectral distribution of solar radiation on the surface of the earth so that the researcher can perform the task entrusted to him either applied or evaluated performance [54]. Two factors cause the spectral wavelength of the solar radiation to exceed (0.2-50)μm when it reaches the Earth's surface. The first the passage of radiation across the atmosphere is dispersed, where the interaction between evaporated water molecules and air that often carries dust as indicated in Figure (2.10). The number and size of particles relative to wavelength is a major factor in scattering. The scattering happens and based on the theory of Rayleigh. The theory of Rayleigh scattering based on the wavelength to the negative fourth power λ^{-4}). for the wavelengths to be at shorter (less than 0.6 µm) the Rayleigh distribution becomes worth [55]. The following table (2.2) shows that solar radiation occupies about 47% of the visible range and this percentage begins to decline due to dust evaporation as we mentioned earlier regarding Iraq's air conditions.

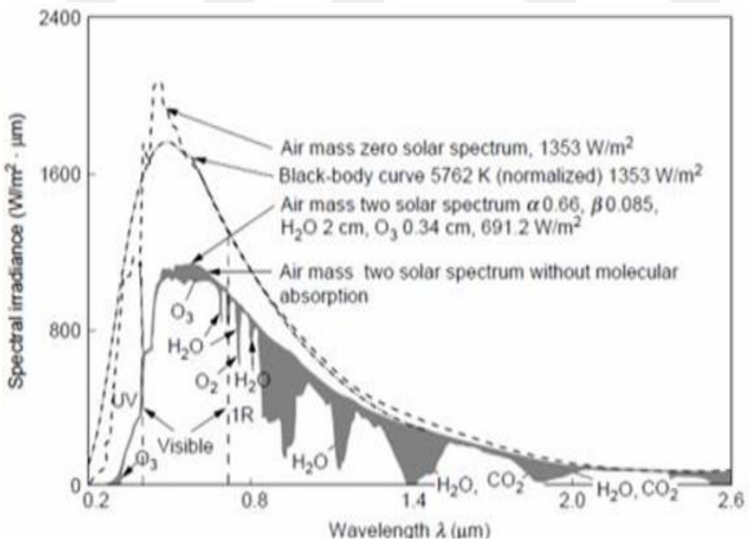

Figure 2.104: The spectral distribution of the solar radiation [34].

Table 2.2: Classification of solar radiation in case spectral [57].

Range	Wavelength(nm)	Percentage %	Solar radiation w/m^2
UV	0-380	7	95
Visible	380-780	47.29	640
IR	780-3000	45.71	618

2.7 Solar Energy Collectors

One of the applications of heat exchangers is solar energy collector. This system converts solar energy into internal energy through a conveyor medium such as air, oil or water. And then carry the solar energy collected from the collector to applied location either directly or to the solar energy tanks according to the application. The solar collectors are divided into two main types: concentrating and stationary concentrating or non-concentrating and used according to the required outputs [56]. A non-concentrating collector has the same area for Receiving a and sucking solar radiation, while a sun-tracking concentrating solar collector Typically has concave reflecting surfaces to receive and focus the sun's beam radiation to a smaller receiving area, in this way increasing the radiation flux. Concentrating collectors is compatible with applications that need high temperatures. As mentioned before, the solar energy collectors are dependent and influenced by the carrier medium of the heat and the outer shell whether it is covered or not [57].

2.8 Stationary collectors

These collectors are always stationary in position and do not moving and track the sun. For this kind of collector there are three classifications:

1. Flat-plate collector (FPC). Figure (2.11)
2. Stationary compound parabolic collector (CPC). Figure (2.12)
3. Evacuated tube collector (ETC). Figure (2.13)

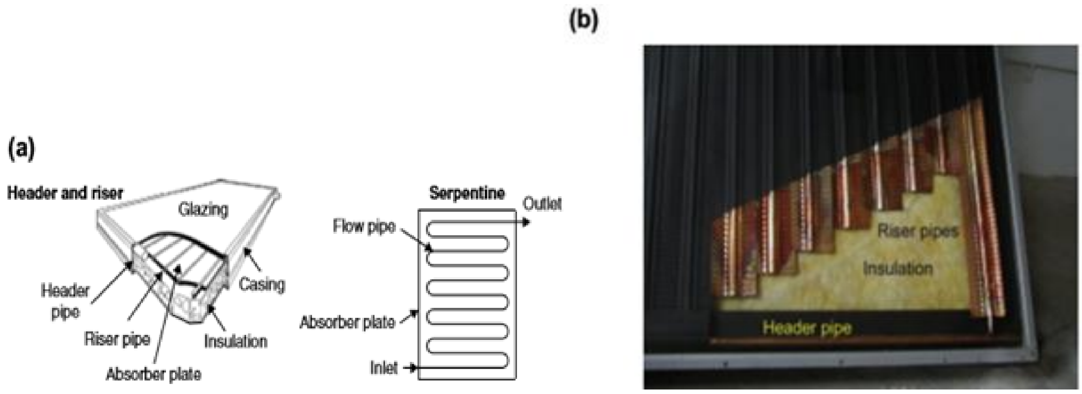

Figure 2.115: The flat-plate collector.

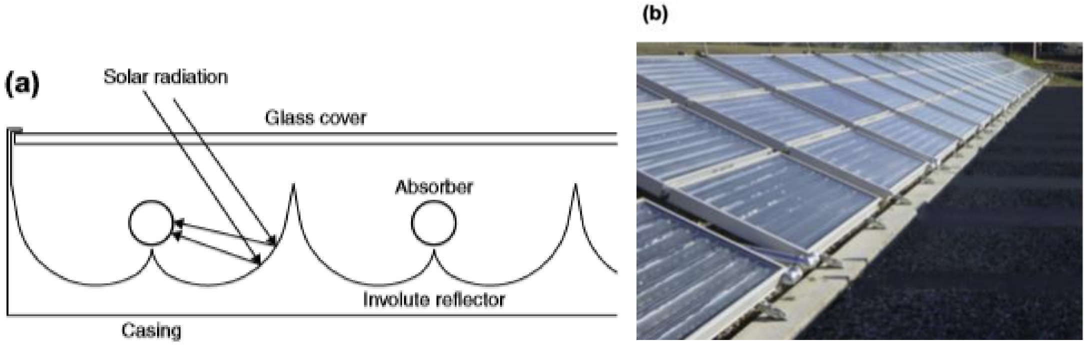

Figure 2.126: The Panel CPC collector with cylindrical absorbers.

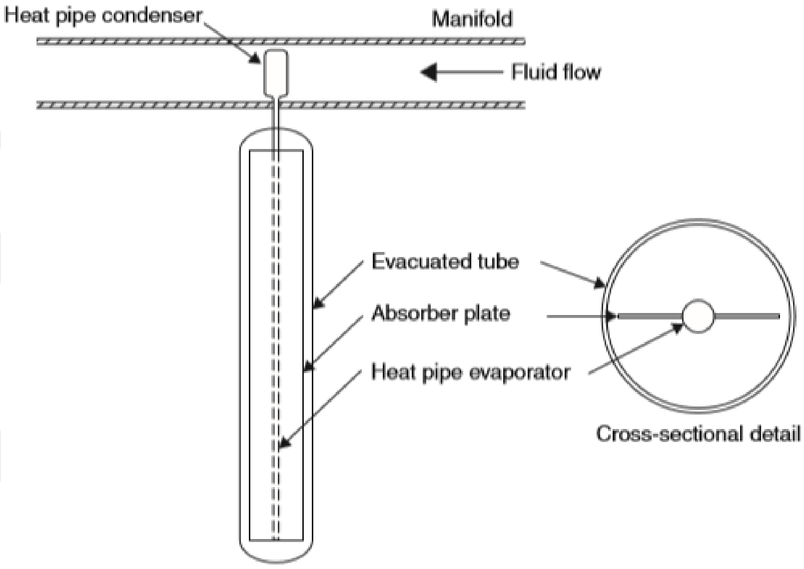

Figure 2.137: The Schematic diagram of an evacuated tube collector.

2.9 Sun-tracking concentrating collectors

One of the most important factors to improve solar energy systems is to reduce losses by increasing the temperature of solar energy produced via reducing the area where these losses occur [58]. Concentrating a large amount of solar thermal on a relatively small space leads to higher heat gain than can occur in a flat panel collector (FPC). This is achieved by putting an optical device in the Middle between the source of radiation and the energy-absorbing surface. The image of the sun has an effect on the classification of concentrating collectors whether they are non-imaging and imaging. In other words, the image of the sun is focused on the receiver or not. In the above-mentioned, The concentrator be the classification non-imaging either types which inter within the category of imaging is as the figure (2.14) [59]:

a. Parabolic trough collector (PTC).
b. Linear Fresnel reflector (LFR).
c. Parabolic dish reflector (PDR).
d. Heliostat field collector (HFC).

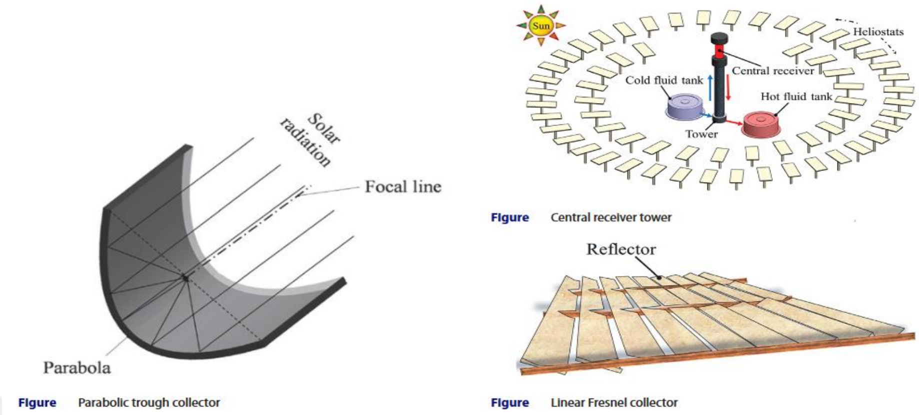

Figure 2.14: The concentrating collector's type non-imaging.

2.10 Parabolic trough collector (PTC)

One of the worthwhile types of solar energy systems is the parabolic trough collector; it is an appliance which takes the shape of the parabola and has a relatively small focal length.it is used for high temperature and perfect performance. This device is characterized by light structure, low technical cost and is suitable for heat operations up to 400 $c°$ [60]. The solar system is formed in several ways, such as a wooden model in the form of the parabola or curvature a sheet of metal, which takes the shape of the parabola so it has the ability to reflect the sun rays. A copper pipe or any other metal with a heat absorber is set straight the focal length of the recipient and preferably coated with the black heat-absorbing material. The radiation on the parabola will be reflected along the length of the pipe as the parabola is routed to the sun. A heat transfer medium is inserted into the tube which receives the concentrated rays and transfers them to other parts within the application [61].

2.10.1 Geometry of parabolic trough collectors

We mentioned above that Concentrating collectors of this type are stabilized by placing an optical device between the absorption surface and the radiation source.

Moreover, there must be thermal and optical analysis processes to complete the task. First, optical analysis processes and starting with the most influential factor is the concentration ratio that is define a ratio of the aperture area to the receiver absorber area and it was written as shown [62]:

$$C = \left(\frac{A_a}{A_r}\right) \tag{2.17}$$

For concentrating collectors usually > 1

2.10.2 Optical analysis of parabolic trough collectors

For geometric analysis the parabola trough collector, Figure (2.15) represents a cross-section of a parabolic trough collector that shows geometric analysis and angles to be considered when designing such as diameter, aperture angle, and concentration ratio [63]: The edge radius r_r: the value of the line which connected between the focal point and the paraboloid extreme hence (the mirror radius,r_r, is maximum). The rim angle (ψ or φ_r): the angle between the incident radiation on the reflector at r_r and the center line of the collector.

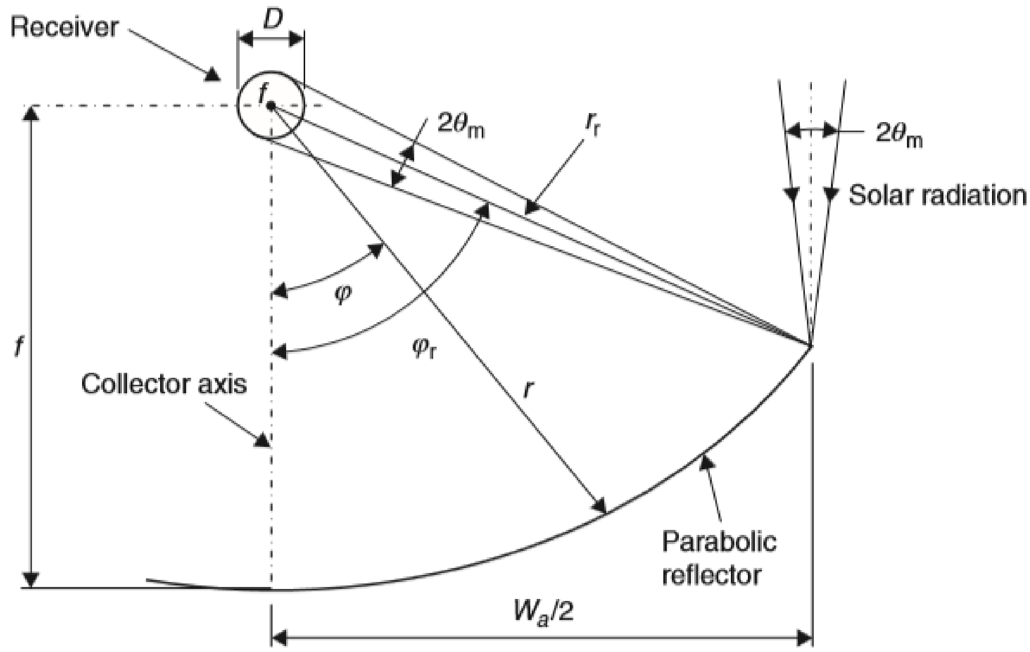

Figure 2.158: The Cross-section of a parabolic trough collector with circular receiver.

The equation form is related to the equation of the coordinate system:

$$y^2 = 4fx \tag{2.18}$$

Hence,

f = Parabola focal distance in (m) and defined as the distance from the focal point to the vertex figure (2.16) [64].

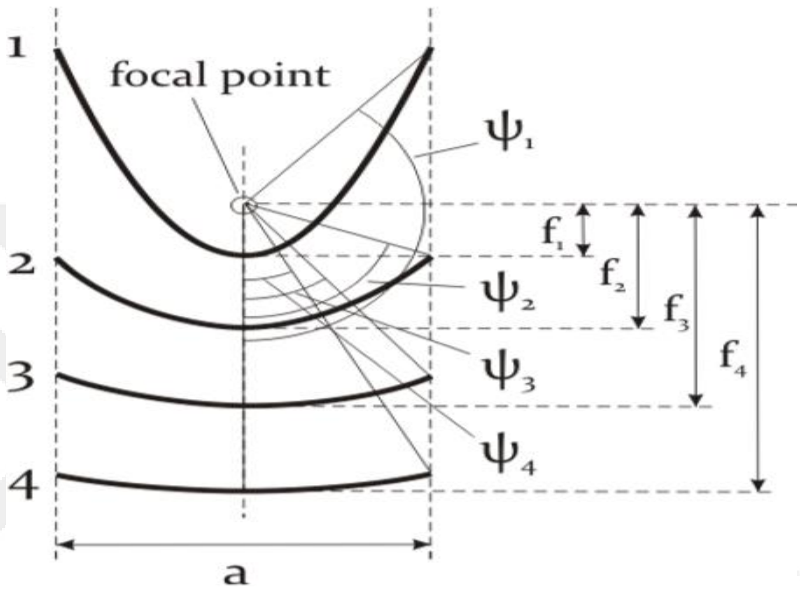

Figure 2.169: The relevance between the rim angle and the focal length for same aperture width.

Diameter (D): according to trigonometry, the required diameter of the receiver size can be obtained. To intercept all the solar image and reverse its brightness and basses on the figure (17) the equation for the diameter will be [65]:

$$D = 2r_r \sin(\theta_m) \tag{2.19}$$

θ_m = Half acceptance angle (degrees).

The radius (r) in the figure (2.15) becomes:

$$r = \frac{2f}{1+\cos(\varphi)} \tag{2.20}$$

φ = The angle is between the collector axis and a reflected beam.

So the rim angle, φ_r the r_r becomes

$$r_r = \frac{2f}{1+\cos(\varphi_r)} \tag{2.21}$$

The aperture of the parabola, W_a is the another considerable parameter associated with the rim angle.

$$W_a = 2r_r \sin(\varphi_r) \quad (2.22)$$

$$W_a = [\, 4f sin(\varphi_r)/(1 + \cos(\varphi_r)] \quad (2.23)$$

$$W_a = 4f tan(\frac{\varphi_r}{2}) \quad (2.24)$$

In case a tubular receiver the concentrating ratio, C = $\frac{W_a}{\pi D}$ (2.25)

After substitution D and W_a the C became

$$C = \frac{\sin(\varphi_r)}{\pi \sin(\theta_m)} \quad (2.26)$$

The C maximum accrued when the $\varphi_r = 90°$ and $\sin(\varphi_r) = 1$

Than

$$C_{max} = \left(\frac{1}{\pi \sin(\theta_m)}\right) \quad (2.27)$$

2.10.3 Thermal analysis

To calculation of total solar energy gain of the receiver requires thermal analysis involving thermal losses (radiation, conduction, convection) and related factors such as the collector efficiency factor F'; the loss coefficient, U_L; and the collector heat removal factor, F_R. Thermal losses from the receiver must be evaluated. The terms U_L indicate the overall heat loss coefficient, which depends on the area of the receiver. In this type of solar collector (PTC), we can do two cases of analysis once when the tube is not covered (bar tube) and the other when it is encased in a glass cover (glazed tube) to reduce thermal losses. In both analyzes, radiation, conductivity, and convection loss will be of great importance to the relevant calculations, the mathematically structure is given as [66]:

$$U_L = h_w + h_r + h_c \quad (2.28)$$

Where

U_L: Over all heat loss coefficient,$W/m^2.k$

h_w: Wind induced convective heat transfer coefficient, W/m^2.k

h_r: The radiation heat transfer coefficient,$W/m^2.k$

h_c: The convection heat transfer coefficient,$W/m^2.k$

The Nusselt number can be used, for the wind loss coefficient

$$h_w = \frac{N_{ua}k_a}{D_g} \tag{2.29}$$

N_{ua}: The Nusselt number of air and can take from the equation [9]:

$$Nu = 0.4 + 0.54(Re)^{0.52} \tag{2.30}$$

0.1< Re < 1000

$$Nu = 0.3(Re)^{0.6} \tag{2.31}$$

1000 < Re < 50000

The absorber pipe is covered with a glass cover, in order to minimize thermal losses. The distance between the glass and the tube shall also be evacuated. In this case, the loss of connection is neglected and the, U_L depends on the receiver area A_r , the equation became:

$$U_L = \left[\frac{A_r}{(h_w+h_{r,c-a})A_g} + \frac{1}{h_{r,r-c}}\right]^{-1} \tag{2.32}$$

$h_{r,r-a}$: Radiation coefficient from cover to ambient and estimated by Equation in (W/m2 K)

$$h_r = 4\sigma\varepsilon T_r^3 \ \ldots\ldots\ldots\ldots\ldots\ldots \tag{2.33}$$

$h_{r,r-c}$: Radiation coefficient from receiver to cover, given by Eq.

$$h_{r,r-c} = \frac{\sigma\left(T_r^2+T_c^2\right)(T_r+T_c)}{\frac{1}{\varepsilon_r}+\frac{A_r}{A_g}\left(\frac{1}{\varepsilon_g}-1\right)} \ \ldots\ldots\ldots\ldots \tag{2.34}$$

A_g : External area of glass covers(m^2).

ε_r: The emittance of the receiver.

ε_g: The emittance of the glass.

σ : Stands for the Stefan Boltzman constant which is: 5.67×10−8 W/m^2k^4.

By neglect the radiation absorbed cover and by using an energy equation balance, we can obtain T_g this temperature is in demand and it is very important to know the properties of the glass cover. They are usually nearly to the ambient temperature than the receiver temperature, the energy balance:

$$A_g\left(h_{r,c-a}+h_w\right)\left(T_g-T_a\right)=A_r\,h_{r,r-c}\left(T_r-T_g\right) \quad (2.35)$$

$$T_g\ =\ \frac{A_r\,h_{r,r-c}T_r+A_g\left(h_{r,c-a+h_w}\right)A_a}{A_r\,h_{r,r-c}+A_g\left(h_{r,c-a+h_w}\right)} \quad (2.36)$$

By iteration we can obtained, T_g which is, evaluated U_L from Eq. (2.32) If you do not get an approximate result (the temperature is various from the original temperature), the process is repeated twice usually not more.

Another important factor is the overall heat transfer coefficient, U_o is the coefficient for heat transfer from the surroundings to the fluid. Depend on the outside tube diameter; this should include the tube wall because the heat flux in a concentrating collector is high. This is given by:

$$U_o\ =\ \left[\frac{1}{U_L}+\frac{D_o}{h_{fi}D_i}+\frac{D_o\ln^{D_o}/_{D_i}}{2k}\right]^{-1} \quad (2.37)$$

D_o, D_i : Receiver outside and inside tube diameter (m).

K : the thermal conductivity for receiver pipe material.

h_{fi} = convective heat transfer coefficient inside the receiver tube (W/m^2K). and can be got from the standard tub flow equation:

$$N_u\ =0.023(Re)^{0.8}(\mathrm{Pr})^{0.4} \quad (2.38.a)$$

for turbulent flow (Re > 2300)

$$N_u\ =4.364=constant \quad (2.38.b)$$

for laminar flow

Hence

Re: Reynolds number =$\left(\frac{\rho V D_i}{\mu}\right)$ μ: fluid viscosity (kg/m s).

Pr: prandtl number = $\left(\frac{c_p\mu}{k_f}\right)$ k_f : thermal conductivity of fluid (W/m K).

The else parameters is the collector efficiency factor, F' and Collector heat removal factor F_R. The coefficient characterizes the efficiency of heat transfer from the absorption surface to the heat transfer fluid is called the collector efficiency factor. It can be considered as a ratio of two heat loss coefficients [67].

$$F' = \frac{\left(1/U_L\right)}{\frac{1}{U_L}+\frac{D_O}{h_{fi}D_i}+\frac{D_O \ln^{D_O}/D_i}{2k}} = \frac{U_o}{U_L} \tag{2.39}$$

Collector heat removal factor F_R refer to the actual useful energy profit of the collector to useful profit if the absorber surface was at the fluid temperature. And it is given by [68]:

$$F_R = \frac{m \cdot c_p}{A_r U_L}\left[1 - e^{\left(\frac{-U_L A_r F'}{m \cdot c_p}\right)}\right] \tag{2.40}$$

Hence: Cp is the precise heat of the fluid.

After these parameters we calculations the collector flow factor F'':

$$F" = \frac{F_R}{F'} = \frac{m \cdot c_p}{A_r U_L F'}\left[1 - e^{\left(\frac{-U_L A_r F'}{m \cdot c_p}\right)}\right] \tag{2.41}$$

To calculate the useful energy delivered from the parabolic trough collector which occurs when the whole collector is at the inlet fluid temperature (maximum quantity), while heat losses to the environment are then at a minimum. There are two ways to calculate useful energy and calculate the efficiency:

- By applying the subsequent equation:

$$Q_u = G_B \eta_o A_a - A_r U_L (T_r - T_a) \tag{2.42}$$

In the equation above, we used only beam radiation, G_B instead of the total radiation because of the nature of this type of concentric collector PTC that relies only on the beam radiation. Furthermore they have been appropriately using convenient areas for the absorbed solar radiation (A_a) and heat losses (A_r). Per unit of collector length, the useful energy gain can be calculated from the form subsequent, in terms of the local receiver temperature, T_r [69, 9]:

$$q'_u = \frac{Q_u}{L}$$

$$q'_u = \frac{G_B \eta_o A_a}{L} - A_r U_L (T_r - T_a) \quad (2.43)$$

For T_f the equation become

$$q'_u = \frac{(A_r/L)(T_r - T_f)}{\frac{D_o}{h_{fi} D_i} + \frac{D_o \ln^{D_o}/_{D_i}}{2k}} \quad (2.44)$$

In case T_r is eliminated from Equations (2.43, 2.44), we get

$$q'_u = F' \frac{A_a}{L} \left[G_B \eta_o - \frac{U_L (T_f - T_a)}{C} \right] \quad (2.45)$$

Hence

$C = \frac{A_a}{A_r}$ represent concentrating ratio, so from equation (2.39)

The collector efficiency factor $F' = \frac{\left({}^1/_{U_L}\right)}{\frac{1}{U_L} + \frac{D_o}{h_{fi} D_i} + \frac{D_o \ln^{D_o}/_{D_i}}{2k}}$ and from equation (2.40)

$F_R = \frac{m \cdot c_p}{A_r U_L} \left[1 - e^{\left(\frac{-U_L A_r F'}{m \cdot c_p} \right)} \right]$, so the useful energy became:

$$Q_u = F_R [G_B \eta_o A_a - A_r U_L (T_r - T_a)] \quad (2.46)$$

We can get the thermal efficiency by dividing the useful energy on the area (A_a) and solar radiation (G_B) which is occurring on the aperture.

$$\eta = F_R \left[\eta_o - U_L \frac{(T_f - T_a)}{G_B C} \right] \quad (2.47)$$

- By calculating the heat associated with the flow rate in depended with the fluid difference temperature as described [70, 71, 72]:

$$Q_u = m^{\cdot} c_p (T_{f_o} - T_{f_i}) \tag{2.48}$$

Hence:

T_{f_i}: The inlet fluid temperature.

T_{f_o}: The exit fluid temperature.

$\eta = \frac{Q_u}{A_a G_B}$, substitution the equation (2.48) we get:

$$\eta = \frac{m^{\cdot} c_p (T_{f_o} - T_{f_i})}{A_a G_B} \tag{2.49}$$

2.11 Introduction of the refrigeration cycle

The process of heat disposal and extrusion outside the limits of the area to be reduced and maintain a temperature less than boundary is called refrigeration Either the air treatment process in terms of temperature, humidity and air cleaning within a specific area is called air conditioning [73]. There are two type of refrigeration:

1- Natural methods.
2- Mechanical or Artificial: this type also it has two type
   i) Air refrigerators
      (a) Reversed Carnot cycle.
      (b) Bell Coleman cycle.
   ii) Vapor refrigerators.
      (a) Vapor compression refrigerator.
      (b) Vapor absorption refrigerator.

2.11.1 Vapor compression refrigerator cycle

The vapor compression refrigeration cycle is a popular technique for carrying heat from a low temperature to a high temperature. It is widely used in all fields and we rely on electric power. It consists mainly of compressor, evaporator, condenser and expansion valve as shown in figure (2.17) [71]. The vapor compression cycle is the classic and basic cycle, it is consuming electrical energy as we mention. It depends on CFC's are working as refrigerants, is big. Furthermore the increasing demand for electricity, Requires burning a high percentage of fossil fuels, which in turn leads to more carbon dioxide emissions. Second, the danger of using traditional cooling media because it has an effect on the environment through penetration of the ozone layer in addition to it is toxic in itself. These issues raise controversy and concern in scientific circles and specialists in the case of continued use. Therefore, prudent alternatives must be taken in parallel with economic and technological growth. This is done by opening renewable energy fields, developing solar energy programs, and so forth.

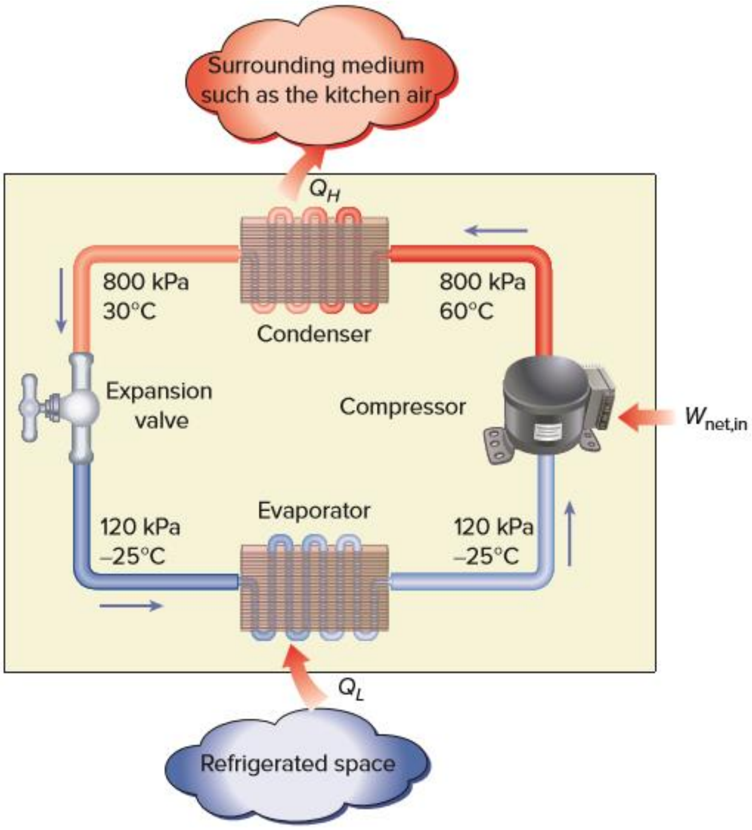

Figure 2.1710: The Basic components of a refrigeration system.

2.11.2 Vapor absorption refrigerator

Recently, the absorption cooling systems have become a success factor in the field of environment and economic and a substitute for compressor cooling systems. Absorption cooling systems can operate at a low level of heat and their obtained are not difficult. They can be found in several directions such as heat associated with exhaust from industrial processes or conventional thermal systems or by direct exploitation of heat exporters such as solar energy or geothermal. The utilization of large amounts of waste heat and the use of available renewable thermal sources help to save the limited fossil energy inventory and reduce the output of combustion emitted in the atmosphere. Moreover, the use of absorption cooling systems reduces the load on the general grid of electricity produced by the compressor cooling systems and reduces thermal pollution and The ozone layer conserves against corrosion as a result of chlorofluorocarbons (CFCs) leaching into the atmosphere [74]. In the nature of the case and because of the characteristic of the vapor absorption cycle, it progresses on the vapor compression cycle. The advantages, contrast and power elements between the two sessions will be discussed in the succeeding section [75].

2.12 The variation between the absorption cooling cycle and the pressure cooling cycle

1- We know that the tremendous progress of industrial processes requires thermal energy for their continuous. This thermal energy is heavily dependent on fossil fuels, which are the main contaminants of environmental pollution resulting in residues that transfer outside to the surrounding environment after operations. Although this undesirable heat can be converted into useful energy using a cooling system by absorption or working pumps by absorption. This measure works to reduce fuel consumption and electric power, which in turn reduces environmental pollution and global warming.

2- Because of the physical thermal properties of chlorofluorocarbons (CFCs), which it is used as a cooling medium in most conventional steam pressure systems, which have hazardous effects on the ozone layer, cooling absorber systems to be the successful option in the future [74].

3- In the vapor compression cycle, work for compression is greater than the absorption cycle, because of the pumping in the vapor absorption cycle pumping involves liquid.

4- In order to carry out the vapor compression task, a high pressure required to be preserved, while the vapor compression cycle can operate in low pressure employ particular working pairs [75].

2.13 Working pairs

All kind of Absorption cycles (heat absorption pump, absorber coolant, and absorbent heat transformer) utilize the waste heat as an economical medium. Because it has a direct impact on reducing electricity consumption and curtailment the negative impact on the environment. The thermodynamic properties of the working pairs of (refrigerant and absorbent) are very important due to the adoption of the performance coefficient on them. Therefore, the research has sought to find pairs of work more suitable and useful with thermal stability, non-crystallization, and corrosion [76].

2.14 Working principle of the absorption refrigeration cycle

The operation of the cooling cycle by absorption requires the addition of heat to the generator. Hence, we will introduce a solar energy system for this purpose. We know the evaporator, the condenser, the generator, and the absorber are the main contents of the absorption cycles. The important part of the cycle is the container (generator, absorber) which are supplied heat from solar energy collector at the same temperature. The evaporator is employed to the zone that needs to be coolant. The increased heat transmit from the condenser and the absorber is utilized for condensing the refrigerant, which is water [75]. The figure (2.18) explain the work of the cycle.

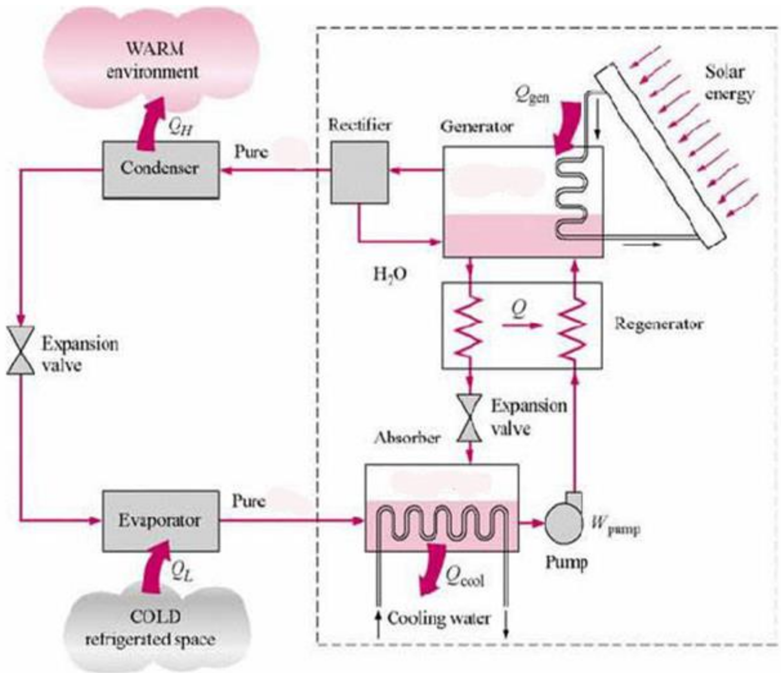

Figure 2.1811: The vapor absorption refrigeration.

CHAPTER THREE

METHODOLOGY

3.1 Introduction

Initially, all parameters included in the design the parabolic trough solar collector (PTSC) were calculated and by using a parabola program, the scheme drawing was carried out on a plate by the CNC machine. Secondly, the computation and the design of the device was finalized, for the purpose of initiating work involving the capture of heat from the sun and carrying it by water to the absorption cooling system. The collector work under of Iraq's climate.

3.2 Data acquired

The data that is focused on recording and installing are temperature. This was done using an electronic device for measuring the temperature, its characteristics and details, as shown below:

a. Kind 2k (Chromel / Alumel), the range between -50 to 1300 C and thoroughness + - 2.2 C.
b. It has the ability to mensuration the upper and lower temperature, and the average between them if it requisite.
c. It characteristic by 5 key with LCD, it has cut out display tip off when the input date be outside the limited which given.
d. Include options for using Celsius or Fahrenheit by only Press one of the buttons to choose one.

Figure 3.112: Digital Thermometer kind 6802II.

3.3 The computation style

After recording the output data obtained from the solar collector, heat gain is calculated from the subsequent equation:

$$Q = \dot{m}\,(h_1 - h_2) \tag{3.1}$$

Hence:

Q = the heat gain from collector kW.

$\dot{m}$ = the mass flow rate kg/sec.

h = enthalpy J/kg.

The flow rate of the mass is measured by placing a certain amount of water (kg) in the absorption tube of the parabolic solar collector and determined the time required to reach the heat, thereafter apply the following equation to calculate the mass flow rate.

$$\dot{m} = \frac{water\ mass\ (kg)}{time} \tag{3.2}$$

3.4 Formation of trough solar collector

The work of the (PTSC) was established through several steps as shown in the subsequent:

3.4.1 Computation of parabola

In the second chapter (2.10.2), we listed the mathematical and engineering analysis of the design of the solar complex. In this section we will list the accounts that have been approved based on what is stated above.

$$A_{abs} = \frac{\pi d^2}{4} + \pi \times d \times l \qquad (3.3)$$

The diameter value of the absorber and length were assumed (0.037, 1.3) m, respectively $A_{abs} = \frac{\pi (0.037)^2}{4} + \pi \times 0.037 \times 1.3$

$A_{abs} = 0.1521\ m^2$

$$C = \frac{A_a}{A_{abs}} \qquad (3.4)$$

then,

$A_a = c \times A_{abs}$

The maximum efficiency to be when the C = 10 [10].

$A_a = 10 \times 0.1521\ m^2 = 1.521 m^2$

Diameter of the Aperture = $\sqrt{\frac{4}{\pi} \times A_a}$ = $\sqrt{\frac{4}{\pi} \times 1.521 m^2}$ = 1.09 m.

$r_{a=} \frac{D_a}{2} = 0.546\ m.$

The half-acceptance angle θ_m is given by (Garg and Prakash) [72].

$$C = \frac{1}{sin^2\theta_m} \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (3.5)$$

$\theta_m = sin^{-1}\sqrt{\frac{1}{C}} = sin^{-1}\sqrt{\frac{1}{10}}$ =18.43°

The rim angle $\varphi_r = 90 - 18.43 = 71.57^{\circ}$

The Focal Length of the parabola is calculated from the equation:

$\frac{f}{D_a} = \frac{1+\cos\varphi_r}{4\sin\varphi_r} = \frac{f}{1.09\text{ m}} = \frac{1+\cos 71.57^{\circ}}{4\sin 71.57^{\circ}}$

$f = 0.378\ m$

From equation (2.21), $r_r = \frac{2f}{1+\cos(\varphi_r)}$ then,

$r_r = \frac{2\times 0.378}{1+\cos(71.57^{\circ})}$ = 0.574 m.

From equation (2.22) $W_a = 2r_r\sin(\varphi_r)$

$W_a = 2 \times 0.574\ \sin 71.57^{\circ}$= 1.08 m.

The dimensions and the cross-section of the parabola are shown in figure (3.2)

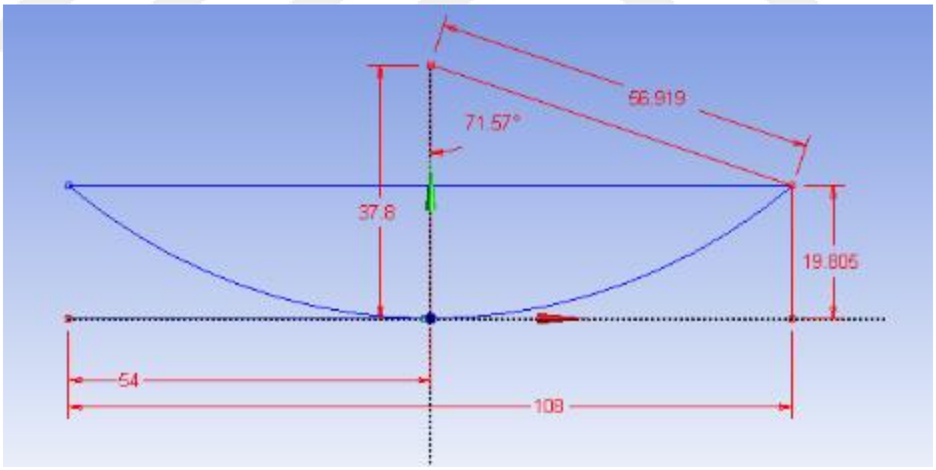

Figure 3.213: The cross-section of the parabola with the dimensions.

3.4.2 The formation of parabola and reflective

A lot of studies have been prepared about the metals used as an inverter for solar radiation and for each metal properties and characteristics. The use of reflective metals varies according to the application. In this work, the aluminum foil sheet was used to reverse the radiation to the absorption tube, that usually in the focal line. The aluminum foil sheet has the ability to form for a parabola shape, lightness weight, and low cost. The ribs were added before construction in the back of a flat reflective panel and were compelled to take the shape of the curve that was designed. The radiations which are reflected are absorbed by the receiver and converted into thermal energy. After the solar energy is picked up, it is transferred to the application prepared via the carrier medium. In this work, the water has been chosen the transfer medium for several reasons the cost of maintenance and transmit are low, in high temperature it has been steady state, and it was safe to utilize.

3.4.3 The formation of the (PTSC) Stand

The supporting structure of the (PTSC) from steel is designed in the form of a letter (L) on each side. Then the two rods were connected to each other by welding. On one side a Movable ruler was added to control (PTSC) rotation and we can be installed it in any angle we need by a screw. The dimensions of the support are as given in Table (3.1).

Table 3.1: Dimensions of support.

Dimension	Value
Length of the Support	1.4 m
Width of the support	1.1 m
Height of the support	1.14 m
Height of the parabola	1.21 m
Thickness of the Support bar	0.04 m

3.4.4 The Absorber pipe of the (PTSC)

Two different forms of different metals from the heat-pipe were used in this research with the same external diameter (37 mm) and the same length (1300 mm). The first is a regular galvanized iron tube coated with black selective coating to absorb the highest amount of reflected radiation. The second is a copper coil with a diameter of 6 mm to achieve an external diameter equal to an external diameter of the iron tube 37 mm, the distance between the roll and other 3 times from the diameter of the copper tube before winding. The copper coil was also painted with selective black paint. The idea of employing a coil absorbent is to increase the surface area of absorption while taking into consideration the cost. Tables (3.2, 3.3) explain the Specifications of Absorber Pipe:

Table 3.2: The dimensions of the galvanized iron tube.

Dimension	Value
External diameter	37 mm
Internal diameter	32 mm
Length of pipe	1300mm

Table 3.3: The dimensions of the coil absorber.

Dimension	Value
External diameter of coil	37 mm
External diameter of pipe coper	6 mm
Length of coil	1300mm
Length of pipe coper	8000mm

3.4.5 Parabolic trough dimension and formation

The aluminum strips were used in pre-designed dimensions and installed on the parabola-shaped mold and executed as indicated in the table (3.4):

Table 3.4: The dimensions aluminum trough.

Dimension	Value
Length	1300 mm
Breadth	1080mm
Thickness	1mm

Figure 3.314: Aluminum parabolic trough.

CHAPTER FOUR

THE EMPIRICAL ACTION

4.1 Introduction

In this section, we discuss the results and factors that are involved in analyzing the outcome of the Solar Collector, which were obtained in practical work. The results were gained from outdoor experimental experience by choosing the clear sky day in September.

4.2 Information of Solar Radiation Intensity Computations

The experiment was conducted in Iraq Babylon city Longitude 44.58° Latitude 32.50°. All data obtained in this section is installed in the following days by placing (0.5 kg) of water inside absorber tub. Firstly, for a regular galvanized iron tube absorber the data were picked up on 26 August 2018 in 9 to evening o'clock by the thermocouple device referred to in Chapter Three. Secondly, for coil copper absorber the data were picked up on August 28th (N is a number of the day, equal 240), as explained in the tables (4.1, 4.2) respectively. The average temperature and the intensity radiation for each summer month of Iraq's weather for 2018 illustrate them in the figures (4.1, 4.2).

Table 4.1: The temperature change by time inside a regular galvanized iron tube absorber PTSC.

Time in (min)	Temperature in (c°)
0	34
5	67.4
10	79
15	83
20	89.7
25	93.7
30	94.5
35	95.4
40	97.2
45	98.5
50	103
55	105.3
60	107.8
65	108.5

Table 4.2: The temperature change by time inside the coil copper absorber PTSC.

Time in (min)	Temperature in (c°)
0	34.5
5	62
10	66.3
15	77
20	81
25	81
30	81.5
35	81.5
40	82
45	82
50	83.4
55	87.5
60	88.9
65	90.7

4.3 Calculation of Heat Gain from the PTSC

In a quick look at the data in Table (4.1) and (4.2), we find that the required temperature in the cooling absorber system was obtained by using galvanized iron tube absorber a faster time than using a copper coil. In this case, the efficiency of PTSC by using the iron tube will great beneficial from the copper coil. This result will discuss in the next chapter.

Model of Calculations by using galvanized iron tube absorber:

For the purpose of calculating the energy gained from the solar collector, it is necessary to know some parameters such as the temperature of entry and exit, area and the mass of water inside the tube.

T_1: The initial temperature of inlet water in the absorber pipe and from table (7), $T_1 = 34c°$

T_2: The initial temperature of outlet waters that outlet from the absorber pipe and from table (4.1)…

$T_2 = 81c°$, this temperature is required for cooling absorber.

A: the PTSC reflected material area and equal 1.43m^2.

$\dot{m}$: The amount of mass inside the pipe absorber and equal 0.5 kg.

t: The time it takes to raise the outlet temperature that required heating the fluid in the generator in the cooling absorber system, this is take from table (4.1) and equal 11 min.

h_1: The enthalpy from saturated water in T_1 and equal (142.38) kJ/kg.

h_2: The enthalpy from saturated water in T_2 and equal (339.115) kJ/kg.

$Q = m(h_{2} - h_1)$

$Q = 0.5 \times (339.115 - 142.38) = 98.36$ kJ.

The amount of heat production per one second

$$q_{gain} = \frac{Q}{t} = \frac{98.36kJ}{660s} = 0.149\ kJ/sec$$

The amount of heat that gain from the sun, it was converted to $W/m^2$by dividing on the PTSC area

$$q_{iron\ abs} = \left[\frac{q_{gain}}{A} \times 1000\right] = \left[\frac{0.149}{1.43}\right] \times 1000 = 104.195\ W/m^2$$

The worst case of solar radiation value was used for Iraq's air conditions during the summer is $540 W/m^2$. The efficiency of the parabolic trough collector by using a regular galvanized iron tube absorber

$Ib = 540\ W/m^2$ The intensity of radiation

$$\eta_{iron\ abs} = \frac{q_{iron\ abs}}{Ib} \times 100 = \frac{104.195}{540} \times 100 = 19.29\%$$ collector efficiency

Model Calculations by using coil copper absorber:

$T_1 = 34.5c°$, $T_2 = 81c°$

A = $1.43m^2$, $m^{\cdot}$=0.5 kg.

t= The time it takes to raise the outlet temperature which required heating the fluid in the section generator in the cooling absorber system, this is take from table (4.1b) and equal 20 min.

h_1: The enthalpy from saturated water in T_1 and equal (144.47) kJ/kg.

h_1: The enthalpy from saturated water in T_2 and equal (339.115) kJ/kg.

$Q = m(h_{2-}h_1)$

$Q = 0.5 \times (339.115 - 144.47) = 97.3225$ KJ.

The amount of heat production per one second

$$q_{gain} = \frac{Q}{t} = \frac{97.3225kJ}{1200s} = 0.0811\ kJ/sec$$

The amount of heat that gains from the sun, it was converted to $W/m^2$by dividing on the PTSC area.

$$q_{copper\ coil} = \left[\frac{q_{gain}}{A} \times 1000\right] = \left[\frac{0.0811}{1.43}\right] \times 1000 = 56.714\ W/m^2$$

From the latest studies that found the intensity radiation = 540 W/m^2

So the efficiency of the PTSC by using a regular galvanized iron tube absorber

$Ib = 540\ W/m^2$ The intensity of radiation

$$\eta_{coil\ abs} = \frac{q_{copper\ coil}}{Ib} \times 100 = \frac{56.714}{540} \times 100 = 10.5\% \text{ collector efficiency}$$

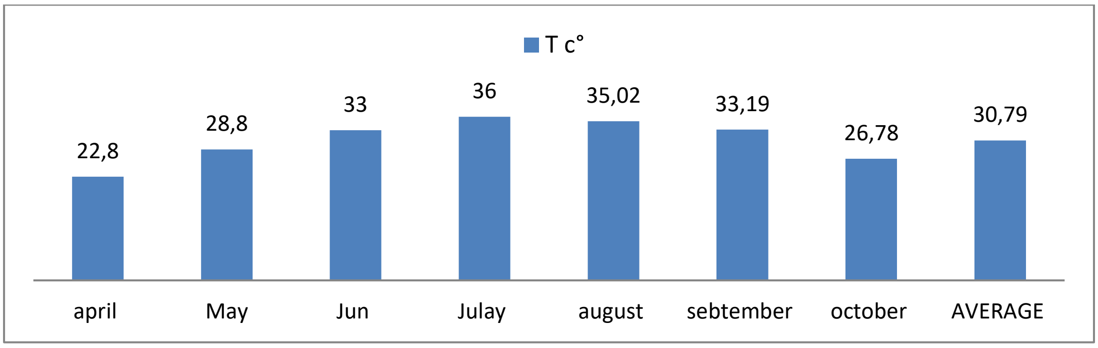

Figure 4.115: Show the average temperature each summer month for Iraq's weather in 2018.

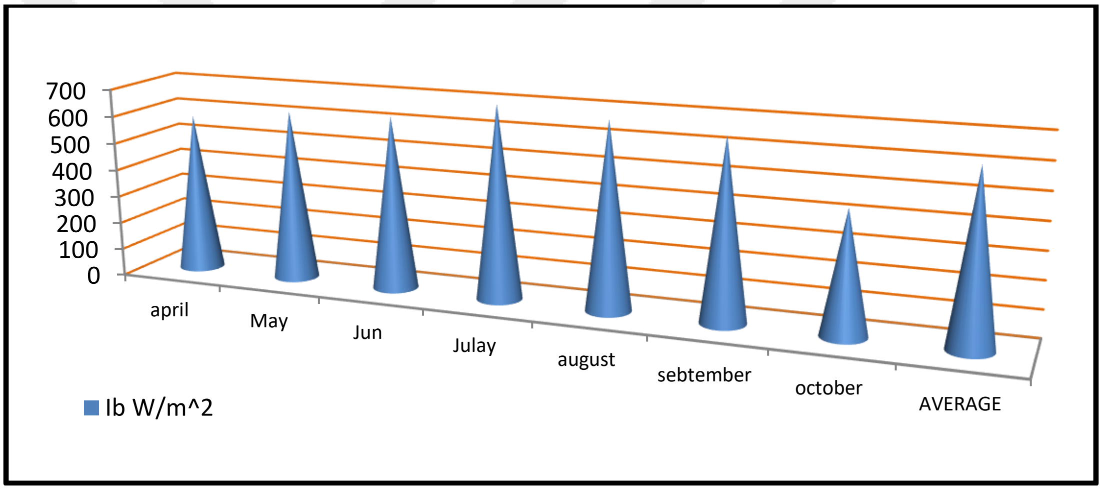

Figure 4.2: Show the intensity radiation each summer month for Iraq's weather in 2018.

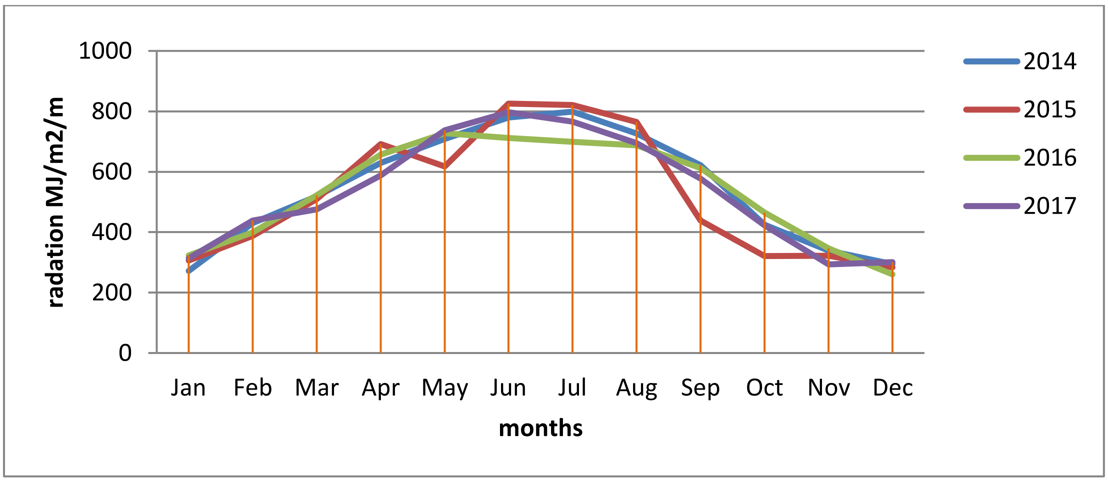

Figure 4.3: The radiation MJ/m2/m of Iraq's weather for a fourth year.

4.4 Heat required for cooling absorption system

The condenser and evaporator contain and vapor its water only. Therefore, the pressure corresponding to each working temperature is the pressure of water vapor saturation and is extracted from the table of water and saturated water vapor characteristics [8]. In addition, the generator pressure is equal to the pressure of the condenser and the pressure of the absorbent is equal to the pressure of the evaporator, so.

$P_1 = P_5 = 0.8135$ kpa

$P_1 = P_5 = 6.633$ kpa

The points for the cycle shown in Fig. 27 are dropped on the equilibrium diagram of the lithium bromide solution attached to this research. The concentration of the solution is indicated in point 1 at 34 C° and 0.8135 kpa. And the concentration of the solution at point 3 at 81C° and pressure 6.633 kpa, then read the enthalpy for the solutions from the concentration knowledge, namely the ratio of lithium bromide in the solution and its temperature from the bromide concentration scheme (Appendix).

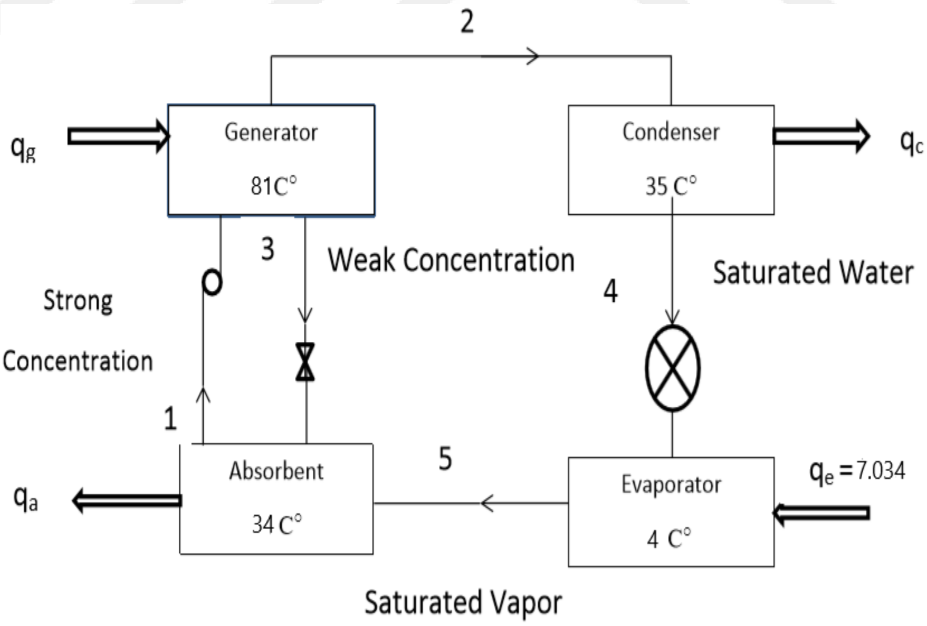

Figure 4.416: Schematic of refrigeration system.

so we can find the values of

x1 = 0.55

x3=0.59

To computation the enthalpies in point one and point three from the figure (4.4), so:

h1= 82 kJ/kg

h3= 208 kJ/kg

The (h4&h5) acquired in the points (4, 5) for saturated and saturated steam, respectively, from the steam table attached to this research at corresponding temperatures, so

h4=159.1 kJ/kg

h5=2505 kJ/kg

The h2 of the superheated vapor in the point (2) we can obtain by applied following equation [8]:

h2=h + (1.84*T2),

h= 2510.1 kJ/kg taken from the saturated vapor table then,

h2=2650 kJ/kg

Computation the mass of cooling fluid circulating in the cycle:

The mass of cooling fluid circulating in the cycle has been constant and we can obtain by dividing the required refrigeration in the unit one kilo watt on the refrigeration of the cycle, so

$m_2 = m_4 = m_5 = \frac{3.517\times 2}{(h5-h4)}$

$m_2 = m_4 = m_5 = 0.002998$ kg/s.

For the solution, the rate of lithium bromide recycling between the generator and the absorber is subject to the equilibrium mass equation as shown:

$m_3 \times x_3 = m_1 \times x_1$ …………….. (1)

And the total mass balance between them is as follows:

$m_1 = m_2 + m_3$ ……………………. (2)

To compensate and solve the equations we get:

$m_1 = 0.04422$ kg/s.

$m_2 = 0.002998$ kg/s.

$m_3 = 0.04122$ kg/s

Application of thermal equilibrium equations for the purpose of calculating the added heat to generator and the heat removed from the condenser and the absorber:

1- Heat rejected from condenser:

$q_c = m_2 \times (h_2 - h_4)$

$q_c = 0.04422 \times (2650 - 159.1)$

$q_c = 7.468\ kw/TR$

2- Heat rejected from absorbent

$q_a = ((m_5 \times h_5) + (m_3 \times h_3) - (m_1 \times h_1))$

$q_a = ((0.002998 \times 2505) + (0.04122 \times 208) - (0.04422 \times 82))$.

$q_a = 12.46\ kw\ /T.R$

3- Heat add to evaporator

$q_e = 3.517 \times 2\ TR$

$q_e = 7.034\ kw\ /T.R$

4- Heat add to generator

$q_{gen} = ((m_2 \times h_2) + (m_3 \times h_3) - (m_1 \times h_1))$

$q_{gen} = ((0.002998 \times 2650) + (0.04122 \times 208) - (0.04422 \times 82))$

$q_{gen} = 12.89$ kw/T.R

We can computation the total heat adds to system by:

$q_{add} = q_e + q_{gen}$

$q_{add} = 7.034 + 12.89$

q_{add} = 19.93 kW /T.R

$q_{rej} = q_a + q_c$

$q_{rej} = 12.46 + 7.468$

q_{rej} = 19.93 Kw /T.R

This is achieved the equilibrium of the cycle which (q_{add}=q_{rej}).

4.5 The computation of PTSC area which required per T.R

In ultimately, we can calculate the space required to add heat to the system equivalent to 2 ton refrigerator:

$$\frac{q_{gen}}{q_{gain}}$$

Hence,

q_{gain} : The amount of heat that gain from the sun by PTSC in $(^{W}/_{m^2})$.

q_{gen} : The amount of heat that added to generator in $(^{W}/_{TR})$.

So,

$$\frac{q_{gen}}{q_{gain}} = \frac{12.89 \times 1000}{104.195} = 123.7\ m^2/2TR$$

The area value which is obtained represents the aim of this study.

CHAPTER FIVE

DISCUSSIONS THE RESULTS

5.1 Results and Discussions

The numerous Invitations that are being launched currently to rationalize the consumption of electricity, whether they were depending on alternative sources of energy to produce electrical energy directly or by using applications that can be operated without resorting to electric energy, such as the topic of our research "cooling by using solar energy”. Focusing on these types of topics helps us to produce electricity in deserted areas that have not reached the electric power networks and also the system gives us the ability to reduce the use of fossil fuels, which results in reduced environmental pollution. The most important results obtained from the research are:

5.1.1 The heat gain from PTSC by using a regular galvanized iron tube absorber and coil tube

Iraq is one of the countries attracting investment in renewable energy where it has the environment qualified to apply the solar energy fields but not exploited. It has a good geologist floor to attract solar radiation, where the annual rate of solar radiation reaches $540W/m^2$.

Figure (5.1, 5.2) shows the heat gain and efficiency of the PTCS by using different absorber tubs (iron tube absorber and coil copper absorber). The results showed that the use of an iron pipe gave us better and higher values of heat which obtained from the solar collector than the copper coil, under the same conditions and amount of water which pass into the PTSC which was converted to vapor in various time. It is known that the copper is more heat transfer than iron, but in this work when the copper absorber was designed in the form of a coil with a distance between the ring and the other, Heat transfer was directly affected and this influence is caused convection heat losses. For this reason, we were needed to an increase in time more than time which needed of iron absorber to reach to the desired temperature and thus the iron pipe was achieved the highest efficiency. Figure (5.3, 5.4) and table (5.1) explain that.

Table 5.1: The various result between the copper absorber and an iron pipe.

	Time to reach 81 c°	Q in kw/m^2	Efficiency %	Cost $
Iron tub	11 minute	104.195	19.29	7
Coil copper tub	20 minute	56.714	10.5	41

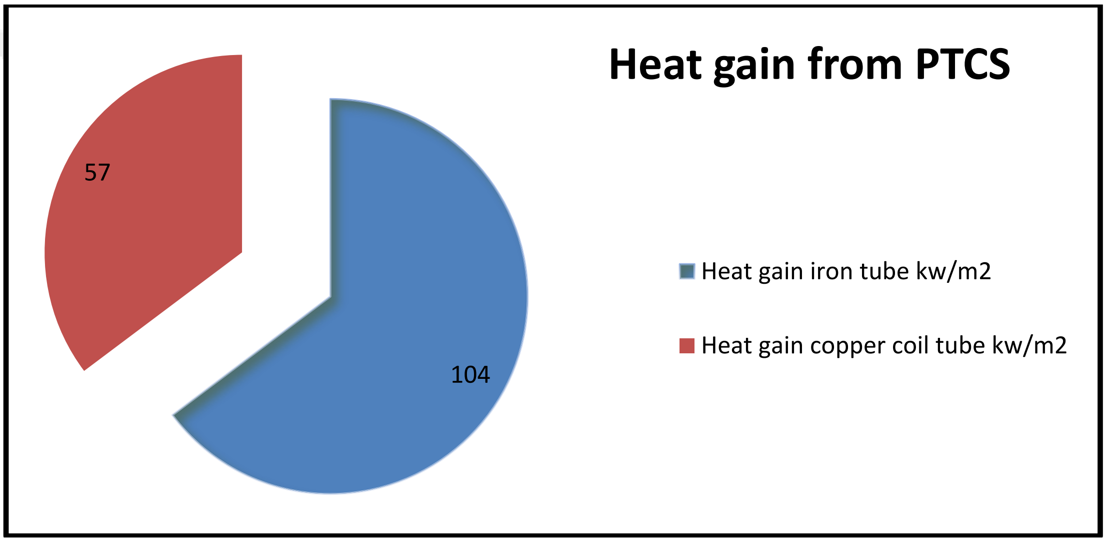

Figure 5.1: Shows the amount of heat gain from the PTSC with various kind of tube.

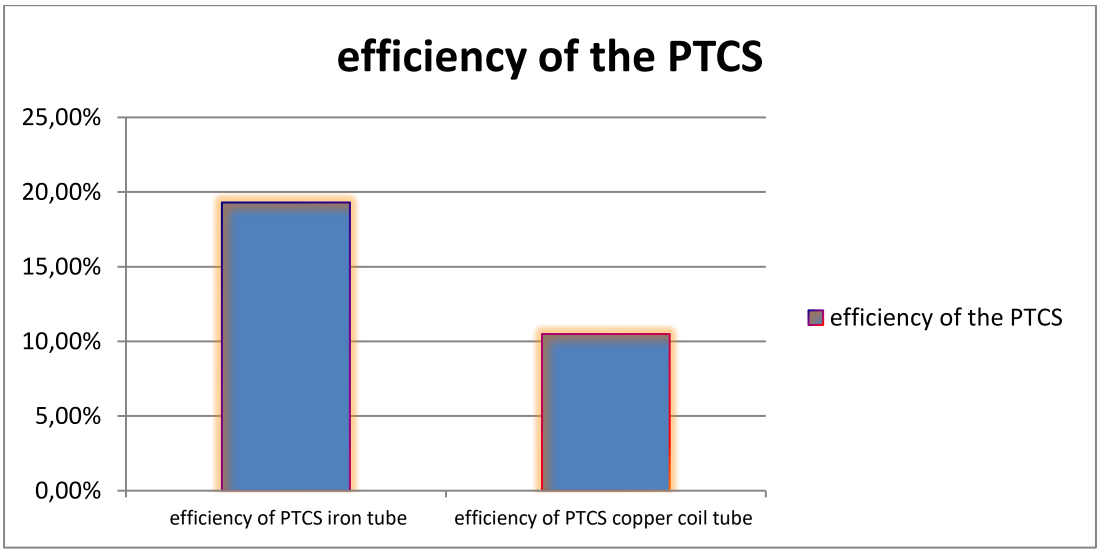

Figure 5.2: The efficiency of the PTCS by utilizes two kind absorber tubes.

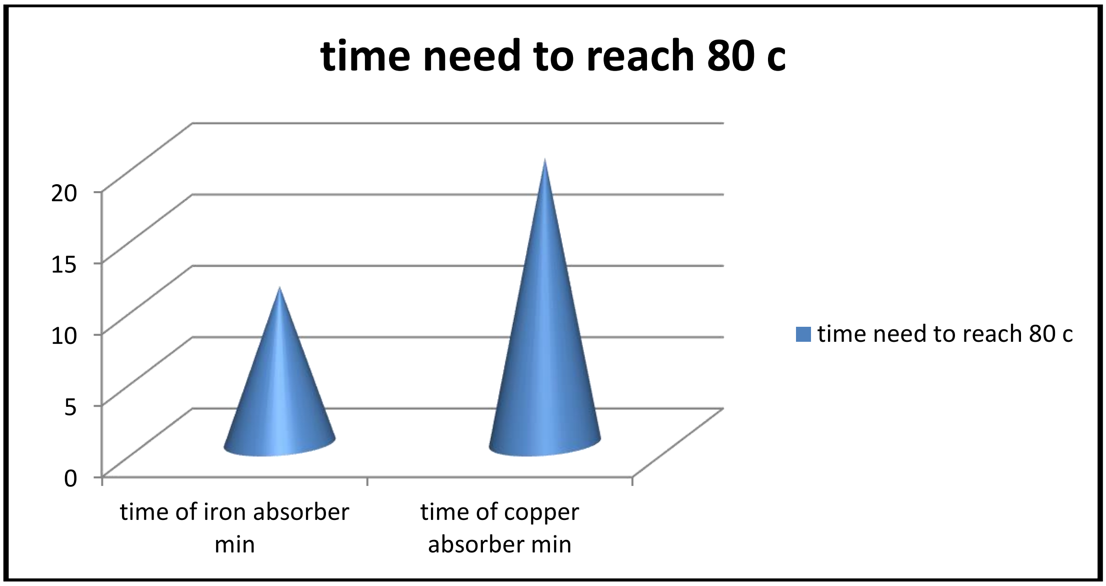

Figure 5.3: The time need to reach 80c°.

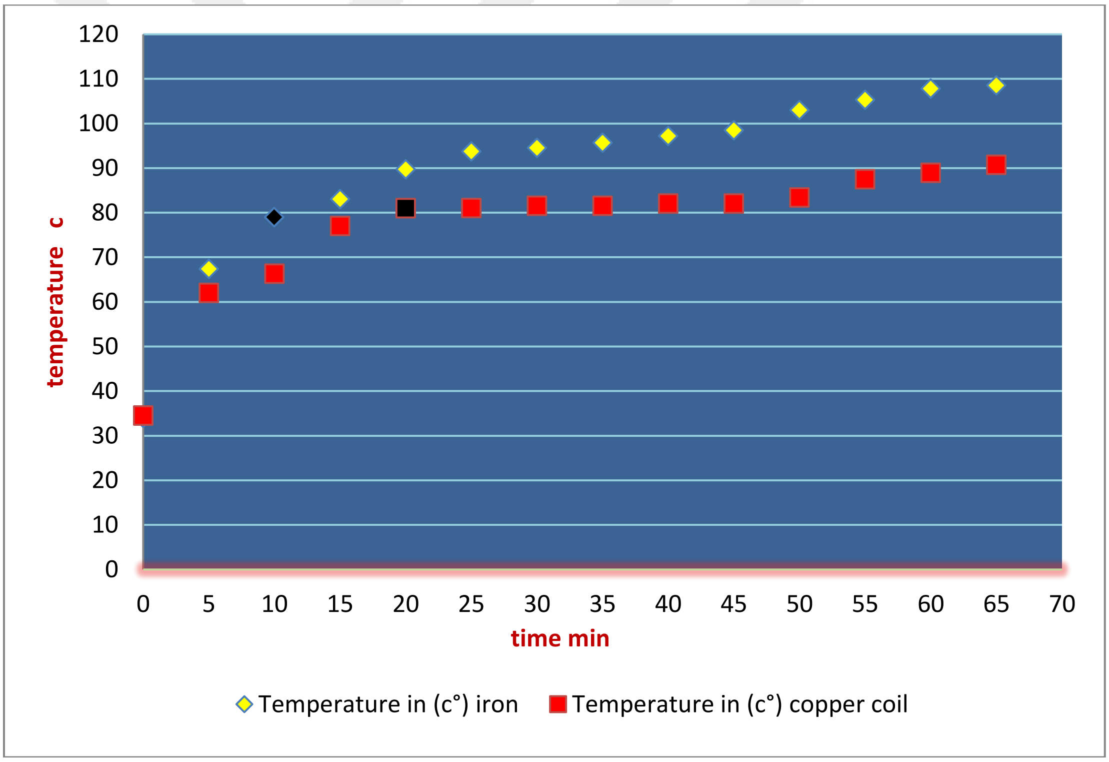

Figure 5.4: The increase of the temperatures with time for iron and copper absorber.

5.1.2 The area and the cost required from PTSC to operate the system

There is more than one factor that determines the efficiency of the solar collector, such as the reflection coefficient, the absorption of the mineral used for absorption, the surrounding atmospheric conditions... etc. The efficiency obtained from the solar collector, which was manufactured from simple local materials, was not high for the above reasons but achieved the desired purpose at very low cost. The cost of our solar collector was decreased about 5 times the ultimate cost of modern PTSC as explained in the following [77]:

Ratio of Our PTSC cost relative to the ultimate PTSC $= \frac{Ultimate\ PTCS - our\ PTSC\ cost}{Ultimate\ PTCS} \times 100\%$

$= \frac{255 - 52}{255} \times 100\% = 79.6\%$ so

We could be computed the cost efficiencies via the following simple formulae:

$$\frac{our\ cost}{ultimate\ cost} \times 100\%$$

$\frac{52\$}{255\$} \times 100\% = 20.4\%$ from the ultimate cost

The relationship between the costs of our solar collector compared to the ultimate efficiency is illustrated by the scheme (32).

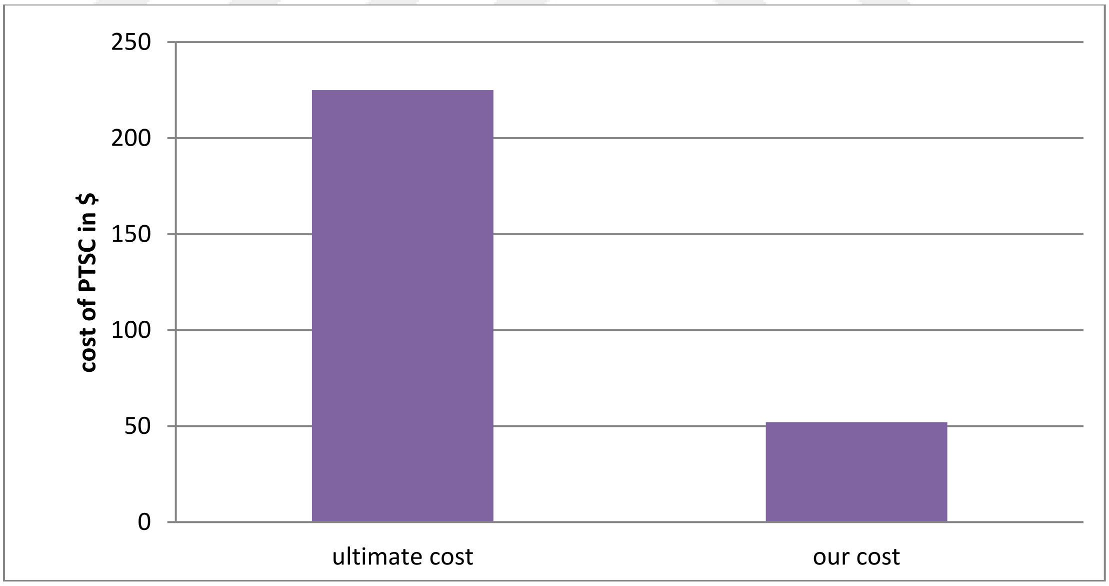

Figure 5.517: The cost comparison of our PTSC with the state of the art system.

5.1.3 The advantage of non-use of electric power

The cost of operation of 1 ton (3.5kw) refrigerator based on the electricity network will be (0.085) dollars per 1 kW according to the Iraqi tariff. In our work, the generator was used instead of the compressor, which does not operate on an electrical source but on solar energy, in other words, the cost of running the system is nothing. Thus, we have savings (0.2975) dollars opposite 3.5 kWh working on the electrical network.

5.1.4 Reduce emission

One of the most important factors that encourage the use of renewable energy is not to depend upon fossil fuels, which is a source of environmental pollution due to the emitted gases. The results obtained from the PTSC indicated that the heat gained equal 0.149 kWh, this value produces about 0.052 kg of carbon dioxide in case utilized the fossil fuels for their production. Hens 1 kWh of energy generates about 0.35156 kg from co2 by using fossil fuels [78].

We could be computed the percentage of co2 that be reduced relative to the 1 kWh energy which produced by using fossil fuels via the following simple formulae:

$$\frac{amount\ of\ (co_2) equivalent\ to\ 0.149\ kwh}{ultimate\ amount\ of\ co_2 equivalent\ to\ 1\ kwh} \times 100\% = \frac{0.052}{0.35} \times 100\% = 15\ \%$$ of 1 kWh energy which produced by using fossil fuels. The scheme (33) shows the amount of co2 which is reduced in our work.

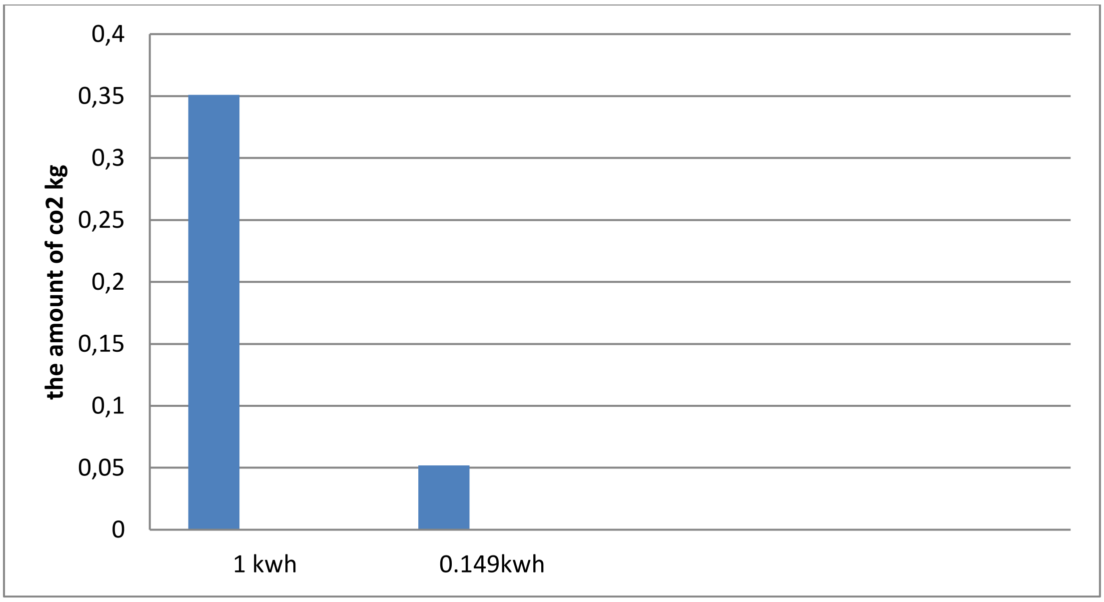

Figure 5.618: The scheme shows the amount of co2 which is reduced.

5.1.5 Absorption refrigeration system

The absorption refrigeration system demands a less temperature in the inlet side; at its evaporator see figure (5.6) in 80^{o}C. at this temperature, the refrigerant has a suitable energy to drive itself during the cycle.

We had needed to calculate the heat added to the absorption system to achieve a cooling capacity of 2 TR. This heat had been gained from the parabolic trough solar collector. The EES program based simulation (see chapter 4) equipped 19.93 kW of heat added for 2 T.R. the heat rejected At steady state operation is equal to the heat added, This achieves equilibrium equation

q_{add}=q_{rej}= 19.93kw/2TR

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The Purpose of this research is to come up with a refrigeration absorber system utilized solar energy as a heat source. The solar system is characterized by the cheap price, easy installation so that it can be used by anyone because it does not need expensive materials or complicated equipment.

The practical results of the study showed that the use of an iron galvanized tube as an absorber gives us the highest efficiency than the copper tube coiled in the solar collector. For this reason, the data extracted from the iron tube were used and applied in the absorption cooling system as a heat source. However, the main objective of this study was not to improve the efficiency of the solar collector but to obtain the required temperature in fast time as possible, by simple installation and fewer prices to operate 2-ton refrigeration absorber system. According to the simulation by EES program, which was prepared to calculate the area of PTCS, it has appeared which required $123.7\,m^2$ of the solar collector to operating. This area is considered small for a country like Iraq, which has large untapped space. In addition, Iraq is still suffering from a severe shortage of electricity and it relies mainly on fossil fuels to operate power plants. This work is good, promising and, compatible with the conditions of Iraq. Apply such as this system will be the seed of renewable energy applications that can be developed.

6.2 Recommendations

From this work, we move towards improvement of performance as possible. Optimization is restricted by low cost and simplicity to reach the benefit for all categories. In case of getting out of the constraints of cost and simplicity of formation, the following recommendations can be taken:

1- Use copper absorption tube coil without working spaces between loops to increase surface area and minimize losses. This, in turn, increases the thermal efficiency of the solar collector.
2- Conducting an experiment to integrate the galvanized iron pipe with a copper coil tube and calculate the thermal efficiency.
3- The use of a heat transfer medium has a higher water absorption characteristic to increase thermal efficiency.

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APPENDIX

Appendix A: The figure (A) shows the chart for lithium-bromide (LiBr) solution to calculate the refrigerant temperature.

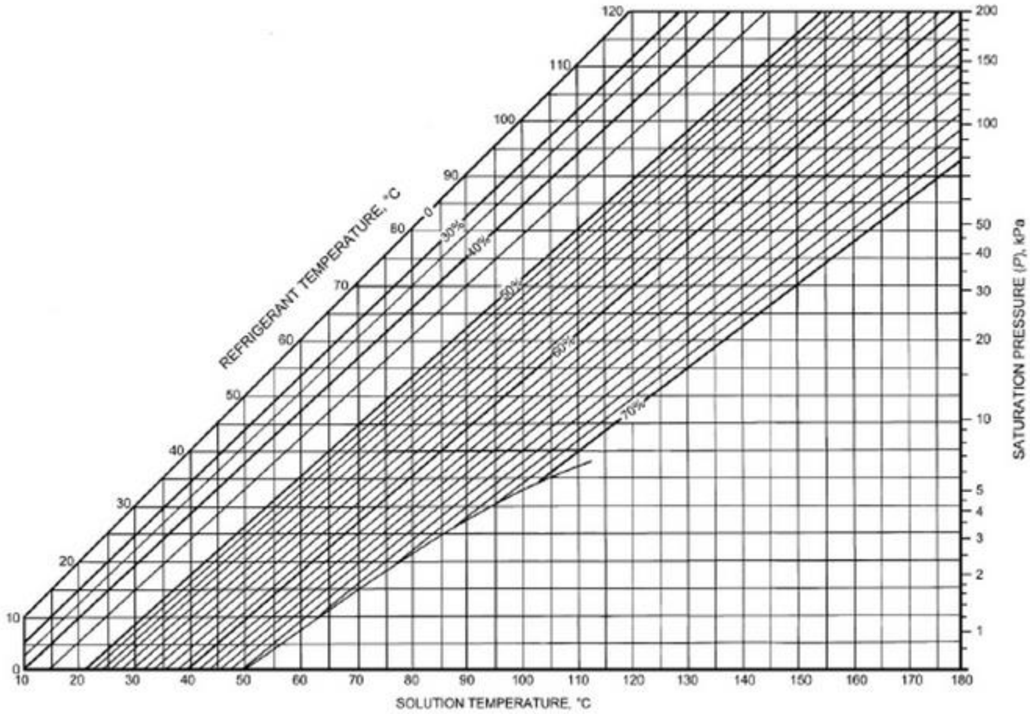

Figure A: Equilibrium chart for lithium-bromide (LiBr) solution.

Appendix B: The figure (B) shows the chart for lithium-bromide (LiBr) solution to calculate the refrigerant temperature.

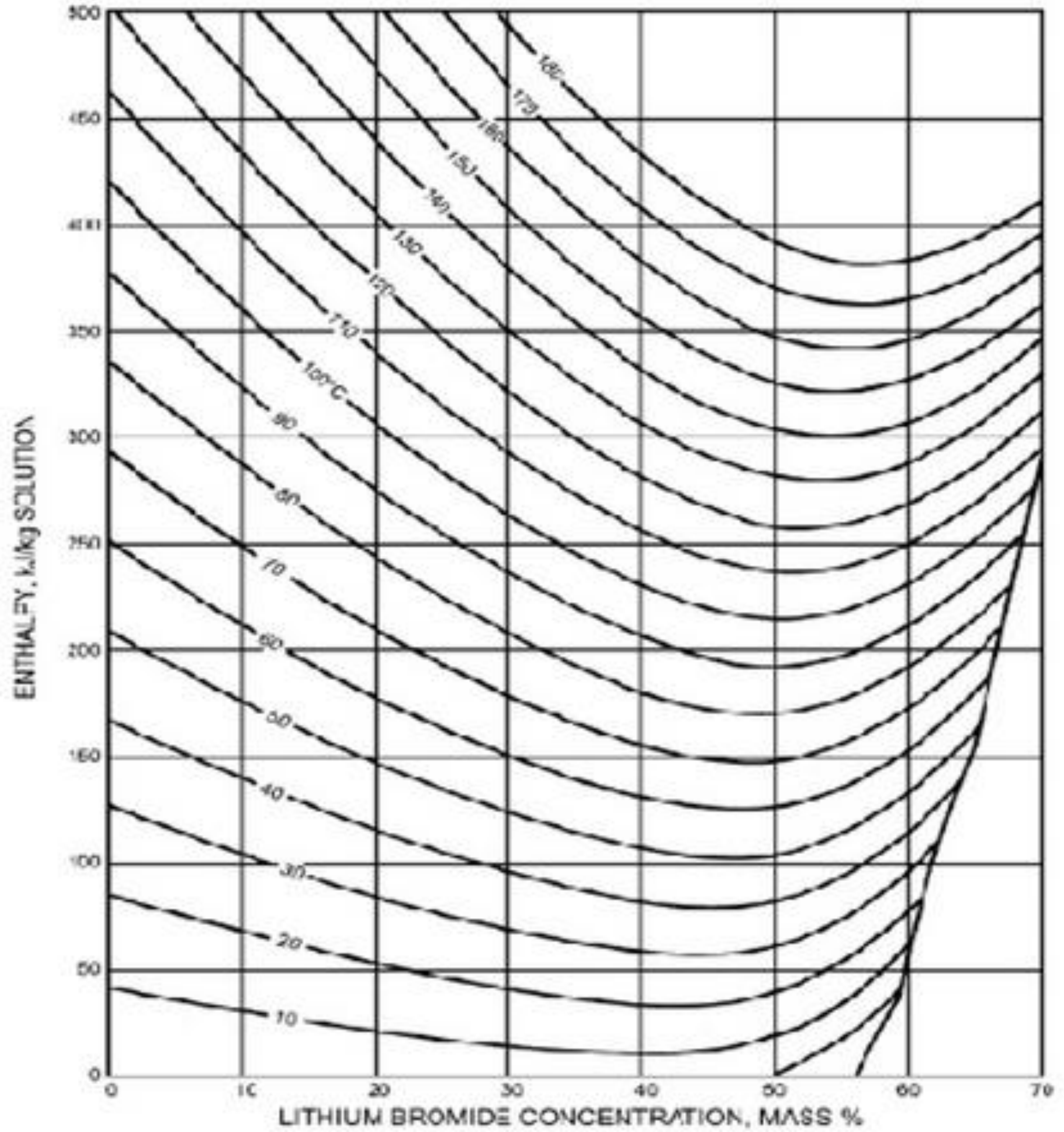

Figure B: Enthalpy-concentration diagram for LiBr solution.