Palestine Polytechnic University

College of Engineering

Mechanical Engineering Department

Refrigeration and Air Conditioning Engineering (HVAC)

Design of Mechanical Systems for Residential Building in Hebron City

By

Muhammad Tomeizh

Ismail Tomeiza

Supervisor

Eng. Mohammad Awad

June 2021

Abstract

This project aims to design the Mechanical systems of a Residential Building located in Hebron city, as this Building consists of five floors, a ground floor in addition to a basement, and the total Building area is 5033 square meters.

In this project, the thermal loads of this building will be calculated and the appropriate HVAC system selected, and the project also includes calculations, selection of materials and preparation of bill of quantities for the HVAC system, ventilation system, water system, sewage system, and firefighting system, and these services will be designed to meet human comfort standards.

الملخص:

يهدف هذا المشروع إلى تصميم الأنظمة الميكانيكية لمبنى سكني يقع في مدينة الخليل حيث يتكون هذا المبنى من خمسة طوابق و طابق أرضي بالأضافة الى طابق تسوية و تبلغ المساحة الأجمالية للمبنى 5033 م^2.

في هذا المشروع ، تم حساب الأحمال الحرارية لهذا المبنى وتم اختيار نظام تكييف الهواء المناسب و يشمل المشروع أيضًا الحسابات وأختيار المواد وإعداد جداول كميات لنظام تكييف الهواء ونظام التهوية ونظام المياه ونظام الصرف الصحي ونظام مكافحة الحرائق و سيتم تصميم هذه الخدمات بحيث تحقق معايير الراحة الإنسانية.

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Chapter One: Introduction

1.1 Introduction

Humans are always trying to improve their lives to be easier and more comfortable, so engineers always try to meet the needs of human beings to achieve the well-being of their lives.

Therefore, HVAC Engineers who work in the field of mechanical services develop mechanical services systems and technologies to achieve the comfort people need in buildings of various types and uses.

For this reason, as HVAC Engineers, we will design a Mechanical system for an apartment building in Hebron city so that this system contains the amenities that a person needs such as air conditioning and heating, etc.

1.2 Project overview

Since old time human was looking for comfort conditions, at this time, human has designed mechanical systems to improve the comfort conditions that human need. Thus, to achieve these conditions of comfort the four relative atmospheric parameters should be maintained and controlled according:

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 objectives

1) Design the mechanical systems inside the residential building.

2) Theoretical calculations for the heating and cooling load.

3) Theoretical calculations and design of plumping system.

4) To be familiar with the mechanical drawings for all mechanical systems.

5) Firefighting, hot & cold-water system.

6) Quantitative calculation for mechanical systems.

1.4 Building description

The residential building consists of five floors and a ground floor in addition to an underground car park and the total area of the building is 5033 square meters.

Each floor contains four apartments, and the basement contains a car park and a water tank with a capacity of 477 cubic meters.

The following table show floors within the residential building and the components of each floor:

Table (1.1) Component of floors

Floor	The contents of the floor
-1	Car parking and water tank.
GF	contains four Apartments
1	contains four Apartments
2	contains four Apartments
3	contains four Apartments
4	contains four Apartments
5	contains four Apartments

and each aapartment contains two bedrooms, kitchen, two Bathrooms, a Salon and a Living Room.

1.5 Project outline

1. Chapter One

Introduction:

This chapter includes overview about the project, project objectives, building description and time planning.

2. Chapter Two

Heating and Cooling Loads:

This chapter consists of the procedures for calculating the heating and cooling load the Revit program will be used to estimate the building's thermal loads.

3. Chapter Three

Variable Refrigerant Flow System (VRF):

This chapter talks about the air conditioning system which is variable refrigerant flow (VRF) and which is considered one of the advanced and Energy-saving air Conditioning systems.

4. Chapter Four

Plumping System:

This chapter include the water distribution calculation and drainage system.

5. Chapter Five

Firefighting system:

This chapter contains the design of the fire extinguishing system in addition to the hydraulic calculations related to the selection of the appropriate pump for the fire extinguishing system.

1.6 Symbols

- HVAC: Heating Ventilation and Air Conditioning.
- VRF: Variable Refrigeration Flow.

1.7 Time Table

Table (1.2): first semester action plan

No. of month / Task	September	October	November	December
Project identification and Put the title				
Writing the introduction and human comfort				
Loads calculations Manual and by Revit 2020				
documentation				

Table (1.3): second semester time table

No. of month / Task	February	March	April	May
Design plumping system				
Calculation plumping system				
Design firefighting System & Calculation firefighting System				
Design VRF system				
drawings preparations for printing & Documentation				

Chapter Two: Heating and Cooling Load Calculation

2.1 Introduction

The main objective of the air conditioning is to maintain the environment in enclosed spaces at conditions that induced the feeling of comfort to all occupants of the space, this feeling of comfort is influenced by a number of main related parameters which are the inside temperature, the humidity and the outside design condition.

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2.2 Human comfort

2.2.1 Introduction of human comfort

The process of comfort heating and air conditioning is simply a transfer of energy from one substance to another, this energy can be classified as either sensible or latent heat energy.

Sensible Heat is heat energy that, when added to or removed from a substance, results in a measurable change 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 the body 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. Additionally, if the surrounding air is too humid, the air is nearly saturated and it is more difficult to evaporate body moisture. If the temperature of the air surrounding the body is too low, however, the body loses more heat than it can produce. The body responds by constricting the blood vessels of the skin to reduce heat loss.

2.2.2 Factors affecting human comfort

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.

2.3 Outside and inside design conditions

These conditions include the dry bulb temperature, relative humidity, and the average air speed, these values were obtained from the Palestinian code and the psychometric chart.

Table (2.1): Outside and inside design conditions

Property	**Inside design condition**		**outside design condition**	
	summer	winter	summer	winter
Temperature (˚C)	24	22	30	4
Relative humidity (%)	50	50	51.3	70
Wind speed (m/s)	….	….	1.4	1.4

2.4 ASHRAE Comfort Chart

ASHRAE is an abbreviation for the American Society of Heating Refrigerating and Air-conditioning Engineers. Its Standard Thermal Environmental Conditions for Human Occupancy describes the combinations of indoor space conditions and personal factors necessary to provide comfort in the effective way. There are no static rules that indicate the best atmospheric condition for making all the individual comfortable because human comfort is affected by several factors such as health, age, clothing, etc. Figure (2.1) shows ASHRAE human comfort chart.

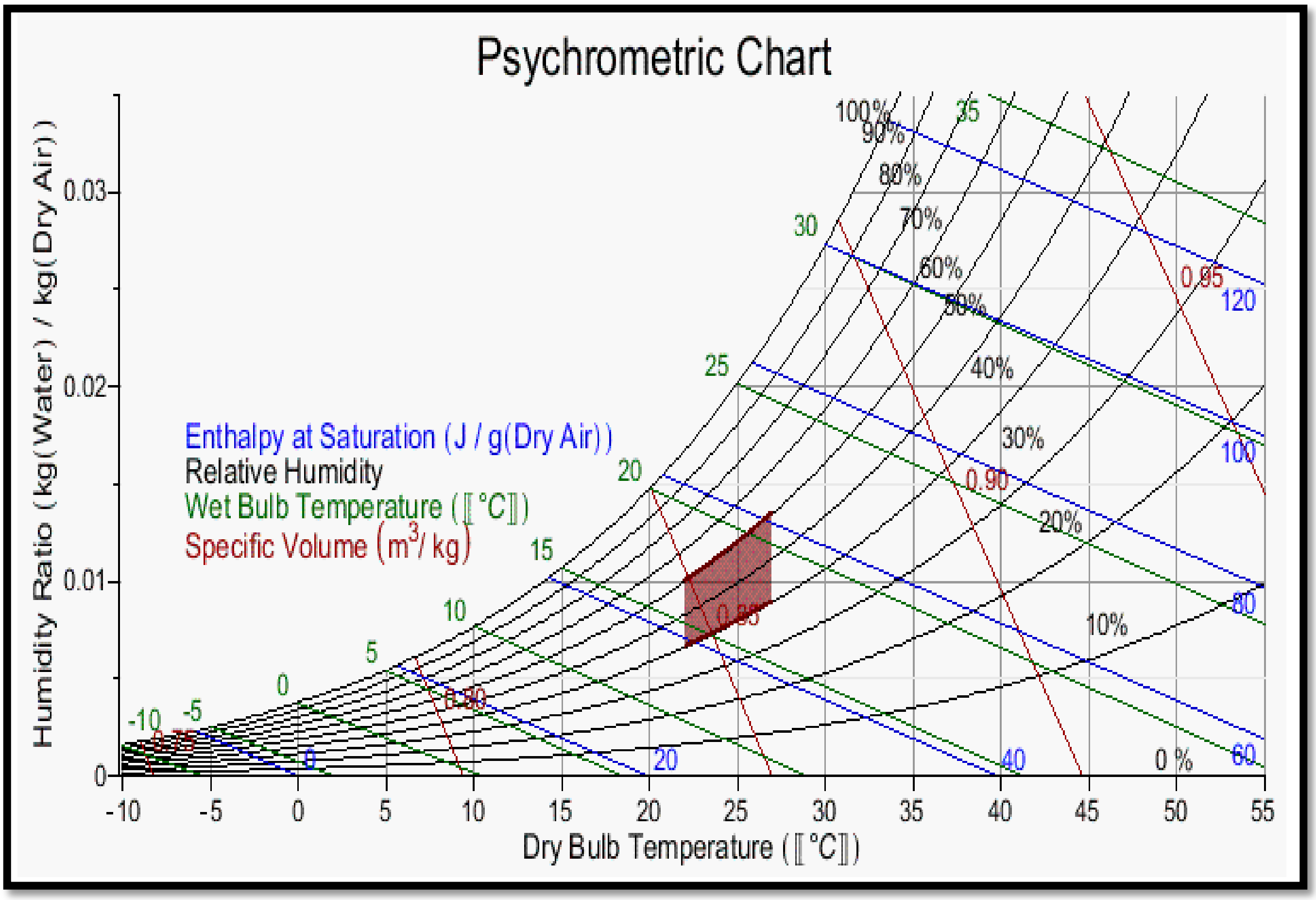


Figure (2.1): Human comfort chart

2.5 Calculations of overall heat transfer coefficient U

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:

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

Where:

Δx: the thickness of the wall [m].

k: Thermal conductivity 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).

2.5.1 The overall heat transfer coefficient (U)

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

1. For external wall:

Table (2.2): Construction of external walls

	Materiel		Δx(m)	K (W/m^2.^{o}C)
5	Stone		0.07	**1.7**
4	concrete		0.13	**1.75**
3	Polystyrene		0.03	**0.03**
2	Cement break		0.07	**0.95**
1	Plaster		0.02	**1.2**

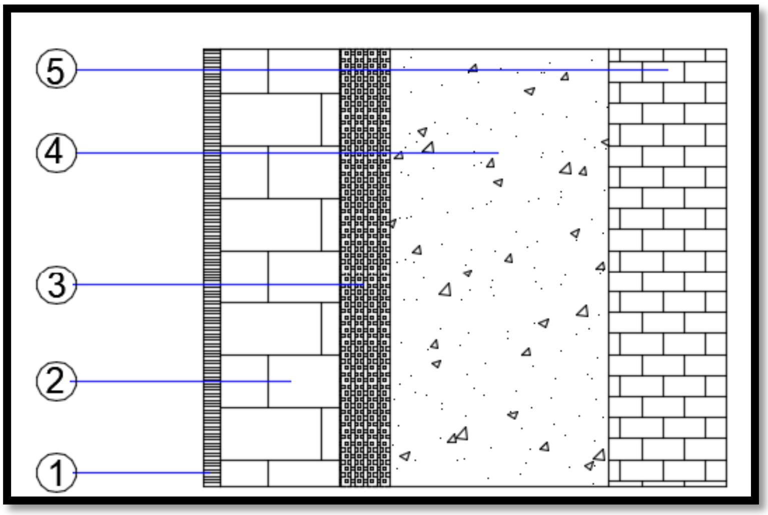


Figure (2.2): External wall construction

R_{in} and R_{out} for the external walls as 0.12 and 0.06(m^2 °C /W), respectively from table (A-27).

$$U_{wall} = \frac{1}{R_{in}+\frac{\Delta x_{st.}}{k_{st.}}+\frac{\Delta x_{con.}}{k_{con.}}+\frac{\Delta x_{poly.}}{k_{poly.}}+\frac{\Delta x_{Brick}}{k_{Brick}}+\frac{\Delta x_{plaster}}{k_{plaster}}+R_{out}} \quad (2.2)$$

$$U = \frac{1}{0.12+\frac{0.07}{1.7}+\frac{0.13}{1.75}+\frac{0.03}{0.03}+\frac{0.07}{0.95}+\frac{0.02}{1.2}+0.06} = 0.7216\ (W/m^2.°C)$$

2. For Internal Wall:

Table (2.3): Construction of internal walls

	Materiel		Δx(m)	K ($W/m^2.^oC$)
1	Plaster		0.02	**1.2**
2	Cement break		0.1	**0.95**
3	Plaster		0.02	**1.2**

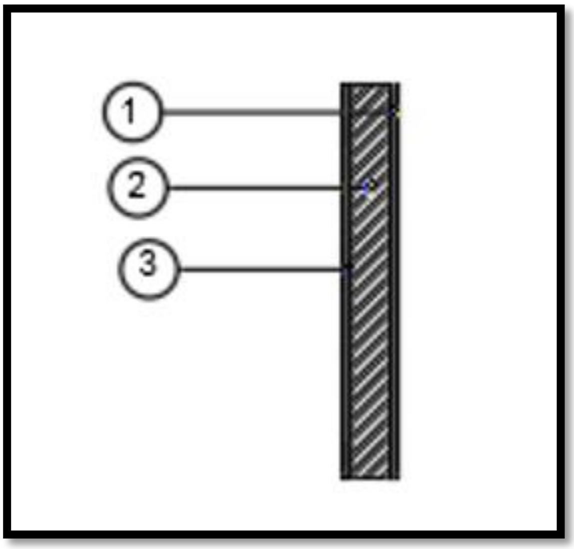


Figure (2.3): Internal wall construction

$$U = \frac{1}{R_{in} + \frac{\Delta x_{(cem).}}{k_{cem.}} + \frac{\Delta x_{plaster}}{k_{plaster}} + \frac{\Delta x_{(cem).}}{k_{cem.}} + R_{out}} \quad (2.3)$$

$$U = \frac{1}{0.12 + \frac{0.02}{1.2} + \frac{0.1}{0.95} + \frac{0.02}{1.2} + 0.12}$$

U = 2.6413 (W/m^2. °C)

3. For Ceiling and Roof:

Table (2.4): Construction of celling

	Materiel		Δx(m)	K (W/m^2.°C)
1	Asphalt		0.02	**0.8**
2	Concrete		0.05	**1.75**
3	Polystyrene		0.05	**0.03**
4	concrete		0.06	**1.75**
5	Brick		0.14	**0.95**
6	Plaster		0.02	**1.2**

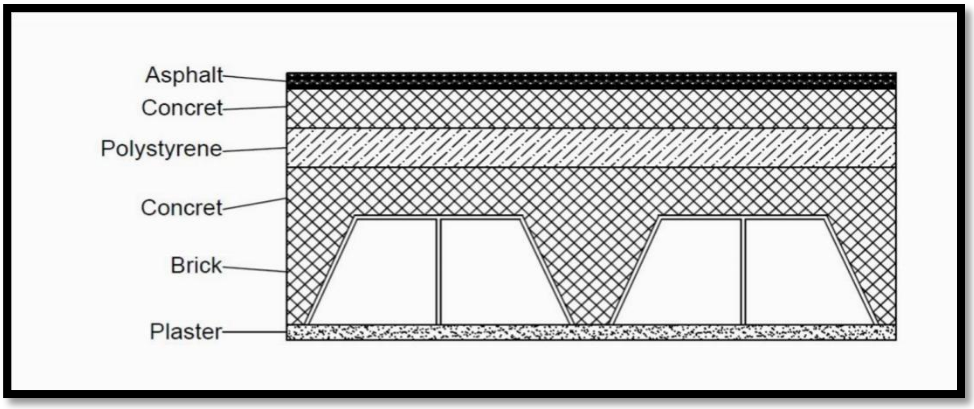


Figure (2.4): Ceiling construction

Because of its construction, the ceiling is divided into two overall heat transfer coefficient one with brick and the other without. R_{in} and R_{out} for the ceiling are 0.1 and 0.04$(W/m^2.°C)$, respectively from table (A-27).

$$U_1 = \frac{1}{R_{in}+\frac{\Delta x_{asph.}}{k_{asph.}}+\frac{\Delta x_{conc.}}{k_{conc.}}+\frac{\Delta x_{poly.}}{k_{poly.}}+\frac{\Delta x_{conc.}}{k_{conc.}}+\frac{\Delta x_{Brick}}{k_{Brick}}+\frac{\Delta x_{Plaster}}{k_{Plaster}}+R_{out}} \quad (2.4)$$

$$U_1 = \frac{1}{0.1+\frac{0.02}{0.8}+\frac{0.05}{1.75}+\frac{0.05}{0.03}+\frac{0.06}{1.75}+\frac{0.14}{0.95}+\frac{0.02}{1.2}+0.04} = 0.49 \ (W/m^2.°C)$$

Similarly, U_2 =0.52 $(W/m^2.°C)$

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

5. For door, from table (A-29), U_d =2.7 $(W/m^2.°C)$, for steel type.

2.6 Heating load calculations

2.6.1 Overview:

Heating load is the rate at which heat energy must be supplied to a space to maintain a given inside design condition.

The heating load of a building consists of the following components:

i. Heat loss through all exposed walls, ceiling, floor, windows, doors, and walls between a heated space and an unheated space (partition walls).
ii. Heat load required to warm outside cold air infiltrated to heated space through cracks (clearances) of windows and doors, and outside cold air infiltrated due to opening and closing of doors and heat gain due to ventilation.

2.6.2 Heat loss calculations:

The main resource of heat loss come from the walls, floor, ceiling, doors, windows and also comes from the infiltration. To calculate each one of them the following equations are to be use:

$$Q=A\times U\times \Delta T \quad (2.5)$$

Where:

Q: Is the heat transfer rate. [kW]

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

ΔT: Is the difference between the inside and outside temperatures [℃]

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

2.6.3 Total heat load calculations

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

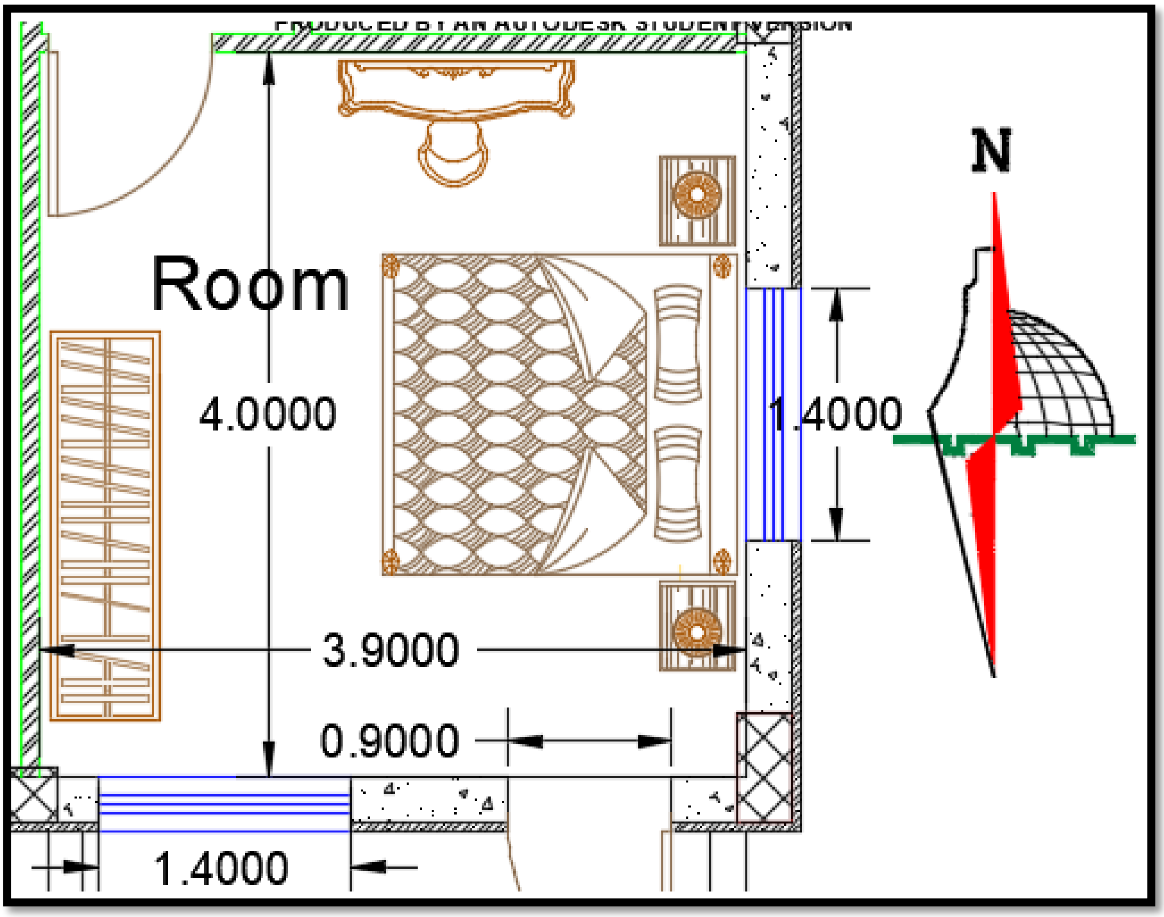


Figure (2.5): The Sample room

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

The height of the room = 3.2 m

The height of the door = 2 m

The height of the window = 1.2 m

Heat loss through ceiling (Q_c):

Area for the ceiling = 4*3.9=15.6 m^2

The area A_1 is equal to:

$A_1 = \frac{4}{5}$ Ac

$A_1 = \frac{4}{5} * 15.6 = 12.5\ m^2$

And the area A2 is equal to:

$A_2 = \frac{1}{5}$ Ac

$A_2 = \frac{1}{5} * 15.6 = 3.12\ m^2$

$Q_c = U_c\ Ac(T_i - T_o)$

$= (U_1A_1 + U_2A_2)\ (T_i - T_o)$

= (0.49*12.5 + 0.52*3.12)
*(22-4)

Q_c = 0.140 kW

Heat loss through floor (Q_f):

No heat loss through floor because; $(T_{in} - T_{out}) = 0$

Heat loss through walls (Q_w):

Area for the Window= 1.4* 1.2 =1.68 m^2

Area for the door =2*0.9 =1.8 m^2

We have two windows in external wall and one door in the Room.

The external wall area is

$A_{ex.\ wall}$ = (7.9*3.2) – ((1.68*2) +(1.8))

=20.12 m^2

The heat loss from external wall is

$$Q_{w.\,ex} = U_{w.} A_{w.\,ex} (T_{in} - T_{out}) \quad (2.6)$$

$= 0.7216 * 20.12 * (22-4)$

$= 0.261$ kW

The unconditioned temperature difference $\Delta T_{adj} = 0.5(T_i - T_o)$

The heat loss from Internal wall is

The unconditioned area is

$A_{w.\,un} = (2.5*3.2) = 8\ m^2$

$$Q_{w\,in} = U_{in\,*} A_{w\,in\,*}\ 0.5(T_{in} - T_{out}) \quad (2.7)$$

$= 2.6413 * 8 * 0.5*(22-4)$
$= 0.190$ kW.

Now, the total heat loss from walls is

$$Q_{w.\,tot} = Q_{w.\,ex} + Q_{w.\,in} \quad (2.8)$$

$= 0.261 + 0.190$

$= 0.451$ kW

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

$$Q_g = U_g A_g (T_i - T_o) \quad (2.9)$$

$= 3.2* (1.68 *2)* (22-4)$

$= 0.\ 193$ kW

Heat loss through door (Q_d):

$$Q_{d\,ex} = U_d A_d (T_i - T_o) \quad (2.10)$$

$= 2.7*1.8*(22-4)$

$= 0.087$ kW

Heat loss through infiltration (Q_{inf}):

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

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

$$Q_{inf} = \frac{V_{f.}}{v_o} \times (h_{in} - h_{out}) \tag{2.11}$$

Where:

T_{in}: inside temperature °C .

T_{out}: outside temperature °C.

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

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

$$\dot{V}_f = K * L\,[0.613(S_1*S_2*V_0)^2]^{2/3} \tag{2.12}$$

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=1…. from table (A-19)

S_2=0.94…. from table (A-20)

V_0=1.4 (m/s) from Palestinian code

And the window is sliding, then:

L = 2[(1.4*2) +(1.2*3)]

=12.8 m

V_f = 0.43*12.8 [0.613(1*0.94*1.4)^2]$^{2/3}$

= 5.72 m^3/h

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

v_o = 0.78 m^3/kg

hi = 43 kJ/kg

ho = 13 kJ/kg

The total heat loss due to infiltration is calculated by equation (2.12) as follows:

Through window

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

$$= \frac{5.72}{0.78} * (43-13)$$

= 0. 220 kW

Through door in

L =2*(0.9+2)

=3.6 m

$V_{f\ door}$ = 0.43*3.6* [0.613(1*0.94*1.4)^2]$^{2/3}$

=1.611 m^3/h

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

$= \frac{1.611}{0.78} * (43\text{-}13)$

= 0.062 kW

$Q_{inf} = Q_{inf,\ door} + Q_{inf,\ w}$ (2.13)

=0.062 + 0.220

= 0.282 Kw.

Heat gain due to ventilation:

The ventilation is used for maintaining a healthy indoor air by introducing a fresh air from outside of the building. And this kind of heat gain can be calculated by using the following equations:

$Q_{ventilation} = m_{ventilation} \times (h_{out} - h_{in})$ (2.14)

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

v_o = 0.78

$V_{f\,=}$ Room volume × No. of times the air changes in the hour (2.15)

$m_v = \frac{V_{f.}}{v_o} = \frac{(4*3.9*3.2)m^3 *(1.5)}{0.78(3600)}$ =0.0266 kg /s

$Q_{ventilation} = 0.0266 \times (43 - 14)$

$Q_{ventilation} =$ 0.771 kW

The total heat loss from the bedroom is

$Q_{tot} = Q_{w,in} + Q_{w,ex} + Q_{ceiling} + Q_g + Q_d + Q_{inv}$ (2.16)

=0.190 +0.261+0.140+0.193+0.087+0.771

=1.642 kW.

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

$Q_{tot} = 1.642 \times 1.1$

$= 1.806$ kW.

2.7 Cooling load:

The cooling load is defined as the rate at which heat energy must be removed from space in order to maintain a given inside design condition.

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 help in selecting the equipment that needed correctly.

The total cooling load of a structure involves:

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

2. Sensible heat gain through solar radiation.

3. Sensible heat and latent heat gain from ventilation and infiltration.

4. Sensible and latent heat due occupancy.

5. Sensible heat gain from the equipment.

2.7.1 Cooling load calculations:

Total cooling load calculations for the sample room Shown in figure (2.5)

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.

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

$$Q = UA\,(CLTD)_{corr.} \quad (2.17)$$

Where:

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

$$(CLTD)_{corr.} = (CLTD + LM)\,k + (25.5 - T_{in}) + (T_{o,\,m} - 29.4)\,f \quad (2.18)$$

Where:

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

LM: latitude correction factor, from Table (A-25)

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 (2.19)

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.

2.7.2 Sample Calculation:

Heat gain through sunlit ceiling ($Q_{ceiling}$):

$Q_c = U_c\, Ac(T_i - T_o)$

$= (U_1A_1 + U_2A_2)\ (Ti - T_o)$

= (0.49*12.5 + 0.52*3.12) *(30-22)

= 0.061 kW

CLTD = 25˚C

LM = 0.5

k = 0.83 for permanently light colour roofs.

f = 1 there is no attic or roof fan.

$(CLTD)_{corr.} = (25+ 0.5) (0.83) + (25.5 - 24) + (24- 29.4) (1)$

$= 17.26$ ˚C

$Q_{ceiling} = U * A * (CLTD)_{corr.}$ (2.20)

$Q_{ceiling} = (0.49*12.5 + 0.52*3.12) * (17.26)$

$= 0. 133$ kW

$Q_{ceiling\ tot} = 0.061 + 0.133$

$= 0.194$ kW

Heat gain through sunlit walls (Qex wall):

$Q_{w.\ ex} = U_{w.} A_{w.\ ex} (T_{in} - T_{out})$ (2.6)

$= 0.7216 * 20.12 * (30-24)$

$= 0.087$ kW

Est Wall:

CLTD = 15˚C

LM = 0.0

k = 0.83 for permanently light colour roofs.

f = 1 there is no attic or roof fan.

$(CLTD)_{corr.} = (15+ 0.0) (0.83) + (25.5 - 24) + (24- 29.4) (1)$

$= 8.55$ ˚C

$A_{Est\ ex\ wall} = 4*3.2$

$= 12.8\ m^2$

$Q_{Est\ wall} = (U_{Est\ ex\ wall} * A_{Est\ ex\ wall})\ (CLTD)_{corr.}$ (2.21)

$= (0.7216 * 12.8) * (8.55)$

$= 0.079$ kW

South Wall:

CLTD = 12 ˚C

LM = -1.6

k = 0.83 for permanently light colour roofs.

f = 1 there is no attic or roof fan.

$(CLTD)_{corr.} = (12\text{-}1.6)\ (0.83) + (25.5 - 24) + (24\text{-} 29.4)\ (1)$

$= 4.73$ ˚C

$A_{South\ ex\ wall}$ =3.9*3.2

$= 12.48\ m^2$

$Q_{South\ wall} = (U_{South\ ex\ wall} * A_{South\ ex\ wall})\ (CLTD)_{corr.}$ (2.22)

$= (0.7216 * 12.48) * (4.73)$

$= 0.043$ kW

$Q_{w.\ ex\ tot} = 0.087 + 0.079 + 0.043$
$= 0.209$ kW

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

From the wall around bathroom:

$T_{un} = T_i + 2/3(T_0 - T_i)$

$= 24 + 2/3 * (30\text{-}24)$

$=28$ ˚C

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

$= 2.6413 * (2.5*3.2) * (T_{un} - T_i)$

$= 2.6413 * (2.5*3.2) * (28 - 24)$

$= 0.084$ kW

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

The amount of solar radiation depends upon the following factors:

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:

$$Q_{Glass} = Q_{tr.} + Q_{conv.} \tag{2.23}$$

Where:

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

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

The transmitted cooling load is calculated as follows:

$$Q_{tr.} = A\,(SHG)\,(SC)\,(CLF) \tag{2.24}$$

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).

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.

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.

SHG in W/m^2 …

*For wall in south direction:

$A = 1.68\ m^2$

$SHG = 227\ W/m^2$

SC = 0.57…with interior shading

CLF = 0.58 at 14:00 clock …

$Q_{tr.\ s} = 1.68 \times 227 \times 0.57 \times 0.58$

$= 0.126\ kW$

*For wall in East direction:

$A = 1.68\ m^2$

$SHG = 678\ W/m^2$

SC = 0.57… with interior shading

CLF = 0.31 at 14:00 clock …

$Q_{tr.\ E} = 1.68 \times 678 \times 0.57 \times 0.31 = 0.201\ kW.$

$Q_{tr.} = Q_{tr.s} + Q_{tr.E} = 0.126 + 0.201 = 0.327\ kW$

$$Q\ conv. = UA\ (CLTD)\ corr. \qquad (2.25)$$

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

$(CLTD)_{corr\text{-}window\ Est.} = (7 + 0)\ 1 + (25.5 - 24) + (24 - 29.4)\ 1$

$= 3.1\ ˚C$

$(CLTD)_{corr-window\ south.} = (7 - 1.6)\ 1 + (25.5 - 24) + (24 - 29.4)\ 1$

$= 1.5\ ^{\circ}C$

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

$= 3.2 \times 1.68 \times 3.1$

$= 0.0166\ kW$

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

$= 3.2 \times 1.68 \times 1.5$

$= 0.008\ kW$

$Q_{conv\ tot} = Q\ conv_{Est.} + Q\ conv_{Est.}$

$= 0.0166 + 0.008$

$= 0.0246\ kW$

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

$= 0.327 + 0.0246 = 0.3516\ kW$

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

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

$\dot{Q}_{Lt.} = \text{light intensity} \times A \times (CLF)_{Lt.}$ (2.26)

Where:

we will take 20W/ m^2

A: floor area = 15.6 m^2

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

$(CLF)_{Lt.} = 0.95$ … from Table (A-5)

$Q_{Lt} = 20 \times 15.6 \times 0.95 = 0.296\ kW$

Heat gain due to infiltration (Q_f):

As the same way in heating load.

K=0.43…..from table (A-13)

S_1=1…..from table (A-19)

S_2=0.94…..from table (A-20)

V_0=1.4 (m/s) from Palestinian code

And the window is sliding ,then:

L = 2[(1.4*2)+(1.2*3)]

=12.8 m

$V_f = 0.43*12.8\ [0.613(1*0.94*1.4)^2]^{2/3}$

$= 5.72\ m^3/h$

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

$v_o = 0.877\ m^3/kg$

hi = 47.8 kJ/kg

ho = 65 kJ/kg

The total heat loss due to infiltration is calculated by equation (2.12) as follows:

Through window

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

$$= \frac{5.72}{0.877} * (65-47.8)$$

= 0. 112 kW

Through door in

L =2*(0.9+2)

=3.6 m

$V_{f\ door}$ = 0.43*3.6* $[0.613(1*0.94*1.4)^2]^{2/3}$

=1.611 m^3/h

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

$$= \frac{1.611}{0.877} * (65-47.8)$$

= 0.031 kW

$Q_{inf} = Q_{inf,\ door} + Q_{inf,w}$ (2.13)

=0.031 + 0.112

= 0.143 kW.

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

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

$Q_{oc.} = Q_{sensible} + Q_{latent}$ (2.27)

$Q_{sensible}$ = heat gain sensible × No. of people × $(CLF)_{oc.}$ (2.28)

Where:

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

heat gain sensible = 70W very light work … from table(A-21)

No. of people = 2

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

$Q_{sensible} = 70 \times 2 \times 0.84 = 0.117$ kW

Q_{latent} = heat gain latent × No. of people (2.29)

Heat gain latent = 30W… very light work from Table (A-21)

$Q_{latent} = 30 \times 2$

= 0.060 kW

Q oc. = 0.117 +0.060

= 0.237 kW.

Heat gain due to ventilation (Q vent.):

The ventilation is used for maintaining a healthy indoor air by introducing a fresh air from outside of the building. And this kind of heat gain can be calculated by using the following equations:

Ventilation air requirements for this room = 7.5 $L/s/m^2$ …..from table (A-26)

the rate of ventilation = (Ventilation air requirements) *(area) (2.30)

= (0.0075) (15.6)

=0.117 m^3/s

Mass flow rate of ventilation air = rate of ventilation / (v_o) (2.31)

= 0.117/0.877

=0.1334 kg/s.

$Q_{inv} = (m) (h_{out} - h_{in})$ (2.32)

= (0.1334) *(65-47.8)

= 2.2945 kW

$Q_{Tot} = Q_{ceiling} + Q_{wall\ un} + Q_{wall\ ex} + Q_{Glass} + Q_{Lt} + Q_{oc.} + Q_{inv}$ (2.33)

=0.194 + 0.084 +0.209+ 0.3516 + 0.296 + 0.237 + 2.294

=3.665 kW

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

Q tot = 3.665 *1.1 = 4.031 kW.

2.7.3 Total Heating and Cooling load for all spaces:

The total cooling and heating load for all spaces and use the rivet software to calculate the load in table (2.5).

Table (2.5): Heating and Cooling Load of each Room(W)

floor number	Cooling load (kW)	Heating load(kW)
Ground floor	99.9	53.46
First floor	99.96	53.3
Second floor	94.54	50.08
Third floor	94.2	49.9
Fourth floor	98.02	52.2
Fifth floor	97.74	51.6

2.8 Sample room summary using Revit:

Table (2.6): Total Cooling and Heating load calculations for the sample room by Rivet software

Space Summary - 103 Space

Back to summary of spaces

Inputs	
Area (m^2)	16
Volume (m^3)	43.65
Wall Area (m^2)	38
Roof Area (m^2)	16
Door Area (m^2)	4
Partition Area (m^2)	0
Window Area (m^2)	3
Skylight Area (m^2)	0
Lighting Load (W)	0
Power Load (W)	168
Number of People	2
Sensible Heat Gain / Person (W)	73
Latent Heat Gain / Person (W)	59
Infiltration Airflow (L/s)	14.8
Space Type	Single Family (inherited from building type)
Calculated Results	
Peak Cooling Load (W)	**4,135**
Peak Cooling Sensible Load (W)	4,110
Peak Cooling Latent Load (W)	25
Peak Cooling Airflow (L/s)	244.2
Peak Heating Load (W)	**1,668**
Peak Heating Airflow (L/s)	125.0

Chapter Three: VRF System

3.1 Introduction

The primary function of all air-conditioning systems is to provide thermal comfort for building occupants. There are a wide range of air conditioning systems available, starting from the basic window-fitted units to the small split systems, to the medium scale package units, to the large chilled water systems, and currently to the variable refrigerant flow (VRF) systems. Variable refrigerant flow (VRF) is an air conditioning system configuration where there is 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 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 [5].

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 [4].

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 [6].

3.2 Variable refrigerant flow description

VRF systems are similar to the multi split systems, which connect one outdoor section to several evaporators. 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 [8].

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 [9].

3.3 Advantages of a VRF system

- **Comfort:**

Comfort by providing “even” cooling or heating when and where it is required. Multiple Types of fan coils and sizes provides design flexibility for different applications. Design software Simplifies selecting and piping design.

- **Installation Advantages:**

VRF systems are lightweight and modular. Each module can be transported easily and fits into a standard elevator.

- **Design Flexibility:**

A single condensing unit can be connected to many indoor units of varying capacity (e.g., 0.6 to 4 tons [2.2 to 14 kW]) and configurations (e.g., ceiling recessed, wall mounted, floor console). Current products enable up to 20 indoor units to be supplied by a single condensing unit. Modularity also makes it easy to adapt the HVAC system to expansion or reconfiguration of the space, which may require additional capacity or different terminal units.

- **Maintenance and Commissioning:**

VRF systems with their standardized configurations and sophisticated electronic controls are aiming toward near plug-and-play commissioning.

- **Energy Efficiency:**

The energy efficiency of VRF systems derives from several factors. The VRF essentially eliminates duct losses, which are often estimated to be between (10-20) percent of total airflow in a ducted system. VRF systems typically include two to three compressors, one of which is variable speed, in each condensing unit, enabling wide capacity modulation. This approach yields high part-load efficiency, which translates into high seasonal energy efficiency, because HVAC systems typically spend most of their operating hours in the range of 40% to 80% of maximum capacity.

3.4 Types of VRF

3.4.1 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 [7].

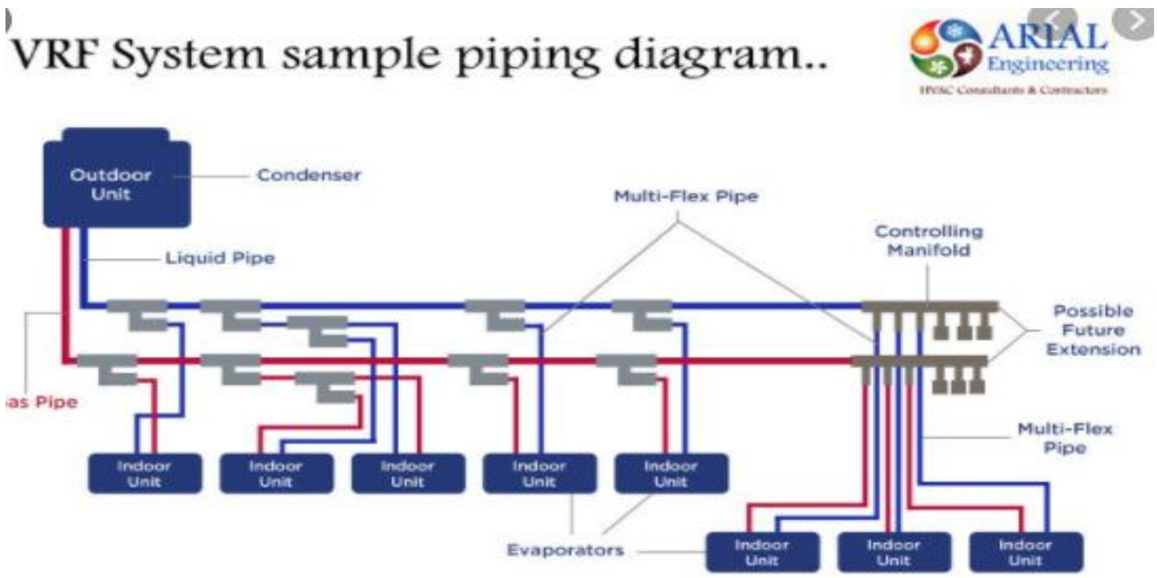
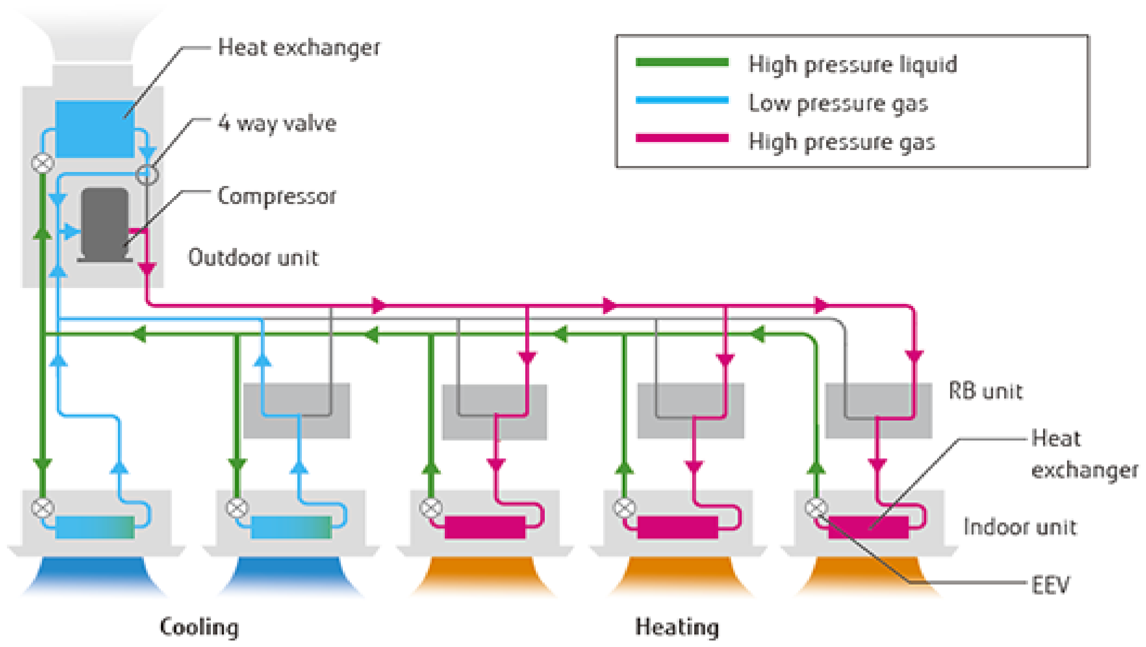


Figure (3.1): VRF heat pump systems

3.4.2 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 [7].



3.5 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 [6].

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.

3.6 Components of VRF systems

3.6.1 Outdoor Units

The outdoor unit contains a heat pump, A heat pump is a machine that by reversing its Refrigeration cycle can provide heating instead of cooling. Because a heat pump uses refrigerant It can upgrade the heat in air at even -15ºC to a usable heat source to heat buildings.

Figure (3.3): Outdoor units

3.6.2 Indoor units

The indoor units were developed to be highly efficient, compact, low noise, and to have user Friendly operation. Care was also taken with the design to make that go well with the interior Decoration and tube easy to install and maintain. Further, a variety of options are available to Achieve an air conditioning environment that is more desirable from the user's perspective.

VRF indoor unit Types:

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

Figure (3.4): Indoor units

3.6.3 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 (or Refnits Joints): 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 are more than two branches lose together.

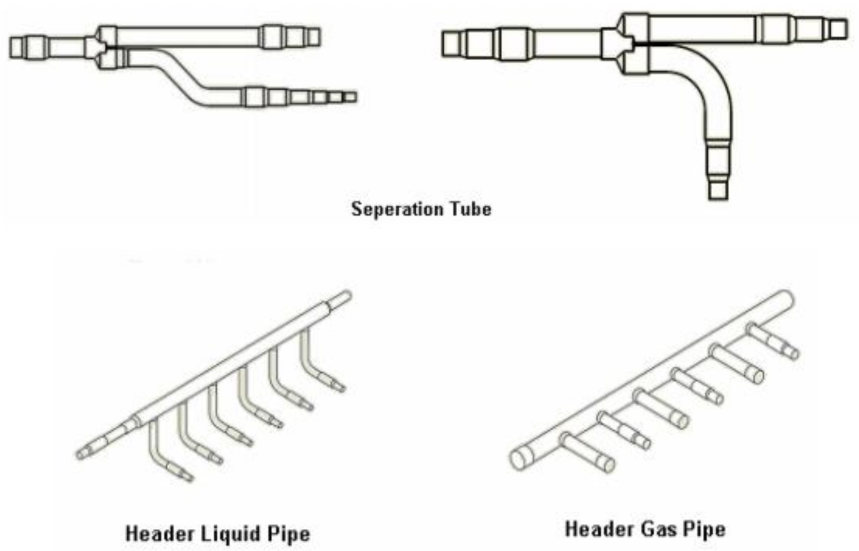


Figure (3.5): Indoor units piping network

3.6.4 Expansion valve

Thermostatic Expansion Valves (TXV) is very important part to control the flow in vrv System As the thermostatic expansion valve regulates the rate at which liquid refrigerant flows into the evaporator, it maintains a proper supply of refrigerant by matching this flow rate against How quickly the refrigerant evaporates (boils off) in the evaporator coil.

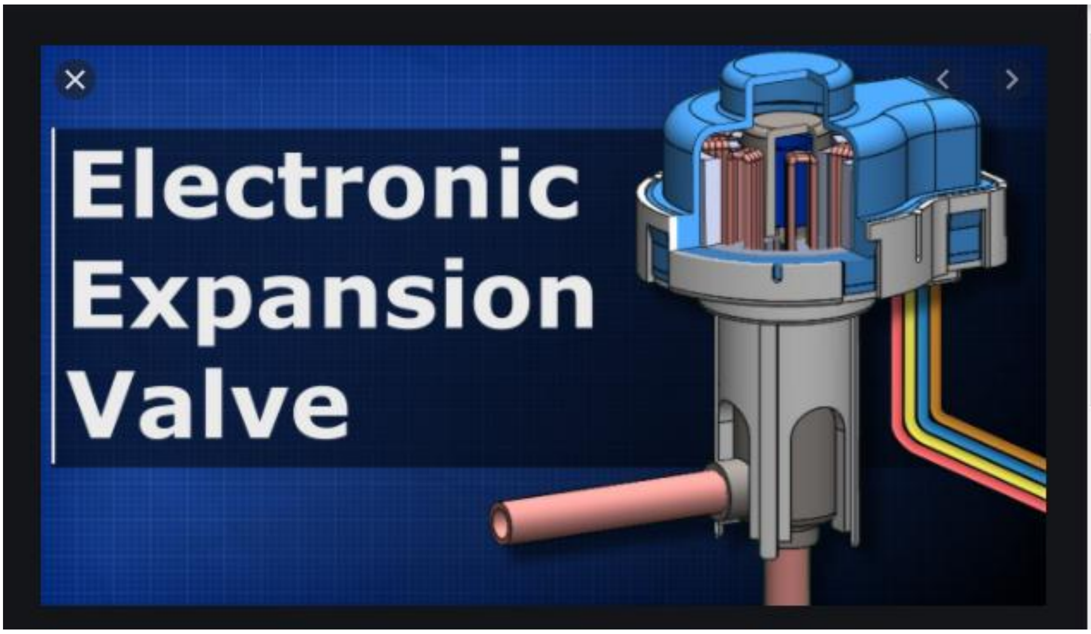


Figure (3.6): Electronic expansion valve EEV

3.7 Design considerations

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. 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 feeding pipes that feed each indoor unit. The maximum allowable length varies among different manufacturers; however, the general guidelines are as follows:

- 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.

Note: The longer the lengths of refrigerant pipes, the more expensive the initial and operating costs.

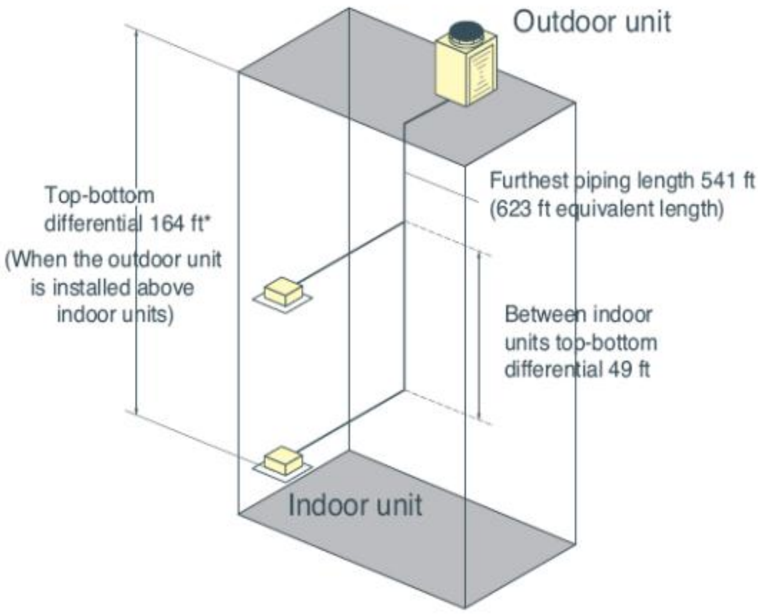


Figure (3.7): Design limits in VRF system

- Building load profile: when selecting a VRF system for a new or retrofit application, the following assessment tasks should be carried out [26]:
    1. 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.
    2. 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.

3.8 Selection units

1- Indoor units:

The selection of the indoor units depends on the cooling and heating capacity of the space. After calculation of the loads and selecting the type of the indoor unit (wall mounted, cassette …) the actual capacities of the unit is to be the same as the heating and cooling loads of the space. The actual capacity is different from the nominal capacity of the unit and that depend on the design condition of the system.

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

Figure (3.8): 4-way cassettes unit

Figure (3.9): Wall mounted

2- Outdoor units:

The selection of the outdoor unit depends on the cooling and heating capacity of all the related indoor units. After selecting all the indoor units and adding the actual capacities then choosing capacity ratio = 1.3 for the system.

Outdoor nominal capacity = (sum (nominal capacity IDU))/CR (3.1)

Note: Selection of each unit done by using the software DVM.

Table (3.1): Selection indoor unit and outdoor module

Floor	Outdoor Module		Indoor unit		
	code	hp.	type	number	code
Ground floor & First floor	AM620HXVAGH1TK	62	4-way cassettes	10	AM056FNNDEH/TK
				8	AM036FNNDEH/TK
				4	AM071FN4DEH/TK
				2	AM045FNTDEH/TK
			Wall mounted	4	AM036KNQDEH/TR
				4	AM056KNQDEH/TR
				4	AM022KNQDEH/TR
				8	AM045KNTDEH/TR
Second floor & Third floor	AM580HXVAGH2TK	58	4-way cassettes	4	AM056FNNDEH/TK
				6	AM036FNNDEH/TK
				4	AM071FN4DEH/TK
				6	AM045FNTDEH/TK
				4	AM028FNNDEH/TK
			Wall mounted	2	AM036KNQDEH/TR
				4	AM056KNQDEH/TR
				4	AM022KNQDEH/TR
				8	AM045KNTDEH/TR
				2	AM028KNQDEH/TR
Fourth floor & Fifth floor	AM600HXVAGH2TK	60	4-way cassettes	10	AM056FNNDEH/TK
				10	AM036FNNDEH/TK
				4	AM071FN4DEH/TK
			Wall mounted	2	AM036KNQDEH/TR
				4	AM056KNQDEH/TR
				8	AM045KNTDEH/TR
				2	AM028KNQDEH/TR
				4	AM022KNQDEH/TR

3.9 Selecting refrigerant piping

The piping system is depend on the amount of refrigerant passing throw the pipe and that depend on the actual load of the unit connected to the pipe.

In this project used Copper Pipes to Connect between all indoor units and all outdoor units in the same system and used T- Joints and Separation Tubes (Refnits Joints).
Sizing the pipe network using the nominal capacity of the units.

Table (3.2): Pipe size for the outdoor unit [27]

Outdoor module	Outdoor unit	Pipe size unit		Pipe size module	
		Liquid (in)	Gas (in)	Liquid (in)	Gas (in)
AM620HXVAGH1TK	AM220FXVAGH/TK	5/8"	1 1/8"	7/8"	2 1/8"
	AM220FXVAGH/TK	5/8"	1 1/8"		
	AM180FXVAGH/TK	1 1/8"	1 1/8"		
AM580HXVAGH2TK	AM260HXVAGH/TK	3/4"	1 3/8"	3/4"	1 5/8"
	AM200FXVAGH/TK	5/8"	1 1/8"		
	AM120FXVAGH/TK	1/2"	1 1/8"		
AM600HXVAGH2TK	AM260HXVAGH/TK	3/4"	1 3/8"	3/4"	1 5/8"
	AM220FXVAGH/TK	5/8"	1 1/8"		
	AM120FXVAGH/TK	1/2"	1 1/8"		

Table (3.3): Pipe size for the (Y & H) - joint

Floor	number of Y-joint	Y-joint model
Ground floor	1	MXJ-YA4119M
	2	MXJ-YA2815M
	1	MXJ-YA2812M
	6	MXJ-YA2512M
	7	MXJ-YA1509M
	2	MXJ-HA2512M
First floor	1	MXJ-YA4119M
	2	MXJ-YA2815M
	1	MXJ-YA2812M
	6	MXJ-YA2512M
	7	MXJ-YA1509M
	2	MXJ-HA2512M
Second floor	1	MXJ-YA3419M
	1	MXJ-YA2815M
	1	MXJ-YA2812M
	6	MXJ-YA2512M
	8	MXJ-YA1509M
	2	MXJ-HA2512M
	1	MXJ-YA3419M
	1	MXJ-YA2815M
	2	MXJ-YA2812M

Third floor	5	MXJ-YA2512M
	7	MXJ-YA1509M
	2	MXJ-HA2512M
Fourth floor	1	MXJ-YA4119M
	2	MXJ-YA2815M
	1	MXJ-YA2812M
	6	MXJ-YA2512M
	7	MXJ-YA1509M
	2	MXJ-HA2512M
Fifth floor	1	MXJ-YA4119M
	2	MXJ-YA2815M
	7	MXJ-YA2512M
	7	MXJ-YA1509M
	2	MXJ-HA2512M

3.10 Ventilation for the parking

In addition to air conditioning and to meet the comfort requirements automatic ventilation is needed in parking , the air flow of the fans is calculated after getting the amount of fresh air needed to each space from ASHRAE code.

Table (3.4): Ventilation for the parking

Space type	Space area m^2	Space area ft^2	Exhaust Rate cfm/ ft^2	Air flow (cfm)
Parking	498	5360	0.75	4020
kitchen	33	355	2 (change per hour)	110

Chapter Four: Plumbing System

4.1 Introduction

The plumbing and sanitary system is an essential part of every house or building. Proper planning and designing of plumbing system are crucial as it takes care of the hygiene requirements of the occupants.

Basic modern plumbing fixtures include toilets, urinals, sinks, bathtubs, showers, laundry tubs, and drinking fountains. In addition, hospitals, laboratories, and industrial buildings require many specialized types of fixtures. Appliances that connected to a plumbing system include dishwashers and laundry washers. Most of these fixtures and appliances require both hot and cold water. Heaters using gas, electricity, boiler water, oil, steam, or solar energy can generate hot water. [10]

Fixtures today are made of impervious materials such as vitreous china, enameled cast iron or steel, stainless steel, and plastic. Piping materials include cast iron, steel, brass, copper, stainless steel, aluminium, plastic, vitrified clay (tile), and concrete. [11]

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 use to this building is Down feed system.

The design procedure is as follows:

Step1: Determine if the suitable system is up-feed or down-feed.
Step2: Determine the number of risers needed and their location.
Step3: Calculate the total water supply fixture unit (WSFU), and then convert to gallon per minute (gpm).
Step4: Determine the minimum flow pressure for the critical fixture unit (fu).
Step5: Calculate the total static head.
Step6: Calculate the pipe friction and equivalent length of the system.
Step7: Use the chart to determine the recommended pipe size.

4.2.2 Calculation of water supply system

4.2.2.1 Calculation of (WSFU) system

The total amount of water required for the building calculated by using the water supply fixture unit technique (WSFU). This technique is used because there are a large number of fixture unit in the system and this makes the technique more accurate.

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

Note: The residential building Contain 24 riser, each riser reaches only one apartment and the flow is equal in all the risers.

Table (4.1): Number of fixture units for riser

Fixture	Lavatory private	Shower head	Water closet private	Kitchen Sink
No. fixture	2	1	2	1

Table (4.2): Fixture units load for riser

Fixture type	No. FU	WSFU	Total WSFU
Water closet private	2	3	6
Lavatory private	2	1	2
Shower head	1	2	2
Kitchen sink	1	2	2
Total	6	--	12

We use the Table (4.2) for estimating demand to calculate the required amount of water:

$$10 \text{ WSFU} \rightarrow 8 \text{ gpm}$$

$$12 \text{ WSFU} \rightarrow X \text{ gpm}$$

$$15 \text{ WSFU} \rightarrow 11 \text{ gpm}$$

$$X = 9.2 \text{ gpm}$$

Table (4.3): Total WSFU and gpm for riser

Riser	Total WSFU	Total gpm
Riser 1	12	9.2
Riser 2	12	9.2
Riser 3	12	9.2
. . . . .	. . . . .	. . . . .
Riser 24	12	9.2
Total	288	220.8

4.2.2.2 Calculation of hot water system

A special boiler will be used in every apartment within the residential building.

Daily consumption = 2 bedrooms x 2 (person/bedroom) = 4 persons

2-person x 50 (lt/day/person) = 100 lt/day, for the first two persons

(4 – 2) person x 30 (lt/day/person) = 60 lt/day, for the other persons

The total human demand = 100 + 60 = 160 lt/day

160 (lt/day) x 0.2641 gal/lt = 42 (gal/day)

Maximum hourly demand (portion of daily use) = (1/7) x42 = 6 gal/h

Duration of peak load = 4 hr

Total peak load = 4 x 6 gal/hr = 24 gal

Storage capacity = 1/5 of daily use = 1/5 x 42= 8.4 gal

So, we choose 8.4/0.2641 = 31.8 lt. ≈ 100 lt (storage tank available in market)

Heating capacity (recovery rate) = 1/7 of daily use= (1/7) x 42 = 6 (gal/h)

As a check, the required recovery:

Required recovery = [Total peak load- (¾) x (storage capacity)] / (duration)

= [(24-(3/4) x 8.4] / 4 = 4.5 (gal/hr) < 6 so it is sufficient.

4.2.2.3 Pipe sizing calculation

The system is divided to 24 risers for water and the system that will use to this building is Down feed system.

Static head = Friction head + 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 fixture pressure.

By friction head loss method:

Static pressure and friction head calculation on all floors:

Friction head = Static head – Flow pressure

Flow pressure = 8 psi

Table (4.4): Static and friction head

Number of floor	Height (m) riser + tank	Height (ft) riser + tank	Static head (psi)	Friction head (psi)
Ground floor	22.2	72.8	31.5	23.5
First floor	18.75	61.5	26.6	18.6
Second floor	15.3	50.2	21.7	13.7
Third floor	11.85	38.9	16.8	8.8
Fourth floor	8.4	27.6	12	4
Fifth floor	4.95	16.2	7	--

Note: 7 psi is less than 8psi (min. flow pressure), so in this case we need a pump for apartments existing in fifth floor to overcome the friction head loss and provide a pressure of 8psi for the fixture.

Hydraulic performance sheet

Part number	**290022151020M**
Description	**DPVE 2/2 B~Thread G 6/4~0,37kW 1x230V~50Hz 2P~~IEC 71-1~Fixed Ca SiC EPDM**

Search criteria	
Medium to be pumped	Water
Flow	9.2 ImpGPM
Pressure	10 PSI

Actual duty point	
Flow	9.94 ImpGPM
Pressure	11.7 PSI
NPSH	10.3 ft
Efficiency	47.2 %
Power	0.17 hp
Frequency	50Hz

Figure (4.1): Pump overcome the friction

Equivalent length = length pipe * 1.5 (4.2)

Table (4.5): Pipe sizing for water riser

Number of Floor	Number of riser	Flow (gpm)	Equivalent length (m)	Equivalent length (ft)	Friction head (psi/100 ft)	Pipe size (in)	Velocity (fps)
Ground floor	1	9.2	48	158	14.9	0.75"	6.2
	2	9.2	52.5	172	13.7	0.75"	6.2
	3	9.2	69	226	10.4	0.75"	5.7
	4	9.2	57	187	12.6	0.75"	6.1
First floor	5	9.2	45	148	12.5	0.75"	6.1
	6	9.2	50.2	165	11.3	0.75"	5.8
	7	9.2	58.5	192	9.7	0.75"	5.8
	8	9.2	54.7	179	10.9	0.75"	5.7
Second floor	9	9.2	49	161	8.5	0.75"	5.2
	10	9.2	48.7	160	8.6	0.75"	5.2
	11	9.2	56.2	184	7.5	1"	5.2
	12	9.2	55.5	182	7.5	1"	5.2
Third floor	13	9.2	45	147	6	1"	5
	14	9.2	51	167	5.3	1"	4.5
	15	9.2	47	154	5.7	1"	4.7
	16	9.2	54	177	5	1"	4.3
Fourth floor	17	9.2	48	157	2.5	1.25"	3.3
	18	9.2	55.5	182	2.2	1.25"	3.1
	19	9.2	44.2	145	2.8	1"	3.4
	20	9.2	52.5	172	2.3	1.25"	3.1
Fifth floor	21	9.2	51	167	6.4	1"	5.2
	22	9.2	58.5	192	5.6	1"	4.8
	23	9.2	41.2	135	7.9	0.75"	5.5
	24	9.2	54	177	6	1"	4.8

4.3.1 Main pipe sizing riser calculation

The building Contains two main risers to transport water from the well to the rooftop reservoirs.

By the head loss method friction, the Main two riser's diameters will be designed:

Pump pressure = 40.9 psi

Pump pressure = Static head + Friction head

40.9 psi = (80 ft * 0.433) + Friction head

Friction head = 6.3 psi

Length pipe (m) = 35

Equivalent length (m) = 35*1.5 =52.5 m = 172 ft

Friction head (psi/100 ft) = 3.7 psi

Table (4.6): Main pipe sizing riser

Main riser	Flow (gpm)	Friction head (psi/100 ft)	Pipe size (in)	Velocity (fps)
Riser 1st	(9.2*12) = 110	3.7	2.5"	7
Riser 2nd	(9.2*12) = 110	3.7	2.5"	7

4.3.2 Pump selection

The pump selected with main pressure provides 40.9 psi and give flow of 111 gpm.

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

Hydraulic performance sheet

Part number	**290252352020V**
Description	**DPVF 25/2 B~Flanged NW65~4kW 400/690V~50Hz 2P~IE3 v2~IEC 112M~Easy Access Ca SiC EPDM**

Search criteria	
Medium to be pumped	Water
Flow	110 ImpGPM
Pressure	40 PSI

Actual duty point	
Flow	111 ImpGPM
Pressure	40.9 PSI
NPSH	12.1 ft
Efficiency	73.5 %
Power	4.32 hp
Frequency	50Hz

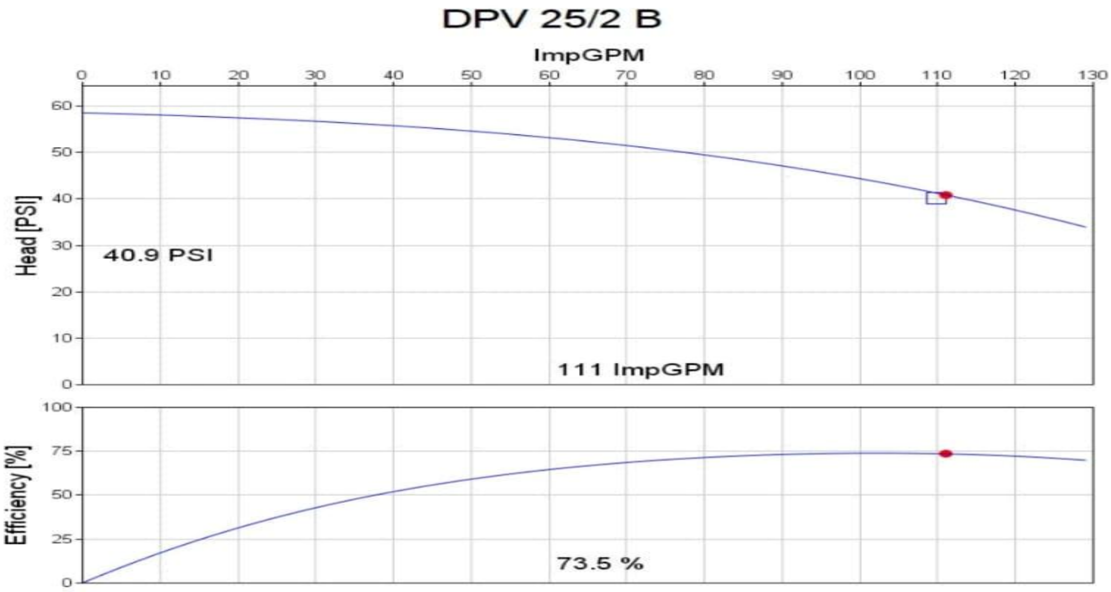


Figure (4.2): Pump data for Main riser

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:

1. Sanitary drainage
2. Storm drainage

4.4.1 Drainage system components

The main components of drainage system are:

1. Fixture units
2. Trap
3. Clean out
4. Drainage pipe
5. Stack and vent pipes
6. Manholes
7. Septic tank or municipal sewage system
8. Accessories

4.4.2 Sanitary drainage

4.4.2.1 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 (A (4.5), A (4.6) A (4.7)).

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:

- Calculation of the number of DFU for each branch by using Table A (4.4)
- Calculation of the number of DFU for each stack
- Choosing the branch pipe diameter by using Table A (4.5)
- Choosing the stack pipe diameter by using Table A (4.6)
- Comparing the stack pipe diameter with branch diameter
- Choosing the building drain pipe diameter by using Table A (4.6)

- To achieve the recommended velocities which are 3 fps in building drain, it will be chosen the slope and flow velocity in building drain by using Table A (4.7).

Table (4.7): Sizing for the first stack

Floor	Plumbing Fixture type	Stack		Branch	
		Total DFU	Diameter (in)	Total DFU	Diameter (in)
Fifth	Water closet & Lavatory	5	4	5	4
Fourth	Water closet & Lavatory	10	4	5	4
Third	Water closet & Lavatory	15	4	5	4
Second	Water closet & Lavatory	20	4	5	4
First	Water closet & Lavatory	25	4	5	4
Ground	Water closet & Lavatory	30	4	5	4

Table (4.8): Sizing for the second stack

Floor	Plumbing Fixture type	Stack		Branch	
		Total DFU	Diameter (in)	Total DFU	Diameter (in)
Fifth	Water closet & Lavatory & Shower	7	4	7	4
Fourth	Water closet & Lavatory &	14	4	7	4

	Shower				
Third	Water closet & Lavatory & Shower	21	4	7	4
Second	Water closet & Lavatory & Shower	28	4	7	4
First	Water closet & Lavatory & Shower	35	4	7	4
Ground	Water closet & Lavatory & Shower	42	4	7	4

Floor	Plumbing Fixture type	**Stack**		**Branch**	
		Total DFU	Diameter (in)	Total DFU	Diameter (in)
Fifth	Kitchen sink	2	4	2	4
Fourth	Kitchen sink	4	4	2	4
Third	Kitchen sink	6	4	2	4
	Kitchen sink	8	4	2	4

Table (4.9): Sizing for the third stack

Second					
First	Kitchen sink	10	4	2	4
Ground	Kitchen sink	12	4	2	4

Note: each apartment contains 3 stacks, all of which have the same of dfu value.

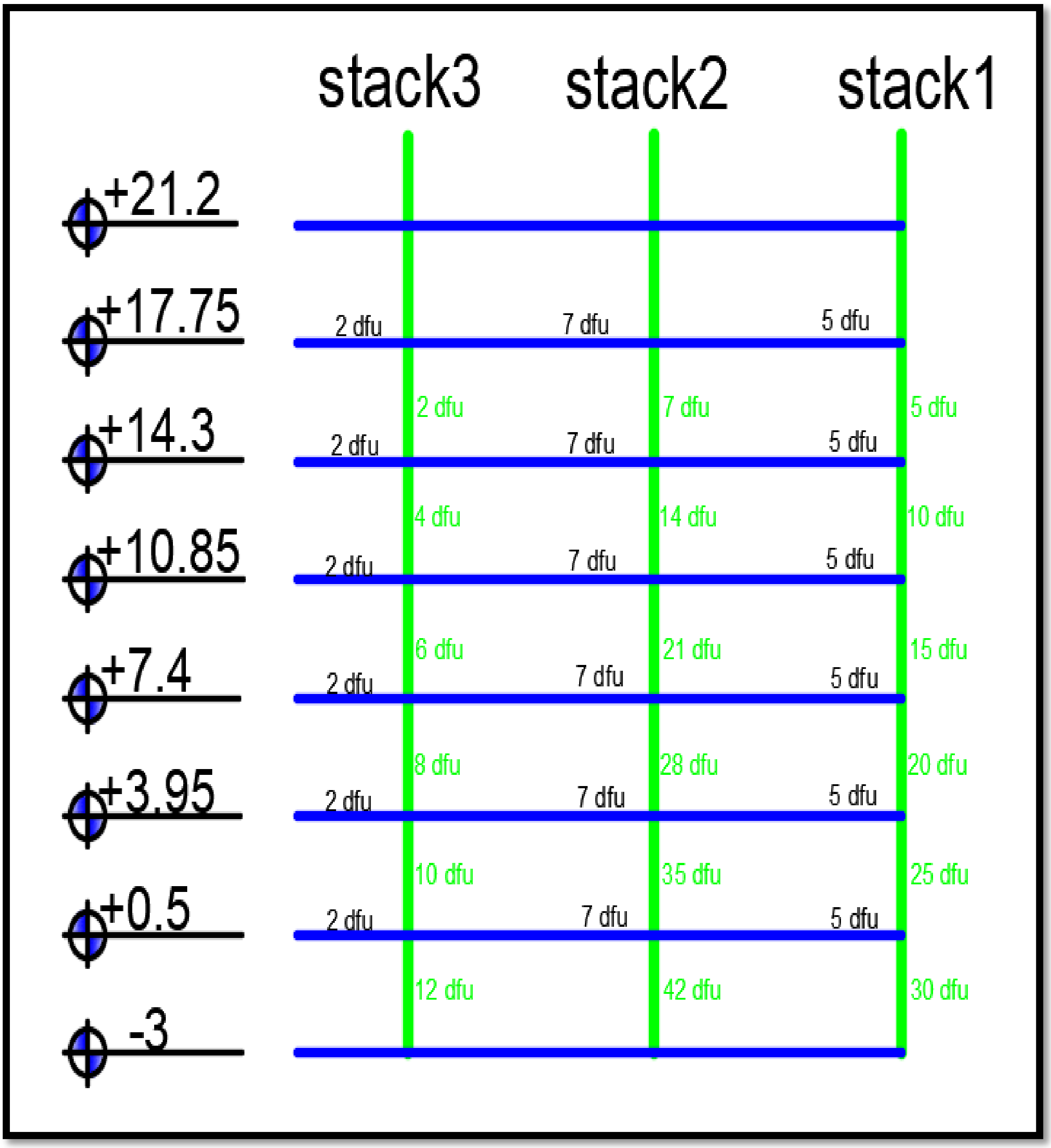


Figure (4.3): 1, 2, 3 stacks

4.5 Storm drainage

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 falls 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 (100-150) m^2 from roof area needs one 4” FD.

Chapter Five: Fire Fighting System

5.1 Overview

5.1.1 Firefighting triangles

Fire: is the rapid oxidation of a material in the exothermic chemical process of combustion, releasing heat, light, and various reaction products. Slower oxidative processes like rusting or digestion are not included by this definition.

There are three (3) components required for combustion to occur:

- Fuel – to vaporize and burn
- Oxygen – to combine with fuel vapor
- Heat – to raise the temperature of the fuel vapor to its ignition temperature

This results in a chemical chain reaction which starts a fire removing any of these elements will extinguish the fire. [12]

The following is the typical "fire triangle", which illustrates the relationship between these three components:

Figure (5.1): Fire triangle

Fire extinguishing system is designed to be built in partnership with Architect engineer to specialize in acting fire safety, Electrical engineer to specialized in fire alarm and Mechanical engineer it is specialized in firefighting.
Also, in design for firefighting system, the main reference is (NFPA) code, national fire protection association. [13]

Founded in 1896, the National Fire Protection Association (NFPA) is a global, non-profits organization devoted to eliminating death, injury, property and economic loss due to fire electrical and related hazards , NFPA membership totals more than 60,000 individuals around the world. [14]

5.1.2 Classifications of Fire:

Not all fires are the same. Per NFPA 10, burning may be classified into one or more of the following fire classes and the firefighting system depends on the type of the fire

Class A

Class A fires are fires in ordinary combustibles such as wood, paper, cloth, rubber, and many plastics.

Class B

Class B fires are fires in flammable liquids such as gasoline, petroleum greases, tars, oils, oil-based paints, solvents, alcohols. Class B fires also include flammable gases such as propane and butane. Class B fires do not include fires involving cooking oils and grease.

Class C

Class C fires are fires involving energized electrical equipment such as computers, servers, motors, transformers, and appliances. Remove the power and the Class C fire becomes one of the other classes of fire.

Class D

Class D fires are fires in combustible metals such as magnesium, titanium, zirconium, sodium, lithium, and potassium.

Class K

Class K fires are fires in cooking oils and greases such as animal and vegetable fats.

5.1.3 Classifications of hazard

In accordance with NFPA, areas are typically classified as being light (low) hazard, ordinary (moderate) hazard, or extra (high) hazard.

Light (low) hazard areas are locations where the quantity and combustibility of Class A combustibles and Class B flammables is low. In these areas, expected fires have relatively low rates of heat release. Light hazard areas may include offices, classrooms, meeting rooms etc.

Ordinary (moderate) hazard areas are locations where the quantity and combustibility of Class A combustible materials and Class B flammables is moderate. Fires with moderate rates of heat release are expected in these areas. Ordinary hazard locations could be offices, malls, light manufacturing or research operations, parking garages, workshops, or maintenance/service areas.

Extra (high) hazard areas are locations where the quantity and combustibility of Class A combustible material is high or where high amounts of Class B flammables are present. Quickly developing fires with high rates of heat release are expected. These locations could be sites for cars repair, aircraft and boat servicing, painting, dipping, and coating, storage areas (tanks, containers etc.).

5.2 General firefighting equipment:

Firefighting systems and equipment vary depending on the age, size, use and type of building construction. A building may contain some or all of the following features:

1) Fire hose cabinet
2) Fire extinguishers
3) Fire hydrant systems
4) Automatic sprinkler systems

5.2.1 Fire hose cabinet:

Fire hose cabinet are provided for use by occupants of the Building as a 'first attack' firefighting measure but may, in some instances, also be used by firefighting is distributed through the floors according to the NFPA code and starting by the exit of the stairs and the next cabinet is after 30m distance from the previous one and that depends on the length of the hose.

Fire hose cabinet are intended to give easy access through the fire hose from water supply in order to stamp out fires. Fire hose cabinet typically come in three main types: grounding, booster and large diameter, all of which feature an increase hose capacity than typical hose reels. [34]

Generally made from canvas or other synthetic materials, fire hoses come in multiple types as well including booster hoses or collapsible hoses, also known as flat hoses. Fire hoses are intended for use when fire extinguishers fail. [13]

The selected type of cabinets is combined with fire extinguisher in the same cabinet as follows:

Figure (5.2): Fire hose cabinet & extinguisher

5.2.2 Fire extinguishers:

Is an active fire protection device used to extinguish or control small fires, often in emergency situations? It is not intended for use on an out-of-control fire, such as one which has reached the ceiling.

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. [13]

The main types of fire extinguishers:

Table (5.1): Fire extinguisher types

Extinguishing Agent	Principle Use
Water	wood and paper fires - not electrical
Foam	flammable liquid fires - not electrical
Carbon dioxide	electrical fires
Dry Chemical	flammable liquids and electrical fires
Wet chemical	fat fires - not electrical
Special Purpose	various (e.g., metal fires)

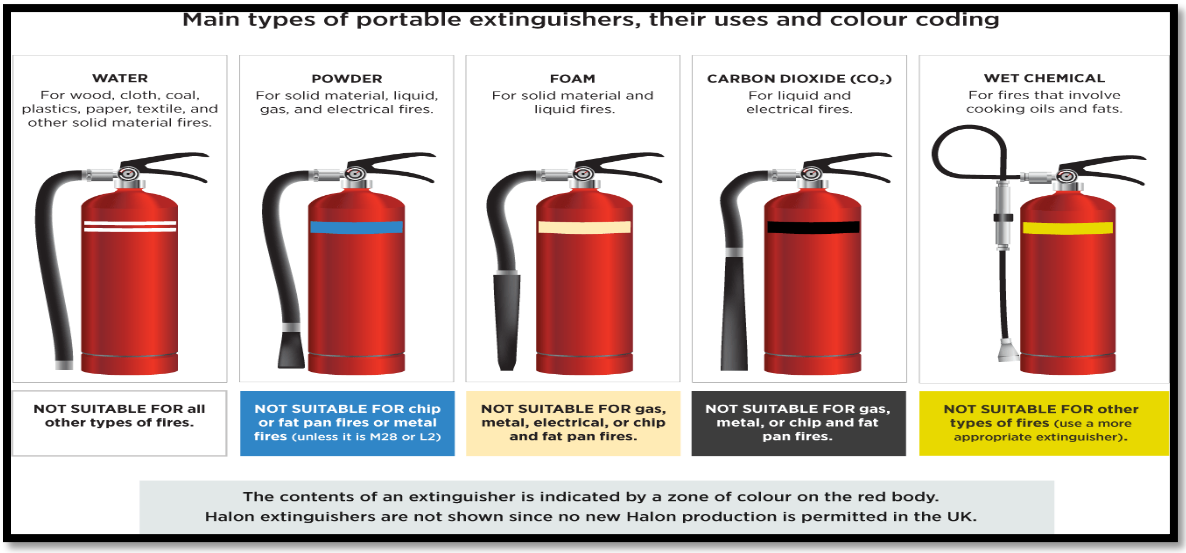


Figure (5.3): Fire extinguisher types

5.2.3 Fire hydrant systems:

Is connection point in the street at front of the Building by which firefighters connect into a water supply to use it in the firefighting process.

It is connected to the firefighting network of the building and have a water flow of 250 gpm.

Fire hydrants are for the sole use of trained fire fighters (which includes factory fire fighting teams) Because of the high pressures, available serious injury can occur if untrained persons attempt to operate the equipment connected to such installations. Fire hydrant systems sometimes include ancillary parts essential to their effective operation such as pumps, tanks and fire service booster connections. These systems must be maintained and regularly tested if they are to be effective when needed. [13]

Figure (5.4): Fire hydrant

5.2.4 Automatic sprinkler systems

Time is essential in the control of fire. Automatic sprinkler systems are one of the most reliable methods available for controlling fires. Today's automatic fire sprinkler systems offer state of the art protection of life and property from the effects of fire. Sprinkler heads are now available which are twenty times more sensitive to fire than they were ten years ago. [15]

There are four basic types of sprinkler systems:

1- A wet pipe system is by far the most common type of sprinkler system. It consists of a network of piping containing water under pressure. Automatic sprinklers are connected to the piping such that each sprinkler protects an assigned building area. The application of heat to any sprinkler will cause that single sprinkler to operate, permitting water to discharge over its area of protection.

2- A dry pipe system is similar to a wet system, except that water is held back from the piping network by a special dry pipe valve. The valve is kept closed by air or nitrogen pressure maintained in the piping. The operation of one or more sprinklers will allow the air pressure to escape, causing operation of the dry valve, which then permits water to flow into the piping to suppress the fire. Dry systems are used where the water in the piping would be subject to freezing.

3- A deluge system is one that does not use automatic sprinklers, but rather open sprinklers. A special deluge valve holds back the water from the piping, and is activated by a separate fire detection system. When activated, the deluge valve admits water to the piping network, and water flows simultaneously from all of the open sprinklers. Deluge systems are used for protection against rapidly spreading, high hazard fires.

4- A pre-action system is similar to a deluge system except that automatic sprinklers are used, and a small air pressure is usually maintained in the piping network to ensure that the system is air tight. As with a deluge system, a separate detection system is used to activate a deluge valve, admitting water to the piping. However, because automatic sprinklers are used, the water is usually stopped from flowing unless heat from the fire has also activated one or more sprinklers.

The selected type in the Building is the wet pipe system, because there is no possibility of water freezing in the pipes.

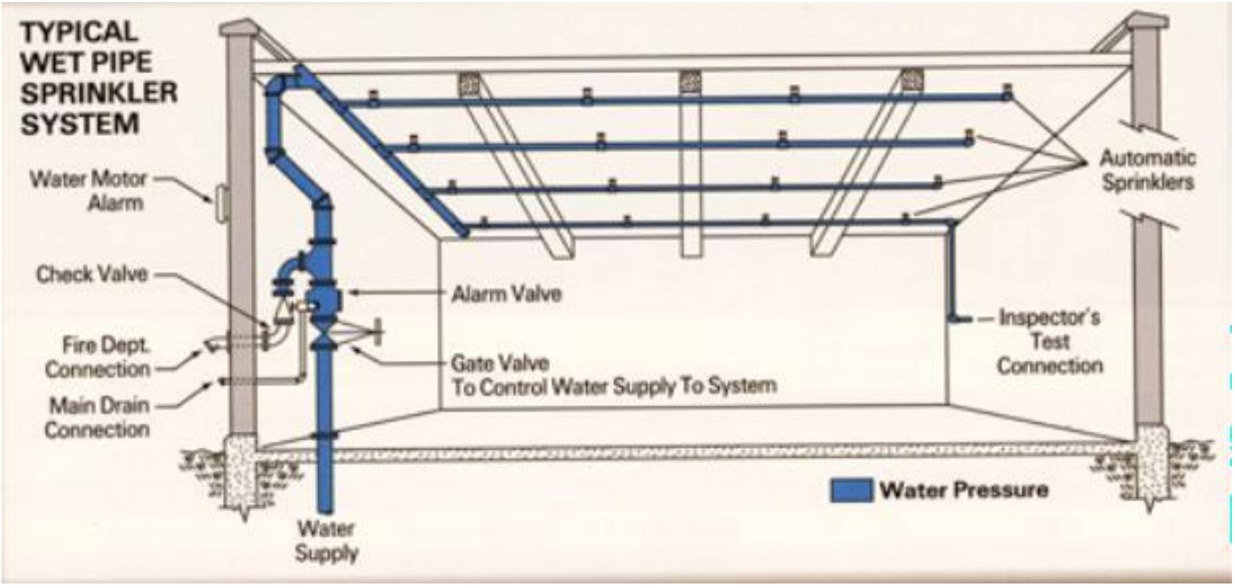


Figure (5.5): wet pipe system

5.2.5 Components of the system:

- **Sprinkler**

Wide range of sprinklers are available and there are two main classifications for them. The first one is the color classification. Every sprinkler bulb has a color and that color identifies the working temperature of the sprinkler. Once the temperature reaches that limit the bulb explode and the water is sprayed out of it and start attacking the fire.

The second classification is according to the location of the sprinkler and there are three main types of sprinkler. first one is pendent sprinkler which located in the false ceiling of the hotel the second type is upright which used in case of no ceiling in the place such like parking the third on its side wall sprinkler which used in case in the ceiling is more than 3 m high.

Operating Temperature Optional

Nozzle Nominal Working Temperature	Max Environment Temperature	Crystal Ball Color Code
57℃	27℃	Orange
68℃	38℃	Red
79℃	49℃	Yellow
93℃	63℃	Green
141℃	111℃	Blue

Figure (5.6): Types of sprinkler

- **Piping system**

Piping system is a critical part of fire sprinkler system the type of the pipe, the coefficient of friction, diameter of the pipe, and distance between pipes all of these parameters have to be determined.

Pipes Types:

a) Black steel
b) Galvanized steel
c) High density polyethylene
d) UPVC poly vinyl chloride

- **Valves**

a) Sectional valves: are used to separate specific parts of the firefighting network for maintenance and repair times and should be automatically supervised.

b) Drain valve: should be placed at the lowest point of the firefighting network to drain the water network for washing& maintenance of the pipes.

c) Non return valve: installed everywhere the water is allowed to flow in only one direction to prevent the pressurized water from flowing in opposite direction.

d) Alarm check valve: in case of fire and a pressure difference happened before and after this valve. It allows the water to flow in a channel to activate a mechanical alarm.

- **Pumps**

Firefighting pumps are special pumps and has to achieve several conditions and they are:

1-The pump must verify required flow and the desired head.

2- When the flow increases to 150% the head must not be less than 65%.

3-The shut of head ranges from 101% to 140%.

Firefighting pumps a continuous water and pumping station supply should always be available and ready to fight fire, the following three pumps should be connected to a suction header (from water tank), and discharged to a discharge header (to firefighting network).

5.3 Fire pump set

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.

5.4 Hydraulic calculations

5.4.1The design procedure

1- Identifies the hazard and it has been identifying for the Building to be Light hazard.

2- Identifies the sprinkler type and in the Building, it is chosen to be pendent in all of the floors and upright in the parking.

3- The sprinklers to be distributed in the building according to NFPA hazard table.

4- Choose the design area. This is the area that has the most water demanding and the max possible head.

5- Calculate the flow and head from the design area.

6- Add the flow of the hose and the landing valve to the total flow in case of combined system.

7- Choose the pumps depending on the flow and the head.

5.4.2 Design area

In the Building and according to NFPA It is the farthest 1500 ft^2=139m^2 from the pumps. So, it is in the 5^{th} floor

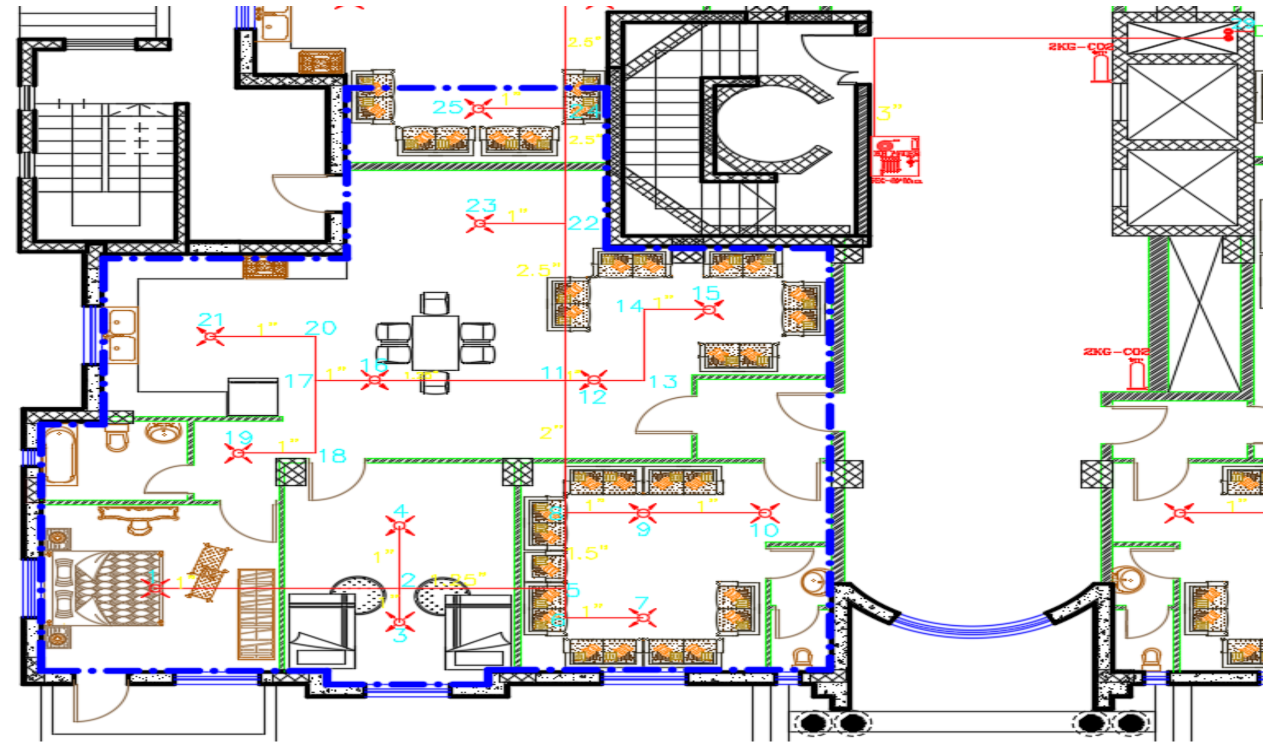


Figure (5.7): Design area

5.4.3 Flow calculations

Number of sprinkler (min) = Design Area / sprinkler area coverage

= 139 / 20.9 = 7 sprinkler.

Note: but, 13 sprinklers were used as shown in Figure (6.5)

Flow for the design area = flow per sprinkler * number of sprinklers

= 13.9 gpm * 13 = 181 gpm

Hose cabinet flow and Landing Valve flow = 500 gpm

5.4.4 Head calculations

Head pump = Static head + Residual head + Friction head

Static head = the level difference head between pumps and the farthest sprinkler

Residual head = the water pressure at the inlet of the sprinkler and depend on the sprinkler

Friction head = friction head throw the pipes and depend on the pipe type, diameter, flow.

5.5 Pump selection

(Pump head = 123 psi & Pump flow = 852 gpm)

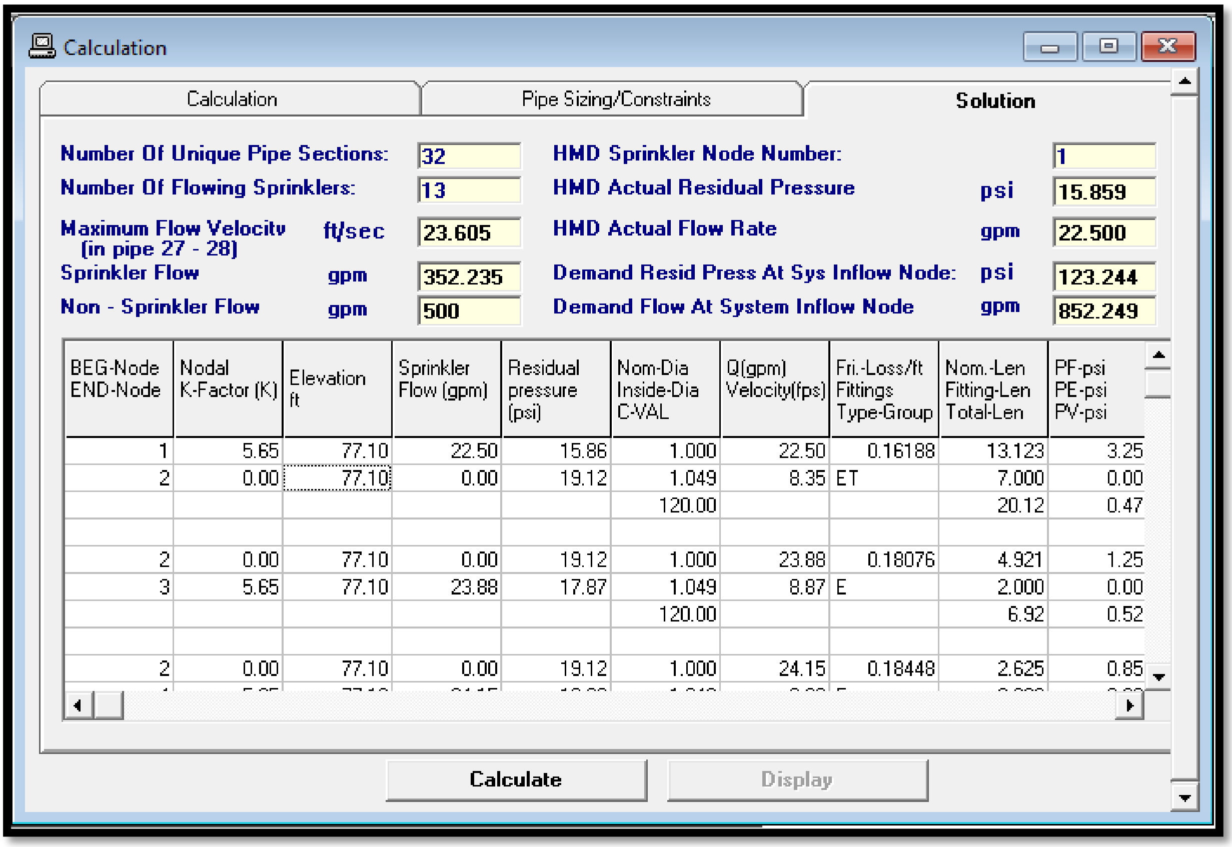


Figure (5.8): Characteristics for a pump by elite software

5.6 Water tank sizing

Water tank is the main source of water that provides the firefighting network and other systems in the project, size of water tank can be calculated with referring to the NFPA 13 code, which mainly depends on the hazard classification and the expectation duration work

Table 11.2.3.1.1 Hose Stream Demand and Water Supply Duration Requirements for Hydraulically Calculated Systems

Occupancy	Inside Hose (gpm)	Total Combined Inside and Outside Hose (gpm)	Duration (minutes)
Light hazard	0, 50, or 100	100	30
Ordinary hazard	0, 50, or 100	250	60–90
Extra hazard	0, 50, or 100	500	90–120

for the system.

Figure (5.9): Total gallon and duration

To calculate the size of the water tank which is to be in accordance with the degree of risk depending on the type of threat that we own:

Volume = total flow rate * duration

= 852.2 gpm*30 min = 25566 gallon = 96.7 m^3

tank sizing = 96.7 m^3

Bill of quantities

Itom NO	DISCRIPTION	Unit	Quality
1	**VRF**		
1.1	**Indoor Units**		
1.1.1	Wall split unit 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 C (summer) 4 C (winter)		
1.1.1.1	AM022KNQDEH/TR	**NO.**	12
1.1.1.2	AM036KNQDEH/TR	**NO.**	8
1.1.1.3	AM045KNTDEH/TR	**NO.**	24
1.1.1.4	AM056KNQDEH/TR	**NO.**	**12**
1.1.1.5	AM028KNQDEH/TR	**NO.**	**4**

1.1.2	4-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	AM045FNTDEH/TK	**NO.**	8
1.1.2.2	AM056FNNDEH/TK	**NO.**	24
1.1.2.3	AM036FNNDEH/TK	**NO.**	24
1.1.2.4	AM071FN4DEH/TK	**NO.**	12
1.1.2.5	AM028FNNDEH/TK	**NO.**	4
1.2	**Out Door**		
1.2.1	AM600HXVAGH2TK	**NO.**	**2**
1.2.2	AM580HXVAGH2TK	**NO.**	**2**
1.2.3	AM620HXVAGH1TK	**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.		
1.3.1	(1/4") in	m	384
1.3.2	(3/8") in	m	195
1.3.3	(1/2") in	m	591
1.3.4	(5/8") in	m	230
1.3.5	(3/4") in	m	76
1.3.6	(7/8") in	m	72
1.3.7	(1 1/8") in	m	105
1.3.8	(1 3/4") in	m	5

1.3.9	(1 5/8") in	m	35
1.3.10	(2 1/8") in	m	28
1.4	**Accessories**		
1.4.1	Refnet Joint	No.	102
1.4.2	Header	No.	12
2	**VENTLATION**		
2.1	Centrifugal Exhaust air Fans set (one duty and one stand-by), complete as per drawings and specifications.		
2.1.1	4020CFM & 40Pa	SET	1
2.1.2	Duct size	m^2	56
2.1.3	Grill for duct	SET	5
	Centrifugal Fresh air Fans set (one duty and one stand-by), complete as per drawings and specifications		
2.1.4	4020CFM & 40Pa	SET	1
2.1.5	Duct size	m^2	72
2.1.6	Grill for duct	SET	5
2.2	Inline centrifugal fans with big air capacity kitchen ventilation.		
2.2.1	110CFM & 10Pa	SET	12
2.2.2	Duct size	m^2	34
2.2.3	Grill for duct	SET	24
2.2.4	185CFM & 13Pa	SET	12
2.2.5	Duct size	m^2	34
2.2.6	Grill for duct	SET	24
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.		
3.1.1	Lifting pumps	No.	2
3.1.2	booster pump	No.	4
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	313
3.2.1.2	25 mm dia pipe (1")	m	310
3.2.1.3	32 mm dia pipe (11/4")	m	105
3.2.1.4	65 mm dia pipe (2 1/2")	m	100
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	300
3.2.2.1	16 mm dia pipe	m	1512
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, 12 outlets	No.	24
3.4	**Water meter**		
3.4.1	Supply, installation and commissioning of water meter for all apartments	No.	25

3.5	**Tank**		
3.5.1	Supply, installation and commissioning of water tank for all apartments white color, consisting of two layers with an outlet 3/4	No.	24
3.5.2	Tank size	m^3	1
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.	7
4.2	**Fittings**		
4.2.1	Tee (1.5")	No.	8
4.2.2	Elbow (1.5")	No.	18
4.2.3	Cross(1.5")	No.	180
4.2.4	Reducer (1"-1.25")	No.	150
4.2.5	Reducer (1.25"-1. 5")	No.	160
4.3	Black seamless steel pipe.		
4.3.1	pipe (1")	ML	732
4.3.2	pipe (1 1/4")	ML	106
4.3.3	pipe (1 1/2")	ML	74
4.3.4	pipe (2")	ML	`88
4.3.5	pipe (2 1/2")	ML	159
4.3.6	pipe (3")	ML	19
4.3.7	pipe (4")	ML	30
4.3.8	pipe (5")	ML	7
4.3.9	pipe (6")	ML	26
4.4	**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.		
4.4.1	Electrical pump : **EP-01** **852 GPM @124 PSI**	No.	1
4.4.2	Diesel pump : **DP-01** **852 GPM @124 PSI**	No.	1
4.4.3	Jockey pump : **JP-01** **85 GPM @134 PSI**	No.	1
4.5	**Fire Extinguisher**		
4.6	upright	No.	51
4.7	Concealed pendent	No.	252
4.9	Siamese connection assembly complete with non-return valves. Outlet of 100m dia, and inlet of 65mm dia.	No.	1
4.10	Supply and install landing valve, complete with fire hose rack.	No.	13
4.11	Supply and install clean agent system with all accessories such as valves, control, nozzles, etc. All complete as per detailed specifications and drawings.	Set	18
4.12	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.	4
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 approved.	No.	670
5	**Drainage System**		
5.2	**Water Closets**		

5.2.1	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.	48
5.3	**Shower Banio**		
5.3.1	Supply install and test shower banio (150cmx60cm) 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.	24
5.4	**Kitchen Sinks**		
5.4.1	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.	24
5.5	**Lavatory**		
5.5.1	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.	48
5.6	**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.		
5.6.1	110 mm dia. (4")	m	558
5.6.2	150 mm dia. (6")	m	99
5.6.3	50 mm dia. (2")	m	338
5.6.4	50 mm dia. (1")	m	210
5.7	**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		
5.7.1	***FT-HDPE*** and with chromium plated cover, mesh and all accessories needed	No.	96
5.7.2	***FD-HDPE*** and with chromium plated cover, mesh and all accessories needed	No.	48
5.8	**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.		
5.8.1	***FLOOR C.O HDPE*** with chromium plated cover, mesh and all accessories needed.		72
5.9	**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)		
5.9.1	50 mm dia. (4")	No.	4
5.9.2	100 mm dia. (3")	No.	4

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	Depth 60 cm - 80 cm Dia 60 cm	No.	8
5.10.2	Depth 80 cm - 140cm. Dia 80 cm	No.	6
6	**Gas SYSTEM**		
6.1	**Gas pipe**		
6.1.1	a) 20mm Gas copper pipe	m	33
5.11.2	b) 8mm gas copper pipe	m	430
6.2	**Gas cylinder**	No.	9
6.3	**Gas collector**	No.	6
6.4	**Gas meter**	No.	24

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Software that was used in this project:

1-AutoCAD 2020.

2-Revit 2020.

3- Fire Elite

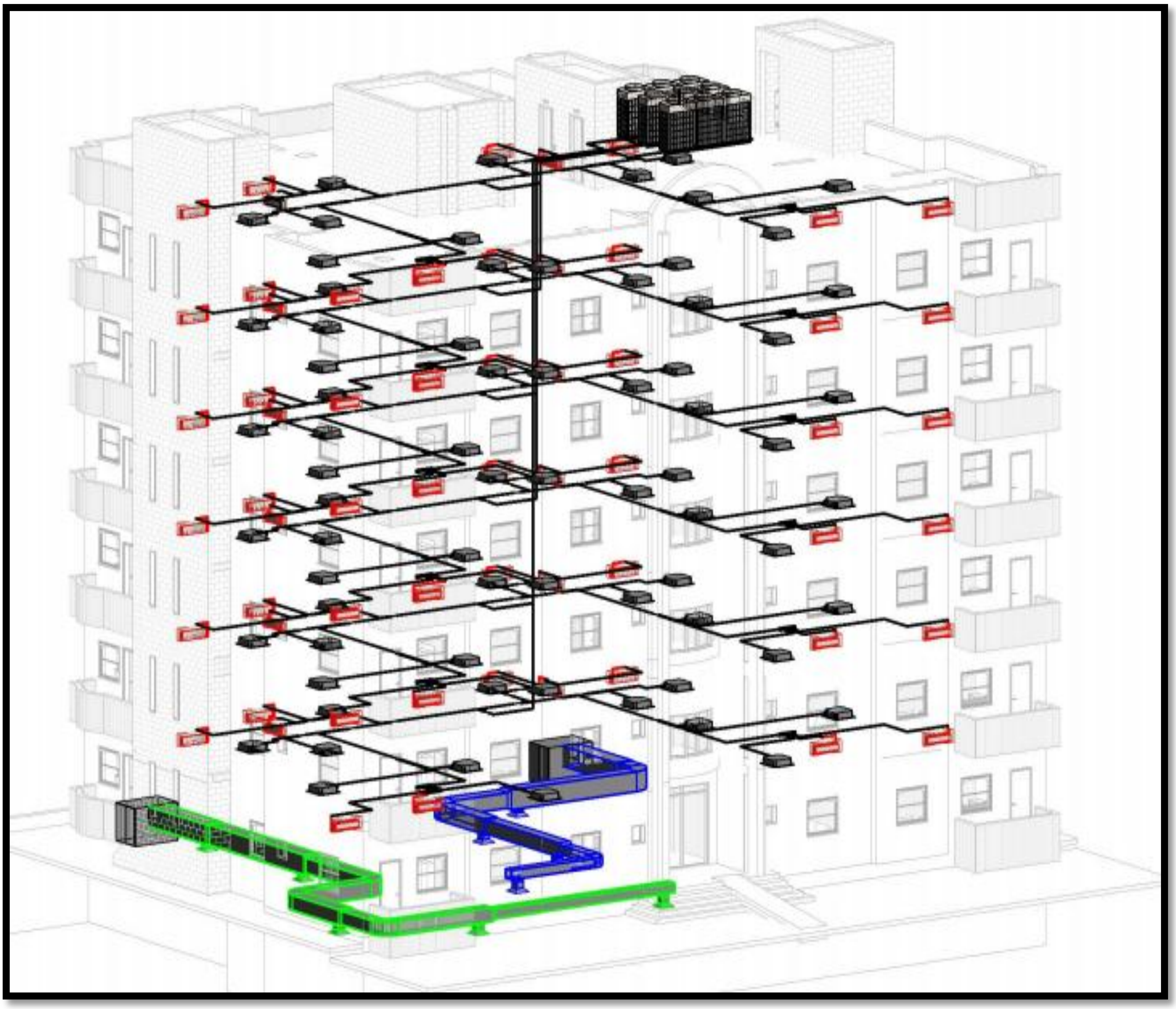
4-Duct Sizer

5- DP Select

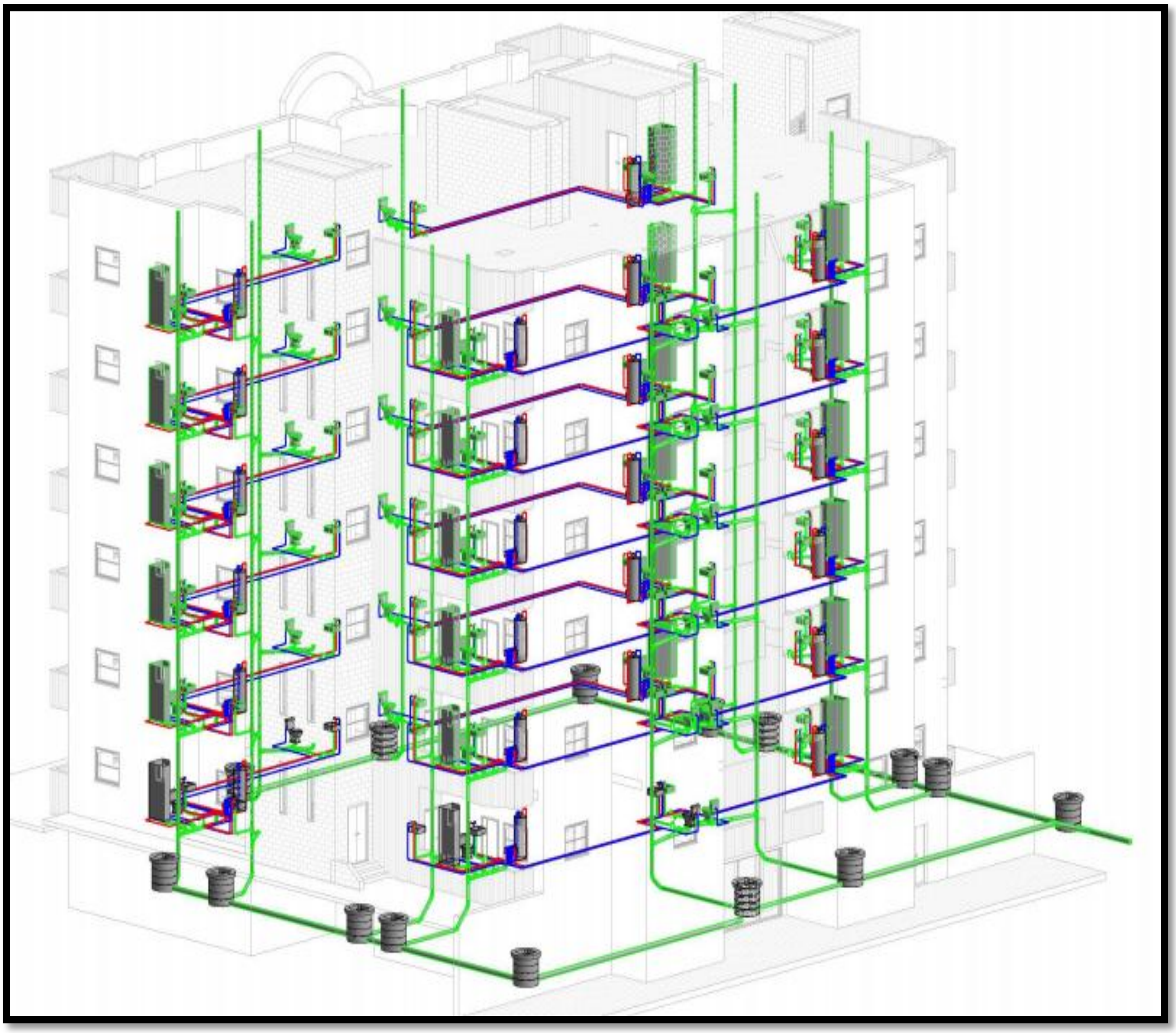
6-DVM

Revit summery

VRF design



Plumbing design



Firefighting design

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/m²·°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
	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
N	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
Shaded	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
	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
NNE	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
	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
NE	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
	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
ENE	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
	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
E	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
	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
ESE	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
	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
SE	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
	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
SSE	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
	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
S	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
	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
SSW	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
	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
SW	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
	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
WSW	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 Glass	Nominal Thickness, mm	Type of Interior Shading				
		Venetian Blinds		Roller Shade		
				Opaque		Translucent
		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, $W/m^2 \cdot K$	
			$h_o = 22.7$	$h_o = 17.0$
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/m^2, 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-19: 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-20: 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-21: 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-25: 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-26: 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-27: 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-28: Overall heat coefficient for windows

TABLE A(2.4) Overall Heat Transfer Coefficient for Windows, W/m^2·°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-29: Overall heat coefficient for wood and metals door

TABLE A(2.5) Overall heat transfer coefficients for wood and metal doors, W/m^2·°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-30 Palestinian code

القيم التصميمية الخارجية	المنطقة المناخية*						
	الضفة الغربية					قطاع غزة	
	الأولى	الثانية	الثالثة	الرابعة	الخامسة	الثالثة	السادسة
درجة الحرارة (°C) شتاء	7	7	5	4	8	5	9
درجة الحرارة (°C) صيفاً	39	39	32	30	34	32	31
الرطوبة النسبية (%) شتاءً: أدنى	60	60	60	62	63	60	62
الرطوبة النسبية (%) شتاءً: أقصى	70	70	72	72	78	72	69
الرطوبة النسبية (%) صيفاً: أدنى	43	43	49	44	55	49	65
الرطوبة النسبية (%) صيفاً: أقصى	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 (18/3) و (19/3) قيماً تصميمية لكافة المناطق المناخية						
درجة يوم تسخين (°C.day) درجة يوم تبريد (°C.day)	لا تتوفر معلومات عن هذه القيم حالياً						

* المناطق المناخية للأراضي الفلسطينية مبينة في الملحق (هـ)

Appendix (B)

B-1: Water supply fixture unit

Table A(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:

Fixture Branch[d]	Number of Fixture Units: Private Use	Number of Fixture Units: 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.

Source. Reproduced with permission from The National Standard Plumbing Code, published by The National Association of Plumbing Heating Cooling Contractors.

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

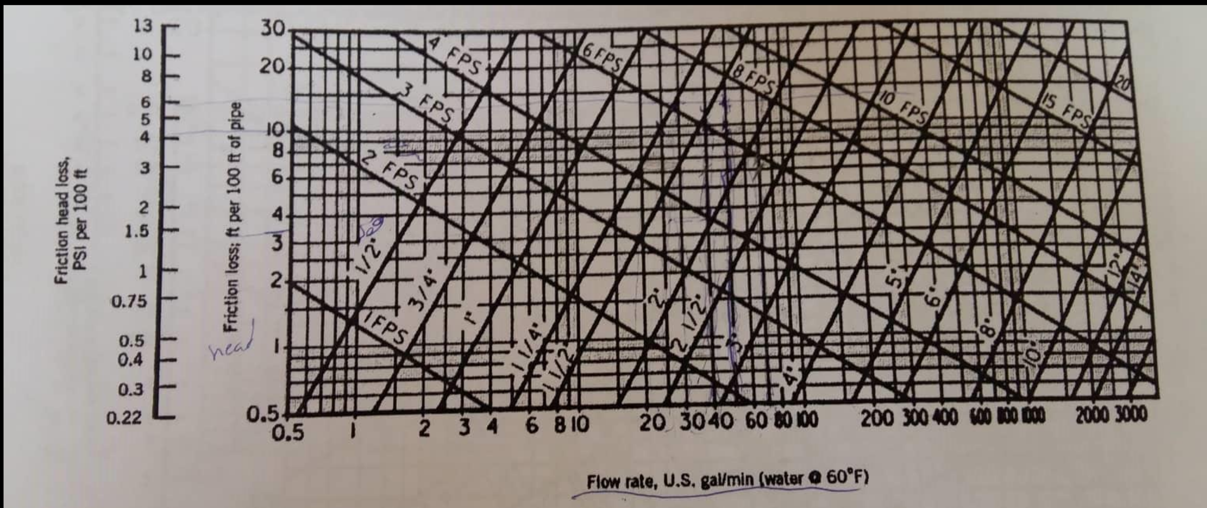


Figure 9.5 Chart of friction head loss in Schedule 40 black iron or steel pipe, for water at 60°F, in feet of water and psi per 100 ft of equivalent pipe length. Pipe sizes are nominal. (Reprinted by permission of the American Society of Heating, Refrigerating and Air-Conditioning Engineers, Atlanta, Georgia, from the 1993 *ASHRAE Handbook—Fundamentals*.)

max 8ft/min

B-3: Minimum pressure required by Typical plumping Fixture

TableA(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[a] in Sloping Drains Flowing Half Full[b]

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
1 1/4							3.40	1.78
1 3/8					3.13	1.34	4.44	1.90
1 1/2					3.91	1.42	5.53	2.01
1 5/8					4.81	1.50	6.80	2.12
2					8.42	1.72	11.9	2.43
2 1/2			10.8	1.41	15.3	1.99	21.6	2.82
3			17.6	1.59	24.8	2.25	35.1	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

[a] Computed from the Manning Formula for 1/2-full pipe, $n = 0.015$.
[b] Half full means filled to a depth equal to one-half the inside diameter.

Note: For 1/4 full, multiply discharge by 0.274 and multiply velocity by 0.701. For 1/3 full, multiply discharge by 0.44 and multiply velocity by 0.80. For 3/4 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	435	3000	435
4000	525	4000	525
5000	600	5000	600
6000	650	6000	650
7000	700	7000	700
8000	730	8000	730
9000	[illegible]	9000	760
10,000	[illegible]	10,000	790

[a] Water Supply Fixture Units

Source: Reproduced with permission from The Na-
tional Standard Plumbing Code published by The Na-

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

Table A(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)[a]	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 of cuspidor	1
Dental lavatory	1
Drinking fountain	1/2
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] 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.	*Maximum Number of Fixture Units That May Be Connected to* 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 [illegible] the Administrative Authority [illegible] public sewers.

[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.

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