Palestine Polytechnic University

College of Engineering and Technology Mechanical Engineering Department

Graduation Project

Design and Building an Integrated Solar Energy Conversion System of Bladeless Turbine

Mechanical Engineering

Project Team

Abd Al-Salam I. Yaseen

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Project Supervisor

Dr: Imad Al_Khatib

Hebron – Palestine

June, 2004

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By
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According to the direction of the project supervisor and by agreement of all the committee members, this project was submitted to Department of Mechanical Engineering in College of Engineering and Technology to partially fulfill to the Bachelor for requirements for the department.

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Abstract

Design and Building an Integrated Solar Energy Conversion System of Bladeless Turbine

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Palestine Polytechnic University – 2004

Supervisor
Dr. Imad Al-Khatib

This project proposes a system that converts solar energy into mechanical energy by integrating concentrating collector and bladeless turbine. Proposed system could achieve high efficiency by depending on energy collected, working fluid, pressure and material used. The bladeless turbine is considered cheaper and simpler compared to conventional blade turbine.

يهدف هذا المشروع إلى تحويل الطاقة الشمسية إلى طاقة ميكانيكية بواسطة نظام متكامل يشمل مجمع للطاقة الشمسية وتربين بدون عنفات. هذا المشروع يمكن أن يحقق كفاءة عالية بالاعتماد على الطاقة المجمعة، المائع المستخدم، الضغط والمواد المستخدمة. التربين بدون عنفات يعتبر غير مكلف وبسيط مقارنة بالتربين التقليدي.

إهداء

إلى الزهرة التي لا تذبل........... **نبع الحنان............ إلى أمي**

إلى الماس الذي لا ينكسر......... **نبع العطاء........... إلى والدي**

إلى ملائكة الأرض............شقائق النعمان......... .. إلى أشقائي

إلى من قتلت رهبانيتي........... **من ملكت قلبي**........إلى حبيبتي

إلى قناديل الدرب........ **للشموع التي لا تنطفئ...... إلى أساتذتي**

إلى رفاق الدرب............ بناة المستقبل............ إلى أصدقائي

إلى صناع الكرامة............ رايات المجد............ إلى شهدائنا

إلى من رفضوا الخضوع......... من طلبوا العزة......إلى أسرانا

إليكم جميعا أحبتي اهدي هذا الجهد المتواضع

فريق العمل

Acknowledgment

We would like to thank our families and our friends for their support and encouragement during the course of the graduation project.

We would also like to thank our supervisor Dr. Imad Al-Khatib for supervising the project. Thanks are also due to Dr. Ishaq Seder, Tawfiq Amro, and Raied Abu- Markheyyeh for their help and valuable comments.

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Chapter One

Introduction

Chapter One: Introduction

As technology develops, our life will be easier and more comfortable. But the technology today depends mainly on energy and in particular electrical energy that are generated from conventional energy sources. The advancement in all sectors of life had led to increasing demand on energy. In some developed countries the doubling time on energy recorded a period of less than 15 years. This growing demand has impacted adversely the environment in the last seventy years, and has raised the alert and concern of the scientists all over the world on the danger of using conventional energy sources that are responsible, through the processes of energy conversion, for climate change, air pollution, etc. The impact on the environment in not the only problem associated with conventional energy resources. These resources are dwindling ones and have no sustainability. Therefore scientists have realized the need for alternative energy resources that could be renewable on one hand and are environmental friendly on the other hand.

One the major renewable energy source is the solar energy, which is found in different forms. Solar Radiation is the main direct source of solar energy and other forms are wind, geothermal, etc. The main advantages of solar energy are that it is renewable, free from monopoly, clean, and could be utilized in non-sophisticated systems. Solar energy has been utilized since the seventies in several countries and in Palestine. Main applications are the heating of water for domestic uses, heating of ponds, direct conversion of solar energy into electrical energy, and so forth.

Thermal applications of solar energy are of three major types: low, medium and high temperature applications. In each application solar energy is absorbed by a conductive material and the thermal energy collected is utilized in a thermal system to heat up a working fluid. In low temperature systems, a flat-plate collection system is used, but in medium and high temperature systems solar radiation is concentrated over an absorber of high conductivity and low emmisivity. In concentration collector temperatures ranging from 60-1000 could be attained.

Concentrated solar energy could be easily converted into other forms of energies, such as electricity, which can be achieved on the basis of Rankin Cycle. In this cycle two major energy conversions are done. The first is the thermal energy addition or removal in the boiler (solar collector) and the condenser (ambient) respectively. The second is the mechanical conversion which is attained in fluid pumping device and in turbine device. The mechanical energy conversion in the turbine could then be converted into electrical energy using the generator.

The advancement in solar energy applications has been achieved through the efforts of scientific research centers in many countries. In Palestine few research centers are involved in solar energy applications, among them is the Renewable Energy and Environment Energy Unit of the Polytechnic University. The unit, which was established in 1999, is underway developing means of utilizing solar energy using the available local and low cost technology aiming at promoting the use of renewable energy in all sectors of the Palestinian society. Students from the department of mechanical energy have worked within the unit in their graduation projects.

Of the graduation projects of solar energy aspect designed and built in the units is the "*High Concentrating Solar Trough System (HCST)*" (Jawad Abdul-Baqi and Muhannad Nassar – 1999) which utilized the principle of solar energy concentrating using a trough type collector. The students have designed a tracking system of two degrees of freedom that enable the trough to fully track the sun. The HCST was designed to be used in a Rankin cycle to produce mechanical energy capable of producing electrical energy.

In 2002 the same principle was used by Ahmad Hattab in a project entitled "Design and Building a *Solar Truncated Cones Dish* (STCD)". The system designed and built used truncated cones to allow concentrating solar radiation in a line receiver (absorber) fixed in the dish focal line. The system use also a two stepping motors to provide full tracking of the sun in order to be used in a power generation cycle.

The presented project is a continuation to what has been accomplished in the unit. It combines both projects as the thermal energy collection and concentrating system with a full tracking electronic circuit. The mechanical energy part is a new paradigm that uses a bladeless turbine. The system presented here is supposed to work in a cycle where conversion efficiency will be higher through avoiding high losses in mechanical friction in addition to avoiding power swept for pumping unit. The idea is to use both the bladeless turbine based on propulsion in a thermosyphone power cycle.

This technical report will shed some light in Chapter three on solar energy basic calculations and known correlations and on traditional solar energy conversion systems used. In Chapter four the solar energy collection and conversion system's components will be presented followed in Chapter five a description of the mechanical energy conversion system's components, including the bladeless turbine will be discussed. There was not enough time to go into testing performance of system's components; it was recommended (Chapter six) to have the testing and modification of the system later by other students of the faculty of engineering.

Chapter Two

Project Cost and Time Plan

Chapter Two: Project Cost and Time Plan

2.1 Project Cost

The cost of the system is divided into two parts:

- Equipments cost that include the cost of the main components of the project. Here, we list the main parts and the approximated costing of each part:

Table (2.1) Estimated Cost

Component	Estimated Cost $
Dish collector	50
The stepper motors	40
Tracking system	10
Pump	40
Bladeless turbine	70
Generator (PMG)	60
Accessories	30
Total	300

- Project team cost which includes all expenses required for the project team to accomplish this project. These costs will not be determined by money.

2.2 Time Plan

The time period given to accomplish the work in this project is limited to two semesters, 15 weeks each. This section shows an illustration to the time plan which applied through the different stages to accomplish the work in the project.

In the first semester, the work is divided into six tasks on 15 weeks. These tasks are the following:

1. Selecting the project idea
2. Discussing the idea
3. Requirements analysis
4. Gathering information related to the project
5. Primary design
6. Report documentation

Table (2.2) shows the tasks of the project and the time of each task.

Table (2.2) Time Scheduling in the First Semester

Task	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Selecting the project idea															
Discussing the idea															
Requirements analysis															
Gathering information															
Primary design															
Documentation															

In the second semester, we began the real implementation of the system. This work is also divided onto 15 week. The main stages of our work at this period include:

1. Buying components
2. Building the solar dish system
3. Building the bladeless turbine
4. Assembling the individual section in one system
5. Testing

Chapter Three

Solar Energy

3.1 Solar Energy and the Earth

3.2 Radiation Intensity

3.3 Solar Thermal System

3.4 Solar Tracking Systems

Chapter Three: Solar Energy

Solar energy is distributed right across the country, requiring neither transportation nor any special infrastructure for its use.The sun provides the earth with a long-term supply of high quality energy at an overall rate nearly 10,000 times mankind's present use. This supply reaches a maximum intensity of more than $1000 W/m^2$ at the earth's surface, sufficient for conversion to other forms such as heat, electricity and combustible materials.

3.1 Solar Energy and the Earth

3.1.1 The Sun and the Earth

The sun is an average star of radius 0.7 million km and a has a mass of about $2x10^{30}$ kg. It radiates energy from an effective surface temperature of about 5000 C^0. From the fusion furnace of the sun, energy is transmitted radically, i.e. outward as electromagnetic radiation called `solar energy' or sunshine. This electromagnetic spectrum, which comprises all the energy radiated by the sun, extends from gamma rays (of wavelength 10^{-10} cm and lower) to radio waves (of wavelength 10^{+5} cm and longer). The quantity of energy radiated by the sun can be estimated from knowledge of the sun's radius and its surface temperature (assuming it to be black body) and this amount to a rate of about $3.8x10^{23}$ kW. (See figure 3.1).

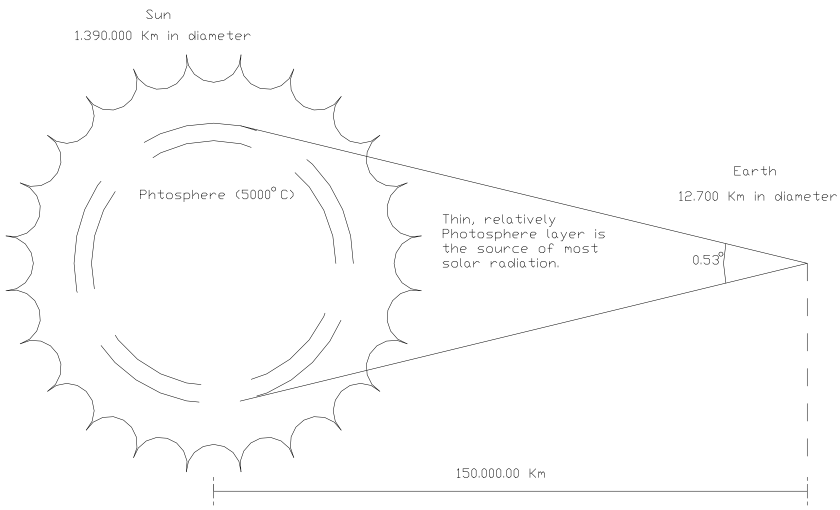

Fig (3.1) the Sun and its Relation to Earth

The earth is at about 150 million km from the sun and has a radius of about 6360 km. The total surface area of the earth is about 510 million km^2, of which only about 21% is land. The earth rotates round the sun in an elliptical orbit at a mean rate of about 30 km/s and at the same time revolves at a rate of 0.5 km/s. The earth's axis of rotation is tilted at 23.45^0 with respect to its orbit about the sun. This orientation is maintained by the earth in its orbital movement. This tilted position together with its daily rotation and yearly revolution accounts for the distribution of solar radiation over the earth's surface and the change in day length. The constituents of the atmosphere up to 100 km are (by volume): Nitrogen - 78.08%, Oxygen - 20.95%, Argon - 0.93%, Water vapor - (0.1 to 2.8%), carbon di oxide - 0.0033% and traces of carbon monoxide, sculptures di oxide, ozone etc. depending on the location (whether it is an industrial location, farmland, etc.).

3.1.2 Solar Radiation at the Earth's Surface

Most solar radiation comes from a relatively thin, relatively cool (5000C°) layer near the sun's surface known as the photosphere. When the sun's energy reaches the earth’s orbit, it contains a harmful percentage of ultraviolet light and even a few gamma rays and X-rays. However, in passing through the earth’s atmosphere, these harmful rays are largely filtered out along with some wavelengths of visible light. It gives the relative strengths of the various wavelengths of sunlight and shows how strengths vary for different wavelengths. The upper curve is the spectrum of sunlight outside the atmosphere and the lower curve is the spectrum of sunlight inside the atmosphere at the earth’s surface. Passing through the atmosphere weakens all wavelengths of light, some far more than others. There are several reasons why the atmosphere “dampens” sunlight and filters out certain wavelengths. Dust, water vapor, and absorption of light by ozone and air molecules are all partly responsible. In addition, the sun’s brightness and spectrum as seen on earth depend on its position in the sky. This effect is obvious during a beautiful sunset, when the light has to pass a longer distances through the atmosphere and suspended dust and other particles filter out the shorter wavelengths, leaving a brilliant orange or red light.

Since the spectrum of sunlight depends on how much atmosphere it must pass through, the term air mass has been coined. Air mass is essentially a measurement of how much atmosphere sunlight must pass through before it reaches the earth. When the sun is directly overhead the amount of atmosphere that sunlight must pass through to reach sea level is called air mass 1. As Fig.2.2 Shows, air mass 2 is the amount of atmosphere sunlight must pass through to reach sea level when the sun is about 30° above the horizon. Air mass 2 is two times greater than air mass 1.

The overall intensity of sunlight (averaged for all wavelengths) is never constant on earth. It varies from zero during the night to a maximum on a clear noon. If a pyranometer or pyroheliometer is set up and monitored during a typical day, the intensity will be seen to move up and down continuously as clouds pass over the sun and air conditions change. Outside the earth's atmosphere, however, sunlight almost never varies in intensity but stays remarkably constant, at 1353 W/m^2.

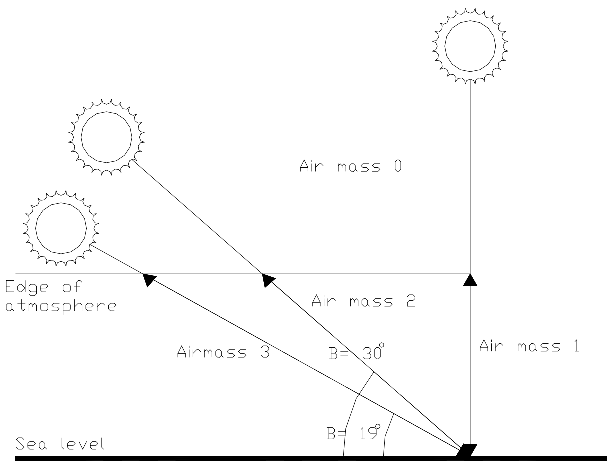

Fig (2.2) Air Masses

This means that any 1 m^2 surface facing the sun always receives about 1353 W/m^2 (as long as it stays 150 million kilometers from the sun, which is the average sun-earth distance). This value is known as the solar constant. Actually, the radiation received outside the atmosphere is not constant but varies $\pm$ 3% over the year owing to variations in the earth-sun distance. It is usually viewed as a constant, however, because of the greater uncertainty in atmospheric attenuation of solar radiation.

3.2 Radiation Intensity

The usual objective in much solar calculation is to determine the solar irradiation of a given surface, i.e. the energy rate per unit area striking the surface. The key equation for this calculation:

$$I_{-} = I_{DN} * \text{Cos}^{-} \qquad (3.1)$$

Where:

I_{-} = total solar irradiation

I_{DN} = direct radiation from sun W/m^2

$^{-}$ = Incident angle

By taking tracking collector, the value of ($^{-}$) equal zero. And from (eq3.1) the intensity amount will become as

$$I_{-} = I_{DN} \qquad (3.2)$$

The direct radiation from the sun will be calculated from the next equation:

$$I_{DN} = \frac{A}{\exp(B/\sin\ \ )} \qquad (3.3)$$

Where:

A: Apparent solar irradiation, W/m^2

B: Atmospheric extinction coefficient, dimensionless.

: The mean monthly value

Values of constant A and B in (eq.3.3) are relative to the period. Where B is constant and the value of A can be determined from table (3.1). Table (3.1) shows the mean monthly climatic average for Hebron. Hebron is located 31.53 north latitude and 35.1- east longitude, at of 1005m above the sea level.

A= 1080 W/m^2

B= 0.21

Table (3.1) the mean monthly climatic average for Hebron.

Month	Max.Temp (C)	Min.Temp (C)	R.W (%)	Wind (Km/day)	Rad. ($Mj/m^2/day$)	Sunshine (hr)	ET_0 Penman (mm/day)
Jan.	١٠.٣	٤.٠	٧٤.٢	٢٩٨	٩.٦	٤.٧	١.٦٤
Feb.	١١.٥	٤.٧	٧٢.٢	٣٠٧	١١.٦	٤.٨	١.٩٤
Mar.	١٤.٦	٦.٥	٦٦.٠	٣٠٤	١٦.٢	٦.٤	٢.٨٧
Apr.	١٩.٦	٩.٩	٥٤.٦	٢٧٦	٢٠.٧	٨.١	٤.٢٧
May.	٢٣.٦	١٣.٢	٤٨.٣	٢٢٤	٢٣.٢	٩.٠	٥.١٨
Jun.	٢٥.٩	١٥.٨	٥١.٠	٢٢٢	٢٢.٥	٨.٣	٥.٤٣
Jul.	٢٧.٢	١٧.٠	٥٦.٨	٢٢٠	٢٤.٢	٩.٦	٥.٦١
Aug.	٢٧.٢	١٧.٠	٥٩.٩	٢٠٩	٢٥.١	١٠.٩	٥.٤٨
Sep.	٢٦.٠	١٥.٩	٦١.٧	١٩٤	٢١.٩	١٠.٢	٤.٦١
Oct.	٢٣.٢	١٤.٠	٥٨.٩	١٩٤	١٨.٣	٩.٨	٣.٧٠
Nov.	١٧.٥	٩.٩	٦٤.١	٢١٠	١٢.٤	٧.٠	٢.٤٥
Dec.	١٢.١	٥.٦	٧٢.٧	٢٤٢	٩.٠	٤.٧	١.٦٥
Total	١٩.٩	١١.١	٦١.٧	٢٤٢	١٧.٩	٧.٨	٤٤.٨٣

And the value of can be determined from table (3.2) by taking the average of the mean monthly ( ) value.

= 53º.

Table (3.2) the mean monthly ( ) value

Hour Month	8	9	10	11	12
Dec.	11.5	20.8	28.7	34	35.8
Jan, Nov.	12.5	22.2	30.5	36.0	37.8
Feb, Oct.	17.2	27.8	36.8	42.8	45.3
Mar, Sep.	23.8	35.4	45.6	53.2	56.1
Apr, Aug.	30.1	42.5	54	63.4	67.6
May, Jul.	34.5	47.2	59.7	70.8	71.3
June	36.4	49.2	61.9	73.9	80.9
Mean	31.2	43.2	55.3	65.3	68.9

Substituting these values in (eq.3.3),

$$I_{DN} = \frac{A}{\exp(B/\sin\ )}$$

$$= \frac{1080}{\exp(0.21/\sin 53)} = 830\text{W/m}^2$$

3.3 Solar Thermal System

The solar thermal systems are divided into two parts: passive solar heating and active solar heating.

The passive heating is achieved by designing the house to let in the solar radiation during the winter and keep out the solar radiation in summer.

The active heating systems use fans and solar collectors to heat the air and move it around the house.

The solar water heater depends on collecting radiation and reflected it to fluid flowing and warm up its temperature.

3.3.1 Passive Solar Heating

Passive solar heating is the capture, storage, and use of the sun's energy for heating without the use of fans or pumps to aid in heat circulation .The solar energy is collected and stored directly in or with the aid of the building itself. In truly passive systems convection, conduction, and radiation are the only means of heat circulation. Some passively heated buildings use elements of active solar heating systems such as fans to help circulate warm air. These are called hybrid systems. Figure (3.3) shows a simple passive solar heating scheme known as the direct-gain approach.

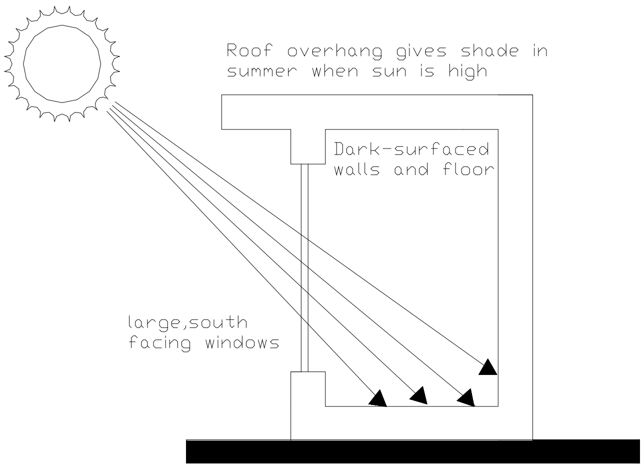

Fig. (3.3) A Direct-Gain Passive Solar Collection Scheme

The incorporation of passive solar heating features into a building should not be confused with simple energy-conserving construction. All structures should be well insulated and well constructed. Windbreaks, solar orientation, partial burying of structures, airlock entries, storm doors, insulated or storm windows, installation of fewer and smaller windows on the north side, and zoning (installation of separate thermostats for warmer and cooler areas of the building) are features that help cut the heating costs of every building .

The constitute of a passive solar heating system is the keys to an effective passive heating system are glazing, mass, and insulation. The most common type of passive system is a direct-gain system. This type of passive heating involves large areas of south-facing glazing that admit sunlight directly into the living space, where it strikes massive structures and is stored as heat. Indirect-gain systems heat the space indirectly; the massive structures are placed between the sun and the living space.

3.3.2 Active Solar Heating

Solar heating systems use working (or active) parts such as pumps, fans, and solar collectors to collect and move solar heat around the home. The sketch below shows a house using an active solar heating system Fig. (3.4). to use solar energy, we must first find a way to collect it. The solar house in the sketch uses a metal solar collector. Dark-colored sheets of metal are placed on the roof of the house. The metal heats quickly, and the dark color helps absorb energy from the sun. The solar collector faces the direction that gets the most sunlight. In the Northern Hemisphere, you would have a solar collector face. South that a liquid circulates through pipes in a solar house.

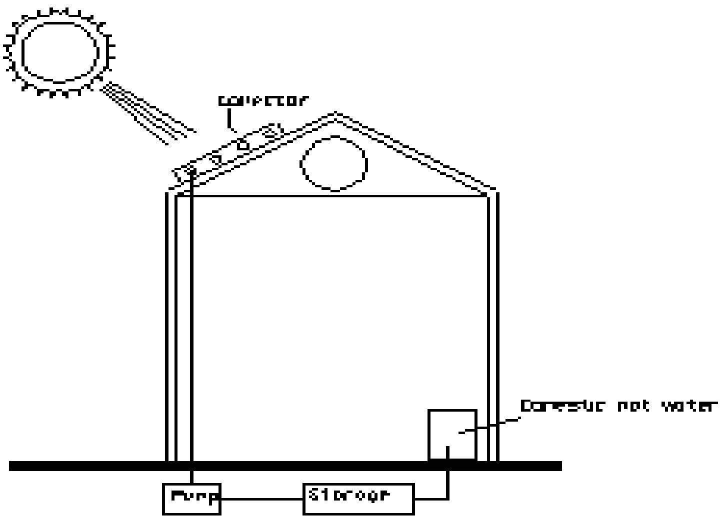

Fig. (3.4) Active Solar Heating System

Solar energy heats the liquid as it moves through the solar collectors. The heated liquid then circulates to a water tank. There, the heat from the liquid is used to heat the water in the tank. Then, the cooled liquid returns to the solar collectors to absorb more solar energy. The heated water from the water tank is used to warm the air that moves through the house.

We can collect solar energy only when the sun shines. At night and on cloudy days, solar houses must use stored solar energy. You know that in the summer, rocks and stones get hot quickly and stay warm even when the sun sets. These materials store heat from the sun. A solar house has cement walls and floors that store heat. Also, the water tank stores water heated by solar energy. In these ways, stored solar energy can help keep the house warm even on a cloudy day. But after a few days of cool, cloudy weather, other energy sources must be used to keep the solar house warm.

3.4 Solar Tracking Systems

Solar radiation arrives at the earth's atmosphere in the form of electromagnetic waves. It is characterize by its short wavelength. A focusing collector employs curved reflecting surfaces to concentrate on to a small target area. The solar radiation intercepted by the entire collector surfaces can yield high temperature in the energy-absorbing medium, depending upon the surface reflectivity and the optical of the curvature of the surface. A focusing collector can concentrate the direct rays of the sun and does not perform satisfactorily when the sky is cloudy.

In order to achieve satisfactory performance, a circular focusing type collector could be designed for continuous and exact tracing of the sun. Tracking can be accomplished by using a two axis mounting mechanism that turns the collector about a horizontal axis and about a vertical axis. The area of this type of collector is limited, and the tracking system is complex and expensive.

Chapter Four

Energy Conversion System Components' Design

4.1 Solar Thermal Energy Conversion System

4.2 Collectors

4.3 Description of Solar Dish Parts

4.4 Thermal Calculation

Chapter Four: Energy Conversion System Components Design

For many years, the inhabitants of the world have had at their disposal abundant sources of energy that could be utilized at low cost in many ways beneficial to mankind. In some respects, energy has been used wastefully, and in the more affluent nations high energy consumption is now judged to be somewhat irresponsible. It has become painfully apparent in the past few years that nonrenewable energy sources are finite and are in danger of depletion, to various degrees, in the not too distant future. Conservation and efficient use of energy must be observed in order to ensure a strong and stable world economy.

Solar and geothermal energy can be used directly for heating. Other energy sources are not directly usable; hence some kind of conversion process must be employed to change the energy to a different form, that is, to one of direct utility. These highly important energy conversion processes produce thermal energy and generate power. An examination of the various energy conversion systems will disclose the economic and practical limitations imposed on their use and indicate the effectiveness that may be anticipated in achieving the energy conversion.

4.1 Solar Thermal Energy Conversion System

Solar thermal conversion systems are the oldest, most advanced and most economical solar conversion systems yet developed. They invariably consist of a mechanism for capture of solar energy, its conversion to heat at a range of temperatures and its use either directly or in the production of electricity or chemicals using heat.

The main differences between the various solar thermal technology types relate to the temperatures achieved.

Systems are available for production of low temperatures (30 to 60 Cº) medium temperatures (80 to 150 Cº) and higher temperatures (350 to 2000 Cº).

4.2 Collectors

Solar thermal collectors are the key component of active solar systems, and are designed to meet the specific temperature requirement and climate conditions for the different end-uses.

There are several types of solar collectors:

- Flat-plate collectors
- Evacuated-tube collectors
- Concentrating collectors

4.2.1 Flat-Plate Collectors

Flat plate solar collectors operate on the principle that when a black sheet of metal is placed in the sun the sheet absorber sunlight, which appears as heat, the plate will gradually heat up until its temperatures is high enough above ambient that the rate of heat gain from absorption of solar rays. (see Fig. (4.1)).

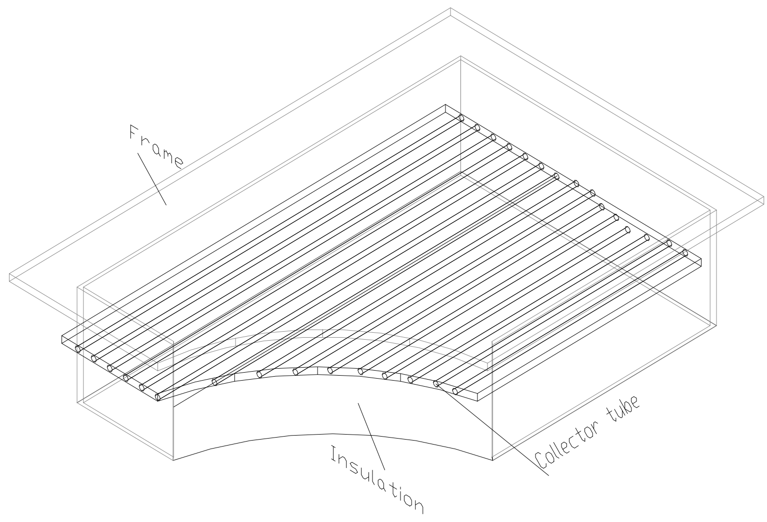

Fig. (4.1) Flat Plate Collector

The simplest mechanism for doing this is to gather the black plate with a transparent cover separated by an air gap this will allow most of the incident light to reach the plate but will severely cut down the rate of heat loss to the ambient.

In actuality, the plate will begin to lose heat to its surrounding at a faster rate, as it becomes hotter and will eventually reach an equilibrium temperature where the rate of heat loss exactly balances the rate of heat gain from solar absorption.

In practice, a hot metal sheet is not of any value by itself, a solar collector involves movement of a fluid, either as air blown over the plate or water flowing through tubes attached to the plate, to carry off the heat that is collected. A well-designed solar collector can convert more than half of the incident solar energy into the circulating fluid as heat, the remainder being lost as heat or reflected light rays to the ambient.

Flat-plate collector's heat liquid as it flows through tubes in or adjacent to the absorber plate. The simplest liquid systems use potable household water, which is heated as it passes directly through the collector and then flows to the house.

Headers or manifolds attached to the tubes admit and discharge the heat transfer medium at the top and bottom of the collector and allow connection to external pipes and the storage unit.

4.2.2 Evacuated-Tube Collectors

This collector consists of several individual glass tubes each containing a black metal pipe or absorber through which the heat transfer medium passes. The space between the black absorber and the glass tube has had all the air evacuated so that a vacuum exists between the absorber and the glass tube. Because the vacuum is such an excellent insulator the evacuated tube loses so little heat to the air that it is able to produce higher liquid temperature than other collectors even in low winter temperature are. (Fig.4.2 shows cross section of evacuated tube collector).

In an evacuated tube collector sunlight enters through the outer glass tube and strikes the absorber where the energy is converted to heat.

The heat is transferred to the liquid flowing through the absorber. The collector consists of rows of parallel transparent glass tubes each of which contains an absorber covered with a selective coating. The absorber typically is of tin tube design although cylindrical absorber also is used.

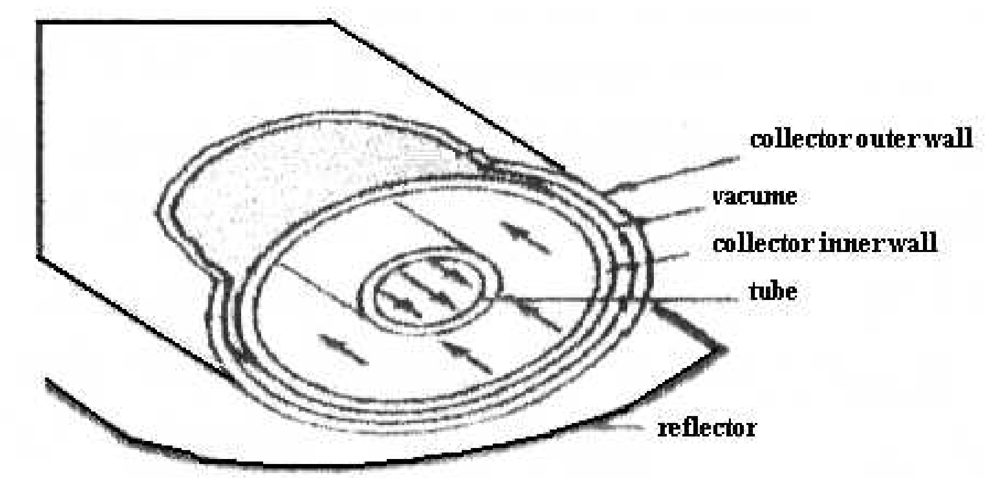

Fig. (4.2) Cross Section of Evacuated Tube Collector

4.2.3 Concentrating Collectors

Concentrating solar collectors are light-to-heat energy convectors, which have a wide variety of uses as shown in Fig. (4.3). One of the best ways to generate high temperatures from sunlight is to concentrate the light; that is, to use a lens or mirror to focus a large area of sunlight onto a small receiving surface. The concentration ratio is a measure of how large the area of collected sunlight is in relation to the area of the small receiver.

The linear concentrator focuses light onto a line, typically a black, fluid-filled tube serving as the absorber. Concentration ratios are not as high as for circular concentrators, but moderately high temperatures can be generated. This greatly simplifies the drive and support mechanisms required.

All concentrating collectors use liquid heat-transfer fluids. Many have a liquid-filled tube as the absorbing surface. Since the absorber is very hot, the tube is usually enclosed by a larger glass tube (often containing a vacuum) to reduce radiative heat losses.

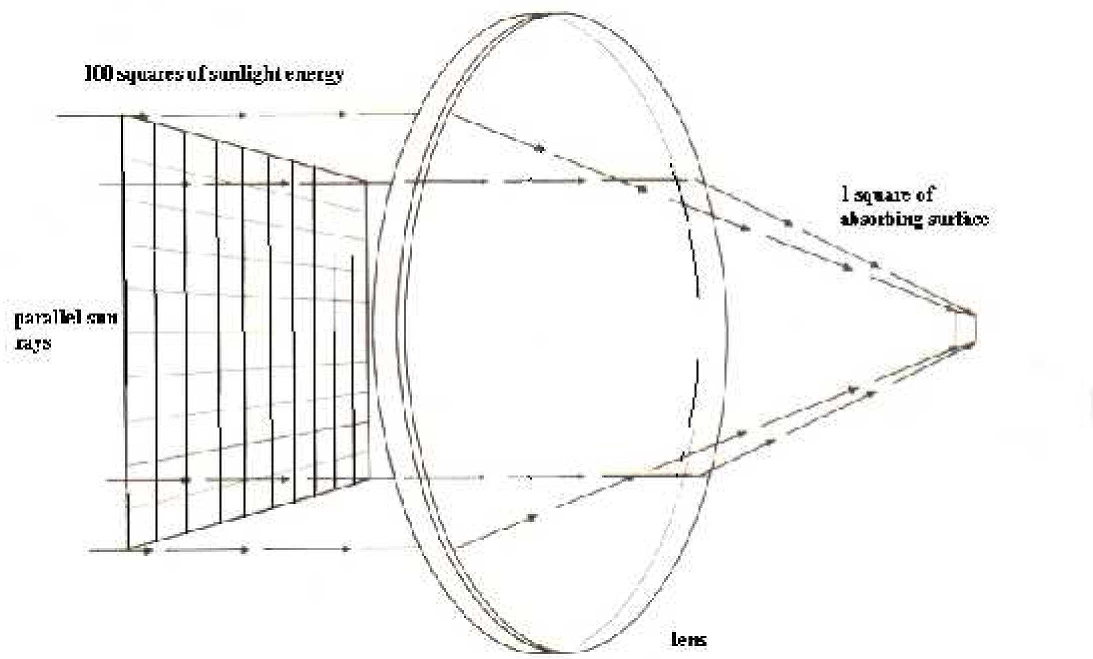

Fig. (4.3) Concentrating Collector

The concentration ratio contains two major parts:

- Parabolic trough system
- Dish system

4.2.3.1 Parabolic Trough System

The sun's energy in this system is concentrated by parabolically curved, trough-shaped reflectors onto a receiver pipe running along the inside of the curved surface. Fig. (4.4). this energy heats oil flowing through the pipe and the heat energy is then used to generate electricity in a conventional steam generator.

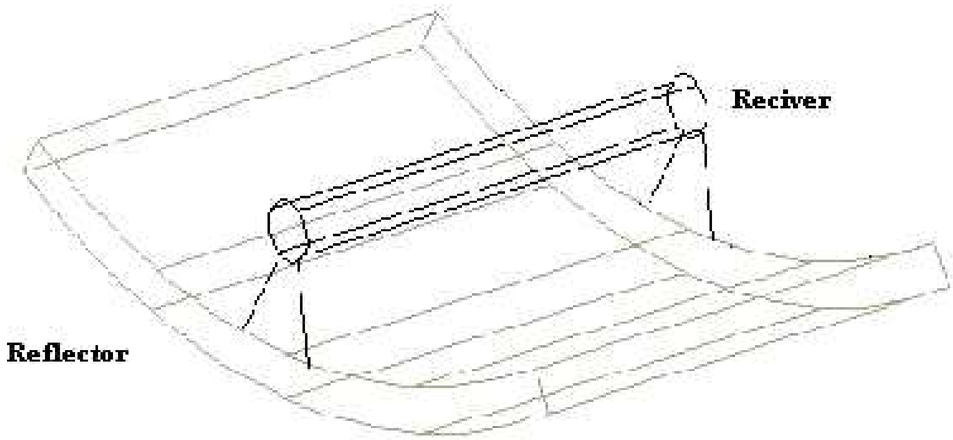

Fig. (4.4) Trough Collector

Trough designs can incorporate thermal storage setting aside the heat transfer fluid in its hot phase allowing for electricity generation several hours into the evening. Currently, all parabolic trough plants are "hybrids," meaning they use fossil fuel to supplement the solar output during periods of low solar radiation. Typically a natural gas-fired heat or a gas steam boiler reheated is used; troughs also can be integrated with existing coal-fired plants.

4.2.3.2 Dish System

The dish, which is more specifically referred to as a concentrator, is the primary solar component of the system. It collects the solar energy coming directly from the sun and concentrates or focuses it on a small area. The resultant solar beam has all of the power of the sunlight hitting the dish but is concentrated in a small area so that it can be more efficiently used. Mirrors reflect the sunlight that hits them, are relatively inexpensive, can be cleaned, amid last a long time in the outdoor environment, making them an excellent choice for time reflective surface of a solar concentrator. The dish structure must track the sun continuously to reflect the beam into the thermal receiver. Fig. (4.5). the concentrating collector that is going to e used is the one designed and manufactured at the university by Ahmad Hattab (2002). This collector has been rehabilitated and adjusted for the system we have developed.

The dish-type collectors have the advantage of higher concentration and much greater utilization of the solar intensity at off-noon hours.

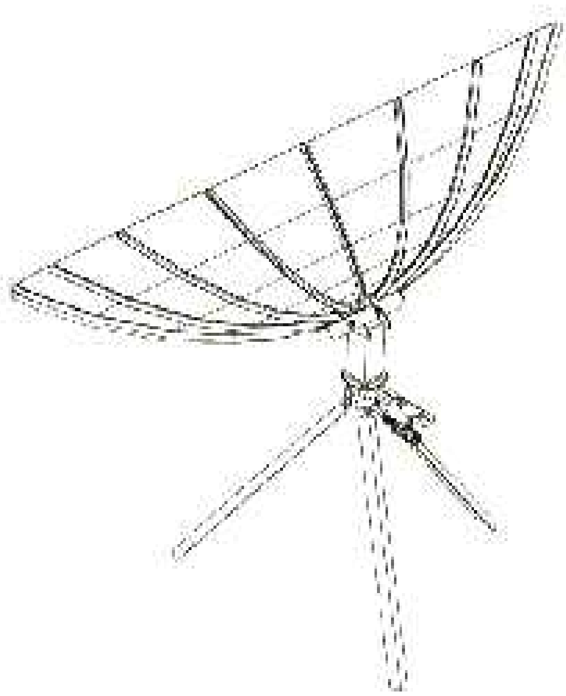

Fig. (4.5) Dish Type Collector

4.3 Description of Solar Dish Parts

The solar system considered consists of set of mirror collectors, absorbing tube inside, tracking system, and tank for energy storage. Inside the absorbing tube of which the working fluid circulates basically form the input line of the dish, and is surrounded by transparent glass tube located concentrically with it.

The solar energy collected is focused on the absorber tube, which is thus heated and transfers energy to the fluid circulation with in it, the hot fluid coming from the collector enters the storage tank of fixed volume; the fluid is taken from this tank and sent to the thermal load.

3.3.1 Solar Dish Reflectors

The reflected plate was selected of stainless steel sheets 0.4 mm thickness; the sheet has high reflectance, which equals 98%. It is shaped in a truncated cones shape that attached onto the dish arms. (See Fig.4.6).

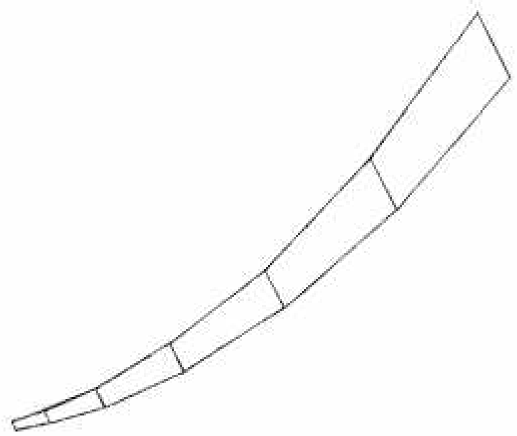

Fig. (4.6) Solar Dish Collector Arm

4.3.2 Solar Dish Arms

The dish is divided into eighteen arms that attached into the dish base. each arm divide into six sections, the reflect sheets attached on the dish arms the sun rays then reflected onto the receiver, this arrangement is led cal Truncated Cones arrangement.

Design of Dish Arms

Consider a ray traveling in air and incident a flat at an angle θ, as in Fig. (4.7) the incident and reflected rays make angles θ_1 and θ_2, respectively, with a line drawn perpendicular to the surface at the point where the incident ray strikes. This line is called the normal to the surface. Experiments show that the angle of reflection equals the angle of incidence.

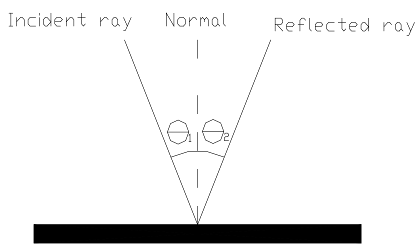

Fig. (4.7) Incident and Reflected Angles

According to the law of reflection $\theta_1 = \theta_2$ the dish arm designed as shown in Fig. (4.8).

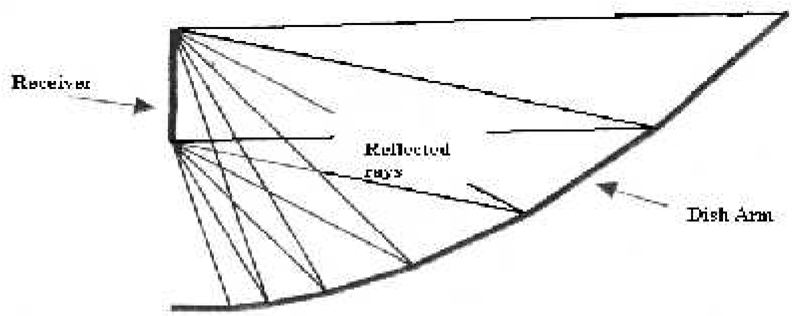

Fig. (4.8) Arm Design

4.3.3 Solar Dish Thermal Receiver

The solar energy collected is focused on the absorber pipe, which heated and transfers energy to the fluid circulating within it. The hot fluid coming from the collector enters the storage tank of fixed volume; the fluid is taken from this tank and sent to the thermal load.

A heat exchanger used to generate the water steam needed in the expander to produce mechanical energy, in the heat exchanger.

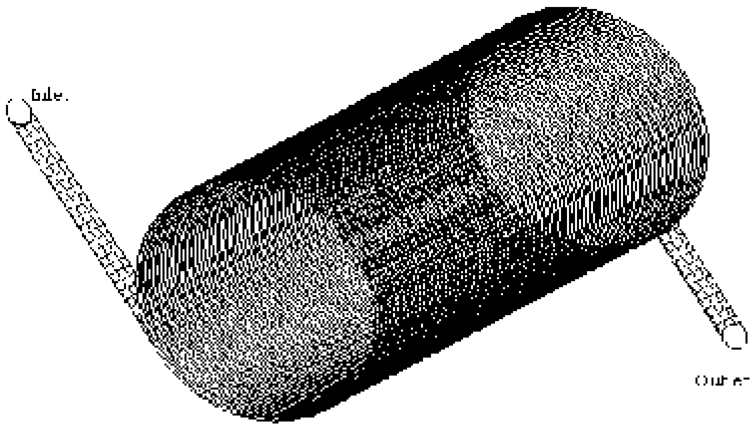

Fig (4.9) Thermal receiver

4.3.4 Dish Base

It is a body that carries the dish arms and fastened on the main movable bases which carry a gear, it has the freedom to move in tow directions. Fig. (4.9). the first move: it goes towards east or west, the second move; it goes towards the north or south, the following finger shows the main part which builds this base.

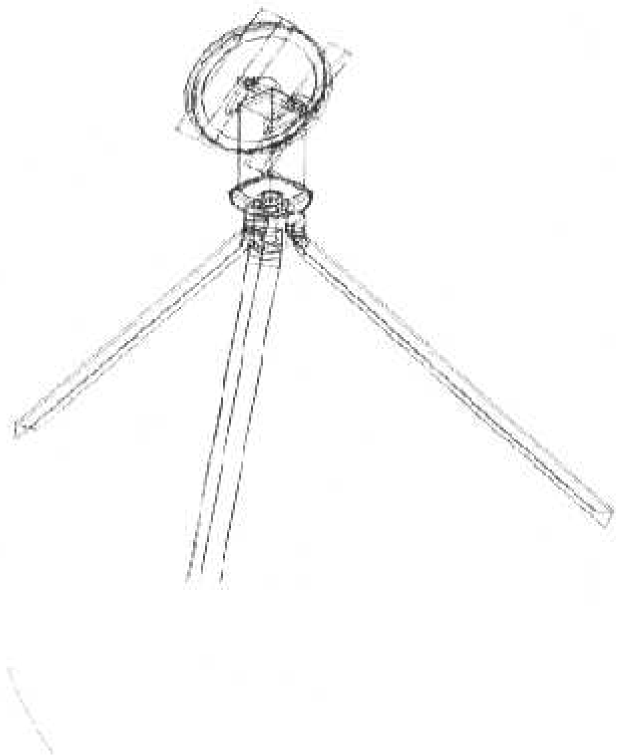

Fig. (4.10) Dish Base

4.3.5 The Stepper Motors

The Dc motor is a power actuator device that delivers energy to load; the Dc motor converts current (Dc) electrical into rotational mechanical energy Fig. (4.11).

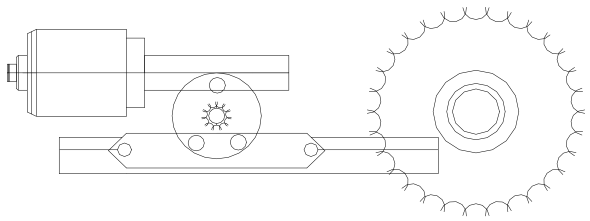

Fig. (4.11). Motor and Gear Set

The motor in Fig. (4.11) have a gear set with gear ratio 4:1.to rotate the dish in east -west direction.

The other motor is used to push or pull the end of the base in vertical direction Fig. (4.12).

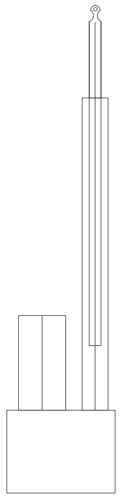

Fig. (4.12). Vertical Motor

4.3.6 Tracking System

Solar collectors or photovoltaic modules can be mounted on a tracking mechanism with 2-Degree of freedom to receive more solar energy. A single-axis tracker follows the sun's apparent east-to-west movement across the sky. A double-axis tracker, in addition to east-west tracking, tilts the solar collector or module to follow the sun's changing altitude angle, slightly increasing energy collection. The use of tracking is only cost-effective if the value of the additional energy by the tracking system exceeds the cost, of purchasing, installing, operating, and maintaining the tracker. The circuit is plotted in Fig. (4.12) Proper orientation is even more crucial for solar concentrating collectors, both solar thermal and photovoltaic. Solar concentrators must track the sun. They cannot tolerate the small deviations in tilt and orientation that are acceptable to non-concentrating collectors.

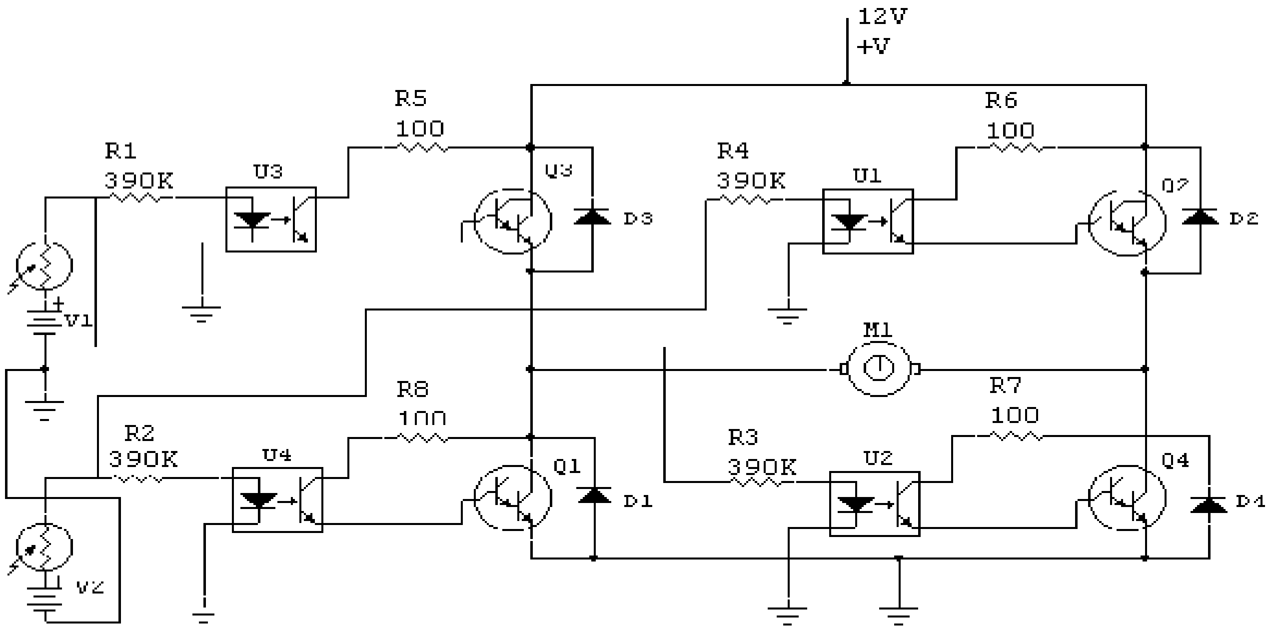

Fig. (4.13). Tracking System

Electrical Circuit

It is a group of electronics and electric parts, which controls the designed system by electrical motors which have been mentioned neatly.

* Working Principle

The photo cells are fastened as a pyramid in the desired direction either west east or north south. The aim is to detect the sun lights and track it.

If the lights fall on one of the cells, voltage difference happens which goes out to the amplifier and this works to enlarge the internal signal it spreads out the transistor and makes the outer signal move towards the engine which limits the circulation.

* Components

1- The Photo Cells:

It is a variable resistance resistor which changes its resistance inversely according to the intensity of light, and for this change in resistance a potential deference generated on the poles of this resistor and transmitted to the amplifiers.

2- Amplifiers:

They consist of a group of transistors and condensers. They are collected on a base of selection and works to enlarge the signals to have two entries and one exit

3- Transistors:

It allows the current to pass through to the motor.

4- Resistors

The function is to prevent the current from passing. There are several types: a fixed resistor and potentiometer

5- Diode

They work to collect the current in the direction of a continuous current $Ac \rightarrow Dc$.

4.3.7 Pump

The hydraulic pump used produce hydraulic pressure in the system, and to push the flow throw the pipes to the focus.

4.4 Thermal Calculations

We can calculate the Heat input cased by reflection on receiver (Q_{in}) by:

$$Q_{in} = I_{DN} * \text{Area of reflector} \qquad (4.1)$$

$$\text{Area of reflector} = \text{Area of collector} – \text{Area of receiver} \qquad (4.2)$$

$$\text{Area of the receiver} = \text{®} * D_r * h \qquad (4.3)$$

Where:

D_r : Diameter of receiver [m].

h: high of receiver [m].

The measurement of the solar conversion system (dish) in our project is:

Area of the receiver =® * 0.1 * 0.2 = 0.06283 m^2

Area of the collector = 3.745m^2

Area of reflector = 3.745 – 0.06283 = 3.682 m^2

Then;

Heat input is

Q_{in} = 830 * 3.682 = 3.056 kW

And the Heat output cased by absorption rays (Q_{out}) by:

$$Q_{out} = m * C_p * (T_{out} - T_{in}) \quad = m * C_p * \Delta T \qquad (4.4)$$

Where:

m: mass flow rate (for fluid) [kg/s]

C_p : is the specific heat of the flow measurement [kJ/ kg.K ^{0}]

ΔT: is the temperature difference between out let and inlet temperature of the Flow measurement [C ^{0}]

Let:

m = 0.07 kg/s , C_p = 0.9 kJ/kg.K ^{0}

$$\Delta T = T_2 - T_1 \qquad (4.5)$$

Where:

T_2 : The outlet temperature from collector [C ^{0}]

T_1: The inlet temperature from collector [C ^{0}]

Q_{out} = 0.07 * 0.9 * (70 – 25) = 2.835 kW

<u>Chapter Five</u>

Mechanical Energy Conversion System Designs

5.1 Conventional Blade Turbine

5.2 System Description of Conventional Blade Turbine

5.3 Ideal Vapor Power Cycle

5.4 System Description of Bladeless Turbine

5.5 Bladeless Turbine

5.6 Nozzle

5.7 Casing

5.8 Freon R-11

5.9 Generator

Chapter Four: Mechanical Energy Conversion System Designs

5.1 Conventional Blade Turbine

Most power producing devices operate on cycles. In this cycle two major energy conversions are done. The first is the thermal energy addition or removal in the boiler (solar collector) and the condenser (ambient) respectively. The second is the mechanical conversion which is attained in fluid pumping device and in turbine device. The mechanical energy conversion in the turbine could then be converted into electrical energy using the generator.

The cycles encountered in actual devices are difficult to analyze because of the presence of complicating effects, such as friction, and the absence of sufficient time for establishment of the equilibrium condition during the cycle. The make an analytical study of a cycle feasible we have to keep the complexities at a manageable level and utilize some idealizations.

Fluid enters the pump (state 1) as saturated liquid and is compressed isentropically to the operating pressure of the collector. The Fluid temperature increases during this isentropic compression process due to a slight decrease in the specific volume of the Fluid Fig. (5.1).

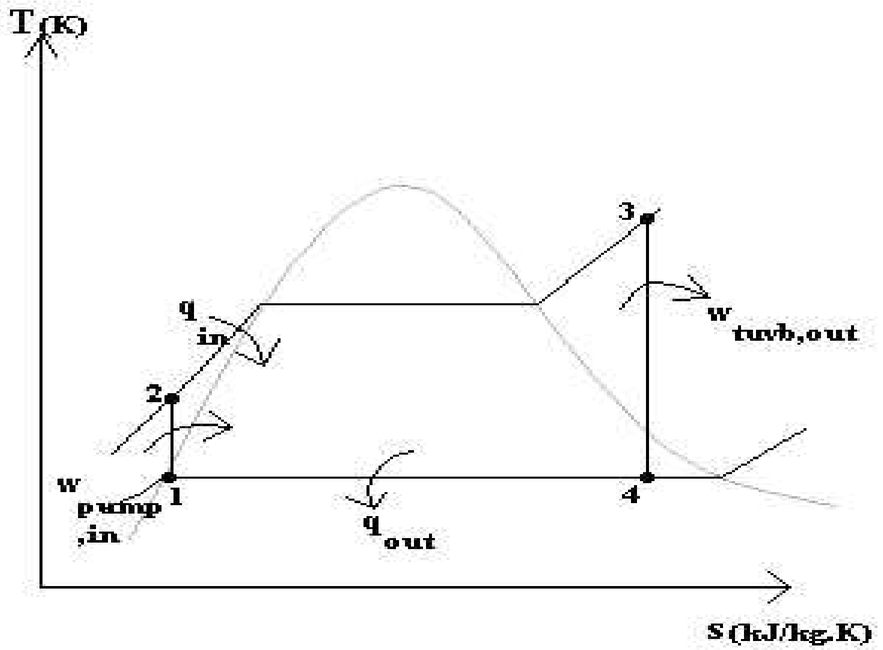

Fig. (5.1) Schematic Draw of T-S Diagram

Fluid enters the collector as compressed liquid (state 2) and leaves as a superheated vapor (state 3). The collector is basically a large heat exchanger where the heat originating from combustion gases, nuclear reactors, or other sources is transferred to the Freon essentially at constant pressure.

The super heated vapor (state 3) enters the turbine, where it expand isentropically and produces work by rotating the shaft connected to an electric generator. The pressure and the temperature of the vapor drop during this process, where vapor enters the condenser (state 4).

At this state, vapor is usually a saturated liquid-vapor mixture with a high quality. Vapor is condensed at constant pressure in the condenser; which is basically a large heat exchanger, by rejecting heat to a cooling medium. Vapor leaves the condenser as saturated liquid and enters the pump, completing the cycle.

5.2 System Description of Conventional Blade Turbine:

When the working fluid heated from T_1 to T_2 in the collector its pressure and phase will change and it will achieve a kinetic energy in the steam. The kinetic energy of steam converts to mechanical energy in turbine. Then through the condenser the vapor release heat to return to its, first phase then the pump pushes the fluid to the collector again. (Fig.5.2).

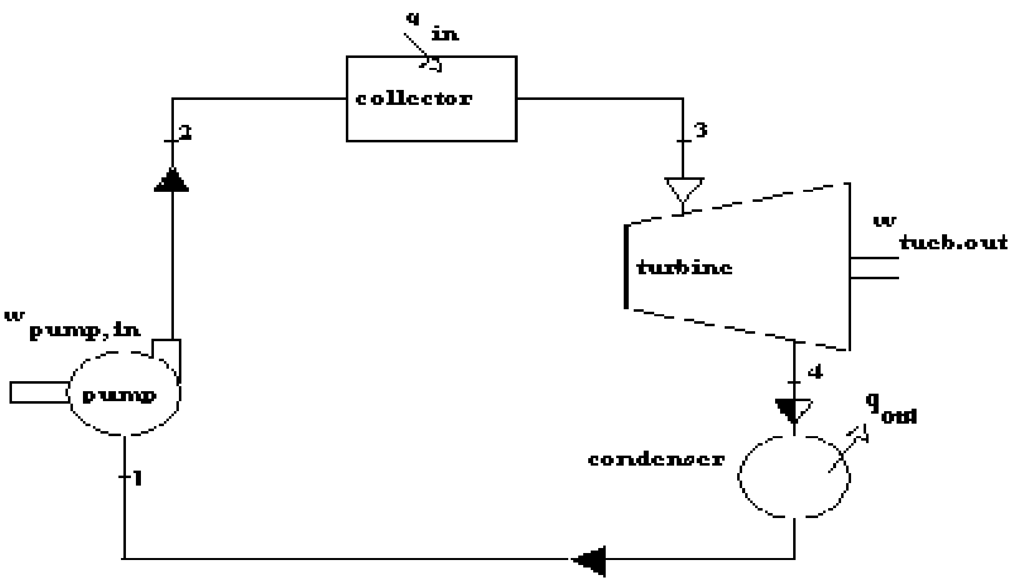

Fig. (5.2) Block Diagram for blade Turbine System

5.3 Ideal Vapor Power Cycle

Applying the steady flow energy equation for the various processes in the simple Rankin cycle (working fluid is Freon); we obtain the following for a unit mass flow rate.

Processes 1-2: Isentropic compression

If we know T_1 and the state is saturated liquid we can determine the P_1, h_1 and v_f from (appendix A).

Where:

T_1: the inlet temperature to the pump [C^o]. (Saturation liquid)

p_1: the pressure inlet the pump [Pa]

h_1: the enthalpy [kJ/kg.K^0]

$v_1 = v_f$: the specific volume [kg/m^3]

s_1 : the entropy fluids inter the pump [kJ/kg.K^0]

T_1 = 30 C^o , p_1 = 1.254 bar , h_1= 225.94 kJ/kg.K^0 , v_1= 0.00683 kg/m^3, s_1= 1.0899 kJ/kg.K^0

Processes 2-3: Constant pressure heating

In this state we know P_2 ($P_2 = P_3$) and s_2 ($s_2 = s_1$)

Where:

p_2 : output pump pressure [Pa]

s_2 : the entropy fluids outlet the pump [kJ/kg.K^0]

h_2 : the enthalpy outlet the pump [kJ/kg.K^0]

v_2 : the specific volume outlet the pump [kg/m^3]

p_2 = 4.05 bar, s_2 = 1.0899 kJ/kg.K^0 , v_2 = 0.006853 kg/m^3 , h_2 = 227.851 kJ/kg.K^0

Processes 3-4: Isentropic expansion

In state 3 we know the temperature and this temperature must be under the critical point.

Now we can determine the P_3, h_3, v_3 and s_3.

Where:

T_3: the output temperature of the collector [Cº]

p_3: output pump pressure [Pa]

s_3: the entropy fluids outlet the pump [kJ/kg.K^0]

h_3: the enthalpy outlet the pump [kJ/kg.K^0]

v_3: the specific volume outlet the pump [kg/m^3]

T_3 = 70 Cº, p_3 = 4.052 bar, h_3 = 423.12 kJ/kg.K^0, v_3 = 0.04621 kg/m^3 , s_3 = 1.6704 kJ/kg.K^0

Processes 4-1: Constant pressure heat removal

In this state we know p_4 ($p_4 = p_1$) and s_4 ($s_4 = s_3$)

Where:

p_4 : output pressure from the blade turbine [Pa]. (Saturation mixture)

s_4 : the entropy fluids outlet the blade turbine [kJ/kg.K^0]

h_4 : the enthalpy outlet the blade turbine [kJ/kg.K^0]

v_4 : the specific volume outlet the blade turbine [kg/m^3]

p_4 = 1.254 bar, s_4 = 1.6704 kJ/kg.K^0, v_4 = 0.13978 kg/m^3, h_4 = 403.95 kJ/kg.K^0

For the pump work, we can use equation (5.1) to write

$$W_{pump} = v_1 (P_2 - P_1) \qquad (5.1)$$

Where:

W_{pump} : the work pump [kJ/kg]

W_{pump} = 0.00683*(405.2 – 125.4) = 1.911 kJ/kg

The quantity of heat supplied is given by

$$q_{in} = h_3 - h_2 \qquad (5.2)$$

Where:

q_{in} : the heat supplied in the collector [kJ/kg]

q_{in} = 423.12 – 227.85 = 195.27 kJ/kg

The quantity of heat rejected is given by

$$q_{out} = h_4 - h_1 \qquad (5.3)$$

Where:

q_{out} : the heat rejected from the condenser [kJ/kg]

q_{out} = 403.95 – 225.94 = 178.01 kJ/kg

The blade turbine work is

$$W_{turbine} = h_3 - h_4 \qquad (5.4)$$

Where:

$W_{turbine}$: the work of the turbine [kJ/kg]

$W_{turbine}$ = 423.12 – 403.95 = 20 kJ/kg

The net work of cycle is

$$W_{net} = W_{turbine} - W_{pump} \qquad (5.5)$$

Where:

W_{net} : the total work [kJ/kg]

W_{net} = 20 – 1.911 = 18.089 kJ/kg

The thermal efficiency could also be determine from

$$¦ = \frac{w_{net}}{q_{in}} \qquad (5.6)$$

Where:

¦ : The thermal efficiency

$$¦ = \frac{18.089}{195.27} = 9.2\ \%$$

If a Carnot cycle were to operate between the same temperature limits as the Rankin cycle, its efficiency would be

$$¦_{Carnot} = 1 - \frac{T_{\min}}{T_{\max}} \qquad (5.7)$$

$$¦_{Carnot} = 1 - \frac{30 + 273.15}{70 + 273.15} = 11.6\ \%$$

5.4 System Description of Bladeless Turbine:

Electricity governs our life and becomes the major energy we deal with since it has extra properties posses other energies. Besides that electricity switches on many devices form our modern life it can be easily to transfer along for distances and can be also modified stared and controlled to be in service in much active fields.

The solar energy is a natural gift, available, cheep, powerful but not easily controlled or stored. This system converts by stages the solar energy to electrical energy.

The first stage is when the solar energy is focused by a collector to obtain heat the working fluid which is the Freon here is heated in the collector its pressure and phase will change and it will achieve a kinetic energy in the steam. The kinetic energy will be developed when the steam gone a cross the nozzle then through the condenser the Freon vapor release heat to return to its, first phase. Then the fluids move to the collector by the deferent in position between the bladeless turbine and the collector. (Fig.5.3).

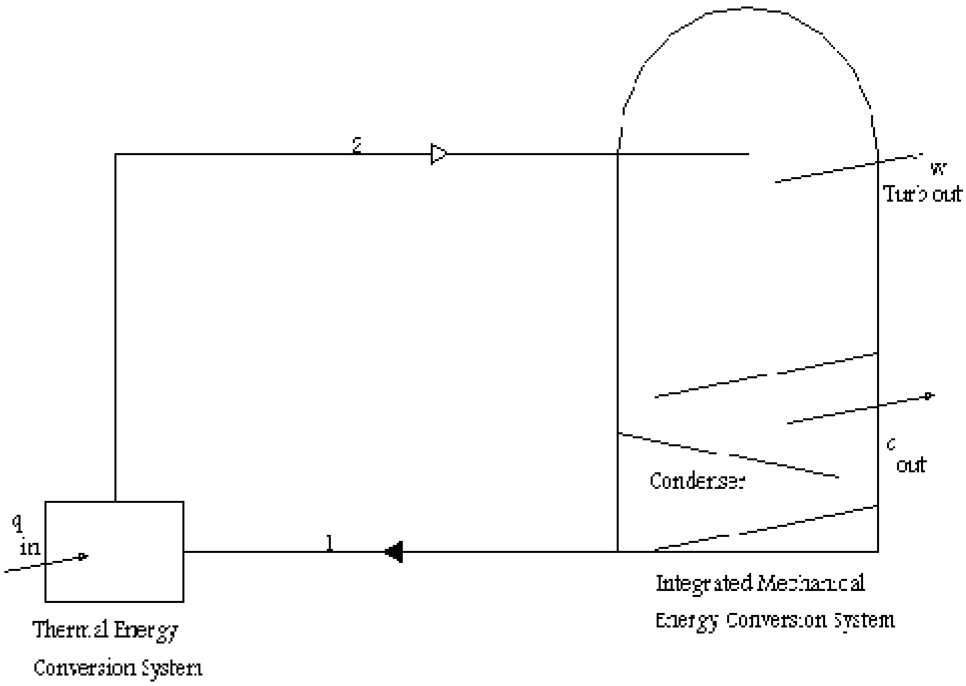

Fig. (5.3) Block Diagram for Bladeless Turbine System

Otherwise the system could be used without the condenser part when using it in a thermosyphone loop. And the thermosyphone loop depend on the deferent temperature between the vapor leaves the bladeless turbine and the vapor inter the bladeless turbine. Because the vapor release some of its heat when it leave the bladeless turbine as shown in Fig.5.4.

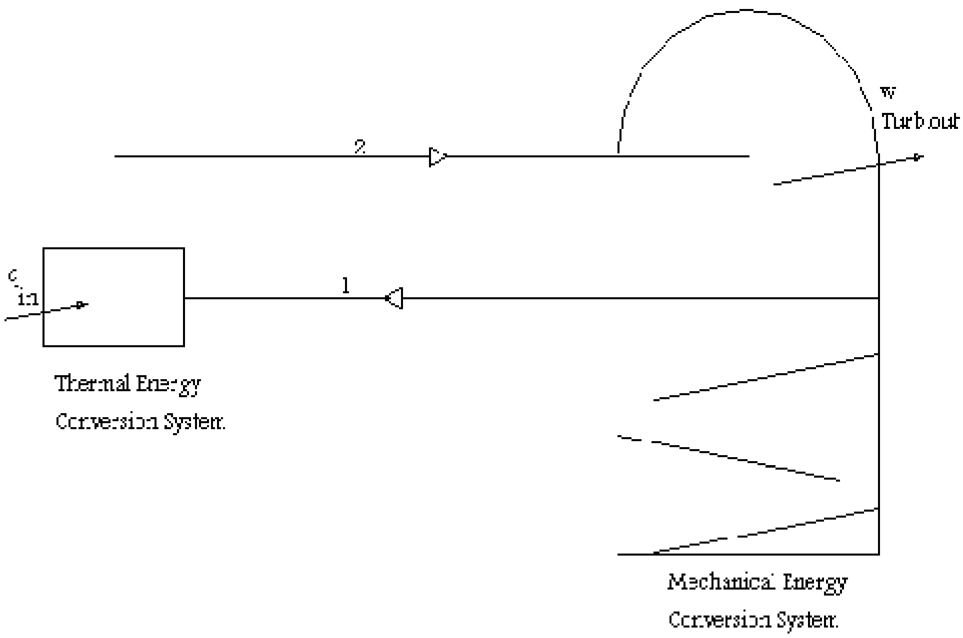

Fig. (5.4) Block Diagram for Bladeless Turbine System
Without condenser

The nozzle we talk about is really one of group of nozzle in bladeless turbine when the steam gone out the nozzle. Thrust force will rotate the bladeless turbine. The output steam will crash with the guiding blades in a case when these plates do general task; this task is help us to increase the thrust force from nozzle when the steam crash this plates. That will be increase the rotational motion of bladeless turbine and reducing loses induced by flow separation and turbulent.

We convert this rotational motion to electrical energy by using drive shaft, this drive shaft has the same rotational motion of bladeless turbine; we connect the shaft with generator to get electrical energy.

After the steam crashes the guiding blades is move down in the case by the different in pressure. The case divide for two parts: the first part includes the bladeless turbine. And the other part includes the condenser (when not thermosyphone). This condenser convert Freon vapor to liquid by using plates, inside this plates there are a fluid. When the vapor passes above the plates it will be release heat to the fluid inside the plates by heat transfer. And the fluid in plates releases the heat by heat transfer with the surrounding.

5.5 Bladeless Turbine

Turbine is rotary engine that converts the energy of a moving stream of water, steam, or gas into mechanical energy. The basic element in a turbine is a wheel or rotor with paddles, propellers, blades, or buckets arranged on its circumference in such a fashion that the moving fluid exerts a tangential force that turns the wheel and imparts energy to it. This mechanical energy is then transferred through a drive shaft to operate a machine, compressor, electric generator, or propeller. Turbines are classified as hydraulic, or water, turbines, steam turbines, or gas turbines. Today turbine-powered generators produce most of the world's electrical energy.

But in these types of turbines there are losses of mechanical energy mainly produced by friction between fluid and blades in addition to mechanical friction. In order to fined a solution for this problem, bladeless turbine could be used in which friction losses cloud be greatly minimized. (as shown in Fig. 5.5).

The bladeless turbine could achieve higher efficiency by utilizing the kinetic energy of Freon vapor flow. The bladeless turbine can be made smaller, lighter, and cheaper than conventional blade turbine. Mechanically, it has the advantage of producing rotating motion directly without the necessity of using a crankshaft, blade or other means of transforming reciprocal to rotary motion.

The bladeless turbine was not invented by any one individual but was the result of work by a number of inventors in the latter part of this century.

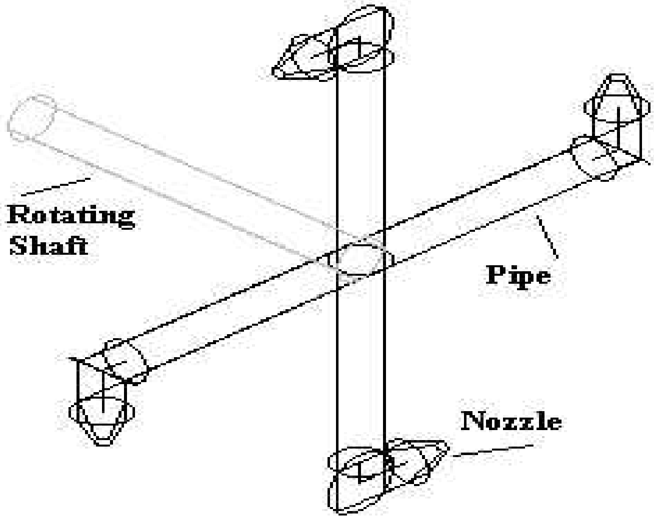

Fig. (5.5) Bladeless Turbine

The action of the bladeless turbine is based on the thermodynamic principle that when a vapor is allowed to expand, its temperature drops, and its internal energy is thereby decreased. This reduction in internal energy is transformed into mechanical energy in the form of an acceleration of the particles of the vapor. This transformation makes a large amount of work energy directly available. At such speeds the energy available is great, even though the particles are extremely light.

5.6 Nozzle

The principle of operation in nozzle depends on mathematician and physicist Daniel Bernoulli. It states that the total energy in a steadily flowing fluid system is a constant along the flow path. An increase in the fluid's speed must therefore be matched by a decrease in its pressure. Bernoulli's principle applies in nozzles, where flow accelerates and pressure drops as the tube diameter is reduced. It is also the principle behind orifice or Venturi flow meters. These meters measure the pressure difference between a low-speed fluid in an approach pipe and the high-speed fluid at the smaller orifice diameter to determine flow velocities and thus to meter the flow rate.

And the gas out from the nozzle describes as a thrust and the thrust a mechanical force can calculated by

$$F= \frac{1}{2} \dot{m} * v^2 \tag{5.8}$$

Where:

F: is the thrust force [N].

$\dot{m}$: The mass of the vapor from nozzle [kg/s].

v: the velocity of Freon vapor when leave the nozzle [m/s].

And we can calculate the velocity of the Freon vapor by

$$Q=A_1 V_1 = A_2 V_2 \tag{5.9}$$

$$A= \pi * \frac{d^2}{4} \tag{5.10}$$

Where:

Q: is the discharge of the pump [m^3/s].

A_1: the cross area of the inlet of the nozzle [m^2].

V_1: the entry velocity to a nozzle [m/s].

A_2 : the cross area of the outlet of the nozzle [m^2].

V_2 : the exit velocity from a nozzle [m/s].

And the torque of the bladeless turbine depend on the length of the bladeless turbine pipe and the thrust force

$$T = F * d \qquad (5.11)$$

Where:

T: the torque of the bladeless turbine [N.m].

F: the thrust force [N]

d: the length of the pipes connect the nozzle [m]

It is generated through the reaction of accelerating a mass of gas. The gas is accelerated to the rear and the bladeless turbine is accelerated in the opposite direction (See Figure 5.5). And the main different between nozzle to another is the discharge of coefficient. And this coefficient decrease and increase by the ratio between the input and out but diameter as shown in Figure (5.6).

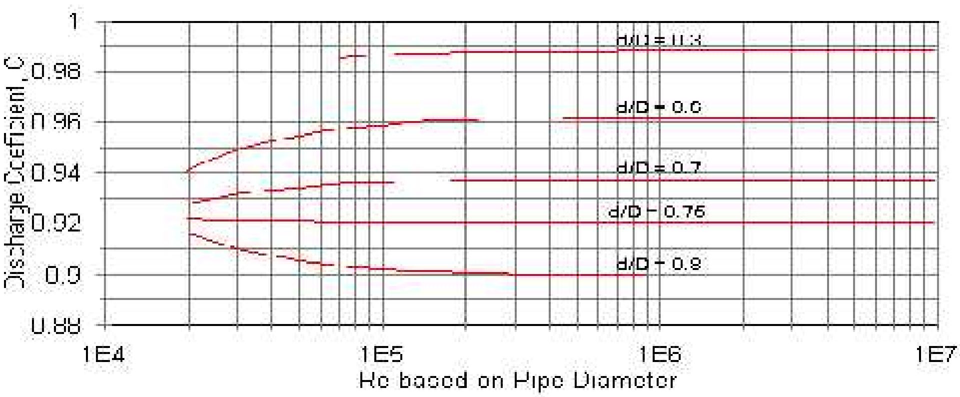

Fig. (5.6) Relation Ship between Discharge Coefficient and Diameter

5.7 Casing

The casing is very important part of the system. The casing serves multi-functions. It is a volute for the bladeless turbine, stator part of the turbine, condenser, generator holder, and rotating shaft casing. The working fluid collected at the casing loose its temperature to the ambient through the fins designed and manufactured as heat exchanger part of the condenser. The casing is drawn in Figure 5.7 below.

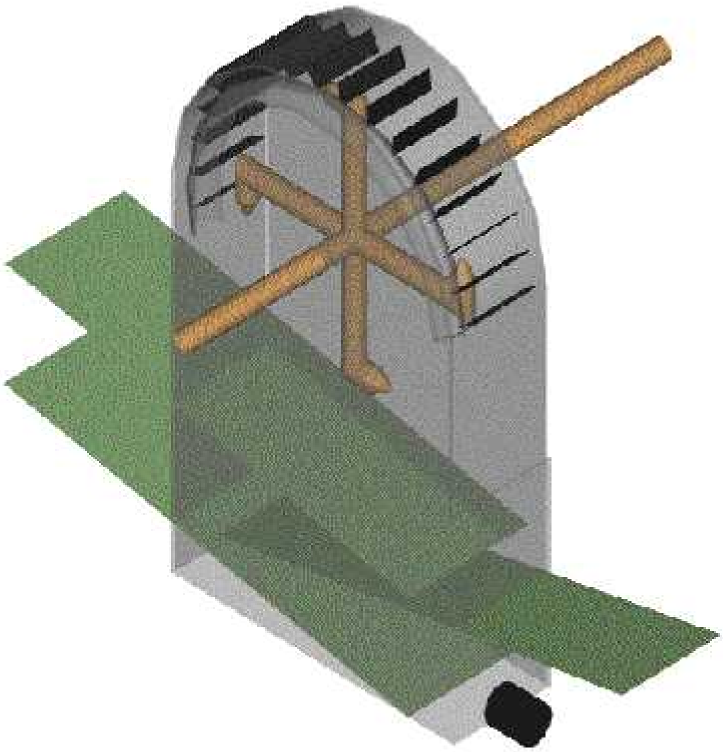

Fig. (5.7) Casing

The heat release in plates equals the heat release in condenser ($q_{condenser}$). It is given by

$$q_{4-1} = h_4 - h_1 \tag{5.12}$$

To calculate the area of plate we must know the position of this plate. This plate is located in two positions; part of these plates inside the case to condensate the vapor and the other part outside the case to ensure the heat transfer between the plate and the surrounding. And the area of the plate inside the case calculated by

$$q = U_{in} * A_{in} * (T_2 - T_1) \tag{5.13}$$

Where:

q: the heat rejected from condenser [kJ/kg].

U_{in}: over all heat transfer coefficient inside the case [W/m^2 .Cº].

A_{in}: surface area inside the case for heat transfer coefficient with definition of U [m^2].

T_1: the temperature of the plate inside the case [Cº].

T_2: the temperature of Freon vapor after it leaves the nozzles[Cº].

The over all heat transfer coefficient U is defined by the relation

$$U_{in} = 1 \div \left[\frac{1}{h_{f_{in}}} + \frac{1}{h_{f_{out}}} \right]_{in} \tag{5.14}$$

Where:

$h_{f_{in}}$: the convection heat transfer coefficient inside the plate inside the case [kJ/kg].

$h_{f_{out}}$: the convection heat transfer coefficient outside the plate inside the case [kJ/kg].

The values of convection heat transfer coefficient can be obtained from a table (5.1).

Table (5.1) typical values of convection heat transfer coefficient

Type of Convection	h_c W/m.Cº
Free Convection of Gases	2 – 25
Free Convection of Liquid	10 -1000
Forced Convection of Gases	25 – 250
Forced Convection of Liquid	50 – 20000
Boiling and Condensation	2500 – 100000

And the area of the plate outside the case calculated by

$$q = U_{out} * A_{out} * (T_4 - T_3) \qquad (5.15)$$

U_{out}: over all heat transfer coefficient outside the case [W/m^2.Cº].

A_{out}: surface area outside the case for heat transfer coefficient with definition of U [m^2].

T_3: the temperature of the surrounding [Cº].

T_4: the temperature of the plate outside the case [Cº].

$$U_{out} = 1 \div \left[\frac{1}{h_{f_{in}}} + \frac{1}{h_{f_{out}}} \right]_{out} \qquad (5.16)$$

$h_{f_{in}}$: the convection heat transfer coefficient inside the plate outside the case [kJ/kg].

$h_{f_{out}}$: the convection heat transfer coefficient outside the plate outside the case [kJ/kg].

Although final heat-exchanger designs will be made on the basis of careful calculations of U, it is helpful to have a tabulation of the overall heat transfer coefficient for various situations which may be encountered in practice. Abbreviated list of values of U is given in table (5.2)

Table (5.2) approximate values of overall heat transfer coefficients.

Physical situation	**U [W/m^2.C^o]**
Double plate glass window	2.3
Steam condenser	1100-5600
Feed water heater	1100-8500
Water to water heat exchanger	850-1700
Finned tube heat exchanger, steam in tubes, air over tubes	25-2280
Finned tube heat exchanger, water in tubes, air a cross tubes	25-55
Gas to gas heat exchanger	10-40
Water to oil heat exchanger	110-350
Plate glass window	6.2
Steam to heavy fuel oil	56-170
Steam to light fuel oil	170-340

And the drive shaft going out from the case and will act on the rotor part of the generator.

5.8 Suggested Working Fluid (Freon R-11)

Refrigerant -11 is a fluorocarbon of the methane series and has a boiling point at atmospheric pressure at standard conditions are 23.81 Cº. R-11 is widely used as a secondary refrigerant and as a solvent like other fluorocarbon refrigerants, R-11 is nonabrasive, nontoxic, and non flammable but dissolves natural rubber.

Freon Properties

Table (5.3) Physical Properties of Freon

Molecular Weight	137.38
Boiling Point	23.81 Cº
Freezing Point	-111 Cº
Critical Temperature	198 Cº
Critical Pressure	4406 Kpa
Critical Volume	1.804 L/Kg
Density	558 Kg/m^3
Thermal Conductivity of Liquid	0.087 W/m. Kº
Thermal Conductivity of Vapor	0.00776 W/m. Kº

5.9 Generator

Generators are devices used to convert mechanical energy into electrical energy, by electromagnetic means. The mechanical energy is the rotational motion from the drive shaft in the bladeless turbine and it is the rotor part for the generator.

We most know the principle of operation of generator to know how it converts the mechanical energy to electrical energy.

Generators consist of two basic units, the field, which is the electromagnet with its coils, and the armature, the structure that supports the conductors which cut the magnetic field and carry the induced current in a generator.

If an armature revolves between two stationary fields poles, the current in the armature moves in one direction during half of each revolution and in the other direction during the other half. To produce a steady flow of unidirectional, or direct, current from such a device, it is necessary to provide a means of reversing the current flow outside the generator once during each revolution. A commentator, a split metal ring mounted on the shaft of the armature. The two halves of the ring are insulated from each other and serve as the terminals of the armature coil. Fixed brushes of metal or carbon are held against the commentator as it revolves, connecting the coil electrically to external wires. As the armature turns, each brush is in contact alternately with the halves of the commentator, changing position at the moment when the current in the armature coil reverses its direction. Thus there is a flow of unidirectional current in the outside circuit to which the generator is connected. DC generators are usually operated at fairly low voltages to avoid the sparking between brushes and commentator that occurs at high voltage. In some newer machines this reversal is accomplished using power electronic devices.

Chapter Six

Conclusion and Future Work

Chapter Six: Conclusion and Future Work

Thermal conversion of solar energy is well known in several places around the world. It is mainly used with the same constraints in different energy conversion stages. The work proposed here is a new approach by which some of the constraints could be eliminated, especially the amount of friction losses, material, size and costs, thermal losses and energy conversion types.

The system has been produced depending on parts available from previous graduation projects. This is an important approach in accumulating the effort and concentrating them for the benefit of the university and the students. The mechanical energy conversion system is considered a new design. It integrated both the bladeless turbine and a "condenser" part in one casing. The use of heat removal plates is important to reach high condensation efficiency in such systems when using the pump otherwise the system could be used without the condenser part when using it in a thermosyphone loop. The bladeless turbine uses a set of guiding blades that helps reducing loses induced by flow separation and turbulent. The unavailability of measuring instruments is one of the main reasons for not conducting proper tests on the system to assess its performance.

The work done represents a new revolutionary idea (paradigm) by which the available solar energy could be utilized to produce mechanical energy. The system designed and produced through the course of the graduation project could be considered as a "prototype" conversion system. Testing the performance of such system under several working conditions could be done. It is worth mentioning here that the system should be tested in a thermosyphone mode once, and with the pump installed. Testing should be concentrated on the system performance and hence optimally sizing of system' components. The system can reduce the friction losses to the minimum by integrating a stator with the bladeless turbine that acts as the rotor. This could be achieved using the principal of permanent magnetic generator (PMG). System testing requires measuring instrumentations, i.e. data loggers, sensors, etc. By doing proper testing one could easily assess the system optimal design.

References

References

A. Internet References

1. "Nozzle", < http://www.grc.nasa.gov/WWW/K-12>, 2002
2. "Thrust", < http://www.grc.nasa.gov>, 2001
3. "Turbine", < http://www.animatedsoftware.com >, 2003

B. Book References

4. Alan T. McDonald," Introduction Fluid Mechanics, Third Edition, John Wily & Sons, Canada, 1985

5. J.P. Holman, "Heat Transfer, Sixth Edition, McGraw-Hill, Singapore, 1986

6. Marian Fisk and H.C. Anderson," Solar Technology, Seventh Edition, Macmillan publishing Company, USA, 1990

7. Yunus A.Qenge, "Thermo Dynamic & Heat Transfer, Froth Edition, Prentice-Hall, New Jersey, 1997