Palestine Polytechnic University

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Mechanical Engineering Department

Refrigeration and Air Conditioning Engineering

Design of Mechanical Systems for Princes Hotel Building

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إهداء

إلى من جرع الكأس فارغاً ليسقيني قطرة حب

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(قل اعملوا فسيرى الله عملكم ورسوله والمؤمنون)

صدق الله العظيم

إلهي لا يطيب الليل إلى بشكرك ولا يطيب النهار إلا بطاعتك.. ولا تطيب اللحظات إلا بذكرك.. ولا تطيب الأخرة إلا بعفوك.. ولا تطيب الجنة الى برؤيتك

الله جل جلاله.......

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إلى الذين مهدوا لنا طريق العلم والمعرفة ......

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"كن عالما ... فإن لم تستطيع فكن متعلما، فإن لم تستطع فأحب العلماء، فإن لم تستطع فلا تبغضهم"

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contents

List of Figure VI

List of Table.......... IX

Chapter One 1

Introduction 1

1.1 Introduction 1

1.2Project overview 1

1.3 project importance 1

1.4 Building description 2

1.5 Project outline 2

1.6 Time table 4

Chapter 2 6

Heating and cooling load 6

2.1 Introduction: 6

2.2 Human comfort: 6

2.2.1 Introduction of human comfort: 6

2.2.2 Factors affecting human comfort [12] 7

2.3 Inside and outside design condition: 7

2.4 ASHRAE Comfort Chart: 8

2.5 Convection Heat Transfer Coefficient 9

2.6 Heating and cooling load : 9

2.7 Calculation of overall heat transfer coefficient : 10

2.8Calculation the overall heat transfer coefficient for room : 10

2.8.1 For external wall: 10

2.8.2 For internal wall: 11

2.8.3 For celling construction: 12

2.8.4 For glass 13

2.8.5 For door 13

2.9Heating load calculation: 14

2.9.1 Introduction: 14

2.9.2 Heating loss calculation: 14

2.9.3 Total heat load calculations 15
2.10 Cooling load: 22
2.10.1 cooling load calculation 22
2.11 Calculations using Revit: 30
2.11.1 Sample calculation 31
Chapter three 32
Variable refrigerant flow system 32
3.1 Introduction: 32
3.2 Variable refrigerant flow system 33
3.3 Types of VRF 35
3.3.1 VRF heat pump systems 35
3.3.2 Heat recovery VRF System 36
3.4 Advantage of VRF system 37
3.5 Disadvantage of VRF system 40
3.6 VRF technology 40
3.7 Components of VRF systems 42
3.8 Design considerations 45
3.9 Units Selection 50
3.10 Selecting refrigerant piping 51
3.11 Ventilation 53
Chapter four 59
Plumbing system 59
4.1 Introduction 59
4.2 Water supply system 60
4.2.1 Overview 60
4.2.2 Calculation of cold and hot water supply system 61
4.2.2.1 Calculation of cold and hot water (WSFU) system 61
4.2.2.2 Pipe sizing calculation 63
4. 3 Water well volume 66
4.4 Drainage system 68
4.4.1 Drainage system components 69
4.4.2 Sanitary drainage 70

4.4.3 Manhole design 71
4.5 Manhole calculation 71
Chapter five 73
Fire fighting system 73
5.1 Introduction 73
5.2 Types of firefighting system 74
5.2.1 Fire extinguishers 74
5.2.2 Fire hose reel 75
5.2.3 Fire hydrant system 76
5.2.4 Automatic sprinkler system 77
5.3 Types of automatic sprinkler system 78
5.3.1 Wet pipe system 78
5.3.2 Dry pipe system 79
5.3.3 Pre-action system 80
5.3.4 Deluge system 81
5.4 Firefighting network components 82
5.5 Firefighting pumps 83
5.5.1 Pumping stations should include 83
5.5.2 Type of pumps 83
5.6 Flow rate calculations 85
5.6.1 Head estimation 86
chapter six 88
Swimming pool heating system 88
6.1 Introduction 88
6.2Filtration cycle 89
6.2.1Components of Filtration cycle 90
6.3 valve 92
6.4 Skimmers 93
6.5 Main drain 93
6.6 Return inlets 94
6.7 Designing of swimming pools 95
6.8 Calculation for swimming pool 95

6.8.1Swimming pool capacity 95
6.8.2 Flow rate 96
6.8.3 Filter selection 96
6.8.4 Skimmer selection 97
6.8.5 Main drain selection 97
6.8.6 Return Inlet Selection 98
6.8.7 Pipe Sizing 99
6.8.8 Pump Selection 100
6.8.9 Heating system 102
6.8.10 Chlorinator 103
References 105
Appendix (A) 107
Appendix (B) 120
Appendix (C) 126
Heat pump Samsung 128
C-6: Size of pipe F 129
C-7: Size of pipe B 129
C-8: Size of pipe B 130
C-9: VRF in door unit Samsung 131
Appendix (D) 132
BILL OF QUANTITIES 138

List of Figure

Figure(2.1):Human comfort chart 9
Figure (2.2) External wall construction 11
Figure (2.3) Internal wall construction 12
Figure (2.4) Ceiling construction 13
Figure (2 (5.Sample room 16
Figure (3.1)indoor units and outdoor units for VRF System 35

Figure :(3.2)VRF heat pump systems[26] 36
Figure :(3.3)Heat recovery VRF system[26] 37
Figure :(3.4)Refrigerant cycle 41
Figure :(3.5)Outdoor units[25] 43
Figure :(3.6)Indoor units 44
Figure :(3.7)Indoor units piping network[26] 44
Figure :(3.8)Insulation 45
Figure :(3.9)Typical VRF system space layout[26] 46
Figure :(3.10)Design limits in VRF system[25] 47
Figure :(3.11)Design limits in VRF system[26] 48
Figure :(3.12)Pipe sizing for VRF system[26] 48
Figure :(3.13)Ceiling unit[30] 50
Figure 4 :(3.14)way cassettes unit[30] 50
Figure :(3.15)cupper pipe 51
Figure :(3.16)calculate pipe diameters[30] 52
Figure :(3.17)bathroom 56
Figure :(4.1) Pump data for cold water first and second riser 67
Figure :(4.2) Pump data for hot water first and second riser 68
Figure (4 :(3.Drainage system components 69
Figure (4 :(4.Manholes details 72
Figure (5.1)Type of extinguishers 75
Figure (5.2) Fire hose reel 76
Figure (5 (3.Fire hydrant system 77
Figure (5 (4.Automatic sprinkler system 78
Figure (5 (5.Wet pipe system 79
Figure (5.6) Dry pipe system 80
Figure (5.7) Pre-action system 81
Figure (5 (8.Deluge system 81
Figure (5 (9.Firefighting network 82
Figure (5 (10.Horizontal split case pump 83
Figure (5 (11.Inline fire pump 84
Figure (5 (12.End suction pump 85

Figure (5 (13.Vertical turbine pump 85
Figure (5.14) Elite Fire Fighting program for the calculation 87
Figure (5 (15.dp pump program for the calculation........ 87
Figure (6.1) Horizontal drop for swimming pool 88
Figure (6.2) Filter shapes 89
Figure (6 (3.Filter parts 90
Figure (6 (4.Components of Filtration cycle 91
Figure (6 (5.Glass filtration media 91
Figure (6 (6.Skimmers 93
Figure (6 (7.Main drain 94
Figure (6 (8.Return inlet 94
Figure (6 (9.Main drain selection 98
Figure (6 (10.Return Inlet Selection 98
Figure (6 (11.Selection of pipe sizing 100
Figure (6 (11.Pump Selection 101
Figure (6 (12.Heat exchanger 102
Figure (6 (13.Catalogue of heat exchanger 103
Figure (6.14) chlorinator 104
Figure (6.1(5 swimming pool rotation system 104
Figure (6.16)Heating Equipment Swimming Pool 104

List of Table

Table(1.1) Building description 2

Table (1.2) Time estimated to work for semester 4

Table (1.3) Time estimated to work for second semester .... **Error! Bookmark not defined.**

Table (2.1): Outside and inside design conditions 8

Table (2.2): External walls Construction 10

Table(2.3):internal wall Construction 11

Table(2.4):Celling construction 12

Table (2.5): Total cooling and heating load for the sample room by Rivet 31

Table (2.6): Total cooling and heating load for the Building 31

Table (3.1) Outdoor unit and pipe size [30] 52

Table (3.2) Size of pipe between the branch joint and indoor unit 53

Table (4.1): Fixture units load for first riser 61

Table (4.2): Total number of fixture units 62

Table (4.3): Total WSFU and gpm for risers 63

Table(4.4): Pipe sizing for cold water riser 65

Table (4.5): Pipe sizing for hot water riser 65

Table (4.6): Diameter of manhole according to their depth 72

Abstract:

This project aims to design the mechanical systems for Princes Hotel which is located in Bethlehem. This building consists of nine floors with an area of 2515.4 m^2. In this project, the thermal loads of this building calculated and the appropriate air conditioning system will be selected. The project also includes calculations, material selection, bill of quantities preparation for air conditioning system, ventilation system, water system, drainage system and firefighting system. These services are definitely designed to check human comfort.

الملخص:

يهدف هذا المشروع إلى تصميم الانظمة الميكانيكية لفندق الاميرة الذي يقع في بيت لحم. يتكون هذا المبنى من عشرة طوابق بمساحة 2515.4م^2. في هذا المشروع ، حيث تم حساب الأحمال الحرارية لهذا المبنى و اختيار نظام تكييف الهواء المناسب. ويشمل المشروع أيضًا الحسابات واختيار المواد وإعداد الفواتير لنظام تكييف الهواء ونظام التهوية ونظام المياه ونظام الصرف ونظام مكافحة الحرائق. تم تصميم هذه الخدمات بالتأكيد للتحقق من راحة الإنسان.

Chapter One

Introduction

1.1 Introduction

The science of air condition and refrigeration is one of the most important sciences necessary to provide a human comfort under different environmental conditions.

Just imagine who life was in such an old time that a person could not adapt to the circumstances at that age

Therefore, it is the engineer's job to devise more efficient and less expensive means and methods to provide human comfort without causing side effects that affect human health.

1.2Project overview

Since old time human was looking for comfort conditions. At this time, human has designed mechanical systems to achieve comfort conditions that he needs. To achieve the required comfort conditions for the human, a heating air conditioning and refrigeration engineer should do the followings:

1. Design the mechanical services for the building.

2. Design air conditioning system for the building.

3. Design firefighting system.

The parameters that are to be controlled and maintained in order to achieve the comfort level are:

1) Temperature of the inside space.

2) Humidity contents of the air.

3) Purity and quality of the inside air.

4) Air velocity and air circulation within the space.

1.3 project importance

1. In order to achieve all means for human comfort.

2. To protect people and expensive things from fire.

1.4 Building description

Al- prince's hotel includes nine floors, one floor underground, one restaurant, one reception hall, basement and seven floors for guests; the total area of the hotel is 2515 m2.

The following table (1.1) show floors within the hotel and the components of each floor:

Table(1.1) Building description

# of floor	Description
-1	Car parking
Ground floor	Reception hall
1	Kitchen Restaurant
2	Hotel rooms of various sizes.
3	Hotel rooms of various sizes.
4	Hotel rooms of various sizes.
5	Hotel rooms of various sizes.
6	Hotel rooms of various sizes.
7	Hotel rooms of various sizes.
8	Roof floor

1.5 Project outline

1. Chapter One

Introduction:

This chapter include overview about the project, project importance, building description and time planning.

2. Chapter Two

Heating and Cooling Loads:

This chapter consist of the procedures for calculating the heating and cooling load.

3. Chapter Three

Variable Refrigerant Flow System:

This chapter talks about the air conditioning system which is variable air flow (VRF).

4. Chapter Four

Plumping System:

This chapter include the water distribution calculation and drainage system.

5. Chapter Five

Firefighting system.

6. **Chapter six** Swimming pool heating system .

1.6 Time table

Table (1.2) Time estimated to work for semester

# of week Task	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Choosing the project	■	■	■												
Visit the library to collect information			■	■											
Reading books			■	■	■										
Put the title					■	■									
Writing the introduction and human comfort							■	■	■						
Calculating the heating and cooling load									■	■	■	■	■	■	
Visit supervisor and take some notation		■			■						■			■	■

Table (1.3) Time estimated to work for second semester

#of week / Task	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Firefighting																
Drawing firefighting system																
Plumping system calculations																
Drawing water system																
Drawing drainage system																
Pumps calculations																
Design VRV system																
Ventilation system																
Drawing VRV system																
Bill of quantity																
catalog																

Chapter 2

Heating and cooling load

2.1 Introduction:

Heating and cooling loads are the measure of energy needed to be added or removed from a space by the HVAC system to provide the desired level of comfort within a space. [1]

The heating and cooling load calculation is the first step of the HVAC design procedure, a full HVAC design involves more than just the load estimate calculation. Right-sizing the HVAC system, selecting HVAC equipment and designing the air distribution system to meet the accurate predicted heating and cooling loads begins with an accurate understanding of the heating and cooling loads on a space.[2]

2.2 Human comfort:

The human comfort depends on many terms or an a many circumstances.

2.2.1 Introduction of human comfort:

Humans generally feel comfortable between temperatures of 22 °C to 27 °C and a relative humidity of 40% to 60%. first cool the air to 14 °C (this removes some of the water from the air), and then heat the air to 24 °C. the heat and mass of water removed in the cooling phase, and the heat added in the heating phase.

Measurable change Sensible Heat is heat energy that, when added to or removed from a substance, results in a in dry-bulb temperature. Latent Heat (hidden) heat energy that is absorbed or released when the phase of a substance is changed. For example, when water is converted to steam, or when Steam is converted to water.

In order for the body to feel comfortable, the surrounding environment must be of suitable temperature and humidity to transfer this excess heat. If the temperature of the air surrounding is too high, the body feel uncomfortably warm. The body responds by increasing the rate of perspiration in order to increase the heat loss through evaporation of body moisture.[3]

2.2.2 Factors affecting human comfort [12]

1. Dry Air: air that has a zero-relative humidity.
2. Moist Air: air that is a mixture of dry air and any amount of water vapor generally, air with a high relative humidity.
3. Humidity: is the amount of water vapor in the air.
4. Saturation: the state of being saturated or the action of saturating.
5. Dry Bulb Temperature: temperature that is usually thought of as air temperature.
6. Wet Bulb Temperature: is the temperature a parcel of air would have if it were cooled to saturation (100% relative humidity) by the evaporation of water into it.
7. Dew-Point Temperature: the temperature at which water vapor starts to condense out of the air (the temperature at which air becomes completely saturated). Above this temperature the moisture will stay in the air. [9]

2.3 Inside and outside design condition:

The inside and outside conditions are obtained from Palestinian code for Bethlehem city, as shown in the following table as shown in Table (2.1).

we choose the design month to be July (in summer) and January (in winter).

Table (2.1): Outside and inside design conditions

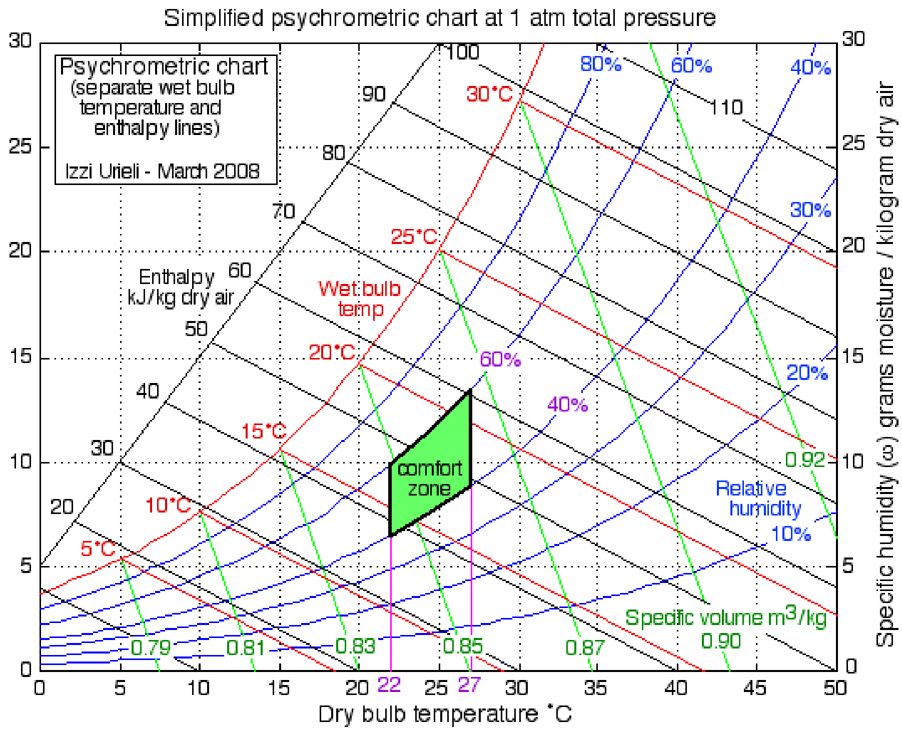
Property	Inside design condition		outside design condition [6]	
	summer	winter	summer	winter
Temperature (˚C)	24	24	30	4.7
Relative humidity (%)	50	50	51.3	70
Wind speed (m/s)	….	….	1.4	1.4

2.4 ASHRAE Comfort Chart:

There is no rigid rule that indicates the best atmospheric condition for comfort for all individuals. This is because human comfort is affected by several factors such as health, age, activity, clothing, food, etc.

Comfort conditions are obtained as a result of tests for which people are subjected to air at various combinations of temperatures and relative humidity's. The results of such tests indicate that a person will feel just about as cool at 24°C and 60% relative humidity as at 26°C and 30% relative humidity.

Studies conducted by ASHRAE with relative humidity between 30% and 70% indicated that· 98% of people feel comfortable when the temperature and relative humidity combinations fall in a comfort zone such as that indicated in the ASHRAE comfort chart of Fig. 2-1. This comfort zone covers a wide range of applications such as houses, offices, schools, hospitals, restaurants, etc.[4]



Figure(2.1):Human comfort chart

2.5 Convection Heat Transfer Coefficient

There are two ways to transfer heat by convection:

1-Forced convection.

2-Free convection.

2.6 Heating and cooling load:

Heating load: it is in winter and it is the rate at which heat must be added to the space in order to maintain the desired conditions in the space.

Cooling load: it is in summer and it is the rate at which heat must be removed from space in order to maintain the desired conditions in the space.

2.7 Calculation of overall heat transfer coefficient:

The overall heat transfer coefficient depends on the layers that the walls, floor and roof consist of and the inside and outside convection heat transfer coefficients. So the overall heat transfer coefficient can be calculated by applying the following equation:

$$U = \frac{1}{R_{th}} = \frac{1}{\frac{1}{h_i}+\frac{\Delta x_1}{k_1}+\frac{\Delta x_2}{k_2}+\cdots+1/h_0} \quad (2.1)$$

Δx: the thickness of the wall [m].

k : Thermal conduction of the material (W/mc)

$\boldsymbol{h_i}$: Convection coefficient of inside wall, floor, or ceiling (W/m^2.C).

$\boldsymbol{h_0}$: Convection coefficient of outside wall, floor, or roof (W/m^2.C). [9]

2.8Calculation the overall heat transfer coefficient for room :

Calculation of overall heat transfer coefficient for walls, ceiling, floor, glass and door :

2.8.1 For external wall:

Table (2.2): External walls Construction

	Materiel	Δx(m)	k (W/m^2.ºC) [5]
1	Stone	0.07	**1.7**
2	concrete	0.12	**1.75**
3	Polystyrene	0.03	**0.03**
4	Plaster	0.03	**1.2**

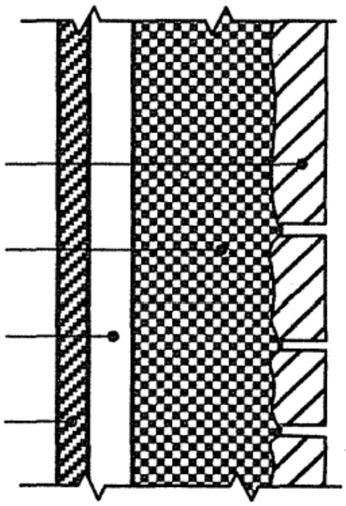


Figure (2.2) External wall construction

R_{in} and R_{out} for the external walls as 0.12 and 0.06(m^2 .°C /W) ,From table (5-2),(5-3).

$$U_{wall} = \frac{1}{R_{in}+\frac{\Delta x_{st.}}{k_{st.}}+\frac{\Delta x_{con.}}{k_{con.}}+\frac{\Delta x_{poly.}}{k_{poly.}}+\frac{\Delta x_{plaster}}{k_{plaster}}+R_{out}}$$

$$U = \frac{1}{0.12+\frac{0.07}{1.7}+\frac{0.12}{1.75}+\frac{0.03}{0.03}+\frac{0.02}{1.2}+0.06} = 0.760\ (W/m^2.°C)$$

2.8.2 For internal wall:

Table(2.3):internal wall Construction

	Materiel	Δx(m)	k (W/m².ºC) [5]
1	Plaster	0.02	1.2
2	Cement break	0.06	0.95
3	Plaster	0.02	1.2

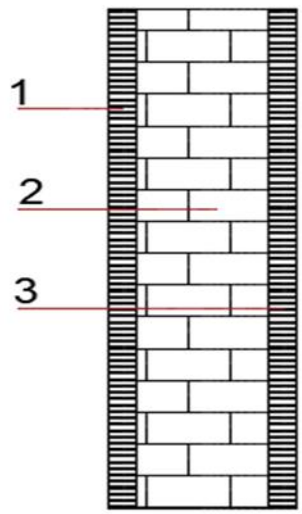


Figure (2.3) Internal wall construction

$$U = \frac{1}{R_{in}\ \frac{\Delta x_{plaster}}{k_{plaster}} + \frac{\Delta x_{(cem).}}{k_{cem.}} + \frac{\Delta x_{plaster}}{k_{plaster}} + R_{out}}$$

$$U = \frac{1}{0.12 + \frac{0.025}{1.2} + \frac{0.05}{0.95} + \frac{0.025}{1.2} + 0.12}$$

$U = 2.99\ (W/m^2.°C)$

2.8.3 For celling construction:

Table(2.4): Celling construction

	Materiel	Δx(m)	k (W/m².ºC) [5]
1	Asphalt	0.02	0.70
2	Concrete	0.04	1.75
3	Polystyrene	0.02	0.03
4	Concrete	0.05	1.75
5	Brick	0.10	0.95
6	Plaster	0.02	1.2

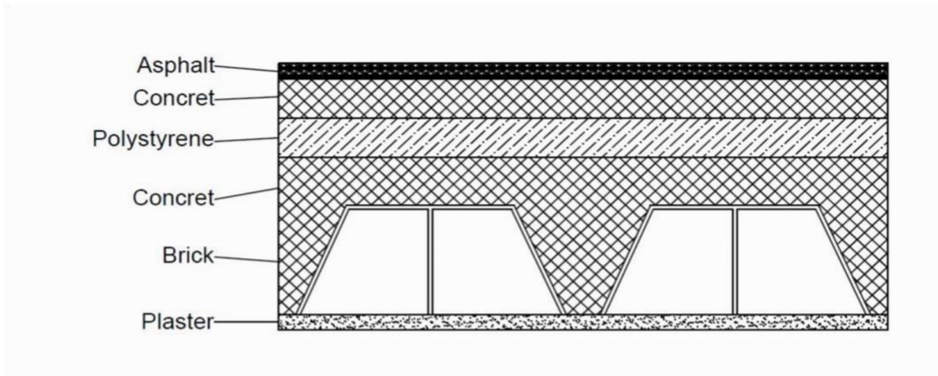


Figure (2.4) Ceiling construction

$$U_1 = \frac{1}{R_{in}+\frac{\Delta x_{asph.}}{k_{asph.}}+\frac{\Delta x_{conc.}}{k_{conc.}}+\frac{\Delta x_{poly.}}{k_{poly.}}+\frac{\Delta x_{conc.}}{k_{conc.}}+\frac{\Delta x_{Brick}}{k_{Brick}}+\frac{\Delta x_{Plaster}}{k_{Plaster}}+R_{out}}$$

$$U_1 = \frac{1}{0.1+\frac{0.02}{0.7}+\frac{0.04}{1.75}+\frac{0.02}{0.03}+\frac{0.05}{1.75}+\frac{0.10}{0.95}+\frac{0.02}{1.2}+0.04} = 1.004\ (W/m^2.\ °C) \text{ with Brick}$$

$$U_2 = \frac{1}{R_{in}+\frac{\Delta x_{asph.}}{k_{asph.}}+\frac{\Delta x_{conc.}}{k_{conc.}}+\frac{\Delta x_{poly.}}{k_{poly.}}+\frac{\Delta x_{conc.}}{k_{conc.}}+\frac{\Delta x_{Plaster}}{k_{Plaster}}+R_{out}}$$

$$U_2 = \frac{1}{0.1+\frac{0.02}{0.8}+\frac{0.04}{1.75}+\frac{0.02}{0.03}++\frac{0.15}{1.75}+\frac{0.02}{1.2}+0.04} = 1.041\ (W/m^2.\ °C) \text{ without Brick}$$

2.8.4 For glass

from table (A-28) , U_g = 3.2 ($W/m^2.\ °C$) , for double glass aluminum frame.

2.8.5 For door

from table (A-29) , U_d = 2.8 ($W/m^2.\ °C$) , for wood door type.

2.9Heating load calculation:

2.9.1 Introduction:

As mentioned before, conventionally steady state conditions are assumed for estimating the building heating loads and the internal heat sources are neglected. Then the procedure for heating load calculations becomes fairly simple. One has to estimate only the sensible and latent heat losses from the building walls, roof, ground, windows, doors, due to infiltration and ventilation.

Equations similar to those used for cooling load calculations are used with the difference that the CLTD values are simply replaced by the design temperature difference between the conditioned space and outdoors.

Since a steady state is assumed, the required heating capacity of the system is equal to the total heat loss from the building. As already mentioned, by this method, the calculated heating system capacity will always be more than the actual required cooling capacity. However, the difference may not be very high as long as the internal heat generation is not very large (i.e., when the building is not internally loaded).

However, when the internal heat generation rate is large and/or when the building has large thermal capacity with a possibility of storing solar energy during day time, then using more rigorous unsteady approach by taking the internal heat sources into account yields significantly small heating small capacities and hence low initial costs.

Hence, once again depending on the specific case one has to select a suitable and economically justifiable method for estimating heating loads.[5]

2.9.2 Heating loss calculation:

Heating loss happen by :

1- walls
2- celling
3- ground
4- doors

5- windows
6- infiltration :by open the doors and windows .
7- ventilation : the heat of existing bodies.

To calculate each one of them the following equations are to be use [5]:

$$Q=U\times A\times \Delta T \quad (2.2)$$

Where:

Q : Is the heat transfer rate. [kW].

U: Is the overall heat transfer coefficient. [$W/m^2.°C$].

A: Is the area of the layer which heat flow through it. [m^2].

ΔT: Is the difference between the inside and outside temperatures [°C] .

2.9.3 Total heat load calculations

Total heat load calculations for the sample room which is located in the fifth floor south east of the building at the wall, windows ,door …… etc. Shown in figure (2.5).

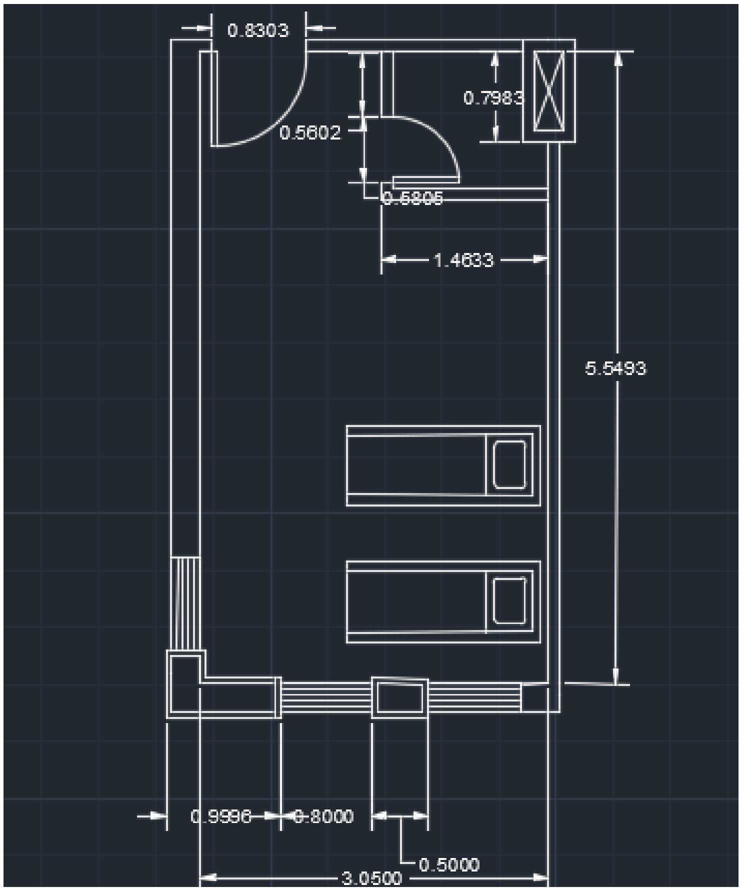


Figure (2.5) Sample room

Calculation the heat loss from the bedroom in the fifth floor as a sample :

The height of the room = 3.10 m

The length of the room=5.55 m

The width of the room =3.05 m

The height of the room door = 2m

The width of the room door=0.83 m

The height of the bath room door=2 m

The width of the bathroom door=0.58 m

The height of the window = 2m
The width of the window=0.80 m

1. **heat loss from the external wall:**

a- the area for the window =(n*h*W): (2.3)

where:

n: number of the window .

h: the hight of the window .

W: the width of the window .

A_{wind}=(3*2*0.80)=4.8 m^2

b- the area for the doors=(2*0.83)+(2*0.58)=2.82 m^2

c- the area for the external wall:

$A_{ex.\ wall}$ =((3.1*3.10)-(2*2*0.80)+(5.55*3.10)-(2*0.80))

=((9.3-3.2)+(16.65-1.6))

=21.15 m^2

The heat loss from external wall is

$$Q_{w.\ ex} = U_{w.} A_{w.\ ex} (T_{in} - T_{out}) \quad (2.4)$$

=0.760 (21.15) (24-4.7)

=0.310 kW

2- the heat loss for internal wall:

a- the area for the room door:
=(2*0.83)=1.66 m^2

b- the area for the bath room door:
=(2*0.58)=1.16 m^2

c- the total area for internal wall:
=((1.46*3)+(0.5*3)+(0.2*3)+(0.79*3)+(1.14*3)+(2.72*3)-(1.66+1.16))
=17.61m^2

The unconditioned temperature (T_{un}) is 20 C

The unconditioned area is
$A_{w\ un}$=(3*3 -2.2)=17.61 m^2

The heat loss from Internal wall is
$Q_{w\ in}=U_{in}\ A_{w\ in}\ (T_{in}-T_{un})$ (2.5)

=2.99 * 17.61*(24-20)

=0.210 kW.

Now, the total heat loss from walls is
$Q_{w.\ tot} = Q_{w.\ ex} + Q_{w.\ in}$ (2.6)

=0.310+0.210

=0.52 kW

Heat loss through the floor and ceiling:

Q floor =Q celling
Qfloor=U1*A1+U2*A2*(T in-Tun) (2.7)
Q floor=(1.004*12.92)+(1.041*4)*(24-20)
Q floor=68.53 W
Q celling=68.53 W

Heat loss through windows ($\dot{Q}_g$):

$Q_g = U_g\ A_g\ (T_i - T_o)$ (2.8)
=3.2 (3*2*0.80) (19.3)
=0.301 kW

Heat loss through the doors (Q_d) :

$Q_d=U_d\ A_d\ (T_i - T_{un})$ (2.9)
=2.8 *2.82 *4
= 0.0315 K

Heat loss through infiltration (Q_{inf}) :

Overview :

Heat loss from the infiltration is uncontrolled air leakage through joints in the construction and cracks around windows and doors .

Infiltration is caused by wind and stack – driven pressure differentials , which prompt air movement within the building envelope .

The total heat load due to infiltration is given by the equation:

$$Q_{inf} = \frac{V_{f.}}{v_o} \times (h_{in} - h_{out}) \quad (2.10)$$

Where:

h_{in}: inside enthalpy temperature (kJ/kg).

h_{out}: outside enthalpy temperature (kJ/kg)

V_f : The volumetric flow rate of infiltrated air in (m^3/h)

v_o: specific volume out (m^3/kg)

$$\dot{V}_f = K * L\,[0.613(S_1*S_2*V_0)^2]^{2/3} \quad (2.11)$$

Where :

K:the infiltration air coefficient.

L: the crack length in meter.

S_1: factor that depends on the topography of the location of the building

S_2: coefficient that depends on the height of the building.

V_0: measured wind speed (m/s).

*The value of K , S_1 and S_2:

K=0.43…..from table (A-13)

S_1=0.9…..from table (A-14)

S_2=0.75…..from table (A-15)

V_0=1.4 (m/s) from Palestinian code

And the window is sliding ,then:

$L = 3[(0.80+2)*2]$
$=16.8$ m
$V_f = 0.43*16.8\ [0.613(0.9*0.75*1.4)^2]^{2/3}$
$=4.81\ m^3/h$
$=1.33*10^{-3}\ m^3/s$

From the psychometric chart one can obtain the following moist air properties that correspond to the given inside and outside design condition :

$v_o = 0.79\ m^3/kg$
$h_i = 48$ kJ/kg
$h_o = 14$ kJ/kg
$\rho_o = 1/ v_o = 1.282\ kg / m^3$

The total heat loss due to infiltration is calculated by equation (2.9) as follows:

Through window:

$Q_{inf,g}=0.057$ kW

Through door:

$L =(2+0.83)*2+(2+0.58)*2 \quad =10.82$ m

$V_f = 0.43*10.82\ [0.613(0.9*0.75*1.4)^2]^{2/3}$

$=3.09\ m^3/h$

$= 8.5*10^{-4} m^3/s$

$Q_{inf,d}=0.0365$ kW

$Q_{inf} = Q_{inf,d} + Q_{inf,w}$

$=0.0365+0.057$

$=0.0935$ kW.

Heat due to gain ventilation :

Ventilation is the process by which clean air (normally outdoor air) is intentionally provided to a space and stale air is removed .

This may be accomplished by either natural or mechanical means.

And this kind of heat gain can be calculated by using the following equations:

$$Q_{ventilation} = m_{ventilation} \times (h_{out} - h_{in}) \qquad (2.12)$$

$$m_f = \frac{V_{f.}}{v_o}$$

V_f = Room volume $\times$ No. of times the air changes in the hour (2.13)

$$m_f = \frac{V_{f.}}{v_o} = \frac{(5.55*3.1*3.05)m^3 *(2*2/3)}{0.79(3600)} \quad = 0.0245 \text{ kg/s}$$

$$Q_{ventilation} = 0.0245 \times 1000 \times (48 - 14)$$

$$Q_{ventilation} = 0.833 \text{kW}$$

The total heat loss from the bedroom is

Q total=Q wall+Qcelling+Q floor+Q windows+Q doors+Q infiltration

+Q ventilation

=0.520+0.068+0.068+0.301+0.0315+0.093+0.833

=2 kW.

Take a safety factor of 10 % for each space of the residence to cover the miscellaneous and emergency heating loads then :

Q_{tot} = 2× 1.10=2.2 KW

2.10 Cooling load:

The cooling load is the amount of heat energy that would need to be removed from a space (cooling) to maintain the temperature in an acceptable range. The heating and cooling loads, or "thermal loads", take into account: the dwelling's construction and insulation; including floors, walls, ceilings, doors, windows and roof.

2.10.1 cooling load calculation:

To achieve the human comfort conditions it is needed to do some calculation to select the proper equipment to have the conditions that it is needed and the cooling load is the most important load that can helps in selecting the equipment’s that needed correctly. [7]

The total cooling load of a structure involves:

1. Sensible heat gain through walls, floors and roof.

2. Sensible heat gain through windows.

3. Sensible heat and latent heat gain from ventilation.

4. Sensible and latent heat due occupancy.

5. Sensible heat gain from the equipment

Direct and diffused solar radiation that absorbed by walls and roofs result in raising the temperature of these surfaces. Amount of radiation absorbed by walls and roofs depends upon time of the day, building orientation, types of wall construction and presence of shading. [8]

The heat transfer rate through sunlit walls or sunlit roofs is will be calculate from the following equation:

$$Q= UA\,(CLTD)_{corr.} \qquad (2.14)$$

Where:

$(CLTD)_{corr.}$: corrected cooling load temperature difference, ˚C [7]

$$(CLTD)_{corr.} = (CLTD + LM)\,k + (25.5 - T_{in}) + (T_{o,m} - 29.4)\,f \qquad (2.15)$$

Where:

CLTD: cooling load temperature difference, ˚C , from Table (A-3) and from Table (A-2)

LM: latitude correction factor, from Table (A-17)

k: colour adjustment factor .

T_{in} : inside comfort design temperature, ˚C

f: attic or roof fan factor.

$T_{o,m}$: outdoor mean temperature, ˚C

$T_{o,m} = (T max + T min) /2$ (2.16)

Where:

T_{max} : maximum average daily temperature, ˚C

T_{min} : minimum average daily temperature, ˚C

T_{max} = 30 ˚C and T min = 18 ˚C are obtained from Palestinian code.

Applying these values in equation (2.18) to obtain the outdoor mean temperature $T_{o,m}$ = 24 ˚C .

Sample room calculation:

1) Calculation the heat gain from the Guest room in the Third floor as a sample :

Heat gain through sunlit roof (Q_{Roof}):

CLTD = 3˚C

LM = 5

k = 0.83 for permanently light colour roofs.

f = 1 there is no attic or roof fan.

$(CLTD)_{corr.} = (3+ 5)(0.83) + (25.5 - 24) + (24- 29.4) (1)$

= 2.74˚C

$Q_{Roof} = (U_1 A_1 + U_2 A_2) (CLTD)_{corr}$ (2.17)

$Q_{Roof} = (1.004 \times 12.92 + 1.041 \times 4) (2.74)$

= 46.95 W

Heat gain through sunlit walls (Q_{wall}):

$\dot{Q}_W$ = zero

$\dot{Q}_s = UA(T_o - T_i)$ (21.8)

=0.760*15.6(30-24)

$\dot{Q}_s = Q_{wall}$=71.136W.

Heat gain through unconditioned walls ($Q_{un.}$):

From the wall around bathroom:

$Q_{un} = U A \Delta T$

$\Delta T = 2/3(30 - 24) = 4$

$Q_{un} = 2.99 \times (1.46*3.10)+(1.14*3.10)-(0.59*2) \times 4$

= 110.4 W

From North wall

$Q_{un.,N.} = U A \Delta T$

$\Delta T = 2/3(T_0 - T_i)$

$Q_{un.,N.} = 2.99 \times (1.13+0.80+0.40+0.22)*3.10 \times 4$

= 118.2 W

$Q_{wall\ un}$ = 110.4+ 118.2

= 228.6 W

Heat gain due to glass (Q_{Glass}):

The amount of solar radiation depends upon the following factors [2]:

1- Type of glass (single, double or insulation glass) and availability of inside shading.
2- Hour of the day, day of the month, and month of the year.
3- Orientation of glass area. (North, northeast, east orientation, etc.).
4- Solar radiation intensity and solar incident angle.
5- Latitude angle of the location.

The maximum cooling load due to the glass window Q_{Glass}, consists of transmitted ($Q_{tr.}$)

And convicted ($Q_{conv.}$) cooling loads as follows:

$$Q_{Glass} = Q_{tr.} + Q_{conv.} \quad (2.19)$$

Where**:**

$Q_{tr.}$: transmission heat gain, W

$Q_{conv.}$: convection heat gain, W

The transmitted cooling load is calculated as follows:

$$Q_{tr.} = A\ (SHG)\ (SC)\ (CLF) \quad (2.20)$$

Where**:**

*SHG: Solar heat gain factor: this factor represents the amount of solar energy that would be received by floor, furniture and the inside walls of the room and can be extracted , from Table (A-12). [9]

*SC: Shading coefficient: this factor accounts for different shading effects of the glass wall or window and can be extracted from Table (A-10) for single and double glass without interior shading or from Table (A-11) for single and double glass as well as for insulating glass with internal shading. [9]

*CLF: Cooling load factor: which Represent the effect of the internal walls, floor, and furniture on the instantaneous cooling load, and extracted from Table (A-8), and (A-9) for glass, and from Table (A-5) and (A-6), for lights and occupants respectively. [9]

SHG in W/m^2 …

A = 0.8*2=1.6 m2

SHG = 227 W/m^2

SC = 0.57…with interior shading

CLF = 0.68 at 14:00 clock …

$Q_{tr.\ s}$= 1.6× 227 × 0.57 × 0.68

= 140.77 W

For wall in east direction:

A = (2*2*0.80) =3.2 m2

SHG = 678 W/m^2

SC = 0.57… with interior shading

CLF = 0.53 at 14:00 clock …

$Q_{tr.\ E}$= 3.2× 678 × 0.57 × 0.53

= 655.4 W.

Q conv. = UA (CLTD) corr. (2.21)

Where**:**

U: Over all heat transfer coefficient of glass ($W/m^2.K$).

A: Out windows Area of heat conduction. (m^2).

$(CLTD)_{corr.}$: Is calculated as the same of walls and roofs and the CLTD value for glass is obtained from Table (A-7)

CLTD = 7 ˚C at 14:00, clock

k = 1 for glass

f = 1 for glass

$(CLTD)_{corr.}$ = (7 + 5) 1 + (25.5 - 24) + (24 - 29.4) 1

= 8.1˚C

$Q_{conv.} = U \times A \times (CLTD)_{corr.}$

$= 3.2 \times 3 * 2 * 0.80 \times 8.1$

$= 124.4$ W

$Q_{tr.} = Q_{tr.s} + Q_{tr.E}$

$= 140.77 + 655.44$

$= 796.21$ W

$Q_{Glass} = Q_{tr.} + Q_{conv.}$

$= 796.21 + 124.4$

$= 920.61$ W

Heat gain due to lights ($Q_{Lt.}$):

Heat gains due to lights are sensible loads and are calculated by the following equation [9]:

$$\dot{Q}_{Lt.} = \text{light intensity} \times A \times (CLF)_{Lt.} \qquad (2.22)$$

Where**:**

Light intensity = 10-30 W/ m² for apartment, so we will take 25W/ m²

A: floor area = 17.20m²

$(CLF)_{Lt.}$: cooling load factor for lights.

$(CLF)_{Lt.} = 0.82$ …......... from Table (A-5)

$Q_{Lt.} = 25 \times 17.20 \times 0.82 = 352.6$W.

Heat gain due to infiltration (Q_f):

As the same way in heating load.

Where**:**

h_{in} : inside enthalpy temperature (kJ/kg).

h_{out} : outside enthalpy temperature (kJ/kg)

V_f : The volumetric flow rate of infiltrated air in (m^3 /h)

V_o : specific volume (m^3/kg)

v_o = 0.877 (outside the room)

h_{in} = 48 kJ/kg

h_{out} = 65 kJ/kg

V_o = 1.4 (m/s) from Palestinian code

V_f =2 m^3/h/m…..from table (A-4)

L= (2W + 2H)(3) for window(double sliding window)

= (2*0.80+2*2) (3)=16.8 m .

Therefore;

$V_{inf,w}$ = 2(16.8)

= 0.00933m3/s.

$$Q_{Total,w} = (V_{inf,w} / v_o)(h_{out} - h_{in}) \quad (2.23)$$

=(0.00933/0.877)(1000)(65-48)

= 180W.

$Q_{inf} = Q_{inf,w}$ = 180W.

Heat gain due to occupants ($Q_{oc.}$):

Sensible heat gains from occupants raise the indoor temperature. Latent heat gains need to be considered if the indoor air is actively dehumidified. Occupancy load schedules are determined through two factors:

1. Maximum occupancy heat gain.
2. Time of day schedules.

Sensible and latent heat gains from occupants must be removed from the conditioned space. The heat gain due to occupants is the following [2]:

$$Q_{oc.} = Q_{sensible} + Q_{latent} \quad (2.24)$$

$Q_{sensible}$ = heat gain sensible × No. of people × $(CLF)_{oc.}$ (2.25)

Where**:**

$(CLF)_{oc.}$: cooling load factor due to occupants.

Heat gain sensible = 70W very light work … from table (A-16) [9]

No. of people = 2

$(CLF)_{oc.}$ = 0.84 at 8 hours after each entry into space is obtained from Table (A-6) [9]

Q sensible = 70 × 2× 0.84

= 117.6 W.

Q latent = heat gain latent × No. of people (2.26)

Heat gain latent = 44W… very light work from Table (A-16)

Q_{latent} = 44 × 2

= 88W.

Q oc. = 117.6 + 88

= 205.6 W.

The total cooling load(Q L)total:

$Q_{Tot} = Q_{Roof} + Q_{wall} + Q_{wall\ un} + Q_{Glass} + Q_{Lt} + Q_{inf.} + Q_{oc.}$

=46.95 + 71.136 +228.6+ 920.61 + 352.6 + 180 + 205.6 + 2431

=4436.5 W

=4.4365 KW.

Take a safety factor of 10 % for each space of the residence to cover the miscellaneous and emergency cooling loads then:

Q tot = 4.4365KW *1.10

= 4.8801 KW.

=1.4 Ton

2.11 Calculations using Revit:

Autodesk Revit is Building Information Modelling (BIM) software for Microsoft Windows, which allows the user to design with parametric modelling and drafting elements.

Building Information Modelling (BIM) is a new Computer Aided Design (CAD) paradigm that allows for intelligent, 3D and parametric object-based design. In this way, Revit provides full bi-directional associativity. A change anywhere is a change everywhere, instantly, with no user interaction to manually update any view.

Revit is one of the most important engineering programs for various engineering specialization. It integrates architecture, buildings, mechanics and electrical engineer.

Where the engineers in various disciplines design together step by step on the Revit agreement between them, produce a three-dimensional model of the final output of the work the integrated design between the engineers facilitates the implementation of the project on the ground. [15].

In this section, the Revit was used to calculate the heating and cooling loads of the hotel the program calculates loads by specifying variables ،Include [11]:

1. Location of the building.

2. Type of building.

3. Project phase.

4. Weather forecast.

5. Overall heat transfer coefficient for ceiling, floor, internal and external wall.

6. Lighting

7. The nature of permanence of people

8. Human comfort through its adoption of Ashrae.

9. Electrical load.

Where the building can be divided into many areas and gives a full picture of the space in terms of the number of windows doors and room area and the nature of each wall for each space, infiltration load due to door and window, It give air flow and heating and cooling load for building. Heating and Cooling load calculation can help you analyze the model.

This is the part of BIM. It is not only a 3D model, but also provides information. In Revit software can choose from three levels of heating and cooling loads reports (simple, standard and 22 detailed) to display the results of the heating and cooling analysis performed on your building model [11].

2.11.1 Sample calculation

Total cooling and heating load calculations for the sample room by Revit software:

Table (2.5): Total cooling and heating load for the sample room by Rivet

Space Summary - 36 Space

Inputs	
Area (m²)	15
Volume (m³)	42.52
Wall Area (m²)	27
Roof Area (m²)	16
Door Area (m²)	1.66
Partition Area (m²)	0
Window Area (m²)	1.6
Skylight Area (m²)	0
Lighting Load (W)	161
Power Load (W)	273
Number of People	2
Sensible Heat Gain / Person (W)	73
Latent Heat Gain / Person (W)	59
Infiltration Airflow (L/s)	0.0
Space Type	Hotel (inherited from building type)
Calculated Results	
Peak Cooling Load (W)	**5,215**
Peak Cooling Month and Hour	July 05:00 ç
Peak Cooling Sensible Load (W)	5,204
Peak Cooling Latent Load (W)	11
Peak Cooling Airflow (L/s)	314.7
Peak Heating Load (W)	**2,250**
Peak Heating Airflow (L/s)	168.7

Table (2.6): Total cooling and heating load for the Building

Building Summary

Inputs	
Building Type	Hotel
Area (m²)	1,435.759
Volume (m³)	4,204.812
Calculated Results	
Peak Cooling Total Load (W)	**233,819**
Peak Cooling Month and Hour	September 3:00 PM
Peak Cooling Sensible Load (W)	232,763
Peak Cooling Latent Load (W)	1,056
Maximum Cooling Capacity (W)	233,819
Peak Cooling Airflow (L/s)	13,532.9
Peak Heating Load (W)	**144,148**
Peak Heating Airflow (L/s)	13,979.7
Checksums	
Cooling Load Density (W/m²)	162.85
Cooling Flow Density (L/(s·m²))	9.43
Cooling Flow / Load (L/(s·kW))	57.88
Cooling Area / Load (m²/kW)	6.14
Heating Load Density (W/m²)	100.40
Heating Flow Density (L/(s·m²))	9.74

Chapter Three

Variable refrigerant flow system

3.1 Introduction:

Air conditioning (also A/C, air conditioner) is the process of removing heat and controlling the humidity (as well as removing dust in some cases) of the air within a building or vehicle, in order to achieve a more comfortable interior environment. This may be achieved using powered devices ('air conditioners'), by passive cooling or by ventilate cooling. Air conditioning is a member of a family of systems and techniques that provide heating, ventilation and air conditioning (HVAC).

After determining the cooling and heating loads of the hotel and ventilation rates for the places to be adapted. We must choose (heating, ventilation and air conditioning system).

The three major functions of heating, ventilation, and air conditioning are interrelated, especially with the need to provide thermal comfort and acceptable indoor air quality within reasonable installation, operation, and maintenance costs. HVAC systems can provide ventilation, and maintain pressure relationships between spaces. The means of air delivery and removal from spaces is known as room air distribution. [23]

The selection of different equipment depends on economic factors determined by the required capacity and nature of use, the quality and cost of energy available to the management, the location of the equipment room, the quality of the air distribution system and the cost of operating the equipment. [22]

The Variable Refrigerant Volume (VRV) systems are non-traditional HVAC systems, in comparison with conventional ducted systems circulating the air or chilled-water throughout the building. The term VRF indicates the ability of the system to vary and control the refrigerant flow through multiple evaporator coils to provide individual temperature control in various mechanical comfort zones. [24]

The VRF technology was introduced by Daikin in the early 80's as an alternative method of cooling and heating in commercial buildings. Today over 25 million individual spaces are being served by this technology. VRV is a very energy efficient and flexible equivalent to a chiller system while it also offers superior comfort compared to traditional air handler terminal units. [25]

3.2 Variable refrigerant flow system

Variable refrigerant flow (VRF) is an air condition system configuration where there is one outdoor condensing unit and multiple indoor units. The term variable refrigerant flow refers to the ability of the system to control the amount of refrigerant flowing to the multiple evaporators (indoor units), enabling the use of many evaporators of differing capacities and configurations connected to a single condensing unit. The arrangement provides an individualized comfort control and simultaneous heating and cooling in different zones. The use of boilers and cooling towers required for the conventional water source systems may not be needed in VRF systems, possibly resulting in lower installation costs. [25]

VRF systems are similar to the multi split systems which connect one outdoor section to several evaporators. However, multi-split systems turn OFF or ON completely in response to one master controller, whereas VRF systems continually adjust the flow of refrigerant to each indoor evaporator. The control is achieved by continually varying the flow of refrigerant through a pulse modulating valve (PMV) whose opening is determined by the microprocessor receiving information from the thermistor sensors in each indoor unit. The indoor units are linked by a control wire to the outdoor unit which responds to the demand from the indoor units by varying its compressor speed to match the total cooling and/or heating requirements. VRF systems promise a more energy-efficient strategy (estimates range from 11% to 17% less energy compared to conventional units) at a somewhat higher cost. [26]

Figure(3.1) indoor units and outdoor units for VRF System

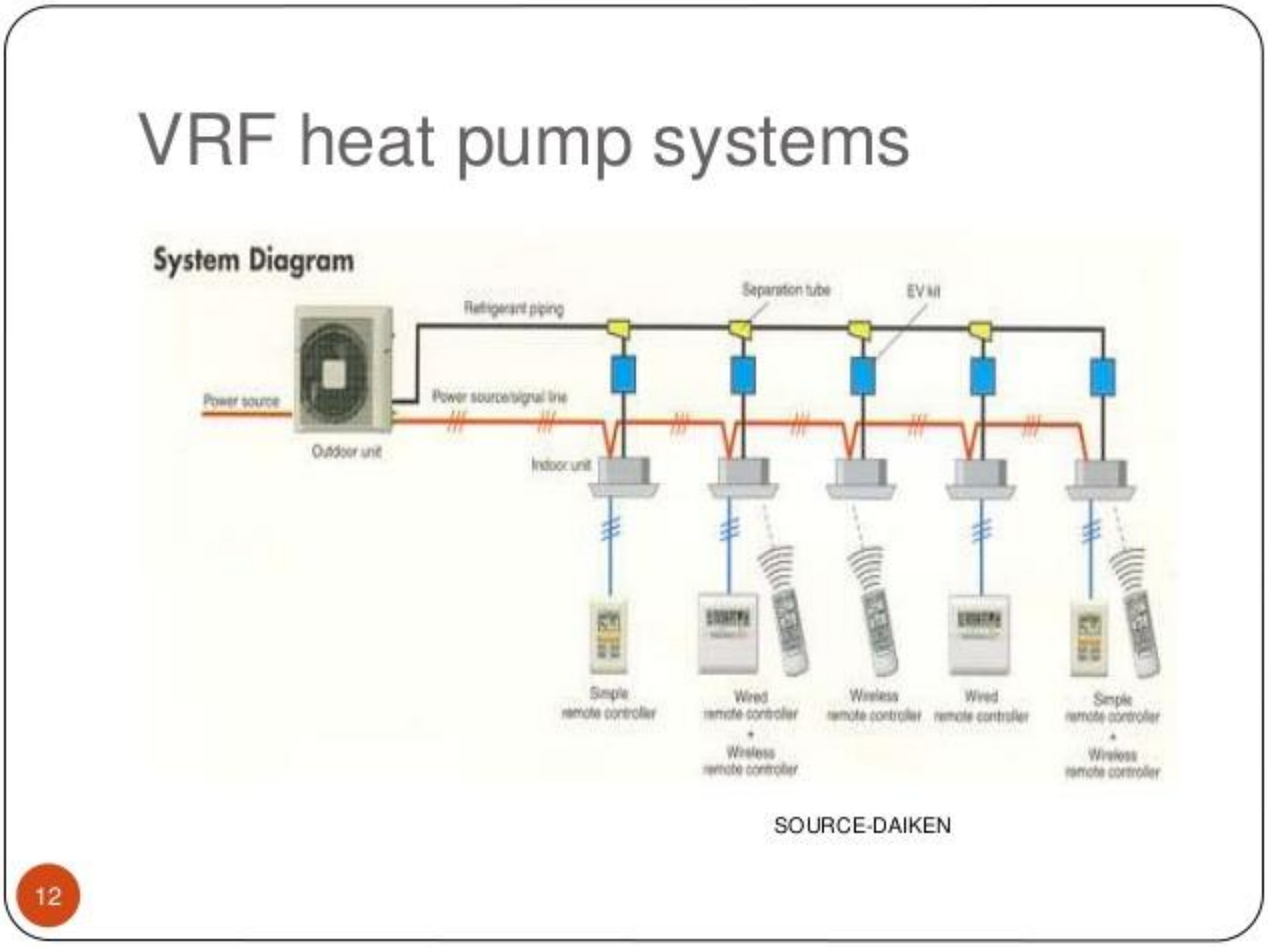
The modern VRF technology uses an inverter driven scroll compressor and permits as many as 48 or more indoor units to operate from one outdoor unit (varies from manufacturer to manufacturer). The inverter scroll compressors are capable of changing the speed to follow the variations in the total cooling and heating load as determined by the suction gas pressure measured on the condensing unit. The capacity control range can be as low as 6% to 100%. [27]

3.3 Types of VRF

VRF systems come in two styles: heat recovery and heat pump.

3.3.1 VRF heat pump systems

VRF heat pump systems permit heating or cooling in all of the indoor units but NOT simultaneous heating and cooling. When the indoor units are in the cooling mode, they act as evaporators; when they are in the heating mode, they act as condensers. These are also known as two pipe systems. [25]



Figure(3.2): VRF heat pump systems]26[

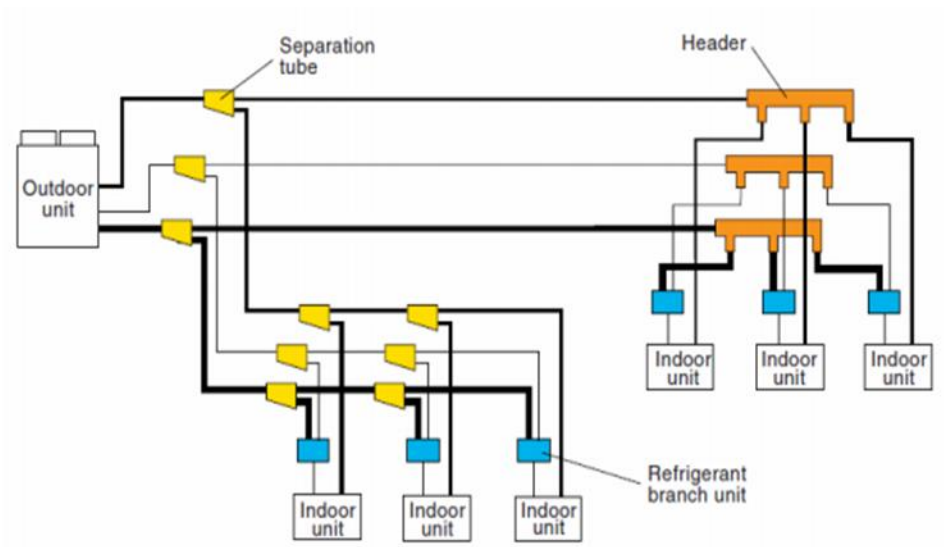
VRF heat pump systems are effectively applied in open plan areas, retail stores, cellular offices and any other area that require cooling or heating during the same operational periods.

3.3.2 Heat recovery VRF System

Variable refrigerant flow systems with heat recovery (VRF-HR) capability can operate simultaneously in heating and/or cooling mode, enabling heat to be used rather than rejected as it would be in traditional heat pump systems. VRF-HR systems are equipped with enhanced features like inverter drives, pulse modulating electronic expansion valves and distributed controls that allow system to operate in net heating or net cooling mode, as demanded by the space. [25]

Each manufacturer has its own proprietary design (2-pipe or 3-pipe system), but most uses a three-pipe system (liquid line, a hot gas line and a suction line) and special valve arrangements. Each indoor unit is branched off from the 3 pipes using solenoid valves. An indoor unit requiring cooling will open its liquid line, suction line valves, and act as an evaporator. An indoor unit requiring heating will open its hot gas and liquid line valves and will act as a condenser. [28]

Typically, extra heat exchangers in distribution boxes are used to transfer some reject heat from the superheated refrigerant exiting the zone being cooled to the refrigerant that is going to the zone to be heated. This balancing act has the potential to produce significant energy savings.



Figure(3.3): Heat recovery VRF system]26[

3.4 Advantage of VRF system

Top 7 advantages of a VRF system

1. Consistent comfort

The compressor unit of a VRF system has the ability to accurately identify the requirements of each zone and send the precise amount of refrigerant needed to each air handling unit. So, a computer room can get more cooling than a south-facing office that gets a lot of sun.

This precise flow **ELIMINATES COLD AND HOT SPOTS AND HUMIDITY ISSUES**, and facilitates the consistent comfort that will help promote employee productivity. When looking into the benefits of VRF systems, outfitting your building with consistent comfort is a no-brainer.

2. Quiet operation

With a VRF system, the louder condensing unit is typically located outside your building or in a mechanical room. And, the VRF's smaller air handlers are smaller and quieter than those associated with a large central unit with bulky ductwork. So **YOU WON'T HAVE LOUD AC NOISE** disrupting business.

3. Energy efficiency

One of the appealing benefits of a VRF system is it promotes energy efficiency. Other systems run at a single speed: on or off. A VRF system is designed to run at varying speeds, suppling the precise amount of refrigerant necessary to cool a room under a room's current condition. This results in the system **RUNNING AT A LOWER CAPACITY AND LESS FREQUENTLY**, which uses less energy.

The system also has the ability to capture heat as part of the cooling process and channel this heat to other locations in the building, which may need heating.

4. Installation flexibility for small spaces

Another one of the advantages of a VRF system is its **COMPACT SIZE AND FLEXIBILITY**. A VRF system travels lightly. There's no need to tie up space for a large maintenance room or service shafts. Distribution fans, hefty pipes to circulate fluids and water pumps are not required for its operation.

Besides these benefits of a VRF system providing for an easier install, it also translates into less space for your air conditioning system and more space for your use. That's a big plus considering the cost of real estate in New York City.

Since VRF systems do not normally require ducts and use relatively small air handlers, it gives you more flexibility for handler locations and obviates the need to take up wall and ceiling space for large ducts. This is welcome news to anyone who does not want to introduce ductwork into high ceilings.

If you're cramped for space, a VRF system is a space-saver because ductwork and mechanical rooms may not be not necessary.

See also: Ductless AC System? NYC: Think VRF for Comfort & Efficiency

5. Heat & cool simultaneously for zoned comfort

One of the attractive benefits of VRF a system is that it can deliver cooled air and heat simultaneously to different zones.

VRF SYSTEMS CAPTURE HEAT RECOVERED FROM THE COOLING PROCESS AND CAN REDISTRIBUTE THIS EXCESS HEAT TO AN AREA OF YOUR BUILDING THAT NEEDS HEAT.

Another one of the advantages of a VRF system is different heating and cooling zones can easily be accommodated. Often different rooms have different heating and cooling demands.

See also: NYC: Need Simultaneous Heating and Cooling? Try VRF Technology

6. State of the art controls & smart technology

Here's one of the advantages of a VRF system that might not have initially entered your thought process. You can actually **USE YOUR MOBILE DEVICE TO SET TEMPERATURE SETTINGS IN DIFFERENT ZONES**. If you're running a commercial establishment, you may even be able to forego the purchase of costly building management software.

Smart technology undeniably is one of the benefits of a VRF system because it's just that – smart. Besides supplying the proper flow of refrigerant to each air handler based on operating conditions, a VRF system is able to track system conditions and provide maintenance alerts. One of the advantages of a VRF system's monitoring capability is it helps ensure the tiptop operation of your climate control system.

7. Fewer breakdowns and less downtime

Without a doubt, one of the big benefits of a VRF system is they tend to break down less frequently. Let's face it, no one wants to be with our conditioning in the dog days of summer. There is less stress on the parts because VRF systems are designed to run only needed and under partial load conditions.

3.5 Disadvantage of VRF system

1. Price per ton is too high.

2. cooling heating simultaneously is limited. (2 or 3 pipe system also very expensive)

3. for high rise building the system cannot be used.

4. for not so high rise building the compressor will be very big to over come additional piping and pressure loss.

5. All manufacturers are not providing this.

6. Limited BMS System and integration with IBMS System is not possible.

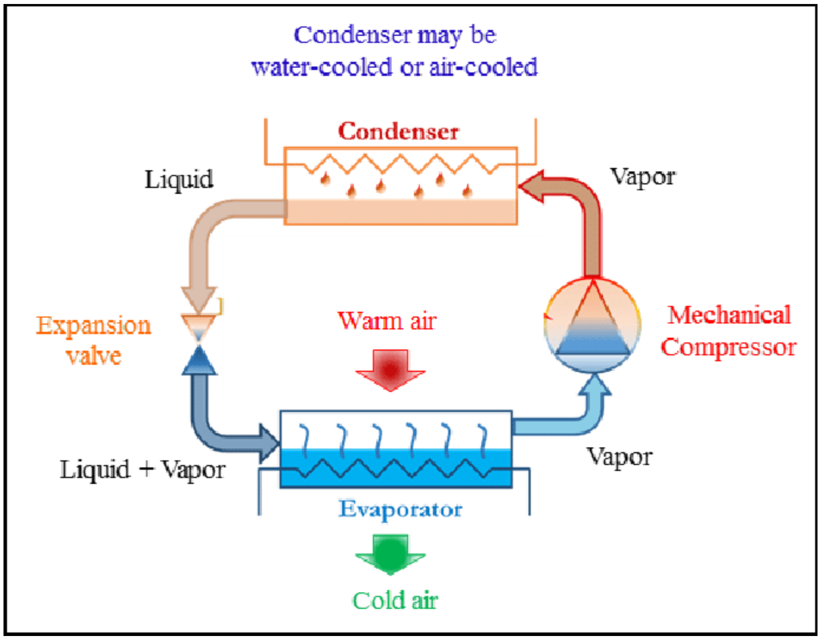
7. Standby system is also limited for critical areas.

8. need to increase tonnage for longer piping.

3.6 VRF technology

VRF technology is based on the simple vapor compression cycle (same as conventional split air conditioning systems) but gives you the ability to continuously control and adjust the flow of refrigerant to different internal units, depending on the heating and cooling needs of each area of the building. The refrigerant flow to each evaporator is adjusted precisely through a pulse wave electronic expansion valve in conjunction with an inverter and multiple compressors of varying capacity, in response to changes in the cooling or heating requirement within the air conditioned space. [24]

The fundamental of an air conditioning system is the use of a refrigerant to absorb heat from the indoor environment and transfer it to the external environment. In the cooling mode, indoor units are supplied with liquid refrigerant. The amount of refrigerant flowing through the unit is controlled via an expansion valve located inside the unit. When the refrigerant enters the coil, it undergoes a phase change (evaporation) that extracts heat from the space, thereby cooling the room. The heat extracted from the space is exhausted to the ambient air. [24]



Figure(3.4): Refrigerant cycle

Refrigeration systems can operate on reverse cycle mode with an inclusion of special 4way reversing valve, enabling the absorption of heat from the external environment and using this heat to raise the internal temperature. When in the heating mode, indoor units are supplied with a hot gas refrigerant. Again, the amount of hot gas flowing through the unit is controlled via the same electronic expansion valve. As with the liquid refrigerant, the hot gas undergoes a phase change (condensation), which releases heat energy into the space. These are called heat pump systems.

Heat pumps provide both heating and cooling from the same unit and due to added heat of compression, the efficiency of a heat pump in the heating mode is higher compared to the cooling cycle.

Expansion valve is the component that controls the rate at which liquid refrigerant can flow into an evaporator coil. [27]

As the evaporator load increases, available refrigerant will boil off more rapidly. If it is completely evaporated prior to exiting the evaporator, the vapor will continue to absorb heat (superheat). Although superheating ensures total evaporation of the liquid refrigerant before it goes into the compressor, the density of vapor which quits the evaporator and enters the compressor is reduced leading to reduced refrigeration capacity.

The inadequate or high super heat in a system is a concern:

- Too little: liquid refrigerant entering a compressor washes out the oil causing premature failure.
- Too much: valuable evaporator space is wasted and possibly causing compressor overheating problems.

Electronic expansion valve EEV in a VRF system functions to maintain the pressure differential and also distribute the precise amount of refrigerant to each indoor unit. It allows for the fine control of the refrigerant to the evaporators and can reduce or stop the flow of refrigerant to the individual evaporator unit while meeting the targeted superheat.

3.7 Components of VRF systems

1- Outdoor Units:

Outdoor is two type:

- Individual outdoor unit: capacity 8 HP, 10 HP and up to 20 HP.
- Outdoor module: up to 80 HP.

Figure(3.5): Outdoor units]25[

2- Indoor Units:

Wide range of Indoor units' capacities 2.2 kW up to 16 kW different types for different applications.

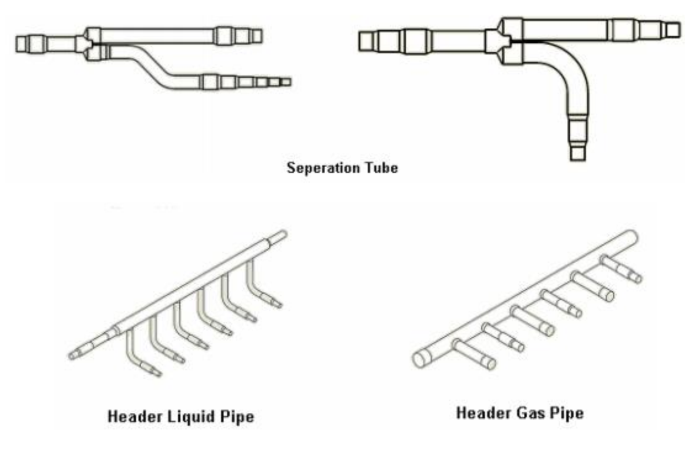
VRF indoor unit:

- 2-way cassette unit.
- 4-way cassette unit**.**
- Slim ducted unit.
- High static ducted unit.
- Ceiling suspended unit.
- Wall-mounted unit

Figure(3.6): Indoor units

3- Piping Network:

- Copper Pipes: copper pipe Connect between all indoor units and all outdoor units in the same system it's may be two pipes or three pipes according to the type of VRF System.
- T- Joints : used to connect the pipes between the outdoor units
- Separation Tubes : Used to distribute refrigerant to two branches and Different dimensions.
- Distribution Headers: used to distribute refrigerant to more than two branches and commonly used if there is more than two branches lose together.



Figure(3.7): Indoor units piping network]26[

4- Insulation:

We use EPDM foam - ethylene propylene diene monomer and PE foam – Polyethylene Foam to insulate piping for:

- Maintain system capacity & efficiency. Avoid heat gains or losses.
- Prevent condensation on piping or insulation.
- Prevent piping system corrosion
- Prevent mold growth from occurring on construction materials.
- Avoid costly lawsuits.
- Avoid property damage from condensation.

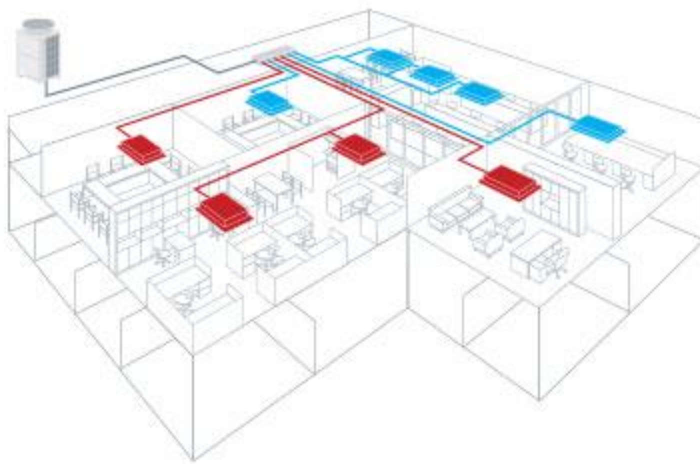
Figure(3.8): Insulation

3.8 Design considerations

- Space layout

The design of a VRF system begins with understanding the space layout. The orientation of the building and the seasons during which peak loads occur must be considered.
The type of load (heating or cooling) and the distribution of loads into zones will depend on the intended use of the space. In turn, these factors will determine whether a heat pump system or heat recovery system will be the most efficient choice. [26]

And Figure (3.9) shows a typical space layout, with zones specified as requiring heating or cooling and the load reflected in the size and type of the indoor units shown.



Figure(3.9): Typical VRF system space layout]26[

- Size of units: the size of the units selected must be considered for impact on the design of the system; smaller units will provide flexibility of zoning and require less piping and less refrigerant per system. [26]
- Piping configuration: flexibility of the piping options available should be considered. A system that provides more options for combining Y-shape joints and headers could minimize the amount of piping and refrigerant used, thus reducing the total cost of the job.

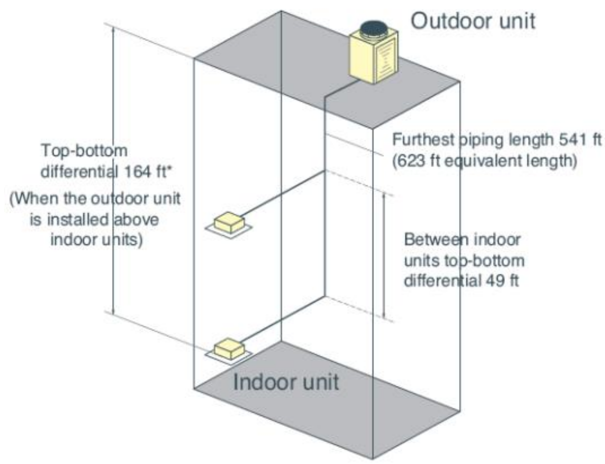
A VRF system offers flexible installation and energy saving cooling and heating comfort and should be considered as an alternative to traditional systems for those applications where zoning or part load operation is required.

- Building characteristics: VRF systems are typically distributed systems the outdoor unit is kept at a far off location like the top of the building or remotely at grade level and all the evaporator units are installed at various locations inside the building. Typically, the refrigerant pipe-work (liquid and suction lines) is very long, running in several hundreds of feet in length for large multi-story buildings.

The long pipe lengths will introduce pressure losses in the suction line and, unless the correct diameter of pipe is selected, the indoor units will be starved of refrigerant resulting in insufficient cooling to the end user.

So it is very important to make sure that the pipe sizing is done properly, both for the main header pipe as well as the feeder pipes that feed each indoor unit. The maximum allowable length varies among different manufacturers; however, the general guidelines are as follows [24]:

- The maximum allowable vertical distance between an outdoor unit and its farthest indoor unit is 164 ft.
- The maximum permissible vertical distance between two individual indoor units is 49 ft.
- The maximum overall refrigerant piping lengths between outdoor and the farthest indoor unit is up to 541 ft.



Figure(3.10): Design limits in VRF system]25[

As stated, the refrigerant piping criteria varies from manufacturer to manufacture, for example for one of the Japanese manufacturer (Samsung), the system design limits are:

- L1: Maximum height difference between outdoor unit and indoor unit = 50m.
- L2: Maximum height difference between indoor unit and indoor unit = 15m.
- L3: Maximum piping length from outdoor unit to first separation tube = 70m.
- [L3+L4+L5+L6]: Maximum piping length from outdoor unit to last indoor unit = 100m
- L6 & L7: Maximum piping length from header to indoor unit = 40m.

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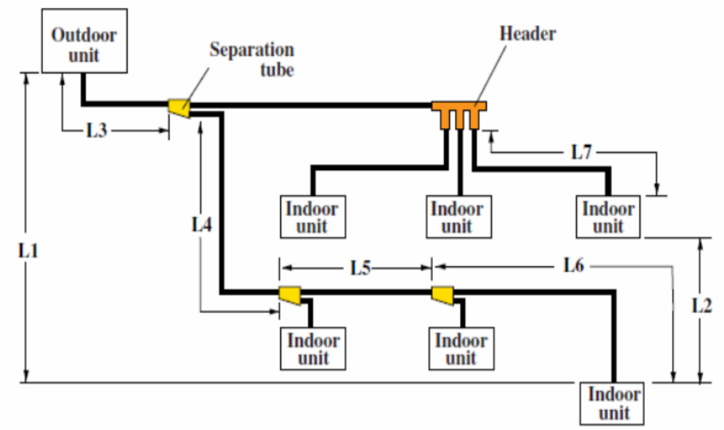
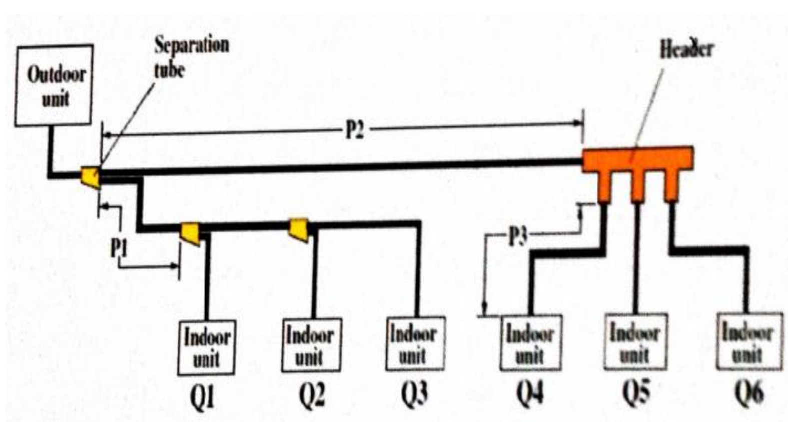


Figure(3.11): Design limits in VRF system]26[

- Size of P1: Depends on the total capacity of (Q1+Q2+Q3).
- Size of P2: Depends on the total capacity of (Q4+Q5+Q6).
- Size of P3: Depends on the total capacity of (Q4).



Figure(3.12): Pipe sizing for VRF system]26[

- Building load profile: when selecting a VRF system for a new or retrofit application, the following assessment tasks should be carried out [29]:

    - Determine the functional and operational requirements by assessing the cooling load and load profiles including location, hours of operation, number/type of occupants, equipment being used, etc.
    - Determine the required system configuration in terms of the number of indoor units and the outdoor condensing unit capacity by taking into account the total capacity and operational requirements, reliability and maintenance considerations.

Building a load profile helps determine the outdoor condensing unit compressor capacity. For instance, if there are many hours at low load, it is advantageous to install multiple compressors with at least one with inverter (speed adjustment) feature.

The combined cooling capacity of the indoor sections can match, exceed, or be lower than the capacity of the outdoor section connected to them. But as a normal practice:

- The indoor units are typically sized and selected based on the greater of the heating or cooling loads in the zone it serves, i.e. maximum peak load expected in any time of the year.
- The outdoor condensing unit is selected based on the load profile of the facility, which is the peak load of all the zones combined at any one given time.

The important thing here is that it is unlikely that all zones will peak at a given time so an element of diversity is considered for economic sizing.

Adding up the peak load for each indoor unit and using that total number to size the outdoor unit will result in an unnecessarily oversized condensing unit. Although an oversized condensing unit with multiple compressors is capable of operating at lower capacity, too much over sizing sometimes reduces or ceases the modulation function of the expansion valve. As a rule of thumb, an engineer can specify an outdoor unit with a capacity anywhere between 70% and 130% of the combined capacities of the indoor units. [25]

3.9 Units Selection

This section talks about selection of outdoor and indoor units of VRF system, depending on the "Samsung VRF catalogue", since this company product is existing in Palestine.
Outdoor and indoor units are selected according to the thermal load of the building.

Indoor unit:

In this project, we used two type of indoor units selected, which is 4 way cassette s and Ceiling mounted .

- Ceiling units will only be used for bedrooms, they are flexible in operation and have an attractive and unobtrusive view as shown in the figure (3.13).

Figure(3.13): Ceiling unit]30[

- 4 Way Ceiling Cassette will be used for restaurants, reception hall, meeting room and the rest of the facilities that are characterized by large areas, and these units have been used because they are characterized by regular and good air distribution to large areas and in the form Figure (3.14) we show the shape of this unit.

Figure(3.14): 4 way cassettes unit]30[

After returning to the catalogs of the Samsung company, it became evident that we can use several indoor units, and we chose these units to suit the change in the thermal load of all rooms:

- 4 way cassettes unit: the unit model is (AM128FN4DEH).
- Ceiling unit: the unit model is(AM056FNCDEH).

Outdoor unit:

After doing the calculation of heating and cooling load for the building, then we have to select the outdoor units depends on two things;

1. The total actual cooling load and the capacity ratio,
2. The capacity ratio is a ratio between the total capacity of the indoor and outdoor capacity and its ranged between (70% – 130 %) .

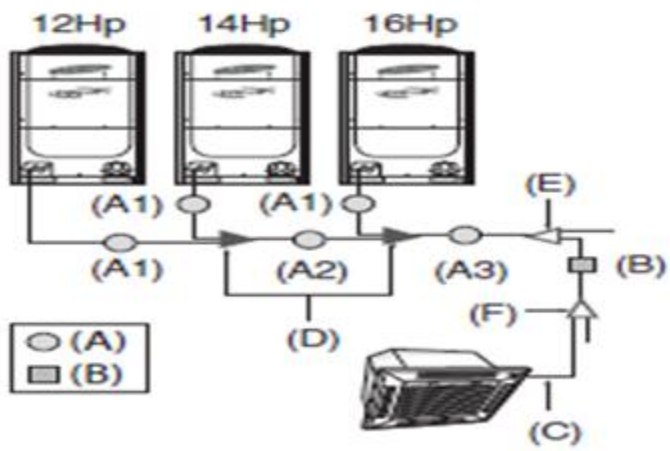
The outdoor unit model is (AM120FXVA) and (AM140FXVA) and(AM220FXVA), here the capacity differs from each other. The first is 12 horsepower, the second is 14 horsepower, and the last is 22 horsepower..

3.10 Selecting refrigerant piping

In these project used Copper Pipes to Connect between all indoor units and all outdoor units in the same system and the figure (3.15) is show the pipe shape.
Refrigerant piping diameter, thickness, and temper is selected according to length, as specified in this section.

Figure(3.15): cupper pipe

In figure (3.16) shows how to calculate pipe diameters:



Figure(3.16): calculate pipe diameters]30[

Where:

A1: Select the pipes according to the outdoor unit capacity .

A2: Select the pipes according to sum of outdoor unit capacities behind the outdoor joint.

A3: Select the main pipe of outdoor units.

Table(3.1) shows the required load from each outdoor unit and shows the required pipe diameters.

Table (3.1) Outdoor unit and pipe size [30]

Quantity	model	Power for each unit	Pipe size liquid	Pipe size gas
2	160HXVFGH/ID	45.0KW/50.4KW	12.7 mm	28.88 mm
4	120HXVFGH/ID	33.6KW/37.8KW	12.7 mm	28.88 mm
2	100/HXVFGH/ID	28.0KW/31.5KW	9.52 mm	22.22 mm

Table (3.2) shows the required load of each indoor unit and clarifies the required pipe diameters that separate the inner unit.

Table (3.2) Size of pipe between the branch joint and indoor unit

Quantity	model	Power for each unit	Pipe size liquid	Pipe size gas
8	AM056FNMDEH/TK	5.6KW/6.3KW	6.35 mm	12.7 mm
3	AM036JNADKH/EU	3.6KW/4.0KW	6.35 mm	12.7 mm
98	AM022FNIDEH/EU	2.2KW/2.5KW	6.35 mm	12.7 mm

3.11 Ventilation

Ventilation is the process of supplying and removing air by natural or mechanical means to and from a building. The design of a building's ventilation system should meet the minimum requirements of the building (Ventilating Systems) regulations.

There are two ways for Ventilation:

• Natural ventilation covers uncontrolled inward air leakage through cracks, windows, doorways and vents (infiltration) as well as air leaving a room (exfiltration) through the same routes. Natural ventilation is strongly affected by weather conditions and is often unreliable. [28]

In case of natural ventilation, the air movement is caused by two factors:

• The difference between indoor and outdoor temperature;

• Wind.

The bigger the both factors are the more intensive is the air change in rooms. This means that in colder weather conditions the rooms and the building is often over-ventilated and in warmer and windless weather, there is a lack of fresh air. As both of these factors are directly dependent on the external climate, the system is considered to be a no controllable system. Users of the building cannot change the air volume rate no more 48 than by switching it ON or OFF; this means by opening and closing the exhaust grilles. [28]

•Mechanical or forced ventilation is provided by air movers or fans in the wall, roof or air conditioning system of a building. It promotes the supply or exhaust air flow in a controllable manner.

Mechanical ventilation systems are considered reliable in delivering the designed flow rate, regardless of the impacts of variable wind and ambient temperature. As mechanical ventilation can be integrated easily into air-conditioning, the indoor air temperature and humidity can also be controlled. [29]

Filtration systems can be installed in mechanical ventilation so that harmful microorganisms, particulates, gases, odours and vapours can be removed.

The airflow rate into a room space, for general mechanical supply and extract systems, is usually expressed in:

1. Air changes per hour.
2. An airflow rate per person.
3. An airflow rate per unit floor area.

An air change per hour (ACH) is the most frequently used basis for calculating the required airflow. Air changes per hour are the number of times in one hour an equivalent room volume of air will be introduced into, or extracted from the room space. [9]

Airflow rate per person are generally expressed as litters per person (L/P), and are usually used where fresh air ventilation is required within occupied spaces.

Airflow rates per unit floor area are similar in effect to air changes per hour except that the height of the room is not taken into consideration.

Mechanical ventilation system in this project is just for bathrooms and kitchens.

The airflow path in mechanical ventilation systems can be controlled, for instance allowing the air to flow from areas where there is a source (e.g. patient with an airborne infection), towards the areas free of susceptible individuals.

Mechanical ventilation can work everywhere when electricity is available.49

Objectives of ventilation

Ventilation in a building serves to provide fresh and clean air, to maintain a thermally comfortable work environment, and to remove or dilute airborne contaminants in order to prevent their accumulation in the air. Air conditioning is a common type of ventilation system in modern office buildings. It draws in outside air and after filtration, heating or cooling and humidification circulates it throughout the building. A small portion of the return air is expelled to the outside environment to control the level of indoor air Contaminants. [28]

Designing of mechanical ventilation

- Using Air changes per hour.

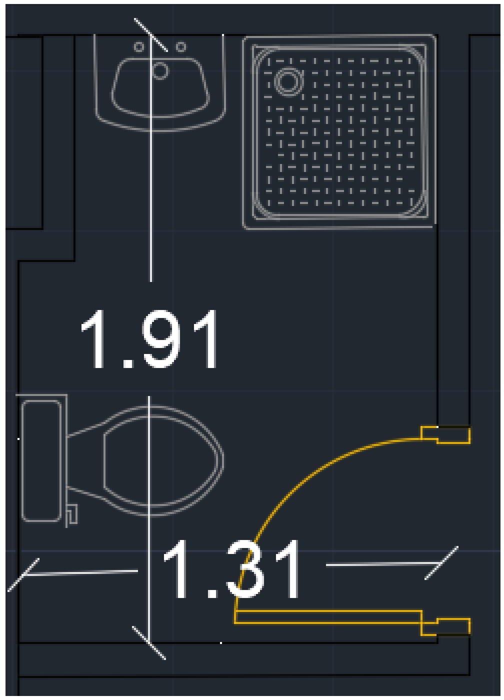
Step One – Use table 4-6 in a appendix Air Changes per Hour identify the required air changes needed for the use of the room.

Step Two - Calculate the volume of the room.

Step Three - Multiply the volume of the room by the required room air changes.

Step Four Divide the answer by 60 minutes per Hour to find the required room cfm.

Required CFM =Volume of the room *Air Changes per Hour /60 Minutes (3.1)



Figure(3.17): bathroom

Sample calculation:

For bathroom:

Volume = Length* Width * Height (3.2)

Volume=1.91*1.31*3.10

Volume=7.8 m3

Number Air Changes per Hour=3

Required cfm=7.8*3*35.3147/60

Required ventilation rate in cfm=13.77 cfm

Required ventilation rate in =6.5 litters/sec.

For kitchen

Volume = Length* Width * Height (3.3)

Volume=3.47*2.68*3.10

Volume=28.8 m3

Number Air Changes per Hour=2

Required ventilation rate cfm=28.8*2*35.3147/60

Required ventilation rate cfm=33.4cfm

Required ventilation rate =16 litters/sec.

Using An airflow rate per person

Step One – Use table 4-5 in an appendix to found minimum outside air requirements for mechanical ventilation.

Step Two – estimate number of person in space.

Step Three - Multiply the number of person by the minimum outside air requirements.

ventilation rate= minimum outside air requirements for mechanical ventilation*# of person (3.4)

Sample calculation :

For restaurant

Ventilation air requirements for dining and cafeteria 10L/s/Person.

Ventilation rate=10*65

Required ventilation rate 650 litters/sec.

Required ventilation rate =1377 cfm

An airflow rate per unit floor area method :

Step One – Use table 4-5in a appendix to found minimum outside air requirements for mechanical ventilation in litter per second per square meter.

Step Two – found area of space in secure meter.51

Step Three - Multiply area by the minimum outside air requirements L/s/m2

ventilation rate= minimum outside air requirements for mechanical ventilation* area (3.5)

Sample calculation

parking

Ventilation air requirements for parking floors 7.5 L/s/m2

Ventilation rate=392*7.5 `

Required ventilation rate 2940 litters/sec.

Required ventilation rate =6229 cfm

Chapter four

Plumbing system

4.1 Introduction

Plumbing is any system that conveys fluids for a wide range of applications.

Plumbing uses pipes, valves, plumbing fixtures, tanks, and other apparatuses to convey fluids.[1] Heating and cooling (HVAC), waste removal, and potable water delivery are among the most common uses for plumbing, but it is not limited to these applications.[2] The word derives from the Latin for lead, plumber, as the first effective pipes used in the Roman era were lead pipes.[3]

Boilermakers and pipefitters are not plumbers although they work with piping as part of their trade and their work can include some plumbing.

Plumbing reached its early apex in ancient Rome, which saw the introduction of expansive systems of aqueducts, tile wastewater removal, and widespread use of lead pipes. With the fall of Rome, both water supply and sanitation stagnated or regressed for well over 1,000 years. Improvement was very slow, with little effective progress made until the growth of modern densely populated cities in the 1800s. During this period, public health authorities began pressing for better waste disposal systems to be installed, to prevent or control epidemics of disease. Earlier, the waste disposal system had consisted of collecting waste and dumping it on the ground or into a river. Eventually the development of separate, underground water and sewage systems eliminated open sewage ditches and cesspools

The use of lead for potable water declined sharply after World War II because of increased awareness of the dangers of lead poisoning. At this time, copper piping introduced as a better and safer alternative to lead pipes. [21]

The most basic human is reliable table supply of potable water and getting rid of human waste products, so the goal of modern plumbing design for building is to safely and reliable, provide domestic water, cold water and remove sanitary waste.

4.2 Water supply system

4.2.1 Overview

There are two type of water distribution system for buildings:

1. Down feed distribution.

2. Up feed distribution system.

The system that will be used in this building is up feed system.

There are two methods commonly used for up feed distribution systems are:

1) The supply of water for the building received from a city main.

2) Private water supply enters into a pneumatic tank pressurized from approximately 35-60 psi pump.

The main pressure that provides in this building is pump pressure.

This section will show the calculation of the total, hot and cold amount of water required for the building by using the water supply fixture unit technique. The cause for selecting this technique is since there is many number of fixture units in the building and that make this technique more accurate. [32]

The design procedure is as follows:

1) draw a rise (plumbing section) on this riser show:

a. Floor to floor height.

b. Run out distance to farthest fixture on each floor.

c. Lengths of piping from the service point to the floor take off points.

2) Show the WSFU for each fixture and total fixture unit on each piping run out.

Use separate fixture units for hot and cold water.

3) Total the fixture units in each branch of the system. Each hot and cold water

riser will require separate diagram and calculation.

4) Show minimum source pressure and the minimum flow pressure required of the most remote outlets.

5) Determine the pressure available for friction head loss from service point to the

final outlet.

6) Determine the required pipe size in each section using friction head loss data

calculated in step 5 and friction head charts .

4.2.2 Calculation of cold and hot water supply system

4.2.2.1 Calculation of cold and hot water (WSFU) system

The total amount of water required for the building is calculated by using the water supply fixture unit technique (WSFU).

Tables (4.1 and 4.2) show the total number of fixture units and the total water supply fixture unit (WSFU) for the first riser .

Table (4.1): Fixture units load for first riser

Fixture type	No. FU	WSFU	Total WSFU	Cold WSFU	Hot WSFU	Total cold	Total hot
Water closet general	2	5	10	--	--	10	0
Water closet private	35	3	105	--	--	105	0

Lavatory general	3	2	6	2*3/4	2*3/4	5	5
Lavatory private	36	1	36	1*3/4	1*3/4	27	27
Shower head	35	2	70	2*3/4	2*3/4	53	53
Clothes washer	0	0	0	0	0	0	0
Kitchen sink	1	4	4	4*3/4	4*3/4	3	3
Total	112	--	231	--	--	203	88

Table (4.2): Total number of fixture units

	Lavatory general	Lavatory private	Water closet general	Water closet private	Kitchen sink	Shower head
Ground floor	0	0	0	0	0	0
1st floor	2	1	2	0	1	0
2nd floor	0	5	0	5	0	5
3rd floor	0	5	0	5	0	5
4th floor	0	5	0	5	0	5
5th floor	0	5	0	5	0	5
6th floor	0	5	0	5	0	5
7th floor	0	5	0	5	0	5
roof floor	0	5	0	5	0	5

Total cold (WSFU) for the 1st riser=203 FU, from table 9.4

200WSFU ----------- 65gpm (from table (B-5))

203WSFU ---------- X gpm

225 WSFU --------- 70gpm

X= 68 gpm , For Cold water first riser

Total HOT (WSFU) for the 1st riser=88 FU, from table 9.4

80 WSFU --------- 39 gpm (from table (B-5))

88WSFU ----------- X gpm

100 WSFU   ----------   44 gpm

X= 41 gpm , For Hot water first riser .

The first riser is the same as the second riser

The total cold (WSFU) for the first and second riser=203*2=406 FU

The total hot (WSFU) for the first and second riser=88*2=176 FU

The total cold by gpm for the first and second riser=86*2=172gpm

The total hot by gpm for the first and second riser=41*2=82 gpm

Table (4.3): Total WSFU and gpm for risers

Riser	Total WSFU CW	Total gpm CW	Total WSFU HW	Total gpm HW
Riser 1st	203	86	88	41
Riser 2nd	203	86	88	41
Total	406	172	176	82

4.2.2.2 Pipe sizing calculation

Using up feed distribution system where the water serve the building by the pump, in this system the pump pressure will be the main pressure and the equation of the flow will be as following:

Pump pressure = Static head + Friction head (loss) + Flow pressure (4.1)

Where**:**

Static head is to overcome the height.

Friction head is to overcome friction in pipes.

Flow pressure is the pressure available at the fixtures when the outlet is wide open and it must be equal or exceed the minimum flow pressure of the critical fixture.

But, some of the above equation parameters can be determined or estimated as following:

1. It is indicated that the minimum flow pressure required for the critical fixture unit is 8 psi.
2. It is indicated that main pressure (pump pressure) is 60 psi.

By friction head loss method:

- Static pressure:

As indicated previously that the building consists of ten floors (floor to floor height is 3.75meters), then as shown in the figure below it appears that the total vertical length from the pump source to the critical fixture (water closet) is 30.4 m.

$$\text{Static pressure} = 26.50 \times 1.42 = 37.63\text{psi} \quad (4.2)$$

- Friction head:

Pipe friction = Main pressure (pump pressure) – Static head – Flow pressure

=60-37.63-8= 14.37 psi
Available friction head= 8.81 psi

Total equivalent length.

We will calculate the equivalent length from the well to the farthest outlet (water closet) at the roof floor at farthest collector.

Since water pipes are using up feed system, we will need the following equation:

Pump head pressure =Friction head + static pressure + minimum flow pressure

- For cold water system:

Total length = 69.9 m.

Water mains to water meter =20 ft.

Water meter to base of second riser =85 ft

Riser length = 85.5 ft

Final run out = 49 ft

Total =240ft

Total equivalent length=240*1.5=360 ft

- For hot water system:

Total length =240 ft

Total equivalent length= 240*1.5= 360 ft.

Uniform friction loss for cold= friction/100ft = available friction head/ total equivalent length.

Friction/100ft =8.81 psi/ (360/100 ft.) = 2.44 (psi/100ft).

Uniform friction loss for hot = friction/100ft = available friction head/ total equivalent length.

Table(4.4): Pipe sizing for cold water riser

Section Number	Flow (gpm)	Equivalent length(ft)	Pipe size (in)	Velocity (fps)
Main	86	360	2	**5.5**
1st riser part #1 (From tap off to ground floor)	80	46	2"	**5.5**
1st riser part #2 (first floor)	77	46	2"	**5**
1st riser part #3 (second floor)	69	46	1.5"	**6.5**
1st riser part #4 (third floor)	58	46	1.5"	**5.5**
1st riser part #5 (fourth floor)	49	46	1.25"	**5.5**
1st riser part #6 (fifth floor)	39	46	1"	**4.1**
1st riser part #7 (sixth floor)	29	46	1"	**4.1**
1st riser part #8 (saventh floor)	21	46	1"	**4.1**
1st riser part #9 (eighth floor)	15	22.13	1"	**4.1**
2st riser part #1 (from tap off to car parking)	86	380	2"	**5**
2st riser part #2 (ground floor)	80	65	1.5"	**6.6**
2st riser part #3 (first floor)	77	45	1.5"	**6.3**
2st riser part #4 (second floor)	69	45	1.5"	**6**
2st riser part #5 (third floor)	58	45	1.5"	**5.2**
2st riser part #6 (fourth floor)	49	45	1.25"	**5**
2st riser part #7 (fifth floor)	39	45	1"	**4**
2st riser part #8 (sixthfloor)	29	45	1"	**4**
2st riser part #9 (seventh floor)	21	45	1"	**4**
2st riser part #10 (eighth floor)	15	46	1"	**4**
Main	172	360	2 "	**5.5**

Table (4.5): Pipe sizing for hot water riser

Section Number	Flow (gpm)	Equivalent length(ft)	Pipe size	Velocity

			(in)	(fps)
1st riser part #1 (From tap off to ground floor)	41	320	1.5"	**5.8**
1st riser part #2 (first floor)	37	40	1.5"	**5.2**
1st riser part #3 (second floor)	32	40	1.25"	**5.5**
1st riser part #4 (third floor)	27	40	1.25"	**5**
1st riser part #5 (fourth floor)	22	40	1"	**5**
1st riser part #6 (sixth floor)	17	40	0.75"	**4.2**
1st riser part #7 (seventh floor)	13	40	0.75"	**4.2**
1st riser part #8 (eighth floor)	7.8	40	0.75"	**4.2**
2st riser part #1 (from tap off to car parking)	41	380	1.5"	**5.2**
2st riser part #2 (ground floor)	37	45	1.5"	**5**
2st riser part #3 (first floor)	32	45	1.5"	**4.8**
2st riser part #4 (second floor)	27	45	1.25"	**5.2**
2st riser part #5 (third floor)	22	45	1.25"	**4.2**
2st riser part #6 (fourth floor)	17	45	1"	**4.7**

4. 3 Water well volume

Calculation for the water well volume needed for the hotel :

(60 gallons per day) is the amount of water needed taken from ASPE (American Society for Plumbing Engineers code).

We have 70 room in our hotel:

So (227.125 L/1000)m^3*79= 18m3 per day.

For 7 days

We need 126 m^3

Add 84 m3 for fire fighting.

4.4 Head estimation

The pump selected with main pressure provides 60 psi and that already choses in residential buildings that mean 4.2 bar.

4.5 Pump selection

Using dp-select software and with filling data into brackets as follow:

For cold water:

Flow=172 gpm = 172*0.23=39.56 m^3/h

Head=4.1 bar

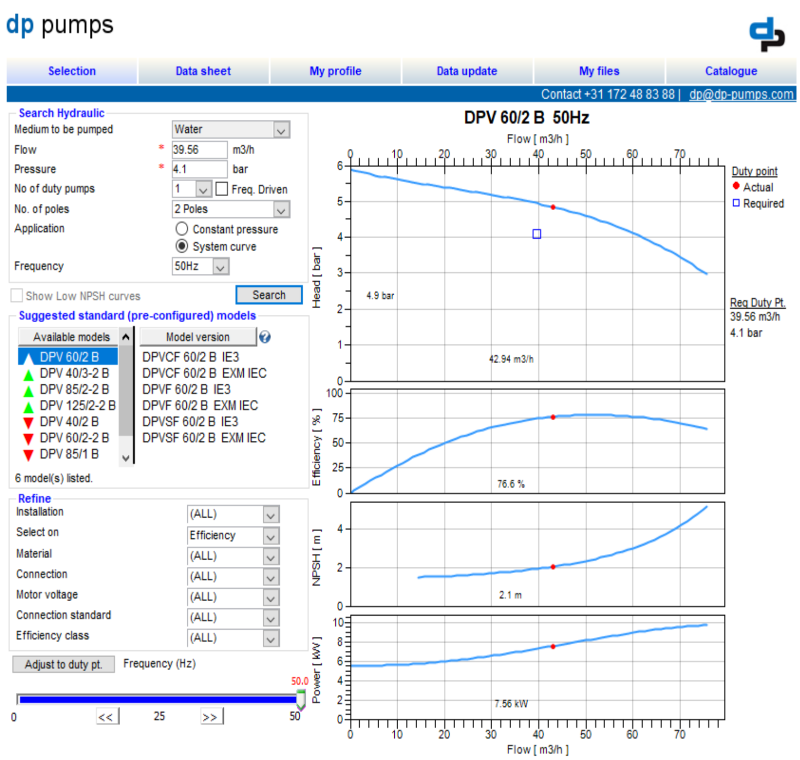


Figure (4.1): Pump data for cold water first and second riser

For hot water :

Flow=82 gpm = 82*0.23=18.86 m3/h

Head=4.1 bar

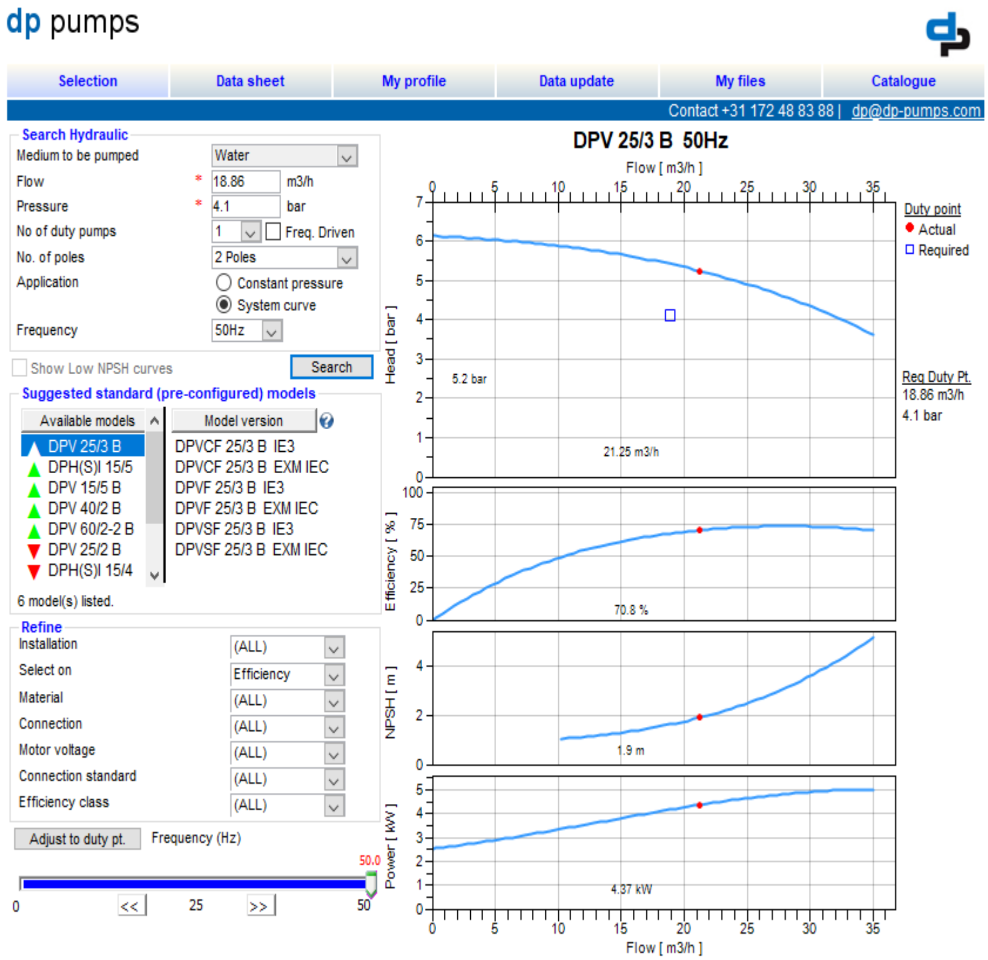


Figure (4.2): Pump data for hot water first and second riser

4.4 Drainage system

The main objective of drainage system is to carry the waste water from the fixture unit to manhole and from the manhole to the septic tank or to the municipal sewage system.

The provision of drainage systems:

- Sanitary drainage
- Storm drainage

4.4.1 Drainage system components

The main components of drainage system are:

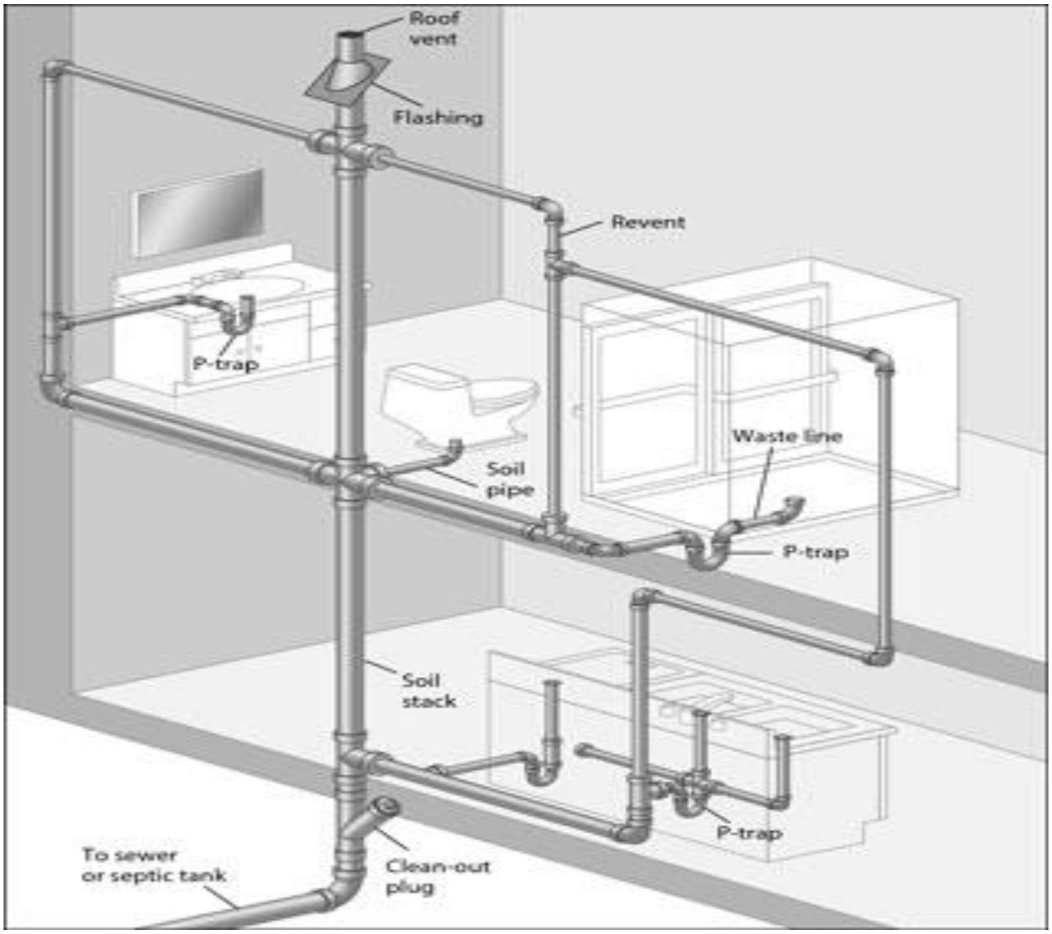


Figure (4.3): Drainage system components

- Fixture units
- Trap
- Clean out
- Drainage pipe
- Stack and vent pipes
- Manholes
- Septic tank or municipal sewage system
- Accessories

4.4.2 Sanitary drainage

Design procedure and pipe sizing

Pipe size is calculated by using a concept of fixture units (DFU) instead of using gpm of drainage water. This unit takes into account not only the fixtures water use but also its frequency of use, which is the DFU has a built–in diversity factor. This enables us, exactly as for water supply to add DFU of various fixtures to obtain the maximum expected drainage flow. Drainage pipes sized for a particular number of drainage fixture units, according to Tables (B-5), (B-4)). These tables are built into the fill factors, which are:

- 50% fill in branches (horizontal pipes)
- (25-33)% fills in stack (vertical pipes)
- 50% fill in building and swear drains

The recommended velocity for drainage piping:

- For branches the recommended velocity is 2 ft/s
- For building pipes the recommended velocity is 3 ft/s
- For greasy flow the recommended velocity is 4 ft/s

Velocity of water flow through drainage piping depends on:

- Pipe diameter
- Slope

Minimum slope requirements for horizontal drainage piping:

- For pipes of diameter ≤ 3" the minimum slope is 1/4”/ft (2%)
- For pipes of diameter ≥ 4" the minimum slope is 1/8”/ft (1%)

Design procedure:

1. Calculation of the number of DFU for each branch by using Table (B-6)
2. Calculation of the number of DFU for each stack
3. Choosing the branch pipe diameter by using Table (B-5)
4. Choosing the stack pipe diameter by using Table (B-5)
5. Comparing the stack pipe diameter with branch diameter
6. Choosing the building drain pipe diameter by using Table (B-5)

The design of the rain collection piping, whether exterior gutters, and leaders, or interior conductors and drain depends upon three factors:

- The amount of rain fall in a specified period of time
- The size of the area being drained
- The degree of pipe fill, that is whether a pipe or gutter runs 50%, 33% or 100% fill

The general rule for the distribution of floor drains (FD):

Every 100 m^2 from roof area needs one 4” FD.

4.4.3 Manhole design

The main purpose of the manholes is to carry the water from stacks to various drainage points. This project contains three types of manhole, which is:

- Sanitary manhole for black water
- Sanitary manhole for gray water
- Sanitary manhole for storm drainage

The design of the manholes depend on the ground and its nature around the building, and so as the first manhole height should not be less than 50 cm, and the depth of the other manholes will depend on the distance between the manholes and the slope of the pipe that connecting them.

According to the table below, it will be estimated the diameter of the manhole according to their depth.

4.5 Manhole calculation

The depth of the first manhole is 60 cm, the calculation of the second manhole done according to the first manhole and so on. The calculations are done by using these equations:

- Depth: (M2 = M1 + (Slope × Distance) + 5 + Level Difference) in cm
- Top level: Manholes face level on the ground
- (Invert level = Top level - Depth) in m
- Outlet level = - (Depth - 0.05) in m

The figure below shows the details of the manholes:

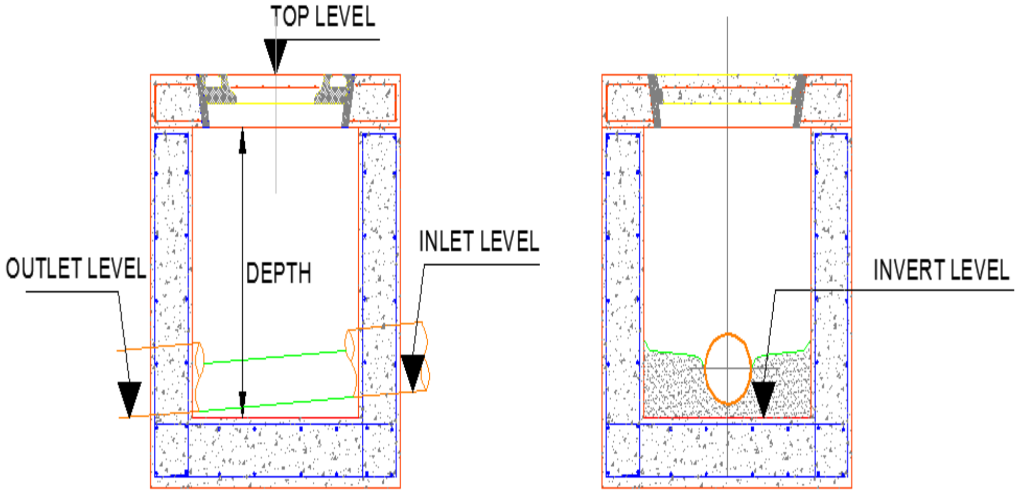


Figure (4.4): Manholes details

Table (4.6): Diameter of manhole according to their depth

Depth (cm)	Diameter (cm)
70-80	60
80-140	80
140-250	100
250-∞	125

Chapter five

Firefighting system

5.1 Introduction

Firefighting system is probably the most important of the building services, as its aim is to protect human life and property, strictly in that order. It consists of three basic parts: a large store of water in tanks, either underground or on top of the building, called **fire** storage tanks. [ ]

For a fire to happen, the following elements are essential:

• Oxidizer to sustain combustion.

• Heat to reach ignition temperature.

• Fuel or combustible material.

This results in a chemical chain reaction which starts a fire, removing any of these elements will extinguish the fire. [11]

Fire extinguishing system is designed to be built in partnership with Architect engineer to specialize in acting fire safety, Electrical engineer to specialize in fire alarm and Mechanical engineer is specialized in firefighting. Also in design for firefighting system, the main reference is (NFPA) code, national fire protection association. [12]

Founded in 1896, the National Fire Protection Association (NFPA) is a global, nonprofit organization devoted to eliminating death, injury, property and economic loss due to fire, electrical and related hazards. The NFPA delivers information and knowledge through more than 300 consensus codes and standards, research, training, education, outreach and advocacy; and by partnering with others who share the NFPA mission. NFPA membership totals more than 60,000 individuals around the world. [13]

Within virtually every building, as well as in transportation and numerous outside applications, there are design and operational features that are guided by NFPA codes and standards. These codes and standards address safety in everything from high-rise buildings to residential single family homes, to nuclear power plants, to fixed guide way trains, to underground mines, to fast food restaurants, to off-shore oil rigs, to food trucks and to on-board navy ships.

5.2 Types of firefighting system

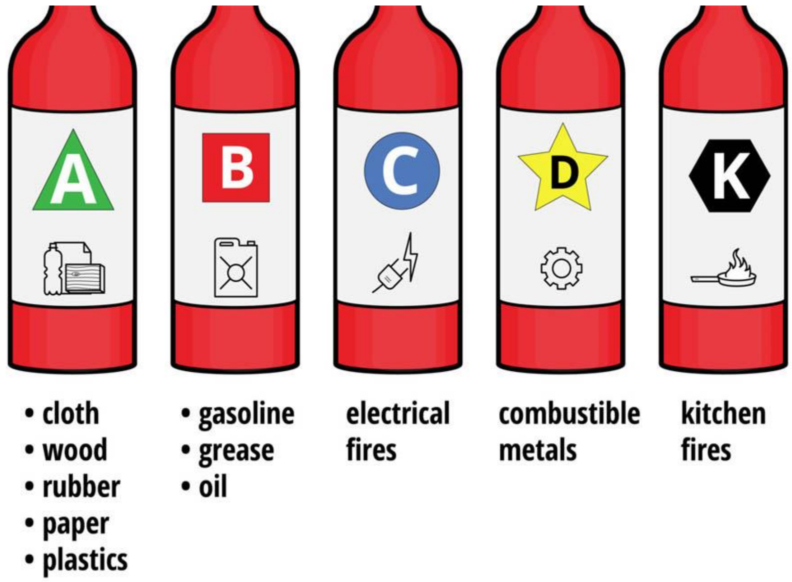
5.2.1 Fire extinguishers

Firefighters are familiar with using hoses and master stream devices for fire attack. But there are times when these aren't the right tools for the job or they aren't immediately available. In these cases, fire extinguishers "handheld firefighters "might be the way to get the job done. Incipient-stage car fires, appliance fires, incipient-stage kitchen fires, equipment fires, electrical fires, small contents fires in a home or commercial occupancy and even laboratory fires may be handled with fire extinguishers under the right conditions. [12]

Extinguishers commonly available on fire apparatus include dry chemical (A-B-C rated or B-C rated) and pressurized water, but apparatus may also carry water extinguishers with foam or other additive, carbon dioxide extinguishers and/or dry powder (Class D agent). Some departments may have access to "clean-agent" extinguishers, or these may be located in areas such as computer rooms. Other extinguishers mounted in buildings will likely be similar to those carried on apparatus, with some commercial kitchens now equipped with Class K units.

Type of extinguishers:

1. Water extinguishers from category A.
2. Foam fire extinguishers from category A B.
3. Dry Chemical fire extinguishers from category A B C K.
4. Clean Agent Halogenated or Clean Agent extinguishers from category A B C.
5. Dry Powder extinguishers from category D.
6. Carbon Dioxide fire extinguishers from category from category B C.



Figure(5.1) Type of extinguishers

5.2.2 Fire hose reel

Fire hose reels are located to provide a reasonably accessible and controlled supply of water to combat a potential fire risk. They are ideal for large high-risk environments such as schools, hotels, factories etc. They are designed to I.S. EN 671 – part 1. Hose reels can come in lengths of 30m of 19mm and 25mm hose.

Fire hose cabinet classes

1) Class 1: standpipe system provides 65-mm (2½-in.) hose connections to supply water for use by fire departments and those trained in handling heavy fire streams. System limitations are pressure reach 7 bars, flow rate 250 gpm, located at all main entrance and exits of the buildings and garages, around the wall buildings and the travel distance is 45.7m with throw distance. [14]

2) Class 2: standpipe system provides 38-mm (1½-in.) hose stations to supply water for use primarily by the building occupants or by the fire department during initial response. System limitations are pressure reach 4.5 bars, flow rate 100 gpm, 30m travel distance and located in corridors, theaters, colleges and near elevators.

3) Class 3: standpipe system provides 38-mm (1½-in.) hose stations to supply water for use by building occupants and 65mm (2½-in.) hose connections to supply a larger volume of water for use by fire departments and those trained in handling heavy fire streams. [14]

The following specifications are installed according to code national fire protection Association NFPA 14 for class 2 F.H.C:

1- The maximum pressure at any point in the system at any time shall not exceed 24.1 bar (350 psi).

2- Maximum Residual Pressure for (1½-in.), F.H.C=6.9 Bar.

3- Hydraulically designed standpipe systems shall be designed to provide the water flow rate required at a minimum residual pressure of 4.5 bar (65 psi) at the outlet of the hydraulically most remote 38-mm (1½-in.) hose station.

4- Standpipes size shall be at least 100 mm (4 in.) (Main riser).

Figure (5.2) Fire hose reel

5.2.3 Fire hydrant system

Fire hydrant installation consists of a system of pip work connected directly to the water supply main to provide water to each and every hydrant outlet and is intended to provide water for the firemen to fight a fire. The water is discharged into the fire engine form which it is then pumped and sprayed over fire.

Figure (5.3) Fire hydrant system

5.2.4 Automatic sprinkler system

Sprinklers systems consist of the network of piping, water supply, **sprinkler** heads, and alarm and detection devices that sense the heat from a fire and automatically distribute water to completely extinguish the fire or control its growth.

A sprinkler head is really an automatic (open once only) tap. The sprinkler head is connected to a pressurized water system. When the fire heats up the sprinkler head, it opens at a preset temperature, thus allowing pressurized water to be sprayed both down onto the fire and also up to cool the hot smoky layer and the building structure above the fire. This spray also wets combustible material in the vicinity of the fire, making it difficult to ignite, thereby slowing down or preventing fire spread and growth. [15]

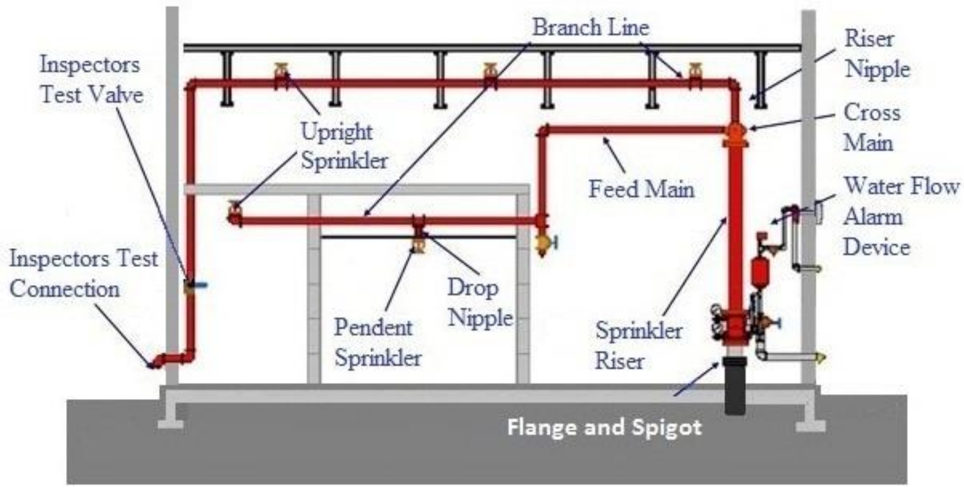


Figure (5.4) Automatic sprinkler system

5.3 Types of automatic sprinkler system

5.3.1 Wet pipe system

The wet pipe sprinkler system is, in general, the most cost-effective, the most versatile as far as protection strategies and pipe installation are concerned, and the easiest to maintain. Its cost effectiveness is based on its having fewer components, requiring less maintenance and testing and having fewer design restrictions than any of the other three types of systems. Wet pipe systems are installed where temperatures will not fall below 40°F (4°C) and where one of the design objectives is to put water on a relatively small fire as quickly as possible.

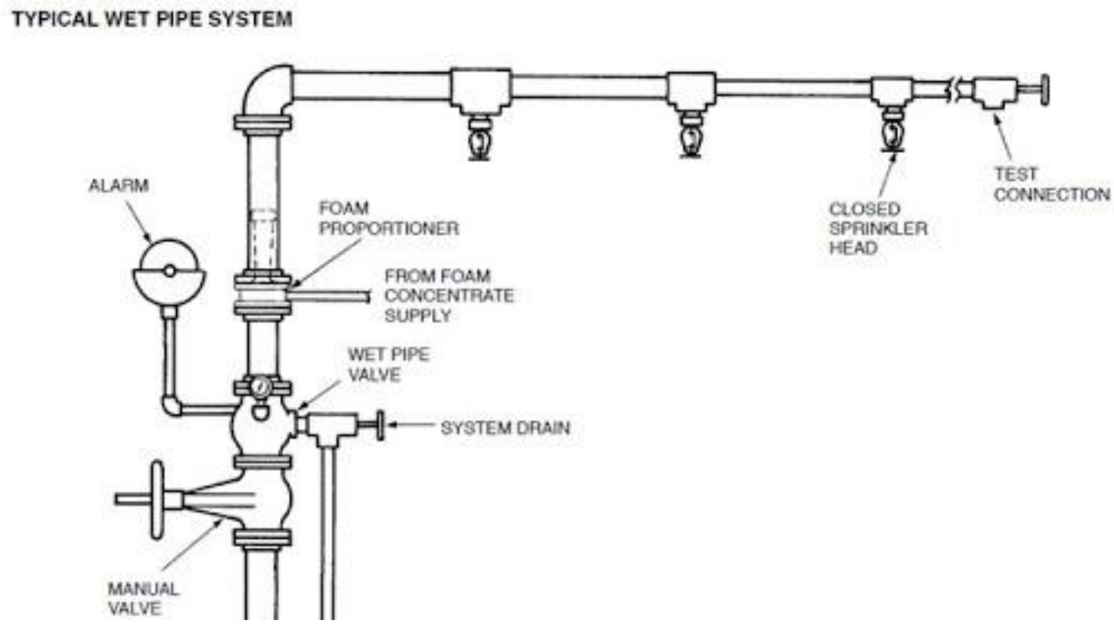


Figure (5.5) Wet pipe system

5.3.2 Dry pipe system

A dry pipe system is similar to a wet system in that it consists of valves, pipes, fittings, alarm initiating devices, and automatic sprinklers; but the main difference is that the pipes are filled with compressed air or nitrogen, not water, and that a dry pipe valve holds the water back.

When the heat from a fire operates the heat responsive element of an automatic sprinkler, the air in the system must be evacuated through the sprinkler opening to reduce the air pressure in the system holding the clapper of the dry pipe valve in the closed position. When enough air has escaped through the sprinkler, through additional sprinkler actuation as the fire grows, or through quick opening devices that are installed on larger systems, then the water fills the piping, eventually reaching open sprinklers and the fire. This delay of water application allows the fire to grow, creating more fire damage; that needs to be a consideration for both the designer and the owner. The dry pipe system is a fire control system only, but may eventually be appropriate for life safety or residential systems.

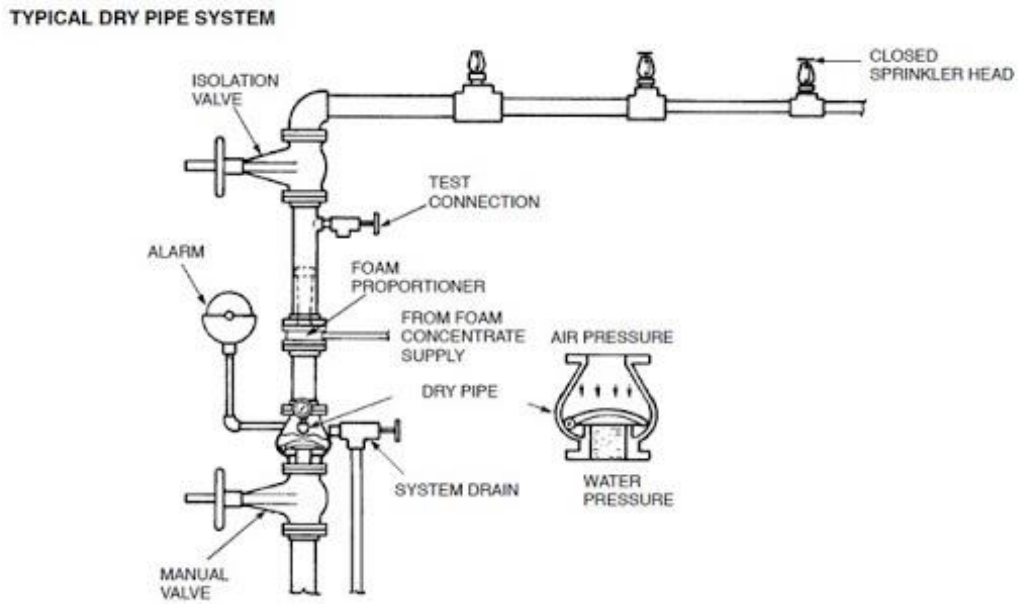


Figure (5.6) Dry pipe system

5.3.3 Pre-action system

The pre-action system is similar to a dry pipe system. It has a similar valve, and in general the same pipe, fittings, alarm initiating devices, and automatic sprinklers. In addition to the sprinkler system, however, the pre-action system incorporates a detection system. Pre-action systems are usually less cost-effective than the dry pipe systems and require additional maintenance and testing as well as maintenance and testing of the detection system. [17]

There are many types of detectors and detection systems that can be used with the pre-action systems. It is in the system designer's best interest to work closely with the owner and the architect to utilize the type of detection system that is appropriate for each specific area or system. An example of such an area is the data or computer room, where the products of combustion can do as much damage to sensitive equipment as the thermal damage from a fire or the resultant application of water. In these rooms, an air sampling detection system may be more appropriate than smoke detectors. The air sampling system may detect particles of combustion before the human eye or nose does and can send signals or warnings before there is actual smoke damage or a fire or before water is necessary. [17]

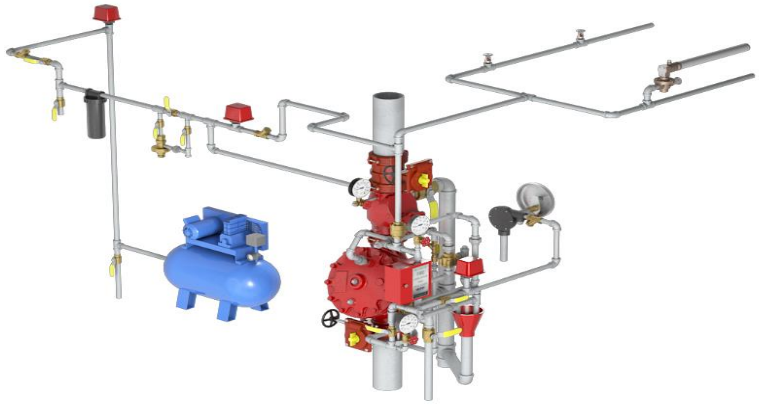


Figure (5.7) Pre-action system

5.3.4 Deluge system

Deluge systems are similar to pre-action systems, in most cases utilizing the same valves, pipe, fittings, alarm initiating devices, automatic sprinklers, and detectors, although all of the sprinklers are open and do not include the heat responsive element. Spray nozzles can be used in deluge systems instead of the open automatic sprinklers. The difference between pre-action and deluge systems is that with the sprinklers open at all times, neither air nor water can be maintained in the piping. The deluge system requires a detection system to operate and signal the deluge valve, opening the valve and allowing water to flow through the piping and discharge through all of the sprinklers or nozzles simultaneously.

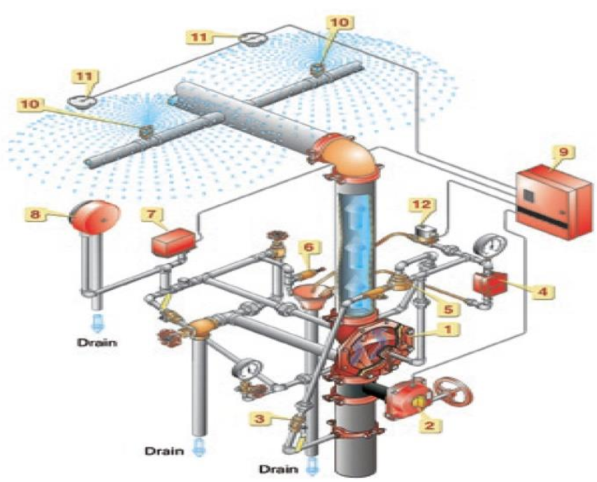


Figure (5.8) Deluge system

5.4 Firefighting network components

- **Water source:**

The main sources of firefighting water are Water Tanks Underground.

- **Pipes:**

1. Black steel
2. Galvanized steel
3. High density polyethylene
4. UPVC poly vinyl chloride

Firefighting pipes should be tested after installation at site to ensure durability of the system. All pipes, fittings, valves and other accessories should be tested at four bars above the working pressure for two hours according to the NFPA13 code.

- **Valves:**

1. Sectional valves: are used to separate specific parts of the firefighting network for maintenance and repair times and should be automatically supervised.
2. Drain valve: should be placed at the lowest point of the firefighting network to drain the water network for washing & maintenance of the pipes.
3. Check valve.
4. Standpipes.

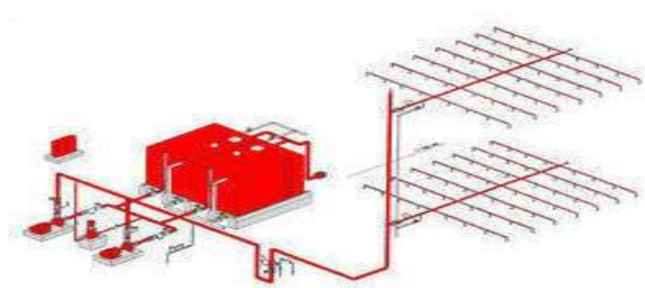


Figure (5.9) Firefighting network

5.5 Firefighting pumps

A fire-fighting pump is a centrifugal pump which is used for pumping fire-fighting water. Fire-fighting pumps can be designed for transportable use (e. g. on fire-fighting vehicles or as portable fire pumps) or for stationary use (e. g. hydrants, sprinkler systems).

5.5.1 Pumping stations should include

1- Electrical firefighting pump.
2- Stand-by Diesel Firefighting Pump. (No need if an extra electric pump is connected to an electric generator).
Diesel pump works if:

- The electrical pump is out of service, or if there is a lack of electricity.
- The electrical pump is working but can't satisfy system water requirements.

3- Jockey Pump: work to make up the system pressure in case of leakage or during the first seconds of fire.
Pumps are selected to supply the system demands on the basis of three key points relative to their rated flow and rated pressure; most fire pumps are sized to exceed its duty point requirement.

5.5.2 Type of pumps

1- Horizontal split case pumps:

This is also called a double suction fire pump because the water pathways direct water to both sides of the impeller. It is also the most common fire pump on the market partly because of the ratings available in this style of pump 250 GPM through 5000 GPM.

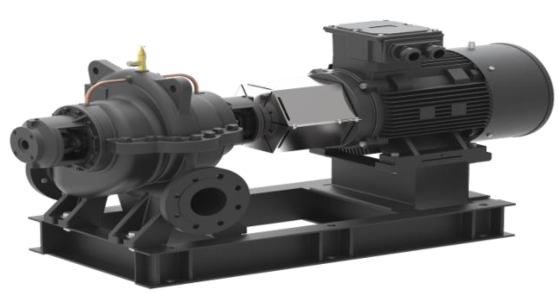


Figure (5.10) Horizontal split case pump

2- Inline fire pumps:

These pumps have expanded in use in the last five years for several reasons, space savings, increase in ratings allowable by NFPA 20 from max of 499 GPM, and then to 750 GPM, to today which is unlimited rating. The largest currently available is 1500 GPM, Cost of installation –these are typically less expensive to install because there is no base plate that requires grouting.

Figure (5.11) Inline fire pump

3- End suction pumps:

A type of centrifugal pump that has a casing with the suction coming in one end and the discharge coming out the top. They are almost always single stage pumps, that is, they have only one impeller.

End suction fire pumps not widely used mostly because they are limited in size per code. They are also slightly more expensive than in line pumps, the one pump application where it is used is small diesel driven applications 500 GPM or l less.

Figure (5.12) End suction pump

4- Vertical turbine pumps:

These are used for vertical turbine pumps these are used for water supplies that are below the suction flange of a fire pump; NFPA 20 states that you have to have a positive suction pressure to a fire pump.

Figure (5.13) Vertical turbine pump

5.6 Flow rate calculations

The flow rate was calculated using Jordanian code and (Elite Fire Fighting) program software, 8 gpm from cabinet and 250 gpm for fire hydrant and 22.6 gpm for sprinkler, and the total flow rate for the system(for sprinklers) is 157 gpm.

5.6.1 Head estimation

$\mathbf{H_{pump} = H_R + H_s + H_f}$ (5.1)

$\mathbf{H_{pump}}$: is the head of pump.

$\mathbf{H_R}$: is the residual pressure.

$\mathbf{H_s}$: is the static pressure.

H : is the friction pressure.

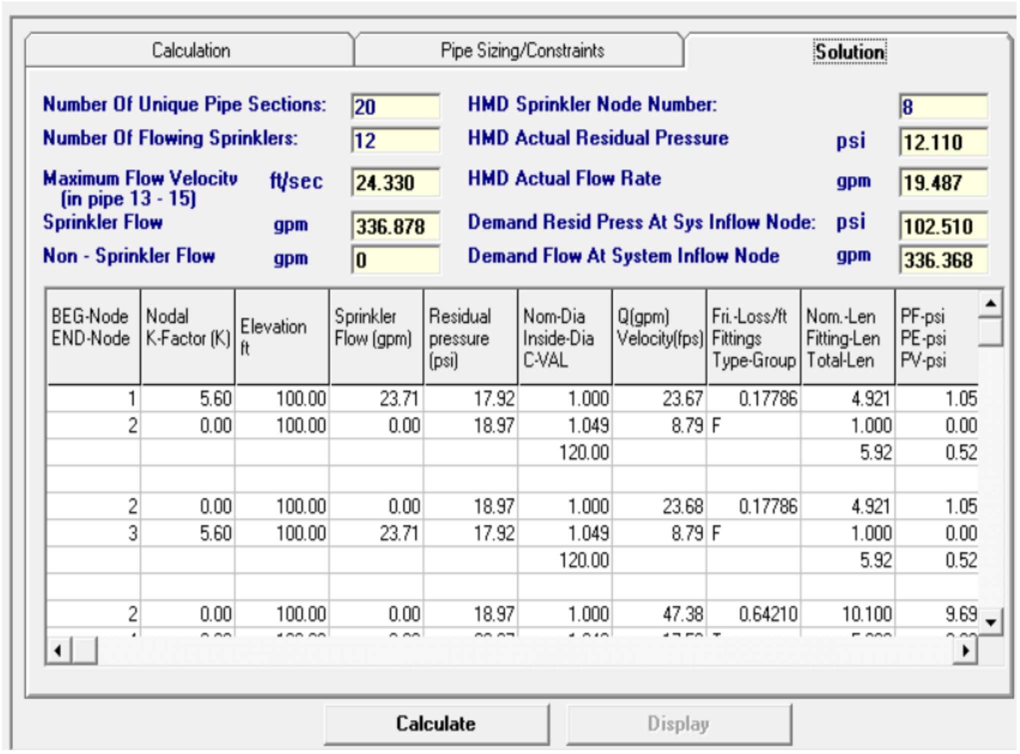
*Static pressure $\mathbf{H_s}$:

for 10.3 m ⟶ 1 bar

32.2m ⟶ X

The Static pressure $\mathbf{H_s}$ = 3.12 bar for the total height.

*We use Elite Fire Fighting program for the calculation of the head and flow rate for the pumps. By this program we enter the inputs (length and diameter of pipes , number of tees and other fittings in each pipe, hazard description) and the outputs are the head and flow required for pumps.


Calculation | Pipe Sizing/Constraints | Solution

Number Of Unique Pipe Sections: 20
Number Of Flowing Sprinklers: 12
Maximum Flow Velocity (in pipe 13 - 15) ft/sec 24.330
Sprinkler Flow gpm 336.878
Non - Sprinkler Flow gpm 0
HMD Sprinkler Node Number: 8
HMD Actual Residual Pressure psi 12.110
HMD Actual Flow Rate gpm 19.487
Demand Resid Press At Sys Inflow Node: psi 102.510
Demand Flow At System Inflow Node gpm 336.368

BEG-Node END-Node	Nodal K-Factor (K)	Elevation ft	Sprinkler Flow (gpm)	Residual pressure (psi)	Nom-Dia Inside-Dia C-VAL	Q(gpm) Velocity(fps)	Fri.-Loss/ft Fittings Type-Group	Nom.-Len Fitting-Len Total-Len	PF-psi PE-psi PV-psi
1	5.60	100.00	23.71	17.92	1.000	23.67	0.17786	4.921	1.05
2	0.00	100.00	0.00	18.97	1.049	8.79	F	1.000	0.00
					120.00			5.92	0.52
2	0.00	100.00	0.00	18.97	1.000	23.68	0.17786	4.921	1.05
3	5.60	100.00	23.71	17.92	1.049	8.79	F	1.000	0.00
					120.00			5.92	0.52
2	0.00	100.00	0.00	18.97	1.000	47.38	0.64210	10.100	9.69

Calculate | Display

Figure)5.14(Elite Fire Fighting program for the calculation

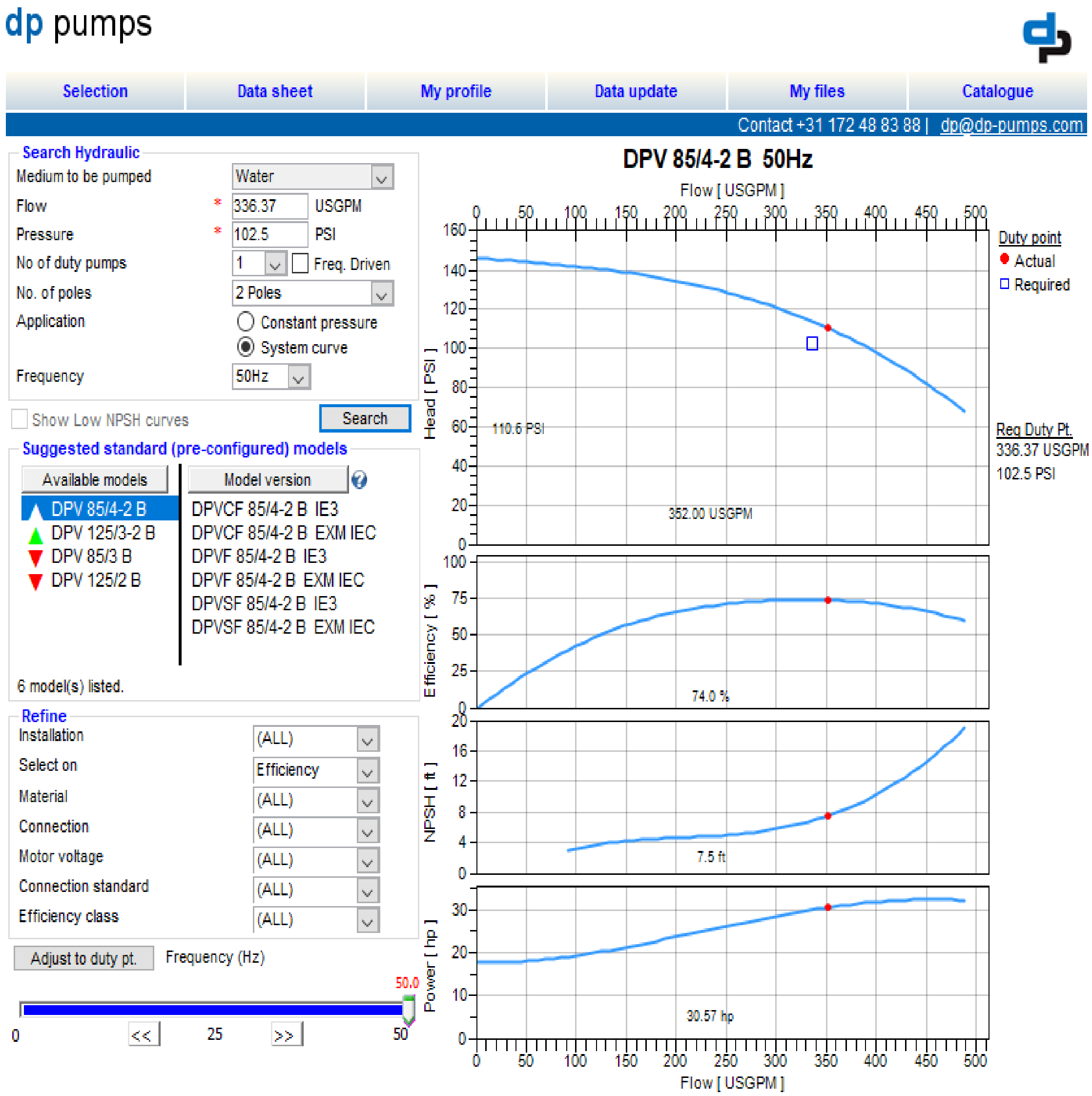


Figure (5.15) dp pump program for the calculation

Chapter Six

Swimming Pool Heating System

6.1 Introduction

- The pool owner requires absolute hygiene crystal clear water & Economy of effort.
- Factors results in pollution of swimming pool.
1. Biological contamination.
2. Rainfall & wind.

Solution to problem of pollution

1. Physical treatment

Supply the pool with filtration system (filter and pump) to eliminate suspended particles from pool water

2. Chemical treatment

Maintain the correct level of sanitizer (Chlorine, bromine, oxygen) to combat micro-organisms by its disinfector action.

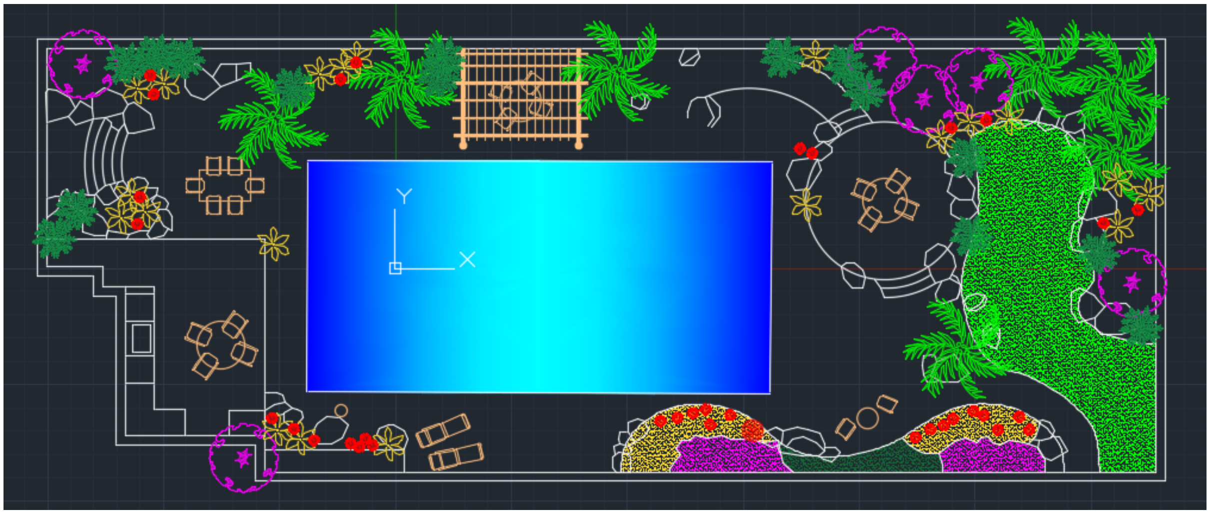


Figure (6.1) Horizontal drop for swimming pool

The four pool types that are available include:

- Above-ground pool.
- Vinyl-liner pool, in-ground.
- Fiberglass pool, in-ground.
- Concrete pool, in-ground.

6.2Filtration cycle

- A suction is taken from the main drain on the bottom of the pool and skimmers at the surface of the pool & fed via suction line through the pump to filter.
- The filtered water is returned to the pool through return inlets.
- Once in the filter, the water is circulated downward through silica sand & suspended particles are retained.
- Usually the initial pressure in the filter is 11.5 psi, due to particles retained in the sand filter, the pressure is going to rise, when the pressure in the filter raises 7 psi with reference to the initial pressure, backwash is needed.

Figure (6.2) Filter shapes

The main duty of the filter is to remove insoluble and suspended particles and should be with a chemical treatment to have:

1. Clean and non-toxic water
2. Tasteless and odourless water
3. Free of bacteria and algae
4. PH balanced to prevent corrosion and scale formations

Figure (6.3) Filter parts

6.2.1Components of Filtration cycle

1. Filter
2. Selector valve (Multi-port valve) 3- Skimmers
3. Main drains
4. Return inlets
5. Pump
6. Pipes Network

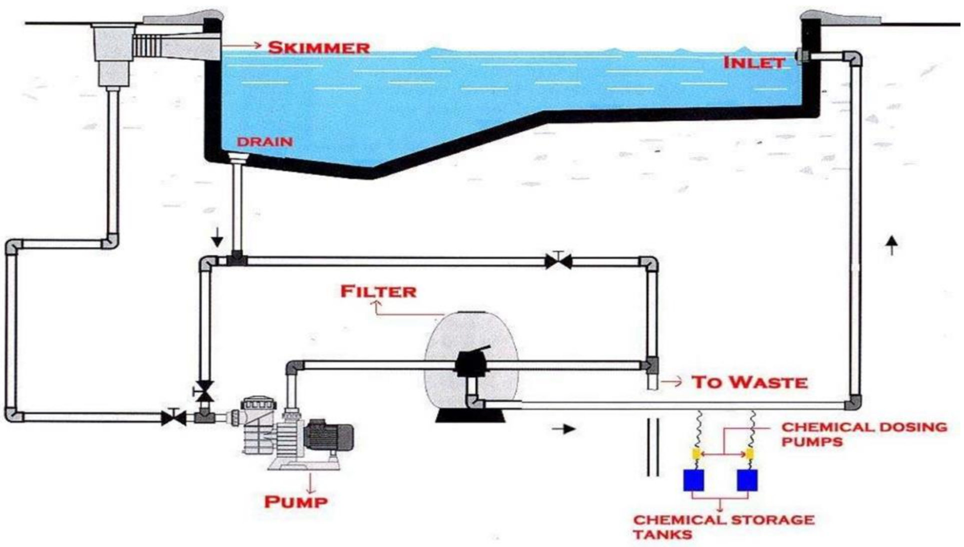


Figure (6.4) Components of Filtration cycle

How filters differ from each other?

1. Tank material (HDPE, Reinforced fiberglass, Gelcoat fiberglass, Resistant plastic …etc.)
2. Max operating pressure
3. Max temperature
4. Capacity
5. Application

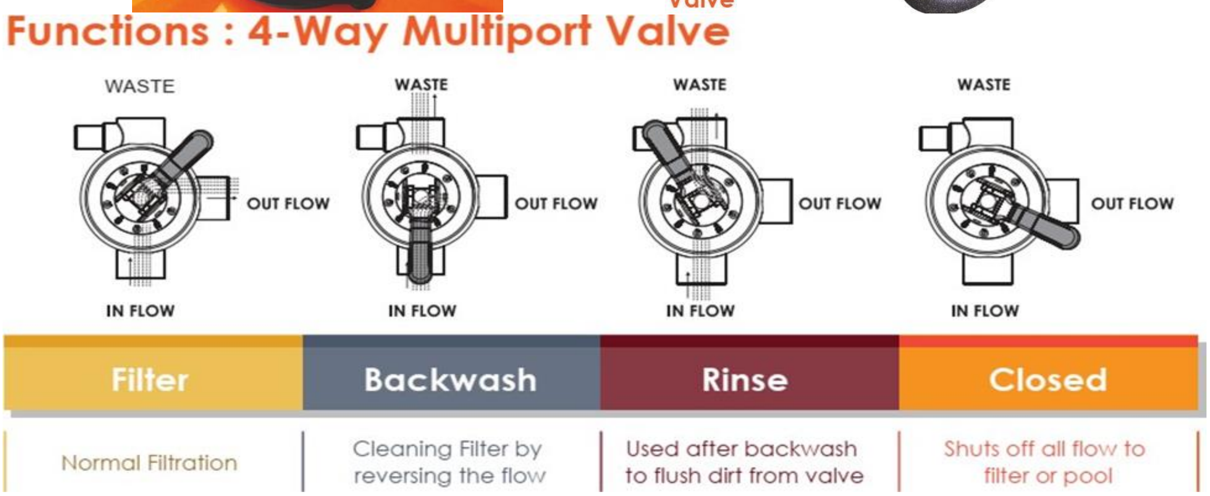
Commercial filters also differ in:

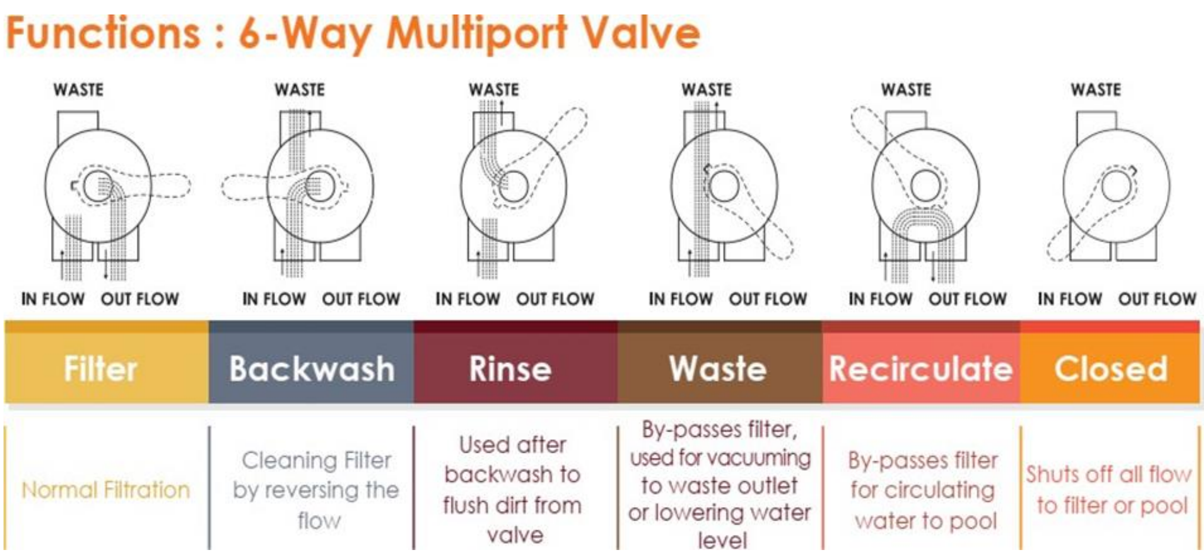
1. Filtration System
2. Design Filtration Velocity

Figure (6.5) Glass filtration media

6.3 valve

Selector valve (Multi-port valve)





6.4 Skimmers

- Primarily used to eliminate surface debris from pool water, therefore should be installed with their mouth facing prevailing winds.
- For pools with 1 to 2 skimmers, they should be placed along the width of the pool at the deep end against the prevailing winds and return inlets.
- For pools with 3 skimmers or more, they should be placed along the length of the pool
- In all cases should be positioned against the return inlets.

Figure (6.6) Skimmers

6.5 Main drain

- It's placed at the bottom of the pool in the deepest point.

Figure (6.7) Main drain

6.6 Return inlets

Their function of return inlets is:

1. To create a current in the swimming pool water using filtered water
2. To direct surface debris to the mouth of the skimmer
3. To create uniform water flow in pools to prevent the dead spots
4. Usually placed a return inlet 0.4 m below water level.
5. Return inlet water flow velocity should be in the range of 0.3 – 1.2 m/s
6. The return inlet should be provided with a moving angle eyeball to direct water up, down, and side.

- The number of return inlets required to depend on the flow rate required and the type of pool

Figure (6.8) Return inlet

6.7 Designing of swimming pools

Swimming pool design depends on:

1. Number and type of bathers
2. Degree of environmental pollution
3. Location – indoor or outdoor pool
4. Wind velocity and direction

Selection of components depends on:

1. Head resistance increase as dirt is build up in the filter.
2. The pump flow rate varies with the variation of the head.
3. Heater resistance increase with time due to Calcareous formation.

If the slope of the bottom is gradual and even if not, we divide the pool into parts each with uniform scale formation slope.

6.8 Calculation for swimming pool

6.8.1Swimming pool capacity

Represents volume of water in pool = pool surface area * average depth Average depth = (shallow end depth + deep end depth) / 2 (6.1)

Length of pool=10.5m

Width of pool=5 m

Depth=1.85 m

Swimming pool capacity=10.5*5*1.85=97.12 m^3

- Turnover time:

- Represent the number of hours required to recirculate pool capacity through filter.
- American code

1. Spa 0.5 hour
2. Wading pool 1 hour
3. School pool 4 hours
4. Hotel and commercial 5-6 hours
5. Residential pools 8-10 hours
6. Indoor pools 10-12 hours

Turnover time used in our country is 4 hours

Why ???

1. Bathing density

1 bather / 4 square meter of pool surface (international code)

2. Swimming clothes

No special clothes used

3. Type of bather

Nobody has a shower before entering the pool

4. Environment
5. Psychological reason

People refuse to turn on the pump for a long time and always don't add the required disinfection.

6.8.2 Flow rate

Flow rate = Pool capacity / Turnover time (6.2)

Units:

Flow rate in cubic meter / hour

Pool capacity in cubic meter

Turnover time hours

Turnover time Units at Palestine =4 hour

Flow rate = 97.12m3/4 hour=24.2 m^3/h

6.8.3 Filter selection

To select the required filter to calculate:

1. Flow rate
2. Filter surface area

Filter surface area (m^2) = Flow rate (m^3/hr) / Filtration velocity ($\frac{m^3/hr}{m^2}$ of filtering surface area) (6.3)

Filtration velocity according to Palestinian code:

Minimum velocity = 8

Maximum velocity = 40

Filter surface area = flow rate / 30

Filter surface area = 24.2 / 30=0.8 m2

6.8.4 Skimmer selection

To select the required quantity of skimmer we have to:

1. Install one skimmer per 25 square meter of pool surface area.

No of skimmers required = pool surface area / 25 (6.4)

2. Taking into account that the total capacity of a skimmers should be approximately equal 50% of the filter flow rate.

No of skimmers required = 50% of flow rate / max flow rate in each skimmer (from catalogues)

Note: We take the largest No calculated from the previous calculations

Install one skimmer per 25 square meter of pool surface area.

The area of pool swimming=length *width=10.5*5=52.5 m^2

# of skimmer = area for pool/25=52.5/25=2 skimmer

6.8.5 Main drain selection

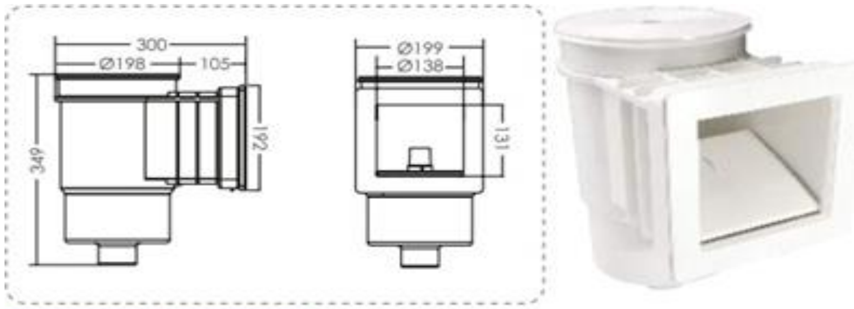
- Usually install more than one main drain
- No of main drain required = 50% flow rate / main drain flow rate (6.5)

Hint: Try to install one main drain each 2 meters from pool width

Assume we select main drain (A1)

No of main drain required = 50% flow rate / main drain flow rate

= 0.5 * 24.2 / 9=2 main drain



Code	Model	Connection	Application	Flow Rate (L/min)
91600302	EM0010-RV	1.5" Internal Threaded	Vinyl Pool	150
91600301	EM0010-RC	1.5" Internal Threaded	Concrete Pool	150

Figure (6.9) Main drain selection

6.8.6 Return Inlet Selection

Taking into account that the total capacity of the return inlets should be equal 100% of the filter flow rate.

No of return inlets required = Flow rate/ return inlet flow rate

No of return inlets required = 24.2/ 9=3return inlet

So the # of return inlets required=3return inlet

Code	Model	Connection	Flow Rate (L/min)
91601211	EM4408(A)	1"/1.5" Class 12 Solvent	50/150
91601234	EM4408(A1)	1"/1.5" Class 15 Solvent	50/150
91601212	EM4408(E)	32mm/50mm PN10 Solvent	50/150
91601235	EM4408(E1)	32mm/50mm PN16 Solvent	50/150

Figure (6.10) Return Inlet Selection

6.8.7 Pipe Sizing

- Pipe is sized to carry the water flow rate without exceeding the maximum head at which the pump will deliver such flow rate.
- Today most pipes used in pool plumbing is PVC plastic pipes (Polyvinyl chloride) since it is:

1. Easy to install
2. Resistance to corrosion
3. Economy in lab or and materials

Pipe sizing consideration:

1. Required flow rate m3/h or gpm in each pipe section
2. Length of plumping runs and equivalent length of fittings
3. The suction line plays a critical part in the wear and efficiency of pump, therefore it should be straight and short, so that the velocity is in the range of (1.6-3.3 ft/s) with a maximum head loss 6ft/100 ft.
4. The sizing of discharge line is based on velocity (3.3-10 ft/s) and max friction head (12ft / 100 ft).
5. Always choose the largest pipe.
6. For Spa Pipes we use CPVC pipes (Chlorinated polyvinyl chloride).

For our swimming pool we have:

Flow rate = 24.2 m^3

No. of skimmers = 2 flow in each skimmer = 8.06 m3/h No. of
main drains =2 flow in each main drain= 4.04m3/h No. of
return inlets =3 flow in each inlet = 8.06 m3/h

Suction: recommended velocity=1.6-3.3 ft/s

Suction:max head loss per 100 ft=6 ft

Discharge: : recommended velocity=3.3-10 ft/s

Discharge: max head loss per 100 ft=12 ft

Pipe number	Suction / discharge	Flow rate m^3/h	Flow rate gpm	pipe size inch	Velocity Ft/s	Head loss Per 100 ft
1	suction	8.06	35.5	2 ½	2.7	1.3
2	suction	16.12	71	4	2	0.4
3	suction	4.04	17.8	2	2.2	1.1
4	suction	20.16	88.7	4	2.6	0.6
5	suction	24.2	106.5	5	1.9	0.2
6	discharge	8.06	35.5	2	3.9	3
7	discharge	16.12	71	2 1/2	5.9	5.1
8	discharge	24.2	106.5	3	5	2.9

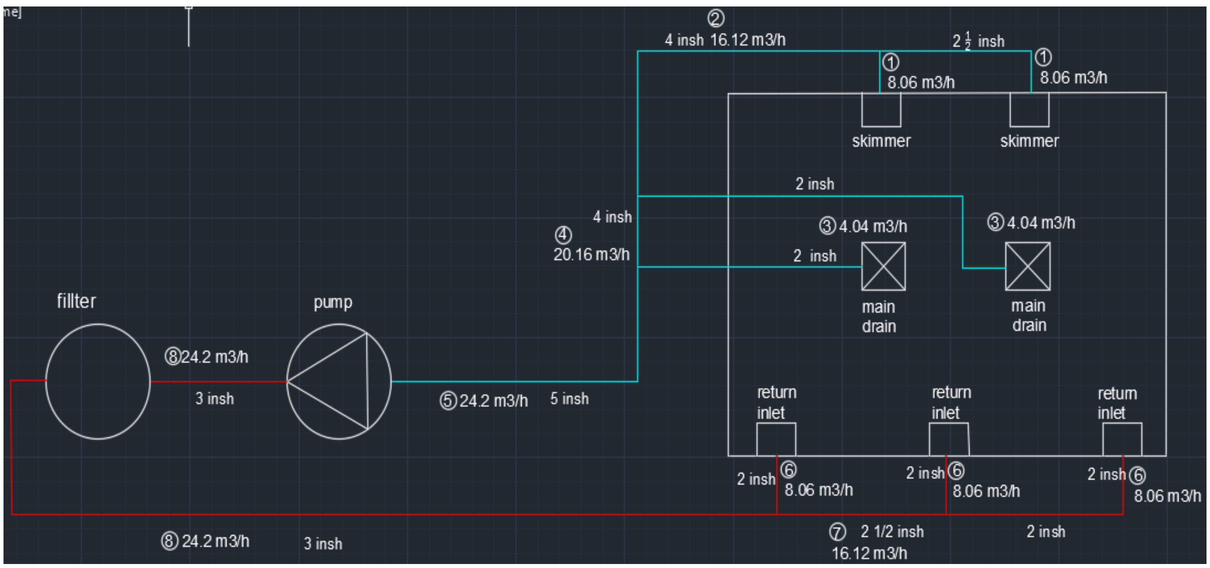


Figure (6.11) Selection of pipe sizing

6.8.8 Pump Selection

- To select any pump we need to determine two values

1. Flow (as we calculated it)
2. Head

Head = Static Head + Dynamic Head (6.6)

Static Head = zero

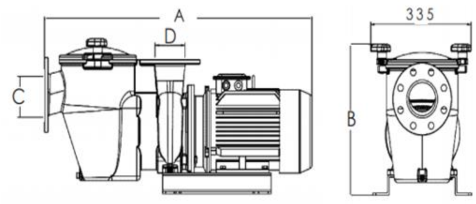
- Dynamic Head = Friction head in filter+ Friction head in (Skimmers + Main drains + return inlets) + Friction head in Suction line+ Friction head in Discharge line

Friction head in filter = 10 psi = 6.7 m

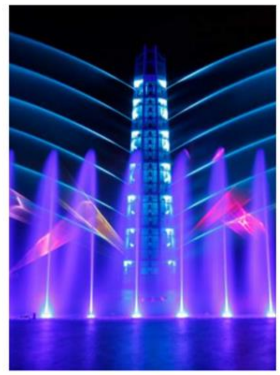
Friction head in (sk. + drains + return) = 1.5 m

Recommended dynamic head = (12 – 14) m

Product Information and Dimensions:



Model 50Hz	Input (kW)	Current (AMP)	Noise (dB)	Head (m) 8	10	12	14	16	18
				Flow Rate (m^3/h)					
SE5.5	4.70	7	72	65	55	42.5	25	--	--
SE7.5	6.40	9	76	77.5	71	62.5	52.5	40	20
SE10	8.60	14	75	111.5	104	97	85	75	55
SE15	12.40	18	78	137.5	132.5	126.5	120	110	101



SE Commercial Pump is designed for large swimming pools, spa pools and water features

Code 380V/50Hz	Model	Connection Size	Horsepower	Output power (kW)	Voltage	Weight (kg)	A mm	B mm	C mm	D mm
88026816	SE5.5	3" / 90mm	5.5hp	4.0	380-420	95	860	415	DN80	DN80
88026811	SE7.5	3" / 90mm	7.5hp	5.5	380-420	100	860	415	DN80	DN80
88026812	SE10	4" / 110mm	10hp	7.5	380-420	118	915	445	DN100	DN100
88026813	SE15	4" / 110mm	15hp	11.0	380-420	130	945	445	DN100	DN100

Figure (6.11) Pump Selection

We choose model SE5.5

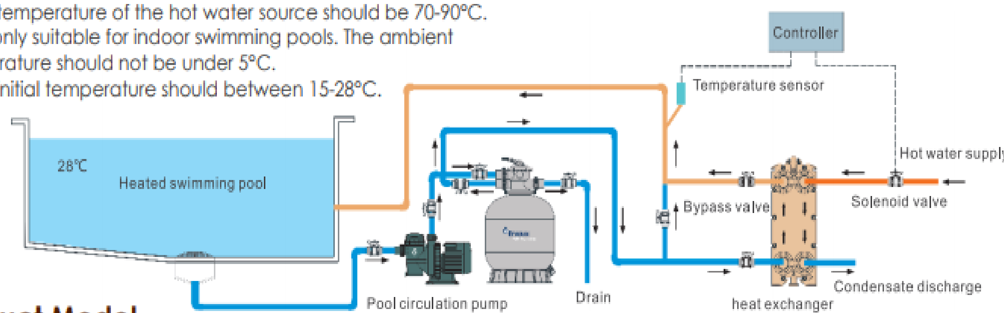
6.8.9 Heating system

Heating plate system:

Flow rate=39.4 m^3/h

Figure (6.12) Heat exchanger

1. The temperature of the hot water source should be 70-90°C.
2. It is only suitable for indoor swimming pools. The ambient temperature should not be under 5°C.
3. The initial temperature should between 15-28°C.



Product Model

12 hours initial heating Heat Exchanger

Code	Model	Volume (m³)	Power (kw)	Heat Source Flow (m³/H)	Total Heat Transfer (m²)	Connection Pipe Diameter (mm)	External Dimensions (mm) A	B	C	Packing Dimensions (mm) Length	Width	Height	Gross Weight (kg)
88540507	BSH25-1.5	100	214	9	1.5	25	275	185	480	295	205	500	42
88540508	BSH40S-3	200	428	18	3	40	305	240	550	325	260	570	59
88540509	BSH50S-5	400	856	37	5	50	485	320	870	505	340	890	170
88540510	BSH50S-6	500	1070	46	6	80	595	420	977	615	440	977	270
88540511	BSH50S-9	800	1690	73	9	80	599	420	977	619	440	977	288
88540512	BSH80A-11	1000	2114	91	11	80	615	420	977	635	440	977	302
88540513	BSH80A-12	1200	2356	109	12	80	723	420	977	743	440	977	309

24 hours initial heating Heat Exchanger

Code	Model	Volume (m³)	Power (kw)	Heat Source Flow (m³/H)	Total Heat Transfer (m²)	Connection Pipe Diameter (mm)	External Dimensions (mm) A	B	C	Packing Dimensions (mm) Length	Width	Height	Gross Weight (kg)
88540414	BSA25-1	100	127	5	1	25	265	185	480	285	205	500	42
88540415	BSA40S-2	200	254	11	2	40	295	240	550	315	260	570	53
88540416	BSA40S-3	400	507	22	3	50	305	240	550	325	340	890	59
88540417	BSA40S-4	500	634	27	4	80	466	320	870	486	340	890	163
88540418	BSA40S-5	800	994	43	5	80	485	320	870	505	440	977	169
88540419	BSA40S-6	1000	1242	53	6	80	595	420	977	615	440	977	270
88540420	BSA40S-7	1200	1490	64	7	80	625	420	977	645	440	977	277
88540421	BSA40S-11	1800	2194	94	11	80	615	420	977	635	440	977	302
88540422	BSA40S-12	2000	2438	105	12	80	723	420	977	743	440	977	309

Figure (6.13) Catalogue of heat exchanger

Choose model BSA40S-5, heat source flow =43 m^3/h

6.8.10 Chlorinator

- Available in different sizes (2 , 3 , 5 and 10 kg)
- 1 kg = 5 drops
- For (0 -100 m3 of water) we have to add 5 kg
- For more than 100m3 we have to add 10 kg
- It's forbidden to let the chlorine enter the filter.
- %chlorine = 2 parts /million

Figure (6.14) chlorinator

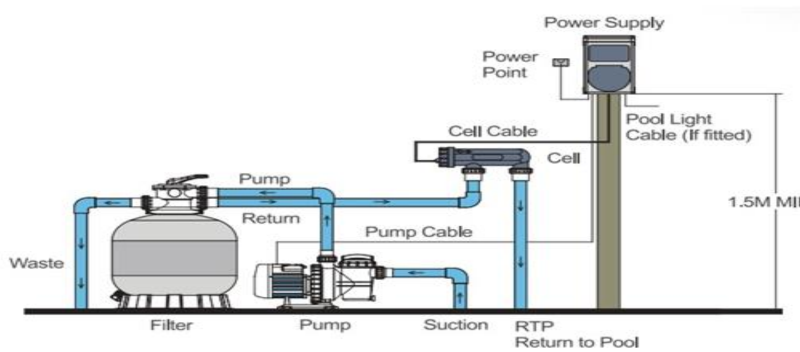


Figure)6.15 (swimming pool rotation system

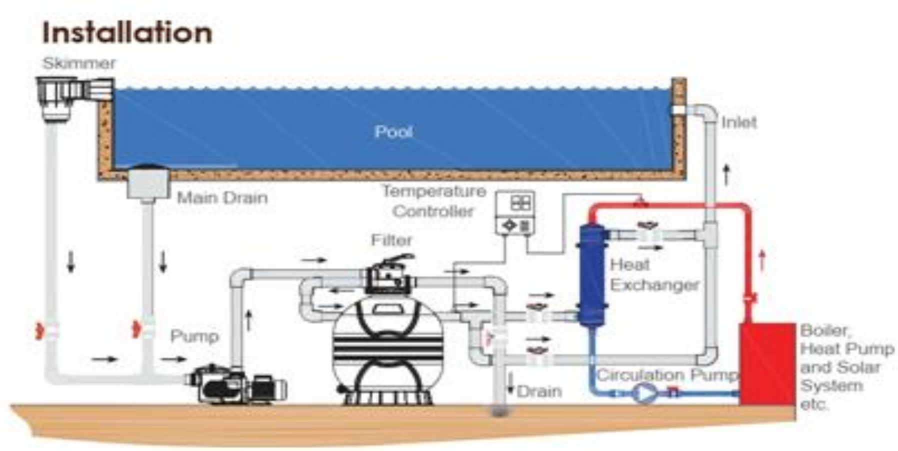


Figure (6.16)Heating Equipment Swimming Pool

References

[1] Rezaie, B. and M.A. Rosen, *District heating and cooling: Review of technology and potential enhancements.* Applied energy, 2012. **93**: p. 2-10.

2. Olesen, B.W. and K. Parsons, *Introduction to thermal comfort standards and to the proposed new version of EN ISO 7730.* Energy and buildings, 2002. **34**(6): p. 537-548.
3. Burdick, A., *Strategy Guideline. Accurate Heating and Cooling Load Calculations*. 2011, IBACOS, Inc., Pittsburgh, PA (United States).
4. Simion, M., L. Socaciu, and P. Unguresan, *Factors which influence the thermal comfort inside of vehicles.* Energy Procedia, 2016. **85**: p. 472-480.
5. Hammad, M., *Heating, and Air Conditioning For Residential Buildings*. 2011.
6. government, M.o.l., *Energy Efficient Building Code*. 2004.
7. Givoni, B., *Comfort, climate analysis and building design guidelines.* Energy and buildings, 1992. **18**(1): p. 11-23.
8. Younes, C., C.A. Shdid, and G. Bitsuamlak, *Air infiltration through building envelopes: A review.* Journal of Building physics, 2012. **35**(3): p. 267-302.
9. Khakre, M.V.V., A. Wankhade, and M. Ali, *COOLING LOAD ESTIMATION BY CLTD METHOD AND HAP 4.5 FOR AN EVAPORATIVE COOLING SYSTEM.* 2017.
10. Sadineni, S.B., S. Madala, and R.F. Boehm, *Passive building energy savings: A review of building envelope components.* Renewable and sustainable energy reviews, 2011. **15**(8): p. 3617-3631.
11. Cote, A.E., *Fire protection handbook*. Vol. 2. 2008: NationalFireProtectionAssoc.
12. Cote, A.E. and P. Bugbee, *Principles of fire protection*. 1988: Jones & Bartlett Learning.
13. Hoskins, B.L. and N. Mueller, *Evaluation of the Responsiveness of Occupants to Fire Alarms in Buildings: Phase 1*. 2019: Fire Protection Research Foundation.
14. Petaway, J.B. and O.C. Gabriel, *Quick release fire hose cabinet*. 1983, Google Patents.
15. Schroll, R.C., *Industrial fire protection handbook*. 2016: CRC press.
16. Jackson, J. and W.D. Roquemore, *Dry pipe fire extinguishing sprinkler system*. 1980, Google Patents.
17. Jackson, E.D., *Fire extinguishing system*. 2008, Google Patents.
18. Curless, M., *Deluge fire sprinkler system*. 2001, Google Patents.
19. Lahiji, N. and D.S. Friedman, *Plumbing: sounding modern architecture*. 1997: Princeton Architectural Press.
20. Manual, F., *PLUMBING, PIPE FITTING, AND SEWERAGE.*

21. *American Society of Plumbing Engineers Plumbing Engineering Design Handbook* 2013.

22. Burroughs, H. and S.J. Hansen, *Managing indoor air quality*. 2004: The Fairmont Press, Inc.
23. McQuiston, F.C., J.D. Parker, and J.D. Spitler, *Heating, ventilating, and air conditioning: analysis and design*. 2004: John Wiley & Sons.
24. Afify, R., *Designing VRF systems.* ASHRAE Journal, 2008. **50**(6): p. 52-55.
25. Goetzler, W., *Variable refrigerant flow systems.* Ashrae Journal, 2007. **49**(4): p. 24-31.
26. Bhatia, A., *HVAC variable refrigerant flow systems.* CED Engineering Course, 2011(M03-014).
27. Duda, S.W., *Applying VRF?* nature, 2010. **15**: p. 2.2.
28. Ahuja, A. and L.B. RCDD, *Integration of nature and technology for smart cities*. 2016: Springer.
29. Kim, D., et al., *Evaluation of energy savings potential of variable refrigerant flow (VRF) from variable air volume (VAV) in the US climate locations.* Energy Reports, 2017. **3**: p. 85-93.
30. Samsung, *Technical Data Book - Samsung*. 2015.
31. Allard, F. and F. Allard, *Natural ventilation in buildings: a design handbook*. 1998: James & James London.
32. Slutsky, A.S., *Mechanical ventilation.* Chest, 1993. **104**(6): p. 1833-1859.

Appendix (A)

A-1: Description of wall construction groups

TABLE 9-5 Description of wall construction groups.

Group No.	Description Of Construction	$U_{ov.}$ $W/m^2 \cdot °C$
	101.6 mm Face Brick + (Brick)	
C	Air space + 101.6 mm face brick	2.033
D	101.6 mm common brick	2.356
C	25.4 mm insulation or air space + 101.6 mm common brick	0.987-1.709
B	50.6 mm insulation + 101.6 mm common brick	0.630
B	203.2 mm common brick	1.714
A	Insulation or air space + 203.2 mm common brick	0.874-1.379
	101.6 mm Face Brick + (H.W. Concrete)	
C	Air space + 50.8 mm concrete	1.987
B	50.8 mm insulation + 101.6 mm concrete	0.658
A	Air space or insulation + 203.2 mm or more concrete	0.625-0.636
	101.6 mm Face Brick + (L.W. or H.W Concrete Block)	
E	101.6 mm block	1.811
D	Air space or insulation + 101.60 mm block	0.868-1.397
D	203.2 mm block	1.555
C	Air space or 25.4 mm insulation + 152.4 mm or 203.2 mm block	1.255-1.561
B	50.8 insulation + 203.2 mm block	0.545-0.607
	101.6 mm Face Brick + (Clay Tile)	
D	101.6 mm tile	2.163
D	Air space + 101.6 mm tile	1.595
C	Insulation + 101.6 mm tile	0.959
C	203.2 mm tile	1.561
B	Air space or 25.4 mm insulation + 203.2 mm tile	0.806-1.255
A	50.8 mm insulation + 203.2 mm tile	0.551
	L.W. Concrete Wall + (Finish)	
E	101.5 mm concrete	3.321
D	101.6 mm concrete + 25.4 mm or 50.8 mm insulation	1.136 - 0.675
C	50.8 mm insulation+101.6 mm concrete	0.675
C	203.2 mm concrete	2.782
B	203.2 mm concrete + 25.4 mm or 50.8 mm insulation	1.061 - 0.653
A	203.2 mm concrete + 50.8 mm insulation	0.653
B	304.8 mm concrete	2.390
A	304.8 mm concrete + insulation	0.642
	L.W. and H.W. Concrete Block + (Finish)	
F	101.6 mm block + air space/insulation	0.914-1.493
E	50.8 mm insulation + 101.6 mm block	0.596-0.647
E	203.2 mm block	1.669-2.282
D	203.2 mm block + air space/insulation	0.846-0.982
	Clay Tile + (Finish)	
F	101.6 mm tile	2.379
F	101.6 mm tile +air space	1.720
F	101.6 mm tile + 25.4 mm insulation	0.993
D	80.8 mm insulation + 10.4 mm tile	0.825
C	203.3 mm tile + air space/25.4 mm insulation	0.857-1.312
B	50.8 mm insulation + 203.2 mm tile	0.562
	Metal Curtain Wall	
G	With/without air space + 25.4 mm/58 to 76.2 mm insulation	0.516-1.306
	Frame Wall	
G	24.4 mm to 76.2 mm insulation	1.010 - 0.459

A-2: Approximate CLTD values for light, medium, and heavy weight construction walls

TABLE 9-6 Approximate CLTD values for light, medium, and heavy weight construction walls, °C.

Solar Time	Wall construction											
	Light				Medium				Heavy			
	N	E	S	W	N	E	S	W	N	E	S	W
8:00	—	16	—	—	—	—	—	—	—	—	—	—
9:00	—	20	—	—	—	6	—	—	—	—	—	—
10:00	—	21	2	—	—	11	—	—	—	—	—	—
11:00	—	18	7	—	—	14	—	—	—	3	—	—
12:00	—	12	12	—	—	15	—	—	—	5	—	—
13:00	2	9	15	5	—	14	5	—	—	7	—	—
14:00	3	7	16	13	—	12	9	1	—	8	—	—
15:00	3	7	14	21	1	10	11	6	—	8	1	—
16:00	4	6	11	27	2	9	12	12	—	8	3	—
17:00	4	5	7	30	2	8	11	17	—	8	5	3
18:00	5	3	4	27	3	7	9	22	—	8	6	7
19:00	2	1	1	17	3	5	7	23	—	7	6	10
20:00	—	—	—	6	3	3	5	20	1	7	6	12

A-3: Approximate CLTD values for sunlit roofs

TABLE 9-3 Approximate CLTD values for sunlit roofs, °C.

Solar Time	Roof Construction		
	Light	Medium	Heavy
10:00	5	—	—
11:00	12	—	—
12:00	19	3	0
13:00	25	8	2
14:00	29	14	5
15:00	31	19	8
16:00	31	23	10
17:00	29	25	12
18:00	24	26	14
19:00	19	25	15
20:00	11	22	16

A-4: Infiltration through window and door crack in cubic meter per hour per meter of crack

TABLE 6–1 Infiltration through window and door crack in cubic meter per hour per meter of crack.[1]

Type of Aperture	Remarks	Wind Speed, km/h 8.0	16.0	24.0	32.0	40.0
Double-hung wood-sash windows (Unlocked)	Average; non-weather-stripped.	0.7	2.1	3.9	5.9	8.0
	Average; weather-stripped.	0.4	1.3	2.4	3.6	4.9
	Poorly fitted; non-weather-stripped.	2.7	6.9	11.1	15.4	19.9
	Poorly fitted; weather-stripped.	0.6	1.9	3.4	5.1	7.1
	Around window frame; masonry wall, uncalked.	0.3	0.8	1.4	2.0	2.7
	Around window frame; masonry wall, calked.	0.1	0.2	0.3	0.4	0.5
	Around window frame; wood frame structure.	0.2	0.6	1.1	1.7	2.3
Double-hung metal windows	Non-weather-stripped; unlocked.	2.0	4.7	7.4	10.4	13.7
	Non-weather-stripped; locked.	2.0	4.5	7.0	9.6	12.5
	Weather-stripped; unlocked.	0.6	1.9	3.2	4.6	6.0
Single-sash metal windows	Industrial; horizontally pivoted.	5.2	10.8	17.6	24.4	30.4
	Residential casement	1.4	3.2	5.2	7.6	10.0
	Vertically pivoted	3.0	8.8	14.5	18.6	22.1
Doors	Well-fitted	2.7	6.9	11.0	15.4	19.9
	Poorly fitted	5.4	13.8	22.0	30.8	39.8

A-5: Cooling load factor (CLF), for lights

Table (A-8) Cooling load factor $(CLF)_{Lt}$, for lights. [3]

Number of hours after lights are turned On	Fixture X[c] hours of operation		Fixture Y[c] hours of operation	
	10	16	10	16
0	0.08	0.19	0.01	0.05
1	0.62	0.72	0.76	0.79
2	0.66	0.75	0.81	0.83
3	0.69	0.77	0.84	0.87
4	0.73	0.80	0.88	0.89
5	0.75	0.82	0.90	0.91
6	0.78	0.84	0.92	0.93
7	0.80	0.85	0.93	0.94
8	0.82	0.87	0.95	0.95
9	0.84	0.88	0.96	0.96
10	0.85	0.89	0.97	0.97
11	0.32	0.90	0.22	0.98
12	0.29	0.91	0.18	0.98
13	0.26	0.92	0.14	0.98
14	0.23	0.93	0.12	0.99
15	0.21	0.94	0.09	0.99
16	0.19	0.94	0.08	0.99
17	0.17	0.40	0.06	0.24
18	0.15	0.36	0.05	0.20

[3] Adapted from Stoecker and Jones, 1982, "*Refrigeration and Air Conditioning*", 2nd ed., MacGraw Hill. (Fixture X = not vented recessed lights and Fixture Y = vented or free-hanging light.)

[4] Adapted from Jones, 1979 "*Air Conditioning applications and Design*", Edward Arnold.

A-6: Cooling load factor due to occupants (CLF), for sensible gain

Table (A-6-2) Cooling load factor due to occupants $(CLF)_{occ.}$, for sensible heat gain.[5]

Hours after each entry into space	Total hours in space							
	2	4	6	8	10	12	14	16
1	0.49	0.49	0.50	0.51	0.53	0.55	0.58	0.62
2	0.58	0.59	0.60	0.61	0.62	0.64	0.66	0.70
3	0.17	0.66	0.67	0.67	0.69	0.70	0.72	0.75
4	0.13	0.71	0.72	0.72	0.74	0.75	0.77	0.79
5	0.10	0.27	0.76	0.76	0.77	0.79	0.80	0.82
6	0.08	0.21	0.79	0.80	0.80	0.81	0.83	0.85
7	0.07	0.16	0.34	0.82	0.83	0.84	0.85	0.87
8	0.06	0.14	0.26	0.84	0.85	0.86	0.87	0.88
9	0.05	0.11	0.21	0.38	0.87	0.88	0.89	0.90
10	0.04	0.10	0.18	0.30	0.89	0.89	0.9	0.91
11	0.04	0.08	0.15	0.25	0.42	0.91	0.91	0.92
12	0.03	0.07	0.13	0.21	0.34	0.92	0.92	0.93
13	0.03	0.06	0.11	0.18	0.28	0.45	0.93	0.94
14	0.02	0.06	0.10	0.15	0.23	0.36	0.94	0.95
15	0.02	0.05	0.08	0.13	0.20	0.30	0.47	0.95
16	0.02	0.04	0.07	0.12	0.17	0.25	0.38	0.96
17	0.02	0.04	0.06	0.10	0.15	0.21	0.31	0.49
18	0.01	0.03	0.06	0.09	0.13	0.19	0.26	0.39

A-7: Cooling load temperature differences (CLTD) for convection heat gain for glass windows

Table (A-7) Cooling load temperature differences (CLTD) for convection heat gain for glass windows.

Solar Time	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
CLTD °C	1	0	–1	–1	–1	–1	–1	0	1	2	4	5	7	7	8	8	7	7	6	4	3	2	2	1

A-8: Cooling load factor (CLF) for glass windows without interior shading

Table (A-5-1) Cooling load factors (CLF) for glass windows without interior shading, north latitudes.

Glass Facing	Building Construction	Solar Time, h																
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
N Shaded	L	0.17	0.14	0.11	0.09	0.08	0.33	0.24	0.48	0.56	0.61	0.71	0.76	0.80	0.82	0.82	0.79	0.75
	M	0.23	0.20	0.18	0.16	0.14	0.34	0.14	0.46	0.53	0.59	0.65	0.70	0.73	0.75	0.76	0.74	0.75
	H	0.25	0.23	0.21	0.20	0.19	0.38	0.45	0.49	0.55	0.60	0.65	0.69	0.72	0.72	0.72	0.70	0.70
NNE	L	0.06	0.05	0.04	0.03	0.03	0.26	0.43	0.47	0.44	0.41	0.40	0.39	0.39	0.38	0.36	0.33	0.30
	M	0.09	0.08	0.07	0.06	0.06	0.24	0.38	0.42	0.39	0.37	0.37	0.36	0.36	0.36	0.34	0.33	0.30
	H	0.11	0.10	0.09	0.09	0.08	0.26	0.39	0.42	0.39	0.36	0.35	0.34	0.34	0.33	0.32	0.31	0.28
NE	L	0.04	0.04	0.03	0.02	0.02	0.23	0.41	0.51	0.51	0.45	0.39	0.36	0.33	0.31	0.28	0.26	0.23
	M	0.07	0.06	0.06	0.05	0.04	0.21	0.36	0.44	0.45	0.40	0.36	0.33	0.31	0.30	0.28	0.26	0.24
	H	0.09	0.08	0.08	0.07	0.07	0.23	0.37	0.44	0.44	0.39	0.34	0.31	0.29	0.27	0.26	0.24	0.22
ENE	L	0.04	0.03	0.03	0.02	0.02	0.21	0.40	0.52	0.57	0.53	0.45	0.39	0.34	0.31	0.28	0.25	0.22
	M	0.07	0.06	0.05	0.05	0.04	0.20	0.35	0.45	0.49	0.47	0.41	0.36	0.33	0.30	0.28	0.26	0.23
	H	0.09	0.09	0.08	0.07	0.07	0.22	0.36	0.46	0.49	0.45	0.38	0.31	0.30	0.27	0.25	0.23	0.21
E	L	0.04	0.03	0.03	0.02	0.02	0.19	0.37	0.51	0.57	0.57	0.50	0.42	0.37	0.32	0.29	0.25	0.22
	M	0.07	0.06	0.06	0.05	0.05	0.18	0.33	0.44	0.50	0.51	0.46	0.39	0.35	0.31	0.29	0.26	0.23
	H	0.09	0.09	0.08	0.08	0.07	0.20	0.34	0.45	0.49	0.49	0.43	0.39	0.32	0.29	0.26	0.24	0.22
ESE	L	0.05	0.04	0.03	0.03	0.02	0.17	0.34	0.49	0.58	0.61	0.57	0.48	0.41	0.36	0.32	0.28	0.24
	M	0.08	0.07	0.06	0.05	0.05	0.16	0.31	0.43	0.51	0.54	0.51	0.44	0.39	0.35	0.32	0.29	0.26
	H	0.10	0.09	0.09	0.08	0.08	0.19	0.32	0.43	0.50	0.52	0.49	0.41	0.36	0.32	0.29	0.26	0.24
SE	L	0.05	0.04	0.04	0.03	0.03	0.13	0.28	0.43	0.55	0.62	0.63	0.57	0.48	0.42	0.37	0.33	0.28
	M	0.09	0.08	0.07	0.06	0.05	0.14	0.26	0.38	0.48	0.54	0.56	0.51	0.45	0.40	0.36	0.33	0.29
	H	0.11	0.10	0.10	0.09	0.08	0.17	0.28	0.40	0.49	0.53	0.53	0.48	0.41	0.36	0.33	0.30	0.27
SSE	L	0.07	0.05	0.04	0.04	0.03	0.06	0.15	0.29	0.43	0.55	0.63	0.64	0.60	0.25	0.45	0.40	0.35
	M	0.11	0.09	0.08	0.07	0.06	0.08	0.16	0.26	0.38	0.58	0.55	0.57	0.54	0.48	0.43	0.39	0.35
	H	0.12	0.11	0.11	0.10	0.09	0.12	0.19	0.29	0.40	0.49	0.54	0.55	0.51	0.44	0.39	0.35	0.31
S	L	0.08	0.07	0.05	0.04	0.04	0.06	0.09	0.14	0.22	0.34	0.48	0.59	0.65	0.65	0.59	0.50	0.43
	M	0.12	0.11	0.09	0.08	0.07	0.08	0.11	0.14	0.21	0.31	0.42	0.52	0.57	0.58	0.53	0.47	0.41
	H	0.13	0.12	0.12	0.11	0.10	0.11	0.14	0.17	0.24	0.33	0.43	0.51	0.56	0.55	0.50	0.43	0.37
SSW	L	0.10	0.08	0.07	0.06	0.05	0.06	0.09	0.11	0.15	0.19	0.27	0.39	0.52	0.62	0.67	0.65	0.58
	M	0.14	0.12	0.11	0.09	0.08	0.09	0.11	0.13	0.15	0.18	0.25	0.35	0.46	0.55	0.59	0.59	0.53
	H	0.15	0.14	0.13	0.12	0.11	0.12	0.14	0.16	0.18	0.21	0.27	0.37	0.46	0.53	0.57	0.55	0.49
SW	L	0.12	0.10	0.08	0.06	0.05	0.06	0.08	0.10	0.12	0.14	0.16	0.24	0.36	0.49	0.60	0.66	0.66
	M	0.15	0.14	0.12	0.10	0.09	0.09	0.10	0.12	0.13	0.15	0.17	0.23	0.33	0.44	0.53	0.58	0.59
	H	0.15	0.14	0.13	0.12	0.11	0.12	0.13	0.14	0.16	0.17	0.19	0.25	0.34	0.44	0.52	0.56	0.56
WSW	L	0.12	0.10	0.08	0.07	0.05	0.06	0.07	0.09	0.10	0.12	0.13	0.17	0.26	0.40	0.52	0.62	0.66
	M	0.15	0.13	0.12	0.10	0.09	0.09	0.10	0.11	0.12	0.13	0.14	0.17	0.24	0.35	0.46	0.54	0.58
	H	0.15	0.14	0.13	0.12	0.11	0.11	0.12	0.13	0.14	0.15	0.16	0.19	0.26	0.36	0.46	0.53	0.56
	L	0.12	0.10	0.08	0.06	0.05	0.06	0.07	0.08	0.10	0.11	0.12	0.14	0.20	0.32	0.45	0.57	0.64

A-9: Cooling load factors for glass windows with interior shading

Table (A-5-2) Cooling Load factors (CLF) for glass windows with interior shading, North latitude.

Fenestration Facing	Solar Time, h																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
N	0.08	0.07	0.06	0.06	0.07	0.73	0.66	0.65	0.73	0.80	0.86	0.89	0.89	0.86	0.82	0.75	0.78
NNE	0.03	0.03	0.02	0.02	0.03	0.64	0.77	0.62	0.42	0.37	0.37	0.37	0.36	0.35	0.32	0.28	0.23
NE	0.03	0.02	0.02	0.02	0.02	0.56	0.76	0.74	0.58	0.37	0.29	0.27	0.26	0.24	0.22	0.20	0.16
ENE	0.03	0.02	0.02	0.02	0.02	0.52	0.76	0.80	0.71	0.52	0.31	0.26	0.24	0.22	0.20	0.18	0.15
E	0.03	0.02	0.02	0.02	0.02	0.47	0.72	0.80	0.76	0.62	0.41	0.27	0.24	0.22	0.20	0.17	0.14
ESE	0.03	0.03	0.02	0.02	0.02	0.41	0.67	0.79	0.80	0.72	0.54	0.34	0.27	0.24	0.21	0.19	0.15
SE	0.03	0.03	0.02	0.02	0.02	0.30	0.57	0.74	0.81	0.79	0.68	0.49	0.33	0.28	0.25	0.22	0.18
SSE	0.04	0.03	0.03	0.03	0.02	0.12	0.31	0.54	0.72	0.81	0.81	0.71	0.54	0.38	0.32	0.27	0.22
S	0.04	0.04	0.03	0.03	0.03	0.09	0.16	0.23	0.38	0.58	0.75	0.83	0.80	0.68	0.50	0.35	0.27
SSW	0.05	0.04	0.04	0.03	0.03	0.09	0.14	0.18	0.22	0.27	0.43	0.63	0.78	0.84	0.80	0.66	0.46
SW	0.05	0.05	0.04	0.04	0.03	0.07	0.11	0.14	0.16	0.19	0.22	0.38	0.59	0.75	0.83	0.81	0.69
WSW	0.05	0.05	0.04	0.04	0.03	0.07	0.10	0.12	0.14	0.16	0.17	0.23	0.44	0.64	0.78	0.84	0.78
W	0.05	0.05	0.04	0.04	0.03	0.06	0.09	0.11	0.13	0.15	0.16	0.17	0.31	0.53	0.72	0.82	0.81
WNW	0.05	0.05	0.04	0.03	0.03	0.07	0.10	0.12	0.14	0.16	0.17	0.18	0.22	0.43	0.65	0.80	0.84
NW	0.05	0.04	0.04	0.03	0.03	0.07	0.11	0.14	0.17	0.19	0.20	0.21	0.22	0.30	0.52	0.73	0.82
NNW	0.05	0.05	0.04	0.03	0.03	0.11	0.17	0.22	0.26	0.30	0.32	0.33	0.34	0.34	0.39	0.61	0.82
HORIZ.	0.06	0.05	0.04	0.04	0.03	0.12	0.27	0.44	0.59	0.72	0.81	0.85	0.85	0.81	0.71	0.58	0.42

A-10: Shading coefficient for glass with interior shading

Table (A-4-2) Shading coefficient (SC) for glass windows with interior shading.

		Type of Interior Shading				
	Nominal Thickness, mm	Venetian Blinds		Roller Shade		
				Opaque		Translucent
Type of Glass		Medium	Light	Dark	White	Light
Single Glass						
Clear, regular	2.5-6.0	—	—	—	—	—
Clear, plate	6.0-12.0	—	—	—	—	—
Clear Pattern	3.0-12.0	0.64	0.55	0.59	0.25	0.39
Heat Absorbing	3	—	—	—	—	—
Pattern or Tinted(gray sheet)	5.0-5.5	—	—	—	—	—
Heat Absorbing, plate	5.0-6.0	0.57	0.53	0.45	0.30	0.36
Pattern or Tinted, gray sheet	3.0-5.5	—	—	—	—	—
Heat Absorbing Plate or Pattern Heat Absorbing	10	0.54	0.52	0.40	0.82	0.32
Heat Absorbing or Pattern	—	0.42	0.40	0.36	0.28	0.31
Reflective Coated Glass	—	0.30	0.25	0.23	—	—
	—	0.40	0.33	0.29	—	—
	—	0.50	0.42	0.38	—	—
	—	0.60	0.50	0.44	—	—
Double Glass						
Regular	3	0.57	0.51	0.60	0.25	—
Plate	6	0.57	0.51	0.60	0.25	—
Reflective	6	0.20-0.40	—	—	—	—
Insulating Glass						
Clear	2.5-6.0	0.57	0.51	0.60	0.25	0.37
Heat Absorbing	5.0-6.0	0.39	0.36	0.40	0.22	0.30
Reflective Coated	—	0.20	0.19	0.18	—	—
	—	0.30	0.27	0.26	—	—
	—	0.40	0.34	0.33	—	—

A-11: Shading coefficient for glass windows without interior shading

Table (A-4-1) Shading coefficient (SC) for glass windows without interior shading.[1]

Type of Glass	Nominal Thickness, mm	Solar Trans.	Shading Coefficient, W/m²·K $h_o = 22.7$	Shading Coefficient, W/m²·K $h_o = 17.0$
Single Glass				
Clear	3	0.84	1.00	1.00
	6	0.78	0.94	0.95
	10	0.72	0.90	0.92
	12	0.67	0.87	0.88
Heat absorbing	3	0.64	0.83	0.85
	6	0.46	0.69	0.73
	10	0.33	0.60	0.64
	12	0.42	0.53	0.58
Double Glass				
Regular	3	—	0.90	—
Plate	6	—	0.83	—
Reflective	6	—	0.20-0.40	—
Insulating Glass				
Clear	3	0.71	0.88	0.88
	6	0.61	0.81	0.82
Heat absorbing*	6	0.36	0.55	0.58

A-12: Solar heat gain factor for sunlit glass

Table (A-3) Solar heat gain factor (SHG) for sunlit glass, W/m², for a latitude angle of 32 °N.

Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
N	76	85	101	114	120	139	126	117	104	88	76	69
NNE/NNW	76	85	117	252	350	385	350	249	110	88	76	69
NE/NW	91	205	338	461	536	555	527	445	325	199	91	69
ENE/WNW	331	470	577	631	656	656	643	615	546	451	325	265
E/W	552	647	716	716	694	675	678	691	678	615	546	511
ESE/WSW	722	764	748	691	628	596	612	663	716	738	710	688
SE/SW	786	782	716	590	489	439	473	571	688	754	773	776
SSE/SSW	789	732	615	445	213	262	303	429	596	710	776	795
S	776	697	555	363	233	189	227	350	540	678	767	795
Horizontal	555	685	795	855	874	871	861	836	770	672	552	498

A-13: Values of infiltration air coefficient for windows

TABLE 6–2 Values of infiltration air coefficient K.[2] for windows.

Window Type	Infiltration Air Coefficient K		
	Average	Minimum	Maximum
Sliding			
Iron	0.36	0.25	0.40
Aluminum	0.43	0.25	0.70
Hung			
Iron	0.25	0.10	0.60
Aluminum (side pivoted)	0.36	0.07	0.70
Aluminum (horizontal pivoted)	0.30	0.07	0.50
PVC	0.10	0.03	0.15

A-14: Values of the factor S1

TABLE 6–3 Values of the factor S_1 of Eq. (6–7).

№	Topography of Location	Value of S_1
1	Protected locations by hills or buildings (wind speed = 0.5 m/s)	0.9
2	Unprotected locations such as sea shores, hill tops, etc.	1.1
3	Locations other than that listed in item (1) or (2) of this table.	1.0

A-15: Values of the factor S2

TABLE 6–4 Values of the factor S_2 of Eq. (6–7).

Location Class	Class 1			Class 2			Class 3			Class 4		
Building Height, m	A	B	C	A	B	C	A	B	C	A	B	C
3	0.47	0.52	0.56	0.55	0.60	0.64	0.63	0.67	0.72	0.73	0.78	0.83
5	0.50	0.55	0.60	0.60	0.65	0.70	0.70	0.74	0.79	0.78	0.83	0.88
10	0.58	0.62	0.67	0.69	0.74	0.78	0.83	0.88	0.93	0.90	0.95	1.00
15	0.64	0.69	0.74	0.78	0.83	0.88	0.91	0.95	1.00	0.94	0.99	1.03
20	0.70	0.75	0.79	0.85	0.90	0.95	0.94	0.98	1.03	0.96	1.01	1.06
30	0.79	0.85	0.90	0.92	0.97	1.01	0.98	1.03	1.07	1.00	1.05	1.09
40	0.89	0.93	0.97	0.95	1.00	1.05	1.01	1.06	1.10	1.03	1.08	1.12
50	0.94	0.98	1.02	1.00	1.04	1.08	1.04	1.08	1.12	1.06	1.10	1.14
60	0.98	1.02	1.05	1.02	1.06	1.10	1.06	1.10	1.14	1.08	1.12	1.15
80	1.03	1.07	1.10	1.06	1.10	1.13	1.09	1.13	1.17	1.11	1.15	1.18
100	1.07	1.10	1.13	1.09	1.12	1.16	1.12	1.16	1.19	1.13	1.17	1.20
120	1.10	1.13	1.15	1.11	1.15	1.18	1.14	1.18	1.21	1.15	1.19	1.22
140	1.12	1.15	1.17	1.13	1.17	1.12	1.16	1.19	1.22	1.17	1.20	1.24
160	1.14	1.17	1.19	1.15	1.18	1.21	1.18	1.21	1.24	1.19	1.22	1.25
180	1.16	1.19	1.20	1.17	1.20	1.23	1.19	1.22	1.25	1.20	1.23	1.26
200	1.18	1.21	1.22	1.18	1.21	1.24	1.21	1.24	1.26	1.21	1.24	1.27

A-16: Instantaneous heat gain from occupants

TABLE 4–2 Instantaneous heat gain from occupants in units of Watts[(a)].

Type of Activity	Typical Application	Total Heat Dissipation Adult Male	Total Adjusted[(a)] Heat Dissipation	Sensible Heat, W	Latent Heat, W
Seated at rest	*Theater*:				
	Matinee	111.5	94.0	64.0	30.0
	Evening	111.5	100.0	70.0	30.0
Seated, very light work	Offices, hotels, apartments, restaurants	128.5	114.0	70.0	44.0
Moderately active office work	Offices, hotels, apartments	135.5	128.5	71.5	57.0
Standing, light work, walking	Department store, retail store, supermarkets	157.0	143.0	71.5	71.5
Walking, seated	Drug store	157.0	143.0	71.5	71.5
Standing, walking slowly	Bank	157.0	143.0	71.5	71.5
Sedentary work	Restaurant	168.5	157.0	78.5	78.5
Light bench work	Factory	238.0	214.0	78.0	136.0
Moderate work	Small-Parts assembly	257.0	243.0	87.0	156.0
Moderate dancing	Dance halls	257.0	243.0	87.0	156.0
Walking at 1.5 m/s	Factory	286.0	285.0	107.0	178.0
Bowling (participant)	Bowling alley	428.5	414.0	166.0	248.0
Heavy work	Factory	428.5	414.0	166.0	248.0

(a) Adjusted heat dissipation is based on the percentage of men, women and children for the application.

A-17: Latitude- month correction factor LM

Table (A-2) Latitude-Month correction factor LM, as applied to walls and horizontal roofs, north latitudes.

Lat.	Month	N	NNE NNW	NE NW	ENE WNW	E W	ESE WSW	SE SW	SSE SSW	S	Horizontal Roofs
16	December	−2.2	−3.3	−4.4	−4.4	−2.2	−0.5	2.2	5.0	7.2	−5.0
	Jan./Nov.	−2.2	−3.3	−3.8	−3.8	−2.2	−0.5	2.2	4.4	6.6	−3.8
	Feb./Oct.	−1.6	−2.7	−2.7	−2.2	−1.1	0.0	1.1	2.7	3.8	−2.2
	Mar/Sept.	−1.6	−1.6	−1.1	−1.1	−0.5	−0.5	0.0	0.0	0.0	−0.5
	Apr./Aug.	−0.5	0.0	−0.5	−0.5	−0.5	−1.6	−1.6	−2.7	−3.3	0.0
	May/July	2.2	1.6	1.6	0.0	−0.5	−2.2	−2.7	−3.8	−3.8	0.0
	June	3.3	2.2	2.2	0.5	−0.5	−2.2	−3.3	−4.4	−3.8	0.0
24	December	−2.7	−3.8	−5.5	−6.1	−4.4	−2.7	1.1	5.0	6.6	−9.4
	Jan./Nov.	−2.2	−3.3	−4.4	−5.0	−3.3	−1.6	−1.6	5.0	7.2	−6.1
	Feb./Oct.	−2.2	−2.7	−3.3	−3.3	−1.6	−0.5	1.6	3.8	5.5	−3.8
	Mar/Sept.	−1.6	−2.2	−1.6	−1.6	−0.5	−0.5	0.5	1.1	2.2	−1.6
	Apr./Aug.	−1.1	−0.5	0.0	−0.5	−0.5	−1.1	−0.5	−1.1	−1.6	0.0
	May/July	0.5	1.1	1.1	0.0	0.0	−1.6	−1.6	−2.7	−3.3	0.5
	June.	1.6	1.6	1.6	0.5	0.0	−1.6	−2.2	−3.3	−3.3	0.5
32	December	−2.7	−3.8	−5.5	−6.1	−4.4	−2.7	1.1	5.0	6.6	−9.4
	Jan./Nov.	−2.7	−3.8	−5.0	−6.1	−4.4	−2.2	1.1	5.0	6.6	−8.3
	Feb./Oct.	−2.2	−3.3	−3.8	−4.4	−2.2	−1.1	2.2	4.4	6.1	−5.5
	Mar/Sept.	−1.6	−2.2	−2.2	−2.2	−1.1	−0.5	1.6	2.7	3.8	−2.7
	Apr./Aug.	−1.1	−1.1	−0.5	−1.1	0.0	−0.5	0.0	5.0	0.5	−0.5
	May/July	0.5	0.5	0.5	0.0	0.0	−0.5	−0.5	−1.6	−1.6	0.5
	June	0.5	1.1	1.1	0.5	0.0	−1.1	−1.1	−2.2	−2.2	1.1
40	December	−3.3	−4.4	−5.5	−7.2	−5.5	−3.8	0.0	3.8	5.5	−11.6
	Jan./Nov.	−2.7	−3.8	−5.5	−6.6	−5.0	−3.3	0.5	4.4	6.1	−10.5
	Feb./Oct.	−2.7	−3.8	−4.4	−5.0	−3.3	−1.6	1.6	4.4	6.6	−7.7
	Mar/Sept.	−2.2	−2.7	−2.7	−3.3	−1.6	0.5	2.2	3.8	5.5	−4.4
	Apr./Aug.	−1.1	−1.6	−1.6	−1.1	0.0	0.0	1.1	1.6	2.2	1.6
	May/July	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5
	June	0.5	0.5	0.5	0.5	0.0	0.5	0.0	0.0	−0.5	1.1
48	December	−3.3	−4.4	−6.1	−7.7	−7.2	−5.5	−1.6	1.1	3.3	−13.8
	Jan./Nov.	−3.3	−4.4	−6.1	−7.2	−6.1	−4.4	−0.5	2.7	4.4	−13.3
	Feb./Oct.	−2.7	−3.8	−5.5	−6.1	−4.4	−2.7	0.5	4.4	6.1	−10.0
	Mar/Sept.	−2.2	−3.3	−3.3	−3.8	−2.2	−0.5	2.2	4.4	6.1	−6.1
	Apr./Aug.	−1.6	−1.6	−1.6	−1.6	−0.5	0.0	2.2	3.3	3.8	−2.7
	May/July	0.0	−0.5	0.0	0.0	0.5	0.5	1.6	1.6	2.2	0.0
	June	0.5	0.5	1.1	0.5	1.1	0.5	1.1	1.1	1.6	1.1

A-18: Minimum outside air requirements for mechanical ventilation

Application	Maximum Occupancy Per 100 m^2	Ventilation Air Requirements	
		L/s/Person	L/s/m^2
Bath, toilets(3)	—	10.0	—
Hotels and motels:			
Bedrooms	—	—	7.5-15 L/s/room
Living rooms	—	—	5-10 L/s/room
Bathes	—	—	15-25 L/s/room
Lobbies	30	2.5-7.5	—
Conference rooms	50	3.5-17.5	—
Assembly rooms	120	3.5-17.5	—
Dormitory sleeping areas	20	8.0	—
Gambling casinos	120	15.0	—

A-19: inside & outside film resistance

Table A(2.2) Inside film resistance, R_i.

Element	Heat Direction	Material Type	R_i $m^2 \cdot °C/W$
Walls	Horizontal	Construction materials	0.12
		Metals	0.31
Ceilings and floors	Upward	Construction materials	0.10
		Metals	0.21
	Downward	Construction materials	0.15

Table A(2.3) Outside film resistance, R_o.

Wind Speed		Less than 0.5 m/s	0.5 - 5.0 m/s	More than 5.0 m/s
Element	Material Type	Outside Resistance R_o, $m^2 \cdot °C/W$		
Walls	Construction materials	0.08	0.06	0.03
	Metals	0.10	0.07	0.03
Ceilings	Construction materials	0.07	0.04	0.02
	Metals	0.09	0.05	0.02
Exposed floors	Construction materials	0.09	—	—

A-20: Overall heat coefficient for windows

TABLE A(2.4) Overall Heat Transfer Coefficient for Windows, W/m²·°C

Material Type and Frames	Wind Speed, m/s					
	Single Glass			Double Glass, 6mm air gap		
	< 0.5	0.5 - 5.0	> 5.0	< 0.5	0.5 - 5.0	> 5.0
Wood	3.8	4.3	5.0	2.3	2.5	2.7
Aluminum	5.0	5.6	6.7	3.0	3.2	3.5
Steel	5.0	5.6	6.7	3.0	3.2	3.5
PVC	3.8	4.3	5.0	2.3	2.5	2.7

A-21: Overall heat coefficient for wood and metals door

TABLE A(2.5) Overall heat transfer coefficients for wood and metal doors, W/m²·°C.

Door Type	Without Storm Door	With Wood Storm Door	With Metal Storm Door
25 mm-wood	3.6	1.7	2.2
35 mm-wood	3.1	1.6	1.9
40 mm-wood	2.8	1.5	1.8
45 mm-wood	2.7	1.5	1.8
50 mm-wood	2.4	1.4	1.7
Aluminum	7.0	—	—
Steel	5.8	—	—
Steel with:			
Fiber core	3.3	—	—
Polystyrene core	2.7	—	—
Polyurethane core	2.3	—	—

A-22 Palestinian code

جدول رقم (3/ 1): القيم التصميمية الخارجية للمناطق المناخية المختلفة

القيم التصميمية الخارجية		المنطقة المناخية*						
		الضفة الغربية					قطاع غزة	
		الأولى	الثانية	الثالثة	الرابعة	الخامسة	الثالثة	السادسة
درجة الحرارة (˚C)	شتاءً	7	7	5	4	8	5	9
	صيفاً	39	39	32	30	34	32	31
الرطوبة النسبية (%)	شتاءً: ادنى	60	60	60	62	63	60	62
	اقصى	70	70	72	72	78	72	69
	صيفاً: ادنى	43	43	49	44	55	49	65
	اقصى	54	54	67	57	66	67	77
سرعة الرياح (m/s)		1	1	1.5	1.4	1.1	1.5	2.8
شدة الاشعاع الشمسي (W/m^2)		تعتبر قيم شدة الاشعاع القصوى للاتجاهات المختلفة في الجدولين (3/ 18) و (3/ 19) قيماً تصميمية لكافة المناطق المناخية						
درجة يوم تسخين (˚C.day)		لا تتوفر معلومات عن هذه القيم حالياً						
درجة يوم تبريد (˚C.day)								
* المناطق المناخية للأراضي الفلسطينية مبينة في الملحق (هـ)								

جدول رقم (1/ 10) معدل سرعة الرياح للمحطات المناخية في الضفة الغربية.

المحطة	1	2	3	4	5	6	7	8	9	10	11	12
القدس	16.3	18.0	18.4	18.5	18.0	19.4	20.4	18.6	17.0	13.0	14.1	16.0
نابلس	8.7	9.5	10.0	10.2	10.7	12.0	12.4	11.7	10.3	7.7	7.8	7.7
جنين	7.5	7.9	7.9	7.9	9.0	9.4	9.7	8.6	7.2	5.4	6.1	7.5
طولكرم	4.3	4.1	3.8	3.4	3.3	2.9	2.9	2.7	2.6	2.9	3.8	4.0
أريحا	8.9	10.4	13.1	16.2	15.8	15.3	16.0	14.8	12.5	9.4	7.9	7.6
الخليل	12.4	12.8	12.6	11.5	9.3	9.3	9.2	8.7	8.1	8.0	8.8	10.1
العروب	8.6	10.1	10.8	9.7	6.5	5.1	5.1	5.4	5.1	5.8	5.8	7.9
الفارعة	4.6	6.5	6.1	3.6	3.3	3.6	6.8	6.5	5.0	2.5	2.5	2.1

Appendix (B)

B-1: Water supply fixture unit

TableA(4.1)Water Supply Fixture Units and Fixture Branch Sizes

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

Water supply outlets not listed above shall be computed at their maximum demand, but in no case less than the following values:

	Number of Fixture Units	
Fixture Branch[d]	Private Use	General Use
3/8	1	2
1/2	2	4
3/4	3	6
1	6	10

[a] For supply outlets likely to impose continuous demands, estimate continuous supply separately and add to total demand for fixtures.

[b] The given weights are for total demand. For fixtures with both hot and cold water supplies, the weights for maximum separate demands may be taken as three-quarters the listed demand for the supply.

[c] A bathroom group for the purposes of this table consists of not more than one water closet, one lavatory, one bathtub, one shower stall or one water closet, two lavatories, one bathtub or one separate shower stall.

[d] Nominal I.D. pipe size.

[e] Some may require larger sizes—see manufacturer's instructions.

[f] Data extracted from Code Table B.5.2.

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B-2: Chart of friction head loss in schedule 40

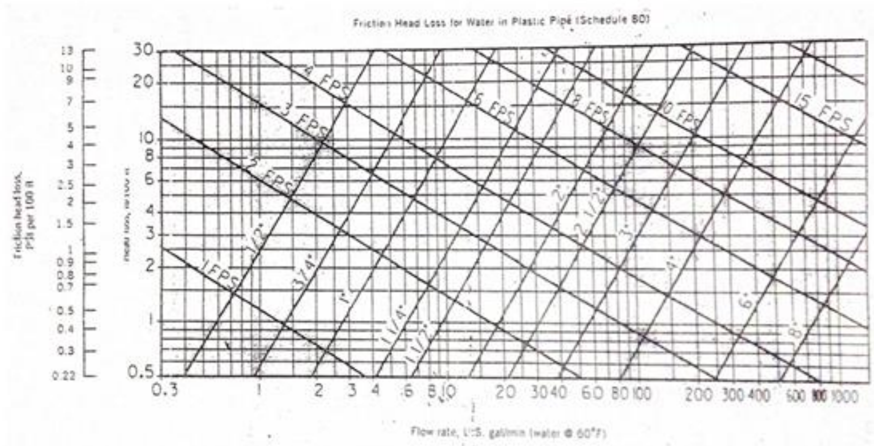

Figure A(4.1) Chart of riction head loss in Schedule 80 plastic pipe for water at 60°F, in feet of water and si per 100 ft of equivalent pipe length. Pipe sizes are nominal. (Reprinted by perm ssion of the American Society of Heating, Refrigerating and Air-Conditioning Engin ers, Atlanta, Georgia, from the 1993 *ASHRAE Handbook—Fundamentals*.)

B-3: Minimum pressure required by Typical plumping Fixture

Table A(4.3) Minimum Pressure Required by Typical Plumbing Fixtures

Fixture Type	*Minimum Pressure, psi*
Sink and tub faucets	8
Shower	8
Water closet—tank flush	8
Flush valve—urinal	15
Flush valve—siphon jet bowl	
floor-mounted	15
wall-mounted	20
Flush valve—blowout bowl	
floor-mounted	20
wall-mounted	25
Garden hose	
5/8-in. sill cock	15
3/4-in. sill cock	30
Drinking fountain	15

Source. EPA Manual of Individual Water Supply System, 1975 and manufacturers' data.

B-4: Chart of friction head loss in schedule 40

TableA(4.7) Approximate Discharge Rates and Velocities* in Sloping Drains Flowing Half Full†

Actual Inside Diameter of Pipe, in.	1/16 in./ft Slope		1/8 in./ft Slope 1%		1/4 in./ft Slope 2%		1/2 in./ft Slope	
	Discharge, gpm	Velocity, fps	Discharge, gpm	Velocity, fps	Discharge, gpm	Velocity, fps	Discharge, gpm	Velocity, fps
1¼							3.40	1.78
1⅜					3.13	1.34	4.44	1.90
1½					3.91	1.42	5.53	2.01
1⅝					4.81	1.50	6.80	2.12
2					8.42	1.72	11.9	2.43
2½			10.8	1.41	15.3	1.99	21.6	2.82
3			17.6	1.59	24.8	2.25	3[illegible].1	3.19
4	26.70	1.36	37.8	1.93	53.4	2.73	75.5	3.86
5	48.3	1.58	68.3	2.23	96.6	3.16	137.	4.47
6	78.5	1.78	111.	2.52	157.	3.57	222.	5.04
8	170.	2.17	240.	3.07	340.	4.34	480.	6.13
10	308.	2.52	436.	3.56	616.	5.04	872.	7.12
12	500.	2.83	707.	4.01	999.	5.67	1413	8.02

*Computed from the Manning Formula for ½-full pipe, $n = 0.015$.

†Half full means filled to a depth equal to one-half the inside diameter.

Note: For ¼ full, multiply discharge by 0.274 and multiply velocity by 0.701. For ⅓ full, multiply discharge by 0.44 and multiply velocity by 0.80. For ¾ full, multiply discharge by 1.82 and multiply velocity by 1.13. For full, multiply discharge by 2.00 and multiply velocity by 1.00. For smoother pipe, multiply discharge and velocity by 0.015 and divide by n value of smoother pipe.

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B-5: table of estimating demand

Table A(4.2) Table for Estimating Demand

Supply Systems Predominantly for Flush Tanks		*Supply Systems Predominantly for Flushometers*	
Load, WSFU[a]	*Demand, gpm*	*Load, WSFU*[a]	*Demand, gpm*
6	5	—	—
10	8	10	27
15	11	15	31
20	14	20	35
25	17	25	38
30	20	30	41
40	25	40	47
50	29	50	51
60	33	60	55
80	39	80	62
100	44	100	68
120	49	120	74
140	53	140	78
160	57	160	83
180	61	180	87
200	65	200	91
225	70	225	95
250	75	250	100
300	85	300	110
400	105	400	125
500	125	500	140
750	170	750	175
1000	210	1000	218
1250	240	1250	240
1500	270	1500	270
1750	300	1750	300
2000	325	2000	325
2500	380	2500	380
3000	[illegible]	3000	435
4000	525	4000	525
5000	600	5000	600
6000	650	6000	650
7000	700	7000	700
8000	730	8000	730
9000	760	9000	760
10,000	790	10,000	790

[a] Water Supply Fixture Units

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...l Standard Plumbing Code, published by The Na-

B-6: drainage fixture unit valves for various plumbing fixture

TableA(4.4)Drainage Fixture Unit Values for Various Plumbing Fixtures

Type of Fixture or Group of Fixtures	*Drainage Fixture Unit Value, dfu*
Automatic clothes washer (2-in. standpipe and trap required, direct connection)	3
Bathtub group consisting of a water closet; lavatory and bathtub or shower stall:	6
Bathtub (with or without overhead shower)*	2
Bidet	1
Clinic sink	6
Clothes washer	2
Combination sink-and-tray with food waste grinder	4
Combination sink-and-tray with one 1-in. trap	2
Combination sink-and-tray with separate 1-in. trap	3
Dental unit or cuspidor	1
Dental lavatory	1
Drinking fountain	½
Dishwasher, domestic	2
Floor drains with 2-in. waste	3
Kitchen sink, domestic, with one 1-in. trap	2
Kitchen sink, domestic, with food waste grinder	2
Kitchen sink, domestic, with food waste grinder and dishwasher 1-in. trap	3
Kitchen sink, domestic, with dishwasher 1-in trap	3
Lavatory with 1-in. waste	1
Laundry tray (1 or 2 compartments)	2
Shower stall, domestic	2
Showers (group) per head	2
Sinks	
surgeon's	3
flushing rim (with valve)	6
service (trap standard)	3
service (P trap)	2
pot, scullery, etc.	4
Urinal, syphon jet blowout	6
Urinal, wall lip	4
Wash sink (circular or multiple) each set of faucets	2
Water closet, private	4
Water closet, general use	6
Fixtures not already listed	
trap size 1¼ in. or less	1
trap size 1½ in.	2
trap size 2 in.	3
trap size 2½ in.	4
trap size 3 in.	5
trap size 4 in.	6

*A shower head over a bathtub does not increase the fixture unit value.

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B-7: Horizontal fixtures branches and stacks

Table A(4.5) Horizontal Fixture Branches and Stacks

Diameter of Pipe, in.	Any Horizontal Fixture Branch,[a] dfu	One Stack of Three Branch Intervals or Less, dfu	Stacks with More Than Three Branch Intervals: Total for Stack, dfu	Stacks with More Than Three Branch Intervals: Total at One Branch Interval, dfu
1½	3	4	8	2
2	6	10	24	6
2½	12	20	42	9
3	20[b]	48[b]	72[b]	20[b]
4	160	240	500	90
5	360	540	1100	200
6	620	960	1900	350
8	1400	2200	3600	600
10	2500	3800	5600	1000
12	3900	6000	8400	1500
15	7000			

[a] Does not include branches of the building drain.

[b] Not more than two water closets or bathroom groups within each branch interval nor more than six water closets or bathroom groups on the stack.

Note: Stacks shall be sized according to the total accumulated connected load at each story or branch interval and may be reduced in size as this load decreases to a minimum diameter of half of the largest size required.

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Table A(4.6) Building Drains and Sewers[a]

Diameter of Pipe, in.	Maximum Number of Fixture Units That May Be Connected to Any Portion of the Building Drain or the Building Sewer — Slope per Foot: 1/16 in.	1/8 in.	1/4 in.	1/2 in.
2			21	26
2½			24	31
3			42[b]	50[b]
4		180	216	250
5		390	480	575
6		700	840	1000
8	1400	1600	1920	2300
10	2500	2900	3500	4200
12	2900	4600	5600	6700
15	7000	8300	10,000	12,000

[a] On site sewers that serve more than one building may be sized according to the current standards and specifications of the Administrative [illegible]

[b] Not over two water closets or two bathroom groups, except that in single family dwellings, not over three water closets or three bathroom groups may be installed.

Source. Reprinted with permission from The National Standard Plumbing [illegible] Association of Plumbing Heating Cooling [illegible]

Appendix (C)

C-1: Human comfort

HUMAN COMFORT

Application	Maximum Occupancy Per 100 m²	Ventilation Air Requirements	
		L/s/Person	L/s/m²
Game rooms	70	3.5-17.5	—
Ice arenas	—	—	2.50
Swimming pools	—	—	2.50
Gymnasium floors	30	10.0	
Ballrooms and discos	100	3.5-17.5	—
Bowling alleys	70	3.5-17.5	
Theaters:			
Ticket booths	60	10.0	—
Lobbies	150	10.0	—
Auditorium	150	8.0	—
Stages, studios	70	8.0	—
Transportation:			
Waiting rooms	100	8.0	—
Platforms	100	8.0	—
Vehicles	150	8.0	—
Workrooms:			
Meat processing	10	8.0	—
Photo studios	10	8.0	—
Darkrooms	10	—	2.50
Pharmacy	20	8.0	—
Bank vaults	5	8.0	—
Printing, duplicating rooms	—	—	2.50
Correctional facilities:			
Cells	20	10.0	—

C-2: Human comfort

131 HUMAN COMFORT

Application	Maximum Occupancy Per 100 m²	Ventilation Air Requirements	
		L/s/Person	L/s/m²
Bath, toilets[3]	—	10.0	—
Hotels and motels:			
Bedrooms	—	—	7.5-15 L/s/room
Living rooms	—	—	5-10 L/s/room
Bathes	—	—	15-25 L/s/room
Lobbies	30	2.5-7.5	—
Conference rooms	50	3.5-17.5	—
Assembly rooms	120	3.5-17.5	—
Dormitory sleeping areas	20	8.0	—
Gambling casinos	120	15.0	—

[1] or 0.35 air change/hour [2] or 50 L/s intermittent or openable window.
[3] or 25 L/s intermittent or openable window.

Note: In some cases, exhaust air from one space is used as a supply air to another space

C-3: vrf in door unit Samsung

2-1. Indoor units

Type	Capacity (kW)												
	2.2	2.8	3.6	4.5	5.6	6.0	7.1	9.0	11.2	12.8	14.0	22.0	28.0
Slim 1 way cassette	●	●	●										
2 way cassette					●		●						
4 way cassette (S)				●	●		●	●	●	●	●		
4 way cassette (600 x 600)	●	●	●	●	●	●							
Slim duct	●	●	●	●	●		●	●	●	●	●		
MSP duct	●	●	●	●	●		●	●	●	●	●		
HSP duct									●	●	●	●	●
Console		●	●		●								
Ceiling					●		●						
Neo Forte	●	●	●		●		●						
Neo Forte (E)	●	●	●	●	●		●						
Floor Standing			●		●		●						

Heat pump Samsung

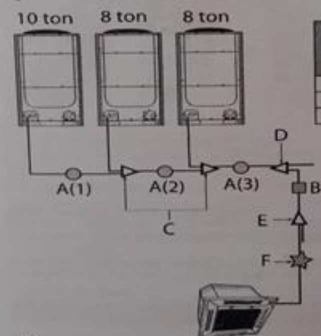
Heat Pump (Standard)

Model	AM080FXVA GH/EU	AM100FXVA GH/EU	AM120FXVA GH/EU	AM140FXVA GH/EU	AM160FXVA GH/EU	AM180FXVA GH/EU	AM200FXVA GH/EU	AM220FXVA GH/EU	AM240HXVA GH/EU	AM260HXVA GH/EU
AM080FXVAGH/EU	1									
AM100FXVAGH/EU		1								
AM120FXVAGH/EU			1							
AM140FXVAGH/EU				1						
AM160FXVAGH/EU					1					
AM180FXVAGH/EU						1				
AM200FXVAGH/EU							1			
AM220FXVAGH/EU								1		
AM240HXVAGH/EU									1	
AM260HXVAGH/EU										1
AM280HXVAGH1EU			1		1					
AM300HXVAGH1EU			1			1				
AM320HXVAGH1EU			1				1			
AM340HXVAGH1EU			1					1		
AM360HXVAGH1EU				1				1		
AM380HXVAGH1EU					1			1		
AM400HXVAGH1EU				1						1
AM420HXVAGH1EU							1	1		
AM440HXVAGH1EU								2		
AM460HXVAGH1EU			2					1		
AM480HXVAGH1EU			1	1				1		
AM500HXVAGH1EU			1		1			1		
AM520HXVAGH1EU			1			1		1		
AM540HXVAGH1EU			1				1	1		
AM560HXVAGH1EU			1					2		
AM580HXVAGH1EU				1				2		
AM600HXVAGH1EU					1			2		
AM620HXVAGH1EU						1		2		
AM640HXVAGH1EU							1	2		
AM660HXVAGH1EU								3		
AM680HXVAGH1EU			2					2		
AM700HXVAGH1EU			1	1				2		
AM720HXVAGH1EU			1		1			2		
AM740HXVAGH1EU			1			1		2		
AM760HXVAGH1EU			1				1	2		
AM780HXVAGH1EU			1					3		
AM800HXVAGH1EU				1				3		

C-5: Size of pipe A

The example in Figure 9 shows a 26-ton capacity heat pump system with pipe diameters specified.

Figure 9. Heat pump system example



Outdoor unit capacity (ton)	Pipe A	Pipe size (OD)	
		Liquid in. (mm)	Gas in. (mm)
10	A(1)	1/2 (12.70)	1-1/8 (28.58)
18	A(2)	5/8 (15.88)	1-1/8 (28.58)
26	A(3)	3/4 (19.05)	1-3/8 (34.92)

Key

A(1): Select based on individual outdoor unit capacity (Table 8, p. 21).
A(2): Select based on the sum of outdoor unit capacity behind the first outdoor unit multi-connection (Table 8, p. 21).
A(3): Select based on the sum of outdoor unit capacity before the first branch joint (Table 9, p. 21).
B: Pipes between branch joints (Table 9, p. 21)
C: Outdoor joints between outdoor units (Table 14, p. 24)
D: First branch joint (Table 15, p. 24))
E: Branch joints to indoor units (Table 16, p. 25))
F: Pipe size between branch joints and indoor units (Table 13, p. 24)

C-6: Size of pipe F

Table 10. Pipe size between the branch joint and indoor unit (F)

Indoor unit capacity (MBH)	Pipe size (OD)	
	Liquid in. (mm)	Gas in. (mm)
Less than 20	1/4 (6.35)	1/2 (12.70)
24-52	3/8 (9.52)	5/8 (15.88)
68-78	3/8 (9.52)	3/4 (19.05)
78-96	3/8 (9.52)	7/8 (22.22)

C-7: Size of pipe B

Table 16. Branch joints connected after the first branch, according to total indoor unit capacity (E)

Branch joints after the first branch (E)	Total indoor unit capacity (MBH)	Model
Y-joint	Less than 51	4YDK1509B0051A
	51—135.9	4YDK2512B0138A
	136—153.9	4YDK2812B0160A
	154—239.9	4YDK2815B0240A
	240—335.9	4YDK3419B0336A
	336—460.9	4YDK4119B0468A
	461 and over	4YDK4422B0999A
High-pressure gas Y-joint (for heat recovery models)	Less than 76	4YDK1500B0080A
	76—239.9	4YDK2500B0240A
	240—461	4YDK3100B0468A

C-8: Size of pipe B

Use Table 9 to determine the size of pipes between branch joints. (Refer to B in Figure 13, p. 32.)

Table 9. Pipe size between branch joints (B)

Indoor unit total capacity (MBH)	Branch pipe size (OD) when pipe is < 147.6 ft (45 m)		Branch pipe size (OD) when pipe is 147.6–295.3 ft (45–90 m)	
	Liquid in. (mm)	Gas in. (mm)	Liquid in. (mm)	Gas in. (mm)
Less than 51	3/8 (9.52)	5/8 (15.88)	1/2 (12.70)	3/4 (19.05)
51-75.9	3/8 (9.52)	3/4 (19.05)	1/2 (12.70)	7/8 (22.22)
76-95.9	3/8 (9.52)	7/8 (22.22)	1/2 (12.70)	1 (25.4)[a]
96-135.9	1/2 (12.70)	1-1/8 (28.58)	5/8 (15.88)	1-1/8 (28.58)
136-153.9	1/2 (12.70)	1-1/8 (28.58)	5/8 (15.88)	1-1/4 (31.75)[b]
154-239.9	5/8 (15.88)	1-1/8 (28.58)	3/4 (19.05)	1-1/4 (31.75)[b]
240-335.9	3/4 (19.05)	1-3/8 (34.92)	7/8 (22.22)	1-1/2 (38.1)[c]
336–460.9	3/4 (19.05)	1-5/8 (41.28)	7/8 (22.22)	1-5/8 (41.28)
461-577	3/4 (19.05)	1 5/8 (41.28)	7/8 (22.22)	2-1/8 (53.98)

(a) If 1 (25.4) pipe is not available on site, use 1-1/8 (28.58) pipe.
(b) If 1-1/4 (31.75) pipe is not available on site, use 1-3/8 (34.92) pipe.
(c) If 1-1/2 (38.1) pipe is not available on site, use 1-5/8 (41.28) pipe.

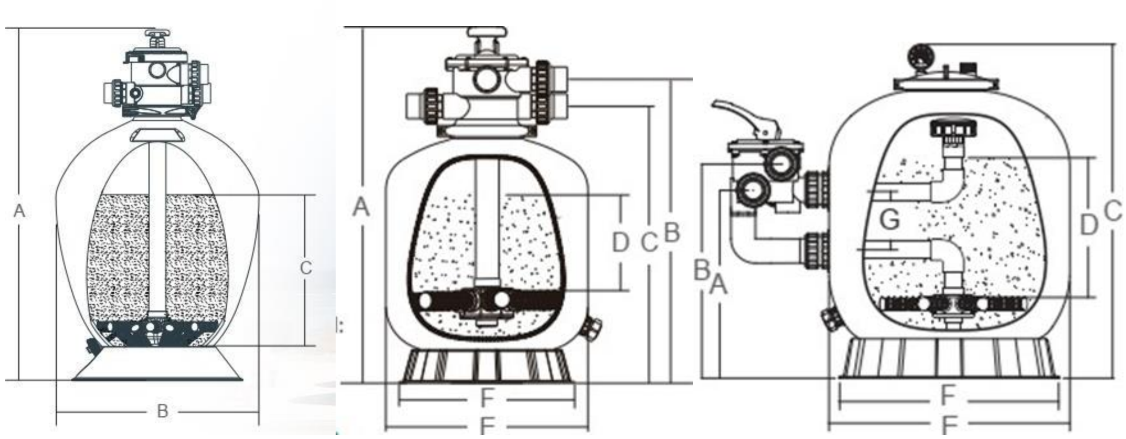
C-9: VRF in door unit Samsung

Heat Pump (Standard)

Type				DVM S(NEW)	DVM S(NEW)
Model Name				AM480HXVAGH1EU	AM500HXVAGH1EU
Power Supply			Ø, #, V, Hz	3,4,380-415,50	3,4,380-415,50
Mode			-	HEATPUMP	HEATPUMP
Performance	HP		HP	48.00	50.00
	Capacity (Nominal)	Cooling	kW	135.20	140.20
			Btu/h	461,300	478,400
		Heating	kW	152.10	157.50
			Btu/h	519,000	537,400
Power	Power Input (Nominal)	Cooling 1)	kW	34.65	36.75
		Heating 2)	kW	34.90	36.90
	Current Input (Nominal)	Cooling 1)	A	55.60	58.90
		Heating 2)	A	56.00	59.20
	MCA		A	118.20	126.90
	MFA		A	125.00	125.00
COP	EER (Nominal Cooling)		-	3.90	3.81
	COP (Nominal Heating)		-	4.36	4.27
	Energy Grade		-	ESEER 6.77	ESEER 6.69
			-	-	-
Compressor	Type		-	BBC Scroll x 4	BBC Scroll x 5
	Output		kW x n	(6.39) + (6.39) +	(6.39) + (4.96x2) +
	Model Name		-	DB-GB066FAVBBGx4	DB-GB066FAVBBGx3 + DB-GB052FAVABGx2
	Oil	Type	-	PVE	PVE
Fan	Type		-	Propeller	Propeller
	Output x n		W	(400.0) + (620.0x2) +	(400.0) + (620.0x2) +
	Air Flow Rate		CMM	220.0 ~ 255.0 ~ 290.0	220.0 ~ 255.0 ~ 290.0
			l/s	3,666.7 ~ 4,250.0 ~	3,666.7 ~ 4,250.0 ~
	External Static Pressure	Max.	mmAQ	8.00	8.00
			Pa	78.40	78.40
Piping Connections	Liquid Pipe		Ø, mm	19.05	19.05
			Ø, inch	3/4"	3/4"
	Gas Pipe		Ø, mm	41.28	41.28
			Ø, inch	1 5/8"	1 5/8"
	Discharge Gas Pipe		Ø, mm	-	-
			Ø, inch	-	-
	Installation Limitation	Max. Length	m	200 (220)	200 (220)
		Max. Height	m	110 (40)	110 (40)
Field Wiring	Power Source Wire		mm²	-	-
	Transmission Cable		mm²	0.75 ~ 1.50	0.75 ~ 1.50
Refrigerant	Type		-	R410A(GWP >150)	R410A(GWP >150)
	Factory Charging		kg	21.60	21.30
Sound	Pressure		dBA	68.00	68.00
	Power			89.00	89.00
External Dimension	New Weight		kg	(190.0) + (235.0) +	(190.0) + (278.0) +
	Shipping Weight		kg	(206.0) + (254.0) +	(206.0) + (297.0) +
	Net Dimensions (WxHxD)		mm	(880x1,695x765) + (1,295x1,695x765) +	(880x1,695x765) + (1,295x1,695x765) +
	Shipping Dimensions (WxHxD)		mm	(948x1,887x832) + (1,363x1,887x832) +	(948x1,887x832) + (1,363x1,887x832) +
Operating	Cooling		°C	-5.0 ~ 48.0	-5.0 ~ 48.0

Appendix (D)

D-1: section filter



Model	A mm	B mm	C mm	D mm	E mm	F mm
	687	784	1686	1000	1050	1000
	1047	1157	1686	1000	1050	1000
	1040	1150	1724	1000	1200	1000

Filter Area (m^2)	Valve Connections	Max Flow Rate	Sand (kg)
0.16	1.5" / 50mm	135lpm 8.10m3/h	45
0.22	1.5" / 50mm	185lpm 11.10m3/h	85
0.32	1.5" / 50mm	260lpm 15.60m3/h	145
0.40	1.5" / 50mm	325lpm 19.50m3/h	210
0.41	2.0" / 63mm	336lpm 20.16m3/h	215
0.53	2.0" / 63mm	435lpm 24.10m3/h	355
0.66	2.0" / 63mm	550lpm 33.00m3/h	470

D-2: Pipe size catalogue

1/2 inches				
Volume Flow (gal/min)	Volume Flow (gal/hr)	Velocity (ft/sec)	Friction Head (ft_{H2O}/100 ft)	Friction Loss (psi/100 ft)
1	60	1.5	4.0	1.7
2	120	3.0	8.0	3.5
5	300	7.4	45.2	19.6
7	420	10.3	83.1	36.0

3/4 inches				
Volume Flow (gal/min)	Volume Flow (gal/hr)	Velocity (ft/sec)	Friction Head (ft/100ft)	Friction Loss (psi/100 ft)
1	60	0.7	0.9	0.4
2	120	1.6	1.7	0.7
5	300	3.9	9.7	4.2
7	420	5.5	11.8	7.7
10	600	7.8	33.8	14.7
15	900	11.8	71.7	31.1

1 inches				
Volume Flow (gal/min)	Volume Flow (gal/hr)	Velocity (ft/sec)	Friction Head (ft/100ft)	Friction Loss (psi/100 ft)
2	120	0.9	0.9	0.4
5	300	2.3	2.6	1.2
7	420	3.3	5.0	2.2
10	600	4.7	9.6	4.2
15	900	7.0	20.4	8.8
20	1200	9.4	34.7	15.0
25	1500	11.7	52.4	22.7
30	1800	14.0	73.5	31.8

3 inches				
Volume Flow (gal/min)	Volume Flow (gal/hr)	Velocity (ft/sec)	Friction Head (ft/100ft)	Friction Loss (psi/100 ft)
5	300	0.3	0.02	0.01
7	420	0.4	0.03	0.01
10	600	0.5	0.04	0.02
15	900	0.8	0.09	0.04
20	1200	1.0	0.2	0.07
25	1500	1.3	0.2	0.1
30	1800	1.5	0.3	0.1
35	2100	1.7	0.4	0.2
40	2400	2.0	0.5	0.2
45	2700	2.2	0.7	0.3
50	3000	2.5	0.8	0.4
60	3600	3.0	1.1	0.5
70	4200	3.5	1.5	0.7
75	4500	3.7	1.7	0.7
80	4800	4.0	1.9	0.8
90	5400	4.5	2.4	1.0
100	6000	5.0	2.9	1.3
125	7500	6.2	4.4	1.9
150	9000	7.5	6.2	2.7
175	10500	8.7	8.3	3.6
200	12000	10.0	10.6	4.6
250	15000	12.5	16.0	6.9

1 1/4 inches				
Volume Flow (gal/min)	Volume Flow (gal/hr)	Velocity (ft/sec)	Friction Head (ft/100ft)	Friction Loss (psi/100 ft)
2	120	0.5	0.2	0.1
5	300	1.3	0.7	0.3
7	420	1.8	1.2	0.5
10	600	2.6	2.3	1.0
15	900	3.9	4.9	2.1
20	1200	5.2	8.3	3.6
25	1500	6.5	12.6	5.4
30	1800	7.8	17.6	7.6
35	2100	9.1	23.4	10.1
40	2400	10.4	30.0	13.0
45	2700	11.7	37.3	16.1
50	3000	13.0	45.3	19.6

1 1/2 inches				
Volume Flow (gal/min)	Volume Flow (gal/hr)	Velocity (ft/sec)	Friction Head (ft/100ft)	Friction Loss (psi/100 ft)
2	120	0.4	0.1	0.04
5	300	0.9	0.3	0.1
7	420	1.3	0.6	0.2
10	600	1.9	1.0	0.5
15	900	2.8	2.2	1.0
20	1200	3.8	3.8	1.6
25	1500	4.7	5.7	2.5
30	1800	5.6	8.0	3.4
35	2100	6.6	10.6	4.6
40	2400	7.5	13.6	5.9
45	2700	8.4	16.9	7.3
50	3000	9.4	20.5	8.9
60	3600	11.3	28.7	12.4

2 inches				
Volume Flow (gal/min)	Volume Flow (gal/hr)	Velocity (ft/sec)	Friction Head (ft/100ft)	Friction Loss (psi/100 ft)
5	300	0.6	0.1	0.04
7	420	0.8	0.2	0.07
10	600	1.1	0.3	0.1
15	900	1.7	0.6	0.3
20	1200	2.2	1.1	0.5
25	1500	2.8	1.6	0.7
30	1800	3.4	2.3	1.0
35	2100	3.9	3.0	1.3
40	2400	4.5	3.8	1.7
45	2700	5.0	4.8	2.1
50	3000	5.6	5.8	2.5
60	3600	6.7	8.1	3.5
70	4200	7.8	10.8	4.7
75	4500	8.4	12.3	5.3
80	4800	8.9	13.8	6.0
90	5400	10.1	17.2	7.5
100	6000	11.2	20.9	9.1

2 1/2 inches				
Volume Flow (gal/min)	Volume Flow (gal/hr)	Velocity (ft/sec)	Friction Head (ft/100ft)	Friction Loss (psi/100 ft)
5	300	0.4	0.05	0.02
7	420	0.5	0.07	0.03
10	600	0.8	0.1	0.05
15	900	1.2	0.3	0.1
20	1200	1.6	0.4	0.2
25	1500	2.0	0.7	0.3
30	1800	2.3	0.9	0.4
35	2100	2.7	1.3	0.5
40	2400	3.1	1.6	0.7
45	2700	3.5	2.0	0.9
50	3000	3.9	2.4	1.1
60	3600	4.7	3.4	1.5
70	4200	5.5	4.5	2.0
75	4500	5.9	5.1	2.2
80	4800	6.2	5.8	2.5
90	5400	7.0	7.2	3.1
100	6000	7.8	8.7	3.8
125	7500	9.8	13.2	5.7
150	9000	11.7	18.5	8.0

5 inches				
Volume Flow *(gal/min)*	Volume Flow *(gal/hr)*	Velocity *(ft/sec)*	Friction Head *(ft/100ft)*	Friction Loss *(psi/100 ft)*
30	1800	0.5	0.03	0.01
35	2100	0.6	0.04	0.02
40	2400	0.7	0.04	0.02
45	2700	0.8	0.06	0.03
50	3000	0.9	0.07	0.03
60	3600	1.1	0.1	0.04
70	4200	1.3	0.1	0.06
75	4500	1.3	0.1	0.06
80	4800	1.4	0.2	0.07
90	5400	1.6	0.2	0.09
100	6000	1.8	0.2	0.1
125	7500	2.3	0.4	0.2
150	9000	2.7	0.5	0.2
175	10500	3.2	0.7	0.3
200	12000	3.6	0.9	0.4
250	15000	4.5	1.3	0.6
300	18000	5.4	1.9	0.8
350	21000	6.3	2.5	1.1
400	24000	7.2	3.2	1.4
450	27000	8.1	4.0	1.7
500	30000	9.0	4.8	2.1

4 inches				
Volume Flow *(gal/min)*	Volume Flow *(gal/hr)*	Velocity *(ft/sec)*	Friction Head *(ft/100ft)*	Friction Loss *(psi/100 ft)*
20	1200	0.6	0.04	0.02
25	1500	0.7	0.06	0.03
30	1800	0.9	0.08	0.04
35	2100	1.0	0.1	0.05
40	2400	1.2	0.1	0.06
45	2700	1.3	0.2	0.07
50	3000	1.4	0.2	0.09
60	3600	1.7	0.3	0.1
70	4200	2.0	0.4	0.2
75	4500	2.2	0.5	0.2
80	4800	2.3	0.5	0.2
90	5400	2.6	0.6	0.3
100	6000	2.9	0.8	0.3
125	7500	3.6	1.2	0.5
150	9000	4.3	1.6	0.7
175	10500	5.0	2.2	0.9
200	12000	5.7	2.8	1.2
250	15000	7.2	4.2	1.8
300	18000	8.6	5.8	2.5
350	21000	10.0	7.8	3.4
400	24000	11.5	9.9	4.3

Model type	-	MSP Duct	
Model name	-	AM056FNMDEH/TK	
Power Supply	Ø,#,V,Hz	1,2,220-240,50Hz	
Image	-		
Nominal capacity	Cooling	kW	5.6
	Cooling (SH)	kW	4.3
	Heating	kW	6.3
Simulated capacity	Cooling	kW	-
	Cooling (SH)	kW	-
	Heating	kW	-
Power Input	Cooling	W	130
	Heating	W	130
Current Input	Cooling	A	1.1
	Heating	A	1.1
Airflow	H/M/L	CMM	14.50 / 13.00 / 11.50
	ESP	mmAq	4
Sound pressure		dB(A)	31 / 35
Piping	Liquid Pipe	mm	6.35
	Gas Pipe	mm	12.70
	Drain	mm	VP25 (OD 32,ID 25)
Power cable		mm2	1.5 ~ 2.5
Communication cable		mm2	0.75 ~ 1.50
Refrigerant	Type	-	R410A
	Control	-	EEV INCLUDED
Dimensions & Weight	Weight	kg	29.000

	Dimensions	mm	900x260x480
Design condition (Cooling)	Outdoor(DB)	°C	40
	Indoor(WB)	°C	17.8
Design condition (Heating)	Outdoor(DB)	°C	0
	Indoor(DB)	°C	15

BILL OF QUANTITIES

Itom NO	DISCRIPTION	Unit	Quality	Price/Unit
1	**VRF**			
1.1	**Indoor Units**			
1.1.1	Ceiling VRF indoor units. Price includes all required electrical and gas connections, and operating perfectly. Price includes hangers, isolating valves, and electrical connection to power source. All connections and installation should be executed according to manufacturer instructions. Selection to be based on medium speed, external air pressure of 0.25 ", indoor temperature of 24 C and outdoor temperature of 30 C (summer) 4.7 C (winter)			
1.1.1.1	nominal capacity 5.6	**NO.**	8	
1.1.1.2	nominal capacity 3.6		3	
1.1.2	1-way cassette VRF indoor units. Price includes all required electrical and gas connections, and operating perfectly. Price includes hangers, isolating valves, and electrical connection to power source. All connections and installation should be executed according to manufacturer instructions. Selection to be based on medium speed, external air pressure of 0.25 ", indoor temperature of 24 C and outdoor temperature of 31.9 C (summer) 5.7 C (winter)			
1.1.2.1	nominal capacity 2.2	**NO.**	98	
1.2	**Out Door**			
1.2.1	AM160HXVFGH/ID	**NO.**	**2**	
1.2.2	AM120HXVFGH/ID	**NO.**	**4**	
1.2.3	AM100HXVFGH/ID	**NO.**	**2**	
1.3	**Piping network**			
	Supply and install drain and insulated copper pipes for refrigerant 410 between indoor units and outdoor unit with sizes according to manufacturer instructions and calculations. Price includes all required fittings, hanging, insulation and digging.			
1.3.2	9.52mm	m	132	
1.3.3	12.7mm	m	162	
1.3.4	15.88mm	m	230	
1.3.5	19.05mm	m	187	
1.3.6	22.22mm	m	143	
1.3.7	28.58mm	m	160	
1.3.8	34.92mm	m	100	

1.3.9	41.28mm	m	80
1.4	**Accessories**		
1.4.1	Refnet Joint	No.	113
1.4.2	Refrigerant Amount (R410 A)	Kg	63.5
2	**VENTLATION**		
	Centrifugal Exhaust Fans set (one duty and one stand-by), complete as per drawings and specifications.		
2.1	500 cfm	No.	3
2.2	1200cfm	No.	4
2.3	2000cfm	No.	1
2.4	2500	No.	1
2.5	6230cfm	No.	1
3	**Water System**		
3.1	**Pumps**		
	Supply, install, test & commission water pump set including motor, interconnecting pipe work, complete with all valves, vents, manifolds, gauges, control panel, level switches, pressure vessel & frequency inverter etc., as per specifications and drawings. 4.2 bar and 172gpm for cold water 4.2 bar and 82 gpm for hot water		
3.1.1	**L.P.** (Lifting pumps set /2 pumps)	SET	1
3.1.2	**C.W.P.-1** (Set/2 booster pump) with	SET	1
3.1.6	**H.W.P** (Set/2 (Directly feeds floors with hot water)	SET	1
3.2	**Pipes**		
3.2.1	Galvanized steel pipes to BS1387 of various sizes for domestic cold and hot water above false ceiling, in walls, etc. Including fittings, supports, expansion loops, thermal insulation cladding of all external and trenches pipes.		
3.2.1.1	20 mm dia pipe (3/4")	m	25
3.2.1.2	25 mm dia pipe (1")	m	36.16
3.2.1.3	32 mm dia pipe (11/4")	m	34.56
3.2.1.4	40 mm dia pipe (1 1/2")	m	70
3.2.1.5	50 mm dia pipe (2")	m	76.5
3.2.2	Pex pipes to BS1387 of various sizes for domestic cold and hot water above false ceiling, in walls, etc. Including fittings, supports, expansion loops, thermal insulation cladding of all external and trenches pipes.	ML	320
3.2.2.1	16 mm dia pipe	m	680
3.3	**Water Manifolds**		
	Supply, install, test and commission wall hung type steel hot and cold water copper manifolds 16 mm dia outlets. The unit price shall include plug and washer, adaptors with O- rings, brackets, drain cocks, isolating ball valves with T-handle on all outlets, automatic air vent on each manifold, and all accessories and works required to complete the work as shown in the drawings and engineers instructions.		
3.3.1	25 mm dia collector, 8 outlets (average)	No.	76

4	**Firefighting System**		
4.1	Fire hose reel cabinet (double compartment) including isolating valve with SS304 fully recessed cabinet, 19 mm dia x 25 m rubber hose, ABC 6 kg powder extinguisher and 4.5 kg CO_2 extinguisher.	No.	9
4.2	Black seamless steel pipe.		
4.2.1	25mm dia pipe (1")	ML	530
4.2.2	31.25 mm dia pipe (1 1/4")	ML	440
4.2.3	37.5 mm dia pipe (1 1/2")	ML	210
4.2.4	mm dia pipe (2")	ML	140
4.2.5	mm dia pipe(2.5")	ML	90
2.4.6	mm dia pipe(3")	ML	55
2.4.7	mm dia pipe(4")	ML	40
4.3	**Pumps** Supply, install, test and commission fire pumps set, complete with all components including duty pump, split case (electric driven), emergency pump (diesel), jockey pump, centrifugal (electric driven). Price shall include electric control panels, pressurized tank, cork and foundation bed, controllers, accessories for all pumps including wiring connections, all components, water measuring devices including flow meter and sensor, pressure gauges, relief valves, gate valves, check valves etc., all electrical works needed to complete the work according to engineer's instructions. 552 gpm and 7.7 bar		
4.3.1	Electrical pump :336 **gpm, 7.067 bar**	No.	1
4.3.2	Diesel pump : 336**gpm, 7.067 bar**	No.	1
4.3.3	Jockey pump 180 gpm, 2.5 bar	No.	1
4.4	**Fire Extinguisher**		
4.5	K-type dry powder fire extinguishers.	No.	22
4.6	CO_2 fire extinguishers.	No.	4
4.7	Self-automatic extinguisher.	No.	6
4.8	Siamese connection assembly complete with non-return valves. Outlet of 100m dia, and inlet of 65mm dia.	No.	1
4.9	Supply and install landing valve, complete with fire hose rack.	No.	11
4.10	Supply and install clean agent system with all accessories such as valves, control, nozzles, etc. All complete as per detailed specifications and drawings.	Set	20
4.11	Supply and install Fire hydrant, pedestal type and maintain stand spot fitted with 75mm twin faced flanged fire hydrant, complete with isolating valve, an automatic shut-off valve, complete with all necessary mechanical fittings.	No.	10
4.12	Supply and install Fire hydrant Cabinet, complete with all needed equipment's.,	No.	10
4.13	Supply, lift into position, install, test, set to work, and commission sprinkler head as following and as per drawings Sprinkler head pendent recessed center link type, Part No. 13577W/B (½ Inch)56 diameter - ORIFICE 15 mm (½ Inch) NPT male connection bronze finish UL/FM	No.	246

	approved.		
4.14	Supply and install fire system for kitchen consists of 6 nozzles, heat detector sense fire and activate the wet chemical cylinder and wet chemical cylinders all according to drawings and specifications.	Set	1
5	**Drainage System**		
5.1	**Water Closets**		
5.1.1	Supply install and test European water closet, heavy duty seat and cover, connection to treated cold water supply and drainage network and all fittings and works required to complete the work as per drawings and as per engineer's instructions. Price shall include hand spray hose (connected to domestic cold water), holding paper, and paper basket.	No.	77
5.2	**Shower Tray**		
5.2.1	Supply install and test shower tray (80cmx80cm) White Vitreous China connected to domestic cold and hot water supply and drainage network and all fittings and works required to complete the work as per drawings and as per engineer's instructions. Price shall include chrome plated shower mixer, chrome plated hand shower completes with flexible hose 150 cm long and chrome plated shower hanger, Pax pipes, 2" and 4" UPVC pipes needed to connect the tray to the nearest main drainage and supply it with water, Single robe/clothes hook with concealed mounting type	No.	70
5.3	**Kitchen Sinks**		
5.3.1	Supply and install stainless steel single bowl kitchenette sink 60x50 cm, complete with faucet with mixer connection to domestic cold and hot water supply and drainage network and all fittings and works required to complete the work as per drawings, specifications and as per engineer's instructions.	No.	2
5.4	**Lavatory**		
5.4.1	Supply and install laboratory molded sink 46x46 cm made of anti-corrosion polypropylene with high resistance to acids, alkaline and base chemicals. Price shall include incorporated overflow, complete with threaded drainpipe, made as a single piece without joints. All according to drawings and specifications and as per engineer's instructions	No.	79
5.5	**UPVC Pipes**		
	Supply, install, and test UPVC pipes and fittings for waste, soil, and rain water drainage services. Price includes all kinds of digging in concrete slabs and walls, supports, hangers and all rubber joints and sealants, syphon and connection to floor drain and flexible connections and all types of fittings. All done according to drawings, specifications and engineer's instructions.		
5.5.1	110 mm dia. (4")	m	390
5.5.2	150 mm dia. (6")	m	65
5.5.3	31.75 mm dia (1 ¼ ")	m	417
5.5.4	50 mm dia. (2")	m	326
5.6	**Floor Drains**		
	Supply, install, and test Floor drain 4" threaded 15x15cm chrome plated cover multi inlet adjustable with trap. All complete with floor clean out plug, HDPE syphon and all types of fittings. The rate shall include		

	excavation and backfilling for all connections with drain pipes and fixtures. All done according to drawings, specifications. Floor Drain, Floor Trap & Floor Gully		
5.6.1	***FD-HDPE*** and with chromium plated cover, mesh and all accessories needed	No.	92
5.7	**Floor Cleanouts**		
	Supply, install, and test heavy duty nonadjustable 11x11 cm floor clean out with HDPE body, with gas and water tight ABS plug and frame, complete with all needed elbow and all types of fittings, all done according to drawings, specifications and the approval of the engineer.		
5.7.1	***FLOOR C.O HDPE*** with chromium plated cover, mesh and all accessories needed.		129
5.8	**Roof Drains**		
	Supply install and test (HDPE) Roof rain water drain size 4" with cover of 20x20 plastic mesh to be connected to rain water vertical pipes with all required fittings, price shall include the piping works until the connection to the vertical rain pipe, all done according to drawings, specifications and the approval of the Engineer. Roof drain HDPE with cover (RD)		
5.81	110 mm dia. (4")	No.	3
5.9	**Roof Vent**		
	Supply and install (HDPE) Roof vent with screened cap for vent stacks including connection to the vent pipe by solvent welding. The rate includes all needed connection accessories, all done according to drawings, specifications and the approval of the Engineer. Roof vent cap HDPE		
5.9.1	100 mm dia. (4")	m	392
5.10	**Manholes**		
	Supply install and test precast concrete manholes of 15 cm thickness for walls and bottom slab with C.I. cover (medium cover) and frame all necessary excavation, blinding of 15cm thickness, back filling as specified to the required depth complete with iron steps, benching and plastering as shown in drawing and in accordance to specification, drawings, and approval of supervisor engineer. With C.I. cover (medium cover) and frame, iron steps as detailed on the drawings.		
5.10.1	Length 80 cm- width 80 cm-depth 80 cm	No.	2
5.10.2	Length 80 cm- width 80 cm-depth 85 cm	No.	2
5.10.3	Length 100 cm- width 100 cm-depth 95.3 cm	No.	1
5.10.4	Length 100 cm- width 100 cm-depth 105.1 cm	No.	1
5.10.5	Length 100 cm- width 100 cm-depth 107 cm	No.	1
5.10.6	Length 120 cm- width 120 cm-depth 121 cm	No.	1
5.10.7	Length 120 cm- width 120 cm-depth 135 cm	No.	1
6	**Swimming pool**		
6.1	Supply and installation of lines for supplying the pool with clean and warm water and the necessary parts and connections from the pump to the swimming pool.		
6.1.1	Skimmer 150L/m	No.	2
6.1.2	Main drain 150L/m	No.	2

6.1.3	Return inlet 150L/m	No.	3
6.1.4	Filter $0.4m^2$, $19.05m^3/h$	No.	2
6.2	Supply and installation of a circulation pump with all the necessary parts and equipment for delivery from the room to the pond.		
6.2.1	pump model SE5.5	No.	1
6.3	Supply and installation of an electric boiler with the necessary connecting parts, accessories and pipes.		
6.3.1	Boiler model BSA40S-5 , heat source flow =43 m^3/h	No.	1
6.4	PVC pipe		
	Extension and installation of plastic pipes and connecting parts of the appropriate diameters and lengths from the equipment room to all parts of the swimming pool		
6.4.1	50mm diameter	m	18
6.4.2	63.5mm diameter	m	10
6.4.3	76.2mm diameter	m	13
6.4.4	110mm diameter	m	12
6.4.5	127mm diameter	m	7