Palestine Polytechnic University

College of Engineering & Technology
Mechanical Engineering Department
Refrigeration & Air Conditioning Engineering

Graduation Project

Design of Mechanical Systems for a Sham Hotel building in Tulkarm city

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Project Name:
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According to the project supervisor and according to the agreement of the testing committee members, this project is submitted to the Department of Mechanical Engineering at college of engineering and technology in partial fulfillment of requirement of (B.SC) degree in engineering of refrigeration and air conditioning.

Supervisor signature

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Abstract

This project aims to design a mechanical systems for a sham hotel which is located in Tulkarm city, Palestine. This building consists of nine floors with a total area of 7700 m^2. In this project, the air conditioning system type (VRF) is used, since it is efficient,. The design of this project includes making the calculations, material selection and determining the table of quantity for the air conditioning system, ventilation system, water system, drainage system and the firefighting system. These services are certainly designed to verify human comfort.

الملخص :

يهدف هذا المشروع إلى تصميم الأنظمة الميكانيكية لفندق الشام الذي يقع في مدينة طولكرم في فلسطين. يتكون هذا المبنى من تسعة طوابق بمساحة إجمالية تبلغ 7700 متر مربع. في هذا المشروع يتم استخدام نظام تكييف الهواء (VRF) لأنه فعال واقتصادي.. يشمل تصميم هذا المشروع إجراء الحسابات واختيار المواد وتحديد جدول الكمية لنظام تكييف الهواء ، ونظام التهوية ، ونظام المياه ، ونظام الصرف ، ونظام مكافحة الحرائق.هذه الخدمات مصممة بالتأكيد للتحقق من راحة الإنسان.

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CHAPTER ONE

INTRODUCTION

1.1 Introduction:

Throughout the ages human beings tried to improve their lives to be easier and more comfortable, and as the Wisdom say: “The necessity is the mother of invention” the engineers always try to meet the needs of humans to achieve the welfare of their lives.

So HVAC engineers develop the mechanical services systems and technologies to achieve the comfort, which the humans need in the buildings.

For this reason the mechanical system will be designed and documented in this project for Al-Sham hotel in Tulkarm city in Palestine.

1.2 Project overview:

Since old time human was looking for comfort conditions . At this time, human has designed mechanical systems to achieve comfort conditions that he need. and to get these conditions that make human in comfort conditions , It should be design and control of the following :

1. To design the mechanical services for the building.
2. Design variable refrigeration flow (VRF) air conditioning system for the building.
3. Design firefighting system.

1.3 Building description:

Al-Sham hotel includes one basement, ground and eight floors for guests, the total area of the hotel is 7700 m^2 and serves 120 person .

1.4 Project outline:

1. Chapter one: Introduction

   This chapter include overview about the project, project objectives, building description and time planning.
2. Chapter two: Heating Loads:

   This chapter consist of the procedures for calculating the heating load.
3. Chapter three: Cooling Loads:

   This chapter consist of the procedures for calculating the cooling load .
4. Chapter four: Variable Refrigerant Flow System

   This chapter talks about the air conditioning system which is variable air flow (VRF).
5. Chapter five: Plumping System.

   This chapter include the water distribution calculation, drainage system.
6. Chapter six: Firefighting system

   This chapter contains the fire extinguishing system .

1.5 Symbols:

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

1.6 Time table:

Table (1.1): Time estimated to work for first semester

Task / No. of week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Choosing the project																
Visit the library to collect information																
Reading books																
Put the title																
Writing the introduction and human comfort																
Calculate the heating and cooling load																
Writing HVAC system																
Visit supervisor and takes some notation																
Plumping system calculations																
Firefighting																
Writing and printing in a scientific way																

Table (1.2): Time estimated to work for second semester

Task \ No. of week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Design VRV system																
Ventilation system																
Pumps calculations																
Drawing water system																
Drawing drainage system																
Drawing VRV system																
Drawing firefighting system																
Bill of quantity																
catalog																

CHAPTER TWO

Heating and Cooling Loads

2.1 Introduction:

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

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

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2.2 Human comfort

2.2.1 Introduction of human comfort

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

Sensible Heat is heat energy that, when added to or removed from a substance, results in a measurable change in dry-bulb temperature.

Latent Heat (hidden) heat energy that is absorbed or released when the phase of a substance is changed. For example, when water is converted to steam, or when Steam is converted to water.

In order for the body to feel comfortable, the surrounding environment must be of suitable temperature and humidity to transfer this excess heat. If the temperature of the air surrounding the body is too high, the body feel uncomfortably warm. The body responds by increasing the rate of perspiration in order to increase the heat loss through evaporation of body moisture. Additionally, if the surrounding air is too humid, the air is nearly saturated and it is more difficult to evaporate body moisture. If the temperature of the air surrounding the body is too low, however, the body loses more heat than it can produce. The body responds by constricting the blood vessels of the skin to reduce heat loss.

2.2.2 Factors affecting human comfort

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

2.3 Outside and inside design conditions:

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

Table 2.1: Outside and inside design conditions

Property	Inside design condition		outside design condition	
	summer	winter	summer	winter
Temperature (˚C)	24	24	35	14
Relative humidity (%)	50	50	70	80
Wind speed (m/s)	….	….	1.4	1.4

2.4 ASHRAE Comfort Chart

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

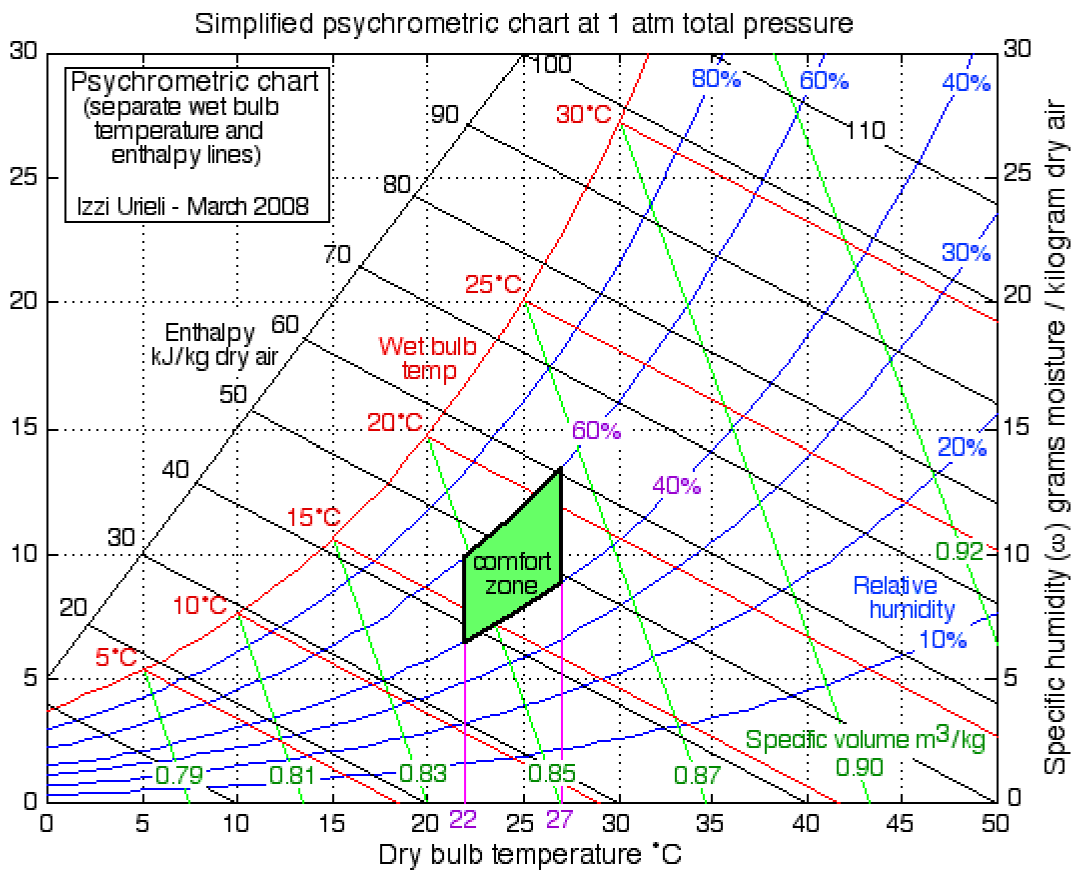


Figure (2.1): Human comfort chart

2.5 Convection Heat Transfer Coefficient

There are two ways to transfer heat by convection:

i. Forced convection.
ii. Free convection.

2.6 Calculations of overall heat transfer coefficient U:

The overall heat transfer coefficient is a measure of the overall ability of a series of conductive and convective barriers to transfer heat.

To calculate the heat gain from walls, ceiling, ground and doors, one need to calculate the value of overall heat transfer coefficient (U) for each one of them.

The value of U is depend in the kind of material that content in walls ,ceiling…. etc .

The amount of load either heating or cooling (from walls , doors… etc) is directly proportional with the value of the U.

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

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

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

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

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

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

$$U = \frac{1}{R_{th}} = \frac{1}{\frac{1}{h_i}+\frac{\Delta x_1}{k_1}+\frac{\Delta x_2}{k_2}+\cdots+1/h_0} \quad (2.11)$$

Where:

Δx: the thickness of the wall [m].

k : Thermal conduction of the metal

$\boldsymbol{h_i}$: Convection coefficient of inside wall, floor, or ceiling ($\boldsymbol{h_i = 9.37\ W/m^2.C^0}$) from the Palestinian code.

$\boldsymbol{h_0}$: Convection coefficient of outside wall, floor, or roof ($h_0 = 22.7\,W/m^2.C^0$) from the Palestinian code.

2.6.1 The heat overall heat transfer coefficient (U):

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

1. **For external wall:**

Table 2.2: Construction of external walls

	Materiel	Δx(m)	K ($W/m^2.^oC$)
5	Stone	0.07	**1.7**
4	concrete	0.13	**1.75**
3	Polyurethane	0.03	**0.04**
2	Cement break	0.07	**0.95**
1	Plaster	0.02	**1.2**

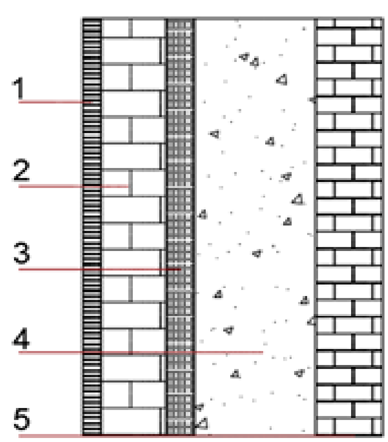


Figure 2.2: External wall construction

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

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

$$U = \frac{1}{0.12+\frac{0.07}{1.7}+\frac{0.13}{1.75}+\frac{0.03}{0.04}+\frac{0.07}{0.95}+\frac{0.02}{1.2}+0.06} \qquad = 0.88\ (W/m^2.°C$$

2. **For Internal Wall:**

Table 2.3: Construction of internal walls

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

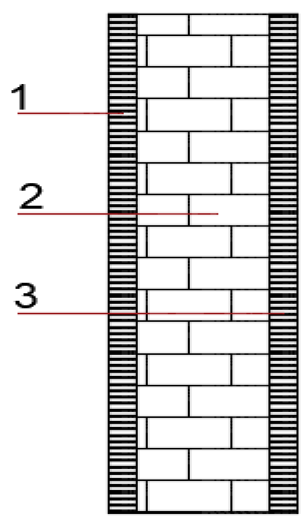


Figure 2.3: internal wall construction

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

$$U = \frac{1}{0.12 + \frac{0.02}{1.2} + \frac{0.1}{0.95} + \frac{0.02}{1.2} + 0.06}$$

$$U = 3.1\ (W/m^2.°C)$$

3. For Ceiling and Roof:

Table 2.4: Construction of celling

	Materiel	Δx(m)	K (W/m².ºC)
1	Asphalt	0.02	**0.8**
2	Concrete	0.05	**1.75**
3	Polystyrene	0.05	**0.03**
4	concrete	0.06	**1.75**
5	Brick	0.14	**0.95**
6	Plaster	0.02	**1.2**

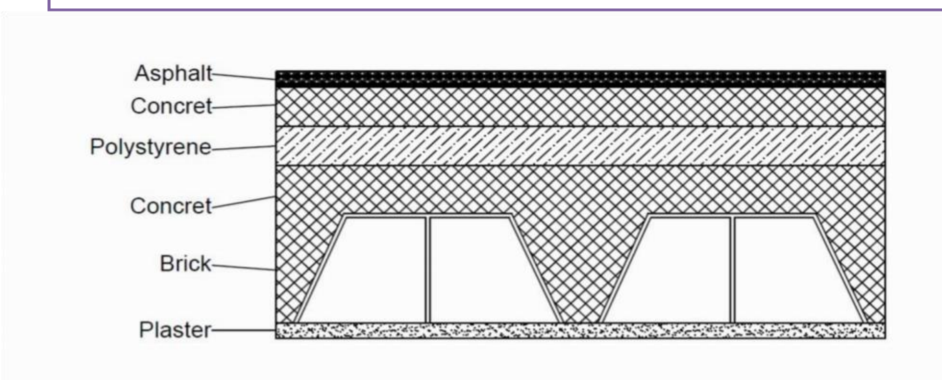


Figure 2.4: Ceiling construction

Because of its construction, the ceiling is divided into two overall heat transfer coefficient one with brick and the other without.

R_{in} and R_{out} for the ceiling are 0.1 and 0.04($W/m^2.°C$), respectively from table (A-27) .

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

$$U_1 = \frac{1}{0.1+\frac{0.02}{0.8}+\frac{0.05}{1.75}+\frac{0.05}{0.03}++\frac{0.06}{1.75}+\frac{0.14}{0.95}+\frac{0.02}{1.2}+0.04} = 0.491\ (W/m^2.°C)$$

Similarly, U_2 =0.953 $(W/m^2.°C)$

4. **For glass** From table (A-28), U_g = 3.2$(W/m^2.°C)$for double glass aluminum frame.
5. **For door** From table (A-29) , U_d = 3.6$(W/m^2.°C)$ for wood door type.

2.7 Heating load calculations:

2.7.1 Overview:

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

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

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

Miscellaneous loads such as emergency heating loads and safety factor heating load.

2.7.2 Heat loss calculations:

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

$$Q = A \times U \times \Delta T \tag{2.12}$$

Where:

Q : Is the heat transfer rate. [kW]

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

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

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

2.7.3 Total heat load calculations

Total heat load calculations for the sample room shown in figure (2.5)

A_{room} = 14 m^2

$A_{Bathroon}$ = 4 m^2

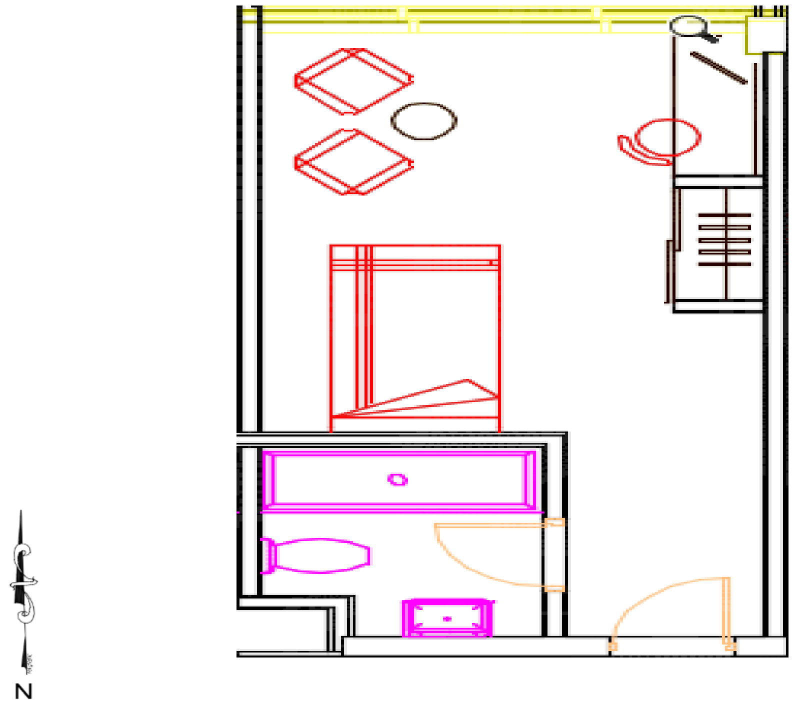


Figure 2. : Sample room

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 showing n Figure (2.4).

The area A_1 is equal to:

$Ac = 6 * 3 - (2*2) = 14\ m^2$

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

$A_1 = \frac{4}{5} * 14 = 11.2\ m^2$

And the area A2 is equal to:

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

$A_2 = \frac{1}{5} * 14 = 2.8\ m^2$

$Q_c = U_c Ac(T_i - T_o)$

$= (U_1 A_1 + U_2 A_2)(T_i - T_{unc})$

$Q_c = (0.516 \times 11.2 + 0.953 \times 2.8)(24-19)$

$Q_c = 42W$

Heat loss through walls (Q_w):

The heat loss from external wall is :

$Q_{wall,ex} =$ zero

The heat loss from internal is :

$Q_{wall,in1\ (east)} = U_w A_w (T_i - T_{un})$

$= 3.1*14*5 = 217$ W

$Q_{wall,in2\ (west)} = U_w A_w (T_i - T_{un})$

$= 3.1*(4*3)*5 = 186$ W

$Q_{wall,in\ (south)} =$ zero

Heat loss through floor (Q_f):

$Q_f = U_f A_f (T_i – T_{un})$

$= 1.93*14*5 = 135$ W

Heat loss through windows (Q_g):

$Q_w = U_g A_g (T_i - T_o)$

$= (3.2) (3×3) (24-14) = 300$ W

Heat loss through external door (Q_d):

$Q_d = U_d A_d$ (Ti - Tun.)

$= (3.6)(2.1×0.9)(24-19) = 34$ 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 :

$$Q_{inf} = \frac{V_f.}{v_o} \times (h_{out} - h_{in}) \qquad (2.13)$$

Where:

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

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

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

V_o: specific volume (m/s)

$v_o = 0.84$ (outside the room)

$h_{in} = 48$ kJ/kg

$h_{out} = 34$ kJ/kg

V_o = 1.4 (m/s) from Palestinian code

L= 2W + 2H for door

L_d = 6 m

L= 3W + 4H for double sliding window

L_w = 21 m

Therefore;

$V_{inf,d}$ = 6 * 5.4

= 0.009 m^3/s

$V_{inf,w}$ = 21 * 2

= 0.011 m^3/s

$Q_{inf} = Q_{inf,d} + Q_{inf,w}$ = 150W + 183.3 W

Q_{inf} = 333.3 W

Heat gain due to ventilation:

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

$$Q_{ventilation} = m_{ventilation} \times (h_{out} - h_{in}) \qquad (2.15)$$

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

V_f = Room volume × No. of times the air changes in the hour (2.16)

$$m_f = \frac{V_{f.}}{v_o} = \frac{(14*3.52)m^3 *(2)}{0.822(3600)} = 0.0333 \text{ kg/s}$$

$$Q_{ventilation} = 0.0333 \times 1000 \times (48 - 35)$$

$$Q_{ventilation} = 0.433\text{kW}$$

$Q_{tot} = Q_c + Q_{w,in} + Q_{w,ex} + Q_f + Q_g + Q_d + Q_{inf} + Q_{vent}$

= 42 + 403+ 0 + 135 + 300 + 34+ 333.3 + 433 = 1680W

$$Q_{tot} = Q_c + Q_{w,in} + Q_{w,ex} + Q_f + Q_g + Q_d + Q_{inf} + Q_{vent}$$

$$= 42 + 403 + 0 + 135 + 300 + 34 + 99.07 + 433 = 1446W$$

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

$$Q_{tot} = 1446 \times 1.10 = 1590 \text{ W.}$$

$$= 1.59kW$$

2) Total heating load calculations for the sample room by Rivit software:

Space Summary - 203 bedroom

Input Data	
Area (m²)	15.29
Volume (m³)	41.32
Wall Area (m²)	11.09
Roof Area (m²)	16.33
Door Area (m²)	3.45
Partition Area (m²)	0.00
Window Area (m²)	7.72
Skylight Area (m²)	0.00
Lighting Load (W)	150
Power Load (W)	550
Number of People	1
Sensible Heat Gain / Person (W)	85.0
Latent Heat Gain / Person (W)	30.0
Infiltration Airflow (m³/s)	0
Space Type	Living Quarters - Hotel
Calculated Results	
Psychrometric Message	The zone this space belongs to had a psychrometric error
Peak Cooling Total Load (W)	2,069.7
Peak Cooling Sensible Load (W)	1,964.8
Peak Cooling Latent Load (W)	104.9
Peak Cooling Airflow	-
Peak Heating Load (W)	613.4
Peak Heating Airflow (m³/s)	0

Heating Components	Total (W)	Percentage	North (W)	South (W)	East (W)	West (W)	Northeast (W)	Southeast (W)	Northwest (W)	Southwest (W)
Wall	44.2	3.11%	6.4	37.8	0.0	0.0	0.0	0.0	0.0	0.0
Window	348.0	24.45%	348.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Door	82.3	5.78%	0.0	82.3	0.0	0.0	0.0	0.0	0.0	0.0
Roof	470.0	33.02%	-	-	-	-	-	-	-	-
Partition	0.0	0.00%	-	-	-	-	-	-	-	-
Skylight	0.0	0.00%	-	-	-	-	-	-	-	-
Infiltration	73.7	5.18%	-	-	-	-	-	-	-	-
Lighting	-74.5	-5.23%	-	-	-	-	-	-	-	-
Power	-273.1	-19.19%	-	-	-	-	-	-	-	-
People	-57.3	-4.02%	-	-	-	-	-	-	-	-
Total	613.4	100%	354.4	120.1	0.0	0.0	0.0	0.0	0.0	0.0

Table 2.5: The Heating load for each room building:

Name of room	Heating load(kW)	Area (m²)	Name of room	Heating load(Kw)	Area (m²)
Room1	0.8	15	room11	2.1	22
Room2	0.7	15	Room12	2	26
Room3	0.7	16	Room13	2	23
Room4	0.7	15	Room14	2	25
Room5	0.7	15	Room15	2.3	31
Room6	1.5	16	Room16	2.3	33
Room7	1.7	16	Room17	1.3	18
Room8	1	15	Room18	1.5	16
Room9	0.9	15	Room19	1.7	16
Room10	1.4	16	Room20	2.5	17

Table 2.6: The Heating load for each Level building:

Name of room	Heating load(kW)	Area (m²)
Ground	45	1003
Level 1	30	375
Level 2	30	375
Level 3	20	262
Level 4	10	305
Level 5	18	193
Level 6	18	193
Level 7	5	72
Level 8	5	75

2.8 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 condition.

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

The total cooling load of a structure involves:

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

2.8.1 Cooling load calculations:

Total cooling load calculations for the sample room shown in figure (2.6).

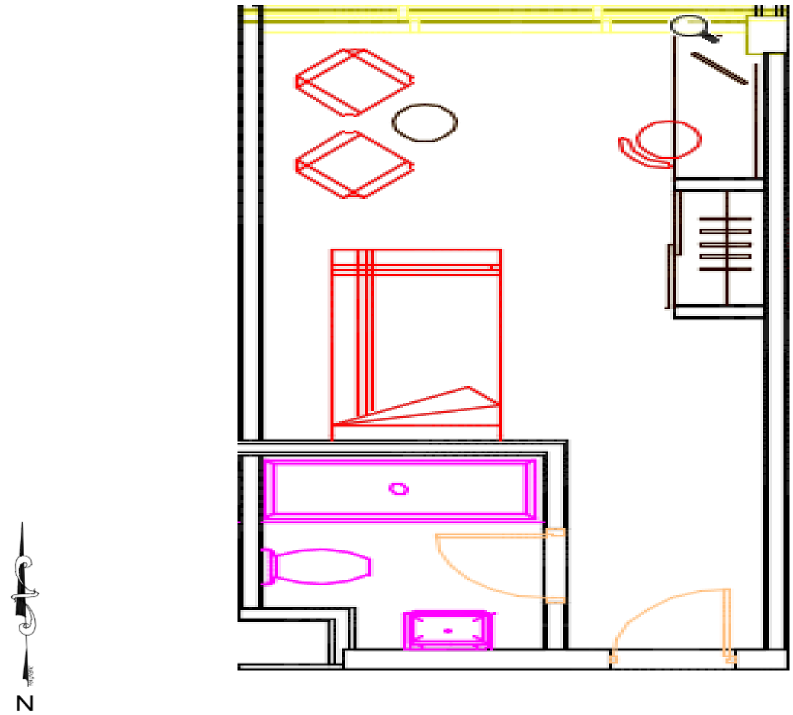


Figure 2.6: Sample room

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

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

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

Where:

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

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

Where:

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

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

k: color adjustment factor .

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

f: attic or roof fan factor.

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

$$T_{o,m} = (T_{max} + T_{min}) /2 \quad \textbf{(}2.19\textbf{)}$$

Where:

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

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

T_{max} = 35 ˚C and T_{min} = 20 ˚C are obtained from Palestinian code.

Applying these values in equation (2.19) to obtain the outdoor mean temperature

$T_{o,m}$ = 27.5 ˚C .

2.8.2 Sample Calculation:

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

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

CLTD = 11 ˚C

LM = 5

k = 0.83 for permanently light colored roofs.

f = 1 there is no attic or roof fan.

$(CLTD)_{corr.} = (11 + 5)\ 0.83 + (25.5 - 24) + (27.5 - 29.4)\ 1$

$= 12.88^{\circ}C$

$$Q_{Roof} = (U_1 A_1 + U_2 A_2)\ (CLTD)_{corr.} \qquad (2.20)$$

$Q_{Roof} = (0.516 \times 11.2 + 0.953 \times 2.8)\ (12.88)$

$= 108.8$ W

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

$\dot{Q}_{ex,Wall} = \dot{Q}_N =$ zero

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

From East wall

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

$= 3.1 \times 18 \times 6$

$= 334.8$ W

From west wall

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

$= 3.1 \times 12 \times 6$

$= 223.2$ W

$Q_{un} = 334.8 + 223.2$

$= 558$ W

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

The amount of solar radiation depends upon the following factors:

i. Type of glass (single, double or insulation glass) and availability of inside shading.
ii. Hour of the day, day of the month, and month of the year.
iii. Orientation of glass area. (North, northeast, east orientation, etc).
iv. Solar radiation intensity and solar incident angle.
v. Latitude angle of the location.

The maximum cooling load due to the glass window Q_{Glass}, consists of transmitted ($Q_{tr.}$ and convicted (Q conv.) cooling loads as follows:

$$Q_{Glass} = Q_{tr.} + Q_{conv.} \quad (2.21)$$

Where:

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

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

The transmitted cooling load is calculated as follows:

$$Q_{tr.} = A\,(SHG)\,(SC)\,(CLF) \quad (2.22)$$

Where:

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

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

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

SHG in W/m^2 …

$A = 9\ m^2$

$SHG = 126\ W/m^2$

SC = 0.57… reflective double from

CLF = 0.84 at 14:00 o'clock …

$$Q_{tr.\,N} = 9 \times 126 \times 0.57 \times 0.86$$

$$= 556W$$

$$Q_{conv.} = UA\,(CLTD)_{corr.} \qquad (2.23)$$

Where:

U: Over all heat transfer coefficient of glass (W/m².K).

A: Out windows Area of heat conduction. (m²).

$(CLTD)_{corr.}$: 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

k = 1 for glass

f = 1 for glass

$$(CLTD)_{corr.} = (7 + 5)\,1 + (25.5 - 24) + (27.5 - 29.4)\,1$$

$$= 11.6^\circ C$$

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

$$= 3.2 \times 9 \times 11.6$$

$$= 334 \text{ W}$$

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

$$= 556 + 334$$

$$= 890 \text{ W}$$

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

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

$$\dot{Q}_{Lt.} = \text{light intensity} \times A \times (CLF)_{Lt.} \tag{2.24}$$

Where:

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

A: floor area = 14 m²

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

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

$Q_{Lt.} = 30 \times 14 \times 0.82$

$= 344.4$ W

Heat gain due to infiltration (Q f):

As the same way in heating load

$$Q_{inf} = \frac{V_{f.}}{v_o} \times (h_{out} - h_{in}) \tag{2.25}$$

Where:

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

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

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

V_o: specific volume (m/s)

v_o = 0.87 (outside the room)

h_{in} = 48 kJ/kg

h_{out} = 100 kJ/kg

V_o = 1.4 (m/s) from Palestinian code

L= 2W + 2H for door

L_d = 6 m

L= 3W + 4H for double sliding window

L_w = 21 m

Therefore;

$V_{inf,d} = 6 * 5.4$

$= 0.009\ m^3/s$

$V_{inf,w} = 21 * 2$

$= 0.011\ m^3/s$

$Q_{inf} = Q_{inf,d} + Q_{inf,w}$ = 538W + 622 W

Q_{inf} = 1160 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:

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

$$Q_{sensible} = \text{heat gain sensible} \times \text{No. of people} \times (CLF)_{oc.} \quad (2.28)$$

Where:

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

heat gain sensible = 70W very light work … from Table A(2.18)

No. of people = 2

(CLF) $_{oc.}$ = 0.84 at 9 hours after each entry into space is obtained from Table (A-21)

Q $_{sensible}$ = 70 × 2× 0.84

= 117.6 W

Q $_{latent}$ = heat gain latent × No. of people **(**2.29**)**

Heat gain latent = 44W… very light work from Table (A-21)

Q $_{latent}$ = 44 × 2

= 88W

Q $_{oc.}$ = 117.6 + 88

= 205.6 W

Heat gain due to ventilation ($Q_{vent.}$):

Mechanical ventilation is required for places in which the inside air is polluted due to activities that place in these spaces as factories, restaurants, closed parking areas, etc. The amount of outside fresh air recommended for mechanical ventilation for different applications. The sensible and total cooling loads required to cool the ventilated air to the inside room temperature is calculating by the following equation:

$$\mathrm{Q_{ventilation}} = \mathrm{m_{ventilation}} \times (\mathrm{h_{out}} - \mathrm{h_{in}}) \qquad (\mathbf{2.30})$$

$$m_f = \frac{V_{f.}}{v_o} \qquad (3.15)$$

V_f = Room volume × No. of times the air changes in the hour (**2.31**)

$$m_f = \frac{V_{f.}}{v_o} = \frac{(14*3.52)m^3*(2)}{0.91(3600)} \quad =0.030 \text{ kg/s}$$

$$Q_{ventilation} = 0.030 \times 1000 \times (100 - 48)$$

$$Q_{ventilation} = 1.56 \text{ kW}$$

The total cooling loss from Sample Room is:

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

=108.8 W+ 558 W+ 890W+ 344.4W+44.45W +205.6 W +1564W

= 3715W

= 3.715kW

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

Q_{tot} = 3715W *1.10

= 4086 W

= 4.086 kW

2) Total cooling load calculations for the sample room by Revit software:

Space Summary - 203 bedrooms

Input Data	
Area (m²)	15.29
Volume (m³)	41.32
Wall Area (m²)	11.09
Roof Area (m²)	16.33
Door Area (m²)	3.45
Partition Area (m²)	0.00
Window Area (m²)	7.72
Skylight Area (m²)	0.00
Lighting Load (W)	150
Power Load (W)	550
Number of People	1
Sensible Heat Gain / Person (W)	85.0
Latent Heat Gain / Person (W)	30.0
Infiltration Airflow (m³/s)	0
Space Type	Living Quarters - Hotel
Calculated Results	
Psychrometric Message	The zone this space belongs to had a psychrometric error
Peak Cooling Total Load (W)	2,069.7
Peak Cooling Sensible Load (W)	1,964.8
Peak Cooling Latent Load (W)	104.9
Peak Cooling Airflow	-
Peak Heating Load (W)	613.4
Peak Heating Airflow (m³/s)	0

Cooling Components	Total (W)	Percentage	North (W)	South (W)	East (W)	West (W)	Northeast (W)	Southeast (W)	Northwest (W)	Southwest (W)
Wall	40.9	1.98%	4.2	36.8	0.0	0.0	0.0	0.0	0.0	0.0
Window	659.7	31.87%	659.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Door	80.0	3.87%	0.0	80.0	0.0	0.0	0.0	0.0	0.0	0.0
Roof	780.7	37.72%	-	-	-	-	-	-	-	-
Skylight	0.0	0.00%	-	-	-	-	-	-	-	-
Partition	0.0	0.00%	-	-	-	-	-	-	-	-
Infiltration	103.6	5.00%	-	-	-	-	-	-	-	-
Lighting	74.5	3.60%	-	-	-	-	-	-	-	-
Power	273.1	13.20%	-	-	-	-	-	-	-	-
People	57.3	2.77%	-	-	-	-	-	-	-	-
Plenum	0.0	0.00%	-	-	-	-	-	-	-	-
Total	2,069.7	100%	663.9	116.8	0.0	0.0	0.0	0.0	0.0	0.0

Table 2.7: The Cooling load for each room building:

Name of room	Cooling load(kW)	Area (m^2)	Name of room	Cooling load(Kw)	Area (m^2)
Room1	2.3	15	room11	9.6	22
Room2	2	15	Room12	3.4	26
Room3	2.2	16	Room13	3.9	23
Room4	2.3	15	Room14	4.1	25
Room5	2.2	15	Room15	4.4	31
Room6	9	16	Room16	5	33
Room7	9	16	Room17	3.7	18
Room8	3.6	15	Room18	3.6	16
Room9	3.6	15	Room19	3.6	16
Room10	4	16	Room20	7.1	17

Table 2.8: The Cooling load for each Level building:

Name of room	Cooling load(kW)	Area (m^2)
Ground	196	1003
Level1	74	375
Level2	74	375
Level3	45	262
Level4	40	305
Level5	35	193
Level6	35	193
Level7	13	72
Level8	10	75

Chapter Three

Variable Refrigerant Flow System

3.1 Variable Refrigerant Flow System

Variable refrigerant flow (VRF) is an air-condition system configuration where there is one outdoor condensing unit and multiple indoor units. The term variable refrigerant flow refers to the ability of the system to control the amount of refrigerant flowing to the multiple evaporators (indoor units), enabling the use of many evaporators of differing capacities and configurations connected to a single condensing unit. The arrangement provides an individualized comfort control, and simultaneous heating and cooling in different zones.

Currently widely applied in large buildings especially in Japan and Europe, these systems are just starting to be introduced in the U.S. The VRF technology/system was developed and designed by Daikin Industries, Japan who named and protected the term variable refrigerant volume (VRV) system so other manufacturers use the term VRF "variable refrigerant flow". In essence both are same.

With a higher efficiency and increased controllability, the VRF system can help achieve a sustainable design. Unfortunately, the design of VRF systems is more complicated and requires additional work compared to designing a conventional direct expansion (DX) system.

3.1.1 Overview

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

The term VRF 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. VRF systems operate on the direct expansion (DX) principle meaning that heat is transferred to or from the space directly by circulating refrigerant to evaporators located near or within the conditioned space. Refrigerant flow control is the key to many advantages as well as the major technical challenge of VRF systems.

Note the term VRF systems should not be confused with the centralized VAV (variable air volume) systems, which work by varying the air flow to the conditioned space based on variation in room loads

3.1.2 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.

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

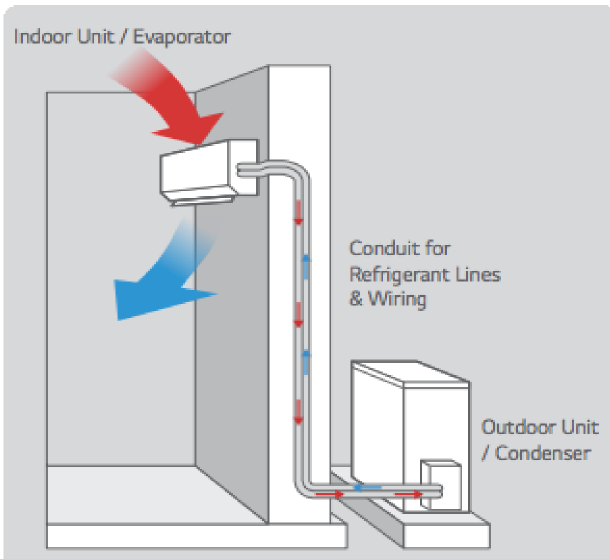


Figure (3.1): Split Air-conditioning System

Advantages of using Split Air-conditioners

• Low initial cost, less noise and ease of installation;

• Good alternative to ducted systems;

• Each system is totally independent and has its own control.

Disadvantages

• There is limitation on the distance between the indoor and outdoor unit i.e. 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 throw 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

3.1.3 Multi-Split Systems

A multi-type air conditioning system operates on the same principles as a split type air-conditioning system however in this case there are ‘multiple’ evaporator units connected to one external condensing unit. These simple systems were designed mainly for small to medium commercial applications where the installation of ductwork was either too expensive, or aesthetically unacceptable.

The small-bore refrigerant piping, which connects the indoor and outdoor units requires much lower space and is easier to install than the metal ducting. Each indoor unit has its own set of refrigerant pipe work connecting it to the outdoor unit.

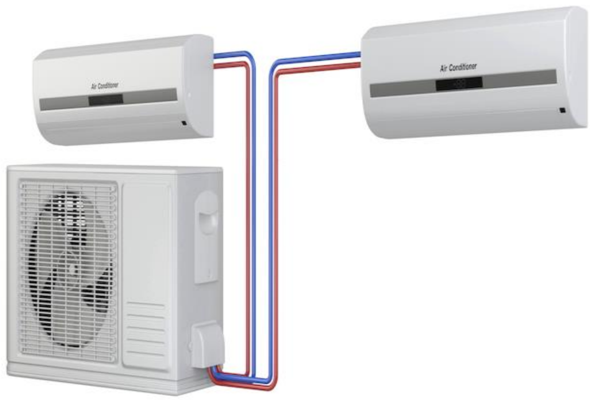


Figure (3.2): Multi-Split Systems

Advantages of Multi-splits

• The fact that one large condenser can be connected to multiple evaporators within the building reduces and/or eliminates the need for ductwork installation completely.

• Multi-splits are suitable for single thermal zone (defined below) applications with very similar heat gains/losses.

Drawbacks

• 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 .

3.1.4 Variable refrigerant flow description

VRF systems are similar to the multi-split systems which connect one outdoor section to several evaporators. VRF systems continually adjust the flow of refrigerant to each indoor evaporator. The control is achieved by continually varying the flow of refrigerant through a pulse modulating valve (PMV) whose opening is determined by the microprocessor receiving information from the thermistor sensors in each indoor unit. The indoor units are linked by a control wire to the outdoor unit which responds to the demand from the indoor units by varying its compressor speed to match the total cooling and/or heating requirements.

VRF systems promise a more energy-efficient strategy (estimates range from 11% to 17% less energy compared to conventional units) at a somewhat higher cost.

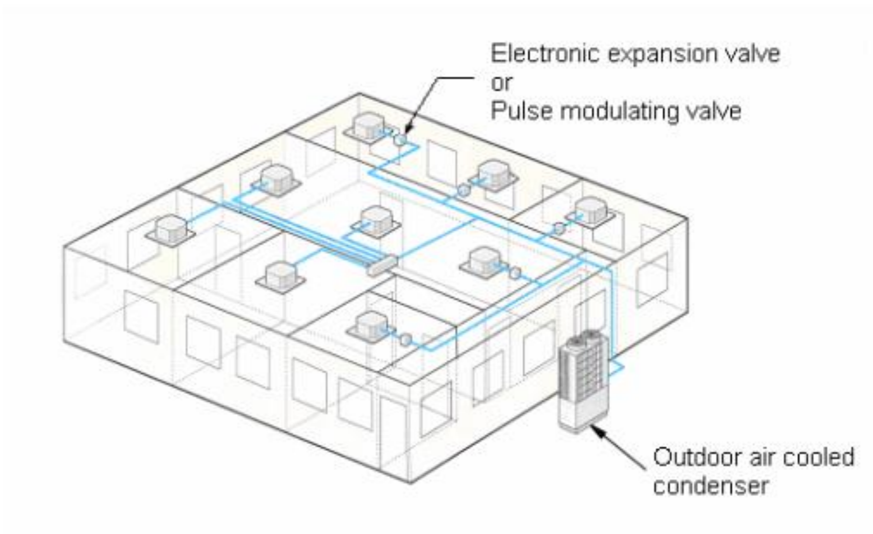


Figure (3.3): VRF System indoor evaporative units

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%.

A schematic VRF arrangement is indicated below:

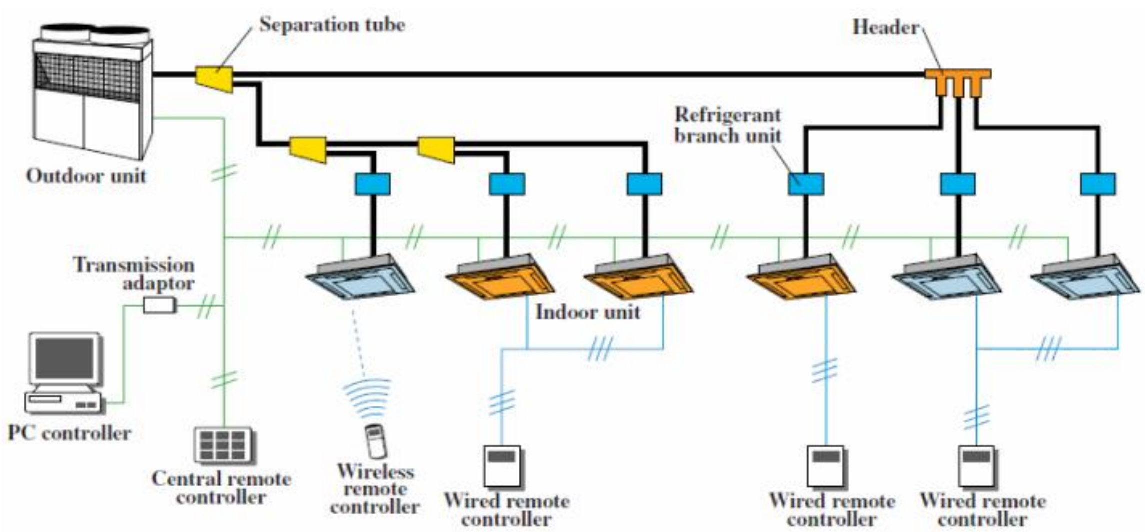
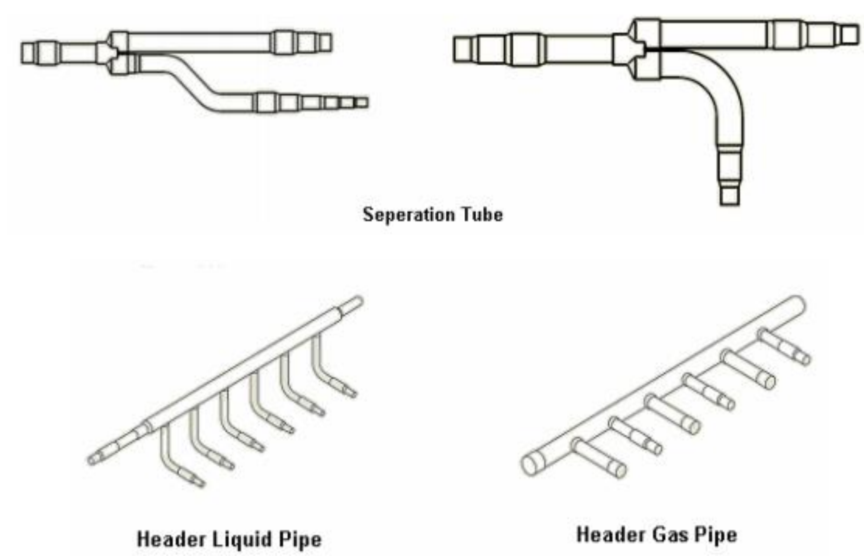


Figure (3.4): A schematic VRF arrangement

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.



[9] **Figure (3.5): Separation and header tubes**

Compared to multi-split systems, VRF systems minimize the refrigerant path and use less copper tubing. Minimizing the refrigerant path allows for maximizing the efficiency of refrigerant work

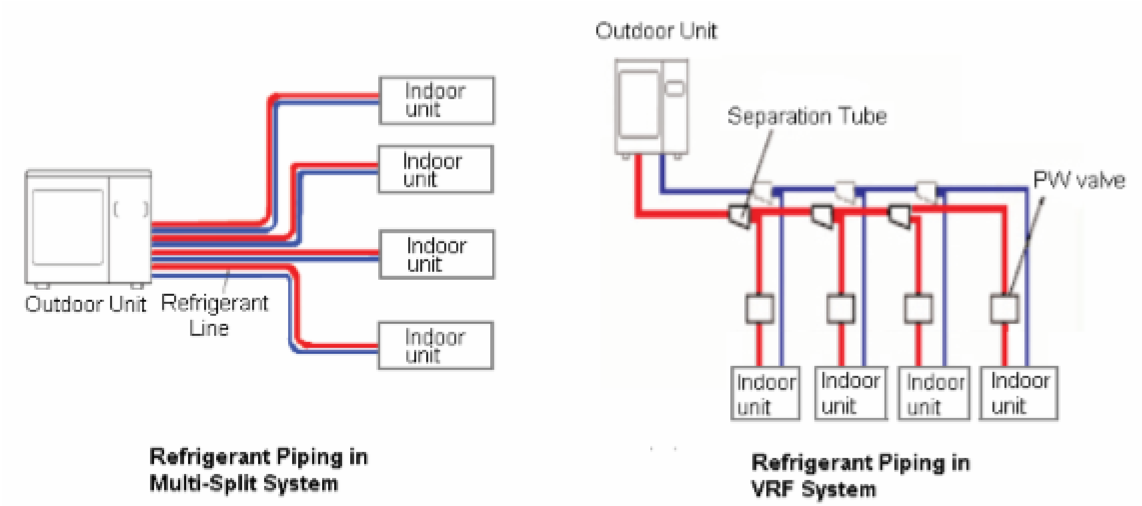


Figure (3.6): Difference VRF System with multiple indoor evaporative units

3.1.5 Types of VRF

VRV/VRF systems can be used for cooling only, heat pumping or heat recovery. On heat pump models there are two basic types of VRF system: heat pump systems and energy recovery.

VRF heat pump systems

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

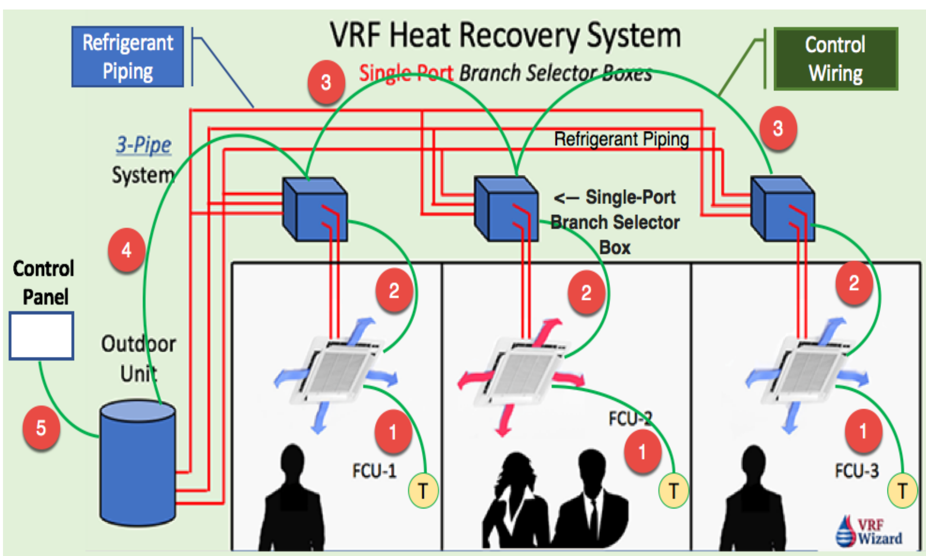
VRF heat pump systems are effectively applied in open plan areas, retail stores, cellular offices and any other areas that require cooling or heating during the same operational periods.

Heat Recovery VRF system (VRF-HR)

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

Each manufacturer has its own proprietary design (2-pipe or 3-pipe system), but most uses a three-pipe system (liquid line, a hot gas line and a suction line) and special valving arrangements. Each indoor unit is branched off from the 3 pipes using solenoid 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.



[9] **Figure (3.7): Heat recovery type VRF system**

VRF-HR mixed mode operation leads to energy savings as both ends of the thermodynamic cycle are delivering useful heat exchange. If a system has a cooling COP (Coefficient of Performance) of 3, and a heating COP of 4, then heat recovery operation could yield a COP as high as 7.

VRF-HR systems work best when there is a need for some of the spaces to be cooled and some of them to be heated during the same period. This often occurs in the winter in medium-sized to large sized buildings with a substantial core or in the areas on the north and south sides of a building. This project deals with VRF heat pump systems.

Refrigerant modulation in a VRF system63.1.

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. [9]

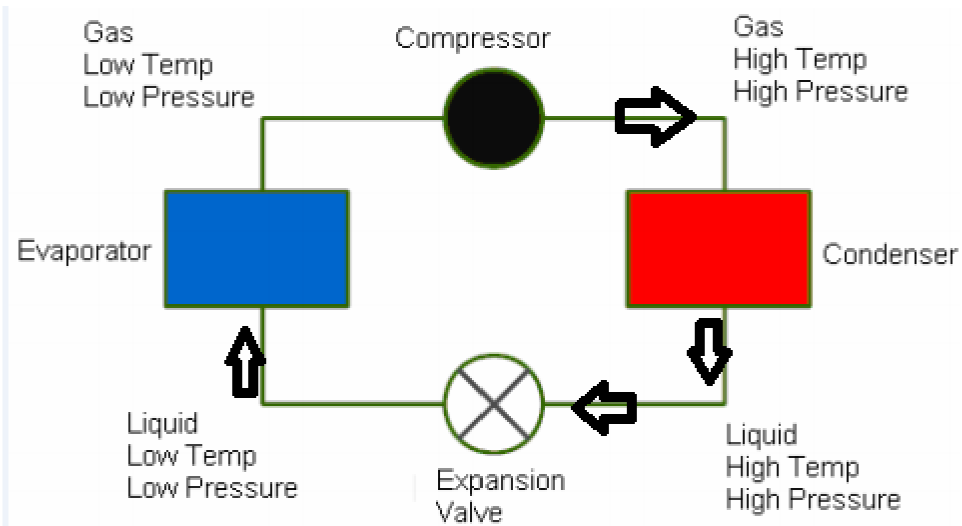


Figure (3.8): Basic refrigeration cycle

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.

Design considerations for VRF system73.1.

Deciding what HVAC system best suits your application will depend on several variables such as 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. [9]

Building Characteristics

VRF systems are typically distributed systems – the outdoor unit is kept at a far off location like the top of the building or remotely at grade level and all the evaporator units are installed at various locations inside the building. Typically the refrigerant pipe-work (liquid and suction lines) is very long, running in several hundreds of feet in length for large multi-story buildings. Obviously, the long pipe lengths will introduce pressure losses in the suction line and, unless the correct diameter of pipe is selected, the indoor units will be starved of refrigerant resulting in insufficient cooling to the end user. So it is very important to make sure that the pipe sizing is done properly, both for the main header pipe as well as the feeder pipes that feed each indoor unit. The maximum allowable length varies among different manufacturers; however the general guidelines are as follows:

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

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

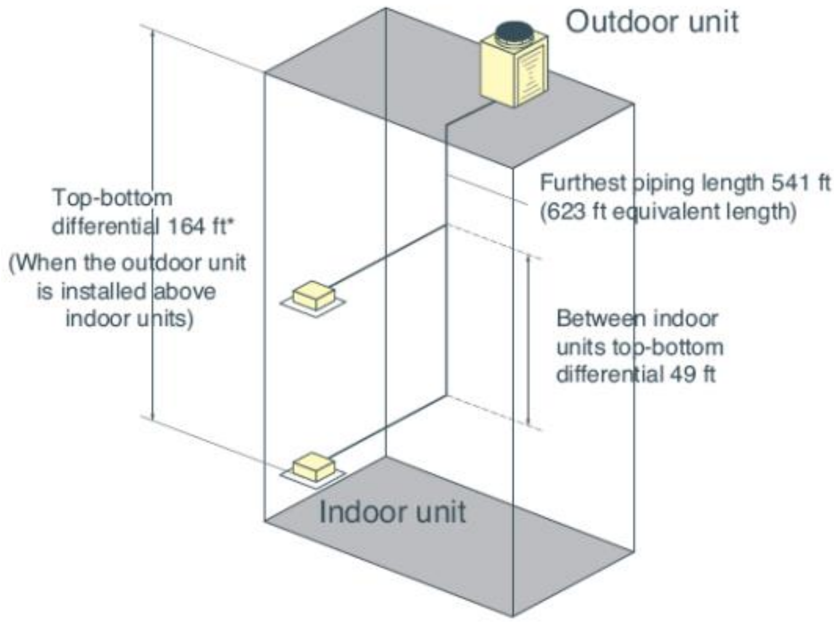
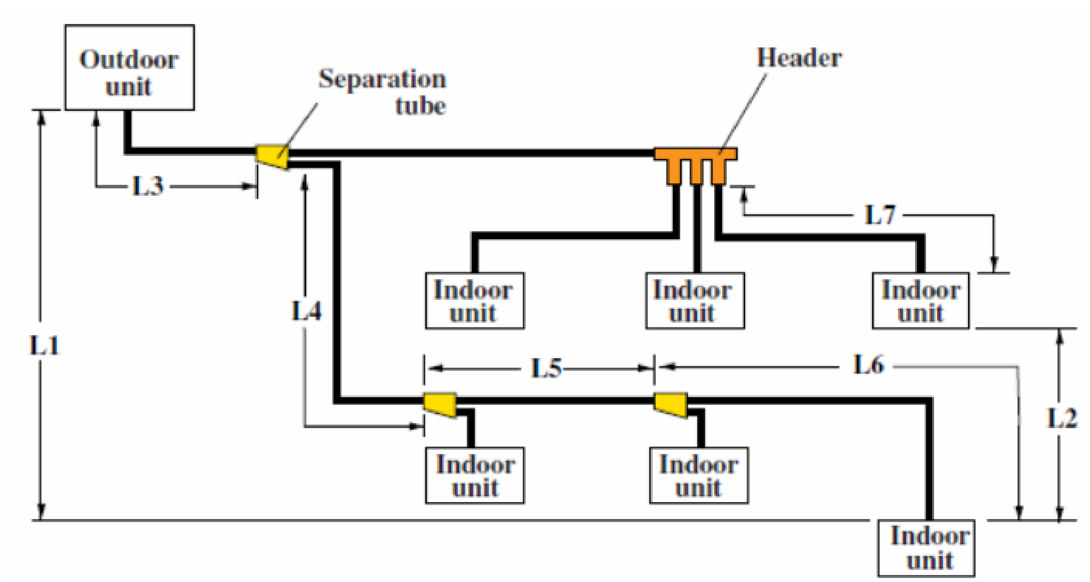


Figure (3.9): Design limits in VRF system

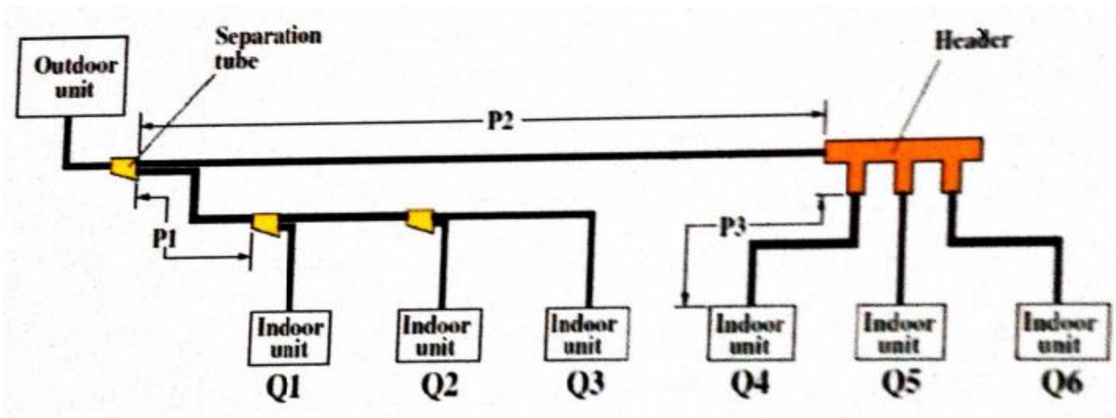
As stated, the refrigerant piping criteria varies from manufacturer to manufacture, for example for one of the Japanese manufacturer (Samsung), the system design limits are: [10]



[9] **Figure (3.10): 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 = 70m

- [L3+L4+L5+L6]: Maximum piping length from outdoor unit to last indoor unit = 100m
- L6 & L7: Maximum piping length from header to indoor unit = 40m
- Total piping length = 200m (Liquid pipe length)



[9] **Figure (3.11): 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)

<u>Building Load Profile</u>

When selecting a VRF system for a new or retrofit application, the following assessment tasks should be carried out:

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

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

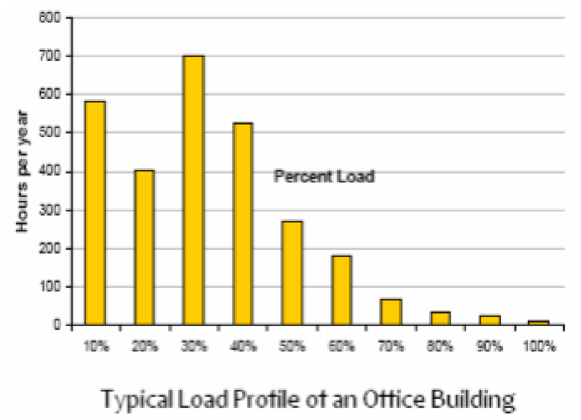


Figure (3.12): Work compressor hours per year

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.

<u>Sustainability</u>

One attractive feature of the VRF system is its higher efficiency compared to conventional units. Cooling power in a VRF system is regulated by means of adjusting the rotation speed of the compressor which can generate an energy saving around 30%.

A VRF system permits easy future expansion when the conditions demand. Oversizing however, should be avoided unless a future expansion is planned.

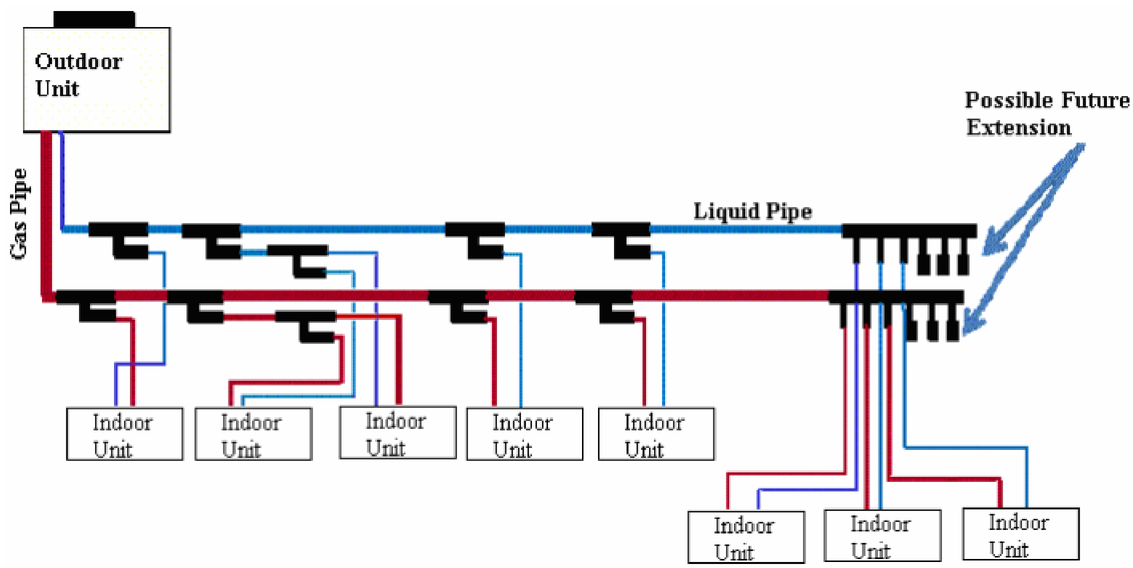


Figure (3.13): Pipe work schematic

Other sustainability factors include:

- Use of non-ozone depleting environment-friendly refrigerants such as R 410a
- Opting for heat pump instead of electrical resistance heating in areas demanding both cooling and heating.

Heat pumps offer higher energy efficiency.

Simultaneous Heating and Cooling

Some manufacturers offer a VRF system with heat recovery feature which is capable of providing simultaneous heating and cooling. The cost of a VRF-HR is higher than that of a normal VRF heat pump unit and therefore its application should be carefully evaluated.

More economical design can sometimes be achieved by combining zones with similar heating or cooling requirements together. For example, the areas that may require simultaneous heating and cooling are the parametric and interior zones. Parametric areas with lot of glazing and exposure especially towards west and south will have high load variations. A VRF heat pump type system is capable of providing simultaneous heating and cooling exceeding 6 tons cooling requirement.

Using VRF heat pump units for heating and cooling can increase building energy efficiency. The designer must evaluate the heat output for the units at the outdoor design temperature. Supplemental heating with electric resistors shall be considered only when the heating capacity of the VRF units is below the heating capacity required by the application. Even though supplemental heating is considered, the sequence of operation and commissioning must specify and prevent premature activation of supplemental heating.

First Costs

The installed cost of a VRF system is highly variable, project dependent, and difficult to pin down. Studies indicate that the total installed cost of a VRF system is estimated to be 5% to 20% higher than air or water cooled chilled water system, water source heat pump, or rooftop DX system providing equivalent capacity. This is mainly due to long refrigerant piping and multiple indoor evaporator exchanges with associated controls. Building owners often have no incentive to accept higher first costs, even if the claimed payback period is short, as the energy savings claims are highly unpredictable.

3.1.8 Advantages of VRF system

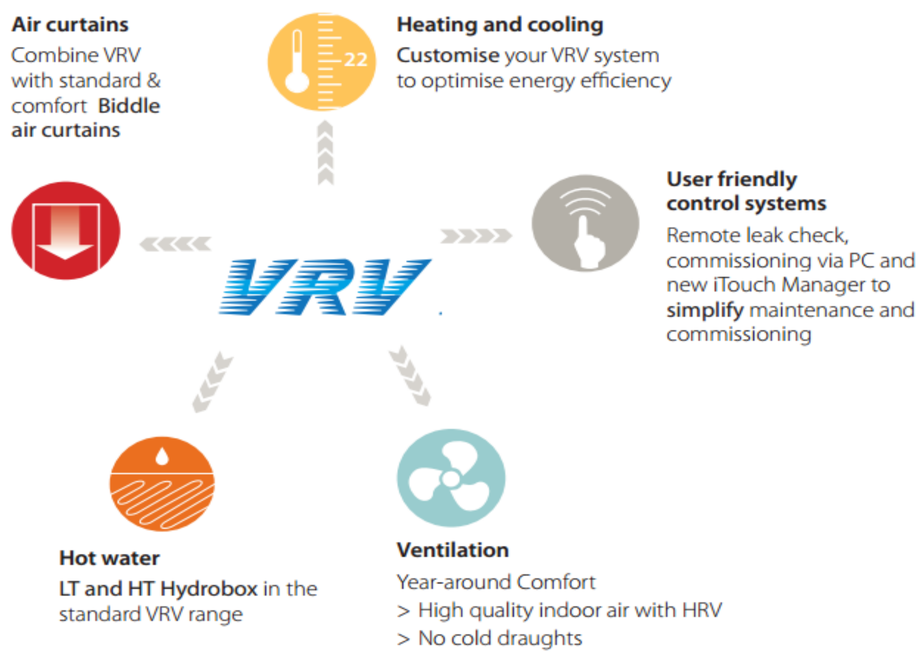


Figure (3.14): VRV provides a total solution for integrated climate control

VRF systems have several key benefits, including:

1. Installation Advantages:

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

2. Design Flexibility:

   A single condensing unit can be connected to many indoor units of varying capacity (e.g., 0.5 to 4 tons [1.75 to 14 kW]) and configurations (e.g., ceiling recessed, wall mounted, floor console). Current products enable up to 20 indoor units to be supplied by a single condensing unit. Modularity also makes it easy to adapt the HVAC system to expansion or reconfiguration of the space, which may require additional capacity or different terminal units.

3. Maintenance and Commissioning**:**

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

4. Comfort:

VRF systems enable wide capacity modulation and bring rooms to the desired temperature extremely quickly and keep temperature fluctuations to minimum. The technology offers excellent dehumidification performance for optimal room humidity regardless of outside conditions. Any area in the building will always be exactly at the right temperature and humidity, ensuring total comfort for their occupants.

• VRF systems are capable of simultaneous cooling and heating. Each individual indoor unit can be controlled by a programmable thermostat. Most VRF manufacturers offer a centralized control option, which enables the user to monitor and control the entire system from a single location or via the internet.

• VRF systems can generate separate billing that makes individualized billing easier.

5. Reduced Noise Levels :

Indoor and outdoor units are so quiet that they can be placed just about anywhere, providing more flexibility on how to use indoor and outdoor space.

Outdoor units can even be placed directly under a window and quiet indoor units are perfect in environments that require minimal disruption like schools, places of worship, libraries and more. When compared to the single split system, a VRF system reduces outside noise levels by almost 5 dB@1m.

6. Flexible Installation:

• VRF systems are lightweight; require less outdoor plant space and offer spacesaving features.

• Because ductwork is required only for the ventilation system, it can be smaller than the ducting in standard ducted systems; thereby, reducing building height and costs;

• When compared to the single split system, a VRF system reduces installation cost by about 30%. A VRF system provides reduction in copper tubing and wiring costs.

7. Reliability.

Continuous operation is possible even if trouble occurs at an indoor unit.

- Indoor Unit

Each indoor unit is controlled individually on the system network. This allows all indoor units continue to run unaffected even if trouble should occur at any indoor unit in one system.

- Outdoor Unit

Continuous operation is possible even in the event of compressor failure. There is no immediate system shutdown if trouble occurs in any compressor. The other compressors can continue to operate on an emergency basis.

8. Energy Efficiency.

VRF technology yields exceptional part-load efficiency. Since most HVAC systems spend most of their operating hours between 30-70% of their maximum capacity, where the coefficient of performance (COP) of the VRF is very high, the seasonal energy efficiency of these systems is excellent.

Energy sub-metering with VRF systems is relatively simple and inexpensive by placing an electric meter on one or a few condensing units. This is a very important feature in the multi-tenant buildings if energy costs are charged explicitly to each tenant rather than being hidden in overall leasing cost.

Concluding…..

VRF provides an alternative realistic choice to traditional central systems. It captures many of the features of chilled water systems, while incorporating the simplicity of DX system

Salient Features:

• Refrigerant flow rate is constantly adjusted by an electronic expansion valve in response to load variations as rooms require more or less cooling. Also, if reversible heat pumps are used, the heating output can be varied to match the varying heat loss in a room;

• An expansion valve or control valve can reduce or stop the flow of refrigerant to each indoor unit, thus controlling its output to the room;

• The overall refrigerant flow is varied using either an inverter controlled variable speed compressor, or multiple compressors of varying capacity in response to changes in the cooling or heating requirement within the air conditioned space;

• A control system enables switching between the heating and cooling modes if necessary. In more sophisticated versions, the indoor units may operate in heating or cooling modes independently of others;

• A VRF system uses inverters or scroll compressors. They are efficient and quiet. and are usually hermetically sealed. Small to medium size units may have 2 compressors;

• Ozone friendly HFC refrigerants; R-410-A and R-407-C are typically used;

• Refrigerant liquid lines tend to be about 3/8" in diameter and gas lines about 5/8" to 3/4" in diameter;

• Central control of a VRV system can be achieved by centralized remote controllers.

VRV/VRF technology is based on the simple vapor compression cycle but the system capabilities and limitations must be fully understood and evaluated carefully to determine its suitability. Before working with VRV/VRF systems, it is strongly recommended that manufacturer's product training be undertaken

3.9.1 Selection units

This section talks about selection of outdoor and indoor units of VRF system, depending on the "Samsung VRF catalogue", since this company product is existing in Hebron.

Outdoor and indoor units are selected according to the thermal load of the building. [10]

<u>Indoor unit</u>

In this project there are many types of indoor units selected, which are wall mounted , cassette M.S.P duct and slim Duct units.

The figure below shows two types of selected units:

Figure (3.15): 360 cassette and slim duct indoor units

MODEL NAME

AVX	C	S	H	022	E	E
①	②	③	④	⑤	⑥	⑦

① Classification

Indoor unit (R410A)	AVX

② Classification by product group

Cassette type	C
Duct type	D
Wall mounted type	W
Convertible type	T

③ Product notation

Cassette type	Slim 1way	S
	2way	2
	Mini 4way	M
	4way	4
Duct type	Slim	S
	Middle static pressure	U
Wall mounted type	MB	B
	Neo Forte	N
	Vivace	V
Convertible type	Ceiling	F
	Console	J

④ Mode

Heat Pump/Heat Recovery	H

⑤ Capacity

x 1/10 kW (3 digits)

Notation	Cooling	Heating
022	2.2	2.5
028	2.8	3.2
036	3.6	4.0
045	4.5	5.0
056	5.6	6.3
060	6.0	6.8
071	7.1	8.0
090	9.0	10.0
112	11.2	12.5
128	12.8	13.8
140	14.0	16.0

⑥ Rating voltage

1Ø, 220V, 60Hz	B
1Ø, 208~230V, 60Hz	C
1Ø, 220~240V, 50Hz	E

⑦ Version

Domestic (KOREA)	0~9
Export	A~Z

And the selection of each unit done by determining the code of it using the code system from DVM plus 3 technical data book as shown in figure below :

Figure (3.16): code system from DVM plus 3

The selected indoor units for the building are listed in the tables below:

Table (3.1): nominal and actual outdoor capacity

Room Name	**Heating Load (Kw)**	**Cooling Load (Kw)**	**Indoor Unit Type**	**Indoor Unit model**
A-Master Bedroom	0.91	1.74	Cassette	AM007FNTDCH/AA
A-Bedroom 1	0.60	0.88	Cassette	AM009FNNDCH/AA
A-Bedroom 2	1.04	1.20	Cassette	AM009FNNDCH/AA
A-Bedroom 3	2.16	1.96	Cassette	AM009FNNDCH/AA
A-Bedroom 4	1.13	2.23	Cassette	AM009FNNDCH/AA
A-Bedroom 5	1.04	1.50	Cassette	AM009FNNDCH/AA
B-Master Bedroom	0.91	1.65	Cassette	AM009FNNDCH/AA
B-Bedroom 1	0.60	0.93	Cassette	AM009FNNDCH/AA
B-Bedroom 2	1.04	1.14	Cassette	AM009FNNDCH/AA
B-Bedroom 3	2.16	0.93	Cassette	AM009FNNDCH/AA
B-Bedroom 4	1.13	2.23	Cassette	AM009FNNDCH/AA

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 (3.2): nominal and actual outdoor capacity

FLOOR	Number of VRF system	Capacity for each system (Kw)		Outdoor selection (code)	
		System 1	System 2	System 1	System 2
Ground	1	40.4	…….	(AM180KXVAGH/TK) (AM220KXVAGH/TK) (AM300KXVAGH/TK)	…………..
First	2	22.9	49.7	3(RVXVRT100GE)	1(RVXVRT120GE) 3(RVXVRT160GE)
Second	2	48.2	53.6	1(RVXVRT120GE) 3(RVXVRT160GE)	4(RVXVRT160GE)
Third	2	48.52	53.3	1(RVXVRT120GE) 3(RVXVRT160GE)	4(RVXVRT160GE)
Fourth	2	35.7	43.4	2(RVXVRT100GE) 1(RVXVRT120GE) 1(RVXVRT140GE)	1(RVXVRT140GE)
Fifth	2	29.6	51.4	1(RVXVRT120GE) 1(RVXVRT140GE)	4(RVXVRT160GE)
sexth					
seventh					

3.2 Mechanical ventilation

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

There are two ways for Ventilation:

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

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

1. Air changes per hour
2. An air flow rate per person
3. An air flow 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.

Air flow 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.

3.2.1 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.

3.2.2 Designing of mechanical ventilation

Steps of designing mechanical ventilation:

- Calculate the required ventilating rate of air by using "Ventilation Rates Calculator" software
- Calculate the volume of the room in (m^3)
- Calculate the flow rate of air by using air changes per hour method

3.2.3 Sample calculation

Using bathroom:

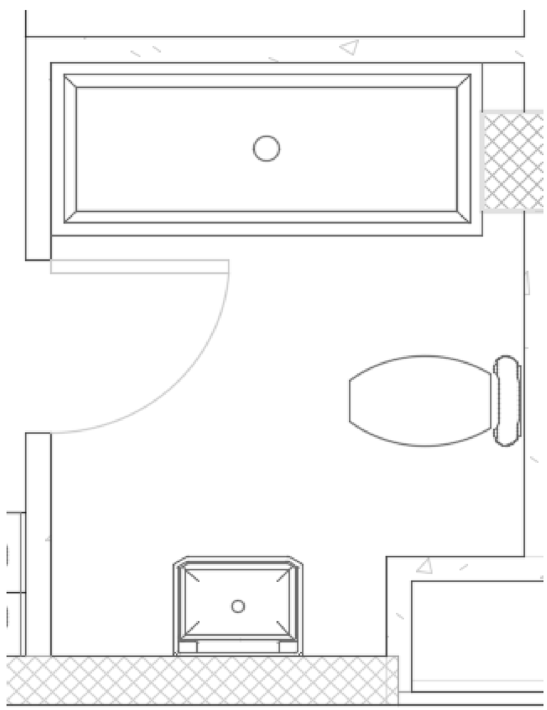


Figure (3.17): Bathroom layout

- The volume is 13 m^3

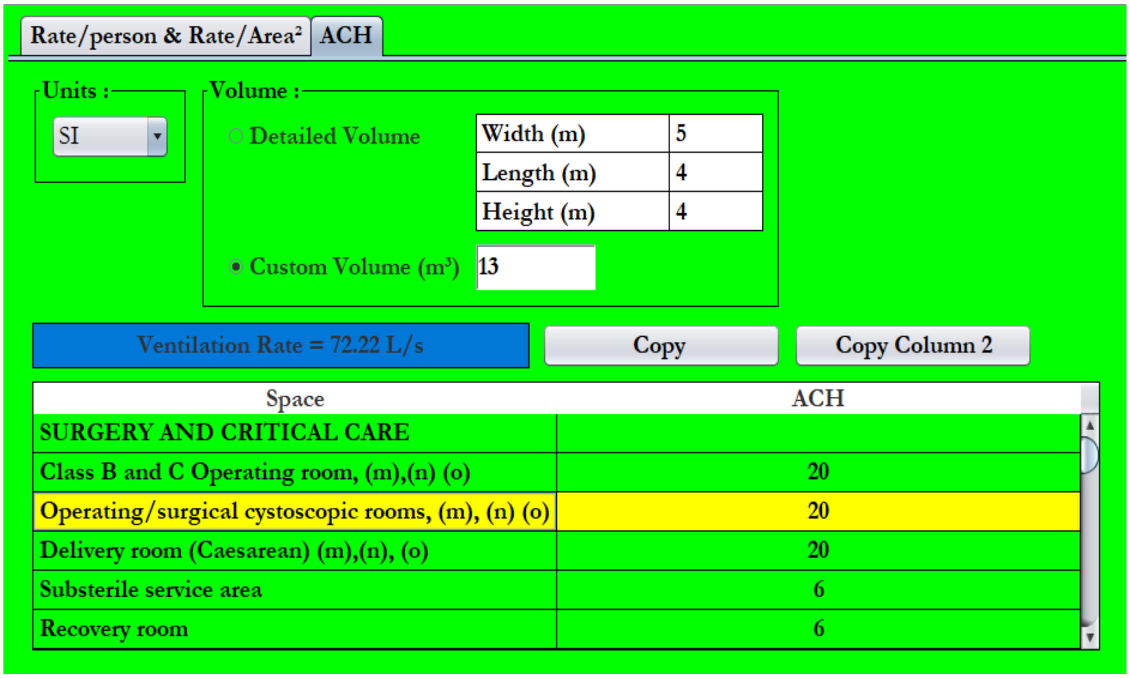


Figure (3.18): Ventilation rates calculator

CHAPTER Four

Plumbing System

4.1 Introduction

There are two main functions of using plumping systems:

1- Water supply system; which provides the building with the required amount of water.

2- Sanitary drainage system; which removes all the usable water from the building.

It is the plumbing technologists' responsibility to design the entire water service and distribution systems for all uses, recognizing the pressure and flow limitations.

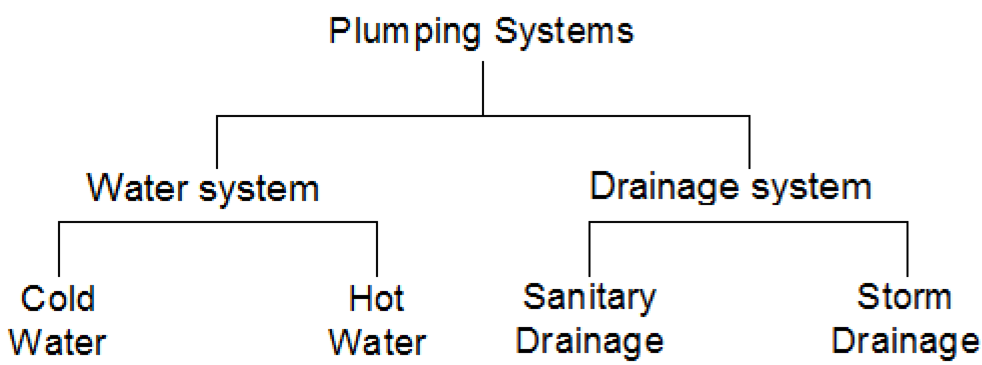


Figure (4.1): Plumping systems

4.2 Water supply system

4.2.1 Overview

There are two type of water distribution system for buildings:

1) Up feed distribution system.

2) Down feed distribution.

The system that will use to this building is up feed system.

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

1) The supply of water for the building is received from a city main.
2) Private water supply enters into a pneumatic tank pressurized from approximately 35-60 psi pump.

The main pressure that provides this building is pump pressure.

The design of main water supply for the building needs to take into consideration the actual and anticipated future consumption. Moreover, size of water main pipe, and required pressure of water are essential.

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

The design procedure is as follows:

1) draw a rise (plumbing section) on this riser show:
   - Floor to floor height.
   - Run out distance to farthest fixture on each floor.
   - Lengths of piping from the service point to the floor take off points.
2) Show the WSFU for each fixture and total fixture unit on each piping run out. Use separate fixture units for hot and cold water.
3) Total the fixture units in each branch of the system. Each hot and cold water riser will require separate diagram and calculation.
4) Show minimum source pressure and the minimum flow pressure required of the most remote outlets.
5) Determine the pressure available for friction head loss from service point to the final outlet.
6) Determine the required pipe size in each section using friction head loss data calculated in step 5 and friction head charts.

4.2.2.1 Fixture units load for the first riser

For a general & private, flush tank system, 1st riser cold water & 1st riser hot water, using Table A(5.1) has the following:

Table (4.1): Fixture units load for 1st riser

Fixture type	No. FU	WSFU	Total WSFU	Cold WSFU	Hot WSFU	Total cold	Total hot
Lavatory, general	9	2	18	2x3/4	2x3/4	13.5	13.5
Water closet, general	6	5	30	-	-	30	-
Bathtub ,private	22	2	44	2x3/4	2x3/4	33	33
Water closet , private	22	1	22	-	-	66	-
Lavatory ,private	22	2	44	2x3/4	2x3/4	16.5	16.5
Urinal , general	2	5	10	-	-	10	-
Total(WSFU)	**-**	**-**	**168**	**-**	**-**	**170**	**63**

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

160 WSFU $\rightarrow$ 57 gpm

170 WSFU $\rightarrow$ X gpm

180 WSFU $\rightarrow$ 61 gpm

X= 59 gpm , For **Cold** water 1st riser

160 WSFU $\rightarrow$ 57 gpm

168 WSFU $\rightarrow$ X gpm

180 WSFU $\rightarrow$ 61 gpm

X= 58.5 gpm , For **Total** water 1st riser

60 WSFU $\rightarrow$ 33 gpm

63 WSFU $\rightarrow$ X gpm

80 WSFU $\rightarrow$ 39 gpm

X= 34 gpm , For **Hot** water 1st riser

For a general & private, flush tank system, 2nd riser cold water & 2nd riser hot water, using Table A(5.2) has the following:

Table (4.2): Fixture units load for 2nd riser

Fixture type	No. FU	WSFU	Total WSFU	Cold WSFU	Hot WSFU	Total cold	Total hot
Lavatory, general	4	2	8	2x3/4	2x3/4	6	6
Water closet, general	4	5	20	-	-	20	-
Bathtub, private	30	2	60	2x3/4	2x3/4	45	45
Lavatory, private	30	1	30	1x3/4	1x3/4	22.5	22.5
Water closet, private	30	3	90	-	-	90	-
Total(WSFU)	**-**		**208**	**-**	**-**	**183.5**	**73.5**

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

180 WSFU → 61 gpm

183.5 WSFU → X gpm

200 WSFU → 65 gpm

X= 61.7 gpm , For **Cold** water 2nd riser

200 WSFU → 65 gpm

208 WSFU → X gpm

225 WSFU → 70 gpm

X= 66.5 gpm , For **Total** water 2nd riser

60 WSFU → 33 gpm

73.5 WSFU → X gpm

80 WSFU → 39 gpm

X= 37 gpm , For **Hot** water 2nd riser

For a general & private, flush tank system, 3rd riser cold water & 3rd riser hot water, using Table A(4.3) has the following:

Table (4.3): Fixture units load for 3rd riser

Fixture type	No. FU	WSFU	Total WSFU	Cold WSFU	Hot WSFU	Total cold	Total hot
Kitchen sink	4	2	8	2x3/4	2x3/4	6	6
Lavatory, private	17	1	17	1x3/4	1x3/4	12.75	12.75
Water closet, general	9	5	45	-	-	45	-
Water closet, private	17	3	51	-	-	51	-
Bathtub, private	17	2	34	2x3/4	2x3/4	25.5	25.5
Dishwasher	3	1	3	-	-	3	-
Lavatory, general	11	2	22	2x3/4	2x3/4	16.5	16.5
Shower, general	9	4	36	4x3/4	4x3/4	13.5	13.5
Total(WSFU)	**-**	**-**	**216**	**-**	**-**	**173**	**74**

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

160 WSFU → 57 gpm

173 WSFU → X gpm

180 WSFU → 61 gpm

X= 62.2 gpm , For **Cold** water 3rd riser

200 WSFU → 61 gpm

216 WSFU → X gpm

225 WSFU → 70 gpm

X= 69 gpm , For **Total** water 3rd riser

60 WSFU → 33 gpm

74 WSFU → X gpm

80 WSFU → 39 gpm

X= 37 gpm , For **Hot** water 3rd riser

Riser	Total WSFU CW	Total WSFU HW
Riser 1st	170	63
Riser 2nd	183.5	73.5
Riser 3rd	173	74

4.2.2.2 Sizing of pipes

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

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

Where:

Static head is to overcome the height.

Friction head is to overcome friction in pipes.

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

By friction head loss method:

1-calculate the head for the riser 1.(1m = 3.28 ft).

floor to floor height is 3.5 m.

Static head = ((#.of floors*floor to floor height)*3.28) +3

Static head = ((4+2*3.5)*3.28)+3 =39.08 ft.

So the static pressure = static head * 0.433 psi/ft = 39.08 * 0.433 = 17 psi.

2-Total equivalent length.

we will calculate the equivalent length from the well to the farthest outlet (Sink faucet) at the fifth floor at farthest collector.

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

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

Must be taken into Account that the velocity for all fixture units should not exceed 8 fps , except for water closet with flush valve of 4fps.

a- **For cold water system:**

Total length = 71 m.

Total equivalent length=71*1.5*3.28= **350 ft**

b- **For hot water system:**

Total length =70 m

Total equivalent length=70*1.5*3.28 = **345 ft**.

3-Minimum flow pressure and friction head:

The minimum required flow pressure at the most remote outlet on the thirteenth floor (Sink faucet) is 8 psi. **From table [3] Appendix B**

a- **For cold water system:**

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

Friction head = 50 – (17+8)= 25 psi.

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

Friction/100ft =25 psi/(**350.3** /100 ft) = 7.14 (psi/100ft).

Table 4.4: Pipe sizing for cold water riser

Section number	Flow (gpm)	Equivalent length(ft)	Pipe size (in)	Friction(psi /100ft)	Velocity (fps)
Pump-1st riser	59	350.3	2"	7.14	8.2
2nd riser section	61.7	118.1	2"	4.23	6.5
3rd riser section	62.2	265.7	2"	5.64	7.2

The diameter will be select for cold riser is 2 in.

b- **For hot water system:**

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

Friction head = 50 – (17+8)= 15 psi.

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

Friction/100ft =25 psi/(348.1 /100 ft) = 7.18 (psi/100ft).

Table 4.5: Pipe sizing for hot water riser

Section number	Flow (gpm)	Equivalent length(ft)	Pipe size (in)	Friction(psi /100ft)	Velocity (fps)
Pump -1st riser	34	348.1	1.5"	7.18	6.5
2nd riser section	37	116.3	1.5 "	8.6	7.8
3rd riser section	37	263.4	1.5 "	3.8	5.8

The diameter will be select for hot riser is 1.5 in.

Look at Figure A(4.2) that shows the details of water supply risers.

4. 3 Water tank volume

Calculation for the water well volume needed for the hotel :

Total demand of water for this hotel is 193.5 gpm

So we have a tank Provides a need of water equal 52.8 m^3/h

In this hotel building we have a wall. This wall has volume equal 550 m^3

4.4 Water pump selection

In order to choose the details of the required water pump we have to determine two main conditions, the amount of total flow rate of demand water and the total head.

4.4.1 Head estimation

The pump selected with main pressure provides 50 psi and that already choses in residential buildings that mean 3.5bar; another way to reach this value is by:

Height of the building for 1st riser = 3.5m * 3floors = 11 m.

Dividing 11 by 10 = 1.1 bar

Adding 1.7 bar for fittings losses the value is almost 2.8 bar

4.4.2 Pump selection

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

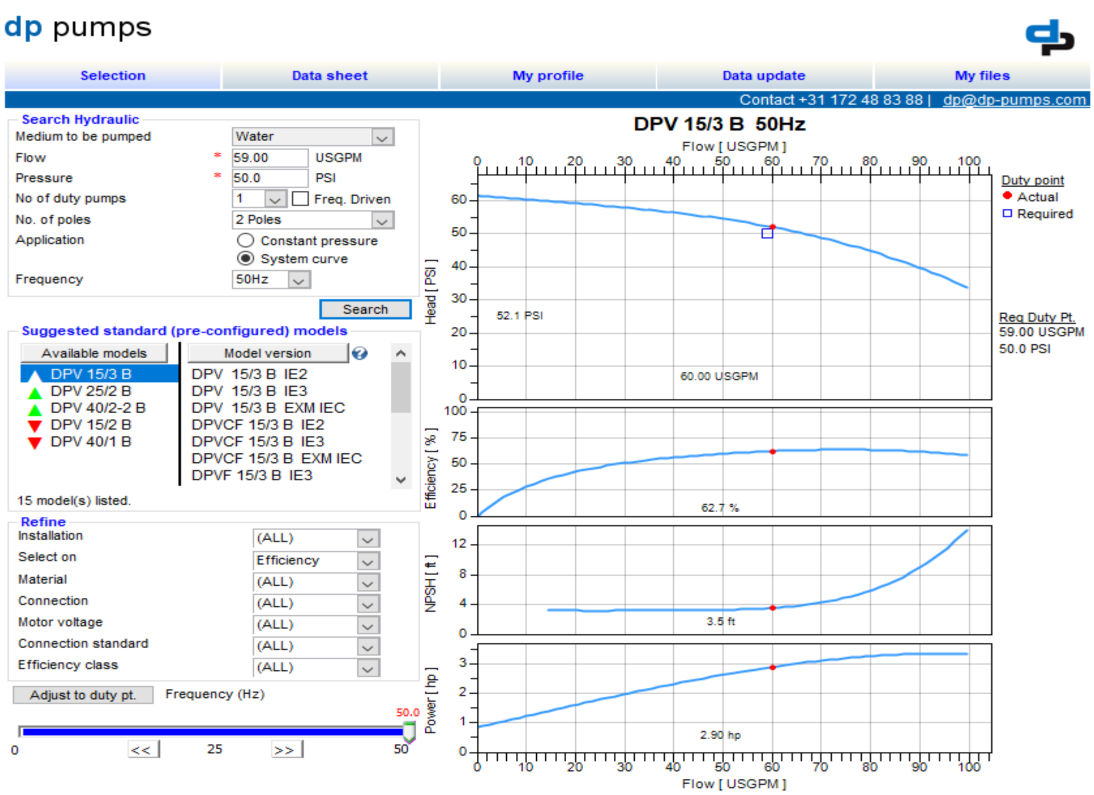


Figure (4.2): Pump data for cold water 1st riser

The pump model selected “DPV 15/3B”on **1st** cold water riser: H = 52.1 psi , Q = 60gpm , eff. =62.7%

The pump model selected “DPV 15/2B”on **2nd**cold water riser: H = 32.7 psi , Q = 64.5gpm , eff. =62.6%

The pump model selected “DPV 15/4B” on **3rd**cold water riser: H = 67.2 psi , Q = 66gpm , eff. =65%

The pump model selected “DPV 10/4 B” on **1st** hot water riser: H = 50.6 psi , Q = 38gpm , eff. =66.7%

The pump model selected “DPV 10/3B” on **2nd** hot water riser: H = 37.7 psi , Q = 38.5gpm , eff. =66.7%

The pump model selected “DPV 10/5B” on **3rd** hot water riser: H = 63.3 psi , Q = 38gpm , eff. =66.6%

4.5 Drainage system

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

The provision of drainage systems:

- Sanitary drainage
- Storm drainage

4.5.1 Drainage system components

The main components of drainage system are:

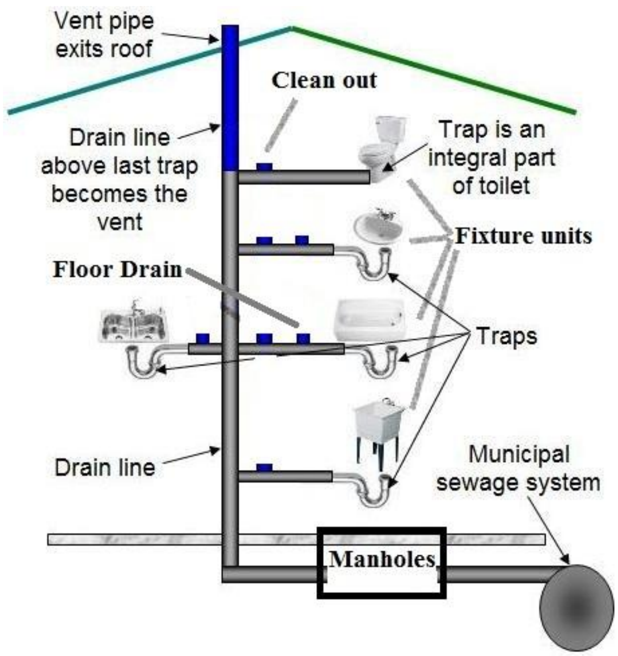


Figure (4.3): Drainage system components

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

This project deals with two types of waste water which is gray and black water, the separation of waste water will rationalize consumption of water and reuse it in irrigation and in flushing water closet.

4.5.2 Sanitary drainage

4.5.2.1 Design procedure and pipe sizing

Pipe size is calculated by using a concept of fixture units (DFU) instead of using gpm of drainage water. This unit takes into account not only the fixtures water use but also its frequency of use, which is the DFU has a built–in diversity factor. This enables us, exactly as for water supply to add DFU of various fixtures to obtain the maximum expected drainage flow. Drainage pipes sized for a particular number of drainage fixture units, according to Tables (A (4.5), A(4.6) A(4.7)). These tables are built into the fill factors, which are:

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

The recommended velocity for drainage piping:

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

Velocity of water flow through drainage piping depends on:

- Pipe diameter
- Slope

Minimum slope requirements for horizontal drainage piping:

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

Design procedure:

1. Calculation of the number of DFU for each branch by using Table A(4.4)
2. Calculation of the number of DFU for each stack
3. Choosing the branch pipe diameter by using Table A(4.5)
4. Choosing the stack pipe diameter by using Table A(4.6)
5. Comparing the stack pipe diameter with branch diameter
6. Choosing the building drain pipe diameter by using Table A(4.6)

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

4.5.2.2 Pipe sizing for waste water:

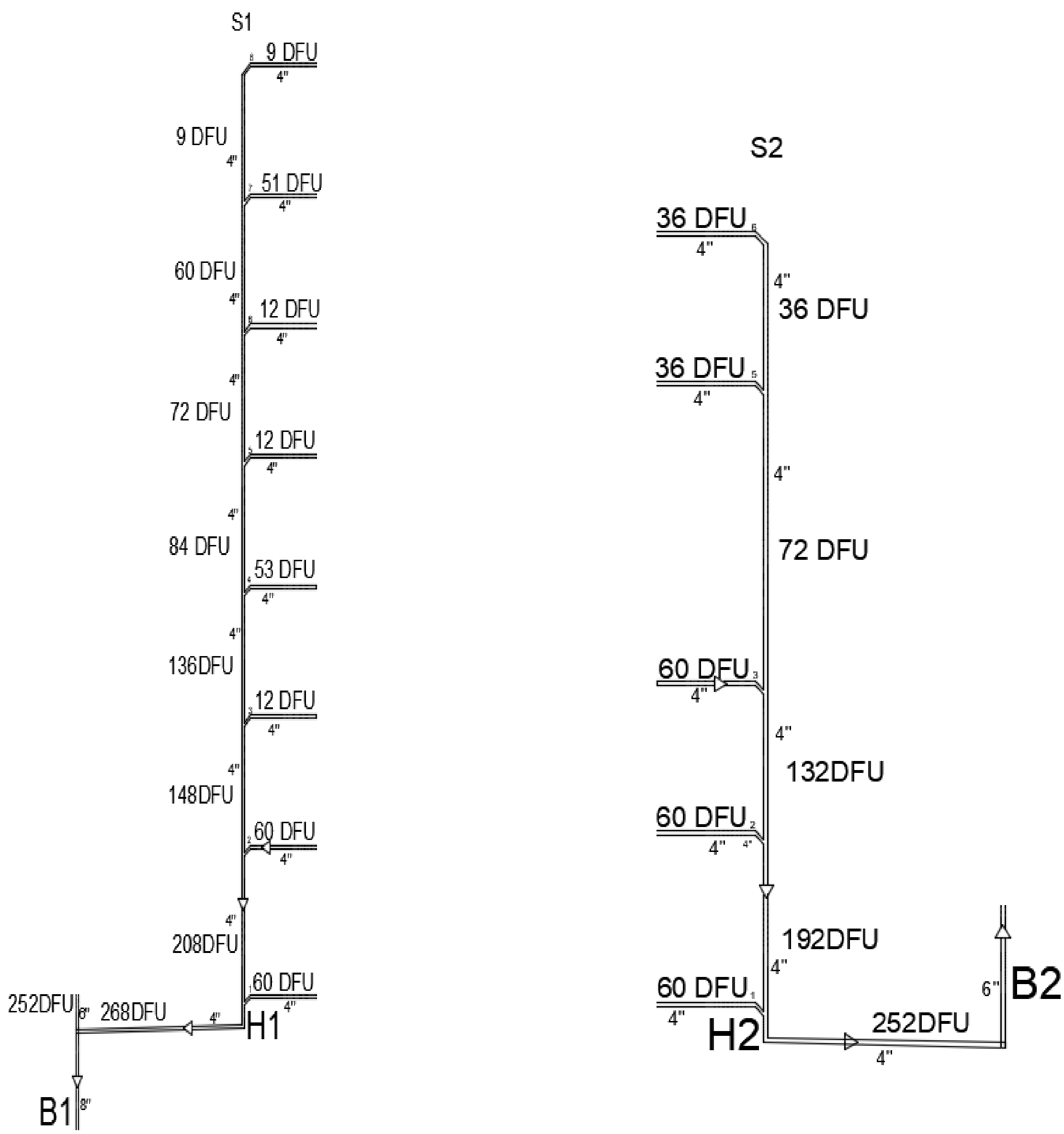


Figure (4.4): Gray water pipe sizing

Table (4.6): Sizing of stack 1

	Stack		Branch	
Floor	Total DFU	Diameter (in)	Total DFU	Diameter (in)
eightieth	9	2 1/2	9	2 1/2
seventh	60	4	51	4
Sixth	72	4	12	3
Fifth	83	4	12	3
Fourth	136	4	53	4
Third	148	4	12	3
Second	208	4	60	4
First	268	4	60	4

Table (4.7): Sizing of stack 2

	Stack		Branch	
Floor	Total DFU	Diameter (in)	Total DFU	Diameter (in)
Sixth	36	2 1/2	36	2 1/2
Fifth	72	4	36	2 1/2
Fourth	72	4	0	1 1/2
Third	132	4	60	3
Second	192	4	60	3
First	252	4	60	3

Therefore, the stack (1,2) & branches design diameter will be 4" .

Table (4.8): Branches of building drain

Branch of building drain	Total DFU	Diameter (in)	Slope (in/ft)	Velocity (ft/s)
H1	268	4	0.25	2.73
H2	252	4	0.25	2.73

Table (4.9): Building drain

building drain	Total DFU	Diameter (in)	Slope (in/ft)
B1	268	6	0.125
B2	520	8	0.125

4.5.3 Storm drainage

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

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

The general rule for the distribution of floor drains (FD):
Every 100 m^2 from roof area needs one 4" FD.

4.5.4 Manhole design

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

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

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

Table (4.10): Diameter of the manhole according to their depth

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

4.5.4.1 Manhole calculation

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

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

The figure below shows the details of the manholes:

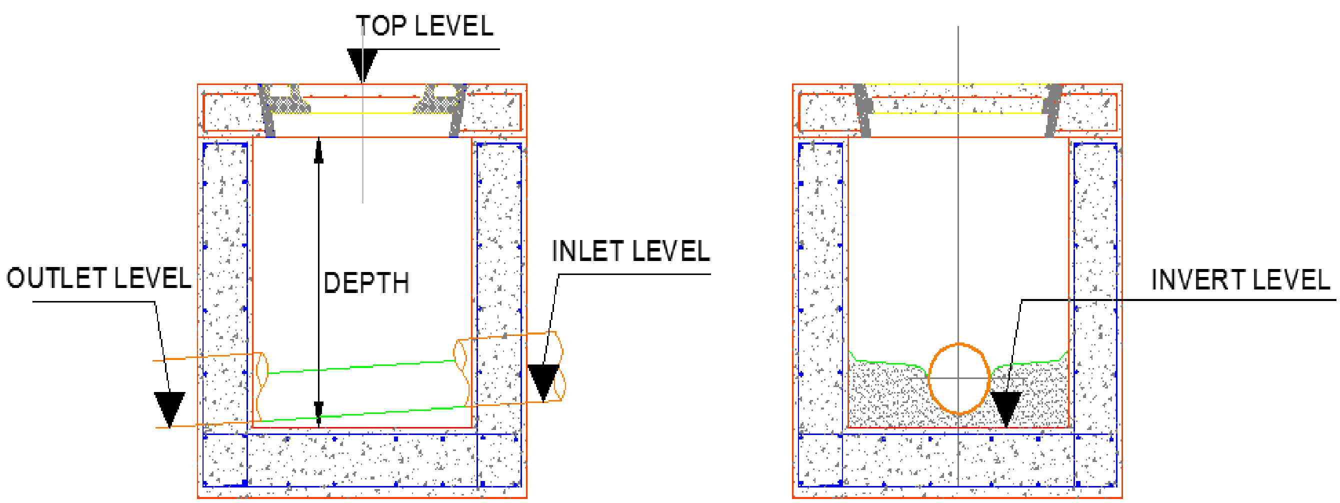


Figure (4.5): Manholes details

Chapter Five

Fire Fighting System

5.1 Introduction

A firefighting system is probably the most important of the building service, as its aim is 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 continues as long as the previous three elements are present correct percentages, and the result of these elements of effective chemicals known as free radicals.[8]

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) British standard.

5.2 Classification of firefighting systems

Firefighting systems are classified to:

1) Water system.

2) Gas system.

3) Foam system.

5.2.1 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.

5.2.2 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, co_2, foam, wet chemical and dry powder extinguisher.

All of design factor for manual gas system can be determined using NFPA 10 code.

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 CO_2.

All of design factors for automatic gas system can be determined using NFPA 12 code. [8]

5.2.3 Foam firefighting system

Is foam used for fire suppression, its role is to cool the fire and to coat the fuel, preventing its contact with oxygen, resulting in suppression of the combustion.

Foam system can be manual such as foam extinguisher or automatic such foam- water sprinkler system.

All of design factors for automatic and manual foam system 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 occurs 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.

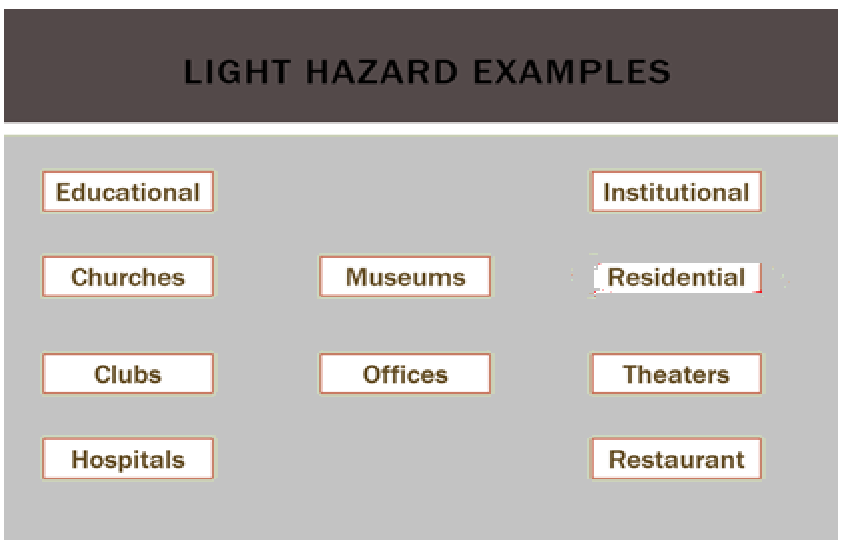


Figure (5.2): Light hazard examples

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.

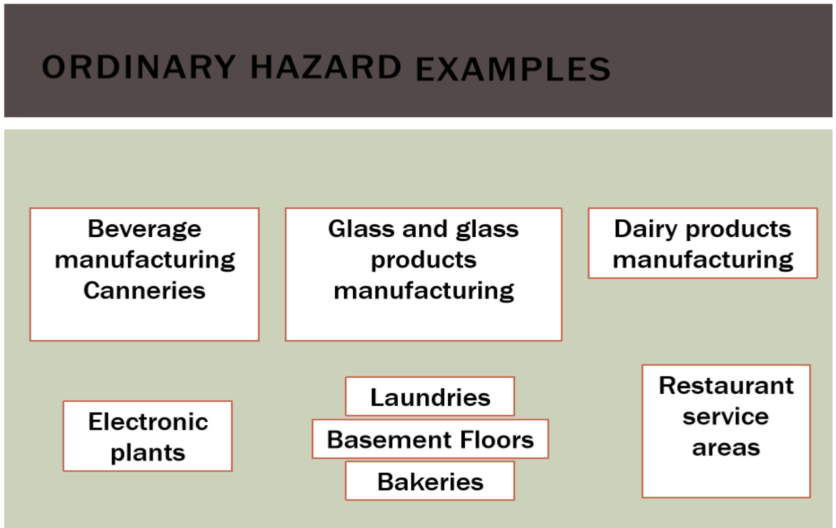


Figure (5.3): Ordinary hazard examples

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.

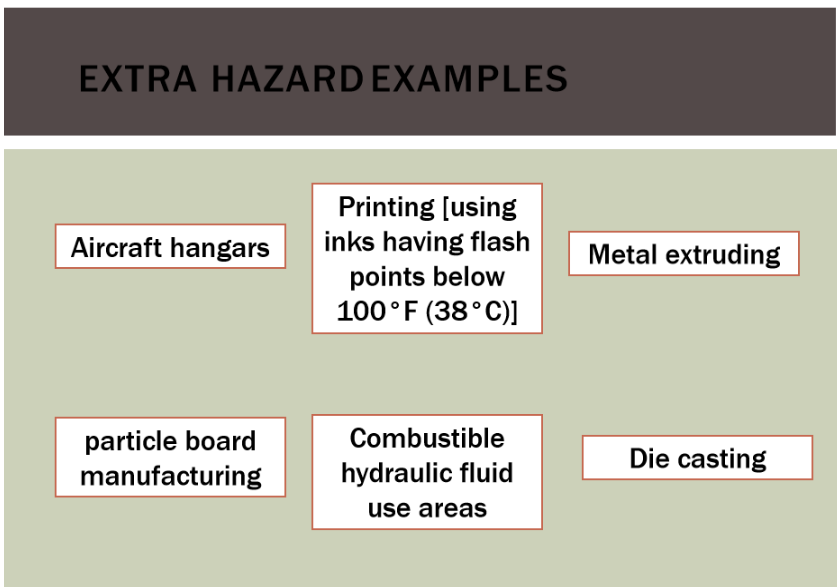


Figure (5.4): Extra hazard examples

So, 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

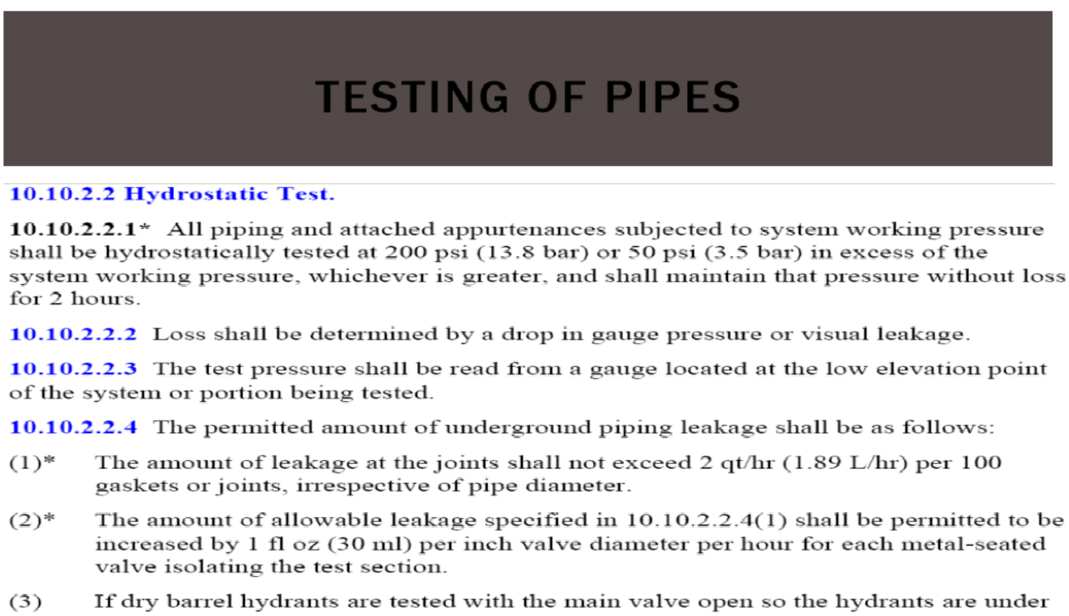
5.3.2.1 Firefighting network Components:

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 4 bars above the working pressure for two hours according to the NFPA13 code.



TESTING OF PIPES

10.10.2.2 Hydrostatic Test.

10.10.2.2.1* All piping and attached appurtenances subjected to system working pressure shall be hydrostatically tested at 200 psi (13.8 bar) or 50 psi (3.5 bar) in excess of the system working pressure, whichever is greater, and shall maintain that pressure without loss for 2 hours.

10.10.2.2.2 Loss shall be determined by a drop in gauge pressure or visual leakage.

10.10.2.2.3 The test pressure shall be read from a gauge located at the low elevation point of the system or portion being tested.

10.10.2.2.4 The permitted amount of underground piping leakage shall be as follows:

(1)* The amount of leakage at the joints shall not exceed 2 qt/hr (1.89 L/hr) per 100 gaskets or joints, irrespective of pipe diameter.

(2)* The amount of allowable leakage specified in 10.10.2.2.4(1) shall be permitted to be increased by 1 fl oz (30 ml) per inch valve diameter per hour for each metal-seated valve isolating the test section.

(3) If dry barrel hydrants are tested with the main valve open so the hydrants are under pressure, an additional 5 fl oz/min (150 ml/min) of leakage shall be permitted for

Figure (5.5): Testing of pipes

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 (with Fusible Link)	Liquid Alcohol in Glass Bulb Color
100 °F / 38 °C	135-170 °F / 57-77 °C	Ordinary	Uncolored or Black	Orange (135 °F / 57 °C) or Red (155 °F / 68 °C)
150 °F / 66 °C	175-225 °F / 79-107 °C	Intermediate	White	Yellow (175 °F / 79 °C) or Green (200 °F / 93 °C)
225 °F / 107 °C	250-300 °F / 121-149 °C	High	Blue	Blue
300 °F / 149 °C	325-375 °F / 163-191 °C	Extra High	Red	Purple
375 °F / 191 °C	400-475 °F / 204-246 °C	Very Extra High	Green	Black
475 °F / 246 °C	500-575 °F / 260-302 °C	Ultra High	Orange	Black
625 °F / 329 °C	650 °F / 343 °C	Ultra High	Orange	Black

Figure (5.6): sprinklers classification

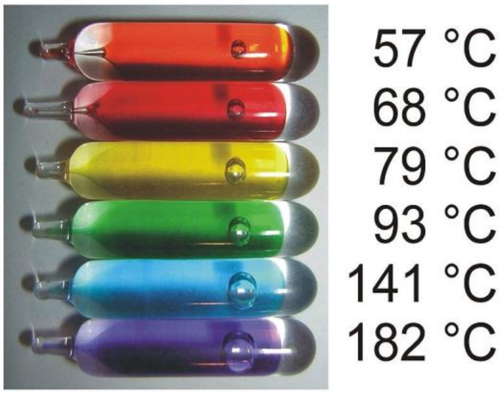


Figure (5.7): The liquid in the glass bulb is color coded to its show temperature rating

So, the sprinklers used in building in ordinary system is pendent sprinkler the liquid glass bulb color is red and the temperature range is (57-77) C (68 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.

Figure (5.8): Fire hose cabinet

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 meter 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.
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.

Class two didn't need any experience to deal with a system for any user on contra with class one, for this reason class 2 is more popular and that is the selected class for cabinet.

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.

Figure (5.9) Portable Fire Extinguishers

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 CO2 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.

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) [8].

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 (5.10): Horizontal split case pump

- Inline fire pumps

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

Figure (5.11): Inline fire pump

- 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 (5.12) 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 (5.13) Vertical turbine pump

5.3.7 Flow rate calculations

The flow rate was calculated using Elite program is equal 317.6 GPM.

So, this building needs 350 GPM

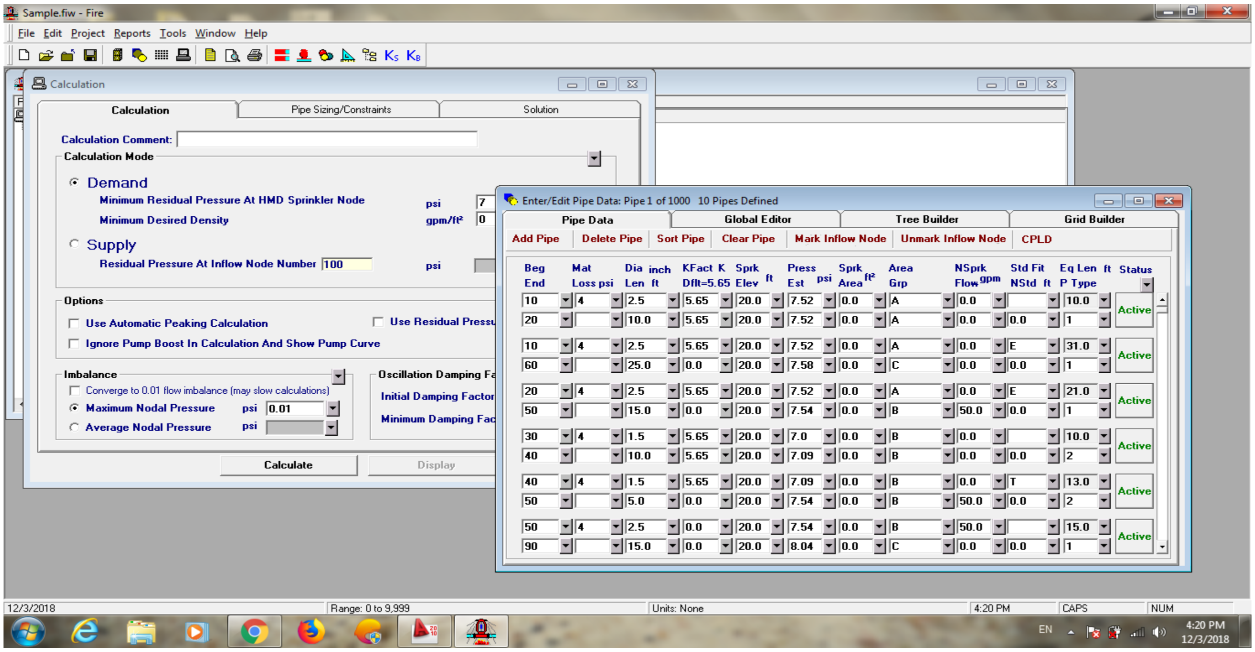


Figure (5.14): Elite calculations

5.3.8 Head estimation

With 31 meter height of the buildings there are 3.1 bars, adding 4.5 bars for cabinet pressure and 1 bar for loss in fittings, so total head equal 8.6 bars.

5.3.9 Water tank sizing

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

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

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

Figure (5.15): Total gallon and duration

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

Volume= total flow rate * duration *(3.785/1000)

= 350gpm*60min*(3.785/1000)

=80 m^3

5.3.10 Pump selection

Total flow rate 350 GPM equal to 80 $m^{\wedge 3}$/h and amount of head 8.6 bars.

The pump installed must satisfy the required flow rate and head, according to the special software for GRUNDFOS Company the inline pump will choose [7].

Pump type: MPFC 3-45

Pump characteristic curves & Efficiency Head curves:

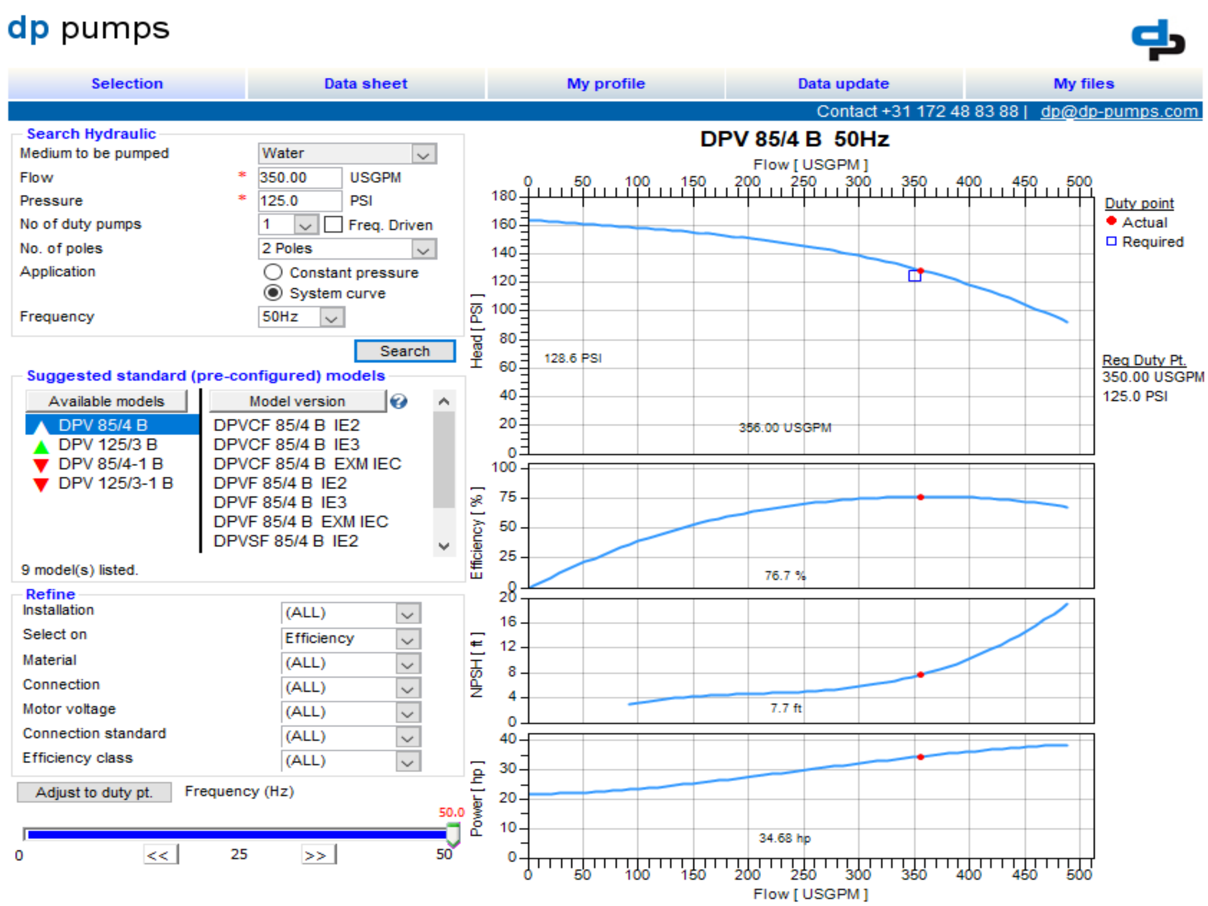


Figure (5.16): Pump characteristic curve & Efficiency Head curves

FIRE FIGHTING

Installation Calculations (software)

NUMBER OF HOSES	PIPE DIAMETER
1	2
2-3	2
4-5	3
6-10	4
>10	5

MAX NUMBER OF SPRINKLER	PIPE DIAMETER
2	1
3	1 ¼
5	1
10	2
20	2
40	3
65	3
100	4
160	5
275	6

Water Temperature (°C)	**20**
Type of Building	**Hotel**
Primary Pipe Type	**Steel Pipes (1)**
Primary Pipe Roughness Factor (µm)	**45**
Secondary Pipe Type	**Steel Pipes (2)**
Secondary Pipe Roughness Factor (µm)	**45**

No	Receptor Type	In.Dia.	Pmf	Qr	Design Density	Maximum area per sprinkler	**Nominal K factor**
		(mm)	(bar)	(l/min)	(mm/min)	(m^2)	
5	Fire hose cabinet	50	4.5	378.5	0.0	0.0	**180.0**
9	**Sprinkler OH roof**	**20**	**0.3**	**0.0**	**5.0**	**12.0**	**80.0**

Piping Calculations

Network Section	Pipe Length (m)	Type of Receptor	Receptors Group	Receptor Flow (l/min)	Peak Capacity (l/min)	Pipe Size (mm)	Water Velocity (m/s)	Fittings friction drop (bar)	Pipes friction drop (bar)	Total Friction Loss (bar)	Required discharge pressure (bar)	DP due to Different Height (bar)
1.2	32.2			634.62	634.620	DN65	2.845	0.170	0.371	0.541		
2.3	0.6	9	1	47.33	47.330	DN25	1.358		0.005	0.005	0.350	2.65
2.4	3.0			587.29	587.290	DN65	2.633	0.104	0.030	0.134		
4.5	2.2			539.96	539.960	DN50	4.079	0.249	0.070	0.320		
5.6	1.2			279.69	279.690	DN40	3.397	0.173	0.036	0.209		
6.7	2.0			150.50	150.500	DN32	2.478	0.092	0.040	0.132		
7.8	4.0			103.17	103.170	DN25	2.959	0.131	0.158	0.289		
8.9	2.4	9	1	55.84	55.840	DN25	1.602		0.030	0.030	0.350	2.65
8.10	0.5	9	1	47.33	47.330	DN25	1.358	0.004	0.005	0.008	0.350	2.65
7.11	0.4	9	1	47.33	47.330	DN25	1.358		0.004	0.004	0.350	2.65
6.12	2.4			129.19	129.190	DN25	3.706	0.206	0.146	0.352		
12.13	2.0	9	1	55.72	55.720	DN25	1.598		0.025	0.025	0.350	2.65
12.14	2.0	9	1	73.47	73.470	DN25	2.107		0.041	0.041	0.350	2.65
5.15	0.8			260.27	260.270	DN40	3.161	0.150	0.021	0.171		
15.16	2.7			212.94	212.940	DN40	2.586	0.050	0.048	0.098		
16.17	2.3	9	1	58.89	58.890	DN25	1.689		0.031	0.031	0.350	2.65
16.18	3.0			94.66	94.660	DN25	2.715	0.110	0.101	0.211		
18.19	3.2	9	1	47.33	47.330	DN25	1.358		0.029	0.029	0.350	2.65
18.20	0.8	9	1	47.33	47.330	DN25	1.358		0.007	0.007	0.350	2.65
16.21	1.7	9	1	59.39	59.390	DN25	1.703		0.024	0.024	0.350	2.65
15.22	0.4	9	1	47.33	47.330	DN25	1.358		0.004	0.004	0.350	2.65
4.23	0.6	9	1	47.33	47.330	DN25	1.358		0.005	0.005	0.350	2.65
1.24	28.0			567.81	567.810	DN50	4.290	0.313	0.985	1.297		
24.25	5.6			189.31	189.310	DN40	2.299	0.061	0.080	0.140		
25.26	4.0			94.66	94.660	DN25	2.715	0.110	0.134	0.245		
26.27	1.5	9	1	47.33	47.330	DN25	1.358		0.014	0.014	0.350	2.35
26.28	1.5	9	1	47.33	47.330	DN25	1.358		0.014	0.014	0.350	2.35
25.29	1.5	9	1	47.33	47.330	DN25	1.358		0.014	0.014	0.350	2.35
25.30	1.5	9	1	47.33	47.330	DN25	1.358		0.014	0.014	0.350	2.35
24.31	15.6	5	1	378.50	378.500	DN50	2.859	0.049	0.251	0.300	4.500	2.65

Fire Pump Calculation

Piping and fittings friction drop DPrz (bar)	1.597
Minimum Discharge Pressure Pfl (bar)	4.5
Pressure Difference due Elevation Dpgeod (bar)	2.65
Main pump Head Pe=DPgeod+DPrz+Pfl (bar)	8.747
Average Water Flow rate of Main Pump Qpm (l/min)	1202.43
Efficiency of Main pump n	0.65
Power on axis of Main pump N=(1/600) * (Qpm*Pe/n) (kW)	26.96835
Efficiency of electric motor Main pump n e	0.83
Power of electric Main pump Ne = N / ne (kW)	32.49198
Efficiency of diesel Main pump np	0.57
Power of diesel Main pump Np = N / np (kW)	47.31289
Jockey pump Capacity Qj = 0.02 x Qpm (l/min)	24.0486
Jockey pump Head Pej=DPgeod+DPrz+Pfl+1 (bar)	9.747
Water Containment into the Network Vtot (l)	269.1555
Pressure Tank Min Volume Vp = 0.04 * Vtot (l)	10.76622
Type of selected Fire Pump	MPFC 3-45
Power of Main pump (kW)	33.6 kW
Power of Jockey pump (kW)	2.2 kW
Pressure Tank Volume (l)	500 lt
Main pump Capacity (l/min)	60-75-85 m3/h
Main pump Head (bar)	85-80-70 m

Water Tank

Average Water Flow rate of Main Pump Qpm (l/min)	1202.43
Min Operation Time t (min)	60
Water Tank Min Volume Vmin = Qpm * t / 1000 (m3)	72.1458
Tank Length a (m)	
Tank Width b (m)	
Tank Heigh c (m)	
Water Tank Volume Vd (m ³)	0

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[2] Heat Transfer a Practical Approach, 2 edition.

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[7] (Fire pump), www.groundfos.com

[8] (Fire catalog),www.normteknik.com.tr

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[10] VRF (Samsung), http://samsungdvm-s.com/

[11] Manhole design, http://www.sewerhistory.org/grfx/components/mholes1.htm

Software :

AutoCAD 2018

Rivit 2018

DVM Samaung

DP Select

Elite

BILL OF QUANTITIES

Itom NO	DISCRIPTION	Unit	Quality	Price/Unit
1	**VRF**			
1.1	**Indoor Units**			
1.1.1	4- way cassette VRF indoor units. Price includes all required electrical and gas connections, and operating perfectly. Price includes hangers, isolating valves, and electrical connection to power source. All connections and installation			

	should be executed according to manufacturer instructions. Selection to be based on medium speed, external air pressure of 0.25 ", indoor temperature of 24 C and outdoor temperature of 31.9 C (summer) 5.7 C (winter)			
1.1.1.1	nominal capacity 14	**NO.**	8	
1.1.2	slim DUCT VRF indoor units. Price includes all required electrical and gas connections, and operating perfectly. Price includes hangers, isolating valves, and electrical connection to power source. All connections and installation should be executed according to manufacturer instructions. Selection to be based on medium speed, external air pressure of 0.25 ", indoor temperature of 24 C and outdoor temperature of 31.9 C (summer) 5.7 C (winter)			
1.1.2.1	nominal capacity 3.6	**NO.**	48	
1.1.3	360 CST VRF indoor units. Price includes all required electrical and gas connections, and operating perfectly. Price includes hangers, isolating valves, and electrical connection to power source. All connections and installation should be executed according to manufacturer instructions. Selection to be based on medium speed, external air pressure of 0.25 ", indoor temperature of 24 C and outdoor temperature of 31.9 C (summer) 5.7 C (winter)			
1.1.3.1	nominal capacity 5.6	**NO.**	3	
1.1.3.2	nominal capacity 4.5	**NO.**	21	
1.1.3.3	nominal capacity 7.1	**NO.**	1	
1.1.3.4	nominal capacity 9.0	**NO.**	2	
1.1.3.5	nominal capacity 11.2	**NO.**	4	
1.1.3.6	nominal capacity 14.0	**NO.**	8	
1.2	**Out Door**			
1.2.1	nominal capacity 180	**NO.**	**3**	
1.2.2	nominal capacity 220	**NO.**	**1**	
1.2.3	nominal capacity 240	**NO.**	**1**	
1.2.4	nominal capacity 300	**NO.**	**3**	
1.3	**Piping network**			
	Supply and install drain and insulated copper pipes for refrigerant 410 between indoor units and outdoor unit with sizes according to manufacturer instructions and calculations. Price includes all required fittings, hanging, insulation and digging.			
1.3.1	6.35mm	M.L	250	
1.3.2	9.52mm	M.L	102	

1.3.3	12.7mm	M.L	420	
1.3.4	15.88mm	M.L	219	
1.3.5	19.05mm	M.L	157	
1.3.6	22.22mm	M.L	143	
1.3.7	28.58mm	M.L	130	
1.3.8	34.92mm	M.L	96	
1.3.9	41.28mm	M.L	97	
1.3.10	53.98mm	M.L	70	
1.4	**Accessories**			
1.4.1	Refnet Joint	No.	96	
1.4.2	Refrigerant Amount (R410 A)	Kg	177	
2	**VENTLATION**			
	Centrifugal Exhaust Fans set (one duty and one stand-by), complete as per drawings and specifications.			
2.1	72.2 l/s	SET	69	
2.2	165 l/s	SET	12	
2.3	87.3 l/s	SET	5	
3	**Water System**			
3.1	**Pumps**			
	Supply, install, test & commission water pump set including motor, interconnecting pipe work, complete with all valves, vents, manifolds, gauges, control panel, level switches, pressure vessel & frequency inverter etc., as per specifications and drawings.			
3.1.1	**L.P.** (Lifting pumps set /2 pumps)	SET	1	
3.1.2	**C.W.P.-1** (Set/2 booster pump) with	SET	1	
3.1.3	**C.W.P.-2** (Set/2 pumps feeds floors from roof tanks) with 1000L pressure vessel	SET	1	
3.1.4	**S.C.W.P.-1** (Set/2 pumps directly feeds floors and feeds hot water boiler with softened water) with 1000L pressure vessel	SET	1	
3.1.5	**RA.W.P.** (Set/2 (From rainwater well to sand filter and floors)	SET	1	
3.1.6	**H.W.P** (Set/2 (Directly feeds floors with hot water)	SET	1	
3.2	**Pipes**			
	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	16 mm dia pipe (1/2")	ML	8,500	
3.2.2	20 mm dia pipe (3/4")	ML	4,480	
3.2.3	25 mm dia pipe (1")	ML	4,000	
3.2.4	32 mm dia pipe (11/4")	ML	3,100	
3.2.5	40 mm dia pipe (11/2")	ML	2,130	

3.2.6	50 mm dia pipe (2")	ML	1,175	
3.2.7	65 mm dia pipe (21/2")	ML	1,500	
3.2.8	80 mm dia pipe (3")	ML	300	
3.2.9	100 mm dia pipe (4")	ML	300	
3.3	**Water Manifolds**			
	Supply, install, test and commission wall hung type steel hot and cold water copper manifolds 16 mm dia outlets. The unit price shall include plug and washer, adaptors with O- rings, brackets, drain cocks, isolating ball valves with T-handle on all outlets, automatic air vent on each manifold, and all accessories and works required to complete the work as shown in the drawings and engineers instructions.			
3.3.1	25 mm dia collector, 5 outlets (average)	No.	464	
4	**Firefighting System**			
4.1	Fire hose reel cabinet (double compartment) including isolating valve with SS304 fully recessed cabinet, 19 mm dia x 25 m rubber hose, ABC 6 kg powder extinguisher and 4.5 kg CO_2 extinguisher.	No.	20	
4.2	**Fittings**			
4.2.1	Tee (1.5")	No.	30	
4.2.2	Elbow (4")	No.	120	
4.2.3	Cross(1.5")	No.	180	
4.2.4	Reducer (1"-1.25")	No.	150	
4.2.5	Reducer (1.25"-1. 5")	No.	160	
4.2.6	Reducer (1.5"-2")	No.	88	
4.2.7	Reducer (2"-2.5")	No.	70	
4.2.8	Reducer(2.5"-3")	No.	35	
4.2.9	Reducer(3"-4")	No.	12	
4.3	Black seamless steel pipe.			
4.3.1	25mm dia pipe (1")	ML	1280	
4.3.2	31.25 mm dia pipe (1 1/4")	ML	640	
4.3.3	37.5 mm dia pipe (1 1/2")	ML	384	
4.3.4	50mm dia pipe (2")	ML	120	
4.3.5	62.5 mm dia pipe (2 1/2")	ML	112	
4.3.6	75mm dia pipe (3")	ML	224	
4.3.7	100 mm dia pipe (4")	ML	86	
4.3.8	150mm dia pipe (6")	ML	67	
4.4	**Pumps** Supply, install, test and commission fire pumps set, complete with all components including duty pump, split case (electric driven), emergency pump (diesel), jockey pump, centrifugal (electric driven). Price shall include electric control panels, pressurized tank, cork and foundation bed, controllers,			

	accessories for all pumps including wiring connections, all components, water measuring devices including flow meter and sensor, pressure gauges, relief valves, gate valves, check valves etc., all electrical works needed to complete the work according to engineer's instructions.			
4.4.1	Electrical pump : **EP-01**	No.	1	
4.4.2	Diesel pump : **DP-01**	No.	1	
4.4.3	Jockey pump : **JP-01**	No.	1	
4.5	**Fire Extinguisher**			
4.6	K-type dry powder fire extinguishers.	No.	23	
4.7	CO_2 fire extinguishers.	No.	3	
4.8	Self-automatic extinguisher.	No.	5	
4.9	Siamese connection assembly complete with non-return valves. Outlet of 100m dia, and inlet of 65mm dia.	No.	1	
4.10	Supply and install landing valve, complete with fire hose rack.	No.	13	
4.11	Supply and install clean agent system with all accessories such as valves, control, nozzles, etc. All complete as per detailed specifications and drawings.	Set	18	
4.12	Supply and install Fire hydrant, pedestal type and maintain stand spot fitted with 75mm twin faced flanged fire hydrant, complete with isolating valve, an automatic shut-off valve, complete with all necessary mechanical fittings.	No.	4	
4.13	Supply and install Fire hydrant Cabinet, complete with all needed equipment's.,	No.	3	
4.14	Supply, lift into position, install, test, set to work, and commission sprinkler head as following and as per drawings Sprinkler head pendent recessed center link type, Part No. 13577W/B (½ Inch)56 diameter - ORIFICE 15 mm (½ Inch) NPT male connection bronze finish UL/FM approved.	No.	670	
4.15	Supply and install fire system for kitchen consists of 6 nozzles, heat detector sense fire and activate the wet chemical cylinder and wet chemical cylinders all according to drawings and specifications.	Set	1	
5	**Drainage System**			
5.1	**Counter Recessed Wash Basin**	No.	69	
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.	88	
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	No.	78	

	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			
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.	5	
5.5	**Laboratory Sinks**			
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.	21	
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")	ML	268	
5.6.2	150 mm dia. (6")	ML	186	
5.6.3	200 mm dia (8")	ML	20	
5.6.4	50 mm dia. (2")	ML	74	
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.	172	
5.7.2	***FD-HDPE*** and with chromium plated cover, mesh and all accessories needed	No.	90	
5.7.3	***FG-HDPE***	No.	13	
5.8	**Floor Cleanouts**			
	Supply, install, and test heavy duty nonadjustable 11x11 cm floor clean out with HDPE body, with gas and water tight ABS plug and frame, complete with all needed elbow and all types of fittings, all done according to drawings, specifications and the approval of the engineer.			
5.8.1	***FLOOR C.O HDPE*** with chromium plated cover, mesh and all accessories needed.		70	
5.8.2	***WALL C.O HDPE*** with chromium plated cover, mesh and all accessories needed.		110	

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.	13	
5.9.2	100 mm dia. (4")	No.	20	
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")	ML	1150	
5.11	**Manholes**			
	Supply install and test precast concrete manholes of 15 cm thickness for walls and bottom slab with C.I. cover (medium cover) and frame all necessary excavation, blinding of 15cm thickness, back filling as specified to the required depth complete with iron steps, benching and plastering as shown in drawing and in accordance to specification, drawings, and approval of supervisor engineer. with C.I. cover (medium cover) and frame, iron steps as detailed on the drawings.			
5.11.1	Depth 60 cm - 80 cm Dia 60 cm	No.	1	
5.11.2	Depth 80 cm - 140cm. Dia 80 cm	No.	2	
5.11.3	Depth 140 cm - 250 cm. Dia 100 cm	No.	2	

Appendix - A

A-1: Description of wall construction groups

TABLE 9-5 Description of wall construction groups.

Group No.	Description Of Construction	$U_{ov.}$ W/m²·°C
	101.6 mm Face Brick + (Brick)	
C	Air space + 101.6 mm face brick	2.033
D	101.6 mm common brick	2.356
C	25.4 mm insulation or air space + 101.6 mm common brick	0.987-1.709
B	50.6 mm insulation + 101.6 mm common brick	0.630
B	203.2 mm common brick	1.714
A	Insulation or air space + 203.2 mm common brick	0.874-1.379
	101.6 mm Face Brick + (H.W. Concrete)	
C	Air space + 50.8 mm concrete	1.987
B	50.8 mm insulation + 101.6 mm concrete	0.658
A	Air space or insulation + 203.2 mm or more concrete	0.625-0.636
	101.6 mm Face Brick + (L.W. or H.W Concrete Block)	
E	101.6 mm block	1.811
D	Air space or insulation + 101.60 mm block	0.868-1.397
D	203.2 mm block	1.555
C	Air space or 25.4 mm insulation + 152.4 mm or 203.2 mm block	1.255-1.561
B	50.8 insulation + 203.2 mm block	0.545-0.607
	101.6 mm Face Brick + (Clay Tile)	
D	101.6 mm tile	2.163
D	Air space + 101.6 mm tile	1.595
C	Insulation + 101.6 mm tile	0.959
C	203.2 mm tile	1.561
B	Air space or 25.4 mm insulation + 203.2 mm tile	0.806-1.255
A	50.8 mm insulation + 203.2 mm tile	0.551
	L.W. Concrete Wall + (Finish)	
E	101.5 mm concrete	3.321
D	101.6 mm concrete + 25.4 mm or 50.8 mm insulation	1.136 - 0.675
C	50.8 mm insulation+101.6 mm concrete	0.675
C	203.2 mm concrete	2.782
B	203.2 mm concrete + 25.4 mm or 50.8 mm insulation	1.061 - 0.653
A	203.2 mm concrete + 50.8 mm insulation	0.653
B	304.8 mm concrete	2.390
A	304.8 mm concrete + insulation	0.642
	L.W. and H.W. Concrete Block + (Finish)	
F	101.6 mm block + air space/insulation	0.914-1.493
E	50.8 mm insulation + 101.6 mm block	0.596-0.647
E	203.2 mm block	1.669-2.282
D	203.2 mm block + air space/insulation	0.846-0.982
	Clay Tile + (Finish)	
F	101.6 mm tile	2.379
F	101.6 mm tile +air space	1.720
F	101.6 mm tile + 25.4 mm insulation	0.993
D	80.8 mm insulation + 10.4 mm tile	0.825
C	203.3 mm tile + air space/25.4 mm insulation	0.857-1.312
B	50.8 mm insulation + 203.2 mm tile	0.562
	Metal Curtain Wall	
G	With/without air space + 25.4 mm/58 to 76.2 mm insulation	0.516-1.306
	Frame Wall	
G	24.4 mm to 76.2 mm insulation	1.010 - 0.459

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

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

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

A-3: Approximate CLTD values for sunlit roofs

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

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

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

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

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

[3] Adapted from Stoecker and Jones, 1982, "*Refrigeration and Air Conditioning*", 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

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

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

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

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

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

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

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

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

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

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

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

A-10: Shading coefficient for glass with interior shading

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

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

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

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

Type of Glass	Nominal Thickness, mm	Solar Trans.	Shading Coefficient, W/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 for sunlit glass

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

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

A-13: Values of infiltration air coefficient for windows

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

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

A-19: Values of the factor S1

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

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

A-20: Values of the factor S2

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

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

A-21: Instantaneous heat gain from occupants

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

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

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

A-25: Latitude- month correction factor LM

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

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

A-26: mechanical ventilation

TABLE A(2.20) Minimum outside air requirements for mechanical ventilation

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	—

A-27: inside & outside film resistance

Table A(2.2) Inside film resistance, R_i.

Element	Heat Direction	Material Type	R_i m²·°C/W
Walls	Horizontal	Construction materials	0.12
		Metals	0.31
Ceilings and floors	Upward	Construction materials	0.10
		Metals	0.21
	Downward	Construction materials	0.15

Table A(2.3) Outside film resistance, R_o.

Wind Speed		Less than 0.5 m/s	0.5 - 5.0 m/s	More than 5.0 m/s
Element	Material Type	Outside Resistance R_o, m²·°C/W		
Walls	Construction materials	0.08	0.06	0.03
	Metals	0.10	0.07	0.03
Ceilings	Construction materials	0.07	0.04	0.02
	Metals	0.09	0.05	0.02
Exposed floors	Construction materials	0.09	—	—

A-28: overall heat coefficient for windows

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

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

A-29: overall heat coefficient for wood and metals door

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

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

Palestinian code

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

القيم التصميمية الخارجية		المنطقة المناخية*						
		الضفة الغربية					قطاع غزة	
		الأولى	الثانية	الثالثة	الرابعة	الخامسة	الثالثة	السادسة
درجة الحرارة (°C)	شتاءً	7	7	5	4	8	5	9
	صيفاً	39	39	32	30	34	32	31
الرطوبة النسبية (%)	شتاءً: ادنى	60	60	60	62	63	60	62
	اقصى	70	70	72	72	78	72	69
	صيفاً: ادنى	43	43	49	44	55	49	65
	اقصى	54	54	67	57	66	67	77
سرعة الرياح (m/s)		1	1	1.5	1.4	1.1	1.5	2.8
شدة الاشعاع الشمسي (W/m²)		تعتبر قيم شدة الاشعاع القصوى للاتجاهات المختلفة في الجدولين (3/18) و (3/19) قيماً تصميمية لكافة المناطق المناخية						
درجة يوم تسخين (°C.day)		لا تتوفر معلومات عن هذه القيم حالياً						
درجة يوم تبريد (°C.day)								
* المناطق المناخية للأراضي الفلسطينية مبينة في الملحق (هـ)								

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

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

Appendix (B)

Table A(4.1) Water Supply Fixture Units and Fixture Branch Sizes

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

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

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

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

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

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

[d] Nominal I.D. pipe size.

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

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

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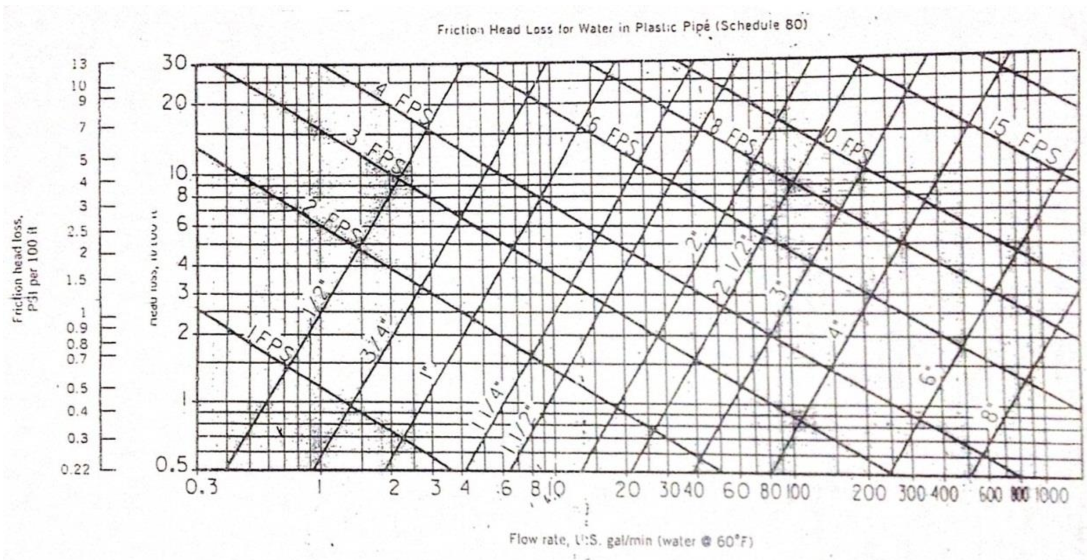

Figure A(4.1) Chart of friction head loss in Schedule 80 plastic pipe for water at 60°F, in feet of water and psi per 100 ft of equivalent pipe length. Pipe sizes are nominal. (Reprinted by permission of the American Society of Heating, Refrigerating and Air-Conditioning Engineers, Atlanta, Georgia,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

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

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

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

TableA(4.7) Approximate Discharge Rates and Velocities[a] in Sloping Drains Flowing Half Full[b]

Actual Inside Diameter of Pipe, in.	1/16 in./ft Slope		1/8 in./ft Slope 1%		1/4 in./ft Slope 2%		1/2 in./ft Slope	
	Discharge, gpm	Velocity, fps	Discharge, gpm	Velocity, fps	Discharge, gpm	Velocity, fps	Discharge, gpm	Velocity, fps
1¼							3.40	1.78
1⅜					3.13	1.34	4.44	1.90
1½					3.91	1.42	5.53	2.01
1⅝					4.81	1.50	6.80	2.12
2					8.42	1.72	11.9	2.43
2½			10.8	1.41	15.3	1.99	21.6	2.82
3			17.6	1.59	24.8	2.25	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 ½-full pipe, $n = 0.015$.

[b] Half full means filled to a depth equal to one-half the inside diameter.

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

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Table A(4.2) Table for Estimating Demand

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

[a] Water Supply fixture units

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Table A(4.4) Drainage Fixture Unit Values for Various Plumbing Fixtures

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

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

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Table A(4.5) Horizontal Fixture Branches and Stacks

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

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

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

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

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

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

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

A(5.2)
As a rule of thumb the following velocities can be used in design of piping and pumping systems for water:

Pipe Dimension		Water	
inches	*mm*	*m/s*	*ft/s*
1	25	1	3.5
2	50	1.1	3.6
3	75	1.15	3.8
4	100	1.25	4
6	150	1.5	4.7
8	200	1.75	5.5
10	250	2	6.5
12	300	2.65	8.5

A(5.3)

Liquid	Absolute Viscosity *) *(Pa s)*
Air	1.983×10^{-5}
Water	1×10^{-3}
Olive Oil	1×10^{-1}
Glycerol	1×10^{0}
Liquid Honey	1×10^{1}
Golden Syrup	1×10^{2}
Glass	1×10^{40}

*) at room temperature

A(5.1)
Capac

In general - as a rule of thumb - keep the suction fluid flow speed below the following values:

Pipe bore		Water	
inches	*mm*	*m/s*	*ft/s*
1	25	0.5	1.5
2	50	0.5	1.6
3	75	0.5	1.7
4	100	0.55	1.8
6	150	0.6	2
8	200	0.75	2.5
10	250	0.9	3
12	300	1.4	4.5

Appendix (D)

A(5.4)

Surface	Absolute Roughness Coefficient - *k* -	
	(m) 10^{-3}	*(feet)*
Copper, Lead, Brass, Aluminum (new)	0.001 - 0.002	$3.33 - 6.7\ 10^{-6}$
PVC and Plastic Pipes	0.0015 - 0.007	$0.5 - 2.33\ 10^{-5}$
Stainless steel	0.015	$5\ 10^{-5}$
Steel commercial pipe	0.045 - 0.09	$1.5 - 3\ 10^{-4}$
Stretched steel	0.015	$5\ 10^{-5}$
Weld steel	0.045	$1.5\ 10^{-4}$
Galvanized steel	0.15	$5\ 10^{-4}$
Rusted steel (corrosion)	0.15 - 4	$5 - 133\ 10^{-4}$
New cast iron	0.25 - 0.8	$8 - 27\ 10^{-4}$
Worn cast iron	0.8 - 1.5	$2.7 - 5\ 10^{-3}$
Rusty cast iron	1.5 - 2.5	$5 - 8.3\ 10^{-3}$
Sheet or asphalted cast iron	0.01 - 0.015	$3.33 - 5\ 10^{-5}$
Smoothed cement	0.3	$1\ 10^{-3}$
Ordinary concrete	0.3 - 1	$1 - 3.33\ 10^{-3}$
Coarse concrete	0.3 - 5	$1 - 16.7\ 10^{-3}$
Well planed wood	0.18 - 0,9	$6 - 30\ 10^{-4}$
Ordinary wood	5	$16.7\ 10^{-3}$

room no.	room area (m)	Required Capasity		Total NOMINAL CAPACITY	Nominal Capacity		SPACE NAME	Unit type	Model Name
		Cooling	Heating		Cooling	Heating			
gr 01	260	52.12	10.3	56.00	14.0	16.0	Stage Room	360 CST (Circle)	AM140KN4DEH/TK
					14.0	16.0		360 CST (Circle)	AM140KN4DEH/TK
					14.0	16.0		360 CST (Circle)	AM140KN4DEH/TK
					14.0	16.0		360 CST (Circle)	AM140KN4DEH/TK
gr 02	193.4	38.69	7.86	42.0	14.0	16.0	Cafeteria	360 CST (Circle)	AM140KN4DEH/TK
					14.0	16.0		360 CST (Circle)	AM140KN4DEH/TK
					14.0	16.0		360 CST (Circle)	AM140KN4DEH/TK
gr 03	167	50.27	9.7	56.00	14.0	16.0	Lobby Room	4 way cassette	AM140FN4DEH/TK
					14.0	16.0		4 way cassette	AM140FN4DEH/TK
					14.0	16.0		4 way cassette	AM140FN4DEH/TK
					14.0	16.0		4 way cassette	AM140FN4DEH/TK
gr 04	177	53.24	10.1	56.00	14.0	16.0	Hall Room	4 way cassette	AM140FN4DEH/TK
					14.0	16.0		4 way cassette	AM140FN4DEH/TK
					14.0	16.0		4 way cassette	AM140FN4DEH/TK
					14.0	16.0		4 way cassette	AM140FN4DEH/TK
gr 05	43.1	12.9	3.2	14.0	14.0	16.0	Meeting Room	360 CST (Circle)	AM140KN4DEH/TK
gr 06	31.57	6.31	2.4	7.1	7.1	5.0	Director Room	360 CST (Circle)	AM071KN4DEH/TK
gr 07	18.9	3.78	1.2	4.5	4.5	3.1	Director Room	360 CST (Circle)	AM045KN4DEH/TK
gr 08	16.3	3.26	1	4.5	4.5	3.1	Director Room	360 CST (Circle)	AM045KN4DEH/TK

F1 01	15.75	3.15	1.2	3.6	3.6	4.0	Bed room No.1	Slim Duct	AM036FNLDEH/TK
F1 02	15.62	3.22	1.3	3.6	3.6	4.0	Bed room No.2	Slim Duct	AM036FNLDEH/TK
F1 03	15.84	3.48	1.4	3.6	3.6	4.0	Bed room No.3	Slim Duct	AM036FNLDEH/TK
F1 04	15.57	3.19	1.2	3.6	3.6	4.0	Bed room No.4	Slim Duct	AM036FNLDEH/TK
F1 05	20.4	3.7	1.8	3.6	3.6	4.0	Bed room	Slim Duct	AM036FNLDEH/TK

							No.5		
F1 06	22.3	3.9	2.0	3.6	3.6	4.0	Bed room No.6	Slim Duct	AM036FNLDEH/TK
F1 07	25.2	4.1	2.2	4.5	4.5	5.0	Bed room No.7	360 CST (Circle)	AM045KN4DEH/TK
F1 08	26	4.2	2	4.5	4.5	5.0	Bed room No.8	360 CST (Circle)	AM045KN4DEH/TK
F1 09	22	8.6	3.1	9.0	4.5	10.0	Bed room No.9	360 CST (Circle)	AM090KN4DEH/TK
F1 10	15.4	3.5	1.5	4.5	4.5	5.0	Bed room No.10	360 CST (Circle)	AM045KN4DEH/TK
F1 11	16.4	3.4	1.4	3.6	3.6	4.0	Bed room No.11	Slim Duct	AM036FNLDEH/TK
F1 12	15.2	3.2	1.8	3.6	3.6	4.0	Bed room No.12	Slim Duct	AM036FNLDEH/TK
F1 13	16.19	3.6	1.7	3.6	3.6	4.0	Bed room No.13	Slim Duct	AM036FNLDEH/TK
F1 14	15.8	3.2	1.3	3.6	3.6	4.0	Bed room No.14	Slim Duct	AM036FNLDEH/TK
F1 15	16.6	3.1	1.6	3.6	3.6	4.0	Bed room No.15	Slim Duct	AM036FNLDEH/TK
F1 16	16.1	3.1	1.6	3.6	3.6	4.0	Bed room No.16	Slim Duct	AM036FNLDEH/TK
F1 17	16.6	3.2	1.7	3.6	3.6	4.0	Bed room No.17	Slim Duct	AM036FNLDEH/TK
F1 18	15.6	3.1	1.2	3.6	3.6	4.0	Bed room No.18	Slim Duct	AM036FNLDEH/TK
F1 19	16.1	3.3	1.4	3.6	3.6	4.0	Bed room No.19	Slim Duct	AM036FNLDEH/TK
F1 20	15.2	3.2	2.01	3.6	3.6	4.0	Bed room No.20	Slim Duct	AM036FNLDEH/TK

F2 01	15.75	3.15	1.2	3.6	3.6	4.0	Bed room No.1	Slim Duct	AM036FNLDEH/TK
F2 02	15.62	3.22	1.3	3.6	3.6	4.0	Bed room No.2	Slim Duct	AM036FNLDEH/TK
F2 03	15.84	3.48	1.4	3.6	3.6	4.0	Bed room No.3	Slim Duct	AM036FNLDEH/TK

F2 04	15.57	3.19	1.2	3.6	3.6	4.0	Bed room No.4	Slim Duct	AM036FNLDEH/TK
F2 05	20.4	3.7	1.8	3.6	3.6	4.0	Bed room No.5	Slim Duct	AM036FNLDEH/TK
F2 06	22.3	3.9	2.0	3.6	3.6	4.0	Bed room No.6	Slim Duct	AM036FNLDEH/TK
F2 07	25.2	4.1	2.2	4.5	4.5	5.0	Bed room No.7	360 CST (Circle)	AM045KN4DEH/TK
F2 08	26	4.2	2	4.5	4.5	5.0	Bed room No.8	360 CST (Circle)	AM045KN4DEH/TK
F2 09	22	8.6	3.1	9.0	9.0	10.0	Bed room No.9	360 CST (Circle)	AM090KN4DEH/TK
F2 10	15.4	3.5	1.5	4.5	4.5	5.0	Bed room No.10	360 CST (Circle)	AM045KN4DEH/TK
F2 11	16.4	3.4	1.4	3.6	3.6	4.0	Bed room No.11	Slim Duct	AM036FNLDEH/TK
F2 12	15.2	3.2	1.8	3.6	3.6	4.0	Bed room No.12	Slim Duct	AM036FNLDEH/TK
F2 13	16.19	3.6	1.7	3.6	3.6	4.0	Bed room No.13	Slim Duct	AM036FNLDEH/TK
F2 14	15.8	3.2	1.3	3.6	3.6	4.0	Bed room No.14	Slim Duct	AM036FNLDEH/TK
F2 15	16.6	3.1	1.6	3.6	3.6	4.0	Bed room No.15	Slim Duct	AM036FNLDEH/TK
F2 16	16.1	3.1	1.6	3.6	3.6	4.0	Bed room No.16	Slim Duct	AM036FNLDEH/TK
F2 17	16.6	3.2	1.7	3.6	3.6	4.0	Bed room No.17	Slim Duct	AM036FNLDEH/TK
F2 18	15.6	3.1	1.2	3.6	3.6	4.0	Bed room No.18	Slim Duct	AM036FNLDEH/TK
F2 19	16.1	3.3	1.4	3.6	3.6	4.0	Bed room No.19	Slim Duct	AM036FNLDEH/TK
F2 20	15.2	3.2	2.01	3.6	3.6	4.0	Bed room No.20	Slim Duct	AM036FNLDEH/TK

F3 01	15.75	3.15	1.2	3.6	3.6	4.0	Bed room No.1	Slim Duct	AM036FNLDEH/TK

F3 02	15.62	3.22	1.3	3.6	3.6	4.0	Bed room No.2	Slim Duct	AM036FNLDEH/TK
F3 03	15.84	3.48	1.4	3.6	3.6	4.0	Bed room No.3	Slim Duct	AM036FNLDEH/TK
F3 04	15.57	3.19	1.2	3.6	3.6	4.0	Bed room No.4	Slim Duct	AM036FNLDEH/TK
F3 05	20.4	3.7	1.8	3.6	3.6	4.0	Bed room No.5	Slim Duct	AM036FNLDEH/TK
F3 06	22.3	3.9	2.0	3.6	3.6	4.0	Bed room No.6	Slim Duct	AM036FNLDEH/TK
F3 07	25.2	4.1	2.2	4.5	4.5	5.0	Bed room No.7	360 CST (Circle)	AM045KN4DEH/TK
F3 08	26	4.2	2	4.5	4.5	5.0	Bed room No.8	360 CST (Circle)	AM045KN4DEH/TK
F3 09	22	8.6	3.1	9.0	4.5	10.0	Bed room No.9	360 CST (Circle)	AM090KN4DEH/TK
F3 10	15.4	3.5	1.5	4.5	4.5	5.0	Bed room No.10	360 CST (Circle)	AM045KN4DEH/TK
F3 11	16.4	3.4	1.4	3.6	3.6	4.0	Bed room No.11	Slim Duct	AM036FNLDEH/TK
F3 12	15.2	3.2	1.8	3.6	3.6	4.0	Bed room No.12	Slim Duct	AM036FNLDEH/TK

F4 01	300	40	10	44.8	11.2	12.5	Gym Club	360 CST (Circle)	AM112KN4DEH/TK
					11.2	12.5	Gym Club	360 CST (Circle)	AM112KN4DEH/TK
					11.2	12.5	Gym Club	360 CST (Circle)	AM112KN4DEH/TK
					11.2	12.5	Gym Club	360 CST (Circle)	AM112KN4DEH/TK

F5 01	20.4	3.7	1.8	3.6	3.6	4.0	Bed room No.1	Slim Duct	AM036KN4DEH/TK
F5 02	22.3	3.9	2.0	3.6	3.6	4.0	Bed room No.2	Slim Duct	AM036KN4DEH/TK
F5 03	25.2	4.1	2.2	4.5	4.5	5.0	Bed room No.3	360 CST (Circle)	AM045KN4DEH/TK
F5 04	26	4.2	2	4.5	4.5	5.0	Bed room No.4	360 CST (Circle)	AM045KN4DEH/TK
F5 05	22	8.6	3.1	9.0	4.5	10.0	Bed room No.5	360 CST (Circle)	AM090KN4DEH/TK
F5 06	15.4	3.5	1.5	4.5	4.5	5.0	Bed room No.6	360 CST (Circle)	AM045KN4DEH/TK
F5 07	16.4	3.4	1.4	3.6	3.6	4.0	Bed room No.7	Slim Duct	AM036KN4DEH/TK
F5 08	15.2	3.2	1.8	3.6	3.6	4.0	Bed room No.8	Slim Duct	AM036KN4DEH/TK

F6 01	20.4	3.7	1.8	3.6	3.6	4.0	Bed room No.1	Slim Duct	AM036KN4DEH/TK
F6 02	22.3	3.9	2.0	3.6	3.6	4.0	Bed room No.2	Slim Duct	AM036KN4DEH/TK
F6 03	25.2	4.1	2.2	4.5	4.5	5.0	Bed room No.3	360 CST (Circle)	AM045KN4DEH/TK
F6 04	26	4.2	2	4.5	4.5	5.0	Bed room No.4	360 CST (Circle)	AM045KN4DEH/TK
F6 05	22	8.6	3.1	9.0	4.5	10.0	Bed room No.5	360 CST (Circle)	AM090KN4DEH/TK
F6 06	15.4	3.5	1.5	4.5	4.5	5.0	Bed room No.6	360 CST (Circle)	AM045KN4DEH/TK
F6 07	16.4	3.4	1.4	3.6	3.6	4.0	Bed room No.7	Slim Duct	AM036KN4DEH/TK
F6 08	15.2	3.2	1.8	3.6	3.6	4.0	Bed room No.8	Slim Duct	AM036KN4DEH/TK

F7 01	55.2	8.0	3.0	9.0	9.0	10.0	Hall Room	360 CST (Circle)	AM090KN4DEH/TK

F7 02	31.3	5.0	2.0	5.6	5.6	6.3	Kitchen	360 CST (Circle)	AM056KN4DEH/TK

F8 01	36	5.0	2.0	5.6	5.6	6.3	Bed room No.1	360 CST (Circle)	AM056KN4DEH/TK
F8 02	37	5.0	2.0	5.6	5.6	6.3	Meeting Room	360 CST (Circle)	AM056KN4DEH/TK