PPU College Of Engineering and Technology
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Mechanical Engineering Department

Air Conditioning and Refrigeration Engineering Program

Bachelor Thesis

Graduation Project

Under Floor Heating System Using Solar Energy For Villa In Hebron City

Project Team

Faisal Osaily
Odai Hrenat

Project Supervisor

Eng. Kazem Osaily

Hebron – Palestine

June, 2012

بسم الله الرحمن الرحيم

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According to the project supervisor and the agreement of the testing committee members, this project is submitted to the department of mechanical engineering at college of engineering and technology in partial fulfillment of the requirement of the bachelor's degree (B.A).

Department Head Signature Supervisor Signature

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Examination Committee

……..…………………. ....…………………….

June,2012

Dedication

To my friends… *To whom help me…*

To my parents… *To my parents…*

To who love me… *To who love me…*

To all who find of their death a way of life to others.

To all martyrs who were killed by no fault of their own except wishing a flourishing future to their home.

To all who are troubled by their conscience and loyalty.

To all who violently love their homes and whom swords were broken without touching their determination.

To all mothers who bring, raise, and present who obliged us to have an ever-increasing recognition of their greatness.

To our supervisor Eng. Kazem Osaily

To Izzat Marji Group Engineers

To our country

To the souls of Palestinian martyrs

To the freedom fighters

To whom their guidance and support made this work possible

Faisal Osaily ***Odai Hrenat***

Acknowledgment

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And finally, our ultimate thanks go to all lectures and doctors, engineers, and laboratories' supervisors. Their efforts and their nice dealing with us improved our characters to become successful engineers in the future.

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Abstract

Under floor heating system using solar energy is a winter heating method that is considered as a part of what is known as panel heating, which uses solar energy instead of using boiler in most cases.

As a result of using diesel and other energy resources that affect environment by pollution and gases emission and affect the ozone layer, and as a result of the high cost of electricity and other energy resources, this system will be the solution which relies on solar energy.

Under floor heating uses low temperature water that will reduce the energy used in heating process and will reduce the heat losses from the system.

Solar energy will give sufficient temperature to heat the water used in under floor heating system. This method will reduce the cost of energy used and will reduce the environmental pollutions.

This project aims to study the principles of design for the villas relying on the heating system in under floor heating and environmental requirements and natural resources of the villa and choose the most appropriate location that meets these requirements and specifications and then exit through the recommendations of this project.

ملخص:

نظام التدفئة تحت البلاط باستخدام الطاقة الشمسية هو نظام للتدفئة في فصل الشتاء والذي يعتمد في اغلب الأحيان على الطاقة الشمسية عوضا عن المرجل في تسخين المياه المستخدمة في هذا النظام.

نتيجة لارتفاع أسعار الوقود والمصادر الأخرى المستخدمة في التسخين وكمية الملوثات الصادرة عنها والتي تؤثر بدورها على طبقة الأوزون؛ كان هذا النظام هو الحل الشامل لهذه المشكلة.

نظام التدفئة تحت البلاط لا يحتاج بطبيعته إلى درجات حرارة عالية وهذا يؤدي بدوره إلى تقليل الطاقة المستخدمة في النظام وما يفقده من طاقة.

يهدف هذا المشروع إلى دراسة مبادئ تصميم فيلا تعتمد على نظام التدفئة تحت البلاط باستخدام الطاقة الشمسية والاحتياجات اللازمة لهذا النظام.

Chapter One

Introduction

1.1 Introduction

Under floor heating system is a winter heating method that is considered as apart of what is known as panel heating. The heated panel in this case is part of the space floor to be heated.

Palestine is characterized by a climate of bitter cold in winter, which we need engineers' search for solutions for architectural, mechanical, thermal, environment and low cost. Giving the high cost of electricity and other energy resources floated the idea of this system which relies on solar energy with a large amount.

This project aims to study the principles of design for the villas relying on the heating system in under floor heating and environmental requirements and natural resources of the villa and choose the most appropriate location that meets these requirements and specifications and then exit through the recommendations of this project.

1.2 General Overview of the Project

As a result of using diesel and other energy resources which affect environment by pollution and gases emission and affect the ozone layer, and as a result of the high cost of electricity and other energy resources, this system will be the solution which relies on solar energy.

1.3 Importance of the Project

Under floor heating uses low temperature water that will reduce the energy used in heating process and will reduce the heat losses from the system.

Solar energy will give sufficient temperature to heat the water used in under floor heating system. This method will reduce the cost of energy used and will reduce the environmental pollutions.

1.4 Objectives of the Project

This project aims to study the principles of design for the villas relying on the heating system in under floor heating and environmental requirements and natural resources of the villa and choose the most appropriate location that meets these requirements and specifications and then exit through the recommendations of this Project.

1.5 Methodology and Project Tools

In the project we will use the scientific research method , and collect data from scientific books, internet, library, companies involved in this field, and people who have experience in this subject.

1.6 Project Boundary

The project will be applied on a schematic of villa supposed to be built in Hebron.

1.7 Budget For Project Tasks

Table 1.1 Budget

Task	**Cost (JD)**
Using Internet	50
Transportation	300
Copy from library	20
Printing papers	30
Sample of under floor layers	600
Total	1000

1.8 Project Outline

The proposal is composed of five chapters as follows:-

Chapter One:- Introduction

This chapter includes an overview of the main objectives, budget, and the project outline.

Chapter Two:- Load Calculation

This chapter includes a calculation of heating load in each space in the villa.

Chapter Three:- Solar Energy

This chapter includes an overview about solar energy, its benefits, applications, and how we can use it as an energy source for heating.

Chapter Four:- Under Floor Heating

This chapter includes an overview about under floor systems, construction, pipe loops, design parameters.

Chapter Five:-Equipment Selection

This chapter includes the main equipment used in under floor heating system using solar energy, how to select it, connections, and controlling.

1.10 Time Planning

The project plan follows the following time schedule, which includes the related task of the project and system analysis.

1.10.1 The first semester time plan

Task\week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Collecting information																
Load calculation																
Collecting information																
Solar energy																
Under floor																
Project documentation																

Figure 1.1: The first time plan

1.10.1 The second semester time plan

Task\week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Collecting information																
Under floor calculation																
Planning by AutoCAD																
Selection																
Project documentation																

Figure 1.2: The second time plan

Chapter Two

Load Calculation

2.1 INTRODUCTION

This chapter will explain the theory needed for design procedure of heating systems to meet best environmental situations for human comfort, which includes some details of heating, ventilation and air conditioning (HVAC). [1]

2.2 Human Comfort

The main objective of air conditioning is to maintain the environment in enclosed spaces at conditions that include the feeling of comfort to human. This feeling of comfort is influenced by a number of air parameters including temperature, humidity, air motion and purity. The purity of the air includes the absence of odors, toxic fumes and suspended particles, such as dust.

The normal body temperature is 37.2 ˚C, which is in more case higher than the ambient temperature. Thus heat is continuously transferred from humans to their ambient air by virtue of this difference in temperature. In general, body cooling takes place in different modes:

1) **Evaporation**

This mode of cooling accounts for the removal of a bout 25% of body heat. There are two mechanics of evaporation and a balancing reaction to respond to varying environment:

- Respiration: This accounts for the difference in the humidity of the air during inhale and exhale. More humidity is carried by exhaust air than by the inhale air.
- Insensible skin moisture: The skin is always covered by a thin film of sweat that evaporates into the surrounding air cooling the skin behind it. It terms insensible because it's a continuous process.

2) **Radiation**:

As the body or the clothing over it is at a higher temperature than the environment, heat loss from the body to the environment takes place continuously. The heat loss from the body by this mode accounts for about 45% of total heat loss of the body

3) **Convection**:

Heat is removed from the body by the air movement around the body; the air movement is due to heating the air in contact with the body, or by the wind in the environment. The heat loss by convection accounts to about 30% of the total heat loss by the body .

4) **Conduction**:

This heat loss results from direct contact of the body with objects in its surrounding. However, as far as normal human beings are considered the heat loss by this mode is negligible.[1]

2.3 Inside Design Conditions:

The name inside design conditions refer to temperature, humidity, air speed and cleanliness of inside air that will induce comfort to occupants of the space at minimum energy consumption. There are several factors that control of the selection of the inside design conditions and expenditure of energy to maintain those conditions:

1) The outside design conditions.

2) The period of occupancy of the conditioned space.

3) The level of activity of the occupants in the conditioned space.

4) The type of building and its use.

Usually the range of temperature difference between inside and outside is 4 to 12˚C. The relative humidity range for the conditioned space varies from 30% to 60%. A dry environment will be felt when the relative humidity falls below 30%, and sickness will be felt at relative humidity above 60%.

The indoor air speed is not designed as a parameter for comfort as long as it moves the treated air to the desired corners and edges of the spaces. However, it is desirable to keep it within the range of 0.1 to 0.35 m/s for comfort, the inside design conditions are:

For winter:

Dry bulb temperature T_d(20 - 23.5) ˚C.

Relative humidity RH = 50%.

For summer:

Dry bulb temperature T_d(22.5 – 26) ˚C.

Relative humidity RH = 50%. [7]

2.4 Ventilation:

Fresh air is required for the maintenance of healthy indoors air. This could be supplied by infiltration. But, if the infiltration is not enough, mechanical ventilation becomes necessary. The amount of the needed fresh air depends on the application. In hospitals, for example, 100% fresh air may be needed. In general, fresh air needed for one or more of the following reasons:

1) Oxygen concentration in the air must be within limits such as provided by 0.16 to 0.2 litters of air per second per person.
2) Carbon dioxide must be removed or diluted such that it does not exceed 0.1% in the air.
3) Body smells and other odors must be removed or diluted. [1]

2.5 Outside Design Conditions

Outside design conditions are very important parameters. They must be evaluated correctly since they will determine whether the air conditioning system will provide the desired comfort or not, whether the system will be undersized or oversized. An undersized system will not provide the desired indoor conditions for comfort. An oversized system will cost more than it should for a proper economical engineering system.

Outside design condition vary considerably with the location. They are determined by averaging conditions which occur over a number of years, and they generally exclude usually high or low values that are reached for a period of time less than 10 days for the summer and winter seasons. In Palestine, the outside design conditions are:

For winter:

Dry bulb temperature T_d = 3 ˚C.

Relative humidity RH = 73%.

For summer:

Dry bulb temperature T_d = 31˚C.

Relative humidity RH = 49%. [7]

2.6 Heating Load Calculation

The heating load of the building is comprised with the following components:

1) Heat loss through the exposed areas which consist of the walls, the roofs, windows, doors, and walls between the space and unheated spaces.
2) Heat required to warm air infiltrated through cracks of windows and doors, and by opening and closing of doors and windows or to warm mechanical ventilation air to the temperature of the space.
3) Domestic hot water load.

4) Miscellaneous heat load required such as for humidification of outside air, for a safety factor, or for emergencies. [1]

The equation used in the calculation of heat transfer through walls is given by:

$$Q = U\,A\,(T_i - T_o) \qquad (2.1)$$

Where,

Q : is the heat transfer rate. [W]

U : the overall coefficient of heat transfer. [W/m^2. ˚C]

A : the area of the wall. [m^2]

T_i : is the inside design temperature. [˚C]

T_o: is the outside design temperature. [˚C] [1]

2.7 Heat Loss by Infiltration

Infiltration is the leakage of outside air through cracks and clearances around the windows and doors. The amount of infiltration depends mainly on the tightness of the windows and doors on the outside wind velocity or the pressure difference between the outside and inside the heat load due to infiltration is given by**:**

$$Qt.f = \left(\frac{V_{inf}}{v_o}\right) * (h_i - h_o) \qquad (2.2)$$

Where,

h_i: Inside enthalpy of infiltrated air in $(\frac{kJ}{kg})$= 47

h_o: outside enthalpy of infiltrated air in $(\frac{kJ}{kg})$ =12

V_{inf} :The volumetric flow rate of infiltrated air in $(\frac{m^3}{s})$

v_o : Specific volume in$(\frac{m^3}{kg})$ at T_o is 0.784 [1]

2.8 Heat Loss by Ventilation

One of the main objectives of ventilation is the removal or the reduction of the produced contaminants. Mechanical ventilation is required for places in which the inside air is polluted due to activities that take place in these spaces such as closed areas. It should be noted that the ventilation heat load is not a part of the space heating load. The ventilation heating load is carried out by the heating coil of the warm air heating system. The following equation is used:

$$Q = \left(\frac{V*N}{3600}\right) * \rho * cp * \Delta T \tag{2.3}$$

Where ,

V: volume of room.

N: number of air change per hour.

cp: specific heat at constant pressure for air "1.005$(\frac{kJ}{kg.^\circ C})$"

ρ: Density of air "1.25 $(\frac{kg}{m^3})$"

ΔT:difreence in temperature. [1]

2.9 Domestic Hot Water Load

The domestic hot water load is generally estimated by assuming a constant daily consumption of hot water. The following equation is used**:**

$$Qw = M_w C_p (T_h - T_c) \quad (2.4)$$

Where ,

M_w: the daily consumption of domestic hot water. [kg/s]

T_h: the hot water supply temperature . [˚C]

T_c : the temperature of the cold water that must be heated to T_h. [˚C]

A widely used value for the daily consumption of domestic hot water is 280 liter per day for each family. This consumption rate can be reduced to 200 liter if a clothes washer is not used.

However, if the family composition is known, a daily consumption of 50 to 75 liter per day for each of the first two members of the family and 30 to 50 liter per day for each additional person is used. Then, for an average family of six members, the domestic hot water consumed daily ranges from 220 to 350 liter per day. [1]

So:

$Qs\ (Domestic) = Mw*Cp*(Th-Tc)/(\Delta t)$

$Qs\ (Domestic)$ = (280*4180*60)/(24*3600) = **9753.3W**

2.10 the overall coefficient of heat transfer:

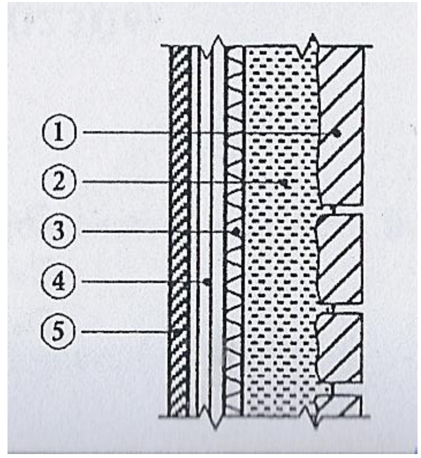
Calculation of "U" for :

1)external wall: consists of two parts:

A)in general as Table (2.1) and section (A-A) [1] which represent the construction of external wall:

Table (2.1)

k W/m.˚C	Thickness M	Layer
2.2	0.07	Hard Stone (1)
1.75	0.1	Concrete (2)
0.034	0.02	Polystyrene (3)
0.72	0.1	Block (4)
1.2	0.01	Cement plaster(5)



Section (A-A)

$$U = \frac{1}{\left(\frac{1}{hfin}\right) + \left(\frac{\Delta x}{Ks}\right) + \left(\frac{\Delta x}{Kc}\right) + \left(\frac{\Delta x}{Ki}\right) + \left(\frac{\Delta x}{Kb}\right) + \left(\frac{\Delta x}{Km}\right) + \left(\frac{1}{hfout}\right)} \quad (2.5)$$

Where,

ks : Thermal conductivity of stone . [W/m.˚C]

kc : Thermal conductivity of concrete. [W/m.˚C]

kb: Thermal conductivity of block . [W/m.˚C]

km : Thermal conductivity of cement plaster. [W/m.˚C]

ki: Thermal conductivity of polystyrene. [W/m.˚C]

hf_{in}: convection coefficient of inside air. [W/m^2.˚C]

hf_{out}: convection coefficient of outside air. [W/m^2.˚C]

So:

$$U = \frac{1}{\left(\frac{1}{9.37}\right) + \left(\frac{0.07}{2.2}\right) + \left(\frac{0.1}{1.75}\right) + \left(\frac{0.02}{0.034}\right) + \left(\frac{0.1}{0.72}\right) + \left(\frac{0.01}{1.2}\right) + \left(\frac{1}{22.7}\right)}$$

$U = 1.02$ W/m^2.˚C

B) as in section (A-A) and Table (2.1) in addition to court layer inside for bathrooms:

$$U = \frac{1}{\left(\frac{1}{hfin}\right) + \left(\frac{\Delta x}{Ks}\right) + \left(\frac{\Delta x}{Kc}\right) + \left(\frac{\Delta x}{Ki}\right) + \left(\frac{\Delta x}{Kb}\right) + \left(\frac{\Delta x}{Km}\right) + \left(\frac{\Delta x}{Kg}\right) + \left(\frac{1}{hfout}\right)} \quad (2.6)$$

Where,

kg: Thermal conductivity of court.

Then we substitute the magnitude in previous equation to get:

$$U = \frac{1}{\left(\frac{1}{9.37}\right) + \left(\frac{0.07}{2.2}\right) + \left(\frac{0.1}{1.75}\right) + \left(\frac{0.02}{0.034}\right) + \left(\frac{0.1}{0.72}\right) + \left(\frac{0.01}{1.2}\right) + \left(\frac{0.005}{1.1}\right) + \left(\frac{1}{22.7}\right)}$$

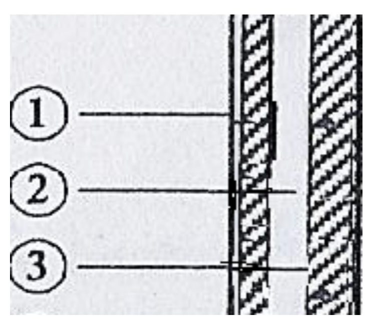
$U = 1.01$ W/m^2.˚C

2) internal wall: consists of five parts:

A) in general as Table (2.2) and section (B-B)[1] which represent the construction of internal wall:

Table (2.2)

k W/m.˚C	**Thickness** m	**layer**
1.2	0.01	Cement plaster (1)
0.72	0.1	Block (2)
1.2	0.01	Cement plaster (3)



Section (B-B)

$$U = \frac{1}{\left(\frac{2}{hfin}\right) + \left(\frac{\Delta x}{Kb}\right) + 2 * \left(\frac{\Delta x}{Km}\right)} \quad (2.7)$$

Then we substitute the magnitude in previous equation to get:

$$U = \frac{1}{\left(\frac{2}{9.37}\right)+\left(\frac{0.1}{0.72}\right)+2*\left(\frac{0.01}{1.2}\right)} = 2.7 \text{ W/m}^2.^\circ\text{C}$$

B) as the section (B-B) and table (2.2) in addition to court layer inside for one face:

$$U = \frac{1}{\left(\frac{2}{hfin}\right) + \left(\frac{\Delta x}{Kb}\right) + 2 * \left(\frac{\Delta x}{Km}\right) + \left(\frac{\Delta x}{Kg}\right)} \quad (2.8)$$

So:

$$U = \frac{1}{\left(\frac{2}{9.37}\right)+\left(\frac{0.1}{0.72}\right)+2*\left(\frac{0.01}{1.2}\right)+\left(\frac{0.005}{1.1}\right)} = 2.68 \text{ W/m}^2.^\circ\text{C}$$

C) as the section (B-B) and table (2-2) in addition to court layer inside for two face:

$$U = \frac{1}{\left(\frac{2}{hfin}\right) + 2 * \left(\frac{\Delta x}{Kg}\right) + \left(\frac{\Delta x}{Kb}\right) + 2 * \left(\frac{\Delta x}{Km}\right)} \quad (2.9)$$

So:

$$U = \frac{1}{\left(\frac{2}{9.37}\right)+2*\left(\frac{0.005}{1.1}\right)+\left(\frac{0.1}{0.72}\right)+2*\left(\frac{0.01}{1.2}\right)} = 2.64 \text{ W/m}^2.^\circ\text{C}$$

D) As Table(2.3) and section(C-C) below[1] "concrete internal wall with two cement plaster faces":

Table (2.3)

k W/m.˚C	Thickness m	Layer
1.2	0.01	Cement plaster (1)
1.75	0.2	Concrete (2)
1.2	0.01	Cement plaster (3)

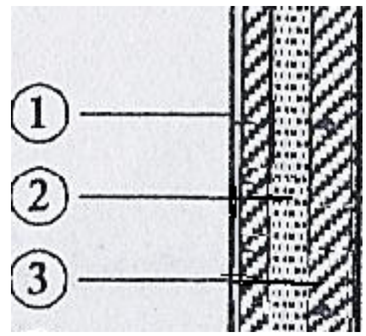


Figure (2.3)

$$U = \frac{1}{\left(\frac{2}{hfin}\right) + \left(\frac{\Delta x}{Kc}\right) + 2 * \left(\frac{\Delta x}{Km}\right)} \quad (2.10)$$

Then we substitute the magnitude in previous equation to get:

$$U = \frac{1}{\left(\frac{2}{9.37}\right) + \left(\frac{0.2}{1.75}\right) + 2 * \left(\frac{0.01}{1.2}\right)} = 2.9 \frac{W}{m^2.c}$$

E)as the section (C-C) and table (2.3) in addition to court layer inside for one face:

$$U = \frac{1}{\left(\frac{2}{hfin}\right) + \left(\frac{\Delta x}{Kc}\right) + 2 * \left(\frac{\Delta x}{Km}\right) + \left(\frac{\Delta x}{Kg}\right)} \quad (2.11)$$

So:

$$U = \frac{1}{\left(\frac{2}{9.37}\right) + \left(\frac{0.2}{1.75}\right) + 2 * \left(\frac{0.01}{1.2}\right) + \left(\frac{0.005}{1.1}\right)} = 2.86 \frac{W}{m^2.c}$$

3) Ceiling: we choose the ceiling construction as figure (2.1) below[1]:

Table (2.4)

k W/m.˚C	**Thickness** m	**Layer**
1.1	0.02	Asphalt mix (1)
1.75	0.05	Concrete (2)
0.034	0.02	Polystyrene (3)
1.75	0.06	Reinforced concert (4)
1	0.18	Block with air gap (5)
1.2	0.01	Plaster (6)

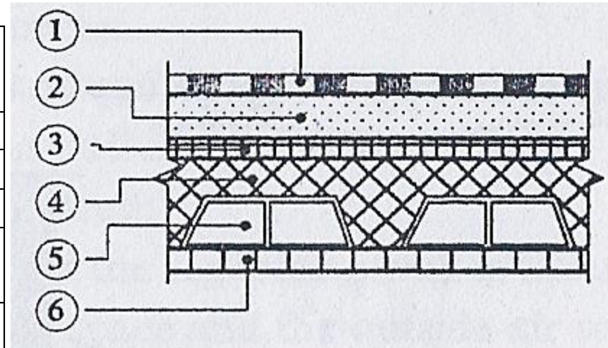


Figure (2.1)

And we know that the material is different in its dividing from one location to another in ceiling, so we divided it to two area which are A1 and A2 expect it construction and we multiplies the magnitude of U for every area in it percentage of all area, where the relation is:

$$Uc = U1 + U2 \quad (2.12)$$

$$Ac = \frac{1}{5}A1 + \frac{4}{5}A2 \quad (2.13)$$

$$U1 = \frac{1}{\left(\frac{1}{hfin}\right) + \left(\frac{\Delta x}{Ka}\right) + \left(\frac{\Delta x}{Kc}\right) + \left(\frac{\Delta x}{Ki}\right) + \left(\frac{\Delta x}{Kd}\right) + \left(\frac{\Delta x}{Km}\right) + \left(\frac{1}{hfout}\right)} \quad (2.14)$$

$$U2 = \frac{1}{\left(\frac{1}{hfin}\right) + \left(\frac{\Delta x}{Ka}\right) + \left(\frac{\Delta x}{Kc}\right) + \left(\frac{\Delta x}{Ki}\right) + \left(\frac{\Delta x}{Kd}\right) + \left(\frac{\Delta x}{Kb}\right) + \left(\frac{\Delta x}{Km}\right) + \left(\frac{1}{hfout}\right)} \quad (2.15)$$

Where,

ka : Thermal conductivity of asphalt mix .

kc : Thermal conductivity of concrete.

kb: Thermal conductivity of block .

km : Thermal conductivity of cement plaster.

ki: Thermal conductivity of polystyrene.

kd: Thermal conductivity of Reinforced concrete.

hf_{in}: convection coefficient of inside air .

hf_{out}: convection coefficient of outside air.

So:

$$U1 = \frac{1}{\left(\frac{1}{9.37}\right) + \left(\frac{0.02}{1.1}\right) + \frac{0.05}{1.75} + \left(\frac{0.02}{0.034}\right) + \left(\frac{0.06}{1.75}\right) + \left(\frac{0.01}{1.2}\right) + \left(\frac{1}{22.7}\right)}$$

$$= 1.2\ W/(m^2.c)$$

$$U2 = \frac{1}{\left(\frac{1}{9.37}\right) + \left(\frac{0.02}{1.1}\right) + \left(\frac{0.05}{1.75}\right) + \left(\frac{0.02}{0.034}\right) + \left(\frac{0.06}{1.75}\right) + \left(\frac{0.18}{1}\right) + \left(\frac{0.01}{1.2}\right) + \left(\frac{1}{22.7}\right)}$$

$$= 0.98 \frac{W}{m^2.c}$$

4) Floor: we choose the Floor construction as figure (2-2) below[1]:

Table (2.5)

k W/m.˚C	Thickness m	Layer
1.1	0.05	Terrazo(1)
0.16	0.05	Mortar (2)
1.05	0. 15	Aggregates (3)
1.4	0.25	Stones (4)

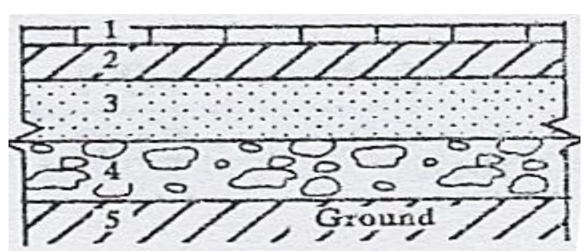


Figure (2.2)

Then the magnitude of U equal :

$$Uf = \frac{1}{\left(\frac{1}{hfin}\right) + \left(\frac{\Delta x}{Ka}\right) + \left(\frac{\Delta x}{Kn}\right) + \left(\frac{\Delta x}{Ky}\right) + \left(\frac{\Delta x}{Kz}\right)} \quad (2.16)$$

$$Uf = \frac{1}{\left(\frac{1}{9.37}\right) + \left(\frac{0.05}{1.1}\right) + \left(\frac{0.05}{0.16}\right) + \left(\frac{0.15}{1.05}\right) + \left(\frac{0.25}{1.4}\right)}$$

$$= 1.272\ W/(m^2.c)$$

Notes:

We calculate the heat loss from floor for the first floor and we neglected it for the second floor because the difference in temperature is approximately equal zero.

before we calculate the magnitude of Q we find the magnitude of ΔT which it equal (Ti-Tg) where:

Ti: the temperature inside the house.

Tg: is the ground temperature and its value is equal [To+(5to 10˚C)] , we take it is equal 10˚C.

5)Windows: we choose sliding double glass aluminum window with 6mm air gap ,depending on wind speed in Hebron of 5m\s and from table (5.4) in heating and air containing for residential building book we take Ug = W/m^2 .˚C.

6) Doors: we have three types of doors for inside and outside, depending on Table (5.5) [1] as Table (2.6) follow:

Table (2.6)

Door type	Overall heat transfer coefficient W/m^2 °C.
40mm-wood	2.8
Aluminum	7
Steel	5.8

2.11 Sample Calculations for Heating load:

We take a guest room in first floor as a sample of our calculation for load calculation:

2.11.1 Wall gain load:

$Q_{(wall)} = U A \Delta T$

-Window area in guest room: A1=(1.4)(1.82)=2.55m^2

And we have three windows in guest room so:

$A1_{total}$= (3)(2.55) = 7.65m^2 .

- Door area in guest room: F2=(1.6)(2.34)=3.744m^2

-Outside wall surface area with windows and door =(5.9+4.4+6+0.95)(3.38)=58.31m^2.

-Total area of outside wall surface for guest room(A) = total area of outside wall surface-(windows area+door area)

A=(58.31-7.65-3.744)

A= 46.9m^2.

Since T_i = 23 °C and T_o= 3 °C for this room, so:

$Q_{(outside\ wall)}$ = (1.02)(46.9)(23-3)

$Q_{(outside\ wall)}$ = 956.76 W

$Q_{(inside\ wall)} = U A \Delta T$

- Aluminum door area in guest room=(2.05)(2)=4.1m^2

-Inside wall surface area with door =(3.15)(3.38)=10.65m^2.

-Total area of inside wall surface for guest room(A) = total area of inside wall surface-(aluminum door area)

A=(10.65-4.1)

A= 6.54m^2.

Since the heating transfer from living room to guest room so the guest room will get plus heating as follow:

$Q_{(inside\ wall)}$ = (2.9)(6.54)(24-23) Since T_i = 24 ˚C for living room

$Q_{(inside\ wall)}$ =19 W

2.11.2 Ceiling and Floor gain load:

In first floor we will neglect the heat transfer from ceiling and floor due to good insulation in it and due too under floor heating from it and because the heat transfer from ceiling and floor is very low, but we will take sample later on second floor to represent how to calculate heat transfer from ceiling.

2.11.3 Windows gain load:

$Q_{(glass\ window)} = U\ A\ \Delta T$

in guest room we have 3 glass windows (A1)

A=(3)(area of A1)

A=(3)(2.55)

$A=7.65m^2$.

$Q_{(glass\ window)}$ = (3.2)(7.65)(23-3)

$Q_{(glass\ window)}$ =490 W

2.11.4 Door gain load:

$Q_{(door)} = U\,A\,\Delta T$

in guest room we have 2 doors, external and eternal from aluminum.

Door area in guest room: F2=(1.6)(2.34)=$3.744m^2$.

$Q_{(external\ door)}$ =(7)(3.744)(23-3)

$Q_{(external\ door)}$ =524.2W.

$Q_{(internal\ door)} = U\,A\,\Delta T$

- Aluminum door area in guest room =(2.05)(2)=$4.1m^2$

$Q_{(internal\ door)}$ = (7)(4.1)(24-23)

$Q_{(internal\ door)}$ =28.7 w " gained from living room".

So $Q_{(total\ door)} = Q_{(external\ door)} - Q_{(internal\ door)}$

$Q_{(total\ door)}$ =*495.5W*

2.11.6 Infiltration Load:

Estimating the volumetric flow rate of infiltrated air into air condition space by using crackage method.

$$V_{inf} = K*L*(\Delta P)^{2/3} \quad (2.17)$$

Where,

K: is the infiltration air coefficient

L:is the crack length in meter.

ΔP:is the pressure deference between inside and outside of the room.

$\Delta P = 0.613(S_1S_2V_0)^2$ (2.18)

Where,

S_1:is a factor that depends on the topography of the location of the building.

S_2:is coefficient that depends on the height of the buildings and the terrain of its location.

V_0:is the measured wind speed in hebron "5m/s".

In this sample depending on aluminum sliding windows and doors and from table (6-2) in heating and air conditioning for residential buildings book we take (k=0.43).

S_1=1 from table (6-3) in heating and air conditioning for residential buildings book.

S_2 =0.69 from table (6-4) in heating and air conditioning for residential buildings book, depending on class (1) category (B) and building height.

That gives:

$\Delta P = 0.613(S_1S_2V_0)^2$

$\Delta P = 0.613(1*0.69*5)^2$

ΔP = 7.3 pa.

For window A1:

L=((2*1.4)+(3*1.82))*3

L=24.78m.

$V_{inf} = 0.43*24.78*(7.3)^{2/3}$

$V_{inf} = 40.1m^3/h$

V_{inf} = 0.01114m^3/s

$$Qt.f = \left(\frac{V_{inf}}{v_o}\right) * (h_i - h_o)$$

$$Qt.f = \left(\frac{0.01114}{0.784}\right) * (47 - 12) * 1000$$

$Qt.f$ =**497.32 W**

For door F2:

L=((2*1.6)+(3*2.34))

L=10.22m.

V_{inf} = 0.43*10.22*(7.3)$^{2/3}$

V_{inf}= 16.54m^3/h

V_{inf}= 0.0046m^3/s

$$Qt.f = \left(\frac{0.0046}{0.784}\right) * (47 - 12) * 1000$$

$Qt.f$ =**205.36 W**

$Q_{total}$for this room is **2663.9 W**

Q_{total}=2.6639 KW

2.12 Tables of Results:

The results of heating calculations for each floor are tabulated below:

Table (2.7): Heating Load for first floor

No. of Room	Inside Temperature C^O	Q_{tot} W
1-1guest bed	23	1241.3
1-2- guest	23	2663.9
1-3- living	24	4233.545
1-4-Bathrooms 1&2	26	2800
1-5-kitchen and bed	20	4414.25
Sum.		15353

Table (2.8): Heating Load for second floor

No. of Room	Inside Temperature C^O	Q_{tot} W
2-1-Main bed	23	3662.7
2-2-bed 1	23	2077
2-3- bed 2	23	1672
2-4-bed 3	23	1497.2
2-5-kitchen and living	22	4146
2-6- bathrooms 1and 2 and 3	26	3398
Sum.		16453

Table (2.9): Heating Load for ground floor

No. of Room	Inside Temperature C ^{o}	Q_{tot} W
3-1-Sport	16	2138
3-2-bathroom	23	1255
Sum.		3393

Total heating load= ($Q_{tot(1st\ floor)}$+ $Q_{tot(2nd\ floor)}$+ $Q_{tot(ground\ floor)}$+domestic water)

Total heating load=44952.3W

Chapter Three

Solar Energy

3.1 Introduction

Solar energy, radiant light and heat from the sun, has been harnessed by humans since ancient times using a range of ever-evolving technologies. Solar radiation, along with secondary solar-powered resources such as wind and wave power, hydroelectricity and biomass, account for most of the available renewable energy on earth. Only a minuscule fraction of the available solar energy is used. Solar energy's uses are limited only by human ingenuity. A partial list of solar applications includes space heating and cooling through solar architecture, potable water via distillation and disinfection, day lighting, solar hot water, solar cooking, and high temperature process heat for industrial purposes. To harvest the solar energy, the most common way is to use panels. Solar technologies are broadly characterized as either passive solar or active solar depending on the way they capture, convert and distribute solar energy. Active solar techniques include the use of photovoltaic panels and solar thermal collectors to harness the energy. Passive solar techniques include orienting a building to the Sun, selecting materials with favorable thermal mass or light dispersing properties, and designing spaces that naturally circulate air. [2]

3.2 Energy from the sun

The Earth receives 174 petawatts (PW) of incoming solar radiation (insulation) at the upper atmosphere. Approximately 30% is reflected back to space while the rest is absorbed by clouds, oceans and land masses. The spectrum of solar light at the Earth's surface is mostly spread across the visible and near-infrared ranges with a small part in the near-ultraviolet.

Earth's land surface, oceans and atmosphere absorb solar radiation, and this raises their temperature. Warm air containing evaporated water from the oceans rises, causing atmospheric circulation or convection. When the air reaches a high altitude, where the temperature is low, water vapor condenses into clouds, which rain onto the Earth's surface, completing the water cycle. The latent heat of water condensation amplifies convection, producing atmospheric phenomena such as wind, cyclones and anti-cyclones. Sunlight absorbed by the oceans and land masses keeps the surface at an average temperature of 14 °C. By photosynthesis green plants convert solar energy into chemical energy, which produces food, wood and the biomass from which fossil fuels are derived

The total solar energy absorbed by Earth's atmosphere, oceans and land masses is approximately 3,850,000 exajoules (EJ) per year. In 2002, this was more energy in one hour than the world used in one year. Photosynthesis captures approximately 3,000 EJ per year in biomass.

The amount of solar energy reaching the surface of the planet is so vast that in one year it is about twice as much as will ever be obtained from all of the Earth's non-renewable resources of coal, oil, natural gas, and mined uranium combined.

From the table of resources it would appear that solar, wind or biomass would be sufficient to supply all of our energy needs, however, the increased use of biomass has had a negative effect on global warming and dramatically increased food prices by diverting forests and crops into befoul production. As intermittent resources, solar and wind raise other issues. [3]

Table 3.1: Yearly Solar fluxes & Human Energy Consumption

Solar	3,850,000 EJ
Wind	2,250 EJ
Biomass	3,000 EJ
Primary energy use (2005)	487 EJ
Electricity (2005)	56.7 EJ

3.3 Application of solar energy

Because traditional energy production methods create environmental and health concerns, it is beneficial for lawmakers and scientists to investigate methods of energy production that are cleaner and more cost-effective. Solar energy has been found to be a very clean type of energy that can reduce pollution and also reduce the costs of energy in homes and businesses. Solar energy uses energy from the sun to react with chemical materials to produce positive and negative charges. When this reaction happens multiple times, energy is created. There are many applications of solar energy available across a range of industries. Knowing how solar energy can be used can help designers, inventors, and scientists develop innovative ways of using the energy for large-scale applications. [2]

1- Architecture applications

Architecture is one field that can use solar energy to its advantage. Architects are charged with designing plans for residential and commercial buildings. Part of designing buildings is integrated energy systems into the plans. These systems can include heating systems, cooling systems, and ventilation systems. Architects also need to account for the equipment needed to produce solar energy when they are designing building plans. Solar cells, solar panels, and other equipment needed to convert the sun's energy into solar energy needed to be integrated into the overall design of the home to ensure that they can function properly. [3]

2-Water heating and pumping

Heating water using electricity can be an expensive undertaking. Even the most energy-efficient gas and electricity-powered water heaters can cost homeowners a lot of money. As these traditional water heaters age, their efficiency decreases and homeowners see even more costs adding up. Using applications of solar energy can help people to reduce their water heating and pumping costs. In a solar water system, solar thermal collectors are used to heat water and then solar energy propels the water through the system. This is much more efficient and has fewer harmful effects than using gas or electricity-powered hot water systems. [4]

3- Solar heating system:

Solar heating systems are generally composed of solar thermal collectors, a fluid system to move the heat from the collector to its point of usage as fig 3.1. The system may use electricity for pumping the fluid, and have a reservoir or tank for heat storage.

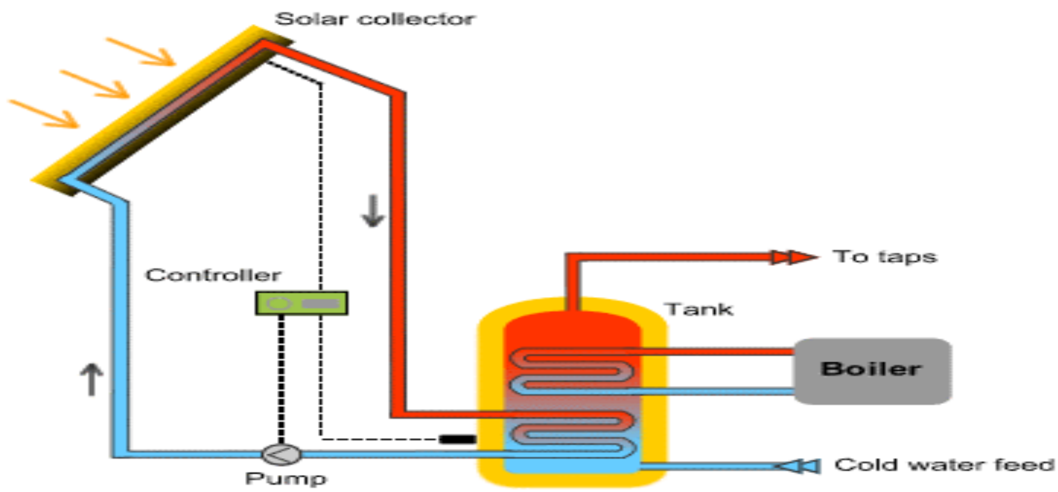


Fig3.1 Solar Thermal (Heating) System (in general)[6]

In many climates, a solar heating system can provide up to 85% of domestic hot water energy. This can include domestic non-electric concentrating solar thermal systems. In many countries, combined hot water and space heating systems (solar comb systems) are used to provide 15 to 25% of home heating energy. Residential solar thermal installations can be subdivided into two kinds of systems: compact and pumped systems. Both typically include an auxiliary energy source (electric heating element or connection to a gas or fuel oil central heating system) that is activated when the water in the tank falls below a minimum temperature setting such as 50 °C. Hence, hot water is always available. The combination of solar hot water heating and using the back-up heat from a wood stove chimney to heat water can enable a hot water system to work all year round in cooler climates without the supplemental heat requirement of a solar hot water system being met with fossil fuels or electricity. [3]

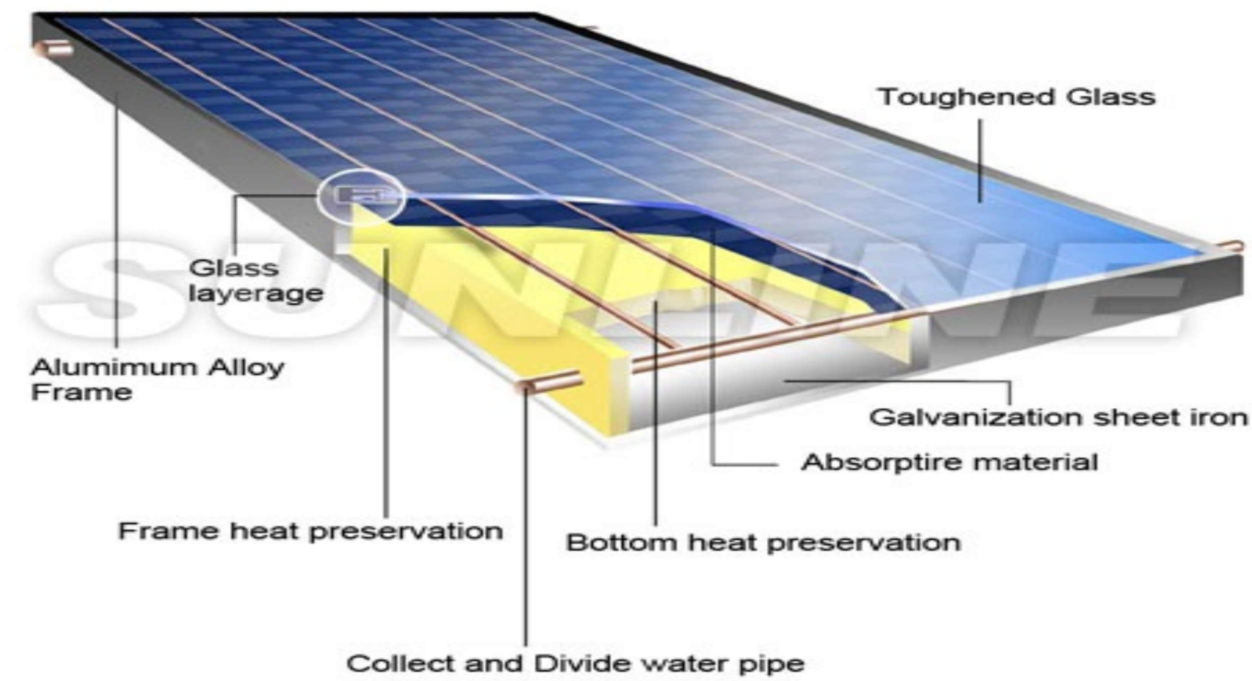
3.4 Flat-plate solar collectors:

A solar collector is a device which intercepts radiant energy from the sun, converts it to thermal energy, and transfers the thermal energy to a circulating fluid.

Flat-plate solar collectors are the most used type of solar panels today. They can be glazed or unglazed. Freezing conditions may limit the efficiency of this kind of collectors. [2]

3.4.1 Liquid flat-plate solar collectors

Common flat-plate collectors use a liquid (water, glycol…) as the heating fluid. They involve a net of flow tubes (where the water or another heating fluid flows), a dark color absorber plate (to absorb the sunlight heat) and a glazing surface. They also comprise an inlet and an outlet connection. The image below shows the interaction of these elements.



Fig(3.2) flat-plate solar collectors [6]

3.4.2 Flat-plate Prices:

The main advantage of flat-plate solar collectors over evacuated-tube ones is their price. And though recent trends in evacuated-tube technology closed part of the gap, flat-plate solar collectors are still a cheaper solution. [2]

3.4.3 Flat plate solar collectors vs. evacuated-tubes collectors

There are good and bad solar collectors... In other words: there are good flat plate collectors that may perform better than poor evacuated-tubes in cold climates (the final performance also depends on the design of the whole solar heater system: issues as the pump consumption, controller, or hot water cylinder location are important). Anyway, in cold climates, evacuated-tubes tend to be a better option (though on average more expensive) than the flat-plate one.

3.4.4 Water Storage tanks:

One main storage tank with $1m^3$ capacity is needed for heat exchange purposes. Two other storage tanks with $1m^3$ capacity each are needed to store any excess hot water if high solar radiation is available.

Control valves are needed to direct hot water running from the collectors to be directed to the main tank or to the extra storage tanks.

The schematic diagram of the system is illustrated in figure 3.3. Bellow.

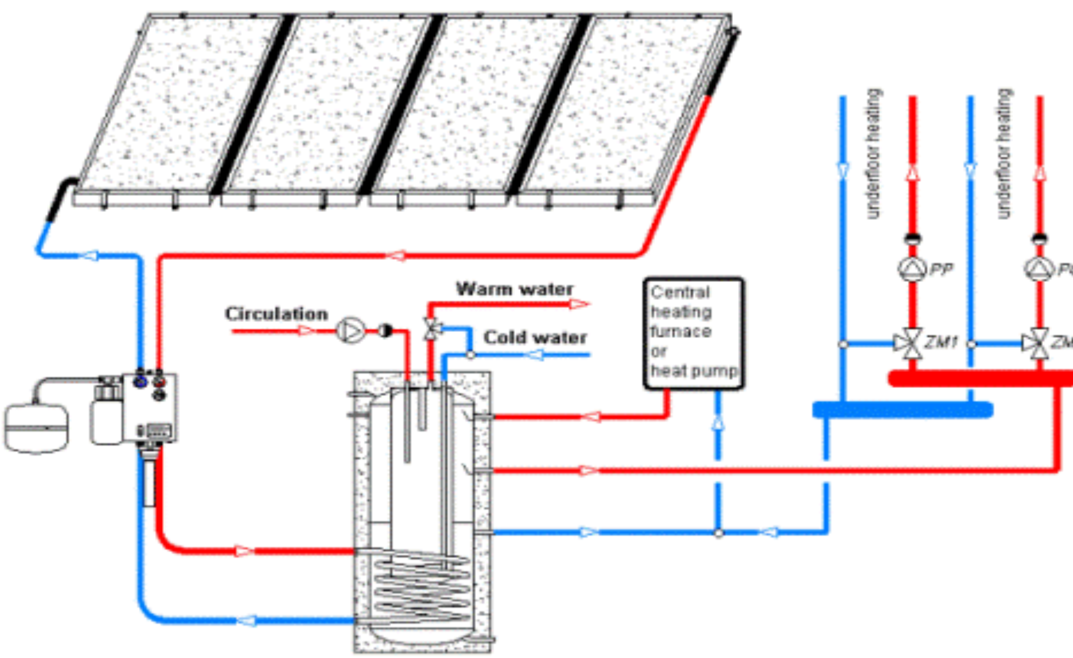


Figure 3.3 [5]

3.4.5 Collectors Spacing

Solar collectors will be arranged in rows facing south. [2] The minimal distance between each row and the other must be not less than 1.7m to reduce the possibility of shading rear rows. The rise of each collector is around 1.2m. According to this figure the distance between every consecutive rows is around 2m, and angle of collector slope is 42^{o}. [2]

Chapter Four

Under Floor Heating

4.1 Introduction

The idea of using the floor as a heat emission surface goes back over two thousand years. Heating systems inspired by this idea were built by the Chinese, Egyptians and Romans. The system adopted by the Chinese and the Egyptians was fairly simple. It consisted of building an underground hearth and sending smoke under the flooring of the rooms to be heated; it was in practice single room heating. The Romans, however, used far more complex advanced systems. Using the smoke from a single external hearth, they were able to heat several rooms and even several buildings, thus achieving the first central-heating type system. However, it was not until the start of this century that under floor heating appeared in its present form. And it was an Englishman, Professor Baker, who was first to patent this type of system using the title "systems for heating rooms with hot water carried by under floor piping.

In the early years after World War II, there were two main reasons for the spread of panel heating . These were the constant unavailability of heat emitters and the ease of insertion of the panels in prefabricated floor slabs.

The technique used consists of burying 1/2" or 3/4" steel tubes in the flooring, without overlying insulating materials. In Europe, from 1945 to 1950, over 100,000 homes were heated by this technique. Very soon, however, it was noted that the equipment was causing numerous physiological problems, such as poor circulation, high blood pressure, headaches and excessive sweating. Problems of this nature were so serious and well-documented that certain European countries set up Commissions to identify the causes.

The results of the various Commissions of inquiry agreed that, in the systems constructed, the physiological problems were due to two values being too high:

1) the surface temperature of the flooring.
2) the thermal inertia of the floor slabs.

It was demonstrated in particular that, in order to avoid feelings of discomfort, the floor temperature should not exceed 28-29°C. In fact, in the systems examined, far higher temperatures were found, even in excess of 40°C. It was also demonstrated that the excessive heat accumulated in the floor slabs of the systems meant overheating of the rooms above physiologically acceptable levels. The Commissions themselves, however, did not publish any negative judgments of panel systems. They demonstrated that these systems, if constructed for a low surface temperature and with a not excessively high thermal inertia, can offer heat comfort greatly superior than that which can be obtained with radiator or convector equipment. Whilst not being a condemnation, the Commissions results in fact constituted a strong disincentive to produce panel systems, and it was some years before they made any significant comeback.

The event which again drew attention to these systems was the energy crisis in the 1970s.Under the impetus of this crisis, almost all European countries issued laws which required efficient heat insulation of buildings, and it was thus possible to heat rooms with less heat and so (in the case of panels) with lower floor temperatures.

In addition, in most cases, the degree of insulation required made it possible to heat the rooms with floor temperatures lower than the physiological maximum, and this in turn made it possible to reduce the thermal inertia of the system. A further reduction in thermal inertia was obtained by producing “floating” floors with heat insulation either under the panels or towards the walls. And it was precisely this innovation, of a legislative and technical nature, which finally made it possible to produce thoroughly reliable panel systems with a high heat output. Nowadays in Europe, the “new” panel systems are installed mainly in the Northern countries, where they are experiencing a deserved success, largely due to the advantages, which they can offer. [5]

4. 2 Advantages of Panel Systems.

The main advantages offered by panel systems relate to [5]:

- Heat comfort.
- Air quality.
- Hygiene conditions.
- Environmental impact.
- The heat usable at a low temperature,
- Energy saving.

4.2.1 Heat Comfort

As shown in Figure (4.1) the ideal curve shown, in order to ensure comfortable heat conditions in a room, slightly warmer areas must be maintained at floor level and slightly cooler ones at the ceiling level. The system most suited to providing these conditions consists of radiating floors, for the following reasons:

1) The specific position of the panels.
2) 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.

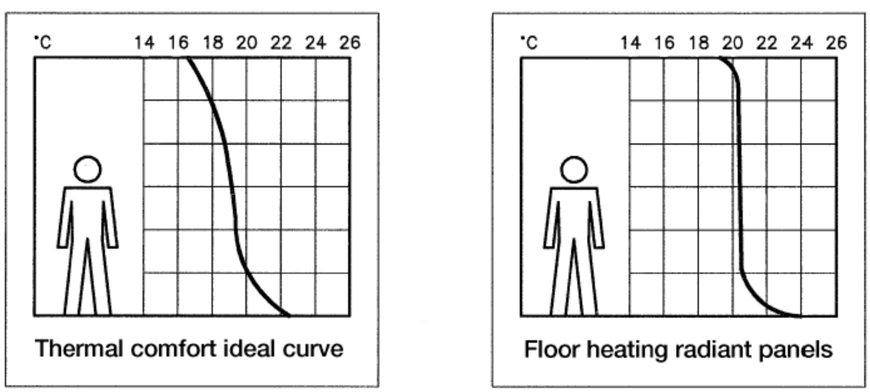


Figure (4.1) Thermal Comfort Curve. [5]

4.2.2 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 (especially in rooms which are not regularly cleaned) can cause allergies and respiratory problems.

4.2.3 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.

4.2.4 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, especially when air-conditioning buildings of historic or architectural importance, where the presence of heater emitters can compromise the balance of the original spaces.
2) They do not restrict freedom of layout, thus allowing the most rational use of the available space.
3) They do not contribute to deterioration of plasterwork, wooden flooring and hardware, as:

• They do not dirty the walls with convection stains.
• They do not allow formation of damp at floor level.
• They considerably restrict cases of internal condensation, as they increase the temperature of the walls near the panel floor slabs.

4.2.5 Heat Usable At Low Temperature

Due to their high dispersion area, panel systems can use the heat-carrying fluid at low temperatures. This characteristic makes their use convenient with heat sources whose efficiency (thermodynamic or economic) increases when the temperature required is reduced, as in the case of:

• Heat pumps.
• Condensing boilers.
• Solar panels.
• Heat recovery systems.

4.2.6 Energy Saving

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

1) The higher operating temperature, which permits (for the same ambient temperature) average savings varying from 5 to 10%.
2) The lower temperature gradient between floor and ceiling, which provides higher energy savings the larger and higher the rooms.

The following are also (although admittedly less important) reasons for energy savings:

• The use of low temperatures which reduces dispersion along the piping,

• The non-heating of the walls behind the radiators,
• The lack of convection movement of the hot air over glazed surfaces.

On average, panel systems, in comparison with traditional systems, produce energy savings of between 10 and 15%.

4.3 Disadvantages of Panel Systems

These relate mainly to aspects connected [5]:
1) With the surface temperature of the floor.
2) The thermal inertia of the system .
3) Difficulties of a design nature.

4.3.1 Limitation Connected with the Surface Temperature of the Floor

According to the standards of DIN the maximum allowed floor temperature for residing zones is (29 ^{o}C) , while that for the edge zones (35 ^{o}C) to avoid conditions of physiological discomfort. On the other hand according to the American Society of Heating, Refrigeration ands Air-conditioning Engineers (ASHREA standards) the surface temperature for residing zones are as follows:

- The maximum surface temperature is (29.4^{o}C) and the optimum is (27.5 ^{o}C for dry surfaces.
- For bathrooms and shower the optimum floor temperature is (33^{o}C).

  These values make it possible to determine the maximum heat output (Q_{max}) which can be transferred by a panel.

According to DIN Standards since the maximum floor temperature is 29^{o}C then the value of heat output by the floor should be equal or less than 100 W/m^{2}.K .

If Q_{max} is less than the required output (Q), there are two possible situations:

1) Q_{max} is less than Q only in a few rooms, in which case additional heat emitters ,wall panels or additional concentrate loop at the perimeter of zone can be used. For example, Q_{max} can come from the panels and the remaining output from radiators.

2) Q_{max} is less than Q in all or most of the rooms, a traditional type system should be used.

4.3.2 Thermal Inertia and Method of Use of Systems

Panel systems are characterized by having a high thermal inertia as, in order to transfer heat, they use the structures in which the panels themselves are buried.

In environments heated with a certain degree of continuity (and good insulation under the panels),the thermal inertia of the system no reviles problems and permits to:

• Good adaptability of the system to the external climatic conditions.

• Slowing down of functions, with system 'on' and 'off' times which are normally two hours.

On the other hand, in environments which are only heated for short periods such as weekend homes, the thermal inertia of the panel system has considerable phase variations between the starting times and the times of actual use. Thus in these cases, other heating systems should be used.

4.3.3 Disadvantages Linked with Design Aspects

Unlike the traditional systems with heat emitters, panel systems require:

• Greater commitment to determine project parameters. In fact, apart from the parameters required to determine the heat losses from the rooms, the design of panel systems also requires detailed knowledge of all the constructional information regarding the floors and floor slabs.

• More complex, laborious calculations, although due to the greater commitment, these can be considerably reduced with the use of computers.

• Less adaptation to variants during the work or when the system is completed, as it is not possible to add or remove panel portions, as is done with radiators.

4.4 Panel Containment Structures

These consist mainly of the floor (or solid foundation on the ground), the insulating material, the slab and the floor tiles[5].

4.5 Pipe Loops Configuration.

Each room must be heated with one or more specific panels. This makes it possible to control room temperatures independently, in other words without altering the heat balance of other rooms.

Three types of pipe loops configurations can be used as follows[5]:

1) Single serpentine configuration. This method yields 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 (4.2) This configuration is used in residences and requires very flexible pipe.

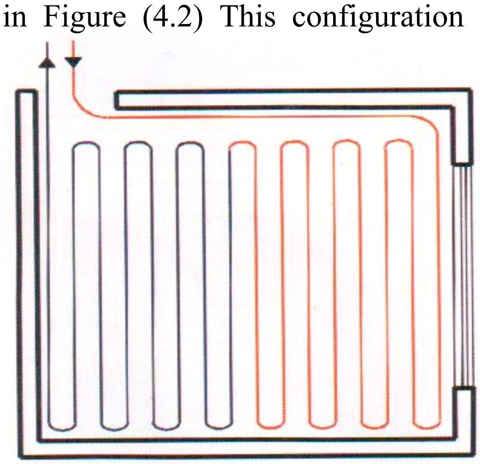
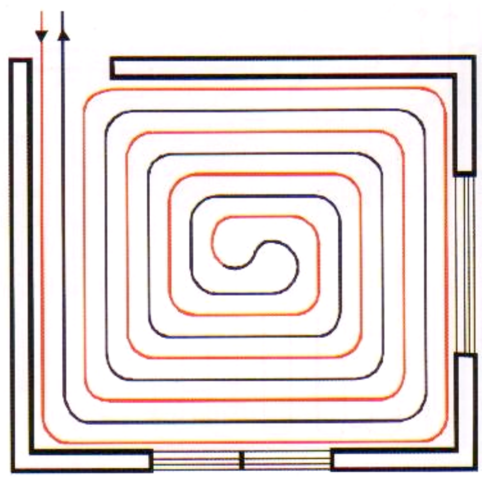


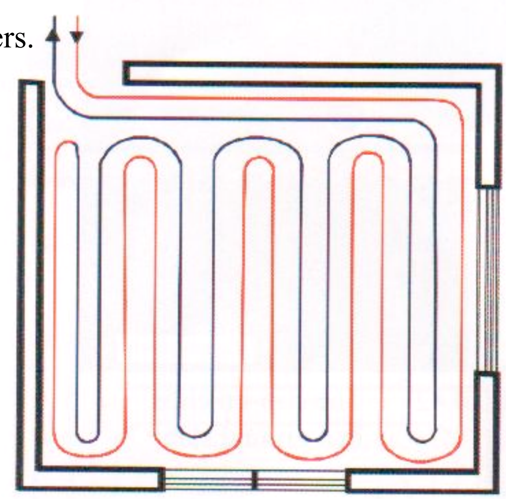
Figure (4.2) Single Serpentine Pipe Arrangement.

2) Helical supply and return configuration. This pipe arrangement is installed in a helical or spiral configuration as shown in Figure (4.3). This method is used in spaces that require high heating loads .



Figure(4.3) 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 (4.4). This pipe configuration gives uniform mean surface temperature but higher variation of floor surface temperature within small area. This method is used for heating large spaces such as mosques and theaters.



Figure(4.4) Parallel Supply and Return Pipes Configuration.

4.6 Panel Heating Design Parameters.

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

1) Pipe loop configuration. A single serpentine pipes and spiral configuration arrangement is usually used for residences of concrete floors. Parallel supply and return pipes configuration is used for heating large space lounges, theaters, etc.

2) Pipe diameter and pipe space. Different pipe spaces and diameters can be used. Based on economical aspects, required floor temperature and required heat flow from the pipes.

The panels can have constant or variable centre-to-centre distances with pipes closer together where there are areas of glass or highly dispersive walls as shown in Figure (4.5) .

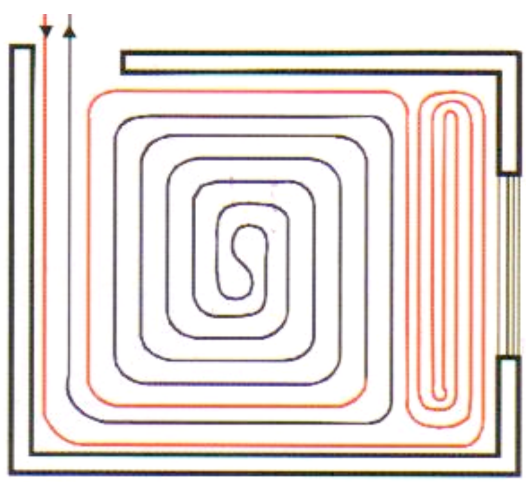


Figure (4.5) Panels with Variable Center to Center Distances.

3) Circulation of water temperature. The limitations on water temperature are to ensure that:

a. Surface temperature is in limits.

b. Screed temperature is also in limit. (DIN standards required that the temperature of cement screed to be less than 60^{o}C to avoid the thermal stress.

The design water temperature used in water flowing through PEX plastic pipe is usually 45^{o}C. on other hand ASHRAE standard required that the maximum water temperature in floor heating is 54.4 ^{o}C. And there is no rigid limitation on the drop of water temperature in the loop. However, an optimum design value is 5-8 ^{o}C.

4) Pipe depth. A pipe depth of 50 mm is usually used. In concrete floors, a pipe depth that ranges between 30 to 70 mm is recommended.

4.7 Under Floor Design.

The design procedure for under floor heating system is summarized as follows.

(1) Calculation of the heat load for each space .

(2) Calculation of the heat flux (W/m^2) by dividing the heat load for the requied space by total floor area of the space .

$$q_L = \frac{Q_L}{A_f} \qquad (4\text{-}1)$$

(3) Evaluation of the floor surface temperature (T_L).

(4) Calculation of required pipes spacing and water temperature with considering the floor temperature and the tiles and floor types (ceramic, mosaic, cement ,oak ,….etc).

(5) Limitation of the spaces between the pipes that will give the required floor temperature at selected water temperature.

(6) Calculation of the reverse heat flow since there is a cold surface on the other side of the heating pipes.

(7) Calculation of the total heat load to be emitted by the pipes (Q_e).

(8) Calculation of the mass flow rate of water for each loop.

(9) Selection of pipe diameter with considering the flow velocity.

(10) Calculation of pressure drop for the longest pipe loop and the pressure drop due to the bending.

(11) The pump of the under floor heating system is selected from the manufacturer catalogues by using the total pressure drop of the longest pipe loop and the total water flow rate for all loops.

(12) Balancing the pressure drop for all pipe loops such that each pipe loop will have the same total pressure drop of that of the longest pipe loop. This is done by controlling the lock shield valve in the return manifold of each loop. This balancing is necessary to circulate the calculated value of water flow rate for each loop.

(13) Boiler selection by using the total Q_e for all loops and domestic hot water.

4.7.1 Calculation of the Heat Load For Each Space

The heat load for each space computed in Chapter 2.

4.7.2 Calculation the heat flux

In order to be able to ensure conditions of physiological well-being, the heat output transferred by the panel must not exceed the maximum output
Where:

q_{max} = 100 W/m^2 in continuously occupied environments;
q_{max} = 150 W/m^2 in bathrooms, showers and swimming pools.
q_{max} = 175 W/m^2 in perimeter areas of rooms rarely used.

If the heat output required (q) is greater than q_{max}, a heat output less than or equal to Q_{max} must be emitted by the panel and the remaining output made up by an integrated heat emitter or additional loop in perimeter.

From the heat load summary in Chapter 2 it is found that $q > q_{max}$ in two cases these are

(L1) and (L2) for that we should use two loops the first one in the perimeter of the (un residential space) with small pipe space to give q /A = 150 W/m^2 and the other one in mid of the (residential space) with average pipe space to give q /A less or equal to 100 W/m^2 so the sum of the two loop output will cover the required heat load.

4.7.3 Evaluation of the Floor Surface Temperature (TL)

The first step in the design of under floor heating is to calculate the required surface temperature that will give the required heat flow to the spaces .

According to the DIN method the total heat output is considered to be nearly twice that of the convection , hence

$$q_L = 8.92(T_L - T_i)^{1.1} \qquad (4\text{-}2)$$

Where :

q_L : Heat output per unit area (W/m^2)

T_L : Floor surface temperature.

T_i : Inside design temperature.

And the optimum inside design temperature for the room atmosphere is between 20-22 ^oC.

4.7.4 Calculation of Required Pipes Spacing and Water Temperature

The next step after finding the required floor surface temperature (T_L) is to find the required pipe spacing (S) and water temperature (T_k) to obtain that (T_L).

Figure (4.6) explain the relation between floor temperatures and water temperatures and pipes space for Ceramics floor which is used in Jordan .

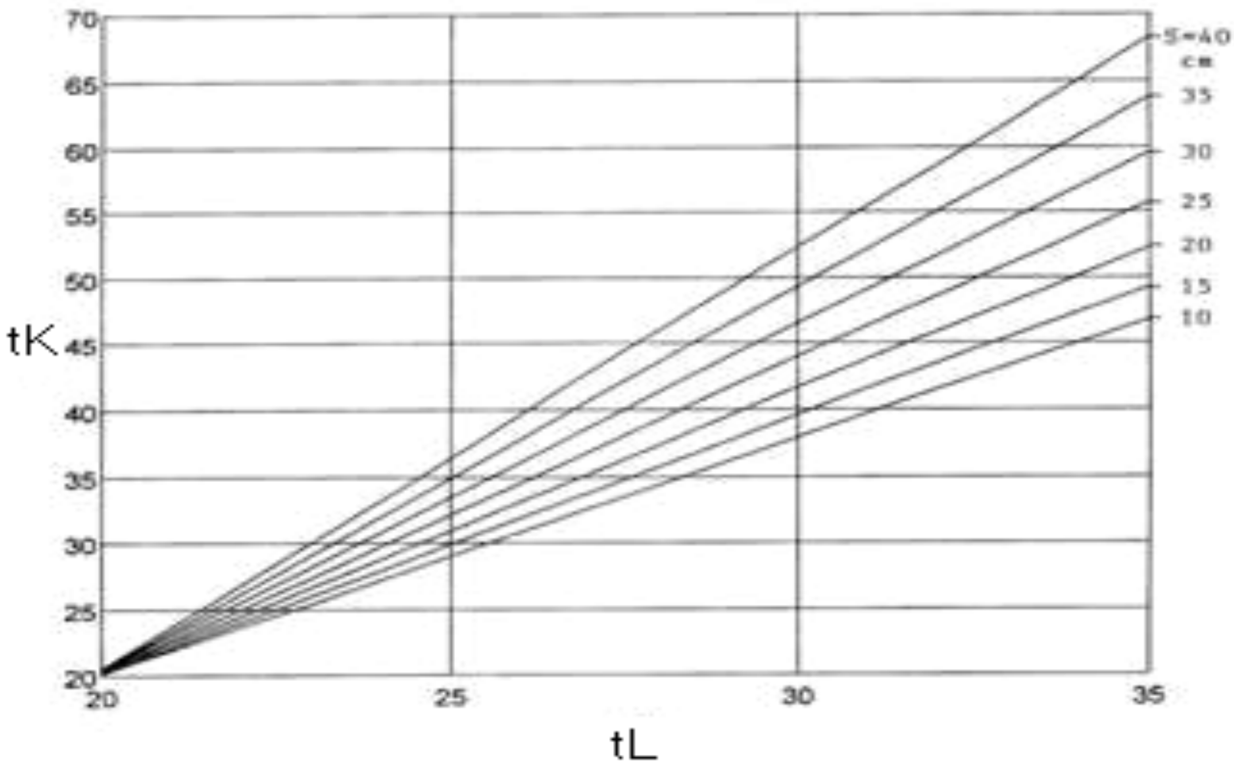


Figure (4.6) Spacing and water for Jordanian materials with Ceramics floor [5]

4.7.5 Calculation of the Reverse Heat Flow

Since there is a cold surface on the other side of the heating pipes then a reveres heat flow occurs. A rough estimate of the reverse heat flow is that it is 10% of the supplied energy for ceiling heating and 25% of the supplied energy for floor heating when poor insulation is used. If the reveres heat flow is to ambient atmosphere or to ground then it is thought of as losses else, it can be thought of as another heating source to the other space.

The reverse heat flow is in two modes: conduction and radiation. To reduce radiation to a minimum, a reflecting aluminum sheet is placed on the top of the insulation. If such technique is not used, the heat loss by radiation cannot be neglected. The aluminum sheet has another main task to distribute screed temperature in-between heating pipes evenly.

Figure (4.7) show the relation between q_k and floor temperature for using 5 cm polystyrene insulators thickness.

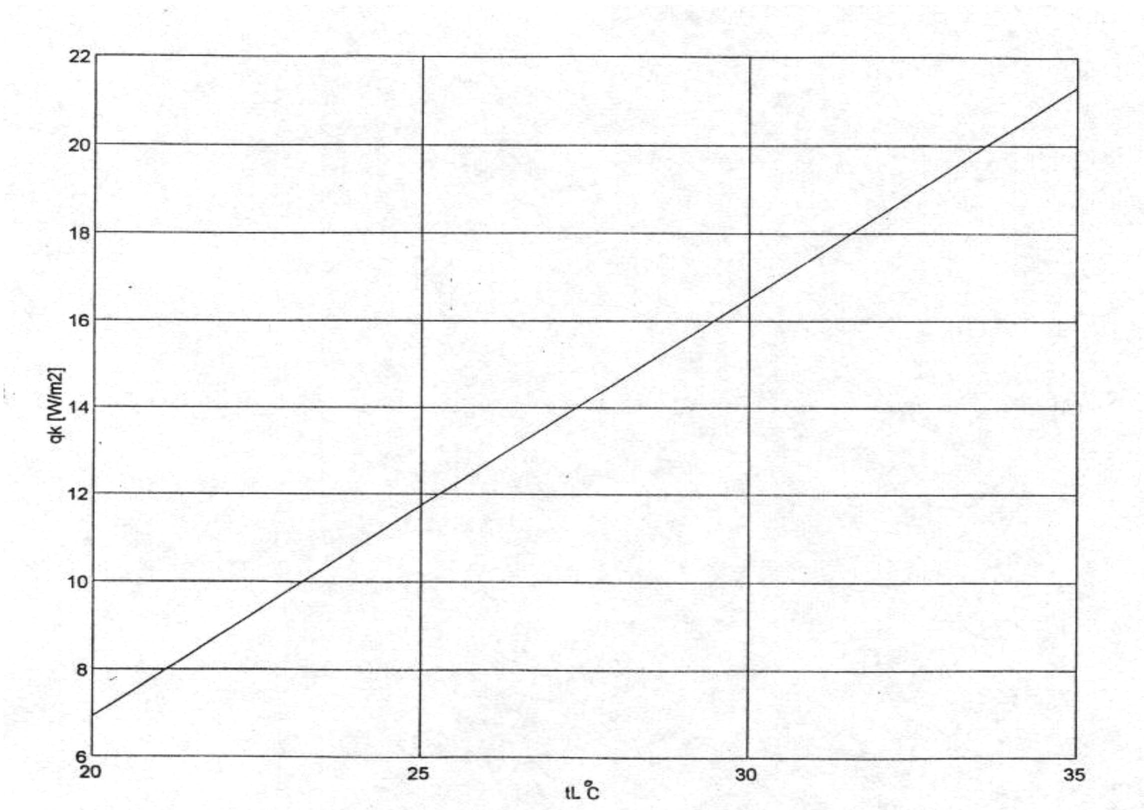


Figure (4.7) Reverse Heat Output Versus (T_L) Using 5 Cm Polystyrene. [5]

4.7.6 Calculation of the Total Heat Load to be Emitted by the Pipes (Qe)

The total heat load must be emitted by the pipe is given by the following Equation:

$$Q_e = (q_L + q_k) \times A_f \qquad (4\text{-}3)$$

4.7.7 Calculation of the Mass Flow Rate Of Water For Each Loop

After calculating T_k and q_k it is needed to find the volumetric flow rate of water in the heating pipe by using the following Equation. [5]

$$Q_e = m_w.cp.\Delta T_w \qquad (4\text{-}4)$$

Where

Q_e : Heat load to be emitted by the pipes.

m_w : mass flow rate of water.

Cp : water specific heat that equal 4.18 KJ/Kg.k

ΔT_w : Water drop temperature

4.7.8 Selection of Pipe Diameter with Considering the Flow Velocity

The selection of pipe diameter depends upon the flow velocity since the inner surface of PEX pipe is quite smooth and scales do not form easily, the limitations to flow velocity for noise consideration is somehow less than that for metallic pipes. The maximum flow velocity is to be 1.2 m/s for residential building and can reach 2.4 m/s for industrial building.[5]

Flow velocity is given by the following Equation:

$$V_w = 4 \times \frac{\left(\frac{m_w}{\rho_w}\right)}{(\pi \times d_i^2)} \qquad (4\text{-}5)$$

Where

V_w : flow velocity (m/s) .

m_w : mass flow rate of water (Kg/s) .

ρ_w : water density (Kg/m^3) .

d_i : Inner diameter (m)

4.7.9 Calculation of the Pressure Drop For the Longest Pipe Loop and the Pressure Drop Due to the Bending

The pressure drop in the pipe per unit length is given by:

$$\Delta p/\Delta L = f \times \rho \times \frac{V_w^{\,2}}{2 \times d_i} \qquad (4\text{-}6)$$

Where

f : Friction coefficient.

ρ : Water density (Kg/m3).

V_w : Flow velocity(m/s).

d_i : Inner diameter (m).

The total pressure drop is then calculated by multiplying (Δp /L) by the total equivalent length of the pipe measured from the drawing directly or calculated from Equation plus the length from manifolds to the zone for the longest loop.

The additional pressure drop due to pipe bending should be taken into consideration. It is given by the following Equation:

$$\Delta PB = N \times K \times \rho \times \frac{V^2_{\ w}}{2} \qquad (4\text{-}7)$$

Where

N : Number of 90^o bends in the loop.

K : Loss coefficient. [5]

And U bend is considered as two 90^o bends.

The total pressure drop across the pipe loop is

$$\Delta P = \Delta PB + \left(\frac{\Delta p}{\Delta L} \times L_{LOOP} \right) \qquad (4\text{-}8)$$

4.8 Sample of Calculation

We take a sample in first floor, and Because of large floor area we will use two loops(L1 and L2).

1- Heat Flux :

From Equation (4-1)

$q_L = Q_L / A_f$

$q_L = 2663.9 / 26.4$

$= 101 \ W/m^2$

2- Floor temperature :

From Equation (4-2)

$q_L = 8.92 (T_L - T_i)^{1.1}$

$101 = 8.92 (T_L - 23)^{1.1}$

$T_L = 32.1 ^oC$

3- Calculation of required pipes spacing and water temperature:

For ceramic floor that used in selected building we can specify the water temperature and pipes spacing with respect to floor temperature by using Figure (4.6) for Ceramics floor.

We can see from Figure (4.6) the Ceramics floor does not need high water temperature and (40-45) ^oC is more suitable to give the required floor temperature at varies spaces, and this reduces the running cost but on other hand increases the initial cost by increasing the loop length.

For $T_L = 32.1\ ^oC$ and $T_k = 45^oC$ the corresponding pipes spacing is 15 cm .
And this pipes spacing give $T_L = 32.8\ ^oC$ exactly.

4- Calculation of the reverse heat flow:

For 5 cm polystyrene insulator thickness we can find the reverse heat flow from Figure (4.7).

At $T_L = 32.8\ ^oC$

$q_k = 19\ W/m^2$

5- Calculation of the total heat load to be emitted by the pipes (Q_e):

From Equation (4-3)

$Q_e = (q_L + q_k)\ A_f$

Loop one (L1) :

$(Q_e)_1 = (q_L + q_k)\ A_f$

$= (101 + 19) \times 13.2$

$= 1584\ W$

Loop two (L2)

$(Q_e)_2 = (q_L + q_k) A_f$

$= (101 + 19) \times 13.2$

$= 1584 W$

6- Calculation of the mass flow rate of water for each loop:

From Equation (4-4)

$Q_e = m_w.cp.\Delta T_w$

$\Delta T_w = 7\ ^oC$

Where $\Delta T_w = (5 \text{ to } 8\ ^oC)$

Loop one (L1)

$(m_w)_1$= 1584/ (4.18 × 1000 × 6)

= 0.054 kg /s

Loop two (L2)

$(m_w)_2$ = 1584/ (4.18 × 1000 × 6)

= 0.054 kg /s

7- Selection of pipe diameter with considering the flow velocity:

From pipes marketing companies catalogues we can specify the pipe diameter with respect to the flow velocity.

We will use PEX 5L (Cross-linked polyethylene, five layers pipe: cross linked polyethylene, adhesives, oxygen barrier, adhesives, cross linked polyethylene,"(shown in figure (4.8)"

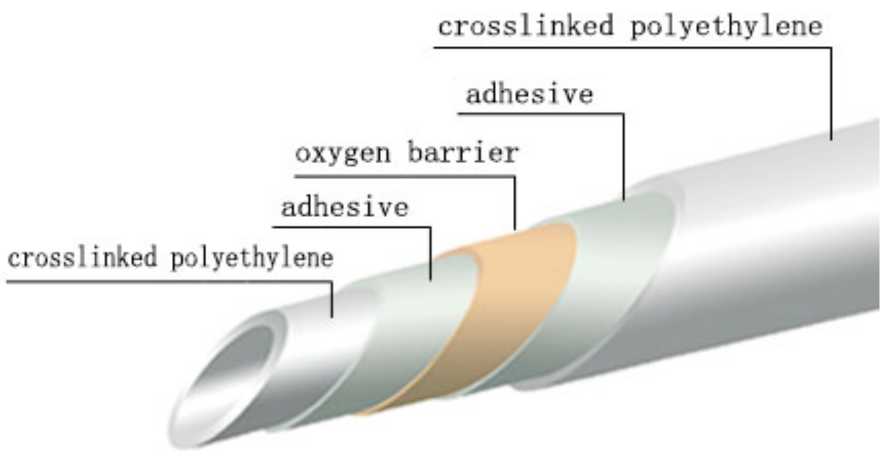


Figure (4.8) Cross-linked polyethylene, five layers pipe.

There is some Specifications for PEX pipes used in first and second floor:

Outer diameter (d_o) = 20 mm.

Thickness = 2 mm .

Inner diameter (d_i) = 16 mm.

From Equation (4-5)

$V_w = 4 (m_w / \rho_w) / (\pi \times d_i^2)$

Loop one (L1)

$= (4 \times 0.054 / 1000) / (\pi \times (0.016)^2)$

$= 0.27$ m /s < 1.2

Loop two (L2)

$= (4 \times 0.054 / 1000) / (\pi \times (0.016)^2)$

$= 0.27$ m /s < 1.2

Hint

In bathrooms and ground floor we will use fan coil units so we will calculate mass flow rate as follow:

$Q_e = m_w.cp.\Delta T_w$

$\Delta T_w = 20\ ^oC$

4.9 Floor design summary

The complete results for the selection building are shown in Tables (4.1) to (4.2) .

Table (4.1) First Floor Under Floor Design Conditions.

Zone	q_L (W/m^2)	T_f ^oC	S cm	T_{fac} ^oC	q_k W/m^2	Qe W	m_w Kg/s	V_w m/s	L_{LOOP} m
Guest R. (L1)	101	32.1	15	32.8	19	1584	0.054	0.27	100.92
Guest R. (L2)	101	32.1	15	32.8	19	1584	0.054	0.27	90.46
Guest Bed	59	28.6	30	29.3	15.8	1575.3	0.054	0.27	79.16
Living R. (L1)	68.4	30.9	20	31.4	17.9	2563.1	0.0875	0.45	136.68
Living R. (L2)	68.4	30.9	20	31.4	17.9	2407.8	0.082	0.44	132.58
Living R. (L3)	68.4	30.9	20	31.4	17.9	372.82	0.013	0.24	25.51
Kitchen and Bed (L1)	114.66	30.2	25	32.3	18.8	3363.2	0.115	0.572	108.29

Kitchen and Bed (L2)	114.66	30.2	25	32.3	18.8	1775	0.061	0.3	68.53
	Mw Total = 0.5205 Kg/s								

$$Mw\ Total = 0.5205 + Mw_{Bathroom1} + Mw_{Bathroom2}$$
$$= 0.5205+0.013+0.02$$
$$= \mathbf{0.5535\ Kg/s}$$

Table (4.2) Second Floor Under Floor Design Conditions.

Zone	q_L (W/m^2)	T_f °C	S cm	T_{fac} °C	q_k W/m^2	Qe W	m_w Kg/s	V_w m/s	L_{LOOP} M
Main Bed (L1)	76.9	30.1	25	32.3	18.8	2526.5	0.086	0.44	119.83
Main Bed (L2)	76.9	30.1	25	32.3	18.8	1505.4	0.051	0.254	67.84
Main Bed (L3)	76.9	30.1	25	32.3	18.8	528.3	0.018	0.25	33.48
Bed 1	66.6	29.2	30	29.3	15.8	2568.4	0.088	0.44	112.13
Bed 2	107	32.5	15	32.6	18.9	1967.82	0.067	0.33	105.64
Bed 3	88.1	31	20	31.4	17.9	1802	0.062	0.31	87.62
Kitchen and Living (L1)	96.7	30.7	20	31.4	17.9	2372.2	0.081	0.4	94.55
Kitchen and Living (L2)	96.7	30.7	20	31.4	17.9	2532.7	0.086	0.43	104.71
	Mw Total = 0.539 Kg/s								

$$Mw\ Total = 0.5205 + Mw_{Bathroom1} + Mw_{Bathroom2} + Mw_{Bathroom3}$$
$$= 0.539+0.015+0.014+0.019$$
$$= \mathbf{0.587\ Kg/s}$$

Mw for ground floor = $Mw_{Sport} + Mw_{Bathroom}$

Mw for ground floor = 0.0255+0.015

Mw for ground floor = **0.0405 Kg/s**

Mw Total in the system = Mw $Total_{1st\ floor}$+ Mw $Total_{2nd\ floor}$+ Mw $_{ground\ floor}$

Mw Total in the system =1.181 Kg/s

Hint:

Bathrooms and Ground Floor will provided by Fan coil Units that will appear at chapter 5.

4.10 Under floor heating system component

There are many different versions of under floor heating systems, the most modern and technically advanced solutions use the following materials:

1- PE damp-proof film

Its used to stop moisture transfer into the screed, to insulate the polystyrene of the insulating panel from any damaging materials, thickness 0.2 mm. (figure 4.9)

Figure (4.9) PE damp-proof film

2- Insulating panel

To limit downward heat dispersion, reduces the material mass to heat and allows the pipes to be fixed, there are three types of panels; studded type, roll-out type, and folding type, they are available in various thicknesses and densities depending on the required characteristics, they are made of expanded closed-cell polystyrene. (figure 4.10)

Figure (4.10) insulating panel (studded type)

3- Edge insulating strip

Cross-linked PE strip which insulating the floating screed from the vertical walls and allows the expansion of the concrete. (figure 4.11)

Figure (4.11) Edge insulating strip

4- PE-X pipe

Silane Cross –linked polyethylene pipe (PE-Xb) with EVOH oxygen diffusion barrier, it allows heating circuits with high technical and mechanical characteristics.(figure 4.12)

Figure (4.12) PE-X pipe

5- Fixing Systems

Clips, staples and cliprails made of plastic material to hold the pipes and the metal mesh in place. Available in various dimensions and shapes. (figure 4.13)

Figure (4.13) kind of under floor Fixing Systems

6- Metal mesh

Galvanized iron electro welded mesh to limit the expansion of the concrete screed and increase the resistance to loads . available in various diameters (2,3and 6mm) depending on application and load. (figure 4.14)

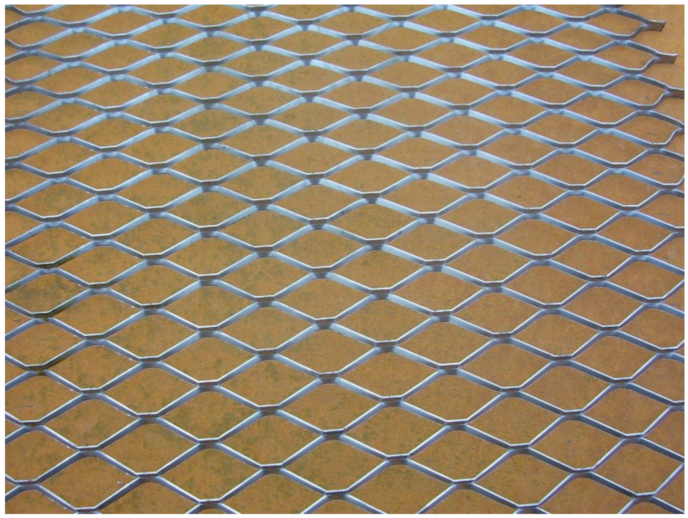


Figure (4.14) Metal Mesh

7-Screed(support layer)

Supporting structure made of concrete with the addition of fluidifying agent, whose function is to release the heat generated by the PEX pipes to the room, the height of the screed varies depends on the design data. (figure 4.15)

Figure (4.15) Screed(support layer)

8- Expansion and contraction joints

Screed longitudinal interruptions created to discharge the stresses (due to the screed expansion and contraction. (figure 4.16)

Figure (4.16) Expansion and contraction joints

9- Additive

Highly fluidifying liquid chemical additive for concrete screeds to improve fluidity, thermal and mechanical characteristic “non toxic”.

After installation the layers of underfloor heating system will be as the figure (4.17) follow.

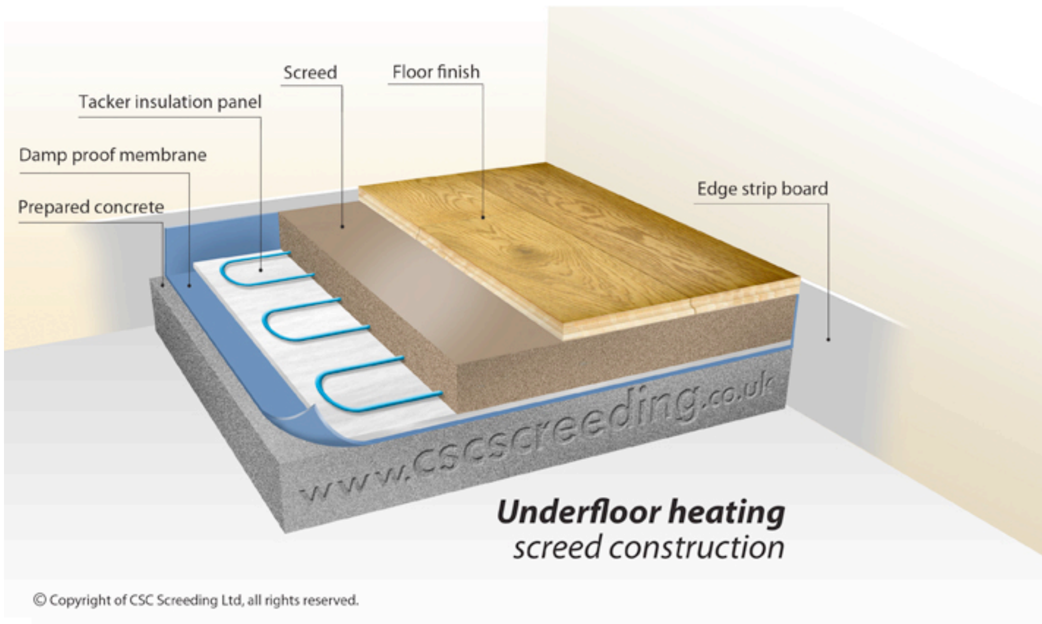


Figure (4.16) Under floor heating system construction

10- Water collector (assembled destitution manifolds)

assembled destitution manifolds are made of low lead content brass CW 614 with low lead content, normalized after mechanical machining. Manifolds are the ideal solution for radiant panel heating systems and are available in various configurations, depending on the characteristics of the systems.

The pre-assempled manifolds consist of 2 bars:

Supply, available in 2 versions, complete with mechanical memory screws or with flow meters.

Return, complete with thermostatic screws, with protection cap, suitable for the automatic control with thermoelectirecal heads.

pre-assembled manifolds are available in 2 sizes, 1" and 1.25", yellow or nickel plated, 2 to 12 outlets and various accessories (plugs, fittings, ball valves, thermometer, by-pass, etc.) see figure (4.17).

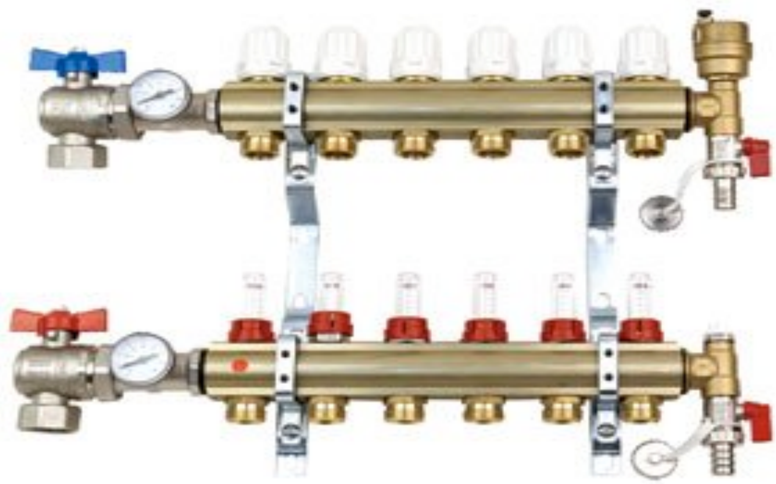


Figure (4.17) pre-assembled manifold

Chapter Five

Equipment Selection

5.1 Introduction:

In this Chapter we will discuss how to select devices and equipment that system needs to operate, how to connect and install some devices andequipment, and the way of controlling this system.

5.2 Fan Coil Selection

For bathrooms and Ground floor we will select fan coil units (Floor Ceiling Type) as figure(5.1).

Figure (5-1)

This figure show the type of fan coil selected. It can be installed on the floor or under the ceiling. With the features of easy and flixable installation, wide range and long distance air supply, good performance, various control function and slim body. It is specially applicable to the hotel, office, meeting rooms, bathrooms, and low space rooms.[5]

Advantage:

Slim design, low noise, plastic case, long life and washable fitter, three-speed motor, light weight and high air volume thanks plastic fan structure.

Model and all of the proprieties shown in the following table (5-1) [5]:

Model			FP-34WM-K	FP-51WM-K	FP-68WM-K	FP-85WM-K
Power system	Type	V-Ph-Hz	220-240V-1Ph-50Hz			
	Input	W	40	40	62	77
Air flow volume	High	CFM	200	300	400	500
	Medium	CFM	146	232	291	375
	Low	CFM	125	155	194	250
Capacity	Cooling	kW	1.8	2.8	3.6	4.5
	Heating	kW	2.8	4.15	5.4	6.75
Water system	Water flow volume	m³/h	0.37	0.50	0.64	0.81
	Pressure drop	kPa	9.8	9.8	36.5	36.5
Sound pressure level		dB(A)	48	48	49	49
Connection pipe size	Water inlet & outlet pipe	inch	3/4"(inner groove)		3/4"(inner groove)	
	Condensing water drain pipe	inch	3/4"(outer groove)		3/4"(outer groove)	
Outline Dimension (W×D×H)		mm	834×238×694	834×238×694	1300×188×600	
Package Dimension (W×D×H)		mm	960×330×830	960×330×830	1414×248×724	
Net weight		kg	26	26	34	
Gross weight		kg	35	35	38	
Loading quantity		40GP	224		220	
		40'HQ	267		244	
standard controller			Wireless remote controller-Y512			

Table (5.1)

In bathrooms and sport hall we choose type (FP-34WM-K) according to load, so seven fan coils needed in this project.

5.3Pressure drop and Circulating pump selection:

In order to select the circulating pump for under floor heating system ,the water flow rate m_w ,and the total pressure drop ΔP,must be specified or calculated ,the total pressure drop consists of pressure drop in the under floor pipe ,manifold ,main supply and return pipe valves and other fitting .

by using previous equation in chapter 4 (4-6,4-7,4-8) we can calculate pressure drop in longest run as following:

$$\Delta p/\Delta L = f \times \rho \times \frac{V_w^{\,2}}{2 \times d_i}$$

$$=0.08*1000*\frac{0.45^2}{2*0.016}$$

=506.25Pa\m

$$\Delta PB = N \times K \times \rho \times \frac{V^2{}_w}{2}$$

$$=46*0.9*1000*\frac{0.45^2}{2}$$

=4191.75 Pa

$$\Delta P = \Delta PB + \left(\frac{\Delta p}{\Delta L} \times L_{LOOP} \right)$$

= 4191.75+(506.25*136.68)

=73.386KPa

This yield us to choose the suitable water circulating pump, and according to this results with water flow rate= 4.252 m^3/h we choose **"Biral A 16 /A 401"** as figure (5.2), (5.3)and table (5.2).

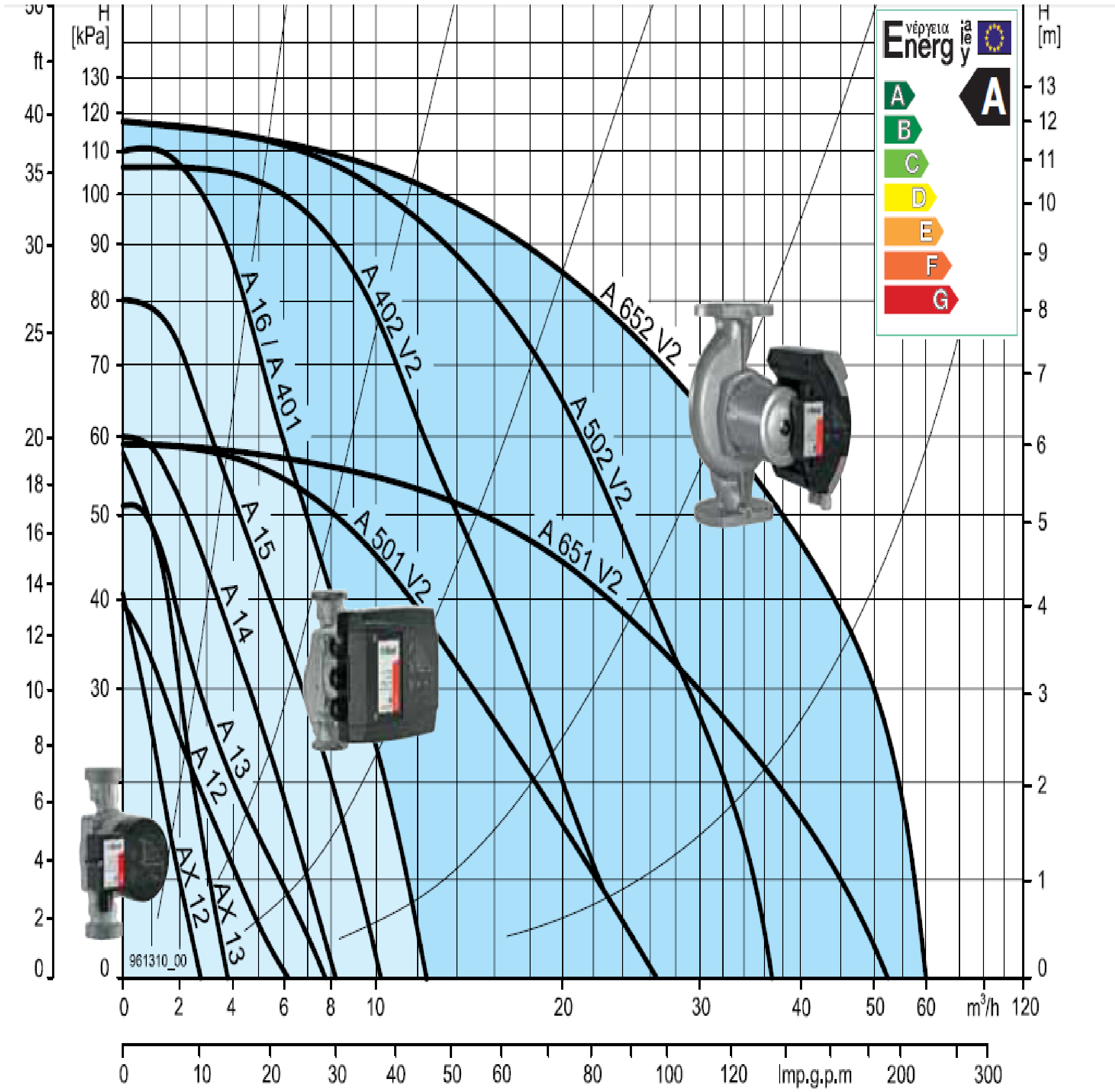

H [kPa]
ft
H [m]
A 652 V2
A 502 V2
A 402 V2
A 16 / A 401
A 651 V2
A 501 V2
A 15
A 14
A 13
A 12
AX 13
AX 12
961310_00
m³/h
Imp.g.p.m
Energy
A

Figure (5.2)

A 401, A 401-1

Installation length	A 401 A 401-1	220 mm 250 mm
Permissible operating pressure		10 bar
Permissible operating temp.		+15°C to +110°C 2)
Ambient temperature		max. 40°C
Required operating pressure at at 75°C water temperature at 95°C water temperature For every ±100 m altitude		500 m a.s.l. 0.10 bar 0.55 bar ±0.01 bar
Weight		7.7 kg
Voltage		1×230 V, 50 Hz
Current	Regulation	0.1...1.25 A
	min	0.14 A
Power	Regulation	8...174 W
	min	8...19 W

To avoid the formation of condensation the media temperature must always be higher than the ambient temperature.

Ambient temp.	Media temperature	
°C	min. °C	max. °C
15	15	95/110 2)
30	30	95/110 2)
35	35	90
40	40	70

2) for short periods, approx. 30 min

The pump is fitted with internal electric motor protection and requires no external motor protection. The pump is provided with fault or operating message (switchable).

Optional:
- Thermal insulation shell
- Control module, signal module

See page 34 for further details

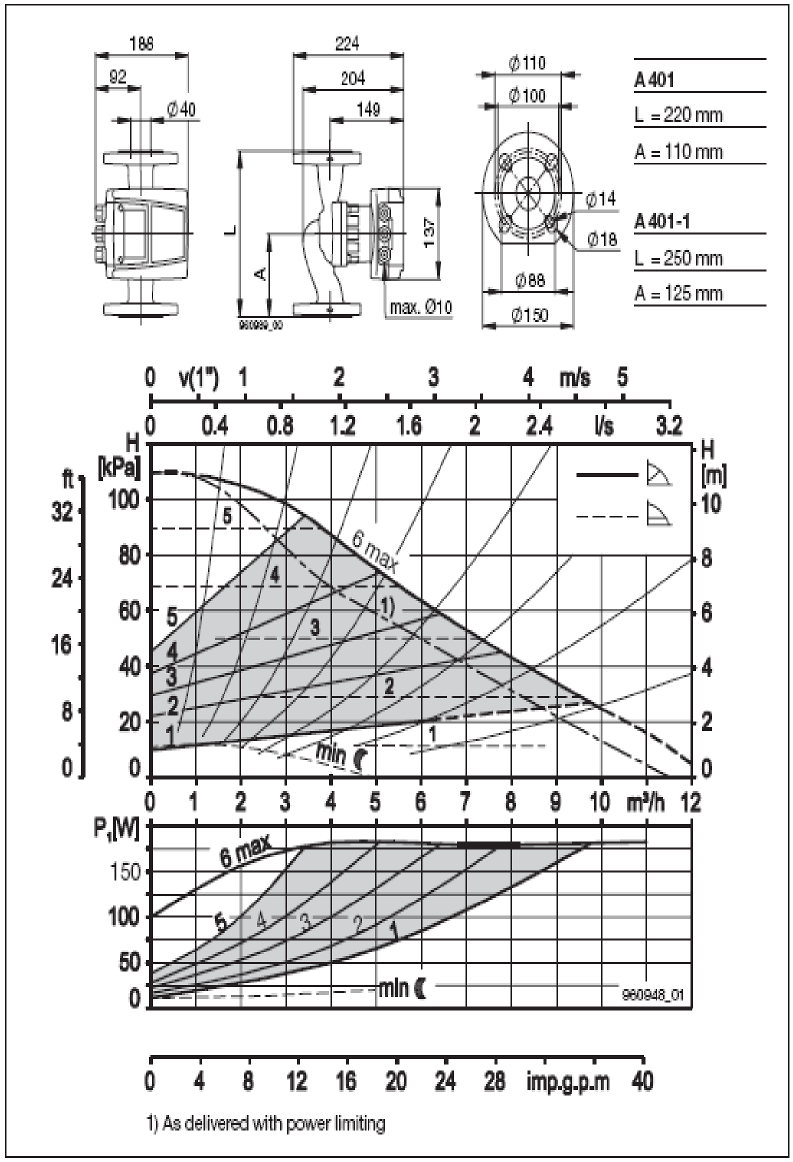


Figure (5.3)

Table (5.2)

Installation Dimentions	Φ 50 mm x 270 mm
RPM	2800
Price $	470

Advantage:

High volumetric efficiency, high pressure capability, high speed circulation, easy to maintain, low noise, available in middle east[5].

5.4 Flat plat collector selection:

There are good and bad solar collectors, In other words: there are good flat plate collectors that may perform better than poor evacuated-tubes in cold climates (the final performance also depends on the design of the whole solar heater system: issues as the pump consumption, controller, or hot water cylinder location are important.

According to the load we have,we chose Neo 2.1 Solar Flat Plate Collector because of high efficiency of gain and suitable area and availability of it. (figure 5.4 and table 5.2)[5]

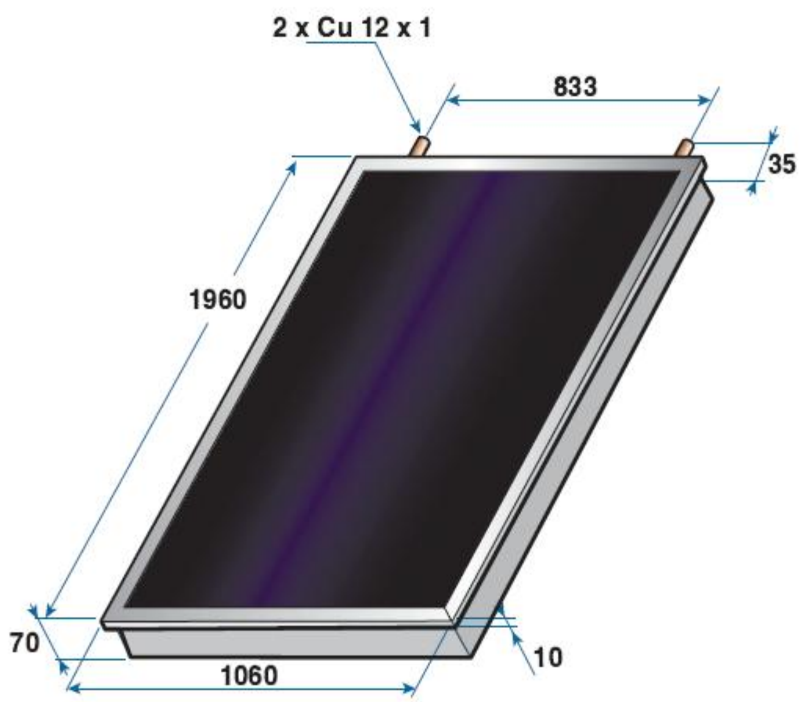


Figure (5.4)

Table (5.2)

Product Name:	Neo 2.1 Solar Flat Plate Collector
Availability:	Available
Price:	$700
Gross Area:	2.1 m^2
Clear C BTU / Day:	28700 BTU
Fluid Volume:	.26 gal

Hints:

1 heating ton = 3.1569 KW

1 heating ton = 12000 BTU

Number of panels = 12units will be needed(depending on IzzatMarji solar application)

5.5Storage tank selection:

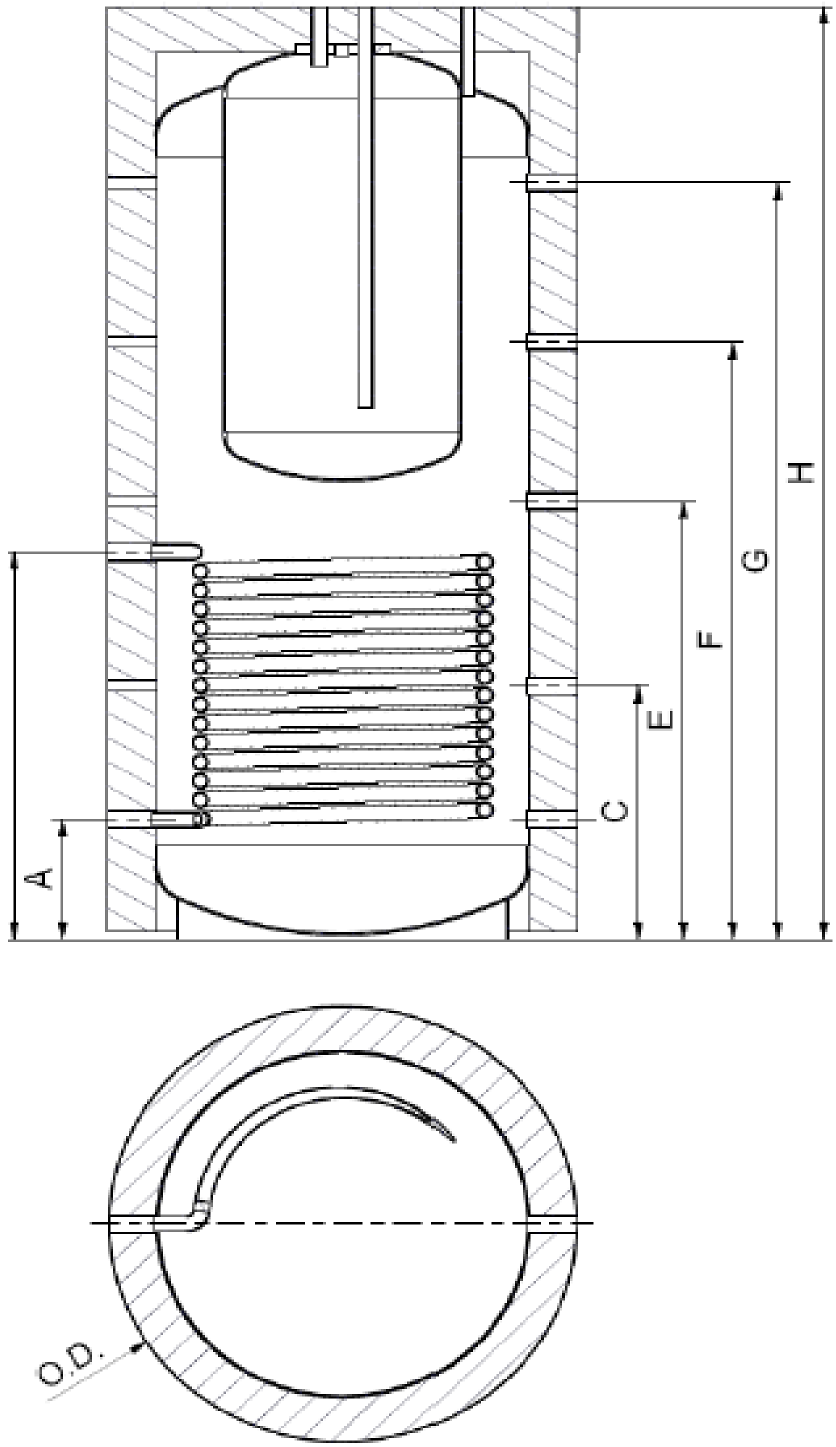
According to water flow rate and domestic usage we choose (Combi cylinders SS-CMB 1000 liter), as figure (5.5), and table (5.3).

Table (5.3)[5]

DIMENSIONAL DATA

Capacity (litre)	Trade Name	O.D. (mm)	A (mm)	B (mm)	C (mm)	E (mm)	F (mm)	G (mm)	H (mm)
572	**SS - CMB 600**	790	310	860	490	1000	1345	1690	2010
804	**SS - CMB 800**	950	380	980	580	1120	1440	1760	2170
1002	**SS - CMB 1000**	990	330	930	530	1170	1590	2010	2390
1498	**SS - CMB 1500**	1150	375	975	575	1215	1635	2055	2470

A 1" Fill-in / 1" Return to Solar collectors
B 1" Flow from Solar collectors
C 1" Return from underfloor heating
E 1" Return to Heat pump
F 1" Underfloor heating draw-off
G 1" Flow from heat pump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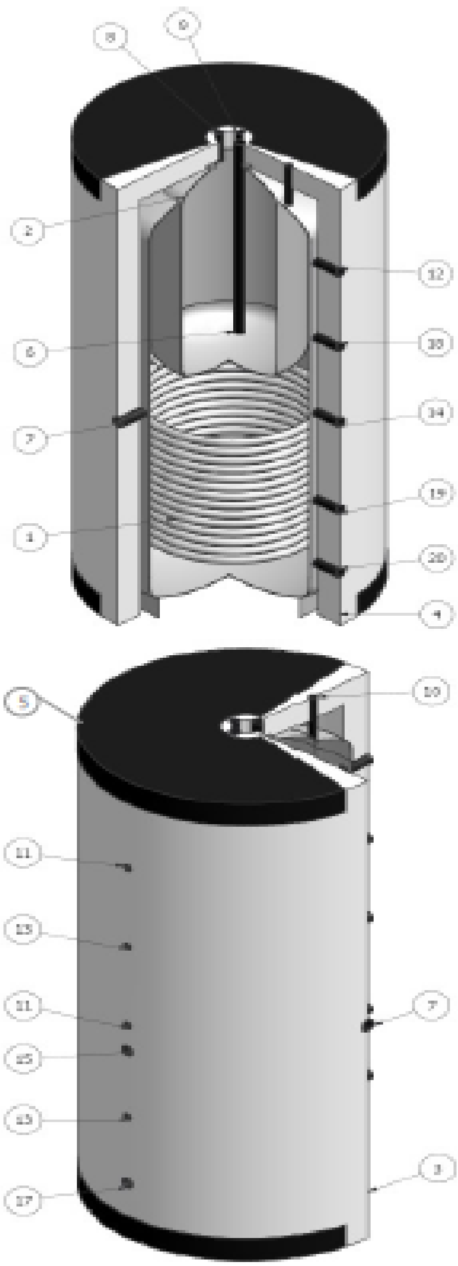
Coh-Me Solar Systems

GENERAL FEATURES



The **SS – CMB range** of Combi cylinders are compatible with solar systems intended to produce **Domestic Hot Water** and **Underfloor Heating.**

Their **"tank-in-tank"** design ensures separation between systems.

The coiled pipe heat eschanger facilitates the heat transfer between **Solar system** and Underfloor Heating.

The Domestic Hot Water cylinder is submerged in the storage tank heated water. The Domestic Hot Water cylinder is manufactured from **Stainless Steel AISI 316L**.

Parts List	
No.	Description
1	Solar Heat exchanger
2	Domestic Hot Water cylinder
3	Insulation
4	PVC outer casing Grey colour
5	Top flat cover black colour
6	Cold water supply (¾")
7	Immersion element (1 ½")
8	Hot water draw-off (¾")
9	T&P valve (½")
10	Air vent (½")
11	Thermometer (½")
12	Flow from heat pump
13	½" Thermostat
14	Return to Heat pump
15	Flow from solar collectors
17	Return to solar collectors
18	Underfloor heating draw-off
19	Return from underfloor heating
20	Fill-in

Figure (5.5)

5.6Boiler selection:

Since the total load Q_t= 44.9 KW, and safety factor = 1.1, then Q_b=1.1*44.9

Q_b= 49.4 KW.

That's leads us to select residential oil boiler type (GT220) as figure (5.6) and table (5.4).

Figure (5.6)

The GT 220sare low temperature cast iron boilers, with an useful output of 40 to 100 kW and high combustion efficiency (up to 95%) with a sealed pressurized combustion chamber to be fitted with a pressure jet fuel oil- or gas burner.[5]

They are available with various control panels and are all factory fitted with domestic hot water priority (except X-Panel) and can be used to control 1-stage burners (B, D control panels), 2-stage burners (B2) or modulating burners (DIEMATIC 3 control panel + AD 217 PCB):

The GT 2200s can be delivered with the choice of a high performance 160- or 250-litre DHW calorifier, fitted with a “Titan Active System®” anode with self-adapting current for the maintenance-free protection of the tank.[5]

Condition of use:

-Boiler :

Max. working temperature: 100°C

Max. working pressure: 4 bars

Safety thermostat: 110°C

- Domestic hot water calorifier :

Max. working temperature: 70°C

Max. working pressure: 10 bars.

Table (5.4)

MODELS

Model		Output in kW	Output in Mcal/h	Control panel: X, see p 4	B (Basic), see p 5	D (Diematic 3), see p 7	B2 (Base 2), see p 7, 8	D + AD 217 (Diematic 3 + PCB AD 217), see p 7, 8
				for controlling 1-stage burner			for controlling burner : 2-stage	2-stage or modulating
For heating only GT 220		40-50	34,4-43,0	GT 224 X	GT 224 B	GT 224 D	-	-
		50-64	43,0-55,0	GT 225 X	GT 225 B	GT 225 D	-	-
		64-78	55,0-67,0	GT 226 X	GT 226 B	GT 226 D	GT 226 B2	GT 226 D + AD 217
		78-92	67,0-79,0	GT 227 X	GT 227 B	GT 227 D	GT 227 B2	GT 227 D + AD 217
		92-100	79,0-86,0	GT 228 X	GT 228 B	GT 228 D	GT 228 B2	GT 228 D + AD 217

5.7 Room temperature control

5.7.1 The Thermoelectric head

The thermoelectric head is an actuators which controls the opening and closing of the valve with thermostatic option on the manifold. The actuators contains a liquid which expands when it is heated by an electric résistance[8].

With their, compact design high resistance and reliable long-termoperation , the thermoelectric head (item 9567Txx) are available for 230V ac or 24V ac power supply ,with or without auxiliary contact to switch of the pump.[8]

Another extremely important characteristic is the possibility to change NO (normally open) heads into NC (normally closed) . (figure 5.7)

Figure (5.7) Thermoelectric head

5.7.2 Wired thermostat and clock thermostat

Figure (5.8) Wired thermostat and clock thermostat

Wired thermostat and clock thermostat can be divided in:

1- Manual mechanical or electronic thermostats.
2- 24 –hours thermostats, programmable by hour bands.
3- 7 –days thermostats, programmable by hour bands.
4- 6 –zone electric switching terminal: this device is used to simplify the connection of room thermostats, load "actuators" and circulating pump.

The switching terminal is used when the connections of thermostats and the relevant load may cause difficulties. Connecting each thermostat (up to 6 units) in the relevant terminal board, the connections with the load (thermoelectric heads, motor-operated valves, etc.) and the circulation pump are extremely simple and tidy[8].

Figure (5.9) 6 –zone electric switching terminal

5.8 System Operation

The room thermostat sends a control signal which activates the relevant RF receiver (micro controller "have central control unit" that's control of the thermoelectric head and the circulating pump) when the detected temperature is lower than the temperature set with the knob. The correspondent receivers output, previously set, is activated and controls the opening of the connecting thermoelectric head, at the same time, the output reserved to the circulating pump control is also activated, the central control unit instead allows the desired temperature to be modified on the room thermostat coupled to it by codifying procedure according to 4 level: comfort, economy, anti-frost and stop[8].(figure 5-10).

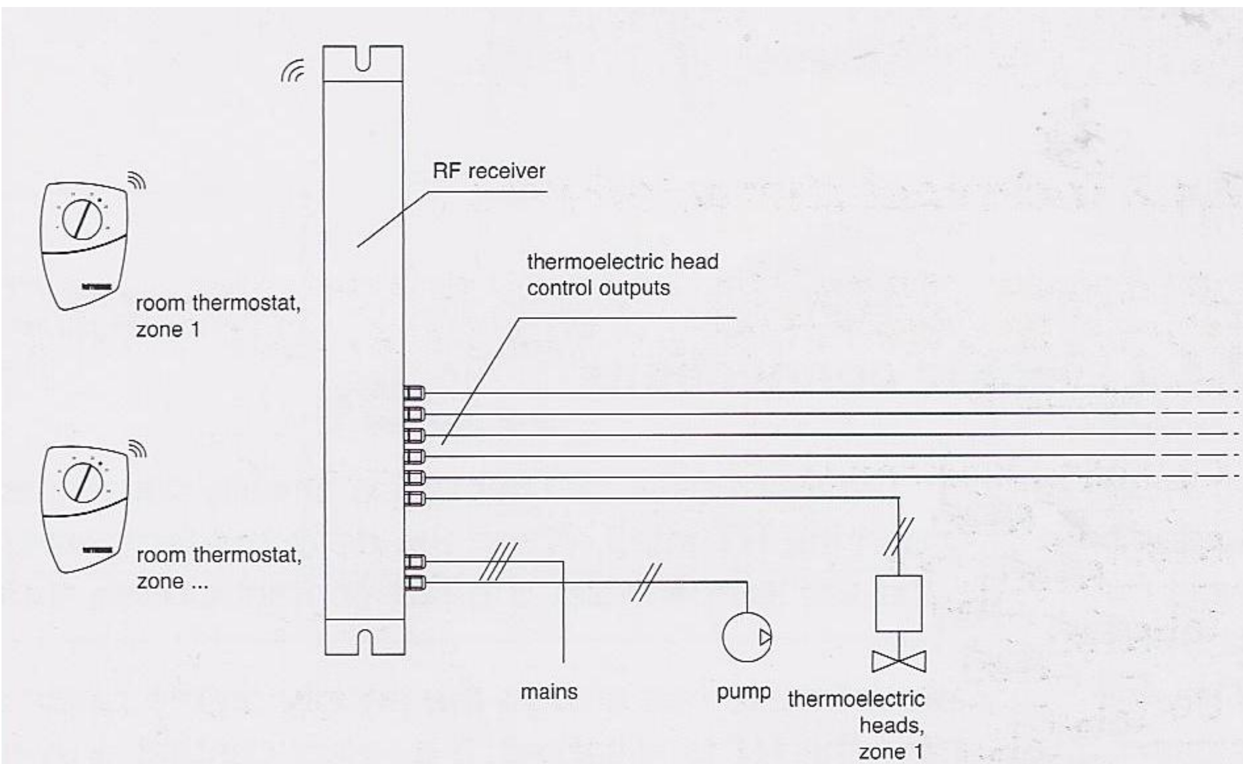


Figure (5-10) System Operation

5.9 Thermal control types

Three different types of thermal control levels are possible according to the control degree and the type and quantity of devices, from the simplest to the most complex types:

- Single zone thermal control.
- Two – zone (or more) thermal control.
- Multi- zone temperature control[8].

5.9.1 Single zone thermal control

This solution is simple and economic, it can be applied when the controlled environment is not too large and there is no need to diversify the temperature controlled room. A single thermostat (or clock thermostat) controls the entire heating system (not the signal radiant circuits) based on the room temperature sensed in the room where it is installed (sample room)[8] (figure 5.11).

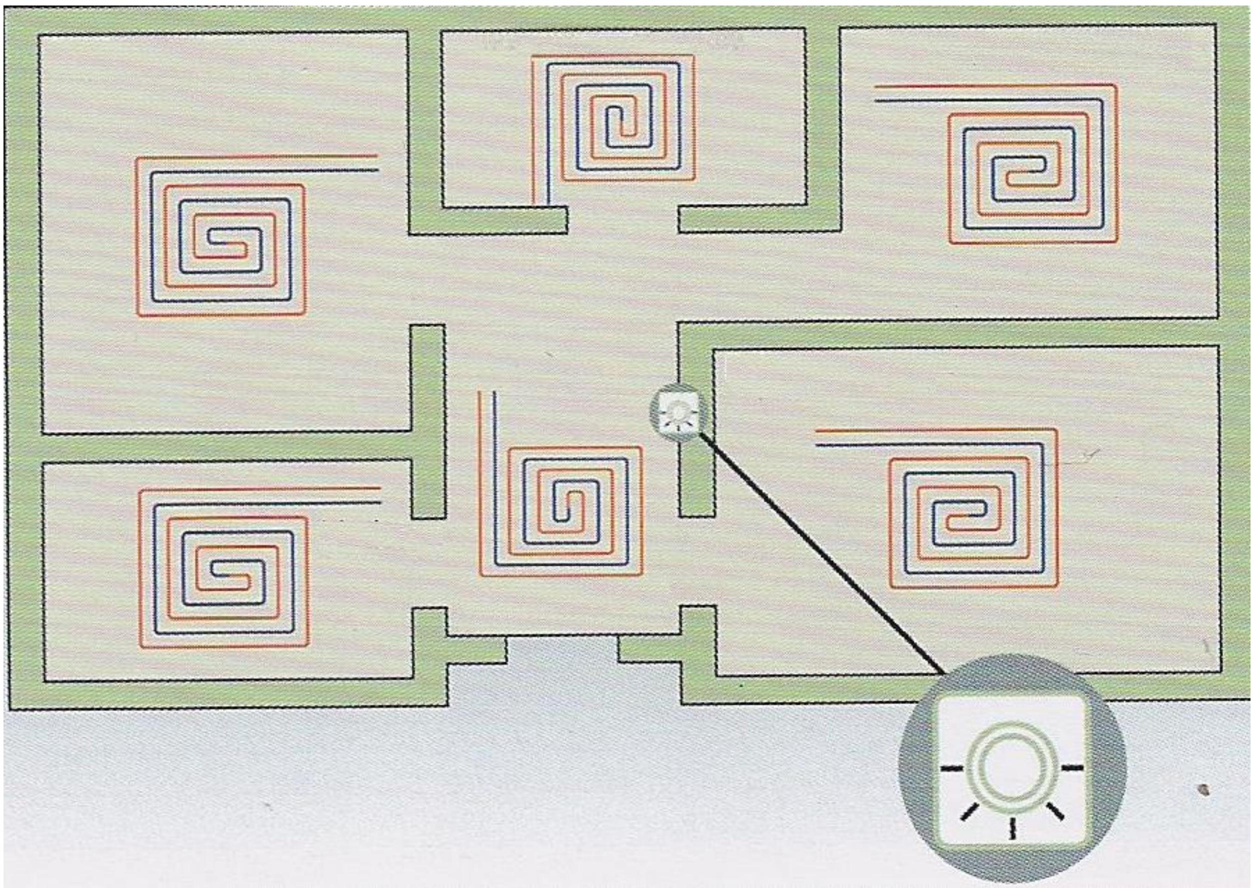


Figure (5-11) Single zone thermal control

Project (Quantity And Budget) Table

Class	Unit	Price Of (1 Unit) (JD)	Quantity	Tot. Price (JD)
$1m^2$ Of Under floor construction with foam, Boiler, and Controls	m^2	45	310	13950
Flat Plate Collector with connections	Num.	400	12	4800
Storage Tank	Num.	600	1	600
Circulating Pump	Num.	500	2	1000
Fan Coil	Num.	300	7	2100
Main Fold Collector	Num.	150	3	450
Flow switch	Num.	20	1	20
Water Solenoid Valve	Num.	40	1	40
Temperature out Sensor	Num.	80	1	80
		Total Cost		23040

Mechanical Bill Quantity					
Item Num.		**QTY**	**Unit**	**Unit Price (JD)**	**Total Price**
	All mechanical works items mentioned in here and after for all project facilities and Units shall include installation, adjustment, testing commissioning, and all required materials, equipment and workmanship to execute the items of construction in accordance with the specifications, drawings, and supervising engineers instructions, complete in place and ready for handing over.				
	Measurements for items with (L.m.) or (M2) Units will be based on net liner distance or net area of the products.				
1	**Water Piping (Galvanized Steel Pipes)**				
1.1	Supply and install, and commission **Galvanized steel pipes** sch. 40. with all necessary fittings like elbow, t, vent.....etc., Of approved quality. Price includes 13mm insulation for hot pipes, 6mm for cold pipes covered by aluminum foil bond.				
a-	3/4" nominal pipe size	120	M		
b-	1" nominal pipe size	35	M		
c-	1 1/4" nominal pipe size	70	M		
1.2	**Cold & Hot Water Collectors**				
	Supply and install, and commission Copper collectors with the following capacities, equipped with shutoff valves on main and branches, air vents and all fittings and accessories required for complete installation. Price includes pex pipes to connect the sanitary fixtures .				
a-	3/4" diameter. (18 outlets)	2	NO.		
b-	3/4" diameter. (6 outlets)	1	NO.		
1.3	**Water Cylinder**				
	Supply and install, and commission Hot water cylinder 1000 litter capacity, solar cylinder , with one solar panel Price includes shutt off valves, non return valves, air vent and safety valve. All connection to water pipes and	1	NO.		

	hangers included.				
1.4	**Centrifugal Pump**				
	Supply and install, and commission Centrifugal pump of $5m^3$/hr flow, 30m head with all required fittings and accessories for complete installation.	1	NO.		
2	**Sanitary Fixtures & Pipes**				
	Supply and install, and commission Internal sanitary sewers network shall be included in the rates of sanitary fixtures and appliances to nearest riser or manhole.				
2.1	**Wash Basin**				
	Supply and install, and commission White vitreous china wash basin. Complete with chrome single lever mixer. And all accessories for complete installation, i.e. chrome plated 13 mm stop	8	NO.		
2.2	**European Toilet**				
	Supply and install, and commission Wall hung White Vitreous China European type Toilet, with concealed flush tank and all accessories.	6	NO.		
2.3	**Bidet**				
	Supply and install, and commission Ceramic bidet with all accessories.	6	NO.		
2.4	**Kitchen Sink**				
	Supply and install, and commission Stainless steel double Bowl Kitchen Sink with tray of dimensions 80/60 cm , the price is also include kitchen type mixer with all accessories.	3	NO.		
2.5	**Shower**				
	Supply and install, and commission Vitreous china shower, complete with shower head, diverter, hand spring, hose, bracket, and all accessories, waste outlet, and required parts for the water supply line and drainage connection as shown in the drawings and specifications.	5	NO.		
2.6	**Floor Trap**				
	Supply and install, and commission 4" Floor traps.	15	NO.		
2.7	**Floor Drain**				

	Ditto, but floor drain	15	NO.		
2.8	**Clean Out**				
	Ditto but 4" Clean out.	13	NO.		
2.9	**UPVC Pipes**				
	Supply and install, and commission Drainage and storm UPVC for risers and underground use with all required fittings, excavation, hanging, and sand surround thick 15 cm for external underground pipes, testing, and refilling with selected compact				
a-	6" diameter	90	M		
b-	4" diameter	170	M		
c-	2" diameter	30	M		
2.10	**Rain Drain**				
	Supply and install, and commission UPVC rainwater roof drain 20cm x 20cm(quality approved).	2	NO.		
2.11	**Rain Water pipes**				
	Supply and install, and commission UPVC rain water pipes down to a free discharge above ground level, with all required digging, plastering, fittings and vent caps.				
	Diameter 100 mm(4")	41	M		
2.12	**Concrete Manholes**				
	Supply and install, and commission Precast concrete circular manholes. Price includes excavation, refilling, reinforced manhole base, concrete rings, Medium duty cast iron cover and plain concrete bedding with smooth sloped grooves.				
a-	Diameter 60 cm and depth up to 97 cm	5			
b-	Diameter 80 cm and depth up to 105 cm	7			
2.13	**Fan Coil Units**				
	Supply, install, test and maintain fan coil unit Floor Ceiling Type, complete with copper tubes with aluminum fins coil, centrifugal fan, electric motor provided with built-in thermal protection, thermostat, washable filter, all electrical wiring from room thermostat (temperature sensor) to the fan coil unit and from fan coil unit to the socket, room thermostat or temperature	7	NO.		

	sensor on return pipe, include Condensate Drain Pipes to be connected to nearest waste pipe or floor drain and all other fittings and accessories necessary to complete the works. (Daikin, Sanyo, Mitsubishi or Equivalent approved), Heating Capacity 2.8 Kw				
2.14	**Mainfolds Distriputers**				
	Supply and install copper collector of high quality manufactured by Giacomini or approved equal). for Underfloor Heating system with 20mm outlets with all accessories valves for each line and vent ,the price includes all fittings (vent, valves, on main line) , fixing above False ceiling with all necessary fixing parts as per drawing and superviser's engineer approval (All Manifold are located above floor).				
a-	26mmΦ, 8 branch with end piece,vent and isolating valve on each branch and all accessories.	2	NO.		
b-	26mmΦ, 2 branch with end piece,vent and isolating valve on each branch and all accessories.	1	NO.		
2.15	**Circulating Pumps**				
	Supply and install, and commission circulating heating horizontal or vertical in-line pump (centrifugal) with direct motor drive (4-pole, 1450rpm motor velocity) through a flexible coupling, complete with two gate valves one at the suction side and one at the discharge side and pressure gauges on both sides of pump and check valve connected on the discharge side and a strainer on the suction side. . The price shall include for spring vibration insulators, steel frame for concrete floating base, with the electrical connections with the electric panel and all control wires, and over load protection and magnetic contactor for each pump as shown in drawings, specifications and approval of supervisor engineer. Type (Biral	2	NO.		

	A16/A401 circulating pumps).				
2.16	**Boiler**				
	Supply and install and test cast -iron boiler of approved trademark with burner with the same type of capacity 220KW . Price includes concrete base, supply and return collectors, safety valve, flow switch, power supply, remote gauge level for the fuel in the boiler room, digital panel.and all external controllers, necessary piping and fittings needed to complete the job such as fuel filter, fuel hoses, valves, fuel fire valve, drains thermometers pressure gauge ,all pipes inside the boiler room must be cladding proper insulated and covered with galvanized steel sheets. The price should also include all electrical works, wirings and cables required, in addition to installing guide instruction boards for commissioning the boiler and putting stickers on all pipes in boiler room showing the pipe use and the flow direction. All is according to drawings and engineer's instructions.	1	NO.		
2.17	**Diesel Tank**				
	Supply and install, and test black steel under ground fuel tank thickness 6mm complete with necessary service manhole with steel cover opening 3mm min thick .Price includes concrete base ,surrounding walls,excavation,back filling with sand of minimum thickness of 0.5 m around the tank steel belt fixations, painted with primary coating and then with final asphalt coating, ,fittings,valves,openings for filling fuel, supply and return fuel, air vent, fuel gauge meter and 19mm copper fuel supply& return pipes to boiler room building manhole with cast iron cover & frame are included . The price should also include gear fuel pump of capacity: 0.5L/s and 2m Head with all necessary fittings and accessories and electrical	1	NO.		

	connections, price also include filling 500 liters of fuel for test and 100 liters daily tank inside boiler room. all are according to drawings, specifications and approval of supervisor engineer.				
2.18	**Heating Flat Plate Collectors**				
	Supply and install copper collectors for central heating system, of approved quality, with all necessary fittings, nipples, nuts, unions, quick shut off valves, branch valves, thermometer gauge brass fittings adapter, automatic vents ..Etc of approved quality. Rate includes hardwood architecture frame with ceramic tiles inside and formayka on sandwich wood cover with double doors for supply and return collectors inside. The price should also supplying and installing 16mm pexgol plastic pipes with its 25mm plastic conduits with 5cm thick concrete layer to fixture units outlets, copper elbows recessed in walls and all civil works needed, all according to plans and engineer's instructions, Collector Neo 2X1 " (For Supply and Retrurn)	12	NO.		
2.19	**Pex-Pipes**				
	Supply and install, and commission PEX 5L (Cross-linked polyethylene, five layers pipe: cross linked polyethylene, adhesives, oxygen barrier, adhesives, cross linked polyethylene, Outer diameter 20 mm, Thickness 2 mm, Inner diameter 16 mm.	1500	M		

Chapter Six

Drawings

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