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Palestine Polytechnic University

College of Engineering & Technology

Mechanical Engineering Department

Graduating Project

The Design of Radiant Floor Heating System Combined with Other Types of Heating System Using Solar Evacuated Tubes

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Hebron – Palestine
June, 2008

جامعة بوليتكنك فلسطين

الخليل-فلسطين

كلية الهندسة و التكنولوجيا

دائرة الهندسة الميكانيكية

اسم المشروع

The Design of Radiant Floor Heating System Combined with Other Types of Heating System Using Solar Evacuated Tubes

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بناءً على نظام كلية الهندسة والتكنولوجيا وإشراف ومتابعة المشرف المباشر على المشروع وموافقة أعضاء اللجنة الممتحنة تم تقديم هذا المشروع إلى دائرة الهندسة الميكانيكية، وذلك للوفاء بمتطلبات درجة البكالوريوس في الهندسة تخصص هندسة الميكاترونكس وهندسة التكييف والتبريد.

توقيع المشرف

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توقيع اللجنة الممتحنة

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توقيع رئيس الدائرة

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Abstract:

Using the solar energy is the popular method to decrease global warming that affect on the earth, so we will use this solar energy to produce heating systems to residential place which contains two floors occupied with six persons. The area is about 167m^2 American style villa. Using a new technology that absorbs the sun rays better than other collectors which we called solar evacuated tubes heat pipe collector.

This project includes the calculation of total load (heating and domestic hot water) of the villa (43 kW), the radiation of our design months in winter is about 381.5 W/m^2 in Hebron city, these values lead us to calculate the collector area which is 63 m^2, this value covers only the heating load (23kW).The maximum actual efficiency of solar heat pipe collector that we reached is about 67% from the sun radiation that collected by the solar heat pipes.

By using the (PLC) programmable Logic Control, we control our system that provide us any information of each components of the system like display the temperatures and know the faults of any parts in it, also the control system serve the users to operate any of the two floors inside the villa.

إهداء

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

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

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

إلى قناديل الدرب...................الشموع التي لا تنطفئ..............أساتذتي

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

إلى صناع الكرامة....................رايات المجد.................الشهداء

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

إليكم جميعا أحبتنا نهدي هذا الجهد المتواضع

ACKNOWLEDGMENT

This project would not have been possible without the assistant of many individuals. We are grateful to theses people, who volunteered their time and advice, especially **Eng: Jamal shweiki**, we are thanking your efforts during preparing this project.

Finally, grateful for the assistant and cooperation of all those who contributed suggestion and reviews.

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Introduction

Chapter One

1.1 Introduction

Using solar energy means taking nothing from nature, and producing no pollutant emissions. The sun has produced energy for billions of years. Solar energy is the sun's rays (solar radiation) that reach the earth.

Many of us knows that solar energy is a good thing, but few really understand why. the renewable energy is clean, bring no pollution and global warming. There are more advantages when using renewable energy than non-renewable energy. Therefore more research and development (R&D) should be carrying out to maximize the usage and efficiency of renewable energy. Also, may renewable energy can fully replace fossil-fuel as soon as possible so that several environmental issues (global warming, pollution...) can be solved.

Solar energy can be converted to **thermal (or heat) energy** and used to:

- Heat water – for use in homes, buildings, or swimming pools.
- Heat spaces – inside greenhouses, homes, and other buildings.

Each of our homes uses quite a lot of hot water and heating, usually supplied by a gas or electric hot water heater. These appliances can be expensive to run and they cause environmental impacts. A great way to make lots of free hot water for the home is with a solar powered hot water heater. Solar water heating systems are cost low, effective and reliable efficient. Solar water heating improves the air quality in our neighborhood by drastically reducing pollution.

1.2: General description for project idea:

In our project we will design a radiant floor system for a villa, that has two floors (American style) and its area (167 m^2), combined with other type of heating system by solar evacuated tubes. In addition of that.

We will collect the solar energy by solar evacuated tube that rise the temperature of the water which we will use for several demands in the villa. The hot water will be collected in a collector tank which connected with the boiler, if the water temperature inside the collector tank is less than needed temperature, the boiler will operate automatically to reach the design temperature.
Hot water will supply the radiator in the bathrooms and WC, under-floor heating in the villa rooms and other demands of hot water. (Washing, cleaning, cooking…etc).

We will controlled the system include circulating pumps, temperature sensors, automatic controllers to activate the circulating pump, and a storage device.

1.3: Project Benefits:

Using solar heating to heat home is becoming more popular with people, not only is it more environmentally friendly but can be very cost effective also. In fact, in many cases it is possible to cut down heating costs by 50% or more by using solar heating as compared to heating your house using more popular heating systems.

In the other hand, there are also a lot of benefit of our main heating system (radiant heating system) such as Easy to install, unobtrusive, No restriction on the placement of furniture, Quiet in use, Very little maintenance is required, Individual room temperature control and No risk of contact with hot surfaces and Fabric temperature of building maintained.

1.4: Project Outlines:

Chapter 1: Introduction:

Overview description and the important of the project. We mentioned the outlines and general topics that include this project.

Chapter2: Under Floor Heating System:

Includes the types of under floor heating, its shapes, the distance between pipes in the same loop, the thickness of concrete slap upon the pipes, procedure to design, location of manifold, the temperature of supply water that provide the heating system, and the advantages of heating system.

Chapter 3: Solar Radiation and Evacuated Tubes:

Include an overview of solar radiation calculation for horizontal and tilted surfaces, data for locally average radiation, solar evacuated tubes and it types, the parameter that affects on it performance, an estimation of no. of solar panel that provide at least the heating load for the villa.

Chapter 4: System Design calculation

Including the calculation of heating load, under-floor heating system, radiators, domestic hot water demand, boiler capacity , and selecting pumps .

Chapter 5: Controlling the System:

Including the system control using PLC, manifolds control using microcontroller, general flow chart for the system, using SCADA program to display the system while operating and that help us to know each parts when its operate.

1.5 Time Table

The project plan follows the schedule below, includes the related tasks of study and system analysis.

Table(1-1).First semester time table.

Task / Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Choosing the project & Identifying the content's project															
Gather information about the project															
Processing project and the adoption map villa															
Studying project component and schematic analysis															
Documentation the chapters															

Table(1-2).Second semester time table.

Task / Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Gather information & choosing the suitable system															
The design of the mechanical system & its calculation															
A field visit to the workshops of the heating system combined with solar system															
Linking the mechanical control system with PLC after the modification															
Documentation the chapters															

1.6 Budget:

Table (1-3) Budget

Task	Cost [NIS]
Transportation	350
Printing	400
Internet	250
PLC	500
2 Sensor (PTC)	140
Total	1640

Chapter Two

Underfloor Heating System

Underfloor Heating System

2.1 Introduction

Imagine being able to get a warm floor without going through the expenses, dirt and fuss. Imagine being able to have a complete heating system which takes zero area.

Underfloor heating is the most efficient mode of heat delivery. It is designed to give comfort at temperatures lower than those used in radiator and convector systems because people and objects are warmed directly through the floor.

2.2 Underfloor heating systems

Most underfloor heating systems are either warm water (wet) systems or electric (dry) systems. Wet underfloor heating systems operate by heat transferring from the water passing through the pipe directly into the floor. Because the whole area of the floor is warm, it heats the room more evenly. Unlike radiators, underfloor heating systems do not need to run at high temperatures.

Typically, the temperature of the water in an underfloor heating system pipe is 45 – 65oC (compare this to approximately 80oC flow and surface temperature of a radiator system)

For Dry Systems, the principle is the same. The difference is that instead of imparting heat from water passing through a pipe, using an electric heating element as the heat source.

2.3 Advantages of Panel Systems

The main advantages offered by panel systems relate to:

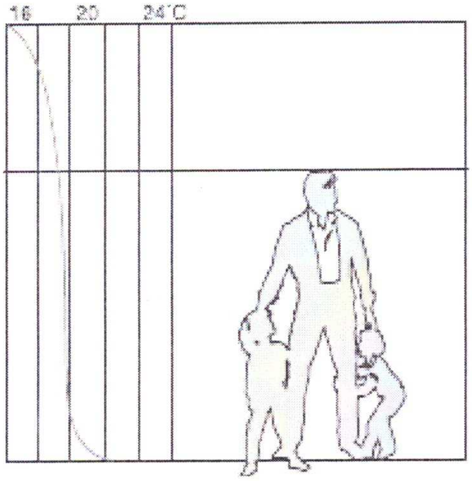
- Heat comfort.
- Air quality.
- Hygiene conditions.
- Environmental impact.
- Energy saving.

2.3.1 Heat comfort

As shown in Figure (1) the ideal curve shown, people feel most comfortable with their feet a little warmer than their heads. The system most suited to providing these conditions consists of radiating floors.

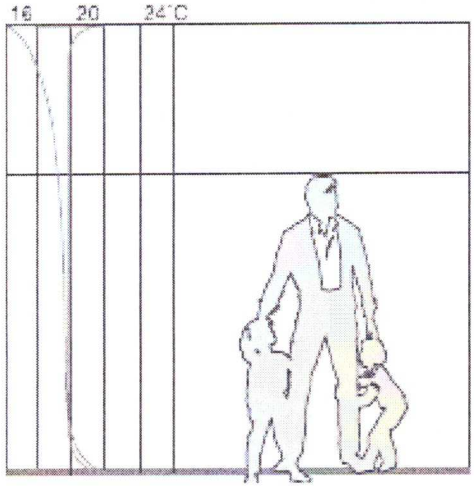
The fact that they give off heat above all by radiation, thus avoiding the formation of convection currents of hot air at ceiling level and cold air at floor level see figure 2.2. Underfloor heating is the heating method that comes closest to producing an ideal room temperature distribution.

Figure (2.1) Thermal Comfort Curve.



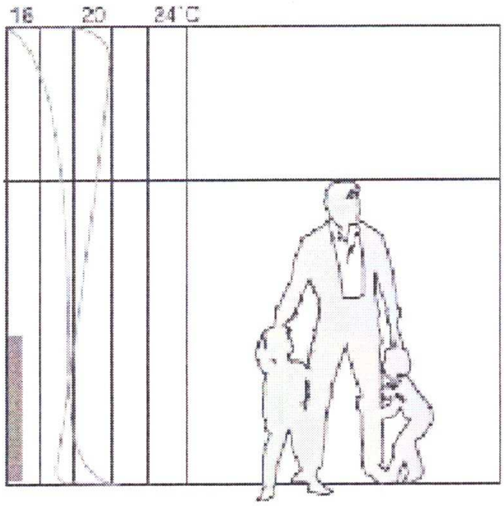
A

Figure (2.1-a) Ideal heating temperature curve



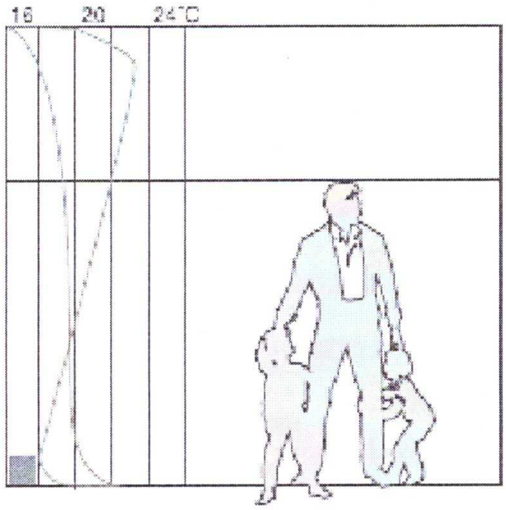
b

Figure (2.1-b) Underfloor heating temperature curve



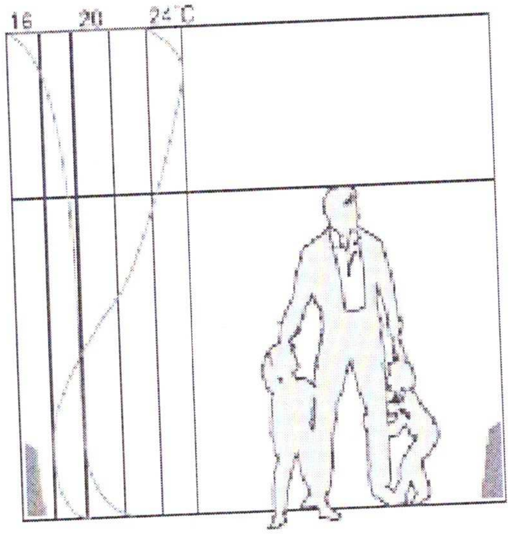
c

Figure (2.1-c) Radiator heating temperature curve



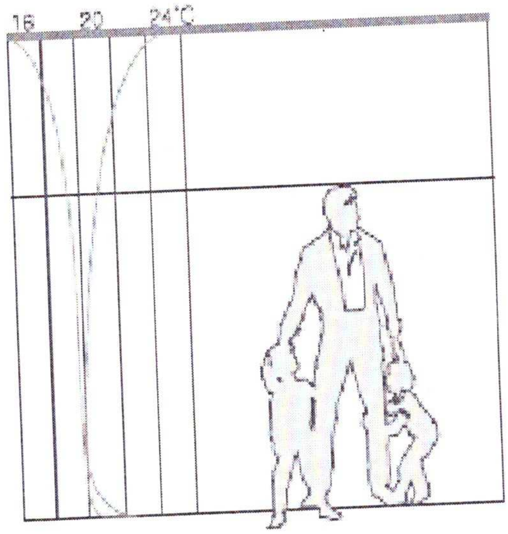
d

Figure (2.1-d) Convector heating temperature curve



e

Figure (2.1-e) Forced air temperature curve



f

Figure (2.1-f) Ceiling heating temperature curve

And Figure (2.1-g) compared Ideal heating temperature curve with Underfloor heating temperature curve

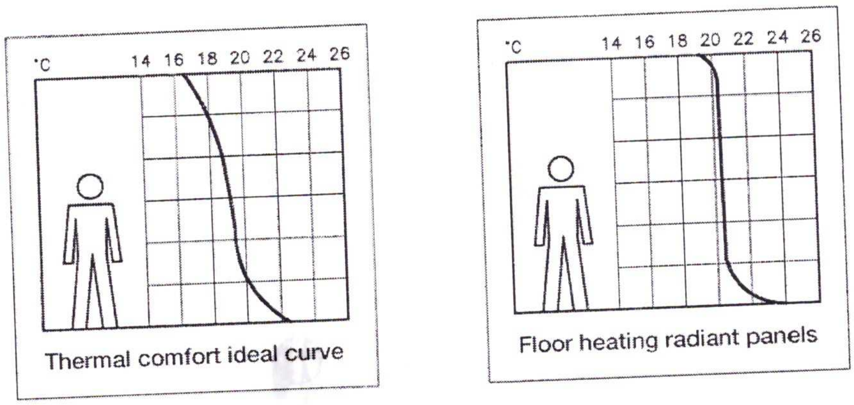


Figure (2.1-g)

Figure (2.2)

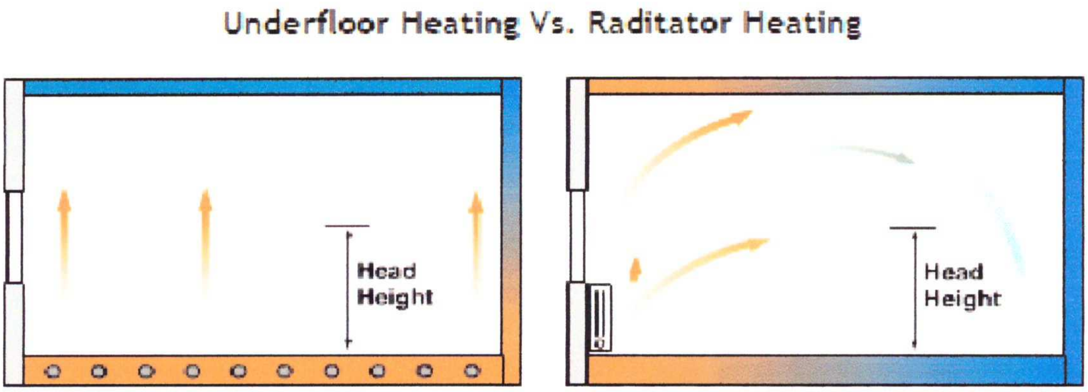


Figure (2-2-a)

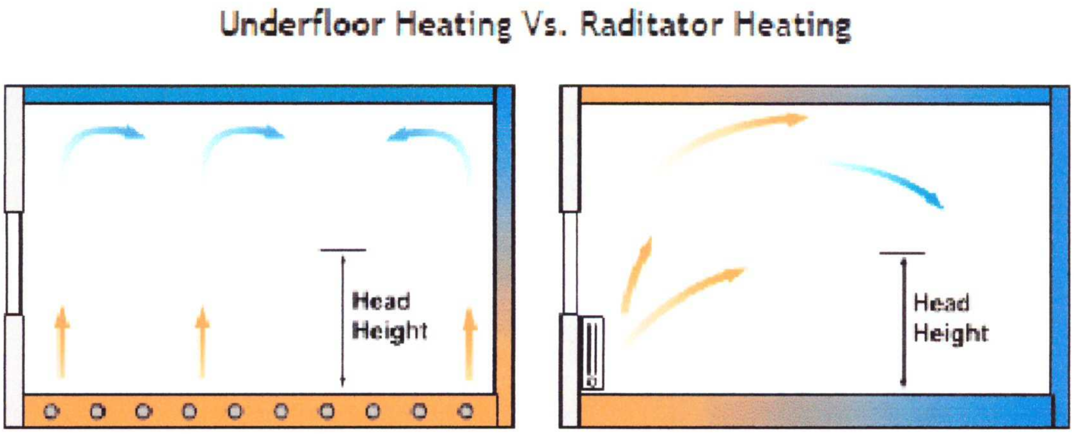


Figure (2-2-b)

2.3.2 Air Quality

Panel heating can prevent two inconveniences which are typical of systems with heat emitters:

1. Burning of the dust in the air, which can cause a feeling of thirst and irritation of the throat.

2. High dust circulation which can cause allergies and respiratory problems

2.3.3 Health Conditions

Panel systems have a positive contribution to maintaining good environmental health conditions as they prevent:

1. The formation of damp floor areas, thus removing the ideal conditions for dust mites and bacteria.

2. The occurrence of moulds on the walls bordering the heated floors.

2.3.4 Environmental Impact

In new buildings panel systems have the least environmental impact because:

1. They do not impose any aesthetic requirements. The invisible nature of the panels is of great importance.

2. They do not restrict freedom of layout, thus allowing the most rational use of the available space.

3. They do not dirty the walls with convection stains.

2.3.5 Energy Saving

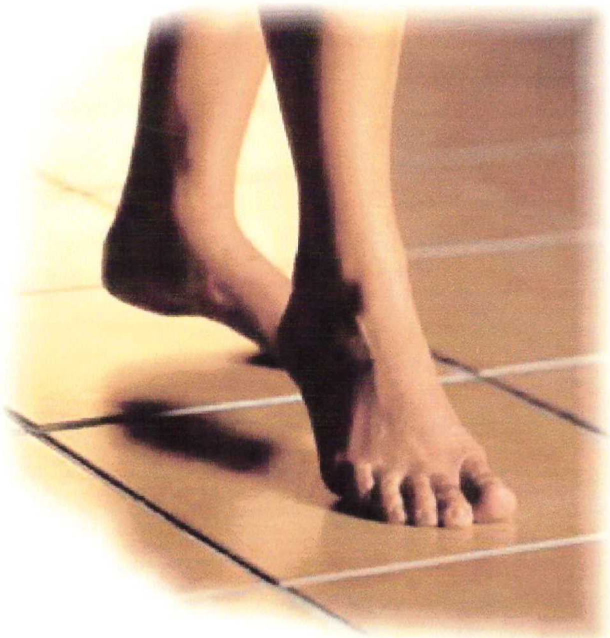
In comparison with the traditional heating systems, panel systems produce considerable energy savings, for two basic reasons:

1- The lower operating temperature.

2- The lower temperature gradient between floor and ceiling.

3- The lack of convection movement of the hot air over glazed surfaces

2.4 Floor temperature



The human foot could be considered to be the body's thermostat. In areas with cold winters, human beings have been concerned about floor temperature for many hundreds of years.

According to the International Standards Association ISO 7730, the most comfortable floor temperatures should range between 19-26°C, It is also important to ensure that the heating effect is dimensioned so that the temperature drop across the floor is no higher than 5°C. A higher temperature drop giving an uneven floor temperature could be perceived by the human foot as uncomfortable, (floor surface temperatures are generally designed to remain at or below 29°C).

2.5 Pipe Loops Configuration

There are three main types of loop configuration for underfloor heating can be used:

(1) Single serpentine configuration. This method yield easy installation of pipes and it can be used for all kind of floor structures. Temperature variations on the floor surface are kept to minimum values within small area. The pipe layout can be easily modified to produce different energy requirements by changing the pipe loop pitch. The pipe loop arrangement of this method is shown in Figure (2.3) this configuration is used in residences and requires very flexible pipe.

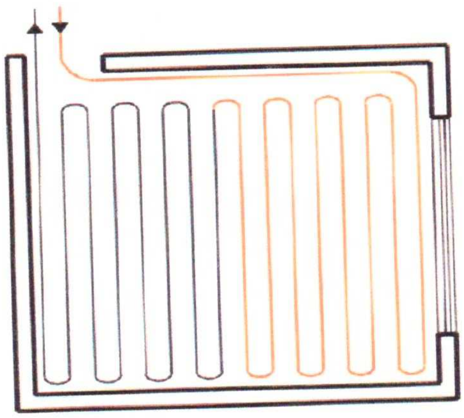


Figure (2-3-a) Single Serpentine Pipe Arrangement.

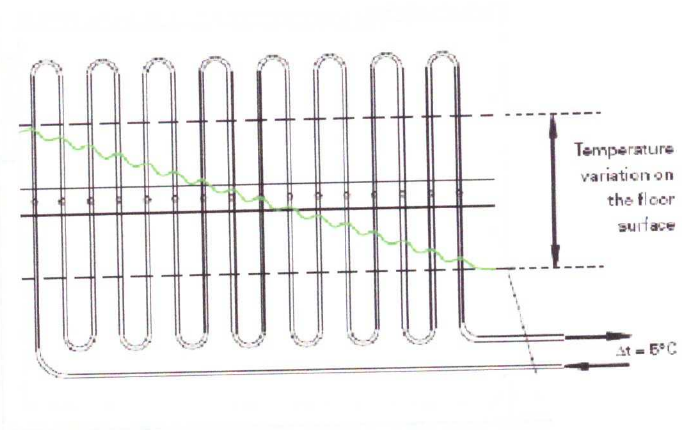


Figure (2-3-b) Temp. Distribution in Single Serpentine Pipe Arrangeme

(2) Helical supply and return configuration. This pipe arrangement is installed in a helical or spiral configuration as shown in Figure (2.4). This method is used in spaces that require high heating loads.

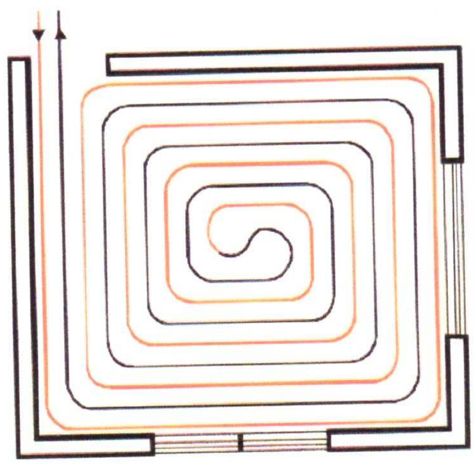


Figure (2-4-a) Helical or Spiral Pipes Arrangement.

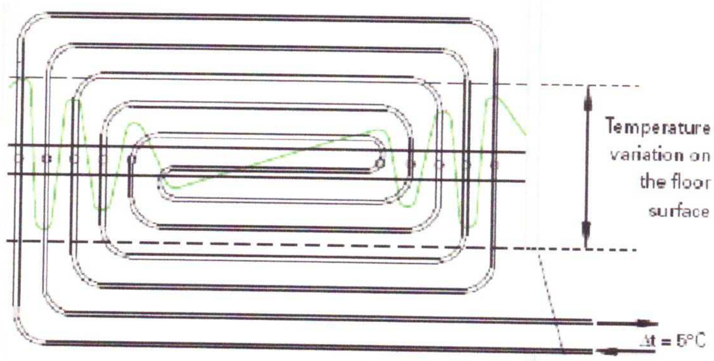


Figure (2-4-b) Temp. Distribution in Helical or Spiral Pipes Arrangement

(3) Parallel supply and return pipes configuration. In this pipe arrangement, the supply and return pipes run in parallel configuration as shown in Figure (2.5). This method is used for heating large spaces such as mosques and theaters.

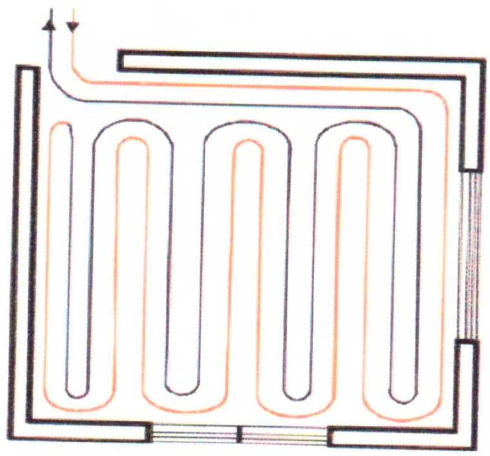


Figure (2-5-a) Parallel Supply and Return Pipes Configuration.

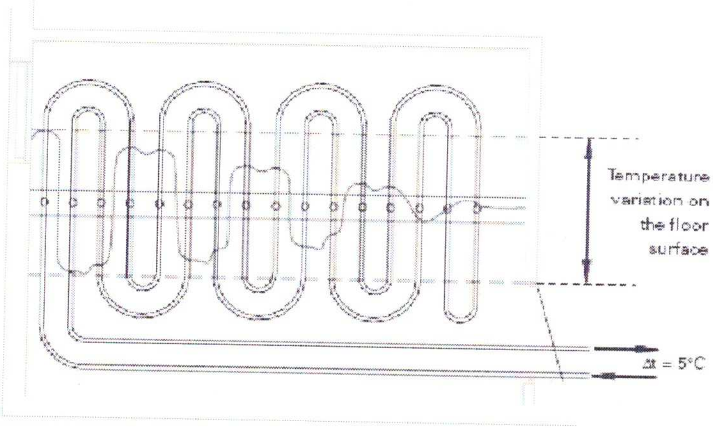


Figure (2-5-b) Temp. Distribution in Parallel Supply and Return Pipes Configuration.

2.6 Design Considerations

The design parameters that must be selected for the panels heating systems are as follows:

(1) Pipe loop configuration: A single serpentine pipes is usually used for residences of concrete floors, so we will use it in our project.

(2) Circulation of water temperature: The design water temperature used in water flowing through PEX plastic pipe is usually (40 – 45)°C. on other hand ASHRAE standard required that the maximum water temperature in floor heating is 54.4 oC. And

there is no rigid limitation on the drop of water temperature in the loop .however; an optimum design value is (5-10) °C.

2.7 Under Floor Design Procedure

The design procedure for underfloor heating system is summarized as follows.
(1) Calculate the heat load for each space and obtain the total heat load for the house The heating load depend on infiltration and heat transfer (loss) due to walls, ceiling, floor, doors, and windows.

a - 1 Heating Load Due Heat Transfer

Heat transfer is the transient flow of thermal energy from one system to another due to temperature difference between the two system .

$$Q = U * A(T_i - T_o) \quad \text{.........(2-1)}$$

Where:

U: over all heat transfer coefficient.

A: area which heat transfer due it.

Ti: inside temperature design.

To: outside temperature design.

$$U = \frac{1}{R} \qquad \text{.....(2-2)}$$

Where:

R: thermal resistance.

$$R = \frac{1}{h_i} + \sum \frac{\Delta x}{k} + \frac{1}{h_o} = R_i + R_o + \sum_{1}^{n} R_n \qquad \text{.....(2-3)}$$

Where:

h : The convection heat transfer coefficient.

k: Thermal conductivity (table A-1).

R_o & R_i : Inside &Outside film resistance (table A-2).

Δx: The distance between the two surface whose temperature are Ti and To.

b - Heating Load Due Infiltration.

Infiltration is the leakage of outside air through cracks or clearances around the windows, and doors. The amount of air infiltration depends mainly on the tightness of the windows, doors, and the outside wind velocity or the pressure difference between the inside and outside of the building.

The total heat load due to infiltration consists of two parts :

1. **Sensible heat load**

$$\dot{Q}_{s,f} = \dot{m}_f C_p (T_i - T_o) \quad \text{.....(2.4)}$$

Where:

$\dot{m}_f$: Mass flow rate of infiltration outside air.

C_p : Specific heat of outside air at constant pressure.

2. **Latent heat load**

$$\dot{Q}_{L,f} = \dot{Q}_{t,f} - \dot{Q}_{s,f} \quad \text{.....(2-5)}$$

$$\dot{Q}_{t,f} = \dot{m}_f (h_i - h_o) \quad \text{.....(2-6)}$$

Where:

$\dot{Q}_{t,f}$: The total heat load due to infiltration.

h_i : The inside enthalpy of infiltrated air, from psychometric chart.

h_o : The outside enthalpy of infiltrated air from psychometric chart.

$\dot{m}$: Mass flow rate of infiltration outside air.

Estimation of Infiltration

Two methods are used to estimate the volumetric flow rate of infiltration air into a space which are

a- The crackage method.

The crackage method is based on the length of the crack or the perimeter of the window or the door, width of the crack .the tightness of the window or the door .

b- The air change method (ACM).

The air volume in a space is replaced by outside air at a certain times per hour. The number of air changes depends on the types of the space. ASHRAE a the use of the number of the changes per hour in computing the infiltration heat load for building ,as indicated in (table A-3).

$$\dot{m} = \rho \dot{V} \quad \text{.....(2-7)}$$

Where:

$\dot{V}$: Volumetric flow rate of infiltration air.

$\rho_{out.air}$ Density of out door air = $1/\upsilon$ .....(2-8)

υ : the specific volume

$$\dot{V} = V_{room} * \text{air change per hour} \quad \text{.....(2-9)}$$

Where:

V_{room} : Room volume.

(2) Calculate the total heat demand qt , in W/m² by dividing the heat load for the space by total floor area of the space by using.

$$\dot{q} = \frac{Q_t}{A} \quad \text{.....(2-10)}$$

(3) Evaluate Flow sure face room temperature (T_f).

$$\dot{q} = h(T_f - T_i) \quad \text{.....(2-11)}$$

Where:

Ti: inside air temperature

h: combined heat transfer coefficient due to radiation and convection from floor surface to the air inside space , (12< h < 14) W/m²K

Note: the value of $\dot{q}_t$ should be less than 100W/m²

(4) Calculate the hot water temperature entering the pipe loop *Tw* by the following equation

$$\overline{T}_w = T_f + \Delta T_{st} + \Delta T_{cov} \quad \text{.....(2-12)}$$

Where:

$\overline{T}_w$: is the average water temperature.

ΔT_{st} : is the temperature drop through floor structure.

ΔT_{cov} : is the temperature drop through floor covering material.

The temperature drop through floor structure ΔTst can be determined by using the following relation:

$$\Delta T_{st} = q_t \times R_{ths} \quad \ldots\ldots (2\text{-}13)$$

Where:

Rths: the thermal resistance of floor structure materials.

The floor consist of concrete construction, we will use 20mm pipe diameter. There a concrete slap, tail, soil and wall to wall carpet upon the pipes .

. R_{th} structure =(R_{th} concert + R_{th} soil + R_{th} tail) =0.075 $m^2.°C/W$

The type and thickness of floor covering materials can influence the temperature drop through the covering layer ΔTcov due to the cover thermal resistance Rthc .to calculate ΔTcov we can use the following relation:

$$\Delta T_{cov} = q_t \times R_{thc} \quad \ldots\ldots (2\text{-}14)$$

Where:

Rthc :the covering thermal resistance

R_{th} carpet = 0.08 $m^2.°C/W$.

Since ΔT_W is limited to 5 "C then the supply water temperature Twi, is given by

$$T_{wi} = \overline{T}_w + 2.5 \quad \text{.......................................(2-15)}$$

(5) Calculate the mass flow rate of the water $\dot{m}_w$ (kg/s) , in the pipe loop required to deliver the heating load for given space $\dot{Q}$.

$$\dot{m}_w = \frac{\dot{Q}}{Cp\Delta T_w} \quad \text{.......................................(2-16)}$$

Where:

Cp: specific heat of water = 4.18 kJ/Kg °C

ΔTw: the temperature difference between supply and return water in the pipe loop ,and it limited to 5 °C , so

$$\dot{m}_w = \frac{\dot{Q}}{20.9} \quad \text{.......................................(2-17)}$$

The total mass flow rate of water $\dot{m}_{wt}$ for all loops is equal to

$$\dot{m}_{wt} = \sum_{n=1}^{n} \dot{m}_{wn} \quad \text{..........(2-18)}$$

Where:

n :number of rooms.

For underfloor heating system ,the water velocity (v) in pipe loop should be greater than 0.2m/s, it is determine from the following relation:

$$v = \frac{\dot{m}_w}{\rho_w A} \quad \text{..........(2-19)}$$

Where:

ρ_w : Water density

A : Cross sectional area of the pipe.

(6) Select the location of the supply and return manifolds and layout the pipe loops for all spaces. Measure the loop length for each space to determine the space that has the longest loop length.

(7) Calculate the pressure drop for the longest pipe loop by using (diagram B-1), we select a pipe diameter of 20 x 2.0 mm. and mass flow rate used value for each loop. The pressure drop in loop is obtained by multiplying the value of pressure drop in kPa/m obtained from diagram (B-1) and loop pipe length.

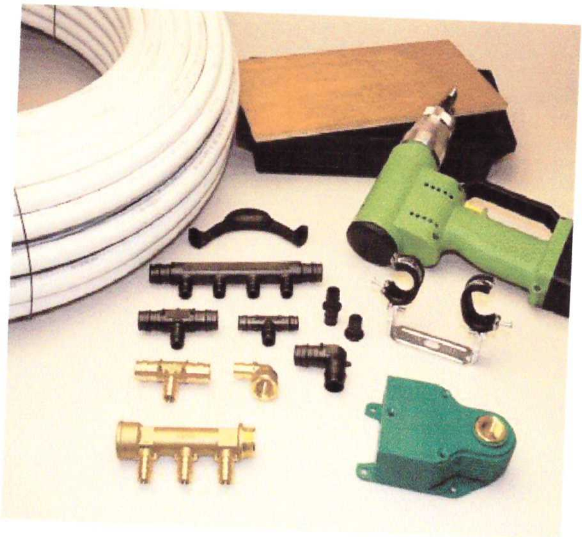
(8) Estimate the pressure drop in the main supply and main return pipes from the boiler to the manifolds. Value (0.2 - 0.5).kPa/m is usually used for estimation.

(9) Balance the pressure drop for all loops: each pipe loop will have the same total pressure drop of the longest pipe loop. This is done by controlling the lock shield valve in the return manifold of each loop(diagram B-2). This balancing is necessary to circulate the calculated value of water flow rate for each loop.

(10) The pump of the underfloor heating system is selected from the manufacturer catalogues(Biral pump-diagram (B-3)) by using the total pressure drop of the longest pipe loop and the total water flow rate $\dot{m}_{wt}$, for all loops.

(11) Boiler selection :By using the total demand for all loops and domestic hot water, we will use fondital catalogue(table A-7).

2.8 Pipes



Their are many types of pipes, but when we use underhloor heating system, specific pipes should chosen, so we will use PEX pipes

2.8.1PEX Pipe Properties

PEX material has features common to most plastics and some which are unique:

1) It is not affected by corrosion or erosion.

2) It is not affected by additives in concrete.

3) Weak thermal expansion forces will not cause cracks either in the PE-X material or In the concrete in which it is laid.

4) It has very low frictional forces.

5) It is flexible enough to allow small bending radii.

Many companies produce PEX pipes and each one have specially designed so we will depend in our project on Wirsbo-PEX pipes. Wirsbo-PEX pipes, are designed for use up to a maximum operating temperature of 95°C.

2.8.2 Pipe depth

In concrete, a depth of 30-70 mm is recommended. The depth of the pipe is directly related to the water temperature this ΔTst can be determined by using eq. (2-13)

2.8.3 Pipe pitch

pipe pitch (distance from center to center loop) of (200 – 300) mm is the most suitable for the best underfloor heating system design and installation

2.8.4 pipes Fixing

The plastic holder band is an accessory that can be supplied with or without barbs.

Holder bands with barbs or clips are suitable when the material beneath is insulation .

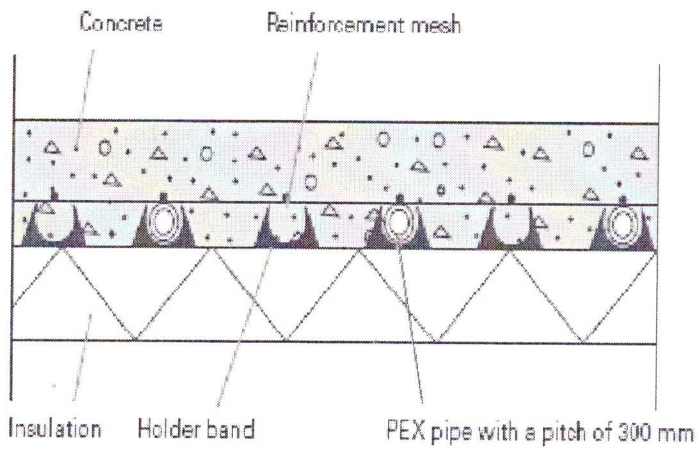
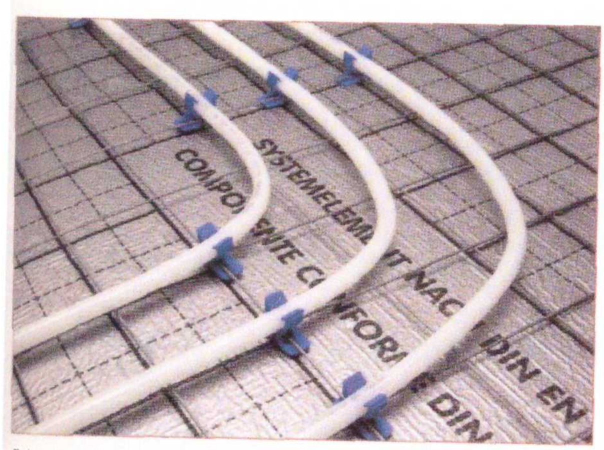


Figure (2.6) Concrete floor on insulation. Pipe loops laid on plastic holder bands with barbs or fixed with clips.

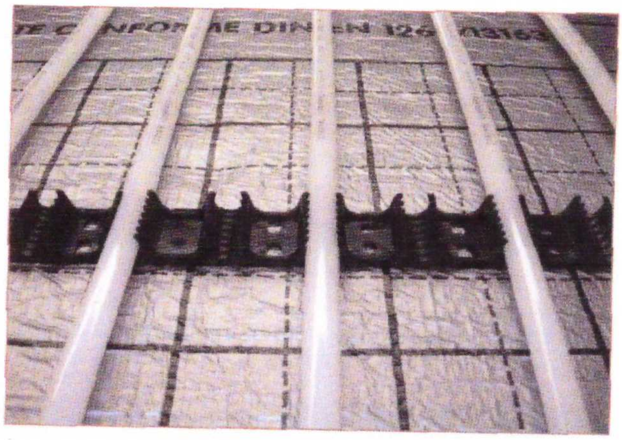
2.8.5 Pipe Fixing Accessories

Clips, staples and clip rails made of plastic material to hold the pipes and the metal mesh in place.

Figure (2.7)

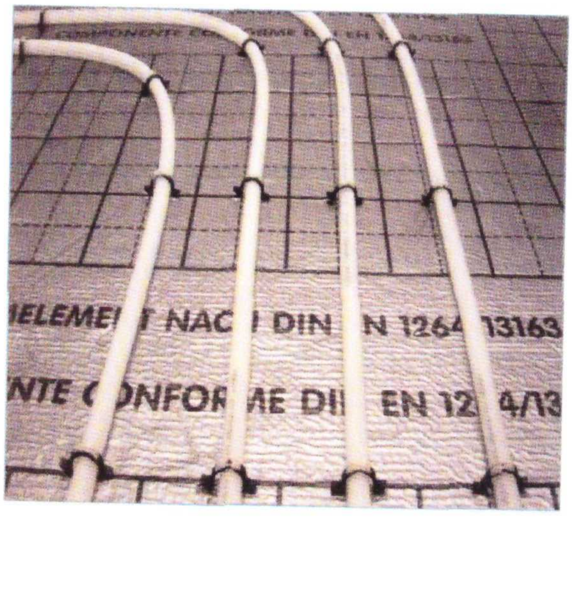


a- fixing the pipe to clips hooked to the mesh



b- fixing the pipe to cliprails

c- fixing the pipe to the insulating panel with clips



2.9Manifolds

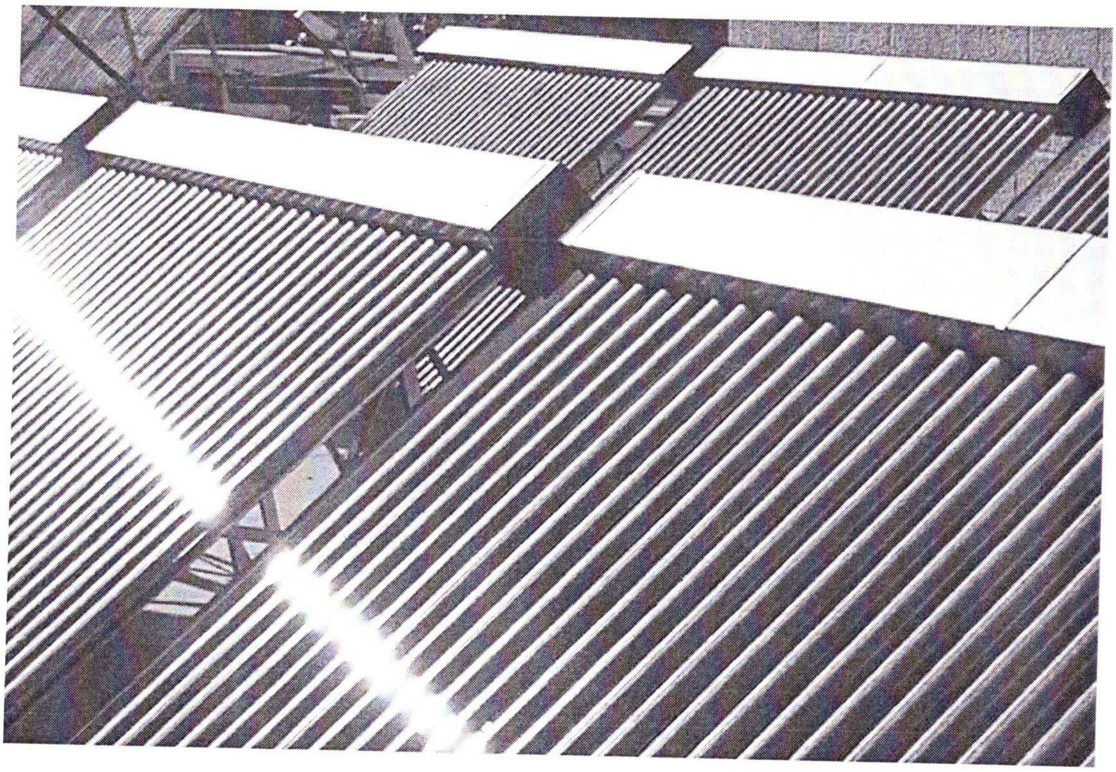
Manifolds can serve until 12 loops. in normal-size houses it is more practical to limit this figure to 8 loops.

The following items should be considered when selecting the location of supply and return manifolds:

(1) Manifolds should be located as near as possible to a center point of the building so that the pipe loops lengths are minimum.
(2) Manifolds location should be selected such that maintenance can be easily accessible.
(3) Selected location should result in minor damage if water leakage occurs.

Chapter Three

Solar Radiation and Evacuated Tubes



Solar Radiation and Evacuated Tubes

3.1 Introduction

The sun has produced energy for billions of years. Solar energy is the sun's rays (solar radiation) that reach the earth. Solar energy is a renewable energy source, is free and does not pollute.

We have always used the energy of the sun as far back as humans have existed on this planet. We know today, that the sun is simply our nearest star. Without it, life would not exist on our planet. We use the sun's energy every day in many different ways.

Solar energy can be converted into other forms of energy, such as heat and electricity.In the 1830s, the British astronomer John Herschel used a solar thermal collector box (a device that absorbs sunlight to collect heat) to cook food during an expedition to Africa.

Solar energy can be converted to thermal (or heat) energy and used to:

- Heat water - for use in homes, buildings, or swimming pools.
- Heat spaces - inside greenhouses, homes, and other buildings.

The design of a solar system requires knowledge of long-term, say monthly, average solar radiation data for the locality under consideration.

Table (3.1): Data table for local solar radiation in Hebron:

Month	Sol. radiation on horizontal. Surface [MJ/m^2]	Monthly av. of ambient. Temp. [C]	Main mean temp. [C]
January	10.025	9.35	4
February	11.942	5.40	4.7
March	17.635	7.75	6.5
April	18.894	12.20	9.9
May	26.645	20.15	13.2
June	27.175	21.20	15.8
July	26.017	22.56	17
August	23.124	21.25	17
September	18.690	19.95	15.9
October	12.934	19.45	14
November	11.721	15.15	9.9
December	9.899	10.15	5.6

These data are obtained from Renewable Energy and Environment Research (RREU) for the years 2006, 2007 & apart of 2008 at our university (PPU).

3.2 Calculation of solar radiation:

The solar radiation can be estimated in several ways, and because it has many types of radiation:

Beam (direct) radiation, diffuse radiation, total solar radiation, irradiance and radiant exposure. So the equation for calculating it is complex sometimes.

The angles and position of solar energy collector are important to gain the maximum amount of solar radiation. In this, we are interested in three angles; collector tilt (slope) angle β: azimuth angle A_z and incidence angle (θ_i). However, to find these angles, other angles should be known.

3.2.1 Declination angle:

Declination (δ): the angular position of the sun at solar noon with respect to plane of equator ($-23 \le \delta \le 23$).

The declination can be found from approximate equation of cooper (1964).

$$\delta = 23.45 \sin\left(360 * \frac{284+n}{365}\right) \qquad (3\text{-}1)$$

Table (3-2) Recommended average days for months and values of (n) by months.

month	n for *i*th day of month	For average day of month		
		date	n	δ
January	*i*	17	17	-20.9
February	31+*i*	16	47	-13.0
March	59+*i*	16	75	-2.4
April	90+*i*	15	105	9.4
May	120+*i*	15	135	18.8
June	151+*i*	11	162	23.1
July	181+*i*	17	198	21.2
August	212+*i*	16	228	13.5
September	243+*i*	15	258	2.2
October	273+*i*	15	288	-9.6
November	304+*i*	14	318	-18.9

December	334+*i*	10	344	-23.0

3.2.2 Azimuth angle (γ):

Is the angle on a horizontal plane between the due-south direction line and the horizontal projection of the sun's rays, with the zero due to south, west positive, and east negative. On the other hand we have an azimuth angle for the collector it self, this angle has the same definition of the sun angle.

The surface azimuth angle for a day will be 0° or 180° depending on latitude and declination. This expressed by:

$$\gamma = \begin{bmatrix} 0, & \phi - \delta \geq 0 \\ 180, & \phi - \delta \leq 0 \end{bmatrix} \quad \text{....................} \quad (3\text{-}2)$$

Where:

ϕ : The latitude = 32°

δ : Declination angle @ January = -20.9°

According the equation (3-2) the latitude in Hebron is 32° and the declination angle in our design month (January) is -20.9 from table (3-2), the azimuth angle will be 0°.

3.2.3 Radiation tilt factor:

Monthly average daily radiation ($\overline{H}_T$) on a tilted surface is given by:

$$\overline{H}_T = \overline{R} \times \overline{H} \qquad [kJ/m^2] \quad \text{....................} (3\text{-}3)$$

Where:

$\overline{H}$: total radiation on horizontal plane [kJ/m^2].

$\overline{R}$: total radiation tilt factor [Dimensionless].

Both are written on monthly mean (average) daily basis. Total radiation tilt factor is the ratio of the total radiation on tilted surface to that on a horizontal surface. It can be written on monthly average daily basis by the following equation

$$\overline{R} = \frac{\overline{H}_T}{\overline{H}} = \left(1 - \frac{\overline{D}}{\overline{H}}\right)\overline{R}_b + \frac{\overline{D}}{\overline{H}}\left(\frac{1+\cos\beta}{2}\right) + \rho_g\left(\frac{1-\cos\beta}{2}\right) \quad \text{.............................(3-4)}$$

Where:

$\overline{D}$:monthly average daily diffuse radiation.

$\overline{R}_b$:ratio of the average beam radiation on the tilted surface to that on the horizontal surface for each month [Dimensionless].

β :tilt angle of the surface from the horizontal = 32+10= 42°

ρ : ground reflectance.

The ground reflectance ρ varies between 0.2 and 0.7 depending upon the extent of snow cover However, in our study, is taken as 0.2. The ratio $\overline{R}_b$ is given by:

$$\overline{R}_b = \frac{\cos(\phi-\beta)\cos\delta\sin\omega_s' + (\pi/180)\omega_s'\sin(\phi-\beta)\sin\delta}{\cos\phi\cos\delta\sin\omega_s + \left(\pi/180\right)\omega_s\sin\phi\sin\delta} \quad \text{...............................(3-5)}$$

Where:

ϕ :latitude.

δ :declination angle.

ω_s :sunset hour angle for a horizontal surface and is given by

$$\omega_s = \cos^{-1}(-\tan\phi \tan\delta) \quad \text{.........(3-6)}$$

$$\omega_s' = \min\begin{bmatrix} \cos^{-1}(-\tan\phi\tan\delta) \\ \cos^{-1}(-\tan(\phi-\beta)\tan\delta) \end{bmatrix} \quad \text{.........(3-7)}$$

Where:

ω_s' :sunset hour angle for a tilted surface.

3.2.4 Estimation of Diffuse Radiation:

Diffuse sky radiation is solar radiation reaching the Earth's surface after having been scattered from the direct solar beam by molecules or suspensoids in the atmosphere. The monthly average clearness index()is the ratio of monthly average daily radiation on a horizontal surface to the monthly average daily extraterrestrial radiation in eq. form:

$$\overline{K}_T = \frac{\overline{H}}{\overline{H}_o} \quad \text{.........(3-8)}$$

The monthly mean daily extraterrestrial radiation is given by:

$$\overline{H}_o = \frac{86400}{\pi} I_{sc}\left[1 + 0.034\cos\left(\frac{360n}{365.25}\right)\right]$$

$$\times\left[\cos\phi\cos\delta\sin\omega_s + \left(\frac{2\pi\omega_s}{360}\right)\sin\phi\sin\delta\right] \quad [J/m^2] \quad \text{.........(3-9)}$$

Where:

I_{sc}: solar constant (approximately equals to 1367 [W/m^2]. Note that "86400" is the number of seconds in 24 hours.

$\overline{K}_T$:can be used to find the monthly average daily diffuse radiation $\overline{D}$

$$\overline{D} = \overline{H}\left(1 - 1.13\overline{K}_T\right) \qquad \text{.......(3-10)}$$

Monthly average daily radiation on tilted surfaces:

$$\overline{H}_T = \overline{H}\left(1 - \frac{\overline{D}}{\overline{H}}\right)\overline{R}_b + \frac{\overline{D}}{2}(1+\cos\beta) + \frac{\overline{H}}{2}(1-\cos\beta)\rho \qquad [\text{kJ/m}^2] \qquad \text{.......(3-11)}$$

By applying these equation on our solar data, we get the Monthly average daily radiation on tilted surfaces:

Table(3.3) Monthly average daily radiation on tilted surfaces:

Month	$\overline{H}_T$ [MJ/m^2]
January	13.729
February	13.26
March	17.721
April	16.002
May	20.079
June	19.65
July	20.062
August	19.455
September	18.233
October	15.969
November	15.886
December	14.791

Table(3-4): Solar radiation on horizontal & tilted surfaces.

Month	Solar Radiation On horizontal plan $[MJ/m^2]$	Solar Radiation On tilted plan $[MJ/m^2]$	Radiation on tilted surfaces $[W/m^2]$/day
January*	10.025	13.729	3813
February*	11.942	13.26	3683
March*	17.63	17.721	4923
April	18.89	16.00	-
May	26.6	20.079	-
June	27.17	19.65	-
July	26.17	20.06	-
August	23.124	18.45	-
September	18.690	18.23	-
October*	12.934	15.96	4333
November*	11.72	15.88	4411
December*	9.899	14.791	4109

*Our design month.

According to the table above, we note that the values of the radiation is more than it in winter. There are two reasons for that in our opinion:

- The incidence angle of the sun in winter is more than its in the summer Fig (3-1).
- The tilted angle β of the collector which we have to choose it to satisfy the radiation in winter.

We should determine the optimum angle that give us the higher radiation in winter .

Our optimum tilted angle β = latitude +10° = 32° + 10° = 42°

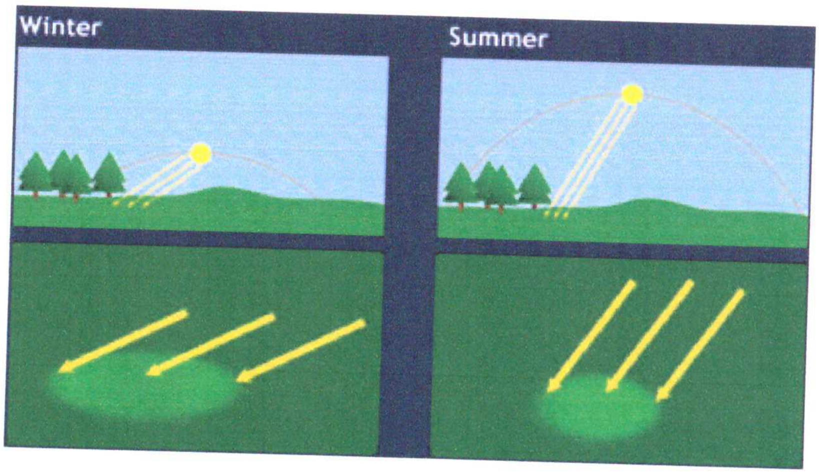


Figure (3-1):

3.3 Solar Evacuated Tubes:

In order to get sufficient irradiance for supply our system with its demand in heating process , there is a new technology for collecting an energy from the sun to convert it to heat, this technology is called the solar evacuated tubes.

Evacuated-tube collectors are typically more efficient at higher temperatures than flat-plate collectors. 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 has fin-tube design (fins increase the absorber surface and the heat-transfer rate).

When evacuated tubes are manufactured, air is evacuated from the space between the two tubes, forming a vacuum. Convective and conductive heat losses are eliminated because there is no air to convict or conduct heat, so evacuated-tube collectors are efficient at higher temperatures and perform well in both direct and diffuse solar radiation. Evacuated-tube collectors are more appropriate for most commercial and industrial applications because they can achieve extremely high temperatures.

3.3.1 Types of solar evacuated tubes:

There are three types of solar evacuated tubes :

- All-glass evacuated tubes
- U tube solar collector.
- Heat pipe collector:

3.3.1.1 All-glass evacuated tubes:

This collector used only in non-pressure service. It has a low efficiency and an operating pressure is about 0.5 bar.

Fig 3-2: glass evacuated tube.

3.3.1.2 U-Tube solar collector.

The U-pipe is made by a straight copper pipe which is bended at certain point. The two segments are parallel, and welding on the two main pipes. Several U-pipes and two main pipes build up a whole water-circuit system. The U-pipe is inserted to the vacuum tube with the aluminum fin. When the solar energy is absorbed by the vacuum tubes, the energy is transferred to the U-pipe crossing the aluminum fin. Then the u pipe is heated.

When the water or other medium flows across the main pipe, they have to flow across the U-pipe because the two main pipes are not linked directly, they are separated. So, the water or medium is heated by the u-pipe and rised a high temperature. The heated water or other medium makes water in the tank hotter and hotter by walking across the coils in the tank.

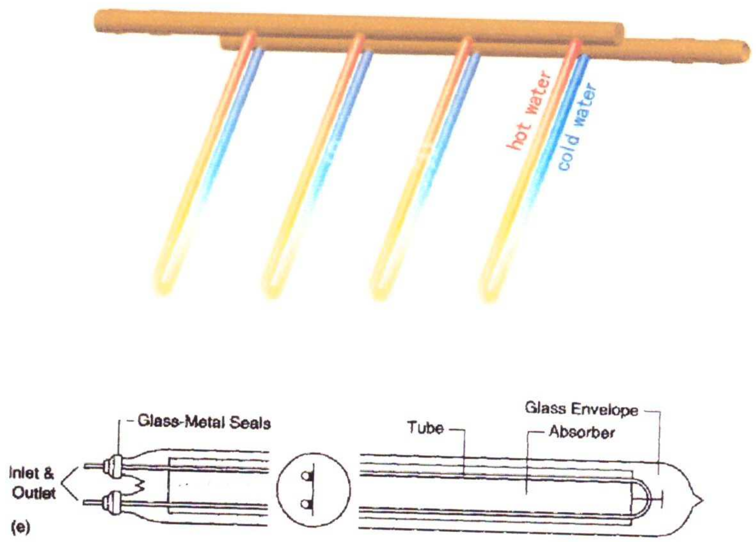


Fig 3-3:U-tube solar collector

3.3.1.3 Heat pipe collector:

The work Principle of heat pipe collectors:

Because of the larger proportion of hot water than cold water, cold water flows downward and hot water goes upward. The water will be heated continuousl between water tank and vacuum tube. In other wards, hot water always floats on cold water.

The hot-water flows to the water tank from the vacuum tubes. Because of the proportion, cold water flows to vacuum tubes from the water tank. The cold water is heated in vacuum tubes. After it becomes hot water, it flows to water tank again. The water circulates constantly between water tank and vacuum tubes; the cold water in water tank will be hotter and hotter.

Finally, all cold water will be heated to be hot water. This is the heating course of cold water.

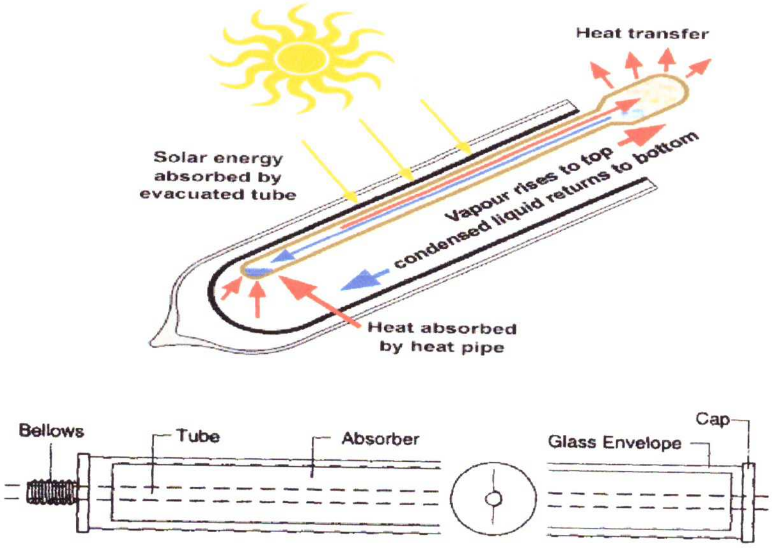


Fig 3-4: solar heat pipe collector.

In our design we decide to select the heat pipe solar collector because it has a high performance that reaches nearly 70% & operating pressure about 6 bar. So this type used for pressurized systems.

3.3.2 Solar Collector Performance and Efficiency:

Calculating solar collector efficiency can be very complicated, taking into consideration many factors such as installation angle, latitude, insolation levels, ambient temperatures, system heat loss, and system configuration

3.3.2.1 Collector performance:

Collector performance is often presented as a graph, or set of three performance variables. The three performance variables for the solar collector as provided by Test Center for Thermal Solar Systems of Fraunhofer ISE (Germany) the Collector test according to EN 12975-1,2:2006.

This test is done for the evacuated tube from type of heat pipe solar collector.

So to calculate the performance of this tube, you have to know a three variables The coefficients (η_0), (a_{1a}) and (a_{2a}) have the following meaning:

η_0: Efficiency without heat losses, which means that the mean collector fluid temperature is equal to the ambient temperature $t_m = t_a$

The coefficients (a_{1a}) and (a_{2a}) describe the heat loss of the collector.

The general formula for estimate the efficiency of the collector is represented by:

$\eta(G,(tm - t_a)) = \eta_0 - a_{1a}(tm - t_a)/G - a_{2a}(tm - t_a)^2/G$

which is taken from report of the collector test (See Appendix C-1)

where:

G = global irradiance on the collector area (W/m2)

t_{in} = collector inlet temperature (°C)

t_o = collector outlet temperature = 70 (°C) [constant]

t_a = ambient temperature (°C)

$t_m = (t_0 + t_{in})/2$

depending on aperture area of 0.936 m2:

$\eta 0a = 0.734$

$a_{1a} = 1.529$ W/m^2 K

$a_{2a} = 0.0166$ W/m^2 K^2

Specification of the tubes

Type: vacuum tube collector heat pipe. without mirror

Material of the cover tube: borosilicate glass

Transmission of the cover tube: ≥ 91 %

Outer diameter of the cover tube: 0.058 m

Thickness of the cover tube: 0.0018 m

Outer diameter of the inner tube 0.047 m

Thickness of the inner tube: 0.0016 m

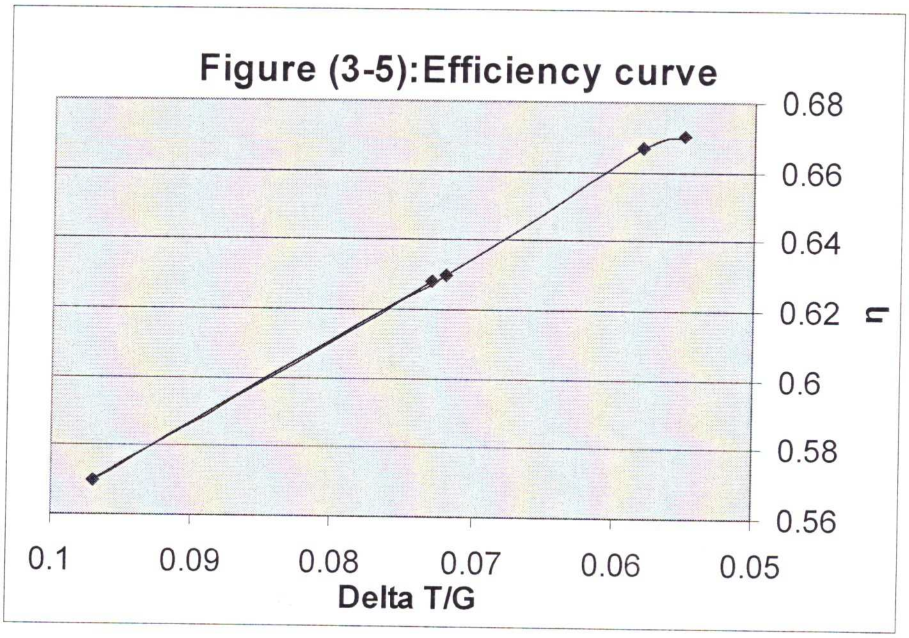
Distance from tube to tube: 0.078 m

Aperture area: 1.720 m x 0.0544 m x 10 tubes = 0.936 m2

Aperture area : projected area of inner diameter of cover tube.

Table 3-5: measured data for efficiency curve.

Month	T_a (°C)	T_m (°C)	T_{in} (°C)	Tm – Ta (°C)	G [W/m²]	(Tm -Ta)/G	η %
1	9.35	37	4	27.56	381	0.073	63
2	5.4	37	4	31.6	326	0.097	57
3	7.75	37	4	29.25	405	0.072	63
10	19.45	40	10	20.55	354	0.058	67
11	15.15	38	6	22.85	412	0.055	67
12	10.15	37	4	26.85	411	0.065	65



3.3.3 Estimation the optimum collector area A_c:

The heating system will be used from 15-Octoberr To 31-March (every winter)

Heating days number per winter = 166 [days/year]

The useful working hours per day = 12 [h / day]

Total heating load per year = 23.5 x166 x12 = 46812[kW /year]

The average solar radiation for 1 m^2 /daily in Hebron shown in Table (3-4)

Total solar radiation energy for 1 (m^2) in winter (Q) = $\sum_{1}^{6} \textit{Monthly Radiation}$

$Q=(3813\times 31)+(3683\times 28)+(4923\times 31)+(4333\times 15)+(4411\times 30)+(4109\times 31)$

Q = 698644 w / m2.winter = 698.6 [kW / m2 . winter]

The absorbed radiation from one solar collector = Q * A_r * η

Where :

η : the average efficiency of heat pipe collector. (63.7%)

A_r: aperture area of solar heat pipe.

The absorbed radiation from one solar collector = 698.6 * 0.936 * 0.637 = 416.5 kW.

- To save 100% of the heating load (23kW) from the sun:

The No. of solar panel = Total heating load per year / Absorbed radiation from one solar collector.

= 46812 / 416.5 = 112 solar panel.

The required area = 112 * 0.936 = 105m^2.

- To save 30% of the heating load from the sun:

Required solar panel = 14044 / 416.5 = 34 solar panel.

The required area = 34 * 0.936 = 31.5m^2

Chapter Four

System Design calculation

System Design calculation

We will do the calculation (heat load, underfloor heating) for the main bed room in the second floor, and we will insert other rooms calculations into tables.

4.1 Heating Load.

4.1.1 Heating Load due Heat Transfer

Table 4-1: Design Data

Design Condition	Indoor	Outdoor
Relative humidity Ø %	55%	65%
Temperature t (°C)	21	4
Enthalpy h (kJ/kg)	44	12

$$\dot{Q} = U * A(T_i - T_o)$$

Where:

T_i: Inside temperature design from table (4-1).

T_o: Outside temperature design from table (4.1).

$$U = \frac{1}{R}$$

$$R = \frac{1}{h_i} + \sum \frac{\Delta x}{k} + \frac{1}{h_o} = R_i + R_o + \sum_{1}^{n} R_n$$

h: The convection heat transfer coefficient.

k : Thermal conductivity from table (A-1).

Δx: The distance between the two surfaces whose temperature are Ti and To.

R_i & R_o: Inside &Outside film resistance from table (A-2)

4.1.1.1 Heat transfer due to glass.

$$A_{glass} = A_{window} * Windows\ number$$

$$A_{glass} = 2.34 * 3 = 7.02m^2$$ .... Table-(4.4)

The frame of windows is aluminium; we can obtain U from table (A-4).

$$\dot{Q}_{glass} = UA_{glass}(T_i - T_o)$$
$$\dot{Q}_{glass} = 3.7 * 7.02 * (21 - 4) = 441.6W$$

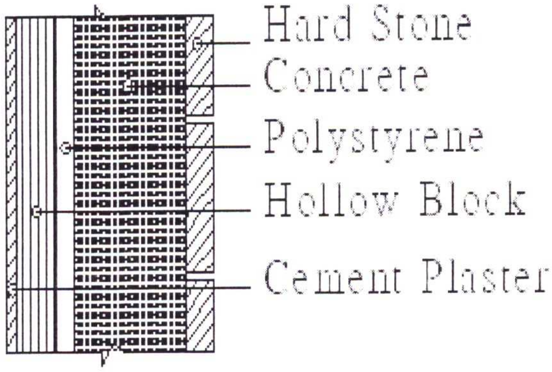
4.1.1.2 Heat transfer due to wall

$$A_{wall} = A_{Twall} - A_{glass} - A_{door}$$
$$A_{wall} = (4.9 + 2.4 + 1.1) * 2.9 - 4.98 - 0.0 = 24.11m^2$$

Table (4-2) Construction of wall

Material	Thickness (m)
Hard Stone	0.05
Concrete	0.20
Polystyrene	0.03
Hollow Block	0.07
Cement Plaster	0.02

Figure (4.1) Construction of Wall



$$R_{tot} = R_i + R_1 + R_2 + R_3 + R_4 + R_5 + R_o$$

$$R_{rot} = 0.31 + \frac{0.05}{2.2} + \frac{0.2.}{1.85} + \frac{0.03}{0.037} + \frac{0.07}{0.21} + \frac{0.02}{0.87} + 0.05 = 2.946 m^2.°C/W$$

$$U = \frac{1}{R_{tot}} = 0.339 W/m^2.°C$$

$$\dot{Q}_{wall} = UA_{wall}(T_i - T_o)$$

$$\dot{Q}_{wall} = 0.339 * 23.72 * (21-4) = 136.7W$$

4.1.1.3 Heat transfer due to ceiling.

$A_{ceiling} = 18.315 m^2$ .... Table-(4.9)

Because of ceiling construction as shown in fig (4.2). The ceiling may be divided into tow areas.

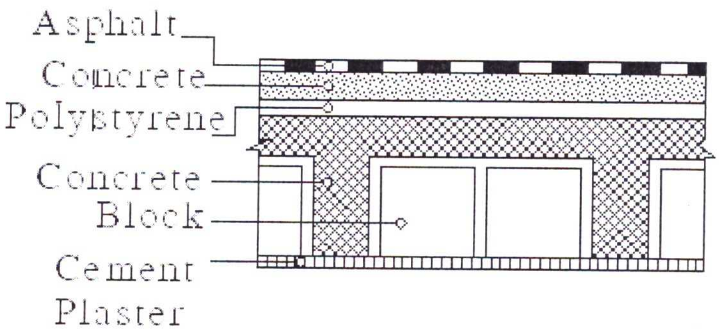
$$A_1 = A_{ceiling} * \frac{4}{5} = 18.315 * \frac{4}{5} = 14.6m^2$$

$$A_2 = A_{ceiling} - A_1 = 18.315 - 14.6 = 3.7m^2$$

Table (4-3) Construction of Ceiling

Material	Thickness (m)
Cement Plaster	0.02
Brick	0.18
Concrete	0.07 upon brick
Polystyrene	0.03
Concrete	0.05
Asphalt	0.02

Figure (4.2) Construction of Ceiling



$$R_{tot} = R_i + R_1 + R_2 + R_3 + R_4 + R_o$$

$$R_{tot} = 0.21 + \frac{0.02}{0.87} + \frac{0.3}{1.85} + \frac{0.03}{0.037} + \frac{0.02}{0.1.2} + 0.05 = 1.367W / m^2.°C / W$$

$$U = \frac{1}{R_{tot}} = 0.731W / m^2.°C$$

$$R_{tot} = R_i + R_1 + R_2 + R_3 + R_4 + R_5 + R_6 + R_o$$

$$R_{tot} = 0.21 + \frac{0.02}{0.87} + \frac{0.18}{0.7} + \frac{0.07}{1.85} + \frac{0.03}{0.037} + \frac{0.05}{1.85} + \frac{0.02}{1.2} + 0.05 = 2.1m^2.°C / W$$

$$U = \frac{1}{R_{tot}} = 0.476W / m^2.°C$$

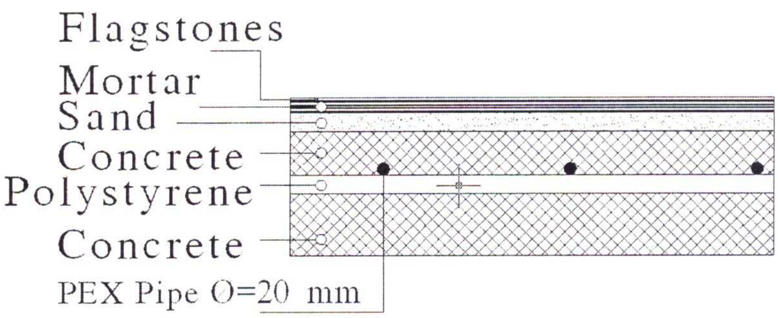
$$\dot{Q}_{\text{ceiling}} = UA_{\text{ceiling}}(T_i - T_o)$$
$$\dot{Q}_{\text{ceiling}} = (A_1 * U_1 + A_2 * U_2) * (T_i - T_o)$$
$$\dot{Q}_{\text{ceiling}} = (0.476 * 14.6 + 0.731 * 3.7) * 17 = 164.1W$$

4.1.1.4 Heat transfer due to floor.

Since the main bed room in the second floor and the design temperature is the same in both floors

$\Delta T = 0$ so $\dot{Q}_{\text{floor}} = o$

But there is heat transfer due to floor in the first floor:



$$R_{tot} = R_i + R_1 + R_2 + R_3 + R_4 + R_5 + R_6 + R_o$$
$$R_{tot} = 0.31 + \frac{0.1}{1.85} + \frac{0.03}{0.037} + \frac{0.01}{0.19} + \frac{0.07}{1.85} + \frac{0.03}{1.4} + \frac{0.02}{1.4} + \frac{0.005}{1.2}$$
$$U = 1.2W / m^2.°C$$

Where:

U from Palestinian code.

$$\dot{Q}_{floor} = U \times A \times (T_i - T_g)$$

Where

T_g : Ground temperature = 10°C.

The ground temperature near the surface of the earth differs with the season of the year and prevailing climate. For winter season, its value can be taken as that of ambient air temperature plus 5 to 10 °C for moderate climate

Table (4-4) Area of walls, doors, ceiling, floor, and windows

Room	$A_{ceiling}$ (m^2)	$A_{all\ wall}$(m^2)	A_{window} (m^2)	A_{door}(m^2)	A_{wall}(m^2)
First Floor					
Guest Room	72.2	75.11	16.44	6	52.67
Office	11.56	9.57	1.2	3	5.37
Salon& Kitchen	52	58.58	16.5	3	39.1
WC1	2.88	4.35	0.45	....	3.9
WC2	2.88	4.35	0.45	....	2.9
Second Floor					
Main Bed Room	18.3	30.74	7.02	....	23.72
Bed Room1	13.7	27.43	7.02	....	20.41
Bed Room2	14.4	11.43	5.5	....	5.93
WC	2.25	4.04	0.45	....	3.61
Bathroom	4.72	5.22	0.45	....	4.77
Main Bathroom	6.24	7.54	0.45	....	4.1
Washing Room	7.1	9.57	0.9	....	8.67
Salon& Kitchen	65.63	59.74	16.5	4.98	38.35

4.1.2 Heating Load Due Infiltration.

We will use the air change method.

$\phi_o = 65\%$

$\phi_i = 55\%$

Using psychromitly chart (B-2):

$\upsilon = 0.79 m^3 / kg$

$$\rho_{out\text{-}air} = \frac{1}{\upsilon} = \frac{1}{0.79} = 1.267 kg / m^3$$

Where:

$\rho_{out.air}$: Density of out door air

$\dot{V}$ = V_{room} * Air change per hour (table A-3)

$\dot{V} = (18.315 * 2.9) * 1 = 53.114 m^3 / h = 0.0147 m^3 / s$

$\dot{m}_f = \rho \dot{V} = 1.267 * 0.0147 = 0.01861 m^3 / s$

$\dot{Q}_f = \dot{m}(h_i - h_o) = 0.01861(44 - 12) = 0.5965 kW$

4.2 Total Heating Load.

$\dot{Q}_{tot.} = \dot{Q}_{glass} + \dot{Q}_{wall} + \dot{Q}_{ceiling} + \dot{Q}_f$

$\dot{Q}_{tot.} = 136.7 + 441.6 + 164.1 + 600 = 1342.4 W = 1.3424 kW$

We will take safety factor (SF) = 20%

$\dot{Q}_{tot,room} = \dot{Q}_{tot} \times 1.2 = 1.3424 \times 1.2 = 1.611 kW$

Similar procedure is followed of calculate the heat load for other rooms. The results summarized in the tables (4-5), and (4-6).

Table (4-5) Heating load due to infiltration

Room	V(m³)	$\dot{V}$ (m³/h)	$\dot{V}$ (m³/s)	$\dot{m}$ (kg/s)	Q(kW)
First Floor					
Guest Room	209.4	209.4	0.0582	0.074	2.359
Office	33.5	33.5	0.0031	0.00393	0.126
Salon& Kitchen	150.8	150.8	0.042	0.06	1.703
WC1	8.4	25.2	0.007	0.0087	0.279
WC2	8.4	25.2	0.007	0.0087	0.279
Second Floor					
Main Bed Room	53.1	53.1	0.015	0.0188	0.6
Bed Room1	39.7	39.7	0.011	0.0139	0.446
Bed Room2	41.8	41.8	0.012	0.0147	0.47
WC	6.5	19.5	0.0054	0.007	0.219
Bathroom		41.1	0.0114	0.0144	0.462
Main Bathroom	18.1	54.3	0.015	0.019	0.609
Washing Room	20.6	20.6	0.0057	0.0072	0.231
Salon& Kitchen	190.3	190.3	0.053	0.0671	2.149

Table (4-6) Heat load for each room

Room	Q_w (W)	Q_g (W)	Q_f (W)	Q_c (W)	Q_d (W)	Q_{inf} (W)	Q_{tot} (W)	Q_{tot}*SF (W)
First Floor								
Guest Room	303.54	1007	866.4	_	142.8	2359	4678.7	5617
Office	31	55.1	138.7	_	71.4	126	422.2	507
Salon& Kitchen	225.3	1038	624	_	71.4	1703	3661.7	4394
WC1	22.5	28.3	34.6	_	_	437	522.4	627
WC2	22.5	28.3	34.6	_	_	437	522.4	627
Second Floor								
Main bed room	136.7	441.6	_	164.1	_	600	1342.4	1611
Bed room1	117.6	441.6	_	122.8	_	446	1128	1354
Bed room2	34.2	346	_	129.1	_	470	979.3	1175
WC	20.8	28.3	_	20.2	_	346	415.3	498
Bathroom	27.5	28.3	_	42.8	_	673	771.6	925
Maim Bathroom	23.6	28.3	_	55.9	_	860	967.8	1161
Washing Room	50	56.6	_	63.7	_	231	401.3	482
Salon& Kitchen	221	1036	_	588.3	519.4	2149	4513.7	5418

$$Qtot = 19.555kW$$

$$Q = Qtot \times SF = 19.555 \times 1.2 = 23.5kW$$

4.3 The Heat Required To the Domestic Hot Water ($\dot{Q}_{DHW}$)

There are six people's lives in the villa

$$2\,persons \times 50liter = 100liter$$
$$4\,persons \times 30liter = 120liter \quad \text{.....(4.1)}$$
$$DHWtot = 100 + 120 = 220liter$$

So, the DHW storage tank capacity =220 liter

$$\dot{Q}_{DHW} = \dot{m}\,Cp\Delta T$$

Where

Cp: specific heat for water

ΔT: difference temp between hot water entering tank; and cold water leaves it =55°C

$\dot{m}$: The amount of water that heated in one hour =220L/3600s = 0.0611 L/s

$$\Rightarrow \dot{Q}_{DHW} = 0.0611 \times 4.18 \times 55 = 14.05kW$$

Water service sizing and water pipe sizing by friction head loss

In this part we will calculate the total demand for hot and cold water to the villa. This contains:

- The no. of fixture unit in each floor in the villa.
- How much the fixture does takes in WSFU.
- We consider the use of these fixtures is a private use and type of the supply control is flush tank.

Table (4-7)

Fix. Unit	No. of units	WSFU	Cold water [WSFU]	Hot water [WSFU]	Total hot & cold[WSFU]
Lavatory	5	¾*1	3.75	3.73	5
Water closet	5	3	15	…..	15
Kitchen sink	2	¾*2	3	3	4
Shower head	1	¾*2	1.5	1.5	2
Bathtub	1	¾*2	1.5	1.5	2
		SUM	**24.75[WSFU]**	**9.75**	**28**

WSFU: Water supply fixture unit (from table A-6-a)

Cold water

24.75 WFSU = 16.85 gpm (converted from table A-6-b)

Cloth washer = 4 gpm only cold

Hot water

9.75 WFSU = 7.813 gpm

Total gpm = 22.8 gpm total demand of water supply

Pipe size for hot water = 1.5 in

4.4 Determination of the boiler

Boiler Capacity = (The total heat losses + Heat required for DHW)*1.15 …… (4.2)

$$= (23.5 + 14.05) \times 1.15 = 43kW$$

From fondital company catalogue table (A-7), we select the boiler that has a capacity of 43kW,

The expansion tank capacity = 200 Liter …………………….. (Table A-8)

4.5 Boiler Chimney

Chimney is used to direct the gaseous combustion product to an elevated location above the surrounding building. The height of the chimney directly influences the production of draft.

The chimney cross-sectional area "Ac" can be calculated using the following relation:

$$A_c = \frac{\dot{m}_g}{\rho_g v} \qquad \text{……………………………………………………………………. (4.3)}$$

Where:

$\dot{m}_g$: Mass flow rate of flue gases leaving the chimney.

ρ_g : The density of hot flue gases.

v : The average velocity, which ranges from (3-5) m/s for natural draft chimney.

Note: The diameter shouldn't be less than 126mm to provide for enough area during start up of the boiler.

Every "1kg" of fuel oil need to "24.2kg" of air to complete combustion. Thus the resulting mass of the flue gases = 25.2kg/kg air. The mass flow rate of fuel consumed in the boiler $\dot{m}_f$ can be calculated from the relation:

$$\dot{m}_f = \frac{\dot{Q}}{\eta CV} \quad \text{.......} \quad (4.4)$$

Where:

$\dot{Q}$: Boiler capacity

η : The combustion efficiency, for diesel fuel = 90.9% ...... (Boiler catalogue A-7)

CV : The calorific value, for diesel fuel = 39000 kJ/kg

In our project, boiler capacity is 43 kW, and diesel used as fuel.

$$\dot{m}_f = \frac{43}{0.909 \times 39000} = 0.00144 kg/s$$

0.00144 kg/s diesel fuel produces: 0.00144 * 25.2 =0.0363 kg/s flue gases.

$\rho_g = 1.1 kg/m^3$

$v = 4 m/s$

$$A_c = \frac{\dot{m}_g}{\rho_g v} = \frac{0.0363}{1.1 \times 4} = 0.00825 m^2 = 82.5 cm^2$$

$D_c = 4A_c \div \pi = 4 \times 0.00825 \div \pi = 0.0105 m = 105 mm \quad < \quad$ 126mm

According to central heating Jordanian code **Dc = 6 in**

4.6 Underfloor Heating System Calculation

1. **Heat Demand for Underfloor Heating System.**

$$\dot{q}_t = \frac{\dot{Q}_{tot,room}}{A_{room,floor}} = \frac{1611}{18.3} = 88W/m^2$$

2. **Flow sure face room temperature (T_f).**

$$\dot{q} = h(T_f - T_i)$$
$$63 = 12(T_f - 21) \Rightarrow T_f = 27.25^oC$$

3. **Hot water temperature entering the room (T_w).**

The floor consist of concrete construction, we will use 20mm pipe diameter. There a concrete slap, tail, soil and wall to wall carpet upon the pipes.

R_{th} structure = (R_{th} concert + R_{th} soil + R_{th} tail) =0.075 $m^2.°C/W$.

R_{th} carpet = 0.08 $m^2.°C/W$.

Where:

R_{th} carpet from Wirsbo catalogue.

R_{th} structure from Palestinian code.

$$\overline{T}_w = T_f + \Delta T_{st} + \Delta T_{cov}$$
$$\overline{T}_w = T_f + [\dot{q}_t (R_{th.str})] + \dot{q}_t * R_{th.carp}$$
$$\overline{T}_w = 28.3 + [88 * (0.075)] + 88 * 0.08 = 41.9^o C$$

$$T_{wi} = \overline{T}_w + 2.5 = 41.9 + 2.5 = 44.4^o C$$

4. Mass flow rate of water ($\dot{m}_w$).

$$\dot{m}_w = \frac{\dot{Q}}{Cp\Delta T_w} = \frac{1.611}{20.9} = 0.078 L/s = 280.8 L/h$$
$$\Delta T_w = 5°C$$

5. Loops Pressure Drop

From Wirsbo pipe diagram (B-1) for 0.078L/S flow rate and 20mm diameter:
Pressure drop per meter = 0.15kPa/m

The pitch between pipes 30cm (from center to center)
Total length of pipe = loops in room + distance to manifold.
The loop layout using single serpentine pipe arrangement .Each 1 m^2 require (3 - 4) m length.

Total length loop = 18.3 * 3.5 +8.1 = 72.1 m
By using Wirsbo diagram ΔP/m = 0.15
Pressure drop through the loop = ΔP/m * length
= 0.15 * 72.1 = 10.8 kPa

6. Valve pressure drop

We estimate it by intersection the flow rate (m/h) with totally open line in Giacomini manifold diagram (B-3):

Valve pressure drop = 2.3kPa

Totally pressure drop = 10.8 + 2.3 = 13.1 kPa

From table-(4-9) the maximum drop pressure in salon for first and second floor

7. Valve Calibration

We estimate the critical loop. Always we determine the mass flow rate for each loop, and we calculated the difference pressure drop between longest pipe loop and other loops, from manifold chart (Giacomini manifold B-3). We calibrate manifold valves in tables (4-8) & (4-9).

Difference = totally pressure drop for longest loop - Pressure drop for each loop

$\Rightarrow$ = 16.44 -10.8 = 5.6 kPa

Valve setting = 4.7 revolution ....from diagram (B-3)

Table (4-8) Design Parameter For Underfloor System " First Floor"								
Room	Guest Room				Office	Salon	Corridor	Kitchen
	Zone 1	Zone 2	Zone 3	Zone 4				
$\dot{Q}$ (W)	1404	1404	1404	1404	507	1738	900	1438
A (m^2)	18	18	18	18	11.56	18	10	15
$\dot{q}$ (W/m^2)	78	78	78	78	44	96.6	90	96
Tf (°C)	27.5	27.5	27.5	27.5	24.6	29	28.5	29
Tw (°C)	39.59	39.59	39.59	39.59	31.42	43.973	42.45	43.88
Twi (°C)	42.09	42.09	42.09	42.09	33.92	46.473	44.95	46.38
$\dot{m}_w$ (L/h)	241.2	241.2	241.2	241.2	86.4	298.8	154.8	248.4
$\dot{m}_w$ (L/s)	0.067	0.067	0.067	0.067	0.024	0.083	0.043	0.069
P (kPa/m)	0.12	0.12	0.12	0.12	0.019	0.17	0.055	0.13
L (m)	62.8	68.3	68.8	61.5	53.3	75.2	35.2	61.3
LDP(kPa)	7.54	8.2	8.3	7.38	1.01	12.8	1.9	8
VPD(kPa)	1.55	1.55	1.55	1.55	0.04	2.5	0.6	1.65
TPD(kPa)	9.09	9.75	9.85	8.93	1.05	15.3	2.5	9.65
Diff (kPa)	7.76	7.1	7	7.92	14.29	2.5	13.4	7.3
VS	4	4.1	4.1	4	1.6	TO	2.7	4.1

Where:

$\dot{Q}$: Total load for each room.

A: Room area.

$\dot{q}$: Heat demand per area.

Tf: Mean floor surface temp.

Tw: Average water temp.

Twi: Supply water temp.

$\dot{m}_w$: Mass flow rate of water.

P : Drop pressure per meter.

LDP: Drop pressure in loop length.

VPD: Valve pressure drop.

TPD: Total pressure drop (LPD + VPD).

Diff: Difference between TPD for longest loop and LPD for other loops.

VS: Valve setting.

Table (4-9) -Design Parameter For Under floor System " Second Floor"							
Room	**Main Bed Room**	**Bed Room1**	**Bed Room2**	**Salon**	**Kitchen**	**Corridor1**	**Corridor2**
$\dot{Q}$ **(W)**	1611	1354	1175	1778	1405	1439	1016
A (m²)	18.3	13.7	14.4	20.6	15	17	12
$\dot{q}$ **(W/m²)**	88	98.8	81.6	86.3	93.7	84.6	84.7
Tf (°C)	28.3	29.2	27.8	28.2	28.8	28.1	28.1
Tw (°C)	41.94	44.514	40.448	41.5765	43.3235	41.213	41.2285
Twi (°C)	44.44	47.014	42.948	44.0765	45.8235	43.713	43.7285
$\dot{m}_w$ **(L/h)**	280.8	234	201.6	306	241.2	248.4	176.4
$\dot{m}_w$ **(L/s)**	0.078	0.065	0.056	0.085	0.067	0.069	0.049
P (kPa/m)	0.15	0.1	0.08	0.17	0.12	0.13	0.07
L (m)	72.1	54.4	47.7	82	64.8	42.3	38.8
LDP(kPa)	10.815	5.44	3.816	13.94	7.776	5.499	2.716
VPD(kP)	2.3	1.4	1.1	2.5	1.5	1.7	0.08
TPD(kPa)	13.115	6.84	4.916	16.44	9.276	7.199	2.796
Diff (kPa)	5.625	11	12.624	2.5	8.664	10.941	13.724
VS	4.7	3.5	3.2	TO	3.8	3.8	2.8

Total pipe length (TPL) = loop1 +loop2 + …… last loop

= 900m^2

Storage tank capacity $_{(heating\ system)}$ = TPL * Pipe cross section area * Safety factor

$$= 900\times\frac{\pi d^2}{4}\times 3 = 900\times\frac{\pi(0.02)^2}{4}\times 3 \cong 1m^3$$

4.7 Load for radiator

The operating temperature of hot water for radiator ranges from (70-90) °C, the usual design range for the drop in hot water temperature across radiator is (10 – 20)°C. The heat rejected as result of this drop in temperature heats the space.

In our project, we suggested that the operating temperature is 70°C.and drop in hot water temperature across radiator is 10°C.

The heat balance equation for a room radiator is given as follows

$$\dot{Q}_r = \dot{m}Cp(Tin - Tout) \quad \text{..} \quad (4\text{-}4)$$

Where:

$\dot{Q}$: Heat required to be delivered by the room radiator in kW

$\dot{m}_w$: Mass flow rate o water flowing through the radiator in kg/s.

Cp: The specific heat of water = 4.186 kJ/kg. °C.

Tout: Temp o the water leaving the radiator in °C.

Tin: Temp o the water entering the radiator in °C.

$$\dot{m} = \frac{\dot{Q}_r}{Cp\Delta T} = \frac{\dot{Q}_r}{41.86}$$

For bathroom:

$$\dot{m} = \frac{0.925}{41.86} = 0.022 kg/s$$

From fondital radiator catalogue-Ladder Type- table (B-4) we select the suitable radiator as shown in table (4-10).

Table (4-10) Design Parameter for Radiator

Floor	**First Floor**		**Second Floor**			
Room	**Toilet1**	**Toilet2**	**Toilet**	**Bathroom**	**Main Bathroom**	**Washing Room**
$\dot{Q}$ **(kW)**	0.627	0.627	0.498	0.925	1.161	0.482
$\dot{m}_w$ **(L/s)**	0.015	0.015	0.02	0.022	0.028	0.012
Model	15/450	15/450	12/450	19/550	15/550 & 8/550	12/450

4.8 Location of manifolds.

Location of manifold should be put it in suitable position to make less length of loops. So we put the manifolds as shown in the project plane.

4.9 Pumps Selection

We will use Biral pump diagram (B-5) to selection the circulating pump for radiators and underfloor heating system (UFHS).

In the first floor

$\dot{m}_{tot} = 0.487\ l/s \quad = 1.8 m^3/h$

TPD = 15.3 kPa ....For critical loop.

Equivalent length (EL) for main supply and return pipe = 30*1.5 = 45m

Pump head = Friction loss + TPD

Friction loss (kPa/m) should be 0.2 – 0.5 kPa

Friction loss = (Pump head – TPD)/ EL

We choose a pump (M12) from Biral pump chart which its head = 26kPa

Friction loss = (16 – 15.3)/45 = <u>0.23 kPa</u>

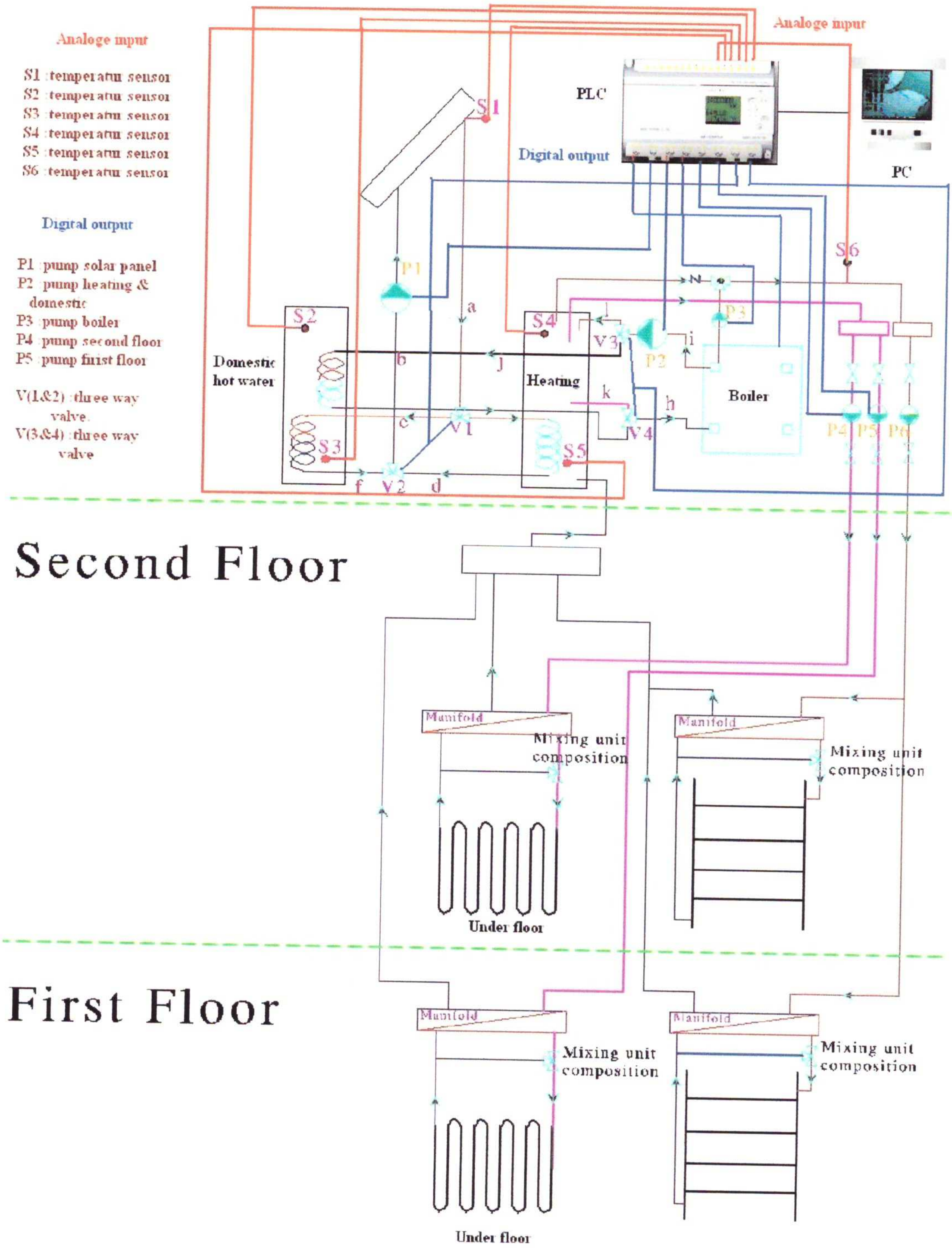
While friction loss during the range $\Rightarrow$ the circulating pump M12 is selected

Table (4-11) Pump Selection

Loop	EL(m)	TPD critical loop (kPa)	Pump	Pump Head (kPa)	Mass flow rate(m^3/h)	Friction Loss (kPa)
(UFHS) First Floor	45	15.3	M12	26	1.8	0.22
(UFHS) Second Floor	48	16.44	M12	27	1.7	0.23
Radiator	51	0.28	M10	22	0.22	0.43

CHABTERT FIVE

Control System (PLC)



Control wiring system

1.1 Overview

To use solar energy as a major source of water heating in the house. This project is designed to have such a capability to control the temperature bikes everywhere in the house. This system is capable of providing each room temperature event, which may be stored in the computer. Sensor any measure temperature in each region due to a feeler computer operating system to determine where the computer sends signals to open the pump and valves .Moreover, this system will work on the rationalization of electric energy consumption and save money.

A PLC (Programmable Logic Control) device is used to control the unit and a SCADA (Supervisory Control and Data Acquisition) software program is designed as a Human Machine Interface (HMI).

Section two

Electrical design and Computer Interface

5.2.1 Introduction

This section concerned with the electrical circuit design, PLC interface and computer interface. There are two microprocessors used in the system; the first is the PLC microprocessor used for controlling the unit and the second for PC computer used for human machine interface through the SCADA program.

The block diagram shown in figure (5.1) represents the whole system which illustrates how the subsystems are connected in order to obtain the interface and to operate the system.

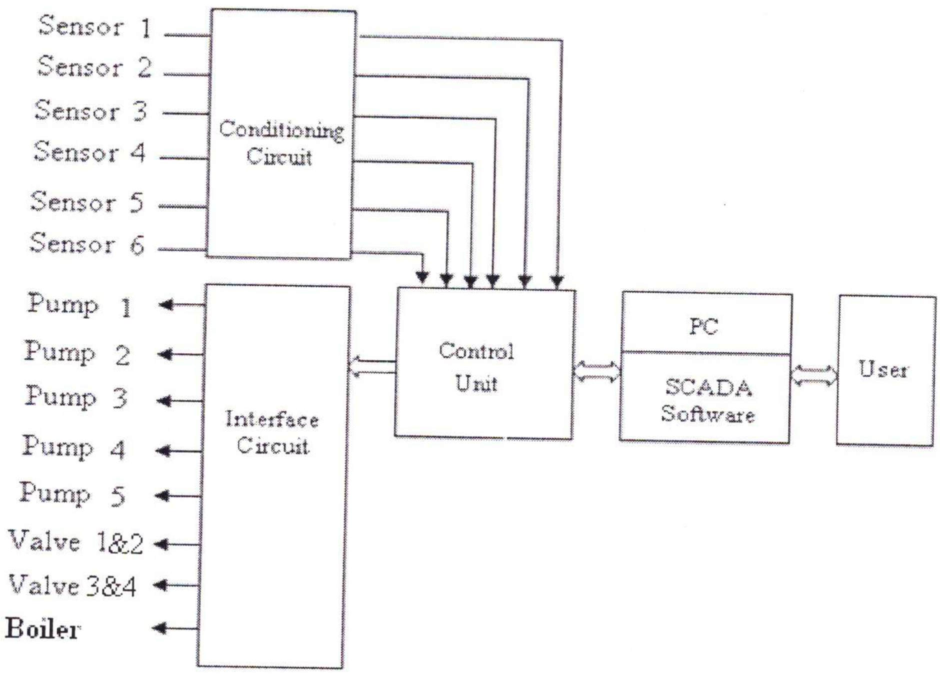


Figure (5.1): The block diagram of the system.

Sensor1 (analog input): water temperature sensor on solar panel.

sensor2 (analog input): up level water temperature sensor for domestic heating water.

sensor3 (analog input): down level water temperature sensor for domestic heating water.

sensor4 (analog input): up level water temperature sensor for heating system.

sensor5 (analog input): down level water temperature sensor for heating system.

sensor6 (analog input): water temperature sensor at line to radiator.

Pump1 (digital output): On /off with solar system.

Pump2 (digital output): On /off with boiler.

Pump3 (digital output): On /off with boiler.

Pump4 (digital output): On /off with first under floor.

Pump5 (digital output): On /off with second under floor.

Valve1&2: On/Off three way valve (normally open).

Valve3&4: On/Off three way valve (normally open).

Boiler (digital output): On/Off.

5.2.2 Sensors

A sensor is a device that produces an output signal for the purpose of sensing of a physical phenomenon that can be fed into processing unit like computer. Sensors transform real-world data into electrical signals.

5.2.2.1 Temperature sensor:

The temperature sensor is used to measure the temperature of the surrounding in order to prevent the temperature is too high the room.

The used temperature sensor is PTC (Positive Temperature Coefficient) thermistor type which has linear characteristic as its resistance varies due to change in temperature.

- Calibration of Temperature Sensor Circuit:

To calibrate the sensor a reference temperature is needed, the first one is (100 C°) " the boiling point of water" and the second is (0 C°) "the ice water", the zero degree centigrade.

An experiment is done for measuring the sensor resistance at different temperature by changing the temperature and then the data is recorded using ohmmeter for the resistance and the digital thermometer for the temperature. The table below shows the relation between the temperature and the sensor resistance.

Table (5.1) Temperature Measurement versus Resistance.

Temperature(C°)	0	19.4	20.2	26	31.1	41.6	52.1	65.4	72.6	85.5
Resistance	805	943	950	1000	1050	1140	1220	1320	1380	1460

This data is plotted using excel as shown in figure (5.2):

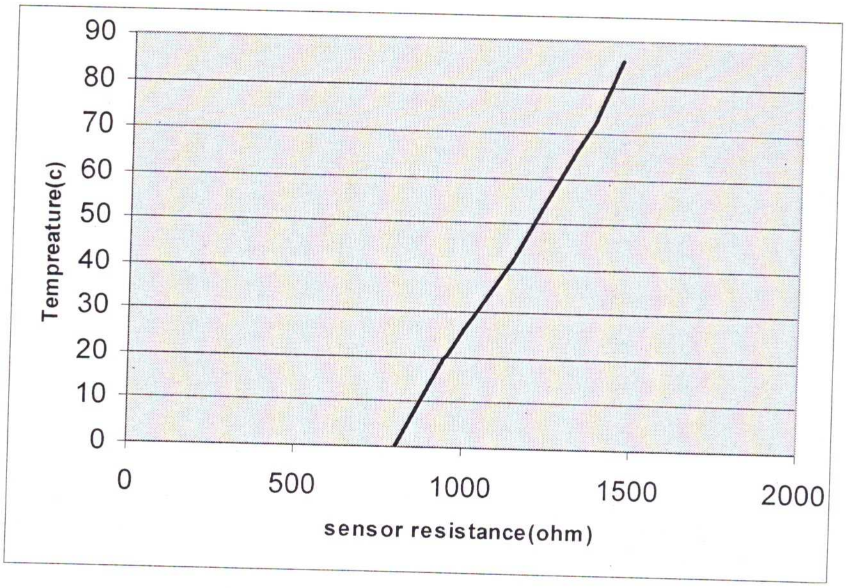


Figure (5.2) temperature versus sensor resistance.

The quarter Wheatstone bridge circuit is used to convert the sensor resistance (RT) to acceptable form for the FAB PLC (voltage), using kerchief's law the currents through the circuit given by these equations:

$$I_1 = \frac{E}{2R} \quad \text{and} \quad I_2 = \frac{E}{R + R_T}$$

$$V_3 = \frac{R_T}{R + R_T} \cdot E \quad \text{and} \quad V_4 = \frac{R}{2R} \cdot E$$

$$V = V_4 - V_3 = \frac{R - R_T}{R + R_T} \cdot \frac{E}{2}$$

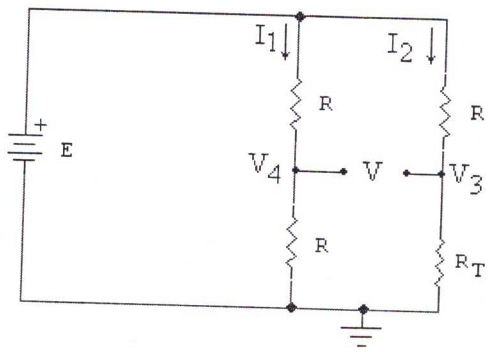


Figure (5.3): Wheatstone bridge circuit.

Let R=500 ohm, E=12volt, then the following table shows the relation between the voltage and sensor resistance.

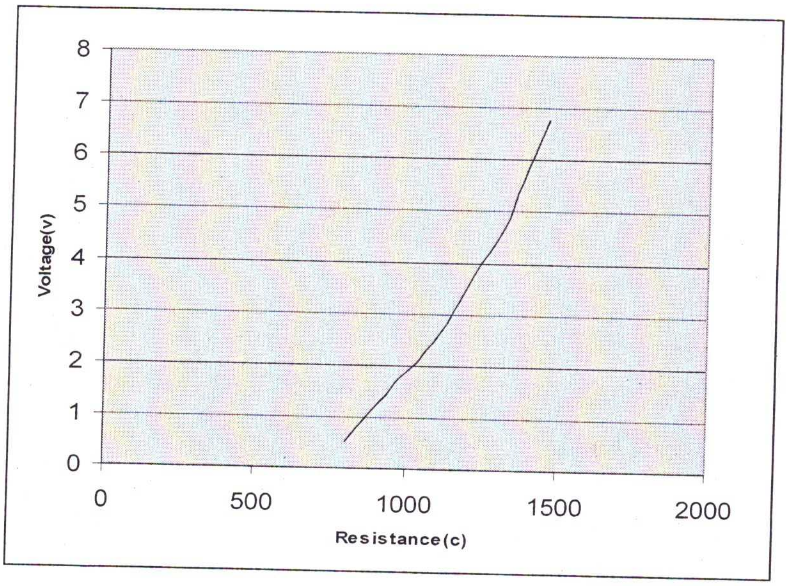


Figure (5.4): voltage versus sensor resistance

Table (5.2): Calculated voltage at different temperature.

Temperature(C°)	0	19.4	20.2	26	31.1	41.6	52.1	65.4	72.6	85.5
resistance(Ω)	805	943	950	1000	1050	1140	1220	1320	1380	1460
voltage(v)	0.52	1.48	1.71	1.86	2.129	2.8421	3.7491	4.6941	5.5949	6.7497

The following figure shows the relation between the bridge output voltage and the sensor resistance.

In order to obtain the bridge output voltage ($V = V_4 - V_3 = \frac{R - R_T}{R + R_T} \cdot \frac{E}{2}$) a differential amplifier is used as shown in the figure below:

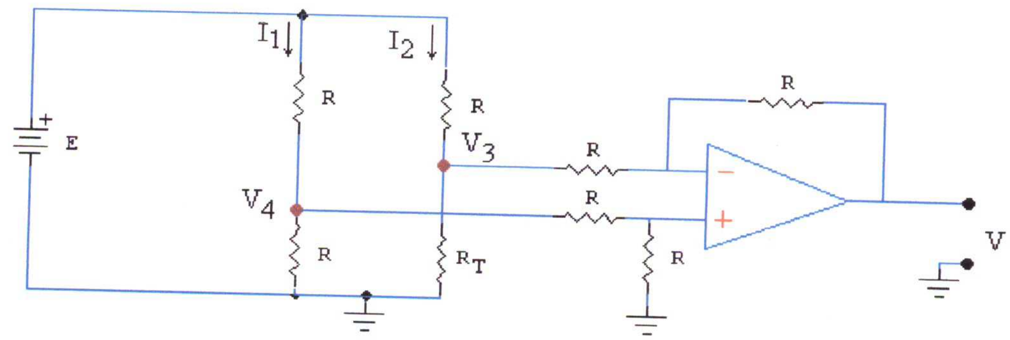


Figure (5.5): Wheatstone bridge with differential amplifier.

Because the output voltage of the previous circuit is in milivolt an amplification circuit is used as shown in the figure below:

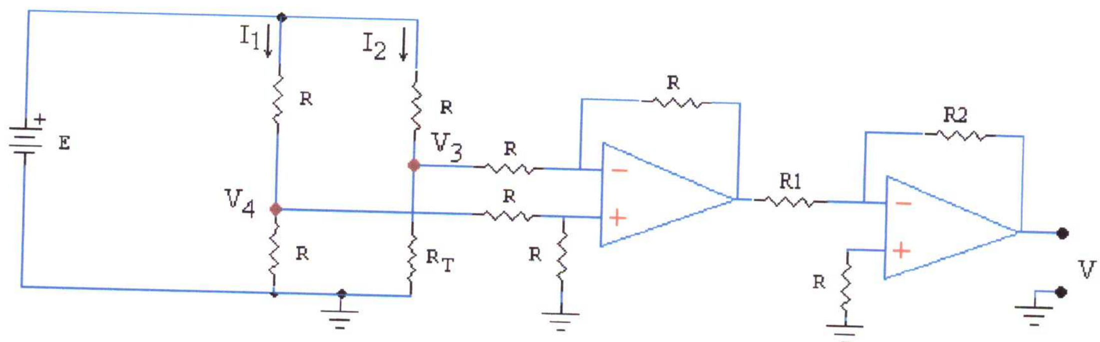


Figure (5.6): Wheatstone bridge with amplification circuit.

5.2.3 Control unit (PLC (Programmable Logic Controller))

Is a microprocessor-based control unit designed for an industrial installation in a power switchboard to control machinery or an industrial process?

The PLC mainly consists of a CPU, memory, and appropriate circuits to receive input/output data.

Input is usually from switches such as push buttons controlled by machine operators or any sensors. The Outputs include lamps, solenoid valves and motors.

The used PLC language is functional block diagram, which enable the control functions of a PLC to be achieved without the need for large number of instructions and complicated programming.

The communication between Fab PLC and computer is done through serial communication (Com1 or Com2). Up to 255 FAB can be connected to the computer using special network.

Figure (5.7) illustrates how the actuators and sensors are connected to the PLC in addition to the software program.

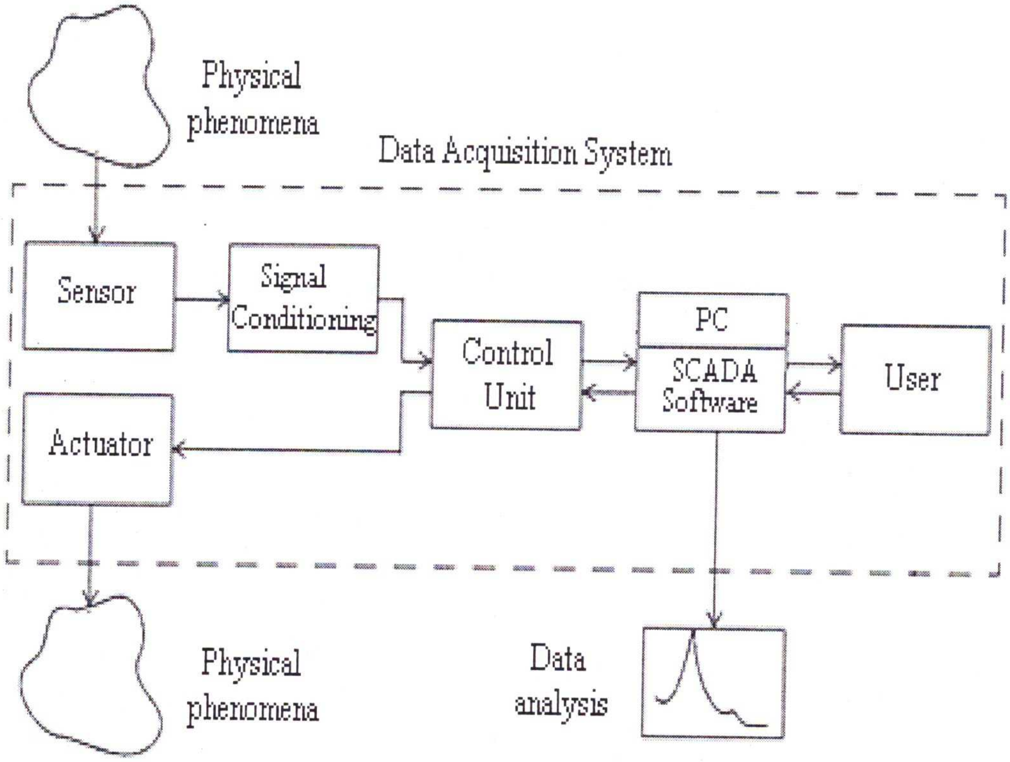


Figure (5.7): data acquisition components.

The required specifications of the PLC are as follow:

- Analog Input Specifications
    - Number of channels needed are six channels :
        - 6 channel for the temperature sensor.
- Digital Output Specifications
    - Number of channels needed are three channels :
        - 5 channel for the pump.
        - 2 channels for the three way valves.
        - 1 chancel boiler

5.2.3.1 Pump Interface

In the project the pump is of 220V, 50 Hz and 0.33 hp, to connect the pump with a PLC a relay circuit is used.

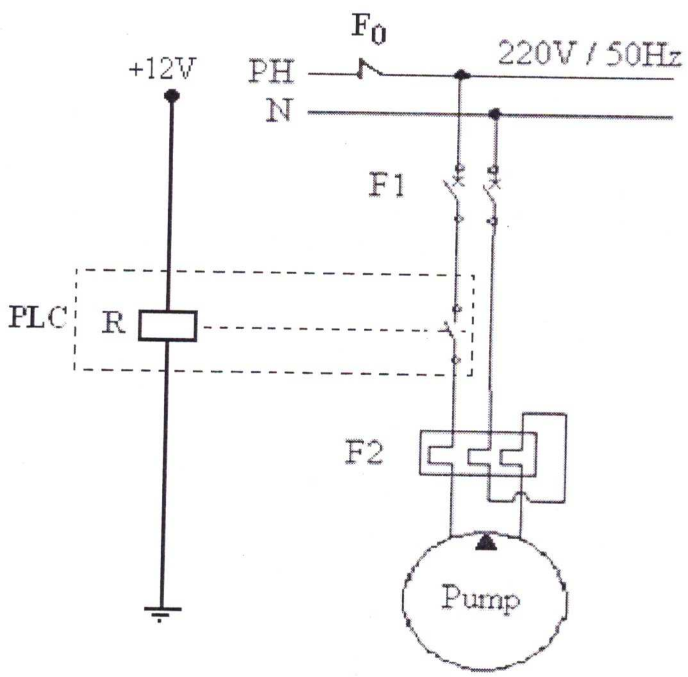


Figure (5.8): Control circuit

R: PLC Relay.

F0: Circuit breaker, 10 Ampere.

F1: Circuit breaker.

F2: Over load value= 2 Ampere.

5.2.3.2 Valves Interface.

The used valves are of 220V AC, 50Hz, and to switch on the valve, output relay is used, as shown in figure (5.9).

When relay coils turns on the relay's contact in control circuit - figure (5.9) – will close, the three way valve (NC) turn on, and then the valve will open and allow water to pass to irrigate the plants.

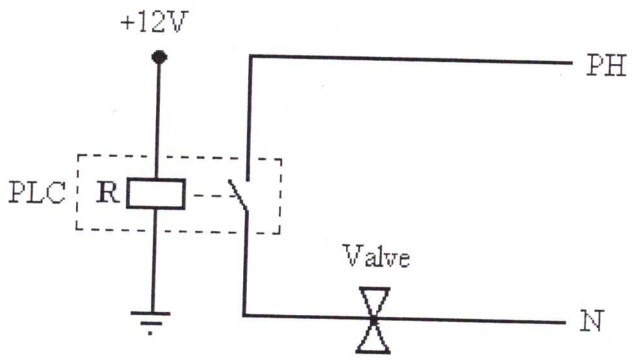


Figure (5.9): valve interface

Section three

Software Design

5.3.1 Introduction.

5.3.2 QuickII Software.

5.3.3 Design system

5.3.4Description system.

5.3.5 SCADA.

5.3.6 Flow Chart.

5.3.1 Introduction:

The basic purpose of an HMI (Human Machine Interface) is to allow easy graphical interface with a process. These devices have been known by a number of names:

- Touch screens
- Displays
- Man Machine Interface (MMI)
- Human Machine Interface (HMI)

These allow the operator to use simple displays to determine machine condition and make simple settings. The most common options are:

- Display machine faults.
- Display machine status.
- Allow the operator to start and stop cycles.
- Monitoring part.

HMI Objectives:

These devices allow certain advantages such as:

- Color coding allows for easy identification (e.g. red for trouble).
- Pictures/icons allow fast recognition.
- Use of pictures eases problems of illiteracy.
- Screen can be changed to allow different levels of information and access.

The general implementation steps are:

1. Layout screens on PC based software.

2. Download the screens to the HMI unit.

3. Connect the unit to a PLC.

4. Read and write to the HMI using PLC memory locations to get input and update screens.

5.3.2Quick software

QuickII is programming software for a FAB PLC controller; it is used for programming and simulation. It can implement the preparation of a control program for FAB. It can also simulate the operation of the edited program and display the operation in a clear manner. This software consists of many control blocks such as digital gates, timers, counters….

Quick Software Features:

1. Easy programming.
2. Simulation for the program.
3. Write/read the desired program into/from FAB PLC.

The following figure shows the executed program that operates the system:

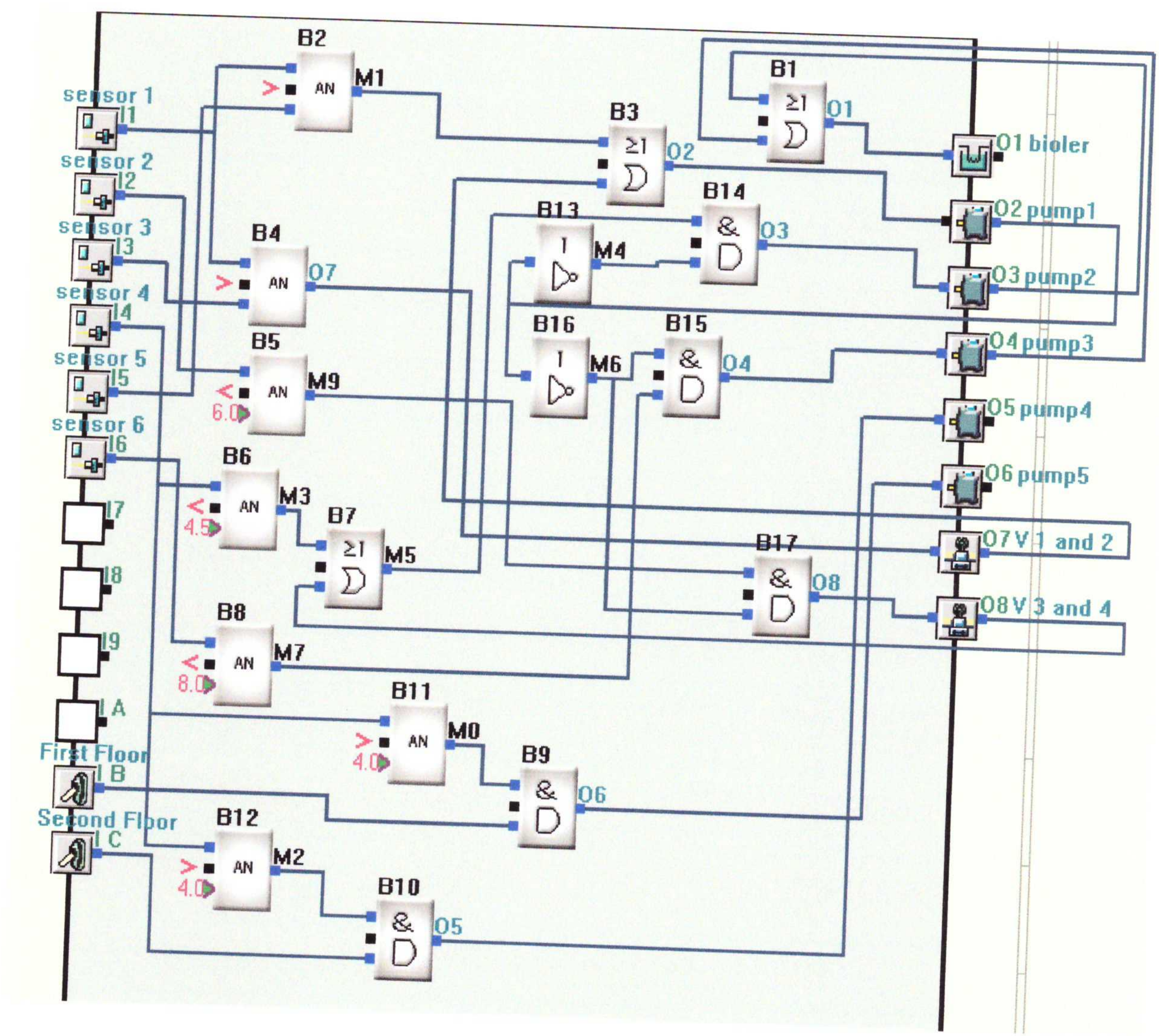


Figure (5.10): software design

5.3.3Design system

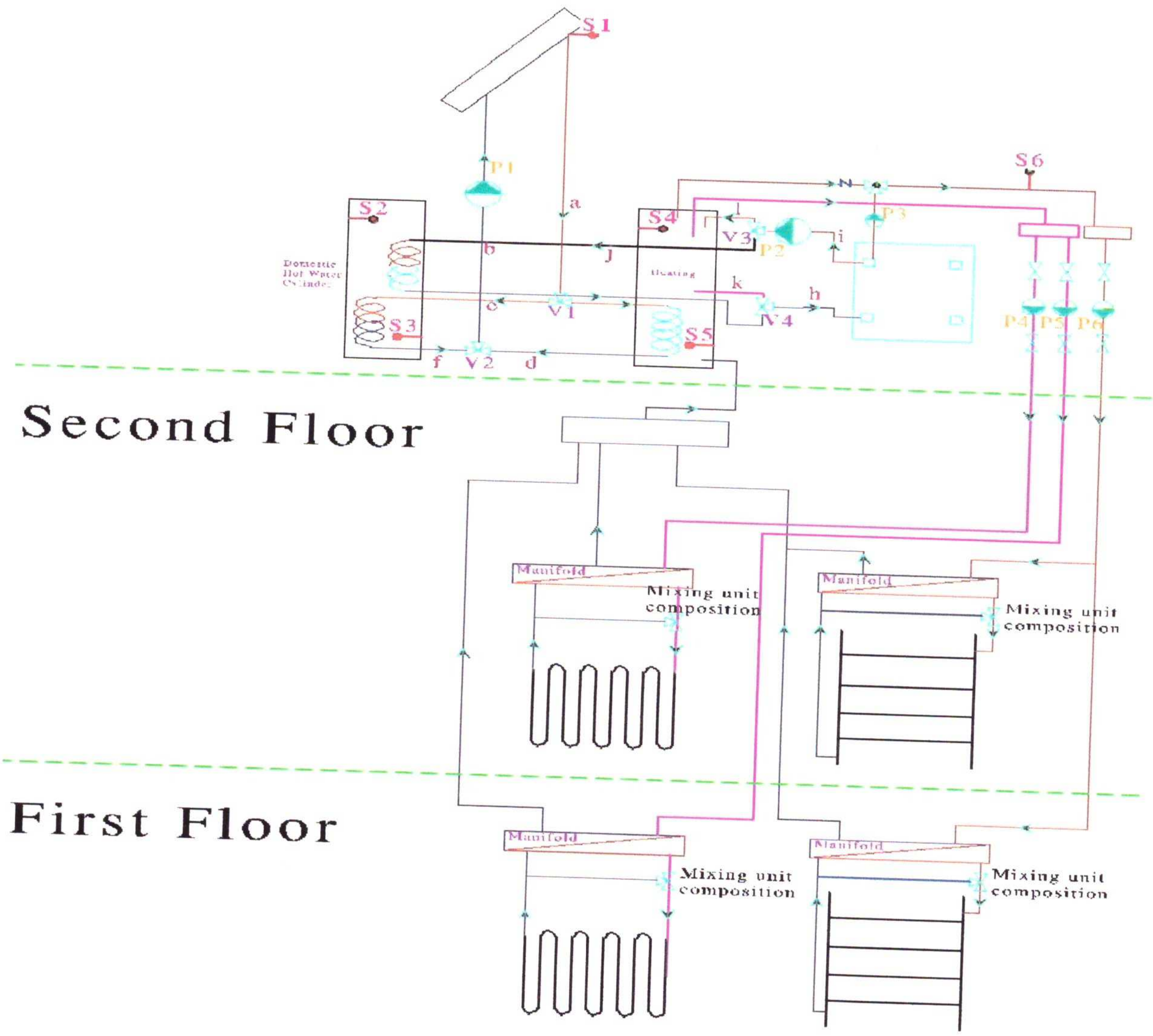


Fig (5.11) Design system

5.3.4.1 Description system.

The PLC principle work based on a comparison between the values of the sensor, and it will be based on the identification of the works. The principle of the system work as follows:

1 - If the temperature (S1) greater than the (S3), valve (1) and valve (2) normally open, which operating pump (1).

2 - If the temperature (S1) greater than the (S5), valve (1) and valve (2) setting is normally open, which operating pump (1).

3 - Pump1 does not operate in the if than S1 less than (S3 and S5).

4 - If the temperature sensor (2) less than (60^0C), then valve (3 and 4) setting will be normally close, boiler and pump 2 will turn on.

5 - If the temperature sensor (4) less than (45^0C), then valve (3 and 4) setting will be normally close, boiler and pump 2 will turn on.

6 - Pump2 does not operate in the event if the (S2) greater than (60^0C) and (S4) more than (45^0C).

7 - If the (S6) less than (70^0C), then the boiler and pump 3 will turn on.

8 - If the (S6) more or equal (70°C) they remain closed.

5.3.4.2 Valve work:

Valve (1):

1-V (1) (without reference electric): the path of a to c.

2-V (2) (in the case of a reference electric): track of the to e.

Valve (2):

1- V (2) (without reference electric): the path of d to b.

2- V (2) (in the case of a reference electric): track of the f to b.

Valve (3):

1- V (3) (without reference electric): the path of the i to l.

2- V (3) (in the case of a reference electric): the path of the i to j.

Valve (4):

2-V (4) (without reference electric): the path of the k to h.

1-V (4) (in the case of a reference electric): track of the g to h.

5.3.5 SCADA:

SCADA stands for Supervisory Control and Data Acquisition, computer remote monitoring and control of processes. As the name indicates, it is not a full control system, but rather focuses on the supervisory level. As such, it is a purely software package that is positioned on top of hardware to which it is interfaced, in general via Programmable Logic Controllers (PLCs).

5.3.5.1 SCADA Software Features:

- PLC monitoring & control.
- Built-In Menus.

- Intuitive Graphical Interfaces.
- Annunciation of Alarms & Events.
- Security Levels.
- Data export to spreadsheet programs (report).
- Real Time & Historical Trending.

5.3.5.2 SCADA benefits:

- The whole system can be controlled & monitored from any remote location.
- Replace large control monitoring panels with a user friendly interface.
- Update systems quickly by modifying software instead of hardware.
- Automated file storage of all data in spreadsheet or database format.
- History of events & alarms for trouble shooting.

Following figure (5.12) shows the SCADA program control & monitoring.

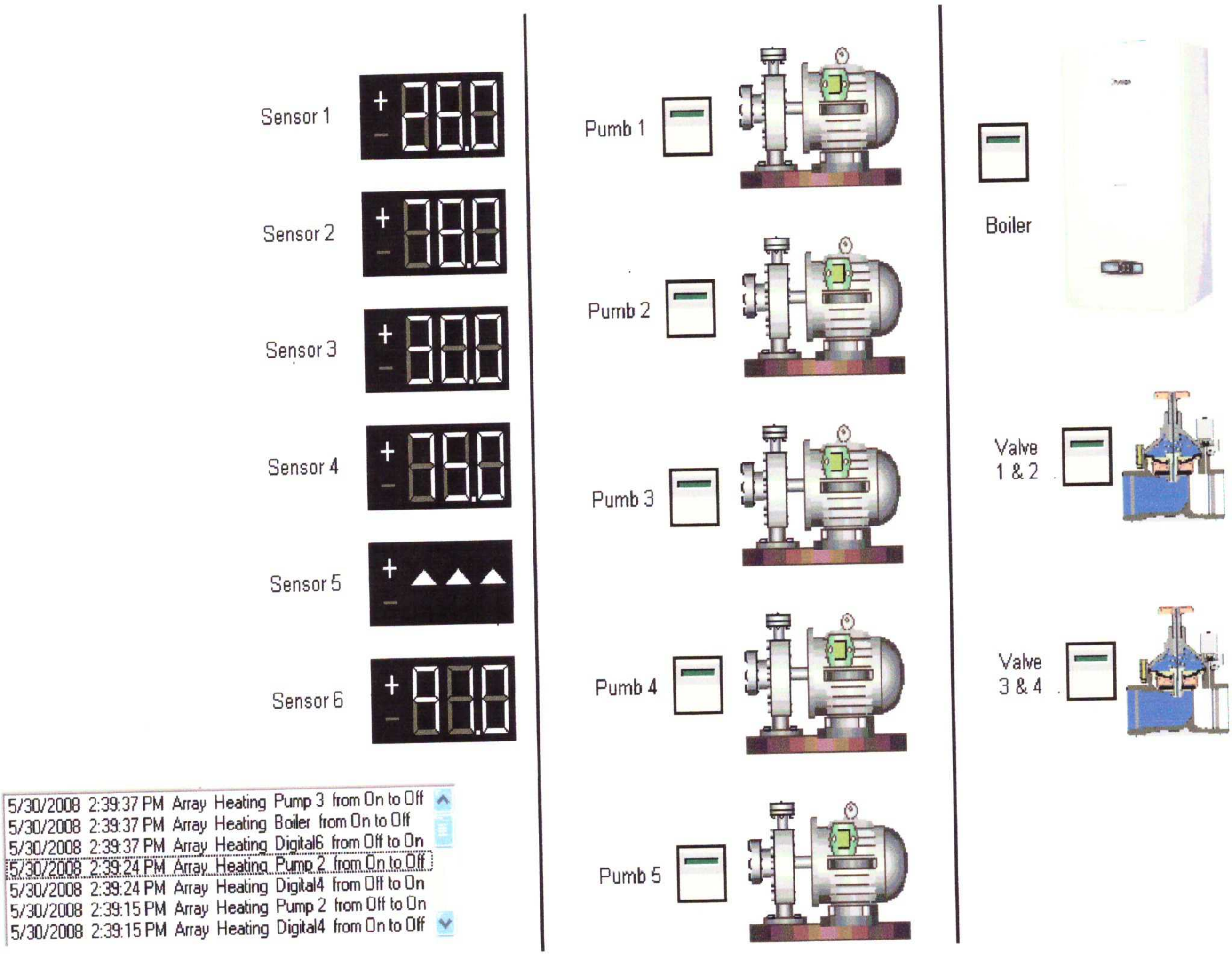


Figure (5.12): SCADA program.

The following figure (5.13) shows the SCADA program report for analog data and digital data.

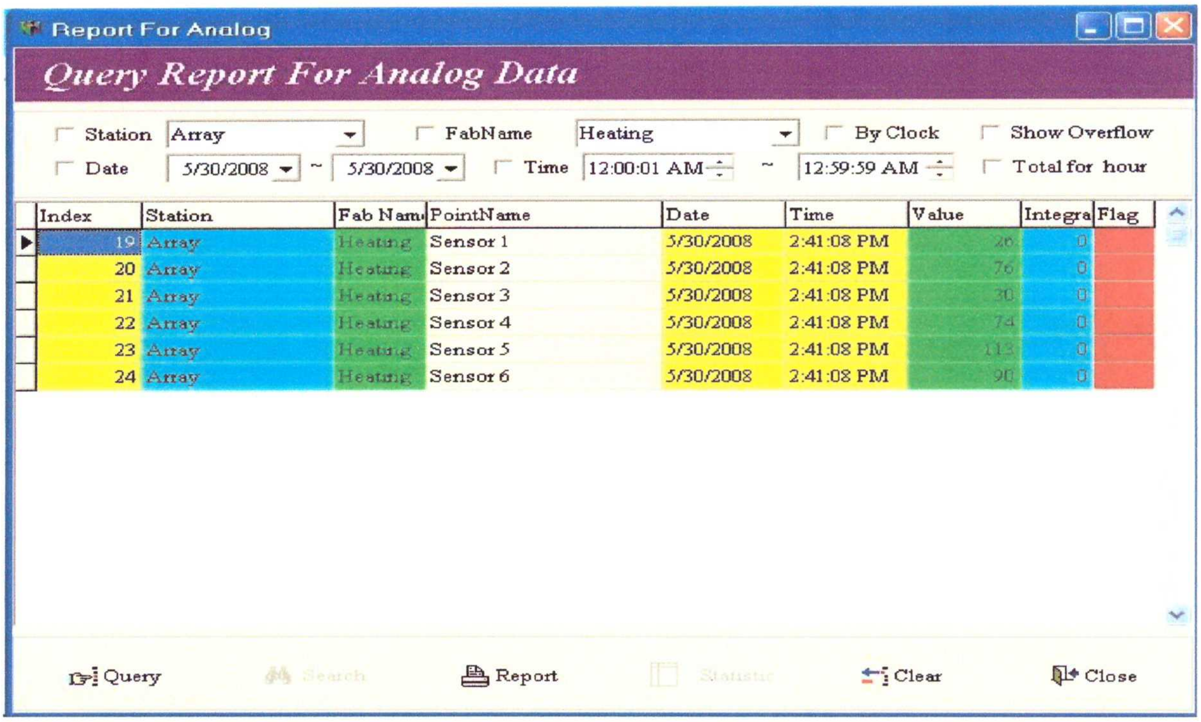
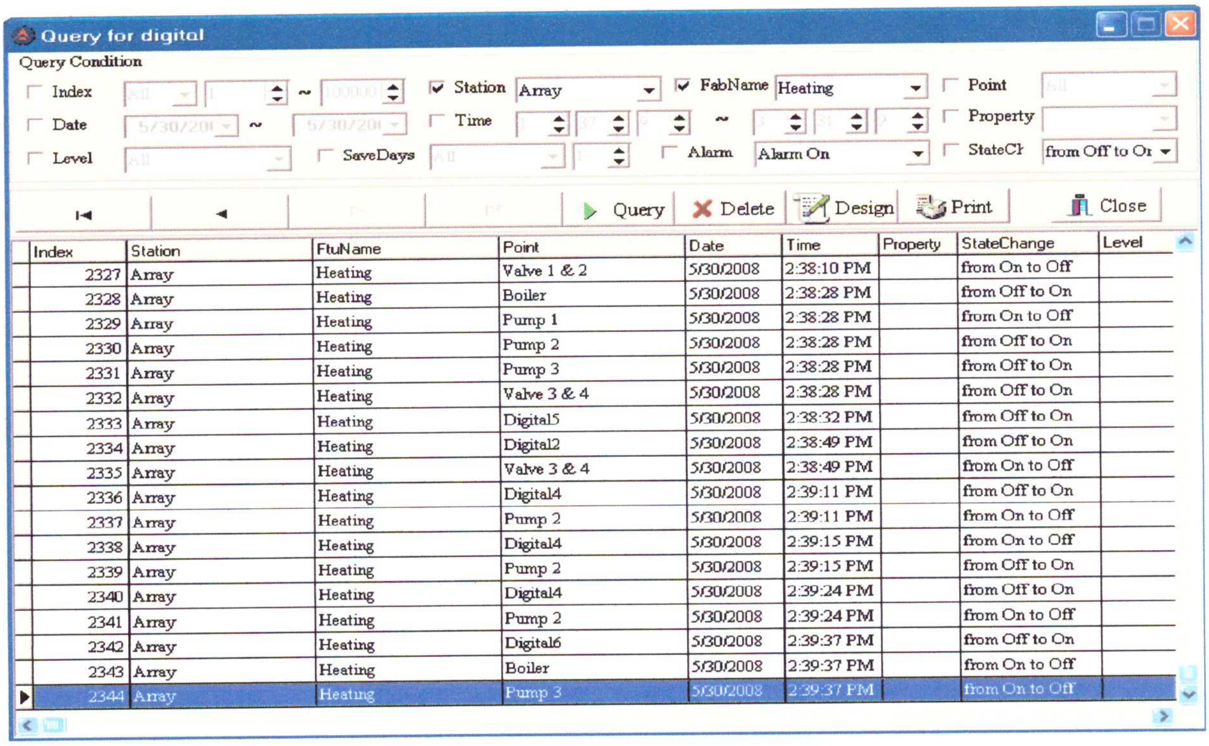


Figure (5.13.a) Analog data report.



Index	Station	FtuName	Point	Date	Time	Property	StateChange	Level
2327	Array	Heating	Valve 1 & 2	5/30/2008	2:38:10 PM		from On to Off	
2328	Array	Heating	Boiler	5/30/2008	2:38:28 PM		from Off to On	
2329	Array	Heating	Pump 1	5/30/2008	2:38:28 PM		from On to Off	
2330	Array	Heating	Pump 2	5/30/2008	2:38:28 PM		from Off to On	
2331	Array	Heating	Pump 3	5/30/2008	2:38:28 PM		from Off to On	
2332	Array	Heating	Valve 3 & 4	5/30/2008	2:38:28 PM		from Off to On	
2333	Array	Heating	Digital5	5/30/2008	2:38:32 PM		from Off to On	
2334	Array	Heating	Digital2	5/30/2008	2:38:49 PM		from Off to On	
2335	Array	Heating	Valve 3 & 4	5/30/2008	2:38:49 PM		from On to Off	
2336	Array	Heating	Digital4	5/30/2008	2:39:11 PM		from Off to On	
2337	Array	Heating	Pump 2	5/30/2008	2:39:11 PM		from On to Off	
2338	Array	Heating	Digital4	5/30/2008	2:39:15 PM		from On to Off	
2339	Array	Heating	Pump 2	5/30/2008	2:39:15 PM		from Off to On	
2340	Array	Heating	Digital4	5/30/2008	2:39:24 PM		from Off to On	
2341	Array	Heating	Pump 2	5/30/2008	2:39:24 PM		from On to Off	
2342	Array	Heating	Digital6	5/30/2008	2:39:37 PM		from Off to On	
2343	Array	Heating	Boiler	5/30/2008	2:39:37 PM		from On to Off	
2344	Array	Heating	Pump 3	5/30/2008	2:39:37 PM		from On to Off	

Figure (5.13.b) Digital data report

5.3.6 Flow Chart

Figure (5.11) illustrates the sequential of the system in getting the data from sensors in order to control the soil moisture.

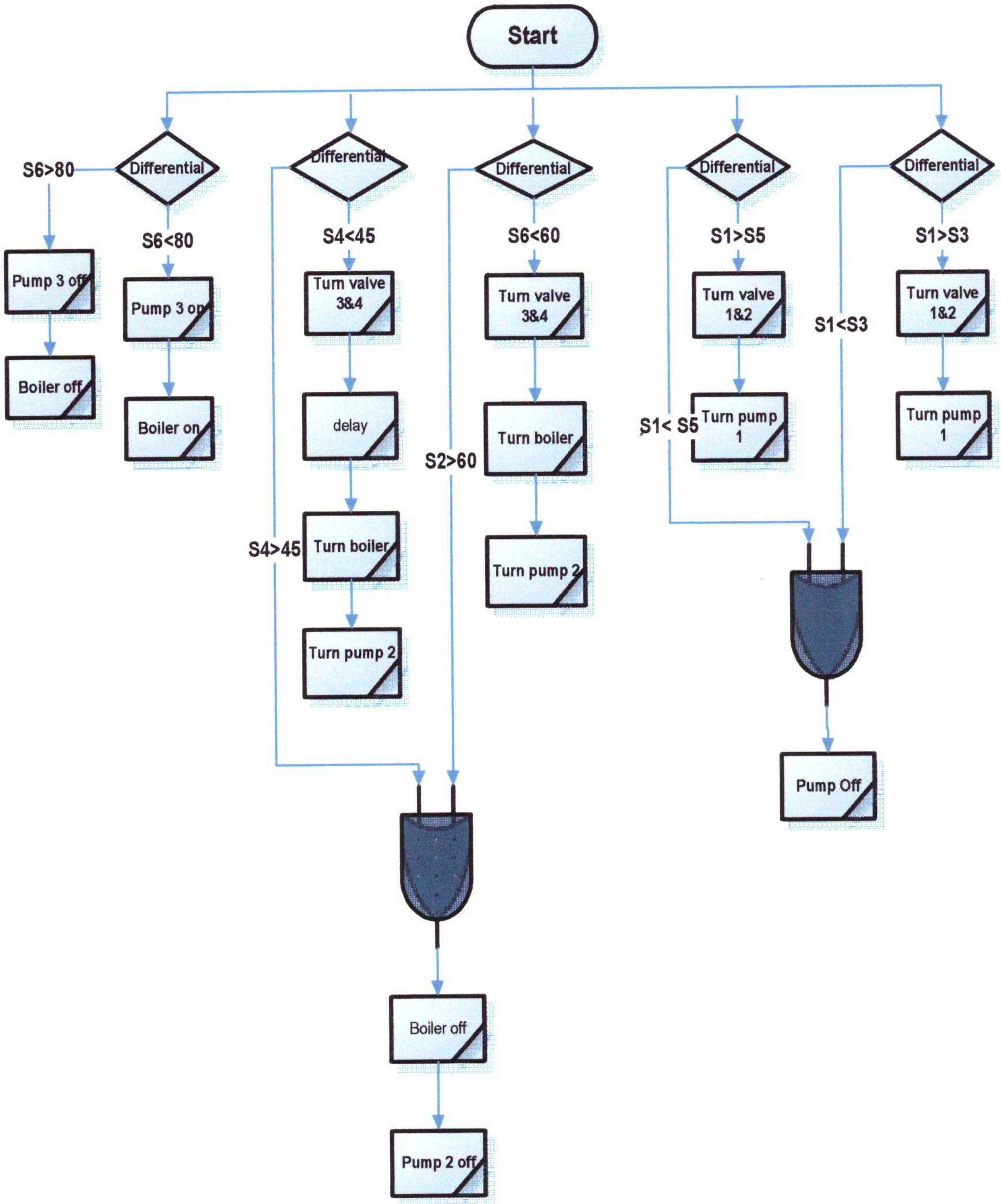


Figure (5.14): flow chart.

Section four

Control manifold (electrical)

5.4.1 Mixing unit composition.

5.4.2 Room temperature control with water compensation.

5.4.3 Heating curve.

5.4.1 Mixing unit composition.

The mixing unit for high temperature circuits includes the following Items:

A) Supply ball valve (water from the boiler).
B) Return ball valve (water to the boiler).
C) Three-way mixing valve.
D) 3-point thermoelectric actuator.
E) 3-speed circulation pump.
F) Immersion probe.
G) Safety contact thermostat.
H) Supply manifold connection.
I) Return manifold connection.
L) Check valve.

M) By-pass with calibration valve.

N) Heating circuit controller.

O) Remote temperature unit.

P) Outside sensor.

T) Thermostat.

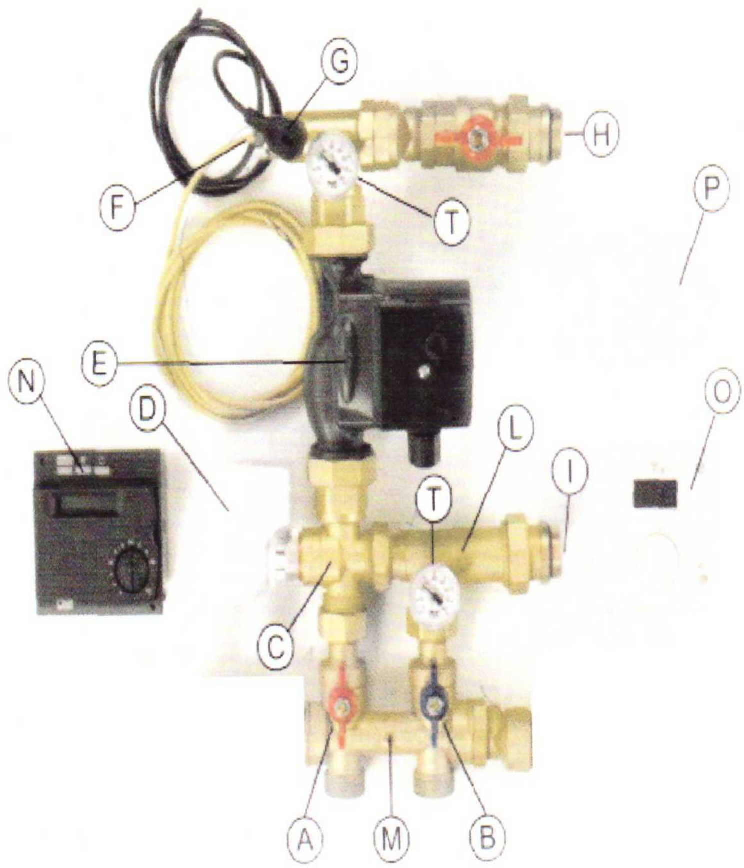


Fig (5.15): include circuit

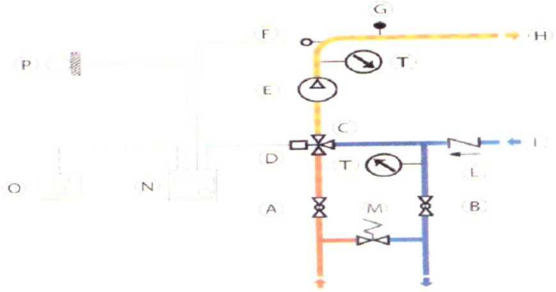
- Water circuit operation

The hot water fed from the boiler, through the ball valve (A), is mixed in the three-way valve (C) with part of the cold water coming from the return circuit (I) of the under floor heating system .the heating circuit controller (N) controls the 3-point thermoelectric actuator (D) based on the difference between the temperature set and the temperature detected by the outside sensor (P). The remote temperature unit (O) allows the control of the heating circuit controller (N) from a point inside the house. The flow temperature to the manifold (H) is controlled by the immersion probe (F) .The pump (E), favoring the mixing of the fluids, ensures delivery head in the radiant panel circuit. The safety thermostat (G) operates the pump electrically; switching it off in the case the present value is exceeded.

The water ,mixed unit it reaches the required temperature , is sent to the flow circuit (H) of the under floor heating system .The cold water coming from the return manifold (I) is partly supplied into the valve (C) and mixed with the hot water coming from the boiler ,and partly returns the boiler through the ball valve (B). The check valve (L) prevents the hot water from the being supplied directly into the pipes.

The by-pass valve (M) allows balancing the system, thus ensuring the minimum flow rate.

Fig (5.16): water circuit operation



- Safety contact thermostat

In the domestic under floor heating system , the water circulating in the pipes should never exceed 55°C,while in mixing units, the water supplied into primary circuit can exceed 70°C, depending the boiler setting .

In the case failure of the thermostatic head, the mixing unit is equipped with a safety contact thermostat which stops the mixing unit's circulation pump, to prevent the hot water from the boiler go straight into the system.

The thermostats main characteristics are:

- Screw mounting.
- Bimetallic type.
- Tripping temperature 55°C.
- Complete with wiring connecter.

Fig (5.17): safety contact thermostat

1- Heating circuit controller

Digital controller can be used to the water temperature in the panel heating system. The circuit includes the following items:

1. Room temperature set point.
2. Setting buttons.
3. Line selection buttons.
4. Display.
5. Operation mode buttons heating circuit :
   - Automatic operation.
   - Continuous operation.
   - Standby.
6. Function button with led for manual operation.
7. Connection facility for PC tool.

Power supply 230V (AC)

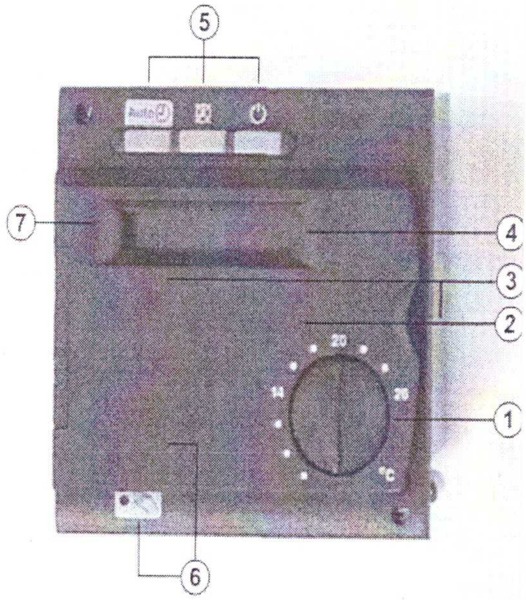


Fig (5.19) heating circuit controller

2- Room temperature unit

The room temperature unit is used for the internal control of the heating circuit controller .it is possible to:

- Modify the active characteristic curve.
- Program room temperature.
- Change the operation parameters of the controller.

Power supply: from the controller.

3- Outside sensor

Probe of the direction of the outside temperature with compensation for wind and sun radiation.

Sensor: NTC (575 Ohm a 20°C)

Regulation range: -50-+70°C

Power supply: from the controller.

Max distances from the controller: 80 meters.

4- Pit probe

Probe for the detection of the flow water temperature to the radiant circuit pit housing.

Regulation range: 0-+95°C

Power supply : from the controller

5- 3-point thermoelectric actuator.

The thermoelectric actuator has to perform the modular control of the hot water flow to the mixing circuit. Without auxiliary contact.

Power supply: 230V (AC).

5.4.3 Heating curve

The heating curve is the ratio between the minimum stated outside temperature and the maximum flow temperature to the heating bodies (e.g. 40°C for floor panel). The heating circuit controller generates the flow temperature set point as a function of the selected heating curve, insuring a content room temperature careless the change of the outside temperature .if a remote sensor is connected, the curve will shift according to the climatic zone and building thermal inertia. Example: setting of the set point given the following graph, established the outside temperature (-5°C) and the state flow temperature (40°C), combine the two valves. The instruction point establishes the set point.

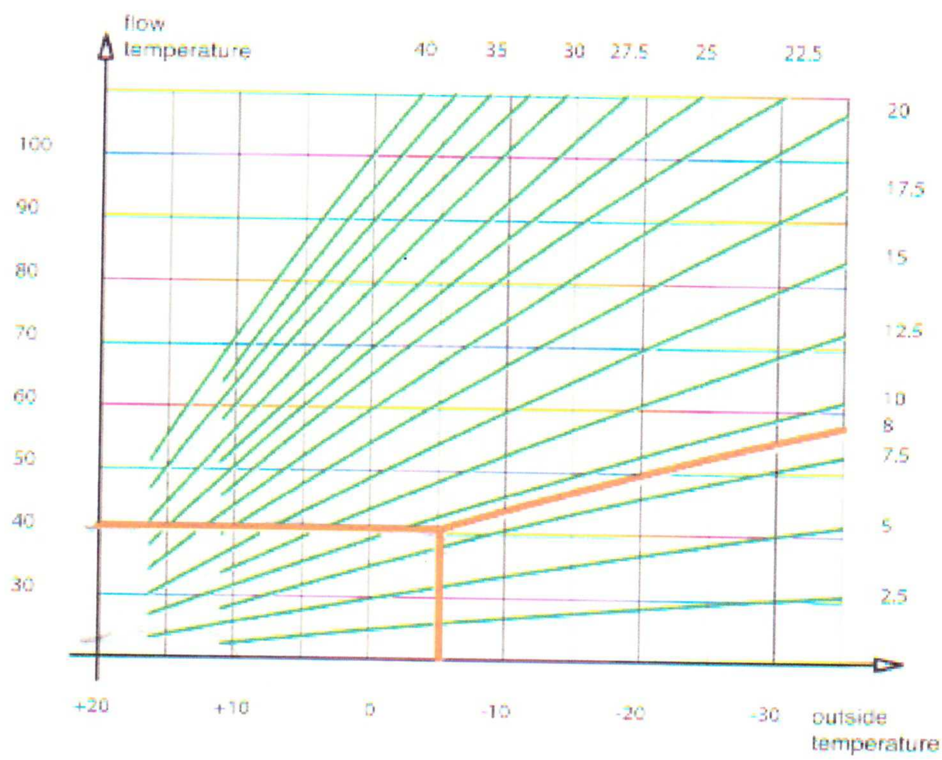


Fig (5.20) curve heating.

Recommendations and suggestion

1- We suggest to use microcontroller to control our system , since it is easy or normal persons to deal with, and cheep than using PLC.

2- We recommend to do test for evacuated tube to extract its parameter and most suitable angle which guide us to best efficiency.

3- We suggest to perform study to make solar panel rotate with sun angle

References:

1) Mohammed A. Alsaad & Mahmoud A. Hammad, Heating and air Conditioning, 2nd edition, National Library Department, Jordan, 2001.

2) John A.Duffie &William A. Beckman, Solar Engineering of Thermal Processes, 3rd edition, John Wiley &Sons, Inc.2006

3) Tiemme, technical Catalogue Underfloor Heating system, Italy, 2007.

4) Wisbo Underfloor Heating System, Sweden, March 2002.

5) Measurement system application and design .E.O. Doebelin, 4th edition .McGraw-Hill, 1990.

6) Engineering Thermodynamics, Work and Heat Transfer. Rogers and May hew, 3rd edition. Longman, 1983.

7) http://www.daviddarling.info/encyclopedia/E/AE_evacuated_tube_collector.html.

8) http://www.underfloorheatingsystems.co.uk/underfloor-heating-features-benefits.html.

9)http://www.energymanagertraining.com/equipment_all/boiler/eqp_Boiler_Types.htm.

10) http://en.wikipedia.org/wiki/Solar_thermal_collector#Evacuated_Tube.

11)http://eammar.en.alibaba.com/product/50393587/51885020/U_type_Vacuum_Tube/Vacuum_Tube_for_U_Type.html

12) http://www.solarserver.de/lexikon/selektive_beschichtung-e.html.

13) Renewable Energy and Environment Research (RREU) at PPU.

14) Energy Efficient Building Code (Palestinian Code)

Appendix

Table (A-1) Thermal Conductivity.

Material	Thermal Conductivity k(W/m.°C)
Polystyrene	0.037
Hard Stone	2.20
Brick (7cm)	0.21
Brick (18cm)	0.72
Mortar	1.4
Asphalt	1.2
Cement Plaster	0.87
Soil	1.4
Ceramic Titles	1.2
Concrete	1.85

Table (A-2) Inside &Outside Film Resistance(Ri & Ro)-m^2K/W

Element	Ri	Ro
Wall	0.31	0.05
Ceiling	0.21	0.05

Table (A-3) Air change per hour in residences application

Kind of Room or Building	Air Change Per Hour
Room with windows or exteriors doors on one side only	1
Kitchens, laundries, bathrooms, ballrooms	2
Toilets, auditorium	3
Room tithe windows or exteriors doors on two sides	1.5

Table (A-4) Overall Heat Transfer Coefficient for Windows (W/m.°C)

Glass Layers	Space Between Double Glass	
	6mm	20mm
Double Glass	3.7	2.7

Table (A.5) Overall Heat Transfer Coefficient for Doors (W/m.°C)

Door Type	Without Storm Door	With Wood Storm Door	With Metal Storm Door
35mm-wood	3.6	1.7	2.2
25mm-wood	3.1	1.6	1.9
40mm-wood	2.8	1.5	1.8
45mm-wood	2.7	1.5	1.8
50mm-wood	2.4	1.4	1.7
Aluminum	7	---	---
Steel	5.8	---	---

Table A-6-a Water supply fixture Branch Size

Fixture[a]	Use	Type of Supply control	Fixture Units[b]	Min.Size of Fixture Branch[d] in.
Bathroom group[c]	Private	Flushometer	8	-
Bathroom group[c]	Private	Flash tank for closed	6	-
Bathtub	Private	Faucet	2	1/2
Bathtub	General	Faucet	4	1/2
Clothes washer	Private	Faucet	2	1/2
Clothes washer	General	Faucet	4	1/2
Combination fixture	Private	Faucet	3	1/2
Dishwasher[f]	Private	Automatic	1	1/2
Drinking fountain	Offices , etc	Faucet 3/8 in	0.25	1/2
Kitchen sink	Private	Faucet	2	1/2
Kitchen sink	General	Faucet	4	1/2
Laundry trays (1-3)	Private	Faucet	3	1/2
Lavatory	Private	Faucet	1	3/8
Lavatory	General	Faucet	2	1/2
Separate shower	Private	Mixing valve	2	1/2
Service sink	General	Faucet	3	1/2
Shower head	Private	Mixing valve	2	1/2
Shower head	General	Mixing valve	4	1/2
Urinal	General	Flushometer	5	3/4[e]
Urinal	General	Flush tank	3	1/2
Water closet	Private	Flushometer	6	1
Water closet	Private	Flushometer/lank	3	1/2
Water closet	Private	Flush tank	3	1/2
Water closet	General	Flushometer	10	1
Water closet	General	Flushometer/lank	5	1/2
Water closet	General	Flush tank	5	1/2

Table A-6-b: For Estimating Demand

Supply Systems Predominantly For Flush Tanks		**Supply Systems Predominantly For Flushometers**	
Load WSFU*	*Demand gpm*	***Load WSFU****	*Demand gpm*
6	5	-	-
10	8	**10**	27
15	11	**15**	31
20	14	**20**	35
25	17	**25**	38
30	20	**30**	41
40	25	**40**	47
50	29	**50**	51
60	33	**60**	55
80	39	**80**	62
100	44	**100**	68
120	49	**120**	74
140	53	**140**	78
160	57	**160**	83
180	61	**180**	87
200	65	**200**	91
225	70	**225**	95
250	75	**250**	100
300	85	**300**	110
400	105	**400**	125
500	125	**500**	140
750	170	**750**	175
1000	210	**1000**	218
1250	240	**1250**	240
1500	270	**1500**	270
1750	300	**1750**	300
2000	325	**2000**	325
2500	380	**2500**	380
3000	435	**3000**	435
4000	525	**4000**	525
5000	600	**5000**	600
6000	650	**6000**	650
7000	700	**7000**	700
8000	730	**8000**	730
9000	760	**9000**	760
10000	790	**10000**	790

WSFU: Water Supply Fixture Units

Table A-7 Cast-Iron Boiler Mod. ELBA

CAST-IRON BOILER Mod. ELBA

MAIN FEATURES

Model		23	33	43	53	63	73
Maximum thermal capacity	kW	27.0	36.5	47.9	57.9	68.4	80.5
Reduced thermal capacity	kW	22.1	30.9	39.5	50.4	60.5	70.1
Maximum thermal power	kW	24.0	33.0	43.6	53.0	63.0	74.5
Reduced thermal power	kW	20.0	28.0	36.0	46.0	55.0	64.0
Efficiency at nominal power	%	88.8	90.5	90.9	91.9	92.0	92.5
Efficiency at 30% capacity	%	89.9	91.4	91.7	92.0	92.5	92.8
Efficiency category		★	★★	★★	★★	★★	★★
Heat loss from the case (Δt = 50°C)	%	1.8	1.4	1.1	0.8	0.7	0.5
Heat loss at the chimney with burner on	%	9.4	8.1	8.0	7.8	7.3	7.0
Heat loss at the chimney with burner off	%	0.1	0.1	0.1	0.1	0.1	0.1
Flue gas temperature (PN)	°C	215	190	187	184	175	170
Flue gas flow rate (methane)	kg/h	49.4	65.7	85.6	102.6	120.6	141.2
Flue gas flow rate (oil)	kg/h	40.0	53.2	69.3	83.1	97.7	114.5
CO_2 content (methane G 20)	%	9÷9,7	9÷9,7	9÷9,7	9÷9,7	9÷9,7	9÷9,7
CO_2 content (combi oil I.4E-20°)	%	12.5÷13	12.5÷13	12.5÷13	12.5÷13	12.5÷13	12.5÷13
Combustion chamber volume	dm³	14.91	22.37	29.83	37.29	44.75	52.21
Water content	l	14.6	18.2	21.8	25.4	29.0	32.6
Number of elements	n°	3	4	5	6	7	8
Load loss on flue gas side	Pa	8	22	30	32	45	60
Load loss on water side	kPa	4.8	5.6	6.0	7.1	10	11.2
Minimum heating water capacity	l/h	680	950	1230	1520	1800	2150
Maximum central heating temperature	°C	82	82	82	82	82	86
Minimum central heating temperature	°C	49	49	49	49	49	49
Maximum operating pressure	bar	4	4	4	4	4	4
System flow/return		1" 1/4	1" 1/4	1" 1/4	1" 1/4	1" 1/4	1" 1/4
Chimney diameter	mm	150	150	150	150	150	150
Burner diameter (M8 screws)	mm	108	108	108	108	108	108
Voltage/frequency	V/Hz	230/50	230/50	230/50	230/50	230/50	230/50
Width	mm	500	500	500	500	500	500
Depth (L)	mm	375	485	595	695	795	895
Height	mm	855	855	855	855	855	855
Net weight of boiler	kg	121	150	177	202	230	259
CE Certificate		49BL3332					

Fondital reserves the right to make necessary modifications without prior information.

fondital

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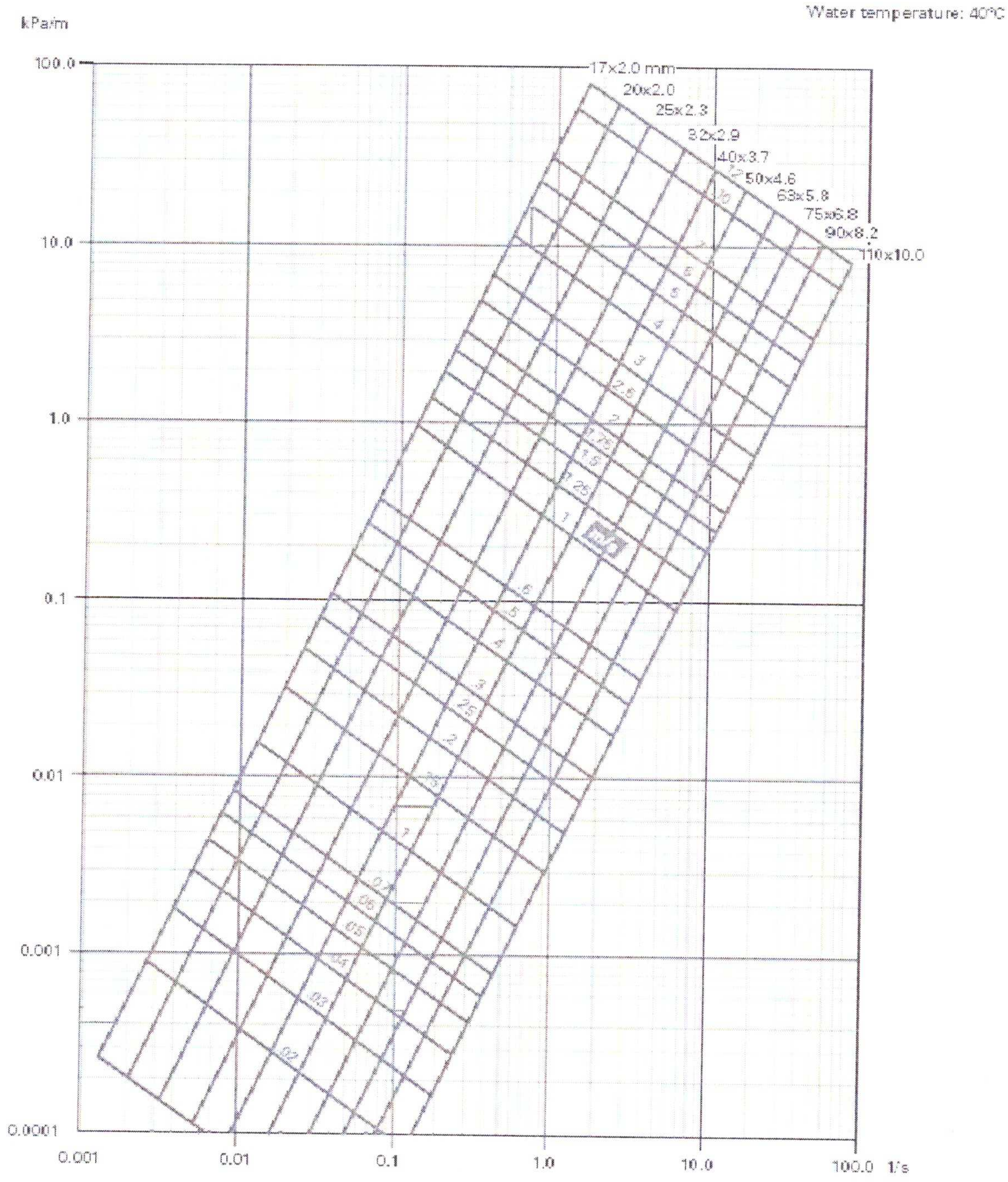
Table (A-8) Expansion tank minimum capacity

Boiler Capacity (kW)	Tank Volume (Liter)
Up to 29	100
58	200
87	250
116	500
175	750
233	1000

Diagram (B-1) Pressure drop monogram Wirsbo-PEX



(B-2) Psychometric Chart

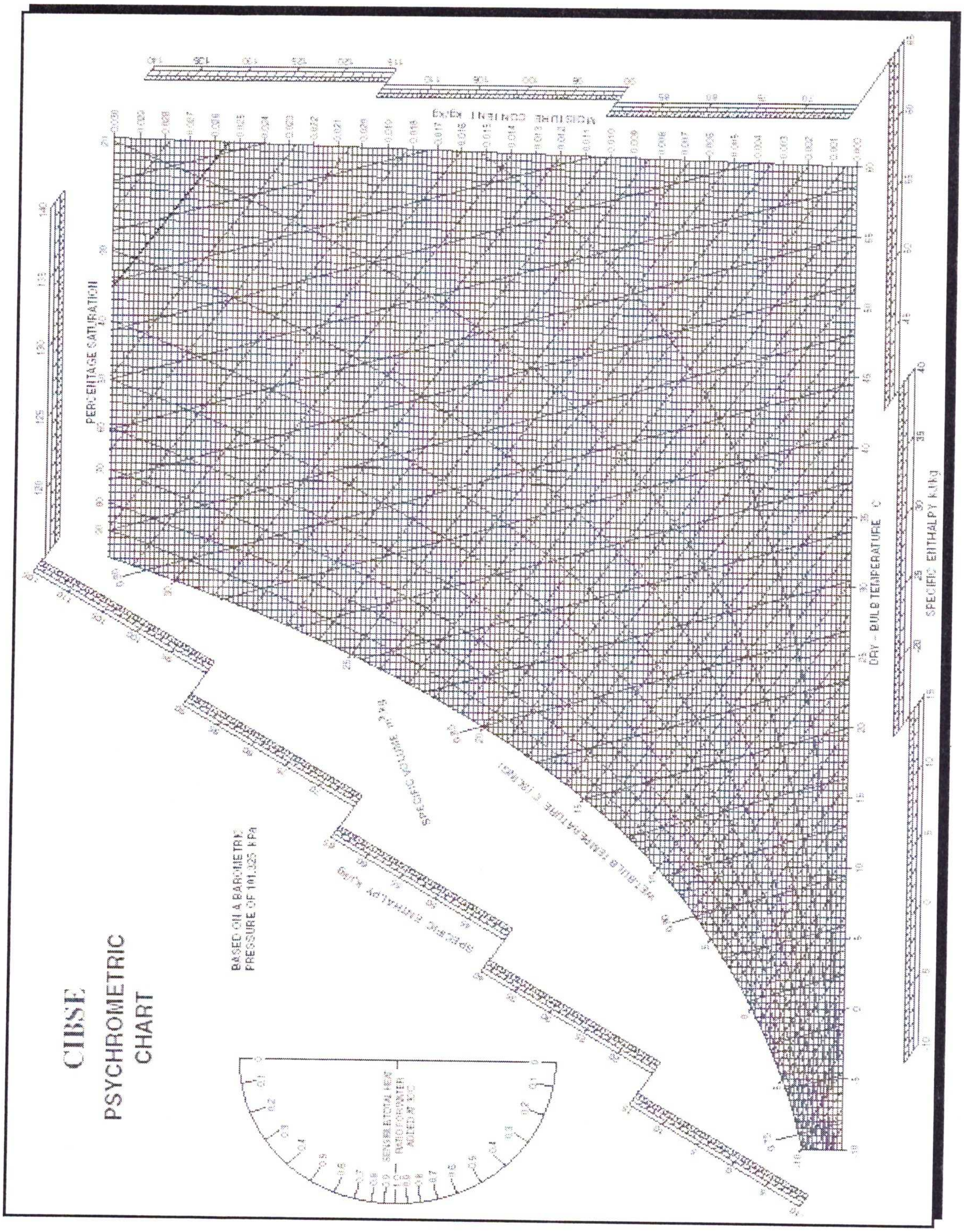
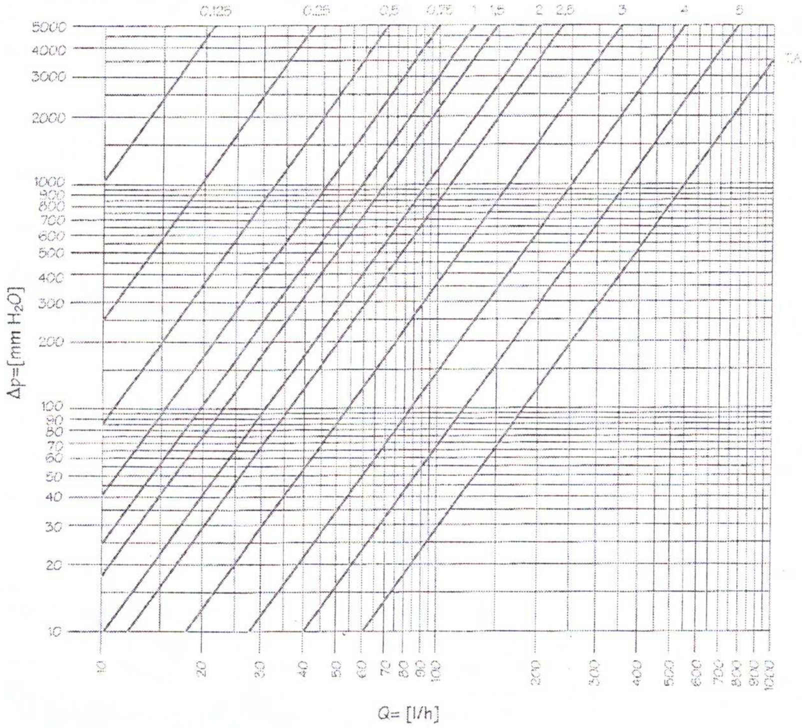


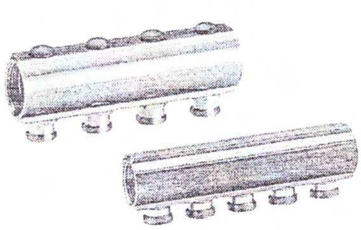
Diagram (B-3) Giacomini manifold



	Kv
0,125	0,03
0,25	0,06
0,5	0,10
0,75	0,14
1	0,18
1,5	0,21
2	0,28
2,5	0,4
3	0,54
4	0,87
5	1,22
T.A.	1,7

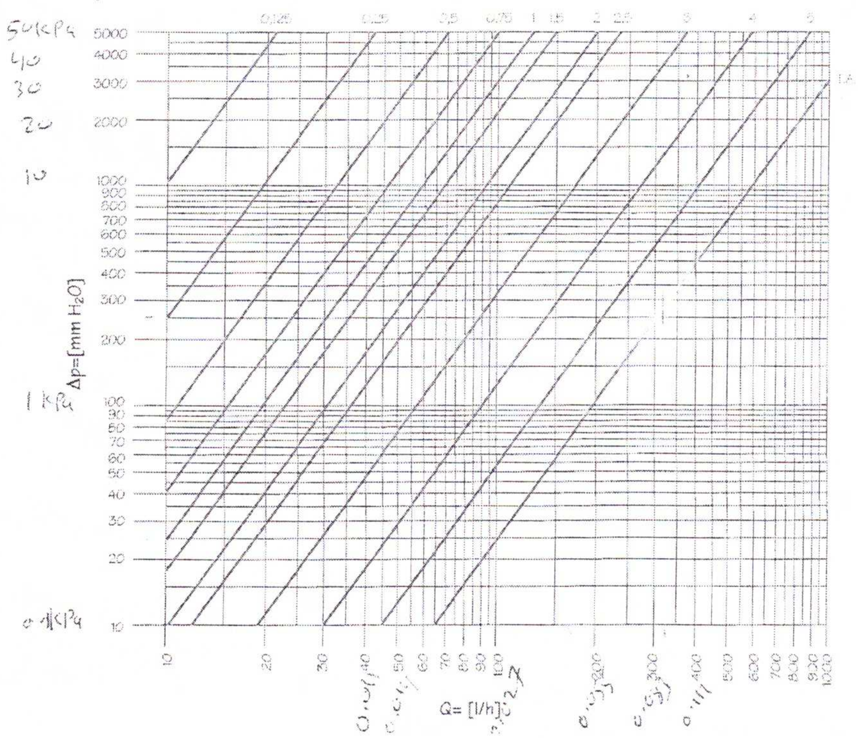
R551S + R553S

1" x 18



I numeri relativi alle curve indicano i numeri di giri di apertura del detentore (T.A.= Tutto Aperto)
The numbers, corresponding to each curve, indicate the lock shield opening turns (T.A.= Fully open)
Les chiffres relatifs aux courbes indiquent le nombre de tours d'ouverture du détendeur (T.A.= complètement ouvert)
Die an den Kurven eingetragenen Zahlen zeigen, wie viele Umdrehungen der Detentor geöffnet ist (T.A.= ganz geöffnet)
Los números de las curvas indican el número de vueltas de apertura del detentor (T.A.= Todo Abierto)
Os números relativos às curvas indicam o número de voltas de abertura do retentor (T.A.= Todo Aberto)
De cijfers in de tabel en bij de curven duiden op het aantal omwentelingen van de spindel (T.A.= Volledig Open)
Цифры, указанные над графиками, соответствуют числу поворотов открытия заслонки
Čísla křivek odpovídají počtu otáček otevření regulačního šroubení rozdělovače. (T.A.= plně otevřeno)
Krzywa przedstawia liczbę obrotów trzpienia do otwarcia zaworu powrotnego (T.A.= całkowicie otwarty)

Collettori di distibuzione
Manifolds
Collecteurs de distribution
Verteiler
Colectores de distribución
Colectores de distribuição
Verdelers
Распределительный коииектор
Sestava rozdělovačů
Profile rozdzielacza



$\Delta P = \left(\frac{Q}{Kv}\right)^2 \times \frac{1}{100}$

ΔP = pressure loss in mm H2
Q = water flow in l/hr

R551S + R553S

11/4" x 18

specific ... of ...

	Kv
0,125	0,03
0,25	0,06
0,5	0,10
0,75	0,14
1	0,18
1,5	0,21
2	0,28
2,5	0,4
3	0,59
4	0,95
5	1,42
T.A.	2,06

(B-4): TOWEL RAILS.

model	Depth	Height	Centre Distance	Length	Thermal capacity ΔT=50 K
	mm	mm	mm	mm	W
8/450	40	800	450	490	**362**
8/550	40	800	550	590	**423**
12/450	40	1120	450	490	**509**
12/550	40	1120	550	590	**602**
15/450	40	1440	450	490	**748**
15/550	40	1440	550	590	**640**
19/450	40	1760	450	490	**791**
19/550	40	1760	550	590	**932**

Max. operating pressure: 600kPa (6 bar)
Heating capacities comply with UNI EN442-2

model	Depth	Height	Centre Distance	Length	Thermal capacity ΔT=50 K
	mm	mm	mm	mm	W
8/450	40	800	450	490	**363**
8/550	40	800	550	590	**423**
12/450	40	1120	450	490	**506**
12/550	40	1120	550	590	**607**
15/450	40	1440	450	490	**643**
15/550	40	1440	550	590	**763**
19/450	40	1760	450	490	**796**
19/550	40	1760	550	590	**933**

Max. operating pressure: 600kPa (6 bar)
Heating capacities comply with UNI EN442-2

Diagram (B-5) Biral pump

Biral Redline