Palestine Polytechnic University

College of Engineering and Technology

Mechanical Engineering Department

Design of Mechanical Systems for Hotel building in Hebron city

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Abstract

This project is about a hotel (Palestine Hotel) located in Hebron city with 6 floors, ground floor, Mezzanine floor and roof with a total area of 2287m^2, both heating and cooling loads were calculated for the hotel using Revit software. It is found that the cooling load (198.8) kW and the heating load (126.386) kW, in this project, the thermal loads of this building has been calculated and the appropriate air conditioning system selected. The project also includes calculations, material selection, prepare bill of quantities for air conditioning system, ventilation system, water system, drainage system and firefighting system.

الملخص

يهدف هذا المشروع الى تصميم الأنظمة الميكانيكة لفندق فلسطين المقترح في الخليل حيث يتكون من تسعة طوابق بمساحه كليه 2287 متر مربع، في هذا المشروع تم حساب الأحمال الحرارية لهذا المبنى وتم اختيار نظام التكييف المناسب, ويشمل المشروع أيضًا الحسابات واختيار المواد وإعداد جداول الكميات لنظام تكييف الهواء ونظام التهوية ونظام المياه ونظام الصرف ونظام مكافحة الحرائق.

CHAPTER ONE

INTRODUCTION

1.1 Introduction:

Air conditioning aims to improve the human life to be easier and more comfortable, and in order to obtain the highest requirements for human comfort, we must treat the air produced from weather conditions, which is hot in summer and cold in winter.

This feeling of comfort is influenced by a number of air related parameters which are inside space temperature, humidity, air motion and its speed and the air purity. The purity of the air and its quality include the absence of odors, toxic fumes and suspended particles, such as dust and dirt's.[1]

Therefore, it is the duty of engineer to provide and develop mechanical systems which help to achieve human comfort.

The goal of modern plumbing design for buildings is to safely and reliably provide domestic water, cooking gas and water for firefighting and to remove sanitary wastes.

1.2 Project objectives:

The project aims to:

1- Design (VRF) air conditioning system HVAC.
2- Design firefighting system.
3- Theoretical calculations and design of plumping system.
4- Theoretical calculations for heating and cooling load for the hotel.
5- Select the equipment.
6- Prepare bill of quantities.

1.3 Building description:

The hotel has six floors and ground floor and parking:
Parking area: 418 m^2
From the first floor to the sixth: floor area = 227 m^2
Roof area: 123 m^2

1.4 Project choice and justifications:

1. This project will create sufficient experiences for the students, which would assist them to have an employment opportunity after graduation.
2. Such projects provide the opportunity to review what have been studied in college of engineering.

1.5 Project scope:

The scope of this project is to design and document the mechanical services systems for hotel.

This project can create a bridge between the engineering study and the local labor market needs.

1.6 Abbreviations:

- HVAC: Heating Ventilation and Air Conditioning.
- WSFU: is water supply fixture units.
- DFU: Drainage fixture unit, calculate the provision of drainage system.
- VRF: v0ariable refrigerant flow.
- GPM: gallon per minute.

1.7 Project overview:

The project generally aims to achieve the highest human comfort conditions for hotel guests and to try to reduce the cost involved in achieving these conditions as much as possible.

1.8 Time table:

Table (1.1) Distribution of work over the semester

Week / Task	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Choosing the project			■	■													
Reading books	■	■	■	■													
Choosing the title					■	■											
Introduction, human comfort						■	■	■	■								
Calculation the heating loads and the cooling loads									■	■	■	■					
Using REVIT to calculate the loads													■	■	■		
Review and Modification															■	■	■

Table 1.2: second semester timetable

	February	March	April	May
Design plumping system	■			
Design of the firefighting system		■	■	
AutoCAD drawings preparations	■	■	■	■
Revit drawings preparations			■	■

CHAPTER TWO

Heating and Cooling Loads

2.1 Introduction:

The heating load is the amount of heat energy that would need to be added to a space to maintain the temperature in an acceptable range.[2]

The cooling load is the amount of heat energy that would need to remove from a space (cooling) to maintain the temperature in an acceptable range.[3]

Another definition to Heating and Cooling load are measure of energy needed to be added or removed from space by the HVAC system to provide the desired level of comfort within a space.

An HVAC load calculation is a mathematical process for measuring several aspects of a building in order to determine the best size, application and style of HVAC system. The purpose is to ensure energy efficiency while also maximizing comfort inside any home.

2.2 Human comfort:

2.2.1 Introduction:

The main aim of air conditioning is to reach to the human comfort, this feeling of comfort is influenced by a number of air related parameters which are inside space temperature, humidity, air motion and its speed and the air purity.[1]

2.2.2 Heat balance of human body:

- The normal human body average temperature is 37.2°C.
- For body thermal equilibrium to be maintained, heat must be produced within the body in amounts equal to the heat loss by the body.
- Metabolism is the biological process by which body cells generate heat from consumed food. The efficiency of this transformation is about 20%.

In general, human body cooling takes place by four different modes:

- **Evaporation:** There are two mechanisms of evaporation, which are respiration and insensible skin moisture.
- **Radiation:** The heat loss from the body by this mode accounts for about 45% of total heat loss of the body.
- **Convection:** The heat loss by convection accounts to about 30% of the total heat loss by the body.

- **Conduction**: is the process of losing heat through physical contact with another object or body

- The rate of heat produced by the body through metabolism **M**, is measured in Met units.
- A Met unit is equal to 58.2 W/m^2 of the surface area of the body.
- This thermal power is consumed in a number of ways, such that the relation between metabolism M and the heat losses from the body must be satisfied by the following relation.

$$\mathbf{M - P = E + R + C + S} \qquad (2.1)$$

Where **M** is the metabolic rate (W), **P** is the power output of the individual, **E** is the rate of heat dissipated by evaporation from the body, **R** is the rate of heat dissipated by radiation from the body, **C** is the rate of heat dissipated by convection, and **S** is the stored or the residual thermal power.

For healthy bodies, S must be zero, i.e., the body remains at a constant temperature. However, if S is positive, the temperature of the body starts rising. This is an indication of sickness. If S is negative, the temperature of the body starts dropping. This is also an indication that the individual is sick.[1]

2.3 Inside and outside design conditions:

The inside design conditions refer to temperature, humidity, air speed, and quality of inside air that will induce comfort to occupants of the space at minimum energy consumption.

Factors that control the selection of the inside design conditions:[1]

(1) The outside design conditions.

(2) The period of occupancy of the conditioned space.

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

(4) The type of building construction and its use.

The relative humidity range for the conditioned space varies from 30% to 60%.

Table (2.1): Outside and inside design conditions

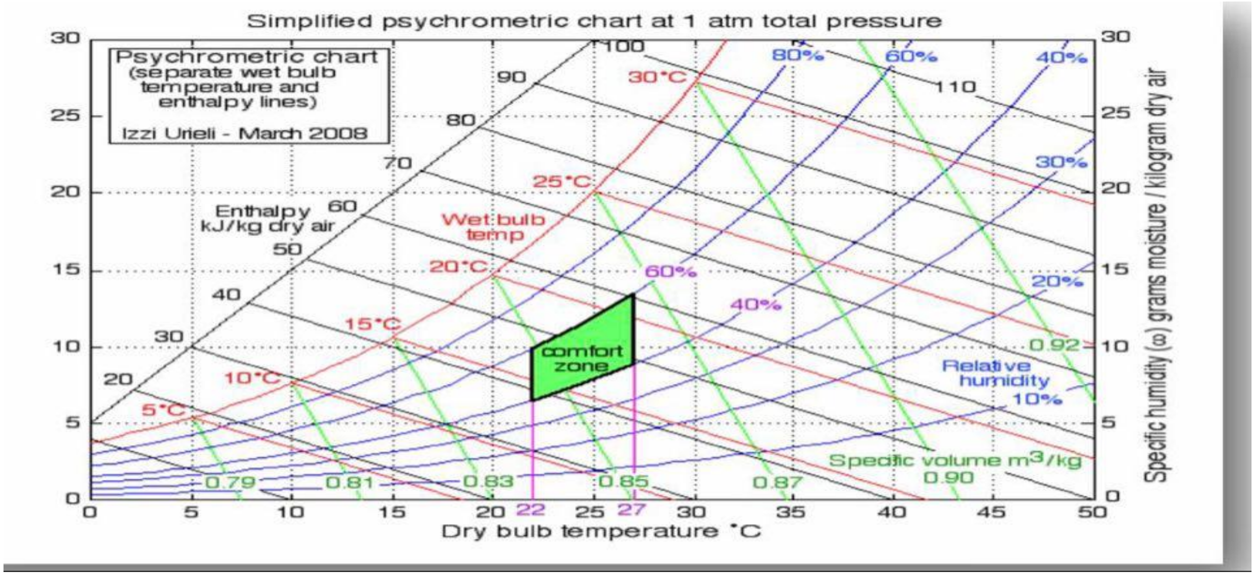
Property	Inside design condition		outside design condition	
	Summer	winter	summer	winter
Temperature (˚C)	24	24	30	4.7
Relative humidity (%)	50	50	51.3	70
Wind speed (m/s)	….	….	1.4	1.4

2.4 ASHRAE Comfort Chart:

ASHRAE is an abbreviation for the American Society of Heating Refrigerating and Air conditioning Engineers. It is 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.[4]

There is no rigid rule that indicates the best atmospheric condition for comfort for all individuals. This is because human comfort is affected by several factors such as health, age, activity, clothing, sex, food, etc. Comfort conditions are obtained as a result of tests for which people are subjected to air at various combinations of temperatures and relative humidity's. The results of such tests indicate that a person will feel just about as cool at 24°C and 60% relative humidity as at 26°C and 30% relative humidity. Studies conducted by ASHRAE with relative humidity between 30% and 70% indicated that· 98% of people feel comfortable when the temperature and relative humidity combinations fall in a comfort zone such as that indicated in the ASHRAE comfort chart. This comfort zone covers a wide range of applications such as houses, offices, schools, hospitals, theaters, restaurants, etc.

Figure (2.1): Human comfort chart



2.5 Calculations of overall heat transfer coefficient U:

U_{in} =Overall heat transfer coefficient for the internal walls.

U_{out} = Overall heat transfer coefficient for the outside walls.

$U_{ceiling}$ = Overall heat transfer coefficient for the ceiling.

U_{floor} = Overall heat transfer coefficient for the ground.

U_{doors} = Overall heat transfer coefficient for the doors.

U_{glass} = Overall heat transfer coefficient for the glass.

$$U = \frac{1}{R_{th}} = \frac{1}{\frac{1}{h_i}+\frac{\Delta x_1}{k_1}+\frac{\Delta x_2}{k_2}+\cdots+1/h_0} \quad (2.2)$$

Where:

ΔX: the thickness of the wall [m].

k: Thermal conductivity of the material.

R_i: inside film resistance wall, floor from appendix A-19 is 0.12, 0.10 respectively then hi=8.33 and 10 W/m^2.C respectively.

R_o: outside film resistance wall, floor, or roof from A-19 is 0.06 and 0.04W/ m^2. C respectively.

h_i: Convection coefficient of inside wall, floor, or ceiling is 8.33 and 10 W/m^2. C respectively.

h_0: Convection coefficient of outside wall, floor, or roof is 16.66 and 25 W/m^2. C respectively.

2.5.1 The overall heat transfer coefficient (U):

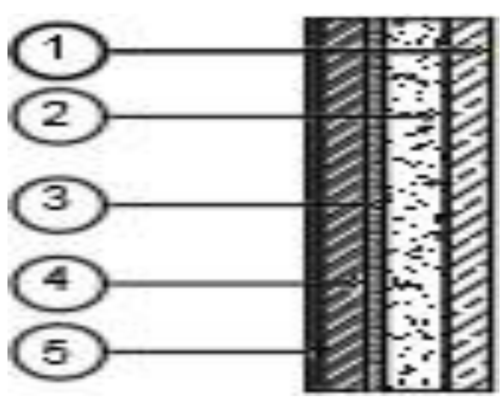
Calculation of overall heat transfer coefficient for walls, ceiling, floor, glass and door.

Table 2.2: Construction of external walls

1. **For external wall: [9]**

	Materiel	**Δx(m)**	**k (W/m.^{o}C)**
1	Stone	0.07	2.2
2	Concrete	0.1	1.2
3	Polyurethane	0.03	0.04
4	cement brick	0.07	1.2
5	Plaster	0.02	1.4

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 appendix (A-19).

$$\boldsymbol{Uwall} = \frac{1}{Rin + \frac{\Delta Xsto.}{Ksto.} + \frac{\Delta Xcon.}{Kcon} + \frac{\Delta Xpoly.}{Kpoly.} + \frac{\Delta Xcem.}{Kcem.} + \frac{\Delta Xplaster}{Kplaster} + Rout}$$

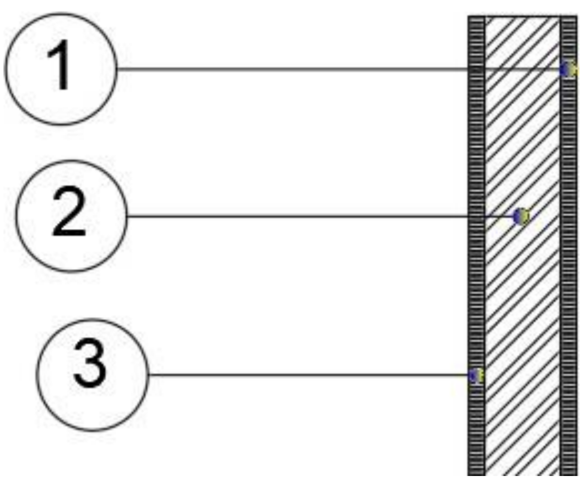
$$\boldsymbol{Uwall} = \frac{1}{0.12 + \frac{0.07}{2.2} + \frac{0.1}{1.2} + \frac{0.03}{0.04} + \frac{0.07}{1.2} + \frac{0.02}{1.4} + 0.06}$$

U = 0.89 (W/m2. C)

Table 2.3: Construction of internal walls

	Materiel	Δx(m)	k (W/m. C)
1	Plaster	0.02	1.4
2	Cement break	0.1	1
3	Plaster	0.02	1.4

Figure 2.3: Internal wall construction



$$\boldsymbol{U\ int.wall} = \frac{1}{Rin + \frac{\Delta Xplaster}{Kplaster} + \frac{\Delta Xcem.}{Kcem.} + \frac{\Delta Xplaster}{Kplaster} + Rout}$$

$$\boldsymbol{U\ int.wall} = \frac{1}{0.12 + \frac{0.02}{1.4} + \frac{0.1}{1} + \frac{0.02}{1.4} + 0.12}$$

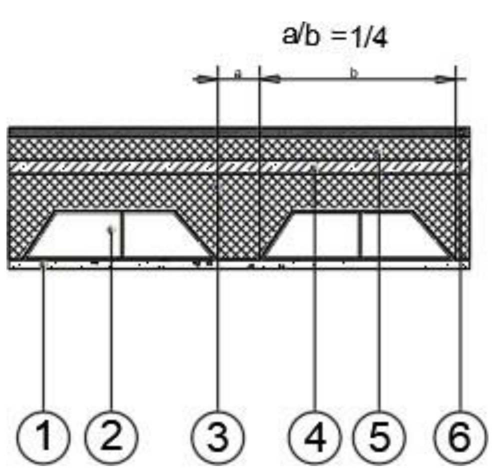
U = 2.71 (W/m2.°C)

2. **For Ceiling and Roof**

Table 2.4: Construction of celling.

	Materiel	Δx(m)	k (W/m.^{o}C) [9]
1	Plaster	0.02	1.4
2	Brick	0.14	1
3	Concrete	0.08	1.2
4	Polystyrene	0.03	0.04
5	Concrete	0.05	1.2
6	Asphalt	0.02	0.7

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-19).

$$\boldsymbol{Uone} = \frac{1}{Rin + \frac{\Delta Xplaster}{Kplaster} + \frac{\Delta X\text{Brick}}{K\text{Brick}} + \frac{\Delta Xcon.}{Kcon.} + \frac{\Delta Xpoly.}{Kpoly.} + \frac{\Delta Xcon.}{Kcon.} + \frac{\Delta Xasph.}{Kasph} + Rout}$$

$$\boldsymbol{Uone} = \frac{1}{0.1 + \frac{0.02}{1.4} + \frac{0.14}{1} + \frac{0.08}{1.2} + \frac{0.03}{0.04} + \frac{0.05}{1.2} + \frac{0.02}{0.7} + 0.04}$$

Uone = 0.84 (W/m2 .°C)

$$\boldsymbol{Utwo} = \frac{1}{Rin + \frac{\Delta Xplaster}{Kplaster} + \frac{\Delta Xcon.}{Kcon.} + \frac{\Delta Xpoly.}{Kpoly.} + \frac{\Delta Xcon.}{Kcon.} + \frac{\Delta Xasph.}{Kasph} + Rout}$$

$$\boldsymbol{Utwo} = \frac{1}{0.1 + \frac{0.02}{1.4} + \frac{0.08}{1.2} + \frac{0.03}{0.04} + \frac{0.05}{1.2} + \frac{0.02}{0.7} + 0.04}$$

Utwo = 0.83 (W/m2. °C)

*For glass from table (A-20), Ug = 3.2(W/m^2. °C) for double glass aluminum frame.
*For door from table (A-21), Ud = 3.6(W/m^2. °C) for wood door type.

2.6 Heat load calculations:

2.6.1 Heat loss calculation:

The main resources of heat loss in buildings 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 used:

Q=A×U×ΔT (2.3)

Where:

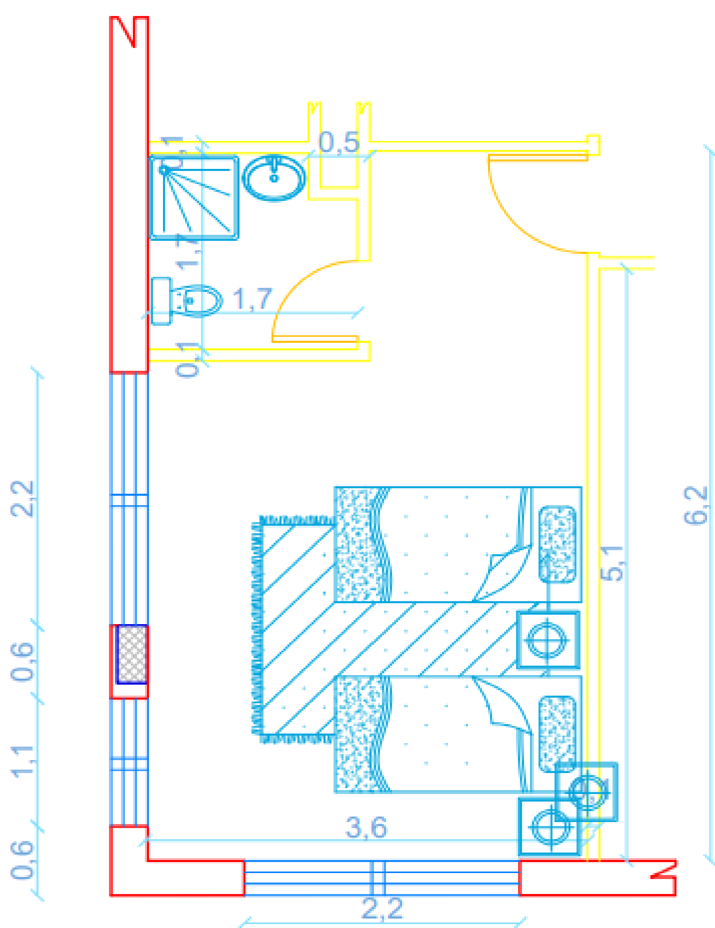
Q: Is the heat transfer rate. [Watt]
A: Is the area of the layer which heat flow through it. [m^2]

ΔT: Is the difference between the inside and outside temperatures. [$^{\circ}C$]
U: Is the overall heat transfer coefficient (W/m. $^{\circ}C$)

2.6.2 Total heat load calculations:

Total heat load calculations for the sample master room which is located in the sixth floor south east of the building as shown in figure (2.5)

Figure 2.5: Sample room



Heat loss through ceiling (Q_c):

Because of its construction, the ceiling is divided into two areas which are area A_1 and area A_2 as shown in Figure (2.4).

The area A_1 is equal to:

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

$$A_1 = \frac{4}{5} * 6.2*3.6 = 17.856 \ m^2$$

And the area A_2 is equal to:

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

$$A_2 = \frac{1}{5} * 6.2*3.6 = 4.464 \ m^2$$

Estimate temperature in adjacent unheated spaces as: $t_{un} = 0.5$ (Tin-Tout)

$$t_{un} = 0.5(23-4.7)$$

$$t_{un} = 9.15$$

$$Q_c = U_c A_c (T_i - T_o)$$

$$Q_c = (U_{one} A_1 + U_{two} A_2)(T_i - T_o)$$

$$Q_c = (0.84*18.856+0.83*7.61)(23-4.7)$$

Q_c=402 W

Heat loss through walls (Q_W):

The heat loss from external wall

$$Q_{ext} = U_W A_W (T_i - T_{out})$$

Aw = total area – windows area

= 3.5*(6.2+3.6) - (2)(2.2+1.1+2.2)

= 34.3 – 11

= 23.3 m^2

Q_{ext}=0.89*(23.3) (23-4.7)

Q_{ext}=379.48W

The heat loss from internal wall is

$$Q_{in} = U_W A_W (T_i - T_{un})$$

Aw = total area – door area

= 3.5*(6.2+3.6) - (2.2×1)

= 32.1 m^2

Heat loss through windows (Q_g):

Q_W = $U_g A_g (T_i - T_o)$

= (3.2)(2)(2.2+1.1+2.2)(23-4.7)

= 487.5 W

Heat loss through external door (Q_d):

$$Q_d = U_d A_d (T_i - T_{un.})$$

Q_d = (3.6)(2.2×1)(23-9.15)

Q_d = 110 W

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:

Qinf = $\frac{vinf}{voutside}\ (hout - hin\ )$ (2.4)

Qinf: The infiltration heat load [W].

vinf :The volumetric flow rate of infiltrated air. [m^3/s]

hout, hin: are the outside and the inside enthalpies of infiltrated air respectively [kJ/kg]

Vinf=$K * L * (\ 0.613\ (s1 *\ s2 *\ v)^2)^{2/3}$ (2.5)

K: the coefficient of infiltration air for windows

L: The crack length [m]

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

S_2: Coefficient that depends on the height of the building and terrain of its location.

v_0: wind speed 1.4 (m/s) from Palestinian code.

The value of K, S1 and S2 is obtained from tables (A-13) (A-14) and (A-15)

respectively. K=0.43, S1=1, S2=0.94, V0=1.4(m/s)

The window is sliding, then:

Lw=[(2.2*2)+(2.2*3)]+ [(2.2*2)+(2.2*3]+ [(1.1*2)+(2.2*3]

Lw=30.8 m

Through door:

L= 2W + 2H for door

Ld=[(2.25*2)+(0.9*2)]

Ld=6.3 m

L=37.1

V_{inf} $=K * L * (\ 0.613\ (s1 *\ s2 *\ v)^2)^{2/3}$

$=0.43 * 37.1 * (\ 0.613\ (1 * 0.94 * 1.4)^2)^{2/3}$

V_{inf} = 16.6 m³/h

Q_{inf} $= \frac{vinf}{voutside}\ (hout - hin\ )$

$=\frac{16.6}{0.78}(48 - 14)$

=724 W

Q_{total} = Qinf + Qd + **Qw + Q in + Qext + Qc** (2.6)

=724 +110+1204.8 +487.5 +401 +379.48

=3306.8W

=3.3kW

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

Q_{total} = 3.3kW*1.10 = **3.63kW**

2.7 Cooling load:

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

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

The total cooling load of a building involves:

1. Sensible heat gain through roof.
2. Sensible heat gain through walls.
3. Sensible heat gain through floors.
4. Sensible heat and latent heat gain from ventilation.
5. Sensible heat gain from the equipment.
6. Sensible and latent heat due occupancy.
7. Sensible heat gain through windows.

2.7.1 Cooling load calculations:

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 calculated by this equation:

$$Q = UA\,(CLTD)_{corr} \qquad (2.7)$$

Where:

(CLTD) corr: corrected cooling load temperature difference, ˚C

$$(CLTD)_{corr} = (CLTD + LM)\,k + (25.5 - T_{in}) + (T_{o,m} - 29.4)\,f \qquad (2.8)$$

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

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

k: color adjustment factor.

Tin: inside comfort design temperature, ˚C

f: attic or roof fan factor.

To, m: outdoor mean temperature, ˚C, To, m = (Tmax + Tmin) /2 (2.9)

Where:

Tmax: maximum average daily temperature, ˚C

Tmin: minimum average daily temperature, ˚C

Tmax = 35 ˚C and Tmin = 14 ˚C are obtained from Palestinian code.

outdoor mean temperature To, m = (Tmax + Tmin) /2

=(35+14)/2

=24.5 ºC

2.7.2 Sample Calculation:

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

Heat gain through sunlit roof (Q Roof):

CLTD = 14 ˚C

LM = 0.5

k = 0.83 for permanently light-colored roofs.

f = 1 there is no attic or roof fan.

(CLTD) corr. = (14 + 0.5)*0.83 + (25.5 - 23) + (24.5 - 29.4)* 1

= 9.93˚C

Q Roof = (U1 A1 + U2 A2) (CLTD) corr. (2.10)

Q Roof = (0.84 ×17.856 + 0.83 ×4.464) × (9.93)

= 186 W

Heat gain through sunlit walls (Q wall):

CLTD at 14:00 o'clock … from table (A-3)

CLTD =15 ˚C

LM = 0

N=0

K=0.83 for permanent medium color walls.

AEX=34.65 m2

(CLTD)corr,ex=(15+0)0.83+(25.5-23)+(24.5-29.4)*1

Q ex=0.89*34.65*10.35

Q ex=320 W

Total heat gain for the internal walls

: Qin = U*A*ΔT

=2.71*34.3*(30-23)

= 650 w

The amount of solar radiation depends upon the following factors :

1. Type of glass (single, double or insulation glass).

2. Solar radiation intensity and solar incident angle.

3. Hour of the day, day of the month, and month of the year.

4. Orientation of glass area.

5. Latitude angle of the location.

The maximum cooling load due to the glass window Q Glass, consists of transmitted (Qtr. and convicted (Q conv.)

cooling loads as follows:

Q Glass = Q tr. + Q conv. (2.11)

Where:

Qtr.: transmission heat gain, W

Qconv.: convection heat gain, W

The transmitted cooling load is calculated as follows:

Q tr. = A (SHG) (SC) (CLF) (2.12)

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.

The transmitted cooling load is calculated as follows:

Q tr. = A (SHG) (SC) (CLF) (2.13)

SHG in W/m2 … from Table (A-12)

A glass = 11 m2

SHG = 473 W/m2

SC = 0.57… reflective double from table A (2.10)

CLF = 0.44 at 14:00 o'clock from table A (2.8)

Qtr. N = 11 × 473 × 0.57 × 0.44

Qtr. N = 1305 W

Q conv. = UA (CLTD) corr. (2.14)

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 o'clock

f = 1 for glass , k = 1 for glass

(CLTD) corr. = (7 + 0.5) 1 + (25.5 - 23) + (24.5 - 29.4) 1 = 5.1˚C

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

$= 3.2 \times 11 \times 5.1 = 180$ W

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

$= 1305 + 180 = 1485$ W

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

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

$\dot{Q}_{Lt.}$ = light intensity × A × $(CLF)_{Lt.}$ (2.15)

Where:

light intensity = 10-30 W/ m^2 for apartment, so we will take 25W/ m^2

A: floor area = 22.3 m^2

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

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

$Q_{Lt.} = 25 \times 22.3 \times 0.82 = 457$W

Heat gain due to infiltration (Q_f):

Qinf = $\frac{vinf}{voutside}\ (hout - hin)$

Where:

h_{in} , h_{out} : are the outside and the inside enthalpies of infiltrated air respectively

[kJ ⁄ kg]

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

V_o : specific volume (m^3/kg)

v_o = 0.85 (outside the room)

h_{in} = 45 kJ/kg

h_{out} = 65 kJ/kg

Vf=number of air change × room volume

=1.5*3.6*6.2*3.5

=117.18m³/h

Qinf total = $\frac{117.18}{0.85*3600}$ $(65-45)$ =0.7660kW =766 w

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:

$Q_{oc.} = Q_{sensible} + Q_{latent}$ (2.16)

$Q_{sensible}$ = sensible heat gain × No. of people × $(CLF)_{oc.}$ (2.17)

Where:

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

sensible heat gain = 70W very light work , from table(A-16)

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 × 2× 0.84

= 117.6 W

Q latent = latent heat gain × No. of people (2.18)

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

Q_{latent} = 44 × 2

= 88W

Q oc. = 117.6 + 88

= 205.6 W.

The total heat gain for Sample Room is:

Qtotal = Q Roof + Qwall + Q Glass + Q Lt + Qinf + Q oc.

=186+320+650+1485+457+766+205.6

= 4070 W

=4.07kW

* Take a safety factor of 10 % for each space of the residence to cover the miscellaneous and emergency cooling loads then: Qtotal= 4.07W *1.10 = 4.477 kW

2.8 Sample room summary using Revit:

In this section, the Revit was used to calculate the heating and cooling loads of the building the program calculates loads by specifying variables ،Include [6]:

1. Location of the building.

2. Type of building.

3. Project phase.

4. Weather forecast.

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

6. Lighting

7. The nature of permanence of people

8. Human comfort.

9. Electrical load.

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

Heating and Cooling load calculation can help you analyze the model. This is the part of BIM. It is not only a 3D model, but also provides information. In Revit software can choose from three levels of heating and cooling loads reports (simple, standard and 22 detailed) to display the results of the heating and cooling analysis performed on your building model [6].

Table 2.5: Space bedroom – 602 summary by Revit software

Inputs	
Area (m²)	18
Volume (m³)	50.43
Wall Area (m²)	28
Roof Area (m²)	13
Door Area (m²)	3
Window Area (m²)	11
Skylight Area (m²)	0
Lighting Load (W)	197
Power Load (W)	334
Number of People	2
Sensible Heat Gain / Person (W)	73
Latent Heat Gain / Person (W)	59
Infiltration Airflow (L/s)	5.5
Space Type	Hotel (inherited from building type)
Calculated Results	
Peak Cooling Load (W)	**4,449**
Peak Cooling Sensible Load (W)	4,559
Peak Cooling Latent Load (W)	-110
Peak Cooling Airflow (L/s)	259.5
Peak Heating Load (W)	**3,174**
Peak Heating Airflow (L/s)	183.7

Table 2.6: The Cooling and heating load for the sample by Revit software

Components	**Cooling**		**Heating**	
	Loads (W)	**Percentage of Total**	**Loads (W)**	**Percentage of Total**
Wall	800	17.98%	1,272	40.08%
Window	2,381	53.53%	1,032	32.50%
Roof	857	19.27%	756	23.83%
Skylight	0	0.00%	0	0.00%
Partition	0	0.00%	0	0.00%
Infiltration	71	1.61%	114	3.60%
Lighting	168	3.77%		
Power	285	6.40%		
People	29	0.66%		
Plenum	0	0.00%		
Total	**4,449**	**100%**	**3,174**	**100%**

Table 2.7: The Cooling and heating loads for first floor building:

Default Spaces

Space Name	Area (m^2)	Volume (m^3)	Peak Cooling Load (W)	Peak Heating Load (W)
101 ROOM	14	36.08	3,101	2,646
102 ROOM	18	50.43	4,386	3,183
103 ROOM	15	42.24	3,391	2,785
104 ROOM	14	39.64	3,015	2,459
105 ROOM	17	47.27	3,600	2,973
106 ROOM	12	33.51	3,037	2,820
107 ROOM	14	40.44	2,812	1,216
108 ROOM	13	38.63	2,610	1,254

Table 2.8: The Cooling and heating load for each Level building:

ZOON	Cooling Load (W)	Heating Load (W)
Ground floor	27902	14220
Mezzanine	12936	9869
First floor	28597	16443
Second floor	30231	15516
third floor	29255	15529
fifth floor	28742	16582
sixth floor	28360	15680
roof floor	13116	6988

Chapter three

VRF system

3.1 Introduction

Variable refrigerant flow (VRF) systems vary the flow of refrigerant to indoor units based on demand. This ability to control the amount of refrigerant that is provided to fan coil units located throughout a building makes the VRF technology ideal for applications with varying loads or where zoning is required.[7]

VRF systems are available either as heat pump systems or as heat recovery systems for those applications where simultaneous heating and cooling is required. In addition to providing superior comfort, VRF systems offer design flexibility, energy savings, and cost effective installation. [7]

3.1.2 History of VRF system

VRF systems are relatively new to the United States. These systems were first invented by the Japanese HVAC company Daikin back in 1982. In Japan, 50% of midsize office buildings and 33% of large office spaces utilize this system. It made its way here in the early 2000s, mainly as an affordable way to heat and cool commercial buildings.[8]

3.1.3 Variable refrigerant system definition

The term variable refrigerant flow refers to the ability of the system to control the amount of refrigerant flowing to each of the evaporators, enabling the use of many evaporators of differing capacities and configurations, individualized comfort control, simultaneous heating and cooling in different zones, and heat recovery from one zone to another. [9]

3.1.4 VRF technology

In a VRF system, multiple indoor fan coil units may be connected to one outdoor unit. The outdoor unit has one or more compressors that are inverter driven, so their speed can be varied by changing the frequency of the power supply to the compressor. As the compressor speed changes, so does the amount of refrigerant delivered by the compressor. [7]

Each indoor fan coil unit has its own metering device that is controlled by the indoor unit itself, or by the outdoor unit. As each indoor unit sends a demand to the outdoor unit, the outdoor unit delivers the amount of refrigerant needed to meet the individual requirements of each indoor unit (Fig 3-1). [7]

These features make the VRF system ideally suited for all applications that have part load requirements based on usage or building orientation, as well as applications that require zoning.[7]

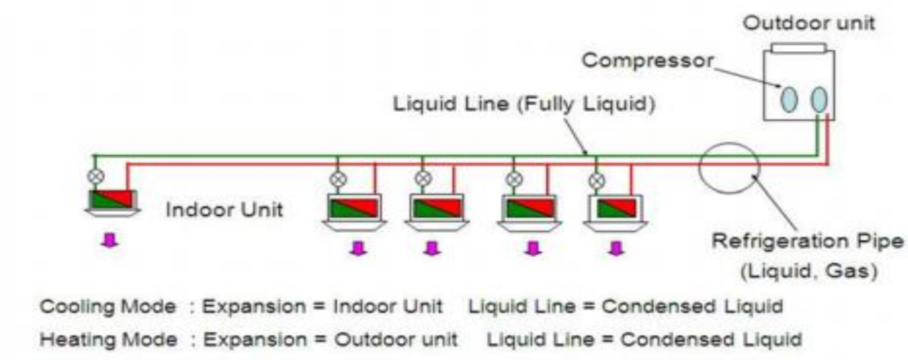


Figure (3- 1) Typical VRF Heat Pump System

3.1.5 How Does a VRF System Work?

The technology behind VRF systems is incredibly complex but thinks of them as an enhanced version of ductless mini-splits. VRF systems use heat pumps or heat recovery systems to provide powerful heating and cooling for all indoor and outdoor units without the use of air ducts.[10]

With a VRF system, your building will have multiple indoor units utilized by a single outdoor condensing unit, either with a heat pump or heat recovery system. The main difference between the two is that the latter can provide simultaneous heating and cooling. The outdoor unit has compressors with inverter-driven fans, which means their speed varies by adjusting the frequency of the power supply. The amount of refrigerant delivered by the compressor is dependent on the rate. When the indoor unit sends a demand to the outdoor unit, the outdoor unit delivers the specific amount of refrigerant to the individual indoor units. VRF technology can perform at a high capacity without the use of ducts, which is one of its many advantages.[10]

3.2 Split Air-conditioning Systems

Split type air conditioning systems are one-to- one systems consisting of one evaporator (fan coil) unit connected to an external condensing unit. Both the indoor and outdoor units are connected through copper tubing and electrical cabling.[11]

The indoor part (evaporator) pulls heat out from the surrounding air while the outdoor condensing unit transfers the heat into the environment.[11]

A split air conditioner consists of an outdoor unit and an indoor unit. The outdoor unit is installed on or near the exterior wall of the room that you wish to cool. This unit houses the compressor, condenser coil and the expansion coil or capillary tubing. The sleek-looking indoor unit contains the cooling coil, a long blower and an air filter.[11]

How does a split air conditioning system work?

In general, air conditioners use certain chemicals that can change their form from a gas to a liquid. This particular system works by a refrigerant being fed into the system's compressor. The refrigerant starts off as a low pressure gas. When the gas heats up and is pressurized, it is then condensed into a liquid. The liquid then travels through condenser tubes and becomes a gas again.[12]

When the gas loses pressure, it also releases heat and becomes cooler, thanks to the refrigerant. Then, when the gas passes back into the compressor, the process repeats itself. This is the main cycle.[12]

Throughout this cycle, the air from a room is pulled into the air conditioning unit and travels over the evaporator coils. This cools the air and pushes it into the room through the indoor air conditioning vents. The air continues to circulate around until a specific temperature is reached. This temperature can be amended remotely by a control. When it is reached, the system shuts off to conserve energy.[12]

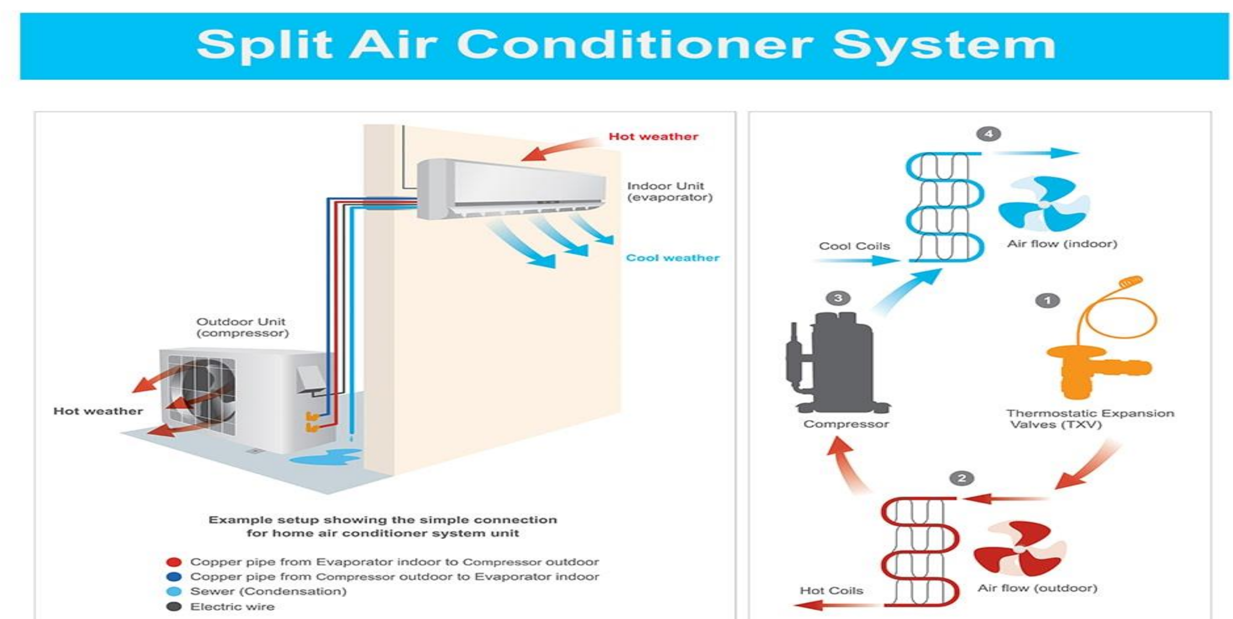


Figure (3.2) Split air conditioning system

The benefits of a split system air conditioner.

Opting for the split system AC can be beneficial for a number of reasons, both for residential and commercial use:[10]

Easy to install.

Even though the process of installing a split system air conditioner is relatively straightforward, it’s important that an engineer does it for you. Once the indoor and outdoor units are set up, all that’s needed is the feeding through of pipework from one to the other and to ensure that holes are sealed and pipes are held into place.

Quiet in operation.

The noisiest parts of the air conditioner such as the fan and the condenser are conveniently placed in the outdoor unit, meaning that the quietest part of the air conditioner is indoors. This means the split system can keep your rooms cool as quietly as possible.

Flexibility.

One of the main advantages of this system is its ability to heat different rooms with multiple cooling units. With the multi split system, you’ll be able to amend the temperatures of different rooms where you see fit thanks to the thermostat and remote control, and only cool the rooms you need to, saving money and energy in the process.

Energy efficient.

Split systems help to reduce the amount of energy used and ensure you’re not wasting power. Multi split system air conditioners have the added benefit of operating more than one indoor unit but is still one of the most energy efficient air con systems around. However, it’s important to choose the right system for your property to prevent energy wastage.

Cost effective.

The average cost of split system air conditioning systems can vary as with any large purchase. As a guide, the system and installation costs can start from around £1000 to £2000 depending on how many units you need and the installation costs. However, split systems can pay for themselves over time, especially with the energy efficiency of them saving you money on your bills each month.

Disadvantages

• There is limitation on the distance between the indoor and outdoor unit. Refrigerant piping can't exceed the limits stipulated by the manufacturer (usually 100 to 150 ft) otherwise the performance will suffer.

• Maintenance (cleaning/change of filters) is within the occupied space.

• Limited air throws which can lead to possible hot/cold spots.

• Impact on building aesthetics of large building because too many outdoor units will spoil the appearance of the building[13]

3.2.1 Multi Split Air-conditioning Systems

A multi split-air conditioner is a type of split air conditioner while a split air conditioner cools only one room at a time, a multi-split air conditioner lets you cool multiple rooms at a time. This is a result of its construction: a split air conditioner consists of one compressor and one air outlet, while a multi-split air conditioner has multiple (up to five) air outlets, all connected to one compressor.

The interior units can be wall-mounted, floor standing or ceiling-mounted, and are connected by refrigerant pipelines and cables to one outdoor unit

How a multi split air conditioner works?

A multi-split AC has one outdoor compressor, connected to four to five indoor air outlets via refrigerant lines rather than a complex duct system. Apart from the refrigerant tubing, the indoor air outlets are connected to the outdoor unit with condensate drain lines and power cables.

Although each indoor air outlets can be separately controlled, they are connected with the same outdoor heat pump unit to absorb or disperse heat. A heat pump works by removing the heat from the outdoor environment and transferring it indoors.

Figure (3.3)Multy split air conditioning system

The advantages of a multi split system air conditioner

Flexibility and convenience

Multi split system air conditioners offer unsurpassed flexibility and convenience, allowing you to choose the right indoor unit for each room of your house. You can install a high capacity air conditioner for larger living rooms and smaller, quieter ones for the bedrooms, all powered by the one outside unit. This allows you to control the temperature and environment in your home on a room by room basis.

Energy efficiency

Energy saving settings, combined with the ability to heat or cool individual rooms, helps to reduce power and running costs. Choosing the right indoor air outlet unit to suit each room also ensures that you're not wasting power. The wrong unit in a room can result in the air not being cooled properly and energy wastage. A unit that's too big for a smaller room also uses more power every time you turn it on compared to a smaller unit running for a longer period of time.

By operating multiple indoor air conditioners from the one external air compressor, multi split system air conditioners are among the most energy efficient of all air conditioners. Choose the most energy-efficient indoor air outlet units for maximum savings on your power bill.

Quiet

Multi split air conditioning systems are peaceful and quiet.

Independent control

By enjoying the ability to individually adjust the temperatures in each room, you'll save money and optimize comfort by heating or cooling individual rooms. You can have up to five separate indoor air outlets, all powered by a single outside compressor and controlled by a wireless remote.

The disadvantages of a multi split system air conditioner

• Inability to provide individual control.

• Multi-split systems turn OFF or ON completely in response to a single thermostat/control station which operates the whole system. These systems are therefore not suitable for areas/rooms with variable heat gain/loss characteristics.

3.2.2 Variable refrigerant flow description

VRFs are typically installed with an air conditioner inverter which adds a DC inverter to the compressor in order to support variable motor speed and thus variable refrigerant flow rather than simply perform on/off operation. [10]

By operating at varying speeds, VRF units work only at the needed rate allowing for substantial energy savings at load conditions. Heat recovery VRF technology allows individual indoor units to heat or cool as required, while the compressor load benefits from the internal heat recovery.

Energy savings of up to 55% are predicted over comparable unitary equipment. this also results in greater control of the building's interior temperature by the building's occupants

The modern VRF technology uses an inverter-driven scroll compressor and permits as many as 48 or more indoor units to operate from one outdoor unit (varies from manufacturer to manufacturer). The inverter scroll compressors are capable of changing the speed to follow the variations in the total cooling/heating load as determined by the suction gas pressure measured on the condensing unit. The capacity control range can be as low as 6% to 100%.[10]

3.2.3 Different types of VRF system

1. Heat Pumps system – 2 pipes

VRF heat pump systems commonly known as 2 pipe, 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.[18]

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

Figure (3.4): Heat pumps type VRF system

2. Heat Recovery System- 3 pipe

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. [18]

Each indoor unit is branched off from the 3 pipes using solenoid box which contains a series of valves. An indoor unit requiring cooling will open its liquid line and suction line valves and act as an evaporator. An indoor unit requiring heating will open its hot gas and liquid line valves and will act as a condenser.

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

Three pipe heat pump systems are effectively applied in open plan areas, retail stores, cellular offices and any other area that require cooling and heating at the same time.[18]

Figure (3.5): Heat recovery type VRF system

3. VRF Water Cooled

Most commonly used are air-cooled systems, using packaged outdoor condensing units, which via refrigeration pipework connect to a number of indoor units. There are however some limitations, pipework runs, mainly vertical risers (although Samsung can have a vertical rise up to 115mtere), plant space, and noise. Where these become an issue then water-cooled systems can be used. They operate as the Air-cooled units, but instead of having a built-in air-cooled heat exchanger they utilize and plate heat exchanger, which transfers the energy into a water loop.

This is connected to a cooling tower or dry cooler which transfers the energy/ heat to the atmosphere. Due to this process, the water-cooled VRF systems can be placed internally with no worry about the vertical risers, in much smaller areas, taking up less space and can be attenuated to meet most environmental requirements. These systems are also ideal for building served by an existing landlords condenser water loop

Figure (3.6): Water cooled type VRF system

Refrigerant modulation in a VRF system

VRV/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. [14]

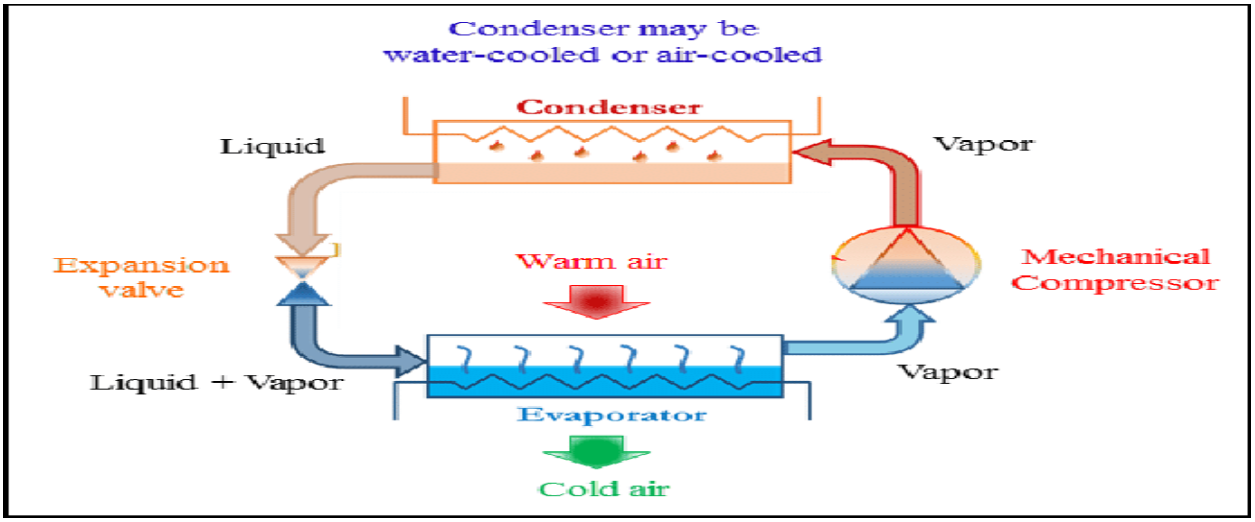


Figure (3.7): Basic refrigeration cycle

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

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

These are called heat pump systems. Heat pumps provide both heating and cooling from the same unit and due to added heat of compression, the efficiency of a heat pump in the heating mode is higher compared to the cooling cycle. Expansion valve is the component that controls the rate at which liquid refrigerant can flow into an evaporator coil.

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

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

• Too little: liquid refrigerant entering a compressor washes out the oil causing premature failure.

• Too much: valuable evaporator space is wasted and possibly causing compressor overheating problems.

The shortcomings of thermostatic expansion valve (TXV) are offset by the modern electronic expansion valve. With an electronic expansion valve (EEV), you can tell the system what superheat you want and it will set it up.

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.

3.3 Design consideration

In deciding if a VRF system is feasible for a particular project, the designer should consider building characteristics; cooling and heating load requirements; peak occurrence; simultaneous heating and cooling requirements; fresh air needs; accessibility requirements; minimum and maximum outdoor temperatures; sustainability; and acoustic characteristics.

Building Characteristics

Although manufacturers routinely increase the maximum allowable refrigerant pipe run, the longer the lengths of refrigerant pipes, the more expensive the initial and operating costs.

Building geometry must be studied carefully. The system should not be considered if the expected pipe lengths or height difference exceed those listed in the manufacturer's catalog. In buildings where several outdoor locations are available for the installation of the outdoor units, such as roof, setback, and ground floor, each condensing section should be placed as close as possible to the indoor units it serves.

The physical size of the outdoor section of a typical VRF is somewhat larger than that of a conventional DX condensing section, with a height up to 6 ft (1.8 m) excluding supports. Indoor units are available in multiple configurations such as wall-mounted, ceiling-mounted cassette suspended, and concealed ducted types. It is possible to combine multiple types of indoor sections with a single outdoor section

The type of load (heating or cooling) and the distribution of loads into zones will depend on the intended use of the space. In turn, these factors will determine whether a heat pump system or heat recovery system will be the most efficient choice.[15]

So it is very important to make sure that the pipe sizing is done properly, both for the main header pipe as well as the feeder pipes that feed each indoor unit. The maximum allowable length varies among different manufacturers; however, the general guidelines are as follows [16]:

- 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.[16]

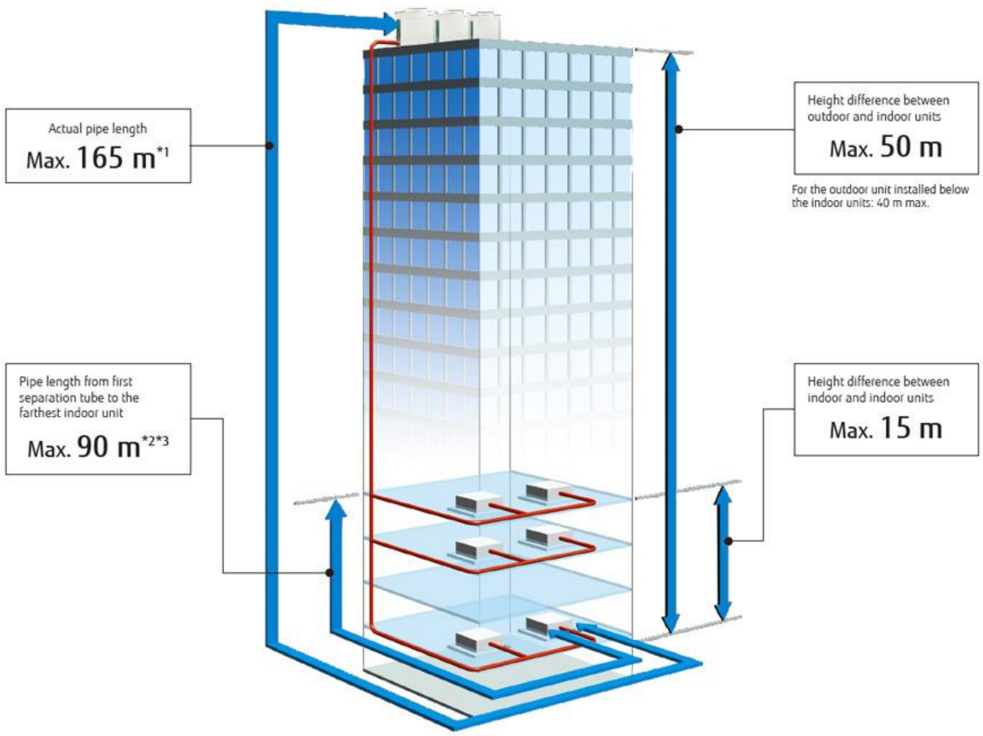


Figure (3.8): Design limits in VRF system for samsung

As stated, the refrigerant piping criteria varies from manufacturer to manufacture, for example for one of the Japanese manufacturer (Samsung), the system design limits are: [17]

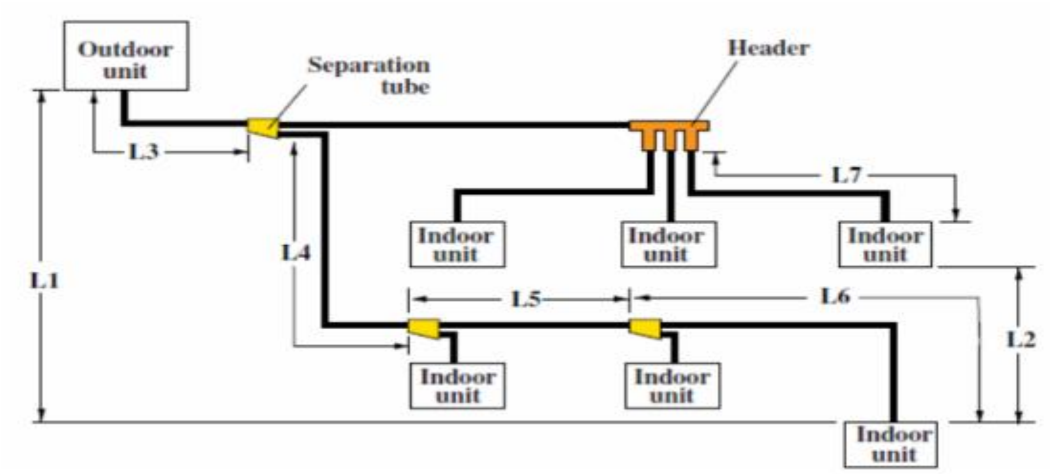


Figure (3.9): Design limits in (Samsung) VRF system

• L1: Maximum height difference between outdoor unit and indoor unit = 50m

• L2: Maximum height difference between indoor unit and indoor unit = 15m

• L3: Maximum piping length from outdoor unit to first separation tube = 70m47

• [L3+L4+L5+L6]: Maximum piping length from outdoor unit to last indoor unit = 100m

• L6 & L7: Maximum piping length from header to indoor unit = 40m

• Total piping length = 200m (Liquid pipe length)

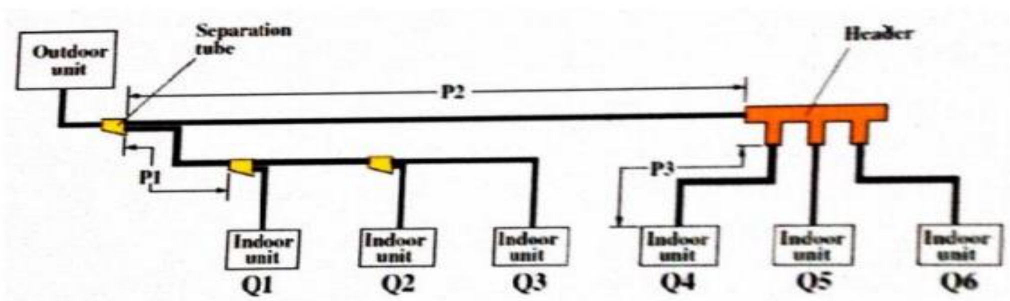


Figure (3.10): Pipe sizing for VRF system

• Size of P1: Depends on the total capacity of (Q1+Q2+Q3)

• Size of P2: Depends on the total capacity of (Q4+Q5+Q6)

• Size of P3: Depends on the total capacity of (Q4)

The combined cooling capacity of the indoor sections can match, exceed, or be lower than the

Capacity of the outdoor section connected to them. But as a normal practice:

• The indoor units are typically sized and selected based on the greater of the heating or cooling

Loads in the zone it serves, i.e. maximum peak load expected in any time of the year.

• The outdoor condensing unit is selected based on the load profile of the facility which is the peak

Load of all the zones combined at any one given time.

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

Adding up the peak load for each indoor unit and using that total number to size the outdoor unit will result in an unnecessarily oversized condensing unit. Although an oversized condensing unit with multiple compressors is capable of operating at lower capacity, too much over sizing sometimes reduces or ceases the modulation function of the expansion valve.

As a rule of thumb, an engineer can specify an outdoor unit with a capacity anywhere between 70% and 130% of the combined capacities of the indoor units.

A schematic VRF arrangement is indicated below:

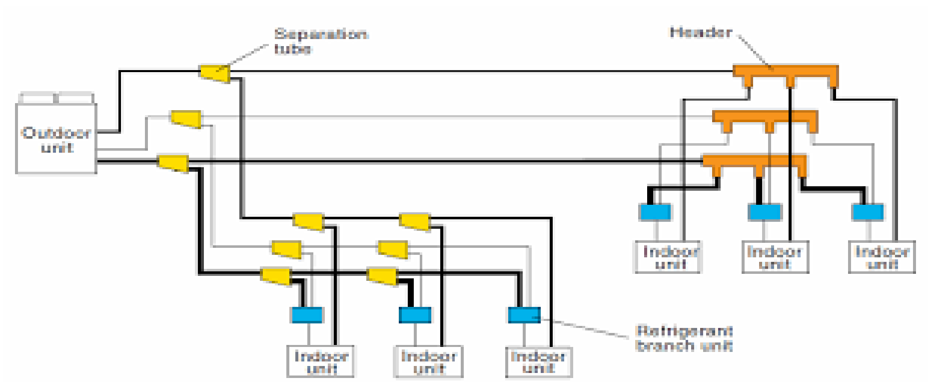


Figure (3.11): A schematic VRF arrangement

VRF systems are engineered systems and use complex refrigerant and oil control circuitry. The refrigerant pipe-work uses a number of separation tubes and/or headers (refer schematic figure above). A separation tube has 2 branches whereas a header has more than 2 branches. Either of the separation tube or header, or both, can be used for branches. However, the separation tube is never provided after the header because of balancing issues.

Figure (3.12): Separation and header tubes

3.4 VRF Heat Recovery vs VRF Heat Pumps for Homes and Commercial applications

1-VRF Heat Recovery

VRF Heat Recovery Systems are mostly used for commercial buildings, so most homes are too small to reap the benefits of a heat recovery system in relationship to the added cost. If you're going to have a lot of different zones (rooms or spaces) (#2 in image below) with different thermal requirements, and the house is large enough (think Mansion) to warrant the added cost, then heat recovery may make sense, but most likely the multi or single zone split-system heat pump system would work best as not all spaces would require conditioning at the same time.[19]

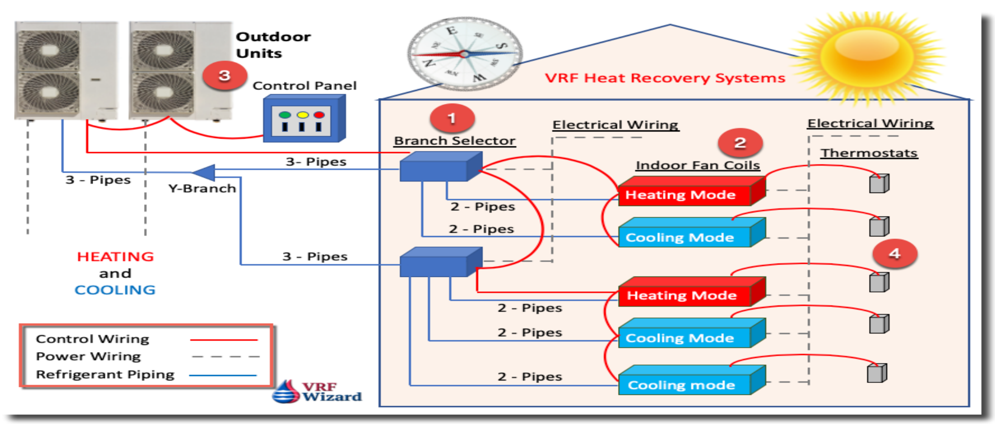


Figure (3.13) VRF Heat Recovery System Diagram

VRF Heat recovery systems allow you to have some rooms in cooling mode while others are in heating mode. If you don't believe this condition will ever exist in your home, then the Split-System Heat Pumps are the easier and more economical answer.

VRF Heat Recovery systems require some form of Branch Selector Box, which provides the control mechanism that directs refrigerant flow to meet the varying demands of the Indoor Fan Coils.

This piece of equipment is not required in a Heat Pump system. This branch selector box will need electrical power and depending on the VRF manufacture would also require a condensate drain, this adds cost to the system.[19]

2- VRF Multi-Split System Heat Pump

The most likely VRF system for a larger home would be the VRF Multi-Split System Heat Pump as opposed to a VRF Heat Recovery System. The VRF Multi-Split system allows you to use multiple indoor units with one or more Outdoor Units, depending on the size of the system.

The only drawback is that you have to choose either heating or cooling for all zones, no simultaneous heating and cooling.[19]

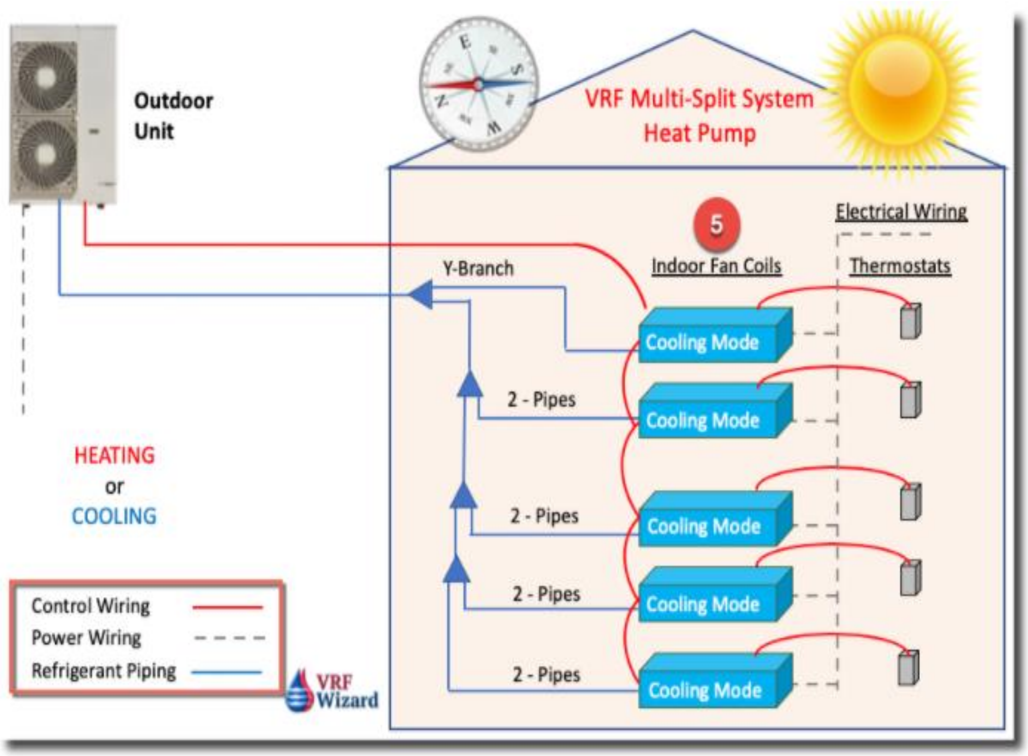


Figure (3.14) VRF Multi-Split System Heat Pump Diagram

System Benefits

- Using a VRF Multi-split system heat pump allows you to have multiple indoor units connected to one outdoor unit. Each manufacture differs in the ratio of indoor units to outdoor unit.
- You can mix the types of indoor units, such as ducted on non-ducted wall mounted units.
- Indoor units can be of different sizes, so you can serve small or larger size rooms using the same single outdoor unit.
- Indoor units can be of different sizes, so you can serve small or larger size rooms using the same single outdoor unit.

3- Single Zone Split System

The easiest to install and the most common residential system would be the single zone split system. This can be cooling only, or a heat pump which provides heating and cooling as required.

You can use one or more of these systems to meet the needs of your space. These can be used to handle various zoning challenges by providing one system for each zone type.

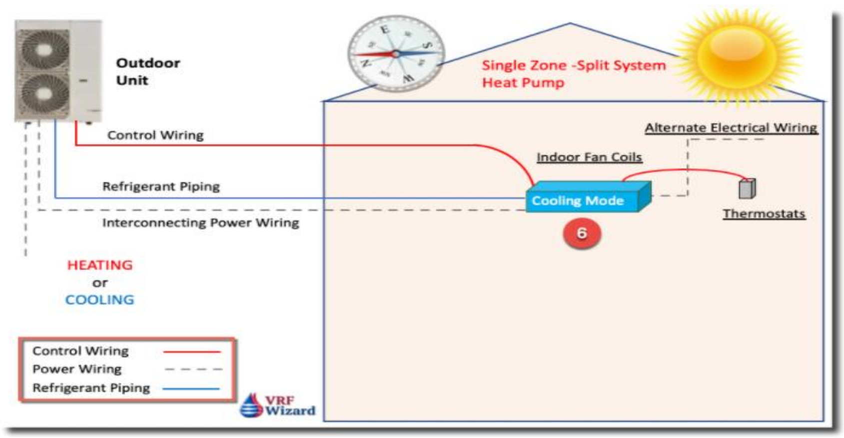


Figure (3.15) Single Zone Split System Heat Pump Diagram

Advantages and Disadvantages

- Easiest system to install and operate.
- Only allows one indoor fan coil unit for every outdoor unit.
- Only allows one zone per outdoor unit.

System Comparison

The VRF Heat Recovery system has the advantage of simultaneous heating and cooling along with some energy savings based on how well the system is diversified and zoned.

The system also allows for a greater number of indoor units per outdoor unit.

It has the disadvantage of requiring additional electrical for the branch Selector Boxes that control the flow of refrigerant. This Selector boxes could also require a condensate drain depending on the VRF manufacture you use, like that of Mitsubishi.

Another disadvantage is that the system is more complex than the standard split system and requires someone knowledgeable in its installation and commissioning.

SPLIT-SYSTEM COMPARISONS			
VRF Wizard System	Single Split System	Multi-Split System	VRF Heat Recovery System
Simultaneous Heating & Cooling	✗	✗	✓
Maximum Number of Indoor Units per Outdoor Unit	1	5+	64
Level of Difficulty Installing	LOW	MEDIUM	HIGH
Requires Additional Electrical Work	✗	✗	✓

Figure (3.16) VRF System Comparison Chart

3.5 VRF advantages

Simultaneous Heating and Cooling

Heat recovery and flexible refrigerant flow make it possible to heat and cool different zones on a single refrigerant piping system at any given time. This also helps increase efficiency by capturing what would have been wasted energy from one space and returning it to the other space as useful energy.[20]

Inverter Driven Compressors

Every outdoor unit is equipped with multiple inverter-driven compressors that provide efficiency and comfort.

Reliability

The operating sequence of the individual compressors is rotated, balancing their operating hours and distributing load evenly. Inverters reduce the risk of compressor failure and eliminate on/off power surges.

Flexibility

. VRF systems provide flexibility on reconfiguration of space for future use and can seamlessly adapt to building changes. Changing space can be easily accommodated with the different styles of indoor units without compromising the comfort level.

Comfort

The system adjusts the flow of refrigerant to each indoor unit based on its operating conditions. It computes the amount of refrigerant required by each indoor unit and controls the refrigerant flow to ensure desired comfort level without over cooling or heating of the space.

VRF advantages on the hotels

Hotels have a lot of people to please and a variety of areas to control. From guestrooms to lobbies to event areas and fitness areas, each space has its own unique demands, which is why VRF zoning systems are the perfect solution. VRF systems provide a multitude of benefits for your hotel:

- Easily customize each area to provide tailored comfort
- Individual zones controlled independently by guests or staff
- Simultaneous cooling and heating
- Optimum set points and operation scheduling
- Highly accurate zone control; indoor units and controllers that sense temperature, humidity, lighting and occupancy
- Quiet operation
- More unobtrusive than traditional systems

VRF is a great space saving solution for your hotel, compared to traditional systems. That's because modular system design can eliminate the need for mechanical rooms and bulky equipment on hotel rooftops. Compact indoor and outdoor units are also perfect for tighter, smaller spaces.

3.6 Selection units

In this section we will determine the outdoor and indoor unit of the VRF system depending on the "Samsung VRF catalogue", since this company product is existing in Hebron.

The indoor unit and the outdoor unit are chosen based on the value of the thermal loads that we have in the building.

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

Figure (3.17) Wall mounted unit

Figure (3.18) Cassette unit

Selection of each unit done by determining the code of it using the code system from DVM plus 3 technical data book they were attached in appendix.

Table 3.1:Indoor unit type ,model ,nominal and actual load [27]

Indoor Unit Type	Indoor Unit model	Nominal load (kW)		Actual cooling load (kW)	
		Coolin g	Heatin g	Coolin g	Heatin g
Wall mounted	AM045FNCDEH	4.5	5	5.8	7
Wall mounted	AM056FNCDEH	5.6	6.3	4.6	5.5
4 way cassette	AM090FN4DEH	9	10	7.3	8.6
4 way cassette	AM112FN4DEH	11.2	12.5	9.1	11
4 way cassette	AM128FN4DEH	12.8	13.8	10.4	12
4 way cassette	AM140FN4DEH	14	16	11.4	13.8
4 way cassette	AM045FN4DEH	4.5	5	3.7	4.8
4 way cassette	AM071FN4DEH	7.1	8	5.8	7
4 way cassette	AM056FN4DEH	5.6	6.3	4.6	5.6

Where:

• Required capacity: The calculated cooling or heating load at desired conditions.

• Nominal capacity: The capacity of the unit at specific conditions determine by the manufacturer.

• Actual capacity: The capacity of the unit at the design conditions.

Table 3.2: Space name, peak cooling load, unit type, model, load and #of unit for 8th using Samsung software:

Room information				Indoor List					
Name	Load			Name	Model name	Nominal Capacity			Simu
	Cooling		Heating			Cooling		Heating	
	TC(kW)	S	TC(kW)			TC(kW)	SHC(kW)	TC(kW)	T
Bedroom (64)	2.84		3.33	Bedroom...	AM045FNQDEH/TK	4.50	3.05	5.00	
Bedroom (65)	2.92		3.42	Bedroom...	AM045FNQDEH/TK	4.50	3.05	5.00	
Bedroom (67)	2.30		3.31	Bedroom...	AM045FNQDEH/TK	4.50	3.05	5.00	
Bedroom (68)	4.35		3.68	Bedroom...	AM045FNQDEH/TK	4.50	3.05	5.00	
Bedroom (69)	2.72		3.53	Bedroom...	AM045FNQDEH/TK	4.50	3.05	5.00	
Bedroom (70)	2.48		3.25	Bedroom...	AM045FNQDEH/TK	4.50	3.05	5.00	
Bedroom (71)	2.82		3.59	Bedroom...	AM045FNQDEH/TK	4.50	3.05	5.00	
Bedroom (72)	3.99		2.87	Bedroom...	AM045FNQDEH/TK	4.50	3.05	5.00	
Corridor	3.37		6.44	Corridor1	AM045FNQDEH/TK	4.50	3.05	5.00	
				Corridor2	AM045FNQDEH/TK	4.50	3.05	5.00	

Table 3.3: Space name, peak cooling load, unit type, model, load and #of unit for 3rd 4th 5th 6th 7th floors using Samsung software

Room information				Indoor List					
Name	Load			Name	Model name	Nominal Capacity			Simu
	Cooling		Heating			Cooling		Heating	
	TC(kW)	S	TC(kW)			TC(kW)	SHC(kW)	TC(kW)	T
Bedroom (52)	2.84		3.25	Bedroom...	AM045FNQDEH/TK	4.50	3.05	5.00	
Bedroom (53)	2.93		3.37	Bedroom...	AM045FNQDEH/TK	4.50	3.05	5.00	
Bedroom (54)	3.29		3.02	Bedroom...	AM045FNQDEH/TK	4.50	3.05	5.00	
Bedroom (55)	4.19		3.59	Bedroom...	AM045FNQDEH/TK	4.50	3.05	5.00	
Bedroom (56)	2.59		4.83	Bedroom...	AM045FNQDEH/TK	4.50	3.05	5.00	
Bedroom (57)	2.44		4.50	Bedroom...	AM045FNQDEH/TK	4.50	3.05	5.00	
Bedroom (58)	2.48		3.47	Bedroom...	AM045FNQDEH/TK	4.50	3.05	5.00	
Bedroom (59)	4.00		3.82	Bedroom...	AM045FNQDEH/TK	4.50	3.05	5.00	
Corridor	3.37		6.44	Corridor1	AM045FNQDEH/TK	4.50	3.05	5.00	
				Corridor2	AM045FNQDEH/TK	4.50	3.05	5.00	

Table 3.4: Space name, peak cooling load, unit type, model, load and #of unit for roof using Samsung software:

Indoor List										
Room information				Indoor List						
Name	Load			Name	Model name	Nominal Capacity			Simultai	
	Cooling		Heating			Cooling		Heating		
	TC(kW)	S	TC(kW)			TC(kW)	SHC(kW)	TC(kW)	TC(k	
Bedroom (76)	4.07		5.25	Bedroom...	AM056FN4DEH/TK	5.60	3.90	6.30		
Bedroom (77)	6.78		4.31	Bedroom...	AM056FN4DEH/TK	5.60	3.90	6.30		
				Bedroom...	AM056FN4DEH/TK	5.60	3.90	6.30		
Corridor	2.66		5.21	Corridor1	AM045FN4DEH/TK	4.50	3.10	5.00		
				Corridor2	AM045FN4DEH/TK	4.50	3.10	5.00		

Table 3.5: Space name, peak cooling load, unit type, model, load and #of unit for 2nd floor using Samsung software:

Indoor List								
Room information				Indoor List				
Name	Load			Name	Model name	Nominal Capacity		
	Cooling		Heating			Cooling		Heating
	TC(k	S	TC(kW)			TC(kW)	SHC(kW)	TC(kW)
Kitchen	2.91		2.78	Kitchen1	AM036FNQDEH/TK	3.60	2.40	4.00
Multi purposes hall	9.60		6.01	Multi purp...	AM056FN4DEH/TK	5.60	3.90	6.30
				Multi purp...	AM056FN4DEH/TK	5.60	3.90	6.30
Restaurant	28.57		26.64	Restaurant1	AM056FN4DEH/TK	5.60	3.90	6.30
				Restaurant2	AM056FN4DEH/TK	5.60	3.90	6.30
				Restaurant3	AM056FN4DEH/TK	5.60	3.90	6.30
				Restaurant4	AM056FN4DEH/TK	5.60	3.90	6.30
				Restaurant5	AM056FN4DEH/TK	5.60	3.90	6.30
				Restaurant6	AM056FN4DEH/TK	5.60	3.90	6.30

Table 3.6: Space name, peak cooling load, unit type, model, load and #of unit for 1st floor using Samsung software:

Indoor List								
Room information				Indoor List				
Name	Load			Name	Model name	Nominal Capacity		
	Cooling		Heati			Cooling		Heating
	TC(kW)	SH	TC(k			TC(kW)	SHC(kW)	TC(kW)
Reception	18.21		13.40	Reception1	AM045FN4DEH/TK	4.50	3.10	5.00
				Reception2	AM045FN4DEH/TK	4.50	3.10	5.00
				Reception3	AM045FN4DEH/TK	4.50	3.10	5.00
				Reception4	AM045FN4DEH/TK	4.50	3.10	5.00
				Reception5	AM045FN4DEH/TK	4.50	3.10	5.00
Office 110	3.45		2.75	Office 110 1	AM036FNQDEH/TK	3.60	2.40	4.00
Room 106	2.38		1.88	Room 1061	AM036FNQDEH/TK	3.60	2.40	4.00
Office 105	2.18		1.80	Office 1051	AM036FNQDEH/TK	3.60	2.40	4.00

Outdoor unit

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

- The total actual cooling load and the capacity ratio.
- The capacity ratio is a ratio between the total capacity of the indoor and outdoor capacity and its ranged between (70% – 130 %) and the outdoor units selection as follow:

Table 3.7: Actual cooling load for 1st 2nd 3rd floors:

Zone name	Actual Cooling load (kW)	Actual Cooling load (Ton)
Ground floor	29.986	8.470
First floor	41.075	11.735
Second floor	28.137	7.94
Total	99.198	28.022

99.198 kW = 28.022 Ton

Take 86% as a compensation ratio

So we have 24.098 Ton

We have 3 outdoor units in this system

From Samsung software the outdoor unit for 1^{st} 2^{nd} 3^{rd} floors:

Table 3.8: The outdoor unit for 1^{st} 2^{nd} 3^{rd} floors

Outdoor List			
Name	Model name	Nominal Capacity	
		Cooling	Heating
		TC(kW)	TC(kW)
Outdoor1	1AM140HXVFGH/ID	40.00	45.00
Outdoor2	1AM140HXVFGH/ID	40.00	45.00
Outdoor3	1AM160HXVFGH/ID	45.00	50.00

:

Table 3.9: Actual cooling load for 3^{rd} 4^{th} 5^{th} 6^{th} 7^{th} 8^{th} and roof floors:

Zone name	Actual Cooling load (kW)	Actual Cooling load (Ton)
Fourth floor	28.137	7.94
Fifth floor	28.137	7.94
Sixth floor	28.137	7.94
Seventh floor	28.137	7.94
Eight floor	27.777	7.846
Roof	14.429	4.075
Total	154.754	43.71

154.754 kW = 43.71 Ton

Take 80 % as a compensation ratio

So we have 34.968 Ton

We have 3 outdoor units in this system

From Samsung software the outdoor unit for 3rd 4th 5th 6th 7th 8th **floors:**

Table 3.10: The outdoor unit for 3rd 4th 5th 6th 7th 8th **floors**

Outdoor List			
Name	Model name	Nominal Capacity	
		Cooling	Heating
		TC(kW)	TC(kW)
New Outdoor1	AM260HXVAGH/TK	73.00	81.90
New Outdoor2	AM260HXVAGH/TK	73.00	81.90
New Outdoor3	AM100FXVAGH/TK	28.00	31.50

3.7 Selecting refrigerant piping

Refrigerant piping diameter, thickness, and temper is selected according to length, as specified in this section.

In these 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 (Refits Joints).

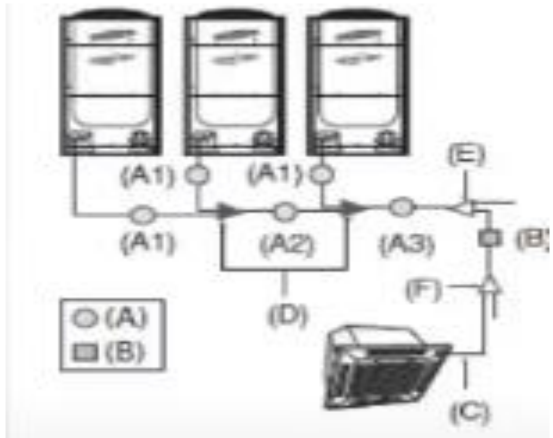


Figure (3.19): Outdoor and indoor unit [21]

Where:

A1: Select the pipes according to the outdoor unit capacity used table attached in appendix.

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

A3: Select the main pipe of outdoor units

Table 3.11: Outdoor unit and pipe size [27]

Outdoor unit	Pipe size mm		Oil balancing pipe size
	Liquid	Gas	
8 hp	9.52 D	19.05 D	
10 hp		22.23 D	
12 hp		25.40	
14 hp	12.70 D		
16 hp			
18 hp			6.35 D
20 hp	15.58 D	28.58	
22 hp			
24 hp			
26-30 hp		31.75 D	
32-34 hp	19.05 D		
36-48 hp		38.10 D	
50-64 hp	22.23 D	44.45 D	

3.8 Ventilation

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

It should be noted that ventilation air is introduced intentionally through the air conditioning equipment. Therefore, ventilation air causes additional load on the cooling and heating coils. on the other hand, infiltrated air is considered as a part of the space heating or cooling loads.

There are two ways for Ventilation:

- Natural ventilation covers uncontrolled inward air leakage through cracks, windows,doorways and vents (infiltration) as well as air leaving a room (exfiltration) through thesame routes.
- Natural ventilation is strongly affected by weather conditions and is oftenunreliable. [22]

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

- The difference between indoor and outdoor temperature;
- Wind.

The bigger the both factors are the more intensive is the air change in rooms. This means that in colder weather conditions the rooms and the building is often over-ventilated and in warmer and windless weather, there is a lack of fresh air. As both of these factors are directly dependent on the external climate, the system is considered to be a non- controllable system. Users of the building cannot change the air volume rate no more than by switching it ON or OFF; this means by opening and closing the exhaust grilles. [22]

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

Mechanical ventilation systems are considered reliable in delivering the designed flow rate, regardless of the impacts of variable wind and ambient temperature. As mechanical ventilation can be integrated easily into air-conditioning, the indoor air temperature and humidity can also be controlled. [23]

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

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

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

An air change per hour (ACH) is the most frequently used basis for calculating the required airflow. Air changes per hour are the number of times in one hour an equivalent room volume of air will be introduced into, or extracted from the room space. [14]

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

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

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

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

Mechanical ventilation can work everywhere when electricity is available.

3.8.1 Purposes of ventilation

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

In general, outside ventilation air must be introduced to the space return air for one or more of the following reasons:

(1) Outside air must be supplied to the inside space at a rate that ranges from 8.0 to 20. 0 liters of air per second per occupant according to the type of application.

(2) Carbon dioxide must be removed or diluted such that it does not exceed 0.1 % of the air by volume

(3) Body smells and other odors must be removed from the air conditioned space or diluted as a result of introducing outside fresh air.

(4) Ventilation air must be introduced to spaces (such as workshops, factories, laboratories etc.) that are characterized by producing various contaminants (such as carbon monoxide, acetone, chlorine, etc.

3.8.2 Designing of mechanical ventilation

Steps of designing mechanical ventilation:

- Calculate the required ventilating rate of air.

- Calculate the volume of the room in (m3)

- Calculate the flow rate of air by using air changes per hour method

3.8.3 Bathroom sample calculation:

Designing of mechanical ventilation

•Using Air changes per hour.

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

Step Two - Calculate the volume of the room.

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

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

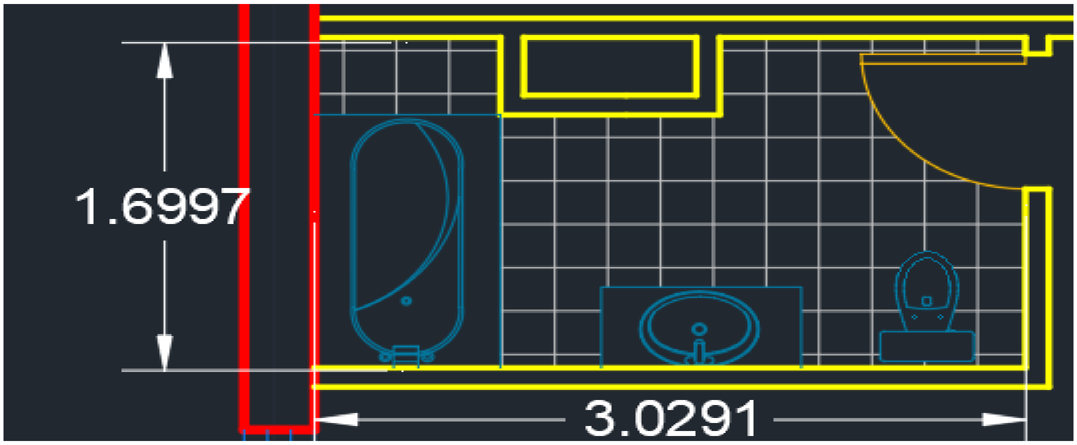


Figure (3.20) Sample bathroom

Sample calculation For bathroom:

Volume = Length* Width * Height (3.3)

= 3.0291 * 1.6997 * 3.5

= 18.019 m^3

Number Air Changes per Hour=3 from appendix

Required m^3/s=18.019*3 / 3600

Required ventilation rate in m^3/s =0.0150

Required ventilation rate = 15.0167 L/s

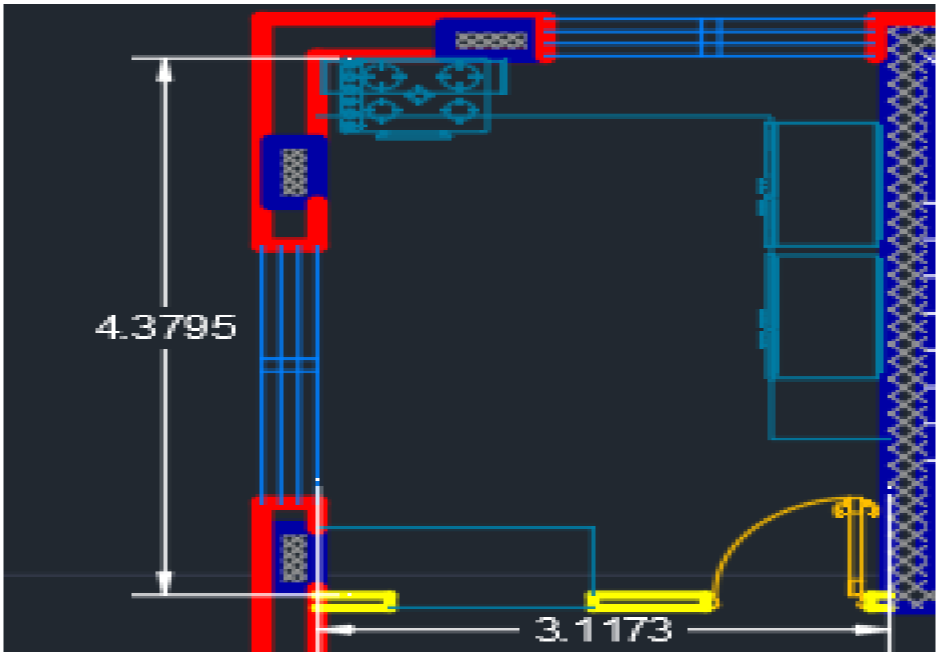


Figure (3.21) Sample Kitchen

For kitchen

Volume = Length* Width * Height

= 4.3795 * 3.1173 * 3.5

= 47.782 m^3

Number Air Changes per Hour=2   from appendix

Required ventilation rate

Required m^3/s = 47.782 *2 / 3600

= 0.0265 m^3/s

Required ventilation rate = 26.5 L/s

Chapter four

Plumbing system

4.1 Introductions

Plumbing, system of pipes and fixtures installed in a building for the distribution and use of potable (drinkable) water and the removal of waterborne wastes. It is usually distinguished from water and sewage systems that serve a group of buildings or a city.

One of the problems of every civilization in which the population has been centralized in cities and towns has been the development of adequate plumbing systems. In certain parts of Europe the complex aqueducts built by the Romans to supply their cities with potable water can still be seen. However, the early systems built for the disposal of human wastes were less elaborate. Human wastes were often transported from the cities in carts or buckets or else discharged into an open, water-filled system of ditches that led from the city to a lake or stream.

Improvement in plumbing systems was very slow. Virtually no progress was made from the time of the Romans until the 19th century. The relatively primitive sanitation facilities were inadequate for the large, crowded population centers that sprang up during the Industrial Revolution, and outbreaks of typhoid fever and dysentery were often spread by the consumption of water contaminated with human wastes. Eventually these epidemics were curbed by the development of separate, underground water and sewage systems, which eliminated open sewage ditches. In addition, plumbing fixtures were designed to handle potable water and water-borne wastes within buildings.[24]

4.2 Water supply system

There are two basic types of water distribution systems for buildings:

1- Up feed distribution system
2- Down feed distribution system

In our design we will use up feed distribution system, and there are two methods commonly used:

1- The supply of water for the building is received from a public street main.
2- private water supply enters into a pneumatic tank (pressurized tank) and is pressurized from approximately 35 to 60 psi

we will use up feed distribution system which private water supply enters into a pneumatic tank (pressurized tank) and is pressurized from approximately 35 to 60 psi,and thus we will use a pump to reach this pressure.[24]

4.2.1 Design Procedure

The procedure for the design of a water distribution system for a building is straightforward. It is assumed that an adequate reliable supply of clean potable water is available. Whether the source is street mains as is usually the case or a private well is immaterial to the technologist whose work begins at the water service entrance. The design procedure is then as follows:

(a) Determine the pressure of the source. Decide whether to use the source directly, reduce the pressure or increase it.

(b) Determine · whether the structure will be treated as a single unit or whether it is necessary to zone it.

(c) Decide whether to use an, up feed or down feed system.

(d) Determine the pressure and flow requirements of all fixtures and all continuous water uses.

(e) Determine maximum instantaneous water demand. This is a combination of fixture use and other water uses in the building.

(f) Determine the service size on the basis of maximum water requirements.

(g) Determine minimum pipe sizes on the basis of required flow rates and pressure for the water use device farthest from the service. This requires use of pipe friction charts or tables or, alternatively, use of the velocity method.

h) Decide on the method of supplying hot water. This includes hot water source and type of circulation system, if any.

(i) Determine water pipe sizes for the entire structure. Pressures of hot and cold water should be equal at fixtures using both, to prevent cross flow during mixing [24]. ,

(j) Design details of the piping system including water service details, hot water supply details, all valuing, location of vacuum breakers, special support details and the like.

(k) Determine location of shock arresters (water hammer eliminators) and any other special devices required.[24]

4.2.2 Calculation of cold and hot water supply system

4.2.2.1 Calculation of cold and hot water (WSFU) system

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

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

Table (4.1): Number of fixture units for the main riser

Floor / Fixture type	Shower head (private)	Lavatory (private)	Lavatory (public)	Water closet (private)	Water closet (public)	Kitchen sink (Hotel)	Bathtub (Private)
Ground floor	0	0	2	0	2	0	0
Mezzanine floor	0	0	2	0	2	1	0
First floor	8	8	0	8	0	0	0
Second floor	8	8	0	8	0	0	0
Third floor	8	8	0	8	0	0	0
Fourth floor	8	8	0	8	0	0	0
Fifth floor	8	8	0	8	0	0	0
Sixth floor	8	8	0	8	0	0	0
The roof	2	2	0	2	0	0	2
Total	50	50	4	50	4	1	2

Table (4.2): Fixture unit load for the main riser

Fixture type	Number of fixtures	WSFU	Cold WSFU	Hot WSFU	Total WSFU	Total Cold	Total hot
Shower head (private)	50	2	2 x ¾	2 x ¾	100	75	75
Lavatory (private)	50	1	1 x ¾	1 x ¾	50	37.5	37.5
Lavatory (public)	4	2	2 x ¾	2 x ¾	8	6	6
Water closet (private flush tank)	50	3	3 x ¾	—	150	150	0
Water closet (public flush tank)	4	5	5 x ¾	—	20	20	0
Kitchen sink	1	4	4 x ¾	4 x ¾	4	3	3

(Hotel)							
Bathtub (Private)	2	2	2 x ¾	2 x ¾	4	3	3
Total	161	__	__	__	336	294.5	124.5

From (A-23) table for estimating demand to determine the required amount of water:

We have 335 WSFU as a total

300 WSFU ⟶ 85 GPM

336 WSFU ⟶ X GPM

400 WSFU ⟶ 105 GPM

From interpolation X = 92.2 GPM = 5.816 L/S

We have 294.5 WSFU as cold water

250 WSFU ⟶ 75 GPM

294.5 WSFU ⟶ X GPM

300 WSFU ⟶ 85 GPM

From interpolation X = 83.9 GPM = 5.293 L/S

We have 124.5 WSFU as a hot water

120 WSFU ⟶ 49GPM

124.5 WSFU ⟶ X GPM

140 WSFU ⟶ 73 GPM

From interpolation X = 49.5 GPM = 3.1229 L/S

Table (4.3): total WSFU and GPM for the riser

The water lines	The main line	cold water riser	Hot water riser
Total WSFU	336	294.5	124.5
Total GPM	92.2	83.9	49.5
Total L/S	5.816	5.293	3.1229

4.2.2.2 Pipe sizing calculation

In our design we will use up feed distribution system which private water supply enters into a pneumatic tank (pressurized tank) and is pressurized from approximately 35 to 60 psi,and thus we will use a pump to reach this pressure.

:

Main pressure (Pump pressure) = Static head + Friction head + Flow pressure

Where:

The static head is to overcome the height.

The friction head is to overcome friction in the pipes.

The flow pressure is to ensure flow, the pressure available at the fixtures when the outlet is wide open and it must be equal or exceed the minimum fixture pressure.

- We will use flush tank so the flow pressure is equal 8 PSI and is considered sufficient for all fixture in a system.

- We determine that the pump head is equal 41.9 meter and equal 59.58 psi.

Figure 4.1 Detail of pump pressure determination

Date	Sep-20	
Fixtures units and equivelant flow is as Jordanian uniform plumbing code		
A. Pump Flowrate :		
Sum of Fixture Units (wsfu) For all Areas =	336	wsfu
Refering to UPC (Hunter curve) we get =	5.816	L/sec
Pump Flowrate=	**5.8**	**L/s**
B. Pump Head :		
# Friction loss Head		
Equivalent length for most hydraulic demand wet area=	43.1	m
Equivalent length with fitting losses =	64.65	m
The pressure drop per meter =	170	Pa/m
Total friction loss =	10990.5	Pa
	1.09905	m
Static Pressure	28.95	
# Minimum residual pressure =	8	
Total head needed is	38.04905	m
Add 10% Safety factor		
Pump Head=	**41.9**	**m**

Static pressure:

As indicated previously that the building consists of six floor, basement, roof, Mezzanine floor and ground floor (floor to floor height is 3.5 meters), and the level of water that we want to pump up is 4 meters lower than the level of the ground floor, so the total vertical length from the pump source to the critical fixture is equal 29.95 m.

1 psi → 0.7 meter of head

X → 29.95 meter of head

➡ Static pressure = 42.78 psi

Friction head:

Main pressure (Pump pressure) = Static head + Friction head + Flow pressure

59.584 psi = 42.78 psi + friction head + 8 psi

➡ Friction head = 8.804 psi

Total equivalent length:

We will determine the total length of piping from the service tap point to farthest fixture at the roof.

- **For cold water system:**

  Total equivalent length = 44.83 m

  Assume 50% additional equivalent length to account fittings

  So the equivalent length = 67.245 m

  1 meter → 3.28 ft
  67.245 → X

➡ The equivalent length = 220.56 ft

- **For hot water system:**

  Total equivalent length = 44.83 m

  Assume 50% additional equivalent length to account fittings

  So the equivalent length = 67.245 m

  1 meter → 3.28 ft
  67.245 → X

➡ The equivalent length = 220.56 ft

We establish a friction loss per 100 ft. by dividing total friction loss by total length and the size the piping accordingly.

8.804 psi → 220.56 FT
X → 100 FT

➡ **Friction head = 4 PSI/100FT**

Assume that all piping is steel pipe (Schedule 40)

Table (4.4): Pipe sizing for the riser

The water lines	The main line	cold water riser	Hot water riser
Flow (GPM)	92.2	83.9	49.5
Equivalent length (FT)	92.2	220.56	220.56
Pipe size (inch)	3 inch	3 inch	2.5 inch
Velocity (fbs)	4 fbs	4 fbs	3.4 fbs
Pressure drop(pa/m)	231 pa/m	194 pa/m	210 pa/m

Table (4.5): Fixture unit load for the Ground floor

Fixture type	Number of fixtures	WSFU	Cold WSFU	Hot WSFU	Total WSFU	Total Cold	Total hot
Lavatory (General)	2	2	2 x ¾	2 x ¾	4	3	3
Water closet (general)	2	5	5 x ¾	5 x ¾	10	10	0
Total	4	__	__	__	14	13	3

From (A-23) table for estimating demand to determine the required amount of water:

We have 14 WSFU as a **total**

10 WSFU ⟶ 8GPM

14 WSFU ⟶ X GPM

14 WSFU ⟶ 11 GPM

From interpolation **X = 10.4 GPM = 0.6561 L/s**

We have 13 WSFU as **cold** water

10 WSFU → 8 GPM

13 WSFU → X GPM

15 WSFU → 11 GPM

From interpolation **X = 9.8 GPM = 0.6183 L/S**

Figure (4.2): Main Pipe size of the ground floor

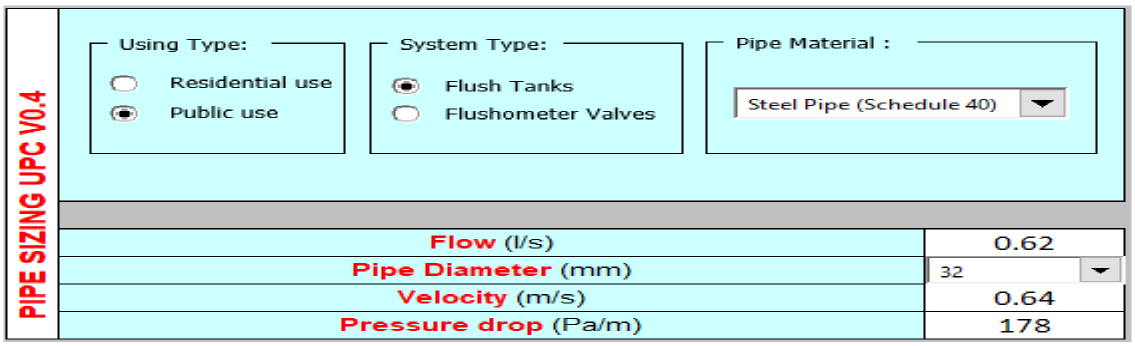


Table (4.6): Fixture unit load for the Mezzanine floor

Fixture type	Number of fixtures	WSFU	Cold WSFU	Hot WSFU	Total WSFU	Total Cold	Total hot
Lavatory (General)	2	2	2 x ¾	2 x ¾	4	3	3
Water closet (general)	2	5	5 x ¾	5 x ¾	10	10	0
Kitchen sink	1	4	4 x ¾	4 x ¾	4	3	3
Total	4	__	__	__	18	16	6

From (A-23) table for estimating demand to determine the required amount of water:

We have 18 WSFU as a **total**

15WSFU → 11GPM

18 WSFU → X GPM

20 WSFU → 14 GPM

From interpolation **X = 12.8 GPM =0.8076 L/s**

We have 16 WSFU as **cold** water

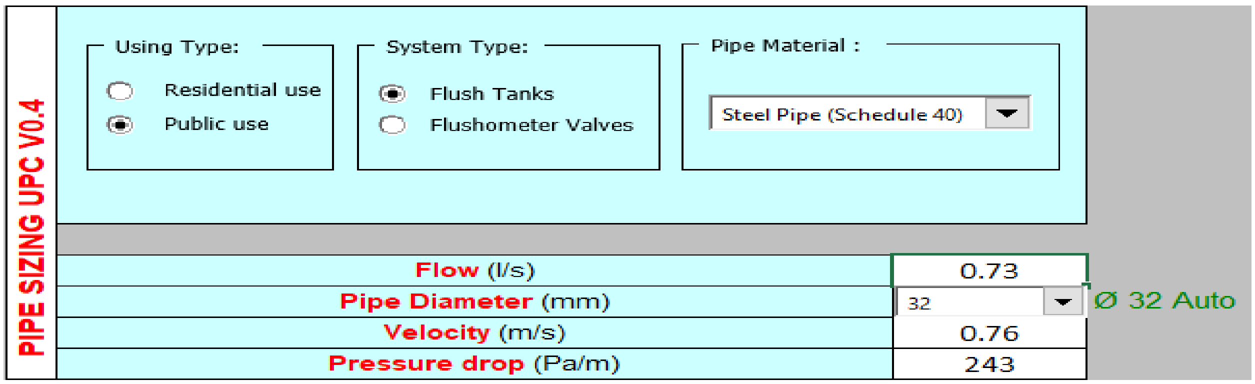
15 WSFU ⟶ 11 GPM

16 WSFU ⟶ X GPM

20WSFU ⟶ 14 GPM

From interpolation **X = 11.6 GPM =0.7318 L/S**

Figure (4.3): Main cold Pipe size of the First floor



We have 6 WSFU as **hot** water

6 WSFU ⟶ 5 GPM = 0.3155 L/S

Figure (4.4): Main hot Pipe size of the First floor

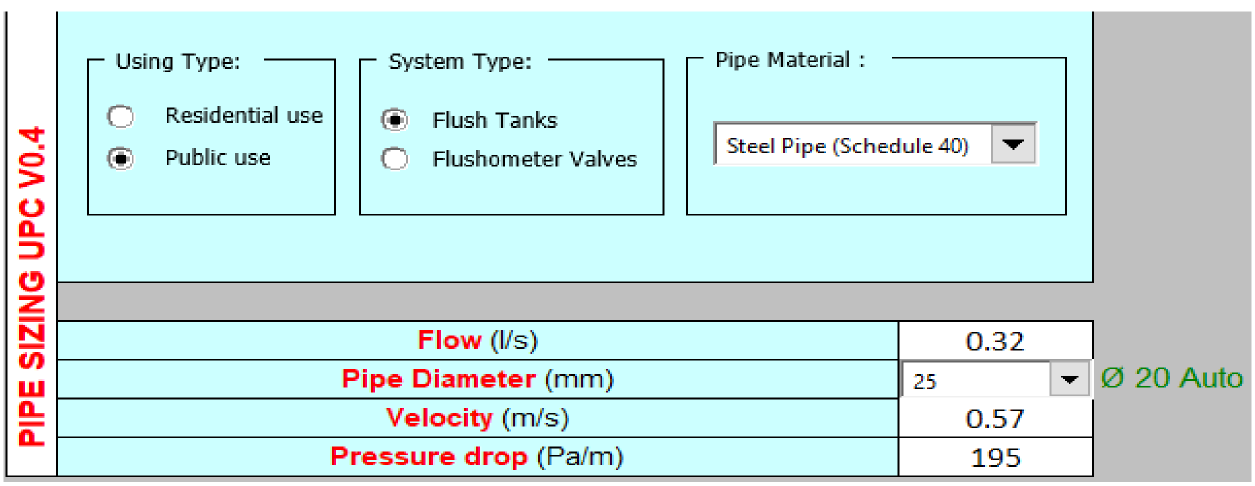


Table (4.7): Fixture unit load for the 1^{st} 2^{nd} 3^{rd} 4^{th} 5^{th} 6^{th} floor

Fixture type	Number of fixtures	WSFU	Cold WSFU	Hot WSFU	Total WSFU	Total Cold	Total hot
Lavatory (private)	8	1	1 x ¾	1 x ¾	8	6	6
Water closet (private)	8	3	3 x ¾	3 x ¾	24	24	0
Shower head (private)	8	2	2x ¾	2 x ¾	16	12	12
Total	4	__	__	__	48	42	18

From (A-23) table for estimating demand to determine the required amount of water:

We have 48WSFU as **Total**

40WSFU → 25 GPM

48 WSFU → X GPM

50WSFU → 29 GPM

From interpolation **X = 28.2 GPM = 1.7791 L/s**

We have 42 WSFU as **cold** water

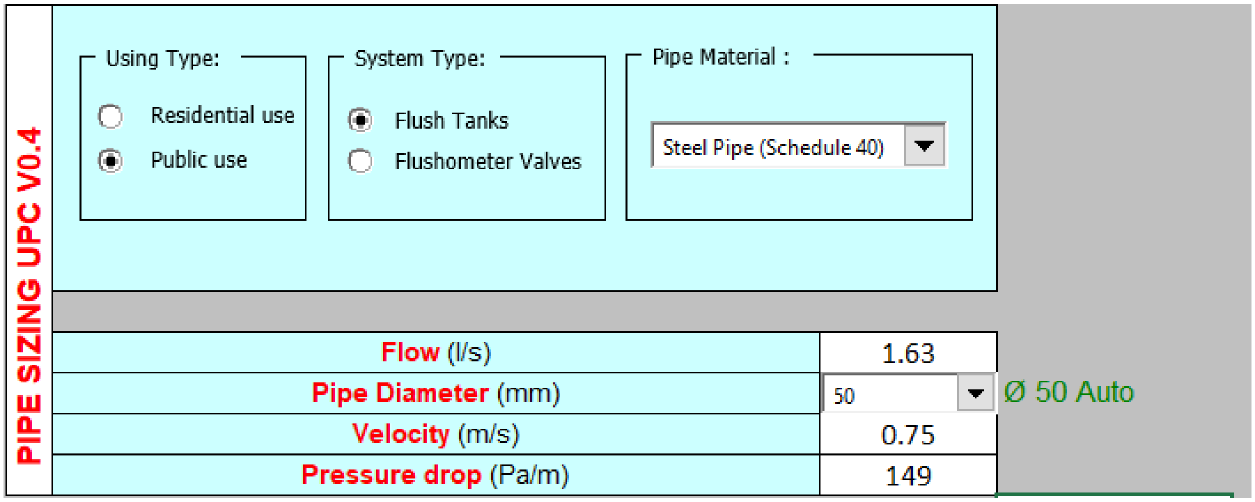
40WSFU → 25 GPM

42 WSFU → X GPM

50WSFU → 29 GPM

From interpolation **X = 25.8 GPM = 1.6277 L/s**

Figure (4.5): Main cold Pipe size of the 1st 2nd 3rd 4th 5th 6th floor



We have 18 WSFU as a **hot** water

15WSFU ⟶ 11GPM

18 WSFU ⟶ X GPM

20 WSFU ⟶ 14 GPM

From interpolation **X = 12.8 GPM =0.8076 L/s**

Figure (4.6): Main hot Pipe size of the 1st 2nd 3rd 4th 5th 6th floor

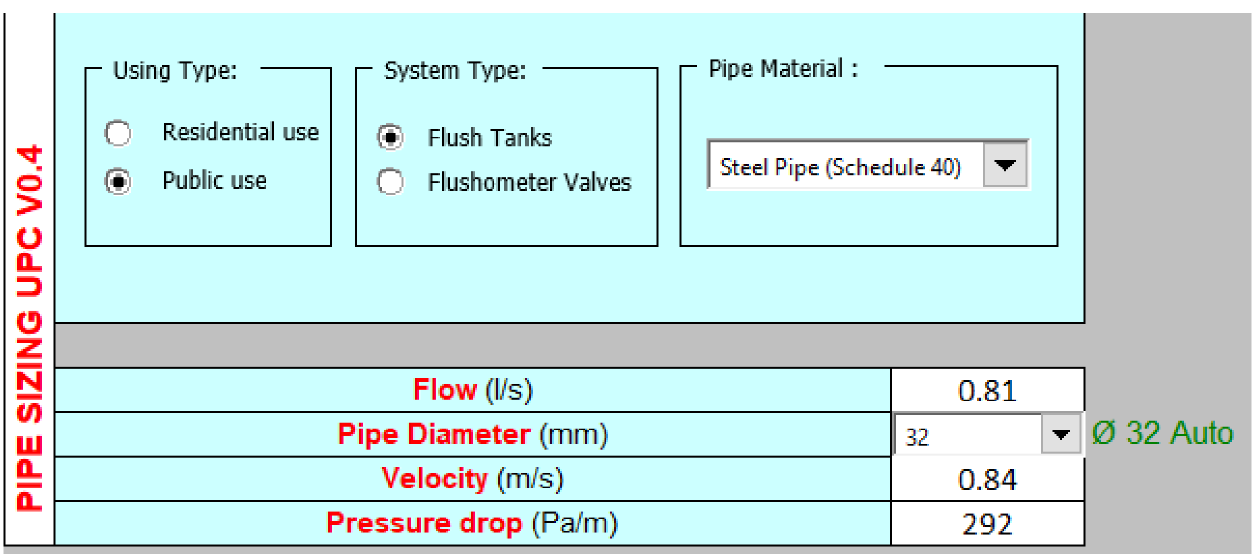


Table (4.8): Fixture unit load for the roof

Fixture type	Number of fixtures	WSFU	Cold WSFU	Hot WSFU	Total WSFU	Total Cold	Total hot
Lavatory (private)	2	1	1 x ¾	1 x ¾	2	1.5	1.5
Water closet (private)	2	3	3 x ¾	3 x ¾	6	4.5	0
Shower head (private)	2	2	2x ¾	2 x ¾	4	3	3
Bathtub (private)	2	2	2x ¾	2 x ¾	4	3	3
Total	4	__	__	__	16	12	7.5

From (A-23) table for estimating demand to determine the required amount of water:

We have 16 WSFU as a **total**

15WSFU ⟶ 11GPM

16 WSFU ⟶ X GPM

20 WSFU ⟶ 14 GPM

From interpolation **X = 11.6 GPM = 0.7318 L/s**

We have 12 WSFU as **cold** water

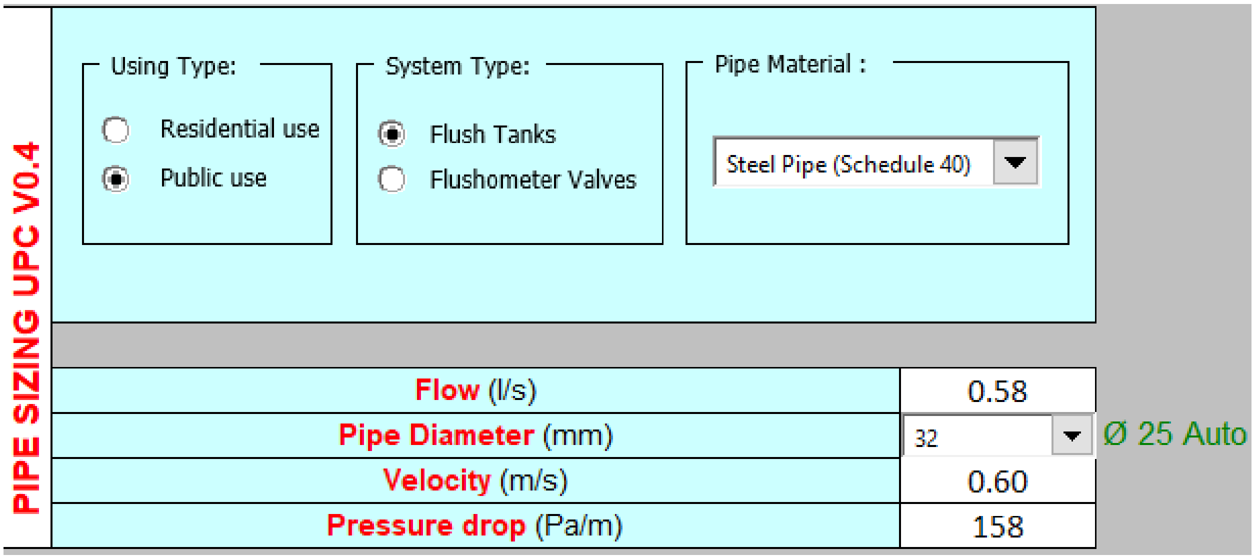
10WSFU ⟶ 8 GPM

12 WSFU ⟶ X GPM

15WSFU ⟶ 11 GPM

From interpolation **X = 9.5 GPM = 0.5804 L/s**

Figure (4.7): Main cold Pipe size of the roof



We have 7.5 WSFU as a **hot** water

6WSFU → 5GPM

7.5WSFU → X GPM

10 WSFU → 8 GPM

From interpolation **X = 6.125 GPM = 0.3864 L/s**

Figure(4.8): Main hot Pipe size of the **roof**

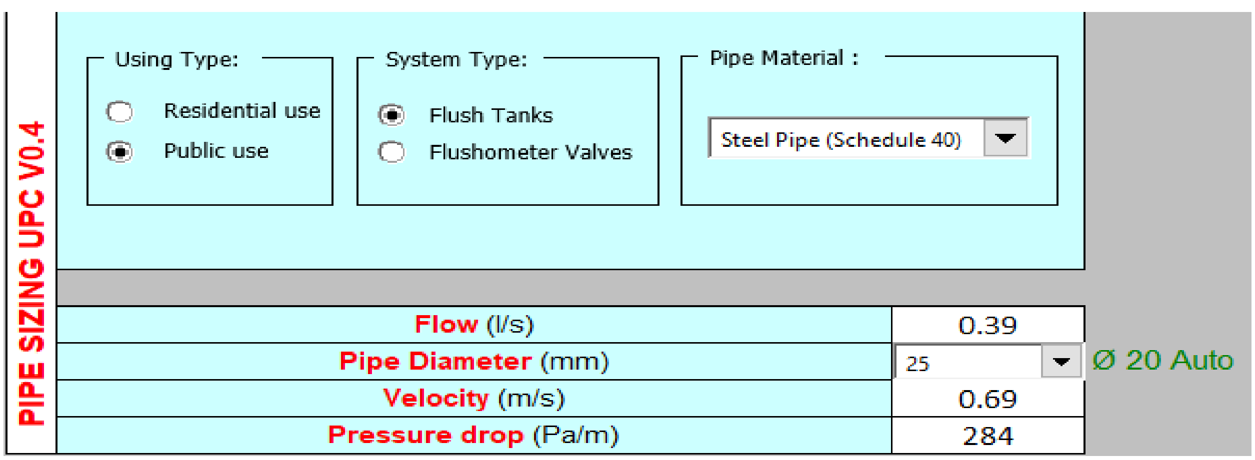


Table (4.9): The cold riser details

Floors	WSFU	Flow (GPM)	Flow (L/S)	Pipe size (mm)	Velocity (m/s)	Pressure drop (Pa/m)
Ground floor	294.5	83.9	5.2933	80	1.11	194
Mezzanine floor	294.5 – 16 = 278.5	80.6	5.0914	80	1.07	180
First floor	278.5 – 42 = 236.5	72.3	4.5614	80	0.96	147
Second floor	236.5 – 42 = 194.5	63.9	4.0315	65	1.30	337
Third floor	194.5 – 42 = 152.5	55.5	3.5015	65	1.13	260
Fourth floor	152.5 – 42 = 110.5	46.625	2.9416	65	0.95	188
Fifth floor	110.5 – 42 = 68.5	35.55	2.2429	50	1.04	271
Sixth floor	68.5 – 42 = 26.5	17.9	1.1293	40	0.86	256
The roof	26.5 – 12 = 14.5	10.7	0.6751	32	0.70	210

Table (4.10): The hot riser details

Floors	WSFU	Flow (GPM)	Flow (L/S)	Pipe size (mm)	Velocity (m/s)	Pressure drop (Pa/m)
Ground floor	124.5	49.9	3.1482	65	1.02	213
Mezzanine floor	124.5 – 6 = 118.5	48.625	3.0678	65	0.99	203
First floor	118.5 – 18 = 100.5	44.125	2.7839	65	0.90	170
Second floor	100.5 – 18 = 82.5	39.625	2.4999	50	1.15	331
Third floor	82.5 – 18 = 64.5	34.35	2.1671	50	1	254
Fourth floor	64.5 – 18 = 46.5	27.6	1.7413	50	0.80	169

Fifth floor	46.5 – 18 = 28.5	19.1	1.205	40	0.92	289
Sixth floor	28.5 – 18 =10.5	8.3	0.5236	32	0.54	131

4.3 water tank volume

Calculation for the water well volume needed for the hotel:
(60 gallons per day) is the amount of water needed taken from ASPE (American Society for Plumbing Engineers code).
We have 53 rooms in our hotel:
60 gallons per day = 0.2727 m^3

So 0.2727 * 53 = 14.45 m^3 per day

For 7 days
We need 7 * 14.45 = 101.1717 m^3
Add 5 m3 for firefighting
So the total volume is equal 106.1717 m^3

4.4 Pump selection

Pumps selection depends on two main properties and these properties are:
1- head (H)
2- 2-flow rate (Q).

Starting selection with:

1) Cold water pump:
We have 83.9 GPM

0.227 M^3/H ⟶ 1 GPM
X ⟶ 83.9 GPM

X= 19.04 M^3/H
Total flow rate = 19.04 m^3/h

Head estimation

Height of the building = 29.95 m convert to psi equals 42.78 psi

Then convert from psi to bar: 36.97 psi = 2.95 bar

Adding 1 bar for fittings losses the value is almost 3.95 bar

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

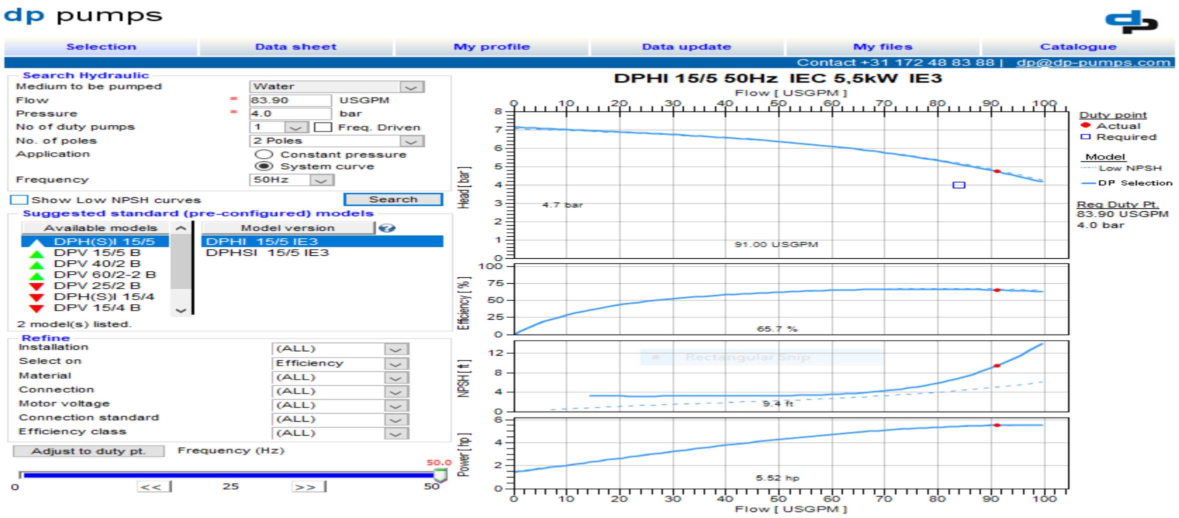


Figure (4.9): Pump data for cold water riser

2) Hot water pump:

By converting WSFU to GPM to m^3/h

0.227 M^3/H ⟶ 1 GPM

X ⟶ 49.5 GPM

X= 11.23 m^3/h

Total flow rate = 11.23 m^3/h

Head = 3.95

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

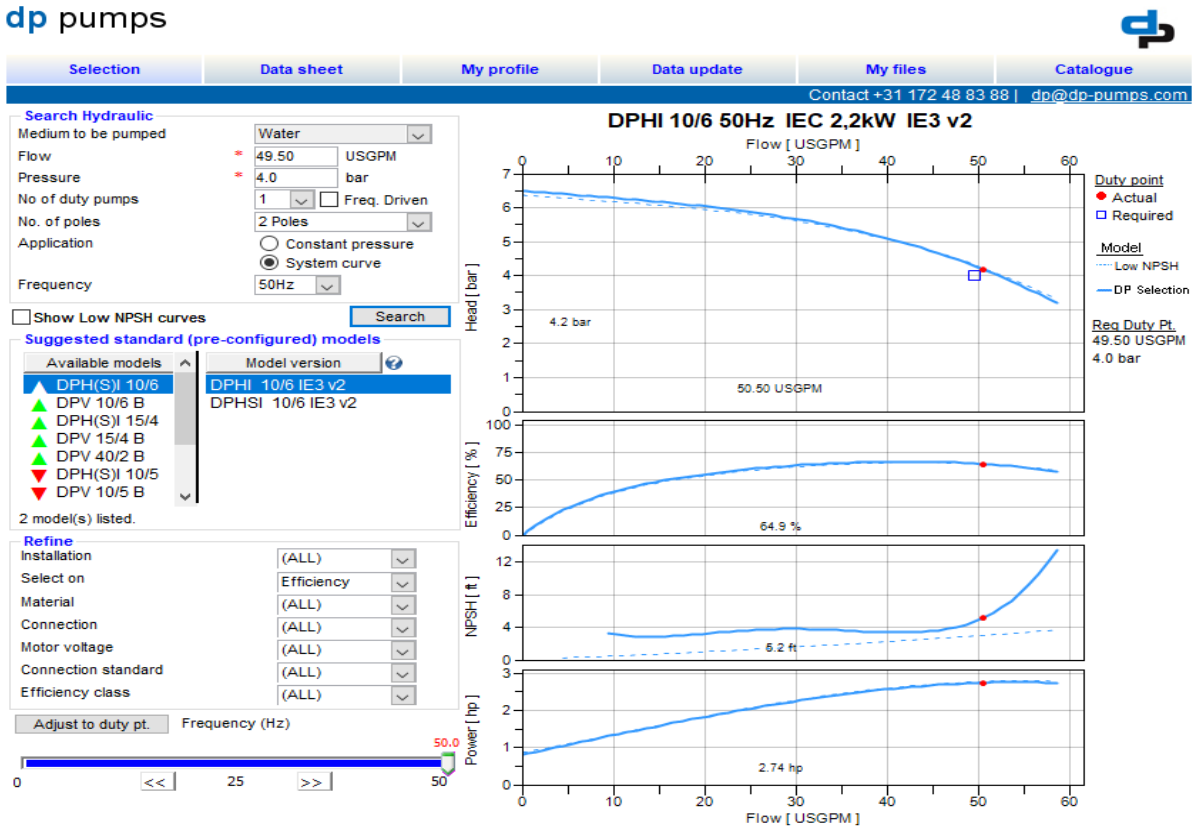


Figure (4.10): Pump data for hot water riser

4.5 Hydro pneumatic tanks

A hydro pneumatic tank contains pressurized air and water. It does not have a bladder and air is in direct contact with the water. The compressed air acts as a cushion exerting or absorbing pressure.

This type of tank serves three main functions:

1. Delivers water within a selected pressure range so the well pump is not continuously running.

2. Prevents a pump from starting up every time there is a minor call for water from the distribution system.

3. Minimizes pressure surges (water hammer). Well pumps and booster pumps work with pressure tanks to maintain a consistent pressure range in the system.

The pressure tank maintains the pumping-cycle rate required to avoid overheating the pump motor and premature motor failure.

Hydro pneumatic tanks work best with an air cushion of ¼ to ½ the tank capacity. This cushion decreases as water absorbs air and the tank loses its ability to pressurize the system. [24]

4.6 DRAINAGE SYSTEM

A sanitary drainage system is a system of piping within public or private premises that conveys sewage or other liquid waste to an approved point of disposal.[24]

The purpose of the sanitary drainage system is to remove effluent discharged from plumbing fixtures and other equipment to an approved point of disposal. [24]

A sanitary drainage system generally consists of: horizontal branches, vertical stacks; a building drain inside the building and a building sewer from the building drain to the point of disposal.

A stack is a main vertical pipe that carries away discharge from within a facility of water closets and urinals (soil stack) or other water waste from equipment and non-sanitary fixtures (waste stack).

The provision of drainage systems:

- Sanitary drainage
- Storm drainage

A normal fixture drainage connection has three parts:

Drain piping: piping before and after the trap to carry away the waste water.

Trap (S siphon): the function of the trap is to provide a seal (water seal) that prevents sewer gases, foul odors, vermin, and other unsanitary substances from entering the building via the drainage pipe.

Vent pipe: the principle function of the vent pipe is to prevent self-siphoning of the trap (and therefore loss of the trap seal).

4.6.1 DRAINAGE 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, which are:

• 50% fill in branches (horizontal pipes)

• (25-33) % fills in stack (vertical pipes)

• 50% fill in building and swear drains

The flow in vertical pipes depends on:

• Pipe size

• Flow rate

• Velocity

• Direction of the fluid entering the stack

• Pipe will friction

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

Velocity of water flow through drainage piping depends on:

• Pipe size

• Slope

Minimum slope requirements for horizontal drainage piping:

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

• For pipes of diameter ≥ 4" the minimum slope is 1/8”/ft (1%)

Design procedure:

1. Calculation of the number of DFU for each branch

2. Calculation of the number of DFU for each stack

3. Choosing the branch pipe diameter

4. Choosing the stack pipe diameter

5. Comparing the stack pipe diameter with branch diameter

6. Choosing the building drain pipe diameter

4.6.2 Pipe sizing for waste water

STACK A:

THIS STACK HAS JUST TWO BRANCHES INTERVALS, WE WILL USE COLUMN 1, 2, 3 IN THE TABLE 10.4

FIRST HORIZONTAL BRANCH HAVE:

FIXTURE UNIT	FLUSH VALVES	LAVATORY	BATHTUB
DFU	4	2	6

4 + 2 +6 = 12 DFU

FROM A () COLUMN 2

12 DFU = 2.1/2 INCH (DIAMETER)

AND FROM COLUMN 3

STACK:

12 DFU = 2.1/2 INCH (DIAMETER)

Stack A:

Table (4.12): Sizing of stack A

Floor / Fixture type	Lavatory (private)	Lavatory (general)	Water closet (general)	Water closet (private)	Kitchen sink	Bathtub (Private)	Total dfu of the branch	Total dfu of the Stack	Diameter of the branch	Diameter of the stack
The roof	2	—	—	4	—	6	12	12	2.1/2 in	2.1/2 in
sixth floor	2	—	—	4	—	2	8	20	2.1/2 in	2.1/2 in
fifth floor	2	—	—	4	—	2	8	28	2.1/2 in	3 in
Fourth floor	2	—	—	4	—	2	8	36	2.1/2 in	3 in
third floor	2	—	—	4	—	2	8	44	2.1/2 in	3 in
second floor	2	—	—	4	—	2	8	52	2.1/2 in	3 in
First floor	2	—	—	4	—	2	8	60	2.1/2 in	4 in
Mezzanine floor	—	2*2=4	6*2=12	—	—	—	16	76	3 in	4 in
Ground floor	—	2*2=4	6*2=12	—	—	—	16	92	3 in	4 in

Table (4.13): Building pipe details

(Building piping)	DFU	diameter	slope	velovity
A	92	4	¼ in.ft	2.73

STACK B:

Table (4.14): Sizing of stack B

Floor / Fixture type	Lavatory (private)	Water closet (private)	Bathtub (Private)	Total dfu of the branch	Total dfu of the Stack	Diameter of the branch	Diameter of the stack
The roof	2	4	6	12	12	2.1/2 in	2.1/2 in
sixth floor	2	4	2	8	20	2.1/2 in	2.1/2 in
fifth floor	2	4	2	8	28	2.1/2 in	3 in
Fourth floor	2	4	2	8	36	2.1/2 in	3 in
third floor	2	4	2	8	44	2.1/2 in	3 in
second floor	2	4	2	8	52	2.1/2 in	3 in
First floor	2	4	2	8	60	2.1/2 in	4 in

Table (4.15): Building pipe details

(Building piping)	DFU	diameter	slope	velovity
B	60	4	¼ in.ft	2.73

STACK C :

Table (4.16): Sizing of stack C

Floor / Fixture type	Lavatory (private)	Water closet (private)	Bathtub (Private)	Total dfu of the branch	Total dfu of the Stack	Diameter of the branch	Diameter of the stack
sixth floor	2	4	2	8	8	2.1/2 in	2.1/2 in
fifth floor	2	4	2	8	16	2.1/2 in	2.1/2 in
Fourth floor	2	4	2	8	24	2.1/2 in	3 in
third floor	2	4	2	8	32	2.1/2 in	3 in
second floor	2	4	2	8	40	2.1/2 in	3 in
First floor	2	4	2	8	48	2.1/2 in	3 in

Table (4.17): Building pipe details

(Building piping)	DFU	diameter	slope	velovity
C	48	3	1/2 in.ft	3.19

STACK D :

Table (4.18): Sizing of stack D

Floor / Fixture type	Lavatory (private)	Water closet (private)	Bathtub (Private)	Total dfu of the branch	Total dfu of the Stack	Diameter of the branch	Diameter of the stack
sixth floor	2	4	2	8	8	2.1/2 in	2.1/2 in
fifth floor	2	4	2	8	16	2.1/2 in	2.1/2 in
Fourth floor	2	4	2	8	24	2.1/2 in	3 in
third floor	2	4	2	8	32	2.1/2 in	3 in
second floor	2	4	2	8	40	2.1/2 in	3 in
First floor	2	4	2	8	48	2.1/2 in	3 in

Table (4.19): Building pipe details

(Building piping)	DFU	diameter	slope	velovity
D	48	3	1/2 in.ft	3.19

STACK E :

Table (4.20): Sizing of stack E

Floor / Fixture type	Lavatory (private)	Water closet (private)	Bathtub (Private)	Total dfu of the branch	Total dfu of the Stack	Diameter of the branch	Diameter of the stack
sixth floor	2	4	2	8	8	2.1/2 in	2.1/2 in
fifth floor	2	4	2	8	16	2.1/2 in	2.1/2 in
Fourth floor	2	4	2	8	24	2.1/2 in	3 in
third floor	2	4	2	8	32	2.1/2 in	3 in
second floor	2	4	2	8	40	2.1/2 in	3 in
First floor	2	4	2	8	48	2.1/2 in	3 in

Table (4.21): Building pipe details

Building piping)	DFU	diameter	slope	velovity
E	48	3	1/2 in.ft	3.19

STACK F :

Table (4.22): Sizing of stack F

Floor / Fixture type	Lavatory (private)	Water closet (private)	Bathtub (Private)	Total dfu of the branch	Total dfu of the Stack	Diameter of the branch	Diameter of the stack
sixth floor	2	4	2	8	8	2.1/2 in	2.1/2in
fifth floor	2	4	2	8	16	2.1/2 in	2.1/2 in
Fourth floor	2	4	2	8	24	2.1/2 in	3 in
third floor	2	4	2	8	32	2.1/2 in	3 in
second floor	2	4	2	8	40	2.1/2 in	3 in
First floor	2	4	2	8	48	2.1/2 in	3 in

Table (4.23): Building pipe details

Section	DFU	diameter	slope	velovity
(Building piping)	48	3	1/2 in.ft	3.19

STACK G :

Table (4.24): Sizing of stack G

Floor / Fixture type	Lavatory (private)	Lavatory (general)	Water closet (general)	Water closet (private)	Kitchen sink	Bathtub (Private)	Total dfu of the branch	Total dfu of the Stack	Diameter of the branch	Diameter of the stack
sixth floor	2	__	__	4	__	2	8	8	2.1/2 in	2.1/2 in
fifth floor	2	__	__	4	__	2	8	16	2.1/2 in	3 in
Fourth floor	2	__	__	4	__	2	8	24	2.1/2 in	3 in
third floor	2	__	__	4	__	2	8	32	2.1/2 in	3 in
second floor	2	__	__	4	__	2	8	40	2.1/2 in	3 in
First floor	2	__	__	4	__	2	8	48	2.1/2 in	3 in
Mezzanine floor	__	__	__	__	2	__	2	50	1.1/2 in	4 in

Table (4.25): Building pipe details

(Building piping)	DFU	diameter	slope	velovity
G	50	4	¼ in.ft	2.73

4.6.3 Vent pipes

- Every vent extends through the roof into outside air
- The stack always extends into fresh air so that it can supply or exhaust air as required by the flow of waste in the drain piping.

Venting performs the following functions:

1- It provides an air vent at each fixture trap. This ensures atmospheric pressure on the outlet side of the fixture trap. This, in turn, prevents the trap seal from being blown out or sucked. Out by pressures generated by drainage flow.

2- It provides a safe path to exhaust sewer gases and foul odors that come from the sewer connection via the drainage piping. Building vent piping acts as. a)ewer vent in the absence (as now recommended) of a building trap and a street level fresh air vent.

3- It fills the drainage piping with fresh air, thus reducing odors, corrosion and the formation of slime in the piping.

Vent pipes calculation:

STACK A:
THIS STACK WITH DFU = 92
TOTAL DEVELOPED LENGTH FOR STACK = 92.518FT

- FROM TABLE 10.7 : FOR A 4'' DRAIN STACK CARRYING 78 DFU A VENT 98.518 FT LONG MUST BE AT LEAST 3" PIPE .

Table (4.26): Sizing of vents pipe

Stack name	Total developed length of stack	Total dfu of the Stack	Vent pipe diameter
A	92.518 ft	92	4 in
B	92.518 ft	60	4 in
C	82.676 ft	48	4 in
D	82.676 ft	48	4 in
E	82.676 ft	48	4 in
F	82.676 ft	48	4 in
G	82.676 ft	50	4 in

4.6.4 Storm drainage

It is important to design adequate and efficient storm drainage as to design a good sanitary drainage system for several reasons including:

1- Rain frequently does not dispose of itself readily, particularly in built-up areas. It floods, forms small and large puddles, turns earth into mud and, frequently, is not rapidly absorbed into the ground.

2-Rain that runs down a building wall causes leaks at windows and other wall penetrations and can cause discoloration of stone facings.

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

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

The general rule for the distribution of floor drains (FD):
Every 100 m2
From roof area needs one 4" FD.

4.6.5 Manhole design

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

• Sanitary manhole for black and gray water

• Sanitary manhole for storm drainage

The design of the manholes depend on the ground and its nature around the building, and so as the first

Manhole height should not be less than 50 cm, and the depth of the other manholes will depend on the distance between the manholes and the slope of the pipe that connecting them.

We only have one main pipe connecting all stacks terminals to manhole and the sewage will be collected on it and then into the public sewer.

Table (4.27): The main building pipe details

	The total DFU	diameter	slope	velocity
The main Building piping	394	6 in	1/8 in.ft	2.52

CHAPTER FIVE

FIR FIGHTING SYSTEM

5.1 Introduction:

A firefighting system is probably the most important of the building service, as its aim to protect human life and property strictly in that order, Fire is a chemical reaction involves the rapid oxidation of the combustible materials, also we can divide the causes of fire by four main parts called the fire tetrahedron and the four ignition components are

1- Fuel (combustible substances).
2- Air (oxygen)
3- Heat (source of ignition)
4- Chain reaction

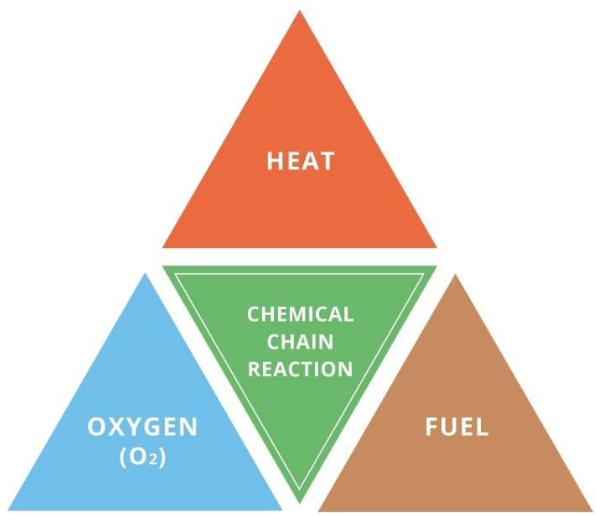


Figure (5.1): fire tetrahedron

The following is a description for this component:

Fuel or combustible substances are the materials flammable to ignition consist of hard, liquid and Gaseous materials such as woods, gasoline and hydrogen.

Air (oxygen) the percentage of the oxygen in natural air is 21% and the percentage which prevents a fire production is to keep more than 16%.

Heat it's the main reason to producing a vapor from materials to occurrence of ignition such as heat produces from electrical sources, smoking etc.

Chain chemical reaction, the fire is continuing as long as the previous three elements are present correct percentages.[25]

Fire work is divided into three sections for engineer:

1) Architect engineer: It is specialized in acting fire safety.

2) Electrical engineer: it is specialized in fire alarm.

3) Mechanical engineer: it is specialized in firefighting.

Also, in design for firefighting system the main reference is (NFPA) code, national fire protection association or (LPC) Legal Practice Course-British standard

5.2 Classification of firefighting systems:

Firefighting systems are classified to:

1) Water system.

2) Gas system.

3) Foam system.

4.2.1 Water firefighting system

It's the system which mainly depend in water to protect from the fire, is the most common use in buildings and factories, also water system can be classified to manual and automatic systems as following:

1) Manual system

Manual system consists of two types of fire system divided to:

a. Fire hose cabinet.

A fire hose cabinet is a high-pressure hose that carries water to a fire to extinguish it. Indoors, it can permanently attach to a building's standpipe or plumbing system, most modern hoses use a synthetic fiber like polyester or nylon filament used in fire hoses that provides additional strength, the usual working pressure of a fire hose can vary between 4 and 12 bars that vary according to the type of fire hose.

b. Fire hydrant.

A fire hydrant is an active fire protection measure, and a source of water provided in most urban, suburban and rural areas with municipal water service to enable firefighters to tap into the municipal water supply to assist in extinguishing a fire, the working pressure is 350 kpa (3.5 bars)

All of design factors for manual water system can be determined using NFPA 14 code.

2) Automatic system.

The water automatic system is represented by a sprinklers system which deals with four types as following:

a. Wet pipe sprinkler system.

A sprinkler system employing automatic sprinklers attached to a piping system containing water and connected to a water supply so that water discharges immediately from sprinklers opened by heat from a fire.

b. Dry pipe sprinkler system.

A sprinkler system employing automatic sprinklers attached to a piping system containing air or nitrogen under pressure, the release of which permits the water pressure to open valve and the water then flow into the piping system and out to the opened sprinklers.

c. Pre-action sprinkler system.

A sprinkler system employing automatic sprinklers attached to a piping system containing air or nitrogen under pressure, with a supplemental detection system (heat, flam and smoke) installed in the same areas as sprinklers.

d. Deluge sprinkler system.

A sprinkler system employing automatic sprinklers attached to a piping system containing water and connected to a water supply through a valve that is opened by the operation of a detection system installed in the same area as the sprinklers, when this valve opens water flow into the piping system and discharges from all sprinklers.

All of design factors for automatic water system can be determined using NFPA 13 code.

5.2. Gas firefighting system

It's the system which mainly depends in several gases to protect from the fire; gas firefighting system can also be classified to:

1) Manual system

Fire extinguishers

is an active fire protection device used to extinguish or control small fires, often in emergency situations, fire extinguisher consists of a hand-held cylindrical pressure vessel containing an agent which can be discharged to extinguish a fire. In general fire extinguishers can be water, co2, foam, wet chemical and dry powder extinguisher. All of design factor for manual gas system can be determined using NFPA 10 code.

Figure (5.2) Fire extinguishers.

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2) Automatic system

Clean agent gases fire extinguisher.

This group of gases are speed in suppressing fires, reducing damages, extinguish a fire quickly and effectively, no ozone depletion, economic, allowing visibility and doesn't require costly clean-up.

These gases are FM-200, NAF 125 (HFC 125), ARGON and CO2. All of design factors for automatic gas system can be determined using NFPA 12 code.

Figure (5.3) clean agent gases fire extinguisher.

All of design factors for automatic gas system can be determined using NFPA 12 code.

5.2.3 Foam firefighting system

Is foam used for fire suppression, its role is to coat the fuel, preventing its contact with air (oxygen), resulting in suppression of the combustion. Foam system can be manual such as foam extinguisher or automatic such foam- water sprinkler system foam system.

All of design factors for automatic and manual can be determined using NFPA 16 code.

5.3 System selection and design

For determination and selection of fire protection system within the establishment and buildings with different objectives and the importance of having a firefighting system, the selection is occurred by referring to know the hazard level in the building in order to select the appropriate system.

5.3.1 Hazard classification

The classification of hazard varies according to the commodities and application of the project.

Light hazard occupancies shall be defined as occupancies or portions of other occupancies where the quantity and/or combustibility of contents is low and fires with relatively low rates of heat release are expected.

Figure (5.4) Light hazard examples

Ordinary hazard occupancies shall be defined as occupancies or portions of other occupancies where combustibility is low, quantity of combustibles is moderate, stockpiles of combustibles do not exceed 8 ft (2.4 m), and fires with moderate rates of heat release are expected

Figure (5.5) Ordinary hazard examples

Extra hazard occupancies shall be defined as occupancies or portions of other occupancies where the quantity and combustibility of contents are very high and dust, lint, or other materials are present, introducing the probability of rapidly developing fires with high rates of heat release but with little or no combustible or flammable liquids.

Figure (5.6) Extra hazard examples

The system hazard in a Hotel building is Ordinary hazard. According to the Ordinary level of hazard the best appropriate system is fire house cabinet and sprinklers systems.

5.3.2 Firefighting network accessories

5.3.2.1 Firefighting network Components:

1. Water source and pumping station the main sources of firefighting water are Water Tanks Underground.

2. Pipes.

a) Black steel.

b) Galvanized steel.

c) High density polyethylene.

d) UPVC poly vinyl chloride.

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

All pipes, fittings, valves and other accessories should be tested at four bars above the working pressure for two hours according to the NFPA13 code.

3. 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) Check valve.

4. Standpipes

5.3.3 Sprinklers

Sprinkler systems are among the most useful tools in your firefighting arsenal. Today’s systems have been shown to reduce deaths and property loss by more than 65 percent. For this reason, fire sprinklers are certainly something you want in your commercial property! But how do fire sprinklers work?

Step 1: Fire Sprinklers Detect Heat

Contrary to popular belief, fire sprinklers are not trigged by smoke. It’s an easy mistake to make, since heat is carried upward with smoke from a fire. But if smoke was the trigger, simply burning your toast in the office kitchen could be enough to drench the kitchen with water from a fire sprinkler head.

Fire sprinklers work because high heat triggers the sprinkler system. When a blaze ignites, the air directly above it heats rapidly. This hot air rises and spreads along the ceiling. When the air is hot enough and reaches a sprinkler head, it triggers a chain reaction.

Most sprinkler heads feature a glass bulb filled with a glycerin-based liquid. This liquid expands when it comes in contact with air heated to between 135 and 165 degrees. When the liquid expands, it shatters its glass confines and the sprinkler head activates

Step 2: Fire Sprinklers Douse the Fire

Each sprinkler head is attached to a pipe that connects to a reliable water source outside the building. When heat activates a sprinkler head, a valve opens, allowing pressurized water from the pipe system to flow out.

It’s important for water in a fire sprinkler system to be pressurized. This allows the water to spray outward in an arc to more thoroughly douse the fire and prevent it from reigniting.

Maximum Ceiling Temperature		Temperature Rating		Temperature Classification	Color Code	Glass Bulb Colors
°F	°C	°F	°C			
100	38	135–170	57–77	Ordinary	Uncolored or black	Orange or red
150	66	175–225	79–107	Intermediate	White	Yellow or green
225	107	250–300	121–149	High	Blue	Blue
300	149	325–375	163–191	Extra high	Red	Purple
375	191	400–475	204–246	Very extra high	Green	Black
475	246	500–575	260–302	Ultra high	Orange	Black
625	329	650	343	Ultra high	Orange	Black

Figure (5.7): sprinklers classification

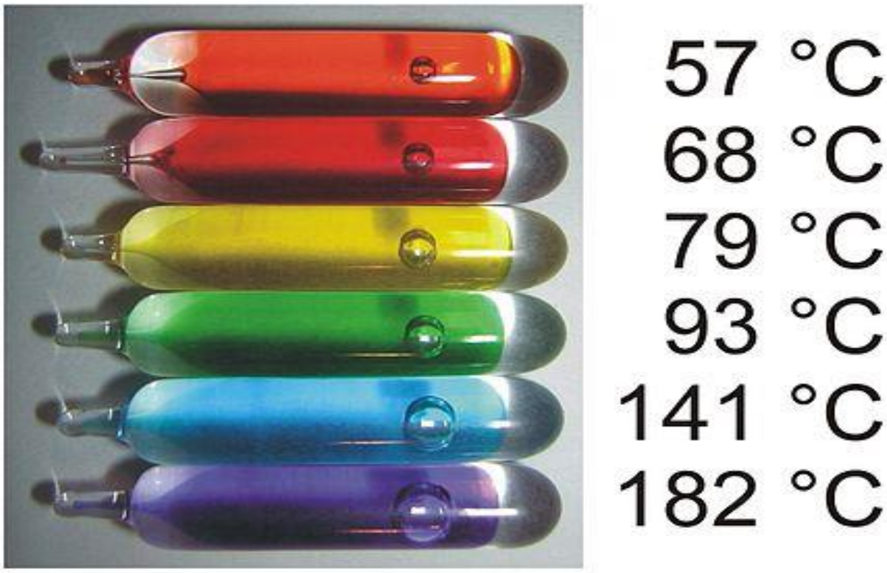


Figure (5.8): The liquid in the glass bulb is color coded to its show temperature rating

The sprinklers used in building with ordinary hazard is pendent sprinkler the liquid glass bulb color is red and the temperature is (57-77) C

5.3.4 Fire hose cabinet

A fire hose is a high-pressure hose that carries water to a fire to extinguish it and classified to two main types that common used:

1. Hose reel: it's a rubber hose coiled on the reel her arm; it's commonly used by individuals within buildings.

2. Hose rack: Is a cloth-reinforced hose riding on rack often used by Civil defense.

Fire hose cabinet is located at the following places:

1) Exit stairs.

2) Entrance of buildings.

3) Garages entrance.

4) Wherever travel distance exceeded 36 meters from another fire hose cabinet.

5.3.4.1 Fire hose cabinet components

1) Cabinet (wall mounted-recessed), there is three type of cabinet here

a) Exposed: be prominent from the wall and out of it a distance of 25 cm, and Fund riding on the surface of the wall.

b) Semi predated: be prominent from the wall a distance of 10 cm, and inside the wall 15 cm.

c) Recessed: be inside the entire wall.

2) Landing valve, a valve to control the water stream, located inside or outside the building.

3) Hose (30 meter)

4) Discharge nozzle

5) Fire extinguisher (optional)

5.3.4.2 Fire hose cabinet classes

1) Class 1: standpipe system provides 65-mm (2½-in.) hose connections to supply water for use by fire departments and those trained in handling heavy fire streams.

System limitations are pressure reach 7 bars, flow rate 250 gpm, located at all main entrance and exits of the buildings and garages, around the wall buildings and the travel distance is 45.7m with throw distance. [26]

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

3) Class 3: standpipe system provides 38-mm (1½-in.) hose stations to supply water for use by building occupants and 65mm (2½-in.) hose connections to supply a larger volume of water for use by fire departments and those trained in handling heavy fire streams. [26]

5.3.4.3 Technical specifications of fire hose cabinet

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

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

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

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

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

5.3.5 Fire extinguishers

Portable fire extinguishers can contain a wide variety of extinguishing agents; the potable fire extinguishers enable an individual with minimal training to extinguish an incipient fire.

A portable fire extinguisher should not be considered as the sole solution to fire protection analysis of a building but, rather, only one of many components of a total fire protection plan.

5.3.5.1 Type of Portable Fire Extinguishers

1. Water extinguishers.
2. Water sprays water extinguishers.
3. Antifreeze solution extinguishers.
4. Foam fire extinguishers, hand and wheeled.
5. Carbon dioxide extinguishers.
6. Clean agent extinguishers.
7. Dry and wet chemical extinguishers, hand and wheeled.

5.3.5.2 Selection of extinguishers

Carbon dioxide extinguishers made by SFFECO Company; all are selected will be distributed in the suitable spaces as shown in the drawings.

5.3.5.3 Carbon dioxide extinguishers

Carbon dioxide is a gaseous fire protection agent, also known by its chemical designation CO_2; normally the air we breathe contains 21% oxygen, 79% nitrogen, and only a trace amount of carbon dioxide, 0.03%. The presence of significantly higher percentages of carbon dioxide in a room cannot be detected by human senses because it is colorless and odorless.

The cylinders for CO_2 Fire Extinguishers are seamless and extruded from high grade Chrome Molybdenum Steel or Manganese Steel or Carbon Steel. Carbon Dioxide is discharged as a white cloud of snow which throttles a fire by eliminating the oxygen. Designed to protect areas where class B (flammable liquids and gases) or Electrical class of fires could occur.93 Carbon dioxide is 1.5 heavier than air, so it forces oxygen out of a room or significantly reduces the concentration of oxygen at breathing level.

5.3.6 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}. Pumping stations should include:

1. Electrical firefighting pump.

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

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

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

5.3.6.1 Types of pumps

- Horizontal split case pumps:

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

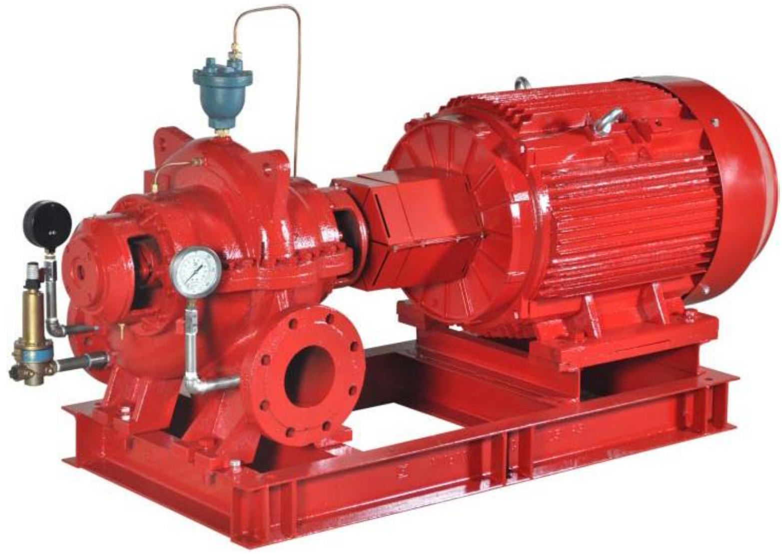


Figure (5.9): Horizontal split case pump

- Inline fire pumps

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

Figure (5.10): Inline fire pump

- End suction pumps

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

Figure (5.11): End suction pump

- Vertical turbine pumps

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

Figure (5.12): Vertical turbine pump

5.3.7 Flow rate calculations

Number of sprinklers = area / protection area limitation per sprinkler.

=150/12.1

=12.3 > 13 sprinkler (min)

Number of sprinklers used is 16

The flow for area = flow per sprinkler * number of sprinklers.

=14*16

=224 gpm

5.3.8 Head estimation

H pump =HR + Hs + Hf

H pump: is the head of pump

HR: is the residual pressure

Hs: is the static pressure

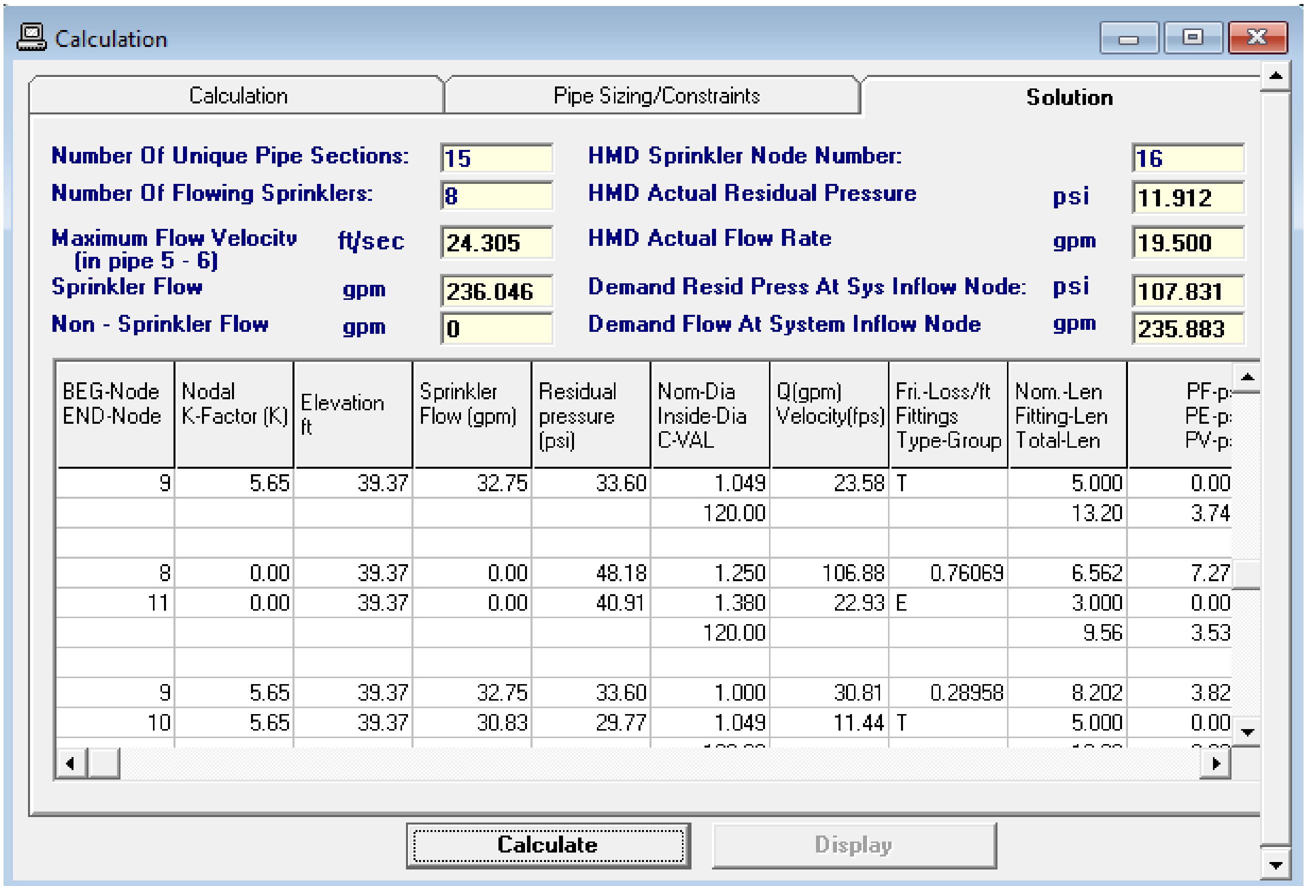
Hf : is the friction pressure

With 30-meter height of the buildings there are 3bars, adding 4.5 bars for cabinet pressure and 1 bar for loss in fittings

H pump=8.5 bar

5.4 Pump selection

Total flow rate 235 GPM equal and ,head 107psi



BEG-Node END-Node	Nodal K-Factor (K)	Elevation ft	Sprinkler Flow (gpm)	Residual pressure (psi)	Nom-Dia Inside-Dia C-VAL	Q(gpm) Velocity(fps)	Fri.-Loss/ft Fittings Type-Group	Nom.-Len Fitting-Len Total-Len	PF-p: PE-p: PV-p:
9	5.65	39.37	32.75	33.60	1.049	23.58	T	5.000	0.00
					120.00			13.20	3.74
8	0.00	39.37	0.00	48.18	1.250	106.88	0.76069	6.562	7.27
11	0.00	39.37	0.00	40.91	1.380	22.93	E	3.000	0.00
					120.00			9.56	3.53
9	5.65	39.37	32.75	33.60	1.000	30.81	0.28958	8.202	3.82
10	5.65	39.37	30.83	29.77	1.049	11.44	T	5.000	0.00

Figure (5.13): pump characteristics from elite software

5.5 Water tank sizing

Water tank is the main source of water that provides the firefighting network water, 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 for the system.

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

= 235gpm*60min (gpm)*(3.785/1000)

=52.3 m^3 tank size

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Software:

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Revit 2018.

Hourly Analysis Program 4.90

New DVM Bro (SAMSUNG)

Pipe Sizing UPC V0.4

ELITE

Appendix - A

A-1: Description of wall construction groups

Group No.	Description Of Construction	$U_{ov.}$ $W/m^2 \cdot {}^\circ C$
	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-2pproximate CLTD values for light, medium, and heavy weight construction walls

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

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

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

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*", 2[nd] 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

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

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

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

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(SG) for glass 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 (SG) for glass windows without interior shading

Type of Glass	Nominal Thickness, mm	Solar Trans.	Shading Coefficient, W/m²·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 (SHG)for sunlit glass

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

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

A-14: Values of the factor S1

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

A-15: Values of the factor S2

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

A-16: Instantaneous heat gain from occupants

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

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

A-17: Latitude- month correction factor LM

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

A-18: outside air requirements for mechanical ventilation

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

A-19: inside and outside film resistance

A(2.2)

Element	Heat Direction	Material Type	R_i $m^2\cdot{}^\circ C/W$
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 Outside film resistance, R_o.

A(2.3)

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, $m^2\cdot{}^\circ C/W$		
Walls	Construction materials	0.08	0.06	0.03
	Metals	0.10	0.07	0.03
Ceilings	Construction materials	0.07	0.04	0.02
	Metals	0.09	0.05	0.02
Exposed floors	Construction materials	0.09	—	—

A-20: Overall heat coefficient for windows

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

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

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

A-22 From Palestinian code

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

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

Appendix (B)

B-1: Water supply fixture unit

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

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

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

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

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

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

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

[d]Nominal I.D. pipe size.

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

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

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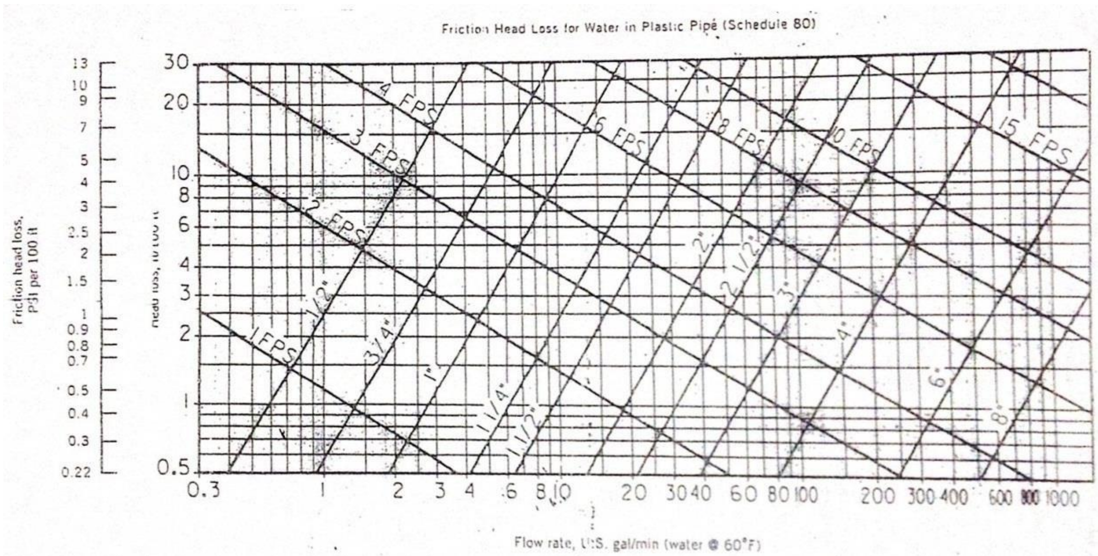
B-2: Chart of friction head loss in schedule 40



FigureA(4.1)Chart of friction head loss in Schedule 80 plastic 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*.)

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

Table A(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
[illegible]	[illegible]	3000	435
4000	525	4000	525
5000	600	5000	600
6000	650	6000	650
7000	700	7000	700
8000	730	8000	730
[illegible]	[illegible]	9000	760
[illegible]	[illegible]	10,000	790

[a] Water supply fixture units

Source. Reproduced with permission from The Na-
[illegible] 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)*	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 1 1/4 in. or less	1
trap size 1 1/2 in.	2
trap size 2 in.	3
trap size 2 1/2 in.	4
trap size 3 in.	5
trap size 4 in.	6

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

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B-7: Horizontal fixtures branches and stacks

Table A(4.5) Horizontal Fixture Branches and Stacks

	Maximum Number of Fixture Units That May Be Connected to			
			Stacks with More Than Three Branch Intervals	
Diameter of Pipe, in.	*Any Horizontal Fixture Branch,[a] dfu*	*One Stack of Three Branch Intervals or Less, dfu*	*Total for Stack, dfu*	*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]

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

[a] On site sewers that serve more than one building may be sized according to the current standards and specifications of the Administrative Authority for 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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Appendix (C)

C-1: Human comfort

HUMAN COMFORT

Application	Maximum Occupancy Per 100 m^2	Ventilation Air Requirements	
		L/s/Person	L/s/m^2
Game rooms	70	3.5-17.5	—
Ice arenas	—	—	2.50
Swimming pools	—	—	2.50
Gymnasium floors	30	10.0	
Ballrooms and discos	100	3.5-17.5	—
Bowling alleys	70	3.5-17.5	
Theaters:			
Ticket booths	60	10.0	—
Lobbies	150	10.0	—
Auditorium	150	8.0	—
Stages, studios	70	8.0	—
Transportation:			
Waiting rooms	100	8.0	—
Platforms	100	8.0	—
Vehicles	150	8.0	—
Workrooms:			
Meat processing	10	8.0	—
Photo studios	10	8.0	—
Darkrooms	10	—	2.50
Pharmacy	20	8.0	—
Bank vaults	5	8.0	—
Printing, duplicating rooms	—	—	2.50
Correctional facilities:			
Cells	20	10.0	—

C-2: Human comfort

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

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

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

C-3 Bill of quantities

	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. **3.95 Bar ,** 19.04 m^3/h for cold water 3.95 Bar, 11.23 m^3/h for hot water			
3.1.2	**C.W.P. 3.95 Bar ,** 19.04 m^3/h	SET	1	
3.1.6	**H.W.P** (Set/2 (Directly feeds floors with hot water)	SET	1	
3.2	**Pipes**			
3.2.1	Galvanized steel pipes to BS1387 of various sizes for domestic cold and hot water above false ceiling, in walls, etc. Including fittings, supports, expansion loops, thermal insulation cladding Of all external and trenches pipes.			
3.2.1.2	25 mm dia pipe (1")	m	121.42	
3.2.1.3	32 mm dia pipe (11/4")	m	105.58	
3.2.1.4	40 mm dia pipe (1 1/2")	m	33.84	
3.2.1.5	50 mm dia pipe (2")	m	97.07	
3.2.1.6	65 mm dia pipe (2 1/2")	m	20.4	
3.2.2.1	16 mm dia pipe	m	530	
3.3	**Water Manifolds 50 x 50 x 50**		1	
3.3	**Water Manifolds 80 x 80 x 50**		1	

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.	52	
5.3	**Shower Tray**			

5.3.1	Supply install and test shower tray (80cmx80cm) White Vitreous China connected to domestic cold and hot water supply and drainage network and all fittings and works required to complete the work as per drawings and as per engineer's instructions. Price shall include chrome plated shower mixer, chrome plated hand shower completes with flexible hose 150 cm long and chrome plated shower hanger, Pax pipes, 2" and 4" UPVC pipes needed to connect the tray to the nearest main drainage and supply it with water, Single robe/clothes hook with concealed mounting type	No.	50	
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.	2	
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.	54	
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	230	
5.6.2	150 mm dia. (6")	m	38	
5.6.3	200 mm dia (8")	m	10	
5.6.4	50 mm dia. (2")	m	240	
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.	54	
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.		54	

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. (2")	No.	4	
5.10	**Roof Vent**			
	Supply and install (HDPE) Roof vent with screened cap for vent stacks including connection to the vent pipe by solvent welding. The rate includes all needed connection accessories, all done according to drawings, specifications and the approval of the Engineer. Roof vent cap HDPE			
5.10.1	100 mm dia. (4")	NO	8	

4	**Firefighting System**			
4.1	Fire hose reel cabinet (double compartment) including isolating valve with SS304 fully recessed cabinet, 19 mm dia x 25 mm rubber hose,	No.	10	
4.2	Black seamless steel pipe.			
4.2.1	25mm dia pipe (1")	M	367.22	
4.2.2	31.25 mm dia pipe (1 1/4")	M	12.64	
4.2.3	37.5 mm dia pipe (1 1/2")	M	37.29	
4.2.4	50 mm dia pipe (2")	M	30.19	

4.2.5	65 mm dia pipe (2.5")	M	39.19	
4.2.6	80 mm dia pipe (3")	M	43.9	
4.3	**Pumps** Supply, install, test and commission fire pumps set, complete with all components including duty pump, split case (electric driven), emergency pump (diesel), jockey pump, centrifugal (electric driven). Price shall include electric control panels, pressurized tank, cork and foundation bed, controllers, accessories for all pumps including wiring connections, all components, water measuring devices including flow meter and sensor, pressure gauges, relief valves, gate valves, check valves etc., all electrical works needed to complete the work according to engineer's instructions.			
4.3.1	Electrical pump : 235 **gpm, 107 PSI**	No.	1	
4.3.2	Diesel pump : 235 **gpm, 107 PSI**	No.	1	
4.3.3	Jockey pump8 gpm, 33 PSI	No.	1	
4.4	**Fire Extinguisher**			
4.5	K-type dry powder fire extinguishers.	No.	18	
4.6	CO_2 fire extinguishers.	No.	2	
4.7	Self-automatic extinguisher.	No.	4	
4.8	Overhead fire sprinklers	No.	23	
4.9	Concealed sprinklers	No.	136	
4.10	Supply and install Fire hydrant, pedestal type and maintain stand spot fitted with 75mm twin faced flanged fire hydrant,	No.	1	