Palestine Polytechnic University

College of Engineering & Technology

Mechanical Engineering Department

Project Name

Technical and Economic Aspects of solar Pool Heating

Project Team

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Graduation Project Evaluation

According to the project supervisor and according to the agreement of the Testing Committee Members, this project is submitted to the Department of Mechanical Engineering at College of Engineering and Technology in partial fulfillments of the requirements of (B.SC) degree.

Supervisor Signature

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Committee signature

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Department Headmaster Signature

……….…………….

Dedication

To our parents who

Spend nights and days doing their best

To give us the best

To all students and who

Wish to look

For the future

To who love the knowledge and

Looking for the new

In this world

Acknowledgment

Our thanks go first to our advisor Eng. Mohammad Awad. His guidance and support made this work possible.His constant encouragement, intuitive wisdom, and resolute leadership was instrumental in completing this world.

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Abstract

The project have a design of swimming pool and solar pool heating system for a building in Hebron city, the total area of this pool is $178m^2$, the design have the solar collector network and comparison between the solar and the diesel.

The project contain the components of the pool and selection of these components, the cost of the solar collector, and the cost of diesel.

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Chapter one

Introduction

1.1 Introduction

The aim of this project is to design a swimming pool and solar pool heating in villa in Hebron by make the correct selection of the components of the swimming pool and make comparison between the solar pool heating and diesel pool heating.

1.2 Scope of the project

This project presents the design of swimming pool and utilities solar energy is used to warm the swimming pool water. The project will include the construction of the swimming pool and all the mechanical parts of swimming pool will be select, And water treatment ,the temperature of the water that heated by solar system in swimming pool should be (27-30)c and the volume of the pool is 320 m^3

1.3Project Objective:

Design a swimming pooland the solar pool heating system and how much cost and compare it with the fuel heating.

1.4 General project descriptions:

This project aims to design a swimming pool recreation water activities for Hebron villa in Hebron city in West Bank.

Type of swimming pool: private, indoor.

Building type: villa.

Building address: Hebron.

Pool surface area: 178 m^2

Pool depth:

-Minimum depth: 0.8 m.

-Maximum depth: 2.8 m.

-Average depth: 1.8 m.

Volume of water: -about 320 m^3

1.5 Time Table:

Table1.1 The Time table for the first semester

Week / Task	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Choosing the Project idea															
General study															
Writing Introduction															
Study of swimming pool															
design of swimming pool															
Study solar energy															

Calculation heat load													■	■	
Documentation													■	■	
Printing															■

Table1.2 The Time table for the second semester

Week / Task	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Calculate the pipe sizing	■	■													
Selecting The Pumps and Other Equipment’s			■	■	■	■									
Selecting the solar collector					■	■	■	■							
Price the solar collector and the liquid fuel									■	■					
Documentation							■	■	■	■	■	■	■	■	
Printing															■

1.7 Project Outline:

Chapter One:-Introduction

It includes an overview about the project, the importance of the heating swimming pool and the reason to work with it .

Chapter Two:- Construction of swimming pool

It includes construction of swimming poolprocessing the wall and floor and installation the tile and mosaic glass.

Chapter Three:- Swimming pool component

It includes basic mechanical swimming pool component and how swimming pool work.

Chapter four:- Swimming pool design

It includes description of solar water heating system, solar collector, pool climate condition, passive solar gain and active solar gain.

Chapter five:- Solar energy

It includes calculating of pipe sizing and selection of pool equipment.

Chapter two

Construction of swimming pool

2.1 The construction of a swimming pool:

The pool constructions requirements according to We could summarize the pool constructions Guidelines for the establishment and licensing of swimming pools, restored the National Committee of the swimming pools. 1999), The following:

- Two sections must be included, the first with low depth and the other with large depth.
- All the front and the side walls of the pool must be vertical at least 1m.
- The pool must be more than 1m deep and less than 2.8m deep.
- The under surface must have a slop of no more than 12:1 from the low area to the high area and no sudden changes in the slop should occur.
- 60-80% of the pool must be less than 1.5m.
- Put ladders or stairs on every 25 m of the pool.
- Taking into account that the ladders inside the pool can't be seen.
- All the internal sides of the pool must be smooth and easy to clean.
- The internal walls must be connected to the bottom surface and rounded without any sharp corners.

2.2 Description of structural concrete pool and processed:

The following figure shows the layered construction of the swimming pool:

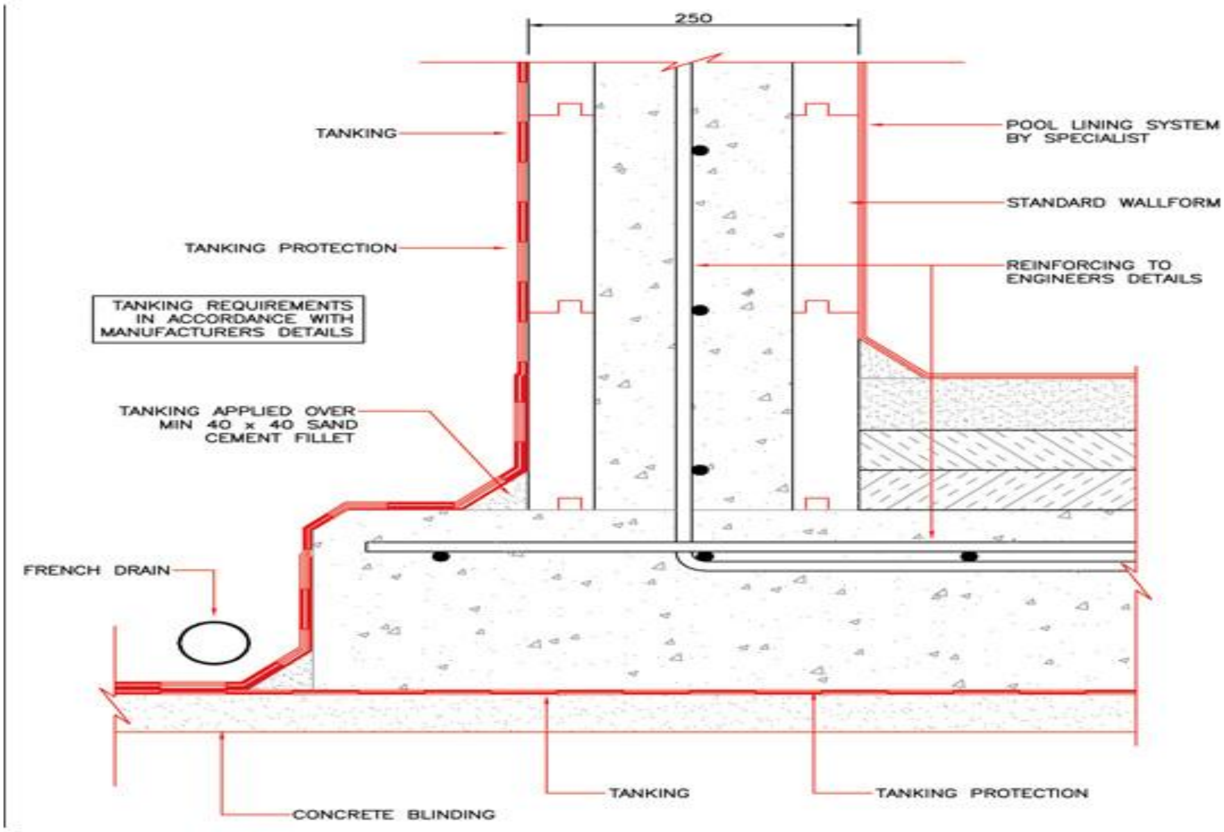

Figure (2.1)

2.2.1 Cement set up:

For a good cement which holds the water and doesn't allow it to leak concrete must meet the following condition:

1- Stamina of the concrete b30 and more.

2- The capability of putting up with the hydrostatic pressures water

3- Decrease the percentage of the water within the concrete (55>wc) so that the concrete will be less prone to leakage.

4- A high ability for operating, by adding chemical components that can liquefy the concrete these can be purchased from market like:

- Super plasticisersMapi fluid line.
- Acrylic-basedhperplasticisersDynamon line.

5- The concrete thickness covering the steel should b not than less 3cm.

6- Apply amount of water on the concrete for 7 days.

7- Adding fiber mish to the processed layer.

2.2.2 Processing construction joints between the walls and the floor:

To avoid leakage of water between the constriction of the wall and the floors using one of the insolate:

- Water stop: a strip rubber has a smooth internal surface the external face is rough so that it can hold the concrete water stop is available in several dimensions in the market, Its width is 30 cm and thickness 1 cm. Its reinforced by iron wires before the concrete is applied on the floor .half of concrete is to be applied on the floor and the other half on the walls.

- Indro stop: a rope rubber, rectangular section (20 *15 mm), (20 *10mm) reinforces the floor of the pool with adhesive material (drop astic) or with iron for reinforcing the walls It swells with water. (45%after 24 hour), (70%after two days) and (120%after 7 days), to prevent leakage.

2.2.3 Processing the walls:

By making the concrete walls smooth, and processing with a layer of insulating cement, by adding materials like (planicrete and Nivoplan) solved in water.

The treatment should happen in the following manner:

- Duration of the work process (from the beginning of the mortar) 3.2 hours.
- 2-30 mm thickness.
- Durability of concrete mortar to tensile strength < 3.5 mpa
- Durability of the cement mortar to pressure < 6.0 mpa.

2.2.4 Processing the floor:

Bymaking the floor smooth and removing the duct, powder and oils that effect the strength of the adhesion of the layer of processed cement with the concrete layer processing the floor with a layer cement isolated with (planicrete and Topcen or Mapecembiders) .

Taken into account in the following layer processing

- The time period before the start of the filing 24 hour.
- Durability of the concrete mortar to pressure 25 mpa.

2.2.5 Adding insulation materials:

Add a layer of concrete to the floor because of the defects after the concrete application The isolation material that is available in the market today is

- **fiber mish:**

This is material consisting of fiber package which disintegrates during the mixing process and as a result he fibers are separated These fibers distribute by regulating themselves inside the concrete and this contributes for additional resistance to cracks. The cracks happen during a specific process. fiber Mish is resistant to shrinkage.

- **Microselica:**

a chemical in the form of powder, working to improve the elements and characteristics of concrete and its applications in construction, Is work to improve even particles of very small components of the article:

Almaekerosalekia "the ability to penetrate the spaces between the particles of cement paste and gravel, and work to fortify the properties of the charge stuffing Microselica interacts silicon dioxide with calcium hydroxide to form calcium silicate Hidoratcsh, which keep the cement together, This increases the strength of the concrete and makes it less permeable.

2.2.6 Installation of tile and mosaic glass:

Add adhesives used in the installation of concrete tiles such as the material (keracrete Powder) in the installation of mosaic glass like the material (Adesilex P10and Isolastic (elastic latex))

Characteristics of the mortar at a temperature of 23℃:

- The Period of time from opening the material to its mixing should not exceed 20 Minutes.
- The Period of work (from the beginning of mixing the mortar) should not exceed 30 minutes.
- The floor is ready to be used after four weeks.

2.2.7 Quick Installation:

This is by Using adhesives which allow the use of the pool after a short time, such as the material (Keracolor and fugolastic or ultracoloar), which added to the mortar or to the porcelain mosaic tiles or to the clinker.

Characteristics of the mortar at the temperature of 23℃:

- Period of time from the material to it mixing must not exceed 20 minutes.
- Period of work (from the beginning of mixing the mortar should not exceed 45 minutes.
- The ground is ready to be used after three days.

2.2.8 Fill the empty spacing:

The other layer insulating paint over the tiles, serves or fill the spaces between the tiles and in the insolating layer are used materials such as (Keracolor and the tiles and In the Fugolasic or ultracoloar), The pool can be filled with water after a period of not less than 48 hours from panting it with this material.

Chapter three

Swimming pool components

3.1 Introduction

A swimming pool, swimming bath, wading pool is an artificially enclosed body of water intended for recreational or competitive swimming, diving. or for other water exercise, or merely cooling off bathing activities that involve swimming pool in the hot day.

3.2 Basic mechanical components of swimming pools

The basic mechanical components of swimming pools are:

1. Skimmers or over flow gutters

Skimmer is mounted in the pool wall at water level, and connects to a branch of the suction piping from the filter pump. Its purpose is to promote surface flow across the pool. Besides drawing in the water, which requires most treatment because of exposure to sun, wind, and rain, it also removes floating dust and debris, level, and oil films before they can accumulate on floor and walls.

Over now gutter. A through in the wall of the pool which may be used for over now and skim he pool surface.

2. Floor drain

The outlet or outlets within the construction of pool floor, which function is to suck or take the pool water into the piping network, then the water enters the filter to be cleaned. Its function is similar to the function of the skimmer or gutter.

3. Return inlets

An opening or fitting through which filtered water enters the pool, it is either wall mounted or floor mounted.

4. Pumps and motors

A pump is a device that raises or transfers fluids from one location to another location, pump are selected for processes to not only raise and transfer fluids but also to meet some other criteria.

There are two main categories of pumps, they are dynamic and displacement pumps. These two categories also have many subcategories of pumps.

Pumps are used for variety applications, in swimming pool the pump used for recirculation system.

5. Filters

Filter is a mechanical device for straining suspended particles from pool water. It deals with particulate matter. It strains out suspended solids down to sub-micron size in order to retain water clarity. It does not remove dissolved salts and other microorganisms. Filtration combined with disinfection produces effective water purification treatment that keeps water:

- Clear and non-toxic.
- Odorless and tasteless.
- Free of bacteria and algae.
- Balanced to prevent corrosion or scale formation.

6. Chlorine device

This device used to control the chlorine in the pool water and it is very important in the chemical treatment of the pool water.

7. Flow meter

A device that measures pressure differential across a calibrated orifice and indicates the rate of flow at that point. Usually expressed in liter per second (L/s). A flow meter is required in each pool and spa recirculation system. The flow meter measures the quantity of water passing a given point in a unit of time.

Recirculation systems deliver hot water to fixtures quickly without waiting for the water to get hot.

8. Pool water heater

The need for pool water heater depends on the purpose of the pool and the general climate. A heated pool is more enjoyable at all times and extends the season at both ends by at least a month. The heater is connected into a loop in the return line from the filter, and may either be gas-fired, electric, or consists of a heat exchanger where steam or water service is available. In our project we will use solar energy to heat the pool.

The heater is more vulnerable to lime deposits and corrosion than other pool equipment. As a result it should be cheeked frequently during the early weeks of operation to ensure that it suffers no adverse effects from the pool water chemistry.

In this project, a solar energy is the source that heating the water of swimming pool.

9. Make-up tank

It is helpful to be able to calculate the amount of make-up water that needs to be added to make up for water loses through filter backwashing, splash-out, evaporation or leaks. To-do so, determines the number of meters of water depth required to fill the pool and your pool's surface area (length * width) and supplement them into the following formula:

Meters of water depth * pool surface area (m^2) = cubic meter of make-up water

10. Multiport valve

The multiport valve is found on most sand filters and D.E. filters today. It allows you to route the water from the pump, through or around your filter in several different ways. This valve will be found on top of your filter (top mount) or on the side of the filter (side mount).By changing the position of the lever on the valve you can route the water from the pump around or through your filter in different ways so that you can perform different maintenance operations on your pool water.

3.3 How swimming pools work

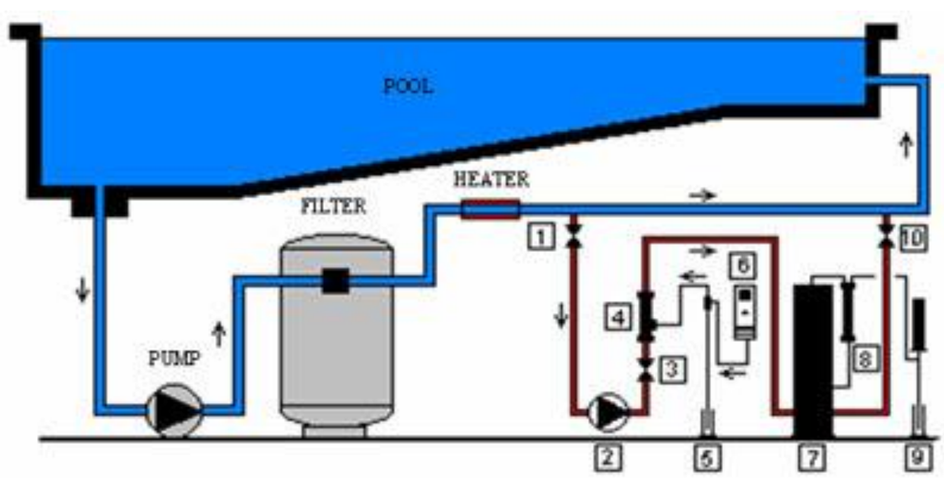

Figure (3.1): circulation of water in swimming pool

The process of pumping water from the pool through the filter system and returning it to the pool is called recirculation. Typical components of the recirculation system include the:

1- Piping Pump, 2- Valves, 3- inlets, 4- outlets, 5- storage tank, 6- pressure gauges, 7- Flow meter

The source of the power used to the water circulation pump. Typically, a centrifugal pump is used to recirculate the pool water.

In the diagram below the arrows represent the direction of water flow.

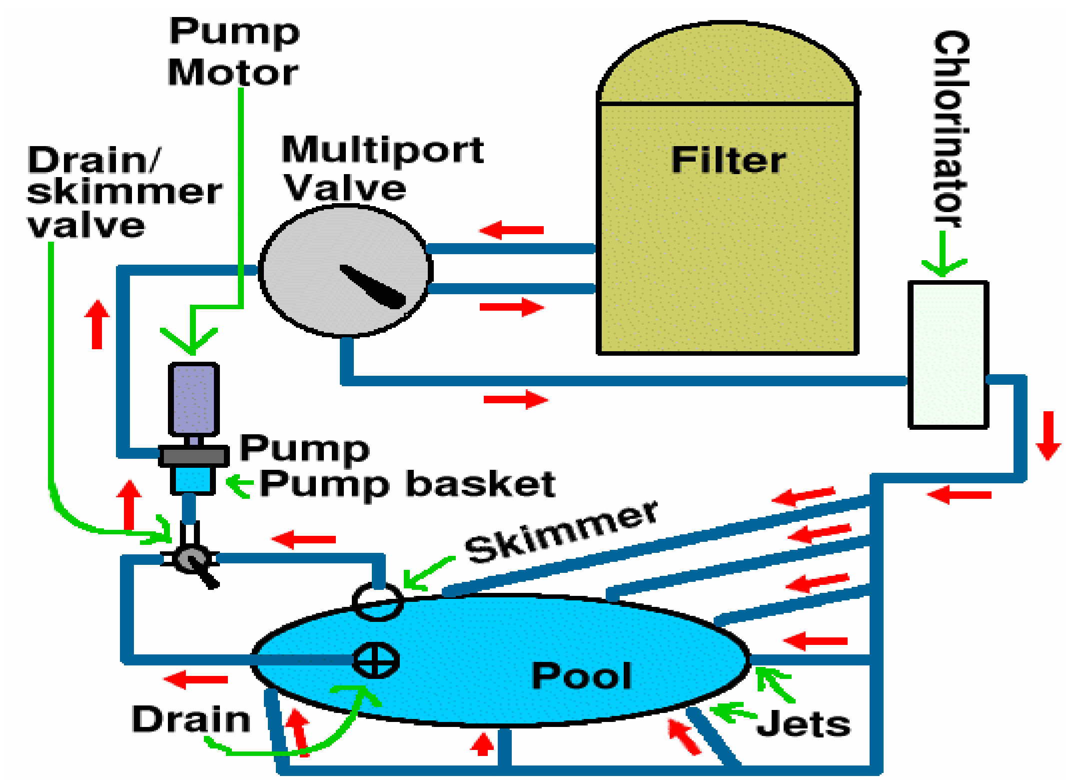

Figure (3.2): simple pool water cycle

Start from the pool; water is sucked out of the pool, usually at two points, the bottom drain and the skimmer or over flow gutter (depend on the pool type), which is indented into the wall in the deep end, near the surface. The surface traps floating debris as it sucks in water. From the drain and skimmer, the water is sucked to a check valve (one way valve). The one way valve determines the percentage of water sucked through the skimmer relative to the drain. It can do this because either the drain and skimmer has their own pipe leading to the way valve.

From the one way valve, the water is sucked into the pump, it is a centrifugal pump. The pump doing tow jobs, the first job include first filtration for the water by the filter in the pump. The second job, it sucks water into the center, and via spinning blades throws it to the outside, where it's shot out into the outgoing pipe.

Coming out of the pump, the water is pushed into the filter valve. The exact configuration of the filter valve depend on the type of filter. The basic use of the filter valve is to either direct the water into the filter or out to the street VI a hose. Obviously normal operation requires direction to the filter. Filters requiring backwashing or rinsing which requires filter valves with additional positions to accomplish those functions.

Next, the water is pushed through the filter. The water passes through and the suspended particles are caught and held by the filter. After the filter has caught too much particles. Matter, its ability to pass water is compromised, in which case either the filter's cartridge must be changed if its cartridge, or it must be backwashing. Filters have a pressure gauge to tell you when they have absorbed too much particulate.

Now cleaned water is pushed out of the filter and into the heater and heating the water by heat exchanger and make the temperature of water suitable for human comfort Cleansed and heating water pushed into the chlorinator, a simple canister which houses solid tablets of chlorine so that they dissolves over time and keep the chlorine level somewhat constant From the chlorinator the water goes through underground pipes back to the pool, where it enters through the water jets on the sides of the pool. Thus completing the water cycle.

3.4 Pool capacity

The first step in pool design is the calculation of the volume water in the pool,

Volume of water = surface area of the pool x average depth

The average depth = (shallow end depth + deep end depth)/2

The formula used above for the calculation of average depth can be used if the slope of the bottom of the pool is gradual and even. If the slope of the bottom is not gradual then we have to treat the pool as two or three parts each with gradual bottom slope, and calculate the volume of each part and then add these volumes together to determine the total water volume of the pool. Volume of a swimming pool is given in units of cubic meters, liters, or gallons.

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Chapter four

Swimming Pool Design

4.1 Pool Capacity Calculations:

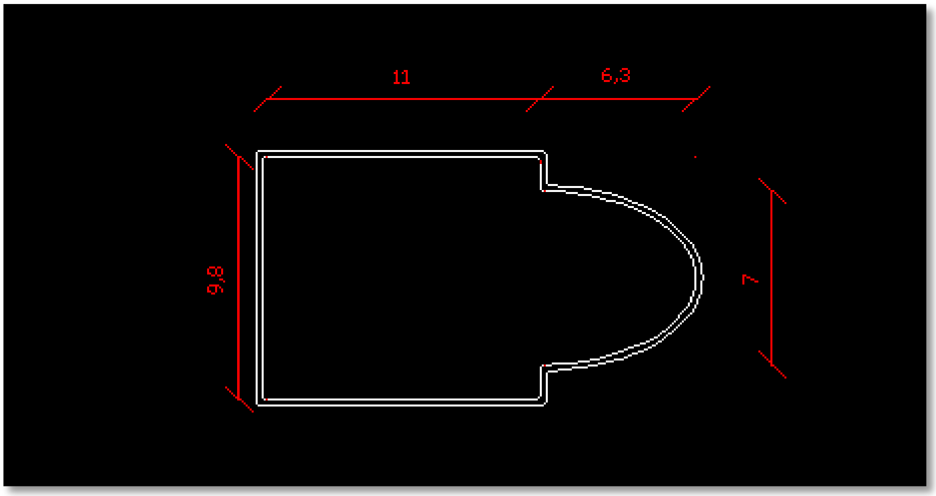

Figure (4.1)swimming pool plane.

Average depth = (Shallow end depth + deep end depth)/2

= (2.8 + 0.8)/2 = 1.8m.

Volume of water = area * average depth

= 178 * 1.8

= 320m^3.

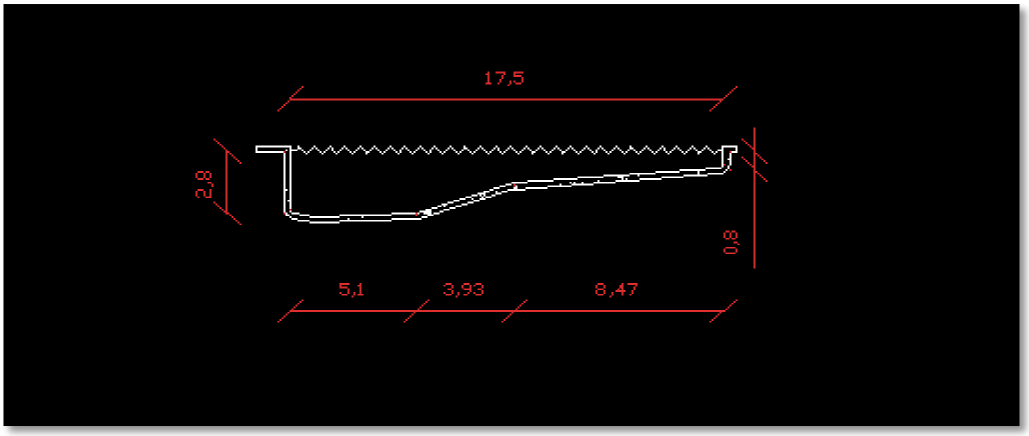

Figure (4.2) swimming pool section.

4.2 Turn Over Time:

In Hebron the turn over time is 4 hr in residential pools.

4.3Filter Sizing and Selection:

4.3.1 Filter Sizing:

Filter flow rate = Total Water Circulation rate (m^3/hr)

$$= \left[\frac{Pool\ water\ volume\ (m^3)}{Pool\ turn\ over\ period\ (hr)}\right]$$

$$= \left[\frac{320}{4}\right]$$

$$= 80\ (m^3/\text{hr})$$

For a filtration velocity of 20m/hr, the efficiency is 100%.

For a filtration velocity of 30m/hr, the efficiency is 70%.

For a filtration velocity of 40 m/hr, the efficiency is 50%.

The filter efficiency between 50-70%, so a 35m/hr filtration velocity.

Filter surface area = $\left[\frac{Filtration\ \ flow\ rate}{Filtration\ \ velocity}\right]$

$$= \left[\frac{80}{35}\right]$$

$$= 2.2m^2.$$

4.3.2 Filter selection:

From Astral company catalogue, we find that the filter of code No 41317, with the following specifications match our design requirements:-

♦ Filter Name: Vesubiofilter.

♦ Filtration surface area: 2.54 m^2.

♦ Filter diameter: 1800 mm.

♦ Filter flow rate = 101 m^3/hr.

♦ Gravel sand (1-2 mm): 550 kg.

♦ Sand (0.4 – 0.8 mm): 3175 kg.

♦ Volume = 2950 m^3.

♦ Weight: 210 kg.

4.4Skimmers selection:

● Number of skimmers = (50% X Total flow rate)/capacity of each skimmer

= pool surface area / 25

= 178 / 25

= 7.12 = 7 skimmers.

Flow rate of each skimmer = (50% × flow rate)/number of skimmers

= (50% × 80) / 7

= 5.7m^3/hr = 25.1gpm.

From Astral company catalogue, we find that the skimmer of code No 11304, with the following specifications match our design requirements:-

♦ Skimmer with wide mouth opening.

♦ Square lid.

♦Skimmer flow rate = 7.5 m^3/hr.

♦ Outlet of 63 mm.

♦ Volume = 0.135 m^3.

♦ Weight: 6.24 kg.

4.5 Main drain selection:

● Number of main drains = (flow rate × 50%)/ flow rate of main drain

= (80 × 50%) / 40

= 1 main drain required.

For this pool two main drains selected.

Flow rate of main drains = 50% × flow rate

= 50% × 80

= 40 m^3/hr = 176gpm.

From Astral catalogue we selected two concrete pool main drains of code No 22360 each of the following specifications:

♦ Main Drain Name: Concrete Pools-Main Drains, square main drain with plastic grille,

Outlet of 90mm.

♦ Recommended flow rate: 22 m^3/hr.

♦ Volume: 0.034 m^3.

♦ Weight: 4.5 kg.

4.6Selection of return inlets:

● Number of required return inlets = $\left[\frac{Filtration\ \ flow\ \ rate}{Flow\ \ rate\ \ of\ \ each\ inlet}\right]$

= pool surface area /25

= 178 / 25

= 7 return inlets.

● $Flow\ rate\ of\ \ each\ return\ inlet$ = $\left[\frac{Filtration\ \ flow\ \ rate}{\text{Number of required return inlets}}\right]$

= $\left[\frac{80}{7}\right]$

= 11.44m^3/hr = 50.3gpm.

From Astral catalogue we selected concrete pool return inlet of code No 15863 each of the following specifications:

♦ Recommended flow rate: 13.5 m^3/hr.

♦ Outlet of 63 mm.

♦ Volume: 0.02 m^3.

♦ Weight: 3.4 kg.

4.7 Pool lighting:

Submerged light is the main light in the pool, where the power of the lamp chosen should be 300 watt per meter square of the pool surface area.

From Astral pool catalogue we select lamp (code 07833) with power 300 watt for half deep pool

Number of lights = pool surface area / 25

= 178/25

= 7 lights.

Distance between lights = pool perimeter/ number if lights

= 50/7

= 7 m.

4.8 Pool ladders:

From Palestinian National Community, each 25m perimeter of we need one ladder.

Number of ladders = pool perimeter/25

= 50/25

= 2 ladders.

From Astral catalogue, we select ladders with the following specification:

Ladders width 500mm

♦ Handrail in hand polished stainless steel (Ø43 mm)

♦ Steps in stainless steel

♦ Compete with fixing anchors earth connection

4.9 Pool pipe sizing:

Pipe Sizing considerations:-

1. Required flow rate of water, measured in gpm or m^3/hr.

2. Length of plumping runs and equivalent length of fittings.

3. The main suction line plays a critical part in the wear and efficiency of the pump. This pipe line should be short, straight and full-pored, allowing a water flow of between

4. (0.5 – 1 m/sec), which equals (1.6 – 3.3 ft/sec), with maximum friction losses 6ft/100ft.

5. All piping on the discharge side of the pump for filtration shall have pipe sizes determined so that the velocity in any pipe should be between (1.0 – 3.0 m/sec), which equals (3.3 – 10.0 ft/sec), with maximum friction losses 12ft/100ft.

6. Pump is weakest at suction side, therefore ensure shortest possible suction runs.

7. In the determination of pipe sizes required,the criteria which could call for the largest pipe size shall govern. The larger the pipe the better, there is less restriction and therefore less strain on all equipment and plumbing. Use the largest diameter pipe and fitting for the job.

8. Use full flow valves and large inlets.

4.9.1Discharge line pipe sizing:

→Note: $1m^3/hr$ = 4.4 gpm.

♦ From the table, at flow rate of 80 m^3/hr (352 gpm)

110 mm pipe diameter has

350→V=9.0ft/s

352→X

400→V=10.2ft/s {by interpolation}

At 352→ velocity of 9.048 ft/sec and friction loss of 5.95ft/100ft.

4.9.2 Return inlets pipe sizing:

♦ From the table, at flow rate 50.3gpm

Select 63 mm pipe diameter has … velocity of 4.9 ft/sec and friction loss of 4.2ft/100ft.

Pipe sizing between RI:

	Flow rate (gpm)	Diameter (mm)	Velocity (ft/sec)	Friction loss (ft/100ft)	Distance (m)
Discharge line	352	110	9.048	5.95	26
RI 1→RI 2	301.7	110	7.7	4.4	4.2
RI 2→RI 3	251.4	110	6.4	3.2	2.5
RI 3→RI 4	201.1	110	5.1	2.1	2.5
RI 4→RI 5	115.8	90	4.8	2.6	2.5
RI 5→RI 6	100.5	90	4.4	2.2	6.5
RI 6→RI 7	50.3	63	4.9	4.2	2.8

Total equivalent length = pipe length × 2

The Total friction head from discharge line is:

$= \sum$ (total equivalent length of each pipe (ft) × friction head for each (ft/100ft))

$$= \sum 26\times2\times3.28\times\left(\frac{5.95}{100}\right)+4.2\times2\times3.28\times\left(\frac{4.4}{100}\right)+2.5\times2\times3.28\times\left(\frac{3.2}{100}\right)+2.5\times2\times3.28\times\left(\frac{2.1}{100}\right)$$

$$+2.5\times2\times3.28\times\left(\frac{2.6}{100}\right)+6.5\times2\times3.28\times\left(\frac{2.2}{100}\right)+2.8\times2\times3.28\times\left(\frac{4.2}{100}\right)$$

$= 14.267\ m.$

4.9.3Suction line pipe sizing:

♦ From the table, at flow rate of 80 m^3/hr (352 gpm)

110 mm pipe diameter has

350→V=9.0ft/s

352→X

400→V=10.2ft/s {by interpolation}

At 352→ velocity of 9.048 ft/sec and friction loss of 5.95ft/100ft.

4.9.4 Skimmers pipe sizing:

♦ From the table, at flow rate 25.1gpm.

Select 63 mm pipe diameter has … velocity of 2.4ft/sec and friction loss of 1.2ft/100ft.

4.9.5 Main drain pipe sizing:

♦ From the table, at flow rate 176 gpm

90 mm pipe diameter has … velocity of 4.0 ft/sec and friction loss of 1.8ft/100ft.

Pipe sizing between skimmers:

	Flow rate (gpm)	Diameter (mm)	Velocity (ft/sec)	Friction loss (ft/100ft)	Distance (m)
Suction line	352	110	5.048	5.95	12.9
Main drain	176	90	4.0	1.8	23
S1→S2	150.9	110	3.8	1.2	3
S2→S3	125.8	110	3.2	0.9	3.5
S3→S4	100.7	90	4.4	2.2	2.5
S4→S5	75.6	90	3.3	1.3	2.5
S5→S6	50.5	75	3.4	1.8	2.5
S6→S7	25.1	63	2.4	1.2	5.8

The total friction head from suction line is:

= ∑ (total equivalent length of each pipe (ft) × friction head for each (ft/100ft))

$$= \sum 12.9\times2\times3.28\times\left(\frac{5.95}{100}\right)+23\times2\times3.28\times\left(\frac{1.8}{100}\right)+3\times2\times3.28\times\left(\frac{1.2}{100}\right)+3.5\times2\times3.28\times\left(\frac{0.9}{100}\right)$$

$$+2.5\times2\times3.28\times\left(\frac{2.2}{100}\right)+2.5\times2\times3.28\times\left(\frac{1.3}{100}\right)+2.5\times2\times3.28\times\left(\frac{1.8}{100}\right)+5.8\times2\times3.28\times\left(\frac{1.2}{100}\right)$$

= 9.519 m.

4.10 Pump selection:

Pump head calculations:

Total head = friction head in suction line + friction head in discharge line + friction head in filter + friction head in main drain, skimmers, and return inlets.

Friction head in suction line = 9.519 m.

Friction head in discharge line = 14.267 m.

Friction head in filter = 6.7 m. (maximum head=3psi+7.1psi = 10.1psi = 6.7m)

Friction head in main drain, skimmers, and return inlets =1.5 m.

Total head = 9.519 m+ 14.267 + 6.7 + 1.5

= 31.9 m.

For the given data of:

-Total head = 31.9 m.

-Flow rate = 80 m^3/hr.

By referring to Astral, we select the two pumpsat series of code No 56633 , which have the following specifications:

♦ Pump name: Kivu pump.

♦ Power: 7.5 HP (230/400V), 50Hz.

♦ Inlet and outlet diameter:150mm, 125mm.

♦ At ahead of 34m, have a flow rate of 80 m^3/hr.

Chapter five

Solar Energy

5.1 Description of Solar Water Heating Systems

Solar water heating systems use solar collectors and a liquid handling unit to transfer heat to the load, generally via a storage tank. The liquid handling unit includes the pump(s) (used to circulate the working fluid from the collectors to the storage tank) and control and safety equipment. When properly designed, solar water heaters can work when the outside temperature is well below freezing and they are also protected from overheating on hot, sunny days. Many systems also have a back-up heater to ensure that all of a consumer's hot water needs are met even when there is insufficient sunshine. Solar water heaters perform three basic operations as show in figure (4.1) below:

Collection: Solar radiation is "captured" by a solar collector.

Transfer: Circulating fluids transfer this energy to a storage tank; circulation can be natural (thermosiphon systems) or forced, using a circulator (low-head pump); and

Storage: Hot water is stored until it is needed at a later time in a mechanical room, or on the roof in the case of a thermosiphon system.

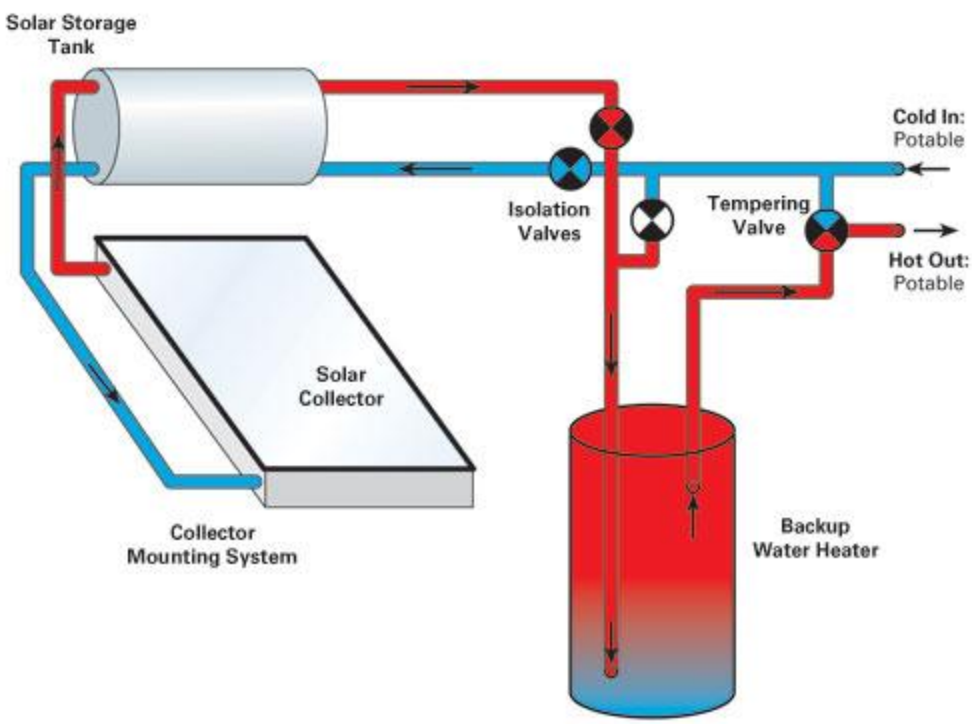

Figure (5.1) Solar hot water system schematic

5.2Solar collector:

Solar collectors capture the sun’s electromagnetic energy and convert it to heat energy. While most direct and indirect active systems use flat-plate collectors, some systems employ evacuated tube collectors, or use collectors that incorporate one or more storage tanks.

Solar energy (solar radiation) is collected by the solar collector's absorber plates. Selective coatings are often applied to the absorber plates to improve the overall collection efficiency. A thermal fluid absorbs the energy collected. There are several types of solar collectors to heat liquids. Selection of a solar collector type will depend on the temperature of the application being considered and season of use (or climate). The most common solar collector types are:

1) Unglazed liquid flat-plate collectors

Unglazed liquid flat-plate collectors, as depicted in Figure (5.2), are usually made of a black polymer. They do not normally have a selective coating and do not include a frame and insulation at the back; they are usually simply laid on a roof or on a wooden support. These low-cost collectors are good at capturing the energy from the sun, but thermal losses to the environment increase rapidly with water temperature particularly in windy locations. As a result, unglazed collectors are commonly used for applications requiring energy delivery at low temperatures (pool heating, make-up water in fish farms, process heating applications, etc.); in colder climates they are typically only operated in the summer season due to the high thermal losses of the collector.

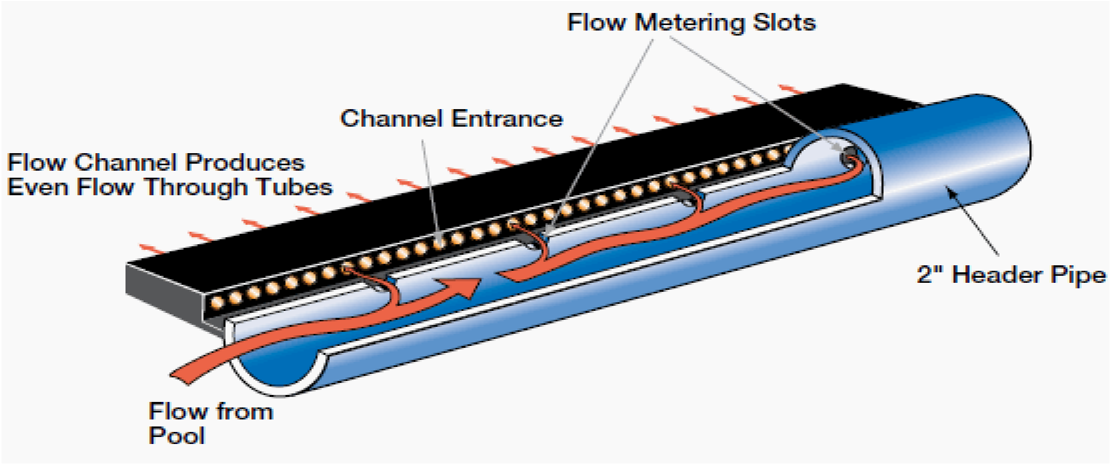

Figure (5.2): unglazed flat plate collector.

2) Glazed liquid flat-plate collectors

In glazed liquid flat-plate collectors, as depicted in Figure (5.3), a flat-plate absorber (which often has a selective coating) is fixed in a frame between a single or double layer of glass and an insulation panel at the back. Much of the sunlight (solar energy) is prevented from escaping due to the glazing (the "greenhouse effect").

These collectors are commonly used in moderate temperature applications (e.g. domestic hot water, space heating, year-round indoor pools and process heating applications).

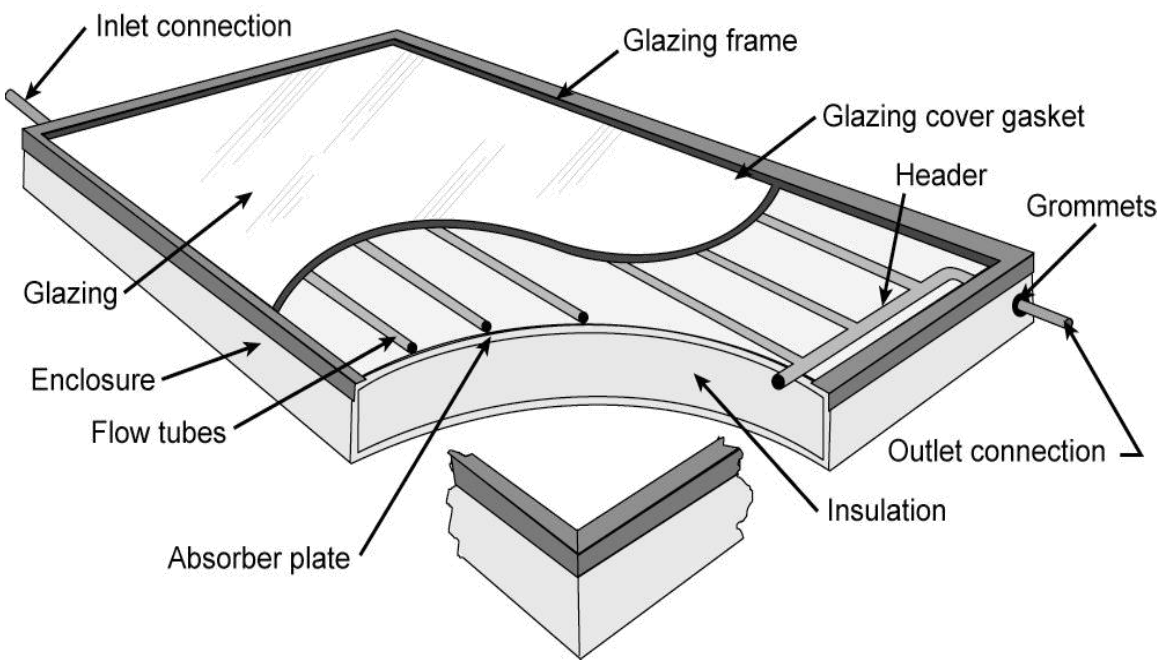

Figure (5.3): Glazed Flat plate collector

3) Evacuated tube solar collectors

Evacuated tube solar collectors, as depicted in Figure (5.4), have an absorber with a selective coating enclosed in a sealed glass vacuum tube. They are good at capturing the energy from the sun; their thermal losses to the environment are extremely low. Systems presently on the market use a sealed heat-pipe on each tube to extract heat from the absorber (a liquid is vaporized while in contact with the heated absorber, heat is recovered at the top of the tube while the vapor condenses, and condensate returns by gravity to the absorber). Evacuated collectors are good for applications requiring energy delivery at moderate to high temperatures (hot water, space heating and process heating applications typically at 60° C to 80° C depending on outside temperature), particularly in cold climates.

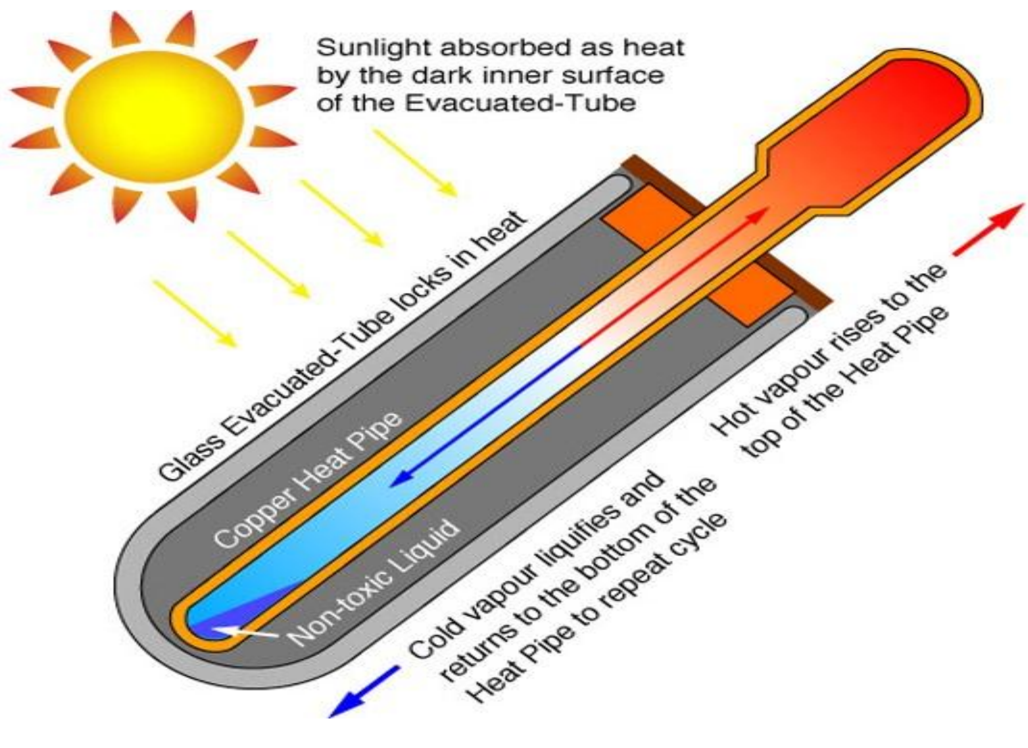

Figure (5.4): evacuated tube solar collector.

5.3 Electrical Boiler

It is reservoir to store and heat the water of the pool with capacity of 150-200 litre. It consist of :

● External cover with 0.5 mm thickness

● Contains Pulitan to prevent heat loss.

● Contains pipes from inside and outside with (3/4) in.

● Contains electrical heating device, a thermostat to link or cut electrical current when necessary, and to keep fixed water temperature inside.

The boiler used in these project to assist the system when the temperature is not reached the request temperature.

5.4 Balance of systems

In addition to the solar collector, a solar water heating system typically includes the following "balance of system" components are:

1. Solar collector array support structure.

2. Hot water storage tank (not required in swimming pool applications and in some large commercial or industrial applications when there is a continuous service hot water flow).

3. Liquid handling unit, which includes a pump required to transfer the fluid from the solar collector to the hot water storage tank (except in thermo siphon systems where circulation is natural, and outdoor swimming pool applications where the existing filtration system pump is generally used); it also includes valves, strainers, and a thermal expansion tank.

4. Controller, which activates the circulator only when useable heat is available from the solar collectors (not required for thermo siphon systems or if a photovoltaic powered circulator is used).

5. Freeze protection, required for use during cold weather operation, typically through the use in the solar loop of a special antifreeze heat transfer fluid with a low toxicity. The solar collector fluid is separated from the hot water in the storage tank by a heat exchanger.

6. Other features, mainly relating to safety, such as overheating seasonal systems freeze protection or prevention against restart of a large system after a stagnation period.

5.5Solar geometry:

In Palestine the latitude angle ($\emptyset$) is 32° , so in winter the tilt angle is:

$\beta = \emptyset - \delta$

$= 32 + 10$

$= 42^\circ$.

This angle is the best angle to obtain the maximum solar radiation shows in the figure.

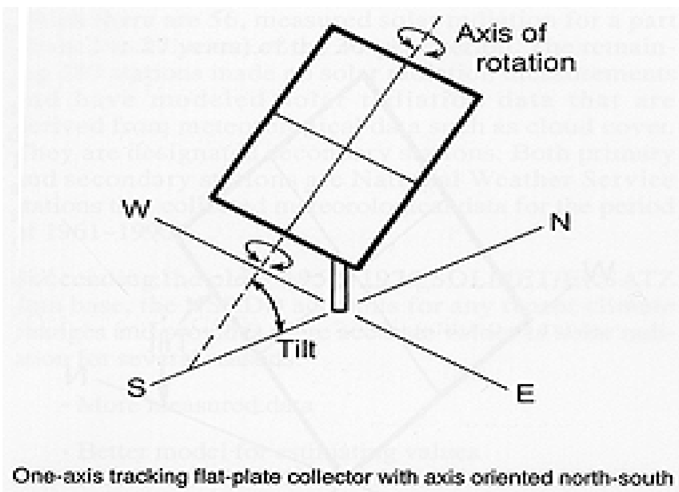

Figure (5.5) Solar geometry.

5.6 Swimming Pool Model:

The energy requirements of the pool are established by assuming that the pool is maintained at the desired pool temperature. Therefore, the model does not include calculations of heat storage by the pool, nor does it consider possible excursions in temperature above the desired pool temperature (both of which would require iterative calculations beyond the scope of a spreadsheet-based tool).

The energy requirements of the pool are calculated by comparing the pool's energy losses and gains. Losses are due to evaporation, conduction, radiation, and the addition of makeup water. Gains include passive solar gains, active solar gains and gains from auxiliary heating. In the sections that follow, those gains and losses are expressed as rates or powers, i.e. per unit time.

The conversion from a power $\dot{Q}$ to the corresponding monthly energy Q is done with a simple formula:

$Q = 86400\ N_{days}\ \dot{Q}$ [RETScreen]

Where:

Q : is the average daily energy collected during a given month..

N_{days} : is the number of days in month and 86,400 is the number of seconds in a day.

$\dot{Q}$: is the energy gain and loss per unit time.

5.7 Pool climatic conditions:

Climatic conditions experienced by the pool depend on whether the pool is inside or outside. In the case of an indoor pool, the following conditions are assumed:

● Dry bulb temperature: the maximum of 27°C (ASHRAE, 1995, p. 4.6) and the ambient temperature.

● Relative humidity: 60% (ASHRAE, 1995, p. 4.6).

● Wind speed: 0.1 m/s. This is consistent with assuming that there are 6 to 8 air changes per hour, i.e. air flows across a characteristic dimension of the pool in 450 s; thus if the pool is 25 m long, assuming a 5 m wide walking area around the pool, one obtains a flow rate of 35/450 = 0.08 m/s; and

● Sky temperature: computed from pool ambient temperature.

5.8 Passive solar gains:

In the case of a pool with a blanket (cover), passive solar gains are expressed as:

$Q_{pass,blanket} = A_p \alpha_c \overline{H}$ [RETScreen]

Where:

A_p : is the area of swimming pool set to $178m^2$.

α_c : is the absorptivity of the blanket, set to 0.4, and

$\overline{H}$: is the monthly average global radiation on the horizontal 5.4kwh/m^2.day.

$Q_{pass,blanket}$ = 178*0.4*5.4 = 284.48 kW.

5.9 Evaporative losses:

There are several methods in the literature to compute evaporative losses, including that of ASHRAE (ASHRAE, 1995) revised by Smith et al. (1994) and those cited in Hahne and Kübler (1994). The RETScreen SWH Project Model adopts the equation of ISO TC 180 (Hahne and Kübler, 1994):

$\dot{Q}_{evap} = A_p h_e \,(P_{v,sat} - P_{v,amp})$ [RETScreen]

Where; $\dot{\boldsymbol{Q}}_{\boldsymbol{evap}}$ is the power (in W) dissipated as a result of evaporation of water from the Pool.

$\boldsymbol{h_e}$ is a mass transfer coefficient, and

$\boldsymbol{P_{v,sat}}$, and $\boldsymbol{P_{v,amp}}$, are the partial pressure of water vapour at saturation and for ambient conditions.

The mass transfer coefficient $\boldsymbol{h_e}$ (in (w/m^2)/Pa) is expressed as:

$h_e = 0.05058 + 0.0669V$ [RETScreen]

= 0.05058 + 0.0669*0.1

= 0.05727 (W/m^2)/pa.

Where; $\boldsymbol{V}$ is the wind velocity at the pool surface, expressed in m/s.

The partial pressure of water vapor at saturation,$\boldsymbol{P_{v,sat}}@_{\mathbf{27°C}}$=0.955*$10^5\,N/m^2$, is calculated with formulae from ASHRAE (1997).

The partial pressure of water vapor for ambient conditions, $\boldsymbol{P_{v,amp}}@_{\mathbf{25°C}}$=0.950*$10^5\,N/m^2$, is calculated from the humidity ratio, also with formula from ASHRAE (1997).

$\dot{Q}_{evap} = A_p h_e \,(P_{v,sat} - P_{v,amp})$ [RETScreen]

= 178*0.05727*(0.955*10^5-0.950*10^5)

= 5.097 kW.

The rate of evaporation of water from the pool, $\dot{\boldsymbol{m}}_{\boldsymbol{eva}}$, in kg/s, is related to $\dot{\boldsymbol{Q}}_{\boldsymbol{eva}}$by:

$$\dot{\boldsymbol{m}}_{\boldsymbol{eva}} = \frac{\dot{Q}_{eva}}{\lambda} = \frac{\mathbf{5097.03}}{\mathbf{2454}} = 2.077 \text{ kg/s.}$$

Where; **λ** is the latent heat of vaporization of water (2,454 kJ/kg).

When the pool cover is on, it is assumed to cover 90% of the surface of the pool and therefore evaporation is reduced by 90%. When the pool cover is off, losses are multiplied by two to account for activity in the pool (Hahne and Kübler, 1994).

5.10 Convective losses:

Convective losses are estimated using the equation cited in Hahne and Kübler (1994):

$$\dot{Q}_{conv} = A_p h_{con} \, (T_p - T_a)$$

Where; $\dot{\boldsymbol{Q}}_{\boldsymbol{conv}}$ is the rate of heat loss due to convective phenomena (in W), $\boldsymbol{T_p}$ is the pool temperature,$\boldsymbol{T_a}$ is the ambient temperature, and the convective heat transfer coefficient is h_{con} expressed as:

$$h_{conv} = 3.1 + 4.1\, V$$

$$= 3.1 + 4.1*0.1 = 3.51\text{W}/m^2.$$

$$\dot{Q}_{conv} = 178*3.51*(27-25)$$

$$= 1.2495 \text{ Kw.}$$

5.11Radiative losses:

Radiative losses to the ambient environment in the absence of pool blanket, (in W) are expressed as:

$$\dot{Q}_{rad\,,\ no\ blanket} = A_p \varepsilon_w \, \sigma \, ({T^4}_p - {T^4}_{sky})$$

Where; $\boldsymbol{\varepsilon_w}$ is the emittance of water in the infrared (0.96).

$\boldsymbol{\sigma}$ is the Stefan-Boltzmann constant (5.669x10-8 (W/m^2)/K^4).

$\boldsymbol{T_p}$is the pool temperature and

$\boldsymbol{T_{sky}}$ is the sky temperature. In the presence of a blanket, assuming 90% of the pool is covered, radiative losses become:

$$\dot{Q}_{rad,\ blanket} = A_p(0.1\varepsilon_w + 0.9\varepsilon_c)\,\sigma\,({T^4}_p - {T^4}_{sky})$$

$$= 178\ (0.1*0.96 + 0.9*0.4)*5.669\times 10^{-8}\ (300.15^4\text{-}298.15^4)$$

$$= 0.9854 \text{ kW}.$$

Where; $\boldsymbol{\varepsilon_c}$ is the emissivity of the pool blanket. Depending on the cover material the emissivity can range from 0.3 to 0.9 (NRCan, 1998). A mean value of 0.4 is used.

5.12 Water makeup losses:

Fresh water is added to the pool to compensate for: evaporative losses, water lost because of swimmers' activity, and voluntary water changes. If $\boldsymbol{f_{makeup}}$is the makeup water ratio entered by the user (which does not include compensation for evaporative losses), expressed as a fraction of the pool volume renewed each week, the rate of water makeup (in kg/s) can be expressed as:

$$\dot{m}_{makeup} = \dot{m}_{eva} + f_{makeup}\,\frac{\rho\ V_p}{7\times 86400}$$

$$= 2.077 + 1.14\,\frac{1000*320}{7\times 86400} = 2.680 \text{ kg/s}.$$

Where; $\boldsymbol{\rho}$ is the water density (1,000 kg/m^3) and $\boldsymbol{V_p}$ is the pool volume set to 320m^3.

$\boldsymbol{f_{makeup}}$is 1.14 kg that come from 10 swimmer swimming of the pool, each swimmer have Wight of 71.1 for week.

The rate of energy requirement corresponding to water makeup, $\dot{Q}_{makeup}$ is:

$$\dot{Q}_{makeup} = \dot{m}_{makeup}\, C_p (T_p - T_c)$$

= 2.680*4200*(27-10)

= 191.352 kW.

Where; $\boldsymbol{T_c}$ is the cold (mains) temperature) and

$\boldsymbol{C_p}$ is the heat capacitance of water (4,200 (J/kg)/ºC).

5.13 Conductive losses:

Conductive losses are usually only a small fraction of other losses. The RETScreen SWH Project Model assumes that conductive losses $\dot{Q}_{cond}$ represent 5% of other losses:

$$\dot{Q}_{cond} = 0.05(\dot{Q}_{evap} + \dot{Q}_{conv} + \dot{Q}_{rad,\ blanket} + \dot{Q}_{makeup})$$

= 0.05(5.097+1.2495+0.000647+191.352)

= 9.884 kW.

5.14 Active solar gains:

In our project we select glazed collectors are described by the following equation (Duffie and Beckman, 1991, eq. 6.17.2):

$$\dot{Q}_{act} = F_R(\tau\alpha)G - F_R U_L\, \Delta T$$

= 0.68*73 – 4.9(10-27) = 10.1329 kW.

Where;

$\dot{Q}_{act}$ is the energy collected per unit collector area per unit time,

F_R is the collector's heat removal factor,

τ is the transmittance of the cover,

α is the shortwave absorptivity of the absorber,

G is the global incident solar radiation on the collector set to 73 w/m^2 from Palestinian code.

U_L is the overall heat loss coefficient of the collector,

and ΔT is the temperature differential between the working fluid entering the collectors and outside.

Values of F_R (τα) and $F_R U_L$ are specified by the user or chosen by selecting a solar collector from the RETScreen Online Product Database. For both glazed and evacuated collectors, F_R (τα) and $F_R U_L$ are independent of wind.

"Generic" values are also provided for glazed and evacuated collectors. Generic glazed collectors are provided with F_R (τα) = 0.68 and $F_R U_L$ = 4.90 (W/m^2)/ºC. These values correspond to test results for ThermoDynamics collectors (Chandrashekar and Thevenard, 1995).

5.15 Energy balance:

The energy rate $\dot{Q}_{req}$ required to maintain the pool at the desired temperature is expressed as the sum of all losses minus the passive solar gains:

$\dot{Q}_{req}$ = max ($\dot{Q}_{eva}$ +$\dot{Q}_{conv}$ +$\dot{Q}_{makeup}$ +$\dot{Q}_{rad}$ +$\dot{Q}_{cond}$ -$\dot{Q}_{pass}$)

= 5.097+1.2495+591.352+0.000647+9.884-284.48

= 323.103 kW.

This energy has to come either from the backup heater, or from the solar collectors.

5.16 Solar collectors:

5.16.1Number of Solar collectors:

The area of each solar collector by (Nieroukh water heater co.) is:

(98cm * 171.5cm) = 1.68 m^2.

Each solar collector gives 6500 kcal.

(1 kW = 860 kcal.)

The total energy = 860 ×323.103

= 277,868.58 kcal

No. of solar collectors = Total energy / energy of each solar collector

= 277,868.58 kcal/6500 kcal

=43 solar collectors.

5.16.2 Storage tank:

Each three solar collectors have a storage tank with capacity 200L.by (Nieroukh water heater co.)

Storage tank capacity = (number of solar collector/3)*200L

= (43/3)×200

= 2866 L.

In our projectwe design a storage tank with capacity 3000 L.

5.16.3 Cost of solar collector:

The price of one solar collector is 450 NIS by (Nieroukh water heater co.)

Price of total solar collector = number of solar collector × 450

= 43 × 450

= 19,350 NIS.

Price of storage tank is 8000 NIS.

Total cost of solar pool heating = Price of total solar collector + Price of storage tank + 150*43 + Price of Electrical Boiler

= 19350 + 8000 + 6450 + 1300

= 35100 NIS/season.

5.17Cost of diesel pool heating:

$M_f = \frac{24\dot{Q} \times DD}{(T_o - T_i) \times CV}\left(\frac{C_d}{\eta}\right)$[heating and air conditioning book]

M_f: mass of the fuel.

DD: degree day method is a term to indicate the heating or cooling loads needed for a given day, month, or season of the year.

DD for winter season = (18.3 - T_{avg}) * days of month.

Q: total heating load.

CV: calorific value and equal 43000 kJ/kg for diesel.

C_d: empirical factor depends on DD and equal.

η: efficiency and equal 0.8 for liquid fuel.

DD for months (Jan, Feb, Mar, Apr, Nov, Dec) = 1228.

$$M_f = \frac{24 \times 3600 \times 323.103 \times 1228}{(27-10)(43,000)} \left(\frac{0.75}{0.8}\right)$$

= 43964.9 kg/season.

= 37370.1 L/season.

The cost of diesel pool heating = number of liters × price of liter

= 37370.1 × 4.8

= 179376 NIS/season.

5.18 comparison between the solar and diesel pool heating:

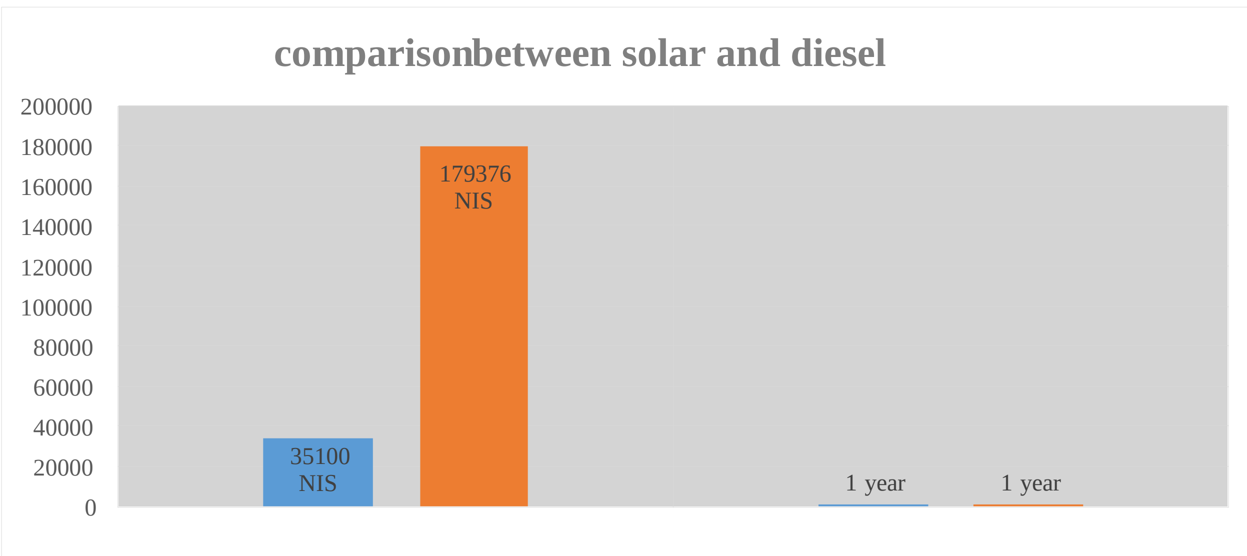

Figure (5.6)

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2) ASHRAE Applications Handbook, American society of Heating, Refrigeration and Air Conditioning Engineer, Inc, 179 Tullie Circle, NE, Atlanta, GA, 30329, USA, 1991
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5) Solar Water and Pool Heating Manual Design and Installation & Repair and Maintenance, FSEC-IN-24, January 2006

APPENDIX A

DESIGN & DOCUMENTATION OF A SWMMING POOL

MECHANICAL WORKS

Item	Description	Unit	Qty.	Unit Rate €	Amount €
1	**Pipes and Fittings** Supply, install, join and test of UPVC pipe (For water supply, return and drain related to swimming pool) confirming to IS : 4985 class IV 10Kg/cm2 including all fittings such as bends, elbows, reducers, tees, unions, couplers, tail piece, flanges etc. The price shall also include all civil works needed for pipes installation, with all needed supports according to specifications. Pipes shall be connected to pumps, equipments, valves, etc. through tail piece flange as per engineer's instructions. The sizes of pipes are as follows:				
	* 110mm CPVC Pipe Diameter		15		
	* 90mm CPVC Pipe Diameter		7		
	* 75mm CPVC Pipe Diameter		8		
	* 63mm CPVC Pipe Diameter		16		
2	**Sand Filter Tanks** Supply and install high rate sand filter tanks, made of fiberglass reinforced plastic (FRP) material, tested against NSF/ ANSI standard 50. Each sand filter should have the capability to back wash each filter at a rate of 80m3/hrof filter bed area, which shall be discharge to waste through suitable gap. The media of filter is sand of suitable grade that meets the manufacture's recommendation. The price shall include all fittings and accessories needed like pressure gauge, manometer, back wash sight glass and air relief valve. The filter system should be provided with valves and pipes to allow isolation, drainage and back washing of individual filters for proper operation Tank Diameter = 1800mm Filter Area = 2.2m2		1		

DESIGN & DOCUMENTATION OF A SWMMING POOL

MECHANICAL WORKS

Item No.	Description	Unit	Qty.	Unit Rate €	Amount €
3	**Swimming Pool Circulating Pumps** Supply, install, test and commission pneumatic Kivu pump set. The set is composed of 2 pumps The price includes all accessories and fittings needed to complete the job, i.e. pre-filters, non-return valves, isolation valves, flexible joints and pressure gauge. The capacity of each pump is: 80 m^3/hr Flow and 34m Static Head.		2		
4	**Solar collector** Supply, install, test and the solar collectors with high efficiency, each solar collector gives 6500Kcal, the price contains all the accessories		43		
5	**Storage tank** Supply, install and test drain storage tank for the solar collector, the price contains all the accessories. The volume of storage tank: 3000L		1		

DESIGN & DOCUMENTATION OF A SWMMING POOL

MECHANICAL WORKS

Item No.	Description	Unit	Qty.	Unit Rate €	Amount €
6	**Pool lighting** Supply, install the pool lighting and all accessories. The number of lighting: 7 Lights.		7		
7	**Pool ladders** Supply, install the pool ladders and all accessories. The number of ladders: 2 Ladders.		2		
8	**Skimmers** Supply, install and test skimmers of the pool, the price contains all the accessories. The number of skimmers: 7 skimmers. ♦Skimmer flow rate = 7.5 m^3/hr.		7		

DESIGN & DOCUMENTATION OF A SWMMING POOL

MECHANICAL WORKS

Item No.	Description	Unit	Qty.	Unit Rate €	Amount €
9	**Return inlets** Supply, install, test and commission the return inlets, the price contains all the accessories. ♦ Recommended flow rate: 13.5 m³/hr.		7		
10	**Main drain** Supply, install, test and the main drain, the price contains all the accessories. ♦ Recommended flow rate: 22 m³/hr.		2		