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Refrigeration and Air Conditioning Engineering

Design of Mechanical Systems for Hotel Building

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Supervisor Signature

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أيام مضت من عمرنا بدأناها بخطوة وها نحن اليوم نقطف ثمار مسيرة أعوام كان هدفنا فيها واضحا وكنا نسعى في كل يوم لتحقيقه والوصول اليه مهما كان صعبا وها نحن اليوم نقف أمامكم ونحن قد وصلنا وبيدينا شعلة علم وسنحرص كل الحرص عليها حتى لا تنطفئ ونشكر الله أولا وأخيرا على أن وفقنا وساعدنا على ذلك.

ثم نتقدم بالشكر إلى القلب الحنون, من كانت بجانبنا بكل المراحل التي مضت, من تلذذت بالمعاناة وكانت شمعه... إلى أمهاتنا الحبيبات, وإلى من علمنا أن نقف وكيف نبدأ الألف ميل بخطوة... إلى يدنا اليمنى إلى تحترق... لتنير دربنا من علمنا الصعود وعيناه تراقبنا ....والدنا.

لمن أمسك بيدينا وعلمنا حرفا حرفا ... سنهدي له نجاحنا اليوم, وإلى من كانوا سندا لنا إلى من لهم الفضل بإرشادنا إلى طريق العلم والمعرفة ولم يبخلوا علينا من علمهم ,وأخص بالذكر مشرفنا الاستاذ المهندس محمد عوض وجميع معلمينا في دائرة الهندسة الميكانيكية عامة وتخصص التكييف والتبريد خاصة على ما قدموه لنا من علم و معرفة ...

كم نحن فخورون بكم أصدقائنا وزملائنا وأحبتنا ومن سهروا معنا في مسيرتنا العلمية... إلى من مدوا أياديهم البيضاء في ظلام الليل وكانوا عونا لنا.

كم نحن فخورون ايضا اننا اليوم نتخرج من اعرق جامعات الوطن وهي جامعة بوليتكنك فلسطين.

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Abstract

This project aims to design the mechanical systems for Al Andalus Hotel which is located in Hebron. This building consists of nine floors with an area of 2223 m^2. In this project, the thermal loads of this building will be calculated and the appropriate air conditioning system will be selected. The project also includes calculations, material selection, bill preparation for air conditioning system, ventilation system, water system, drainage system and fire fighting system. These services are definitely designed to check human comfort.

الملخص:

يهدف هذا المشروع إلى تصميم الانظمة الميكانيكية لفندق الأندلس الذي يقع في الخليل. يتكون هذا المبنى من تسعة طوابق بمساحة 2223م^2. في هذا المشروع ، سيتم حساب الأحمال الحرارية لهذا المبنى وسيتم اختيار نظام تكييف الهواء المناسب. ويشمل المشروع أيضًا الحسابات واختيار المواد وإعداد الفواتير لنظام تكييف الهواء ونظام التهوية ونظام المياه ونظام الصرف ونظام مكافحة الحرائق. تم تصميم هذه الخدمات بالتأكيد للتحقق من راحة الإنسان.

Chapter one: Introduction

1.1 Introduction:

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. [1]

For this reason the mechanical system will be designed and documented in this project for Al-Andalus hotel in Hebron 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 needs. To achieve the required comfort conditions for the human brings, a heating air conditioning and refrigeration engineer should do the followings:

1.Design the mechanical services for the building.

2. Design air conditioning system for the building.

3. Design fire fighting system.

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

1) Temperature of the inside space.

2) Humidity contents of the air.

3) Purity and quality of the inside air.

4) Air velocity and air circulation within the space.

1.3 Building description:

Al-Andalus hotel includes nine floors , two floors underground , basement and six floors for guests, the total area of the hotel is 2223 m^2 .

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

Table (1.1)Component of floors

Floor	Description
-2	For general services and for laying the necessary equipment.
-1	Car parking.
GF	Reception and office .
1	Kitchen and Restaurants.
2	Hotel rooms of various sizes.
3	Hotel rooms of various sizes.
4	Hotel rooms of various sizes.
5	Hotel rooms of various sizes.
6	Roof floor.

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 and Cooling Loads:

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

3. Chapter Three

Variable Refrigerant Flow System:

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

4. Chapter Four

Plumping System:

This chapter include the water distribution calculation and drainage system.

5. Chapter Five

Fire fighting 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 (1.2) Time estimated to work for semester

Task \ 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									■	■	■	■	■	■		
Visit supervisor and takes some notation	■		■		■		■		■	■	■		■		■	■

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

1.7 Budget:

Tasks	Cost(NIS)
Using internet	150
Printing papers	400
Reprinting paper	100
Total	650

Chapter 2: Heating and Cooling Load

2.1 Introduction:

Heating and cooling loads are the measure of energy needed to be added or removed from a space by the HVAC system to provide the desired level of comfort within a space. [2]

The heating and cooling load calculation is the first step of the HVAC design procedure, a full HVAC design involves more than just the load estimate calculation. Right-sizing the HVAC system, selecting HVAC equipment and designing the air distribution system to meet the accurate predicted heating and cooling loads begins with an accurate understanding of the heating and cooling loads on a space. [3]

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 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. [4]

2.2.2 Factors affecting human comfort [2]

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. [5]

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.

Table (2.1): Outside and inside design conditions

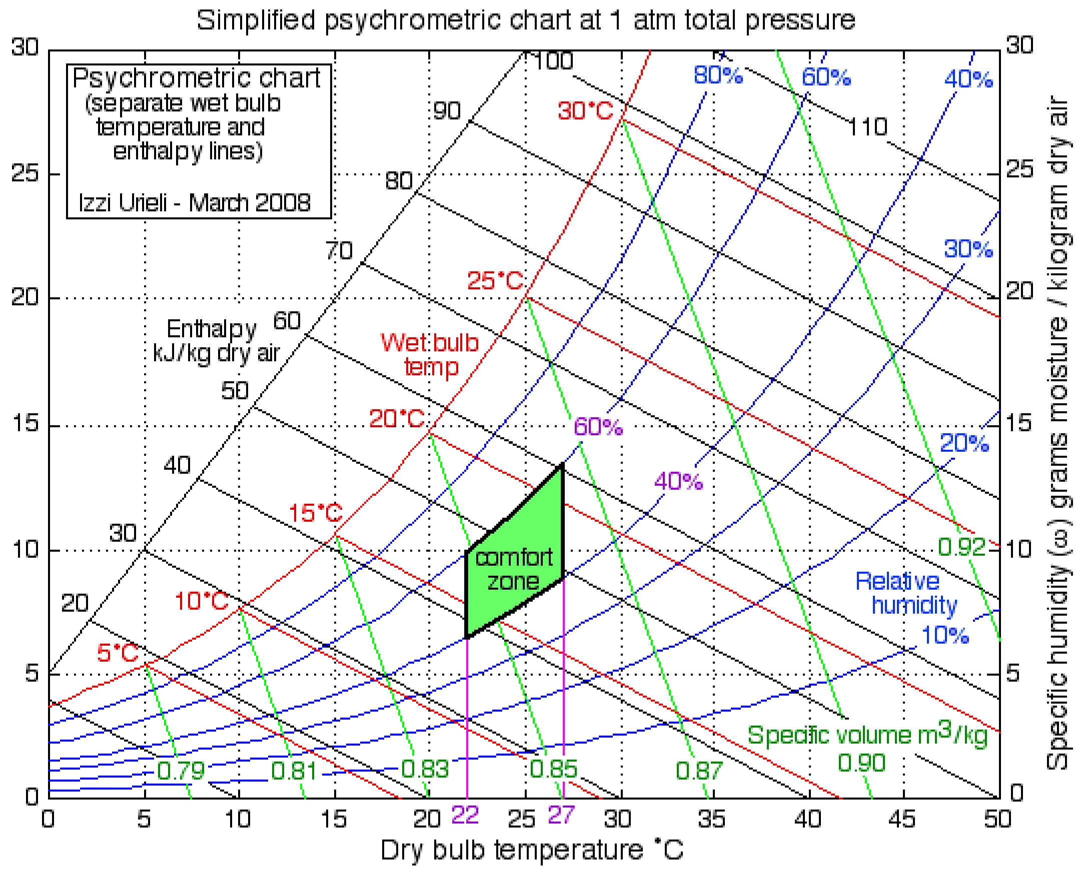
Property	Inside design condition		outside design condition [6]	
	summer	winter	summer	winter
Temperature (˚C)	24	24	30	4.7
Relative humidity (%)	50	50	51.3	70
Wind speed (m/s)	….	….	1.4	1.4

2.4 ASHRAE Comfort Chart

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. [7]

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, and figure (2.1) shows ASHRAE human comfort chart .

Figure (2.1): Human comfort chart [5]



2.5 Convection Heat Transfer Coefficient

There are two ways to transfer heat by convection:

1-Forced convection.

2-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.

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

Where:

Δx: the thickness of the wall [m].

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

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

h_0 : Convection coefficient of outside wall, floor, or roof ($W/m^2.C$). [5]

2.6.1 The overall heat transfer coefficient (U)

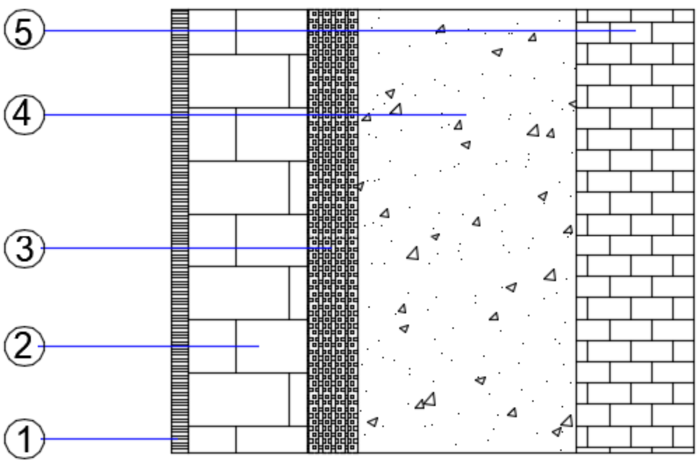
Calculation of overall heat transfer coefficient for walls, ceiling, floor, glass and door :

1. For external wall

Table (2.2): Construction of external walls

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

Figure (2.2): External wall construction



R_{in} and R_{out} for the external walls as 0.12 and 0.03(m^2.°C /W), respectively from table (A-27).

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

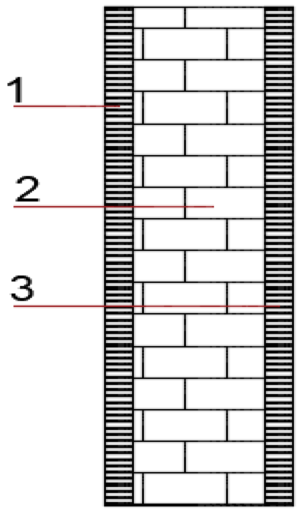
$$U = \frac{1}{0.12+\frac{0.07}{1.7}+\frac{0.13}{1.75}+\frac{0.03}{0.03}+\frac{0.07}{0.95}+\frac{0.02}{1.2}+0.06} = 0.738\ (W/m^2.°C)$$

2. For Internal Wall

Table (2.3): Construction of internal walls

	Materiel	Δx(m)	k (W/m².°C)[5]
1	Plaster	0.025	**1.2**
2	Cement break	0.05	**0.95**
3	Plaster	0.025	**1.2**

Figure (2.3): Internal wall construction



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

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

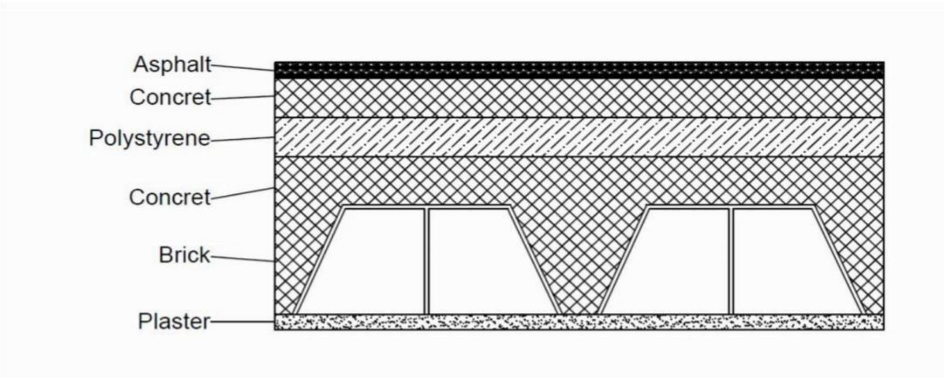
$$U = 2.99\ (W/m^2.°C)$$

3. For Ceiling and Roof

Table (2.4): Construction of celling

	Materiel	Δx(m)	k (W/m^2.°C)[5]
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 0.02$(W/m^2.°C)$, respectively from table (A-27) .

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

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

$$U_2 = \frac{1}{R_{in}+\frac{\Delta x_{asph.}}{k_{asph.}}+\frac{\Delta x_{conc.}}{k_{conc.}}+\frac{\Delta x_{poly.}}{k_{poly.}}+\frac{\Delta x_{conc.}}{k_{conc.}}+\frac{\Delta x_{Plaster}}{k_{Plaster}}+R_{out}} \quad (2.5)$$

$$U_2 = \frac{1}{0.1+\frac{0.02}{0.8}+\frac{0.05}{1.75}+\frac{0.05}{0.03}++\frac{0.2}{1.75}+\frac{0.02}{1.2}+0.04} = 0.51\ (W/m^2.°C)$$

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 [5]:

$$Q = A \times U \times \Delta T \qquad (2.6)$$

Where:

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

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

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

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

2.7.3 Total heat load calculations

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

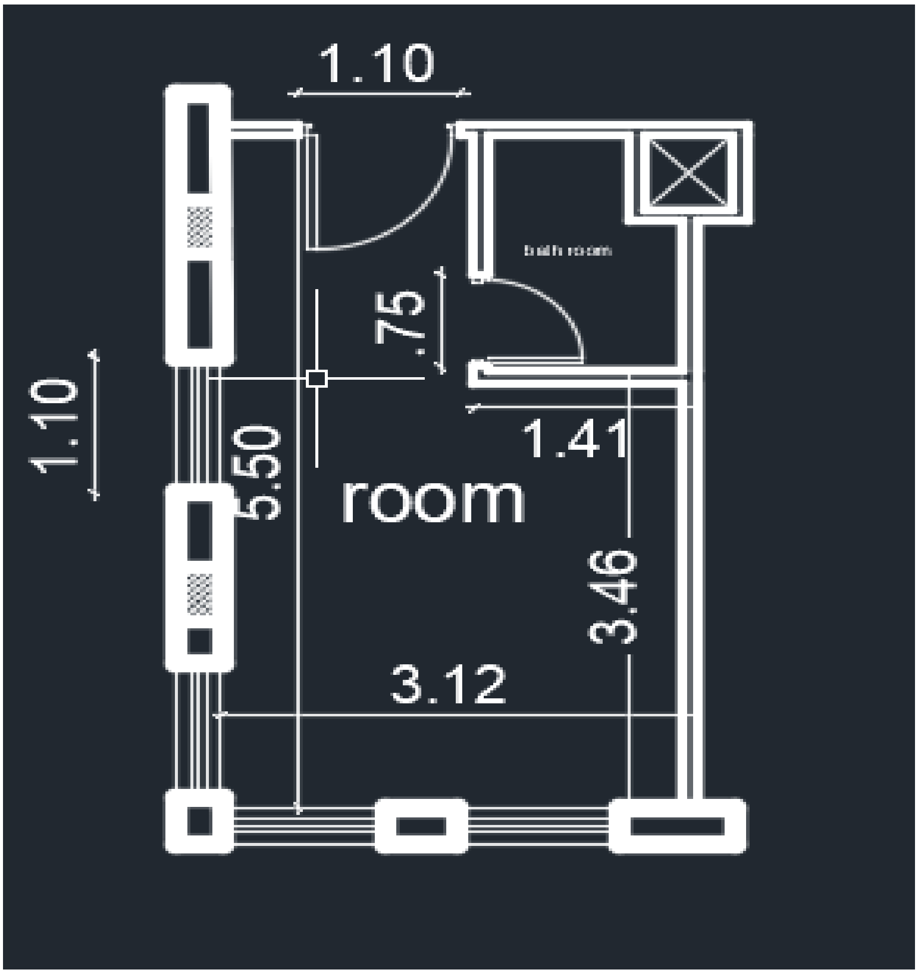


Figure (2.5): The Sample room

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

The height of the room = 3m

The height of the door = 2m

The height of the window = 2m

Heat loss through ceiling (Q_c) :

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

Heat loss through floor (Q_f) :

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

Heat loss through walls (Q_w) :

Area for the Window= 1.10* 2 =2.2 m^2

Area for the door =2*1.10 =2.2 m^2

We have four window in external wall

<u>The external wall area is</u>

$A_{ex. wall}$ = ((5.50+3.12)*3-(4*2.2))
=17.06 m^2

The heat loss from external wall is

$Q_{w. ex} = U_{w.} A_{w. ex} (T_{in} - T_{out})$ (2.7)

=0.738 (17.06) (24-4.7)

=0.2429 kW

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

The heat loss from Internal wall is

The unconditioned area is

$A_{w un}$=(3*3 -2.2)=6.8 m^2

$Q_{w in}=U_{in} A_{w in} (T_{in}-T_{un})$ (2.8)

=2.99 * 6.8*(24-20)
=0.081 kW.

Now, the total heat loss from walls is

$Q_{w. tot} = Q_{w. ex} + Q_{w. in}$ (2.9)

=0.2429+0.081
=0.3239 kW

Heat loss through windows (Q_g):

$Q_g = U_g A_g (T_i - T_o)$ (2.10)

=3.2 (2.2*4) 19.3

=0.594 kW

Heat loss through external door (Q_d) :

$Q_d = U_d A_d (T_i - T_{un})$ (2.11)

=3.6 *2.2 *4

=0.0316 kW

Heat loss through infiltration (Q_{inf}) :

Infiltration is the leakage of outside air through cracks and clearances around the windows and doors. The amount of infiltration depends mainly on the tightness of the windows and doors on the outside wind velocity or the pressure difference between the outside and inside of the room [8].

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

$$Q_{inf} = \frac{V_{f.}}{v_o} \times (h_{in} - h_{out}) \quad (2.12)$$

Where:

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

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

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

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

$$\dot{V}_f = K * L [0.613(S_1*S_2*V_0)^2]^{2/3} \quad (2.13)$$

Where :

K:the infiltration air coefficient.

L: the crack length in meter.

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

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

V_0: measured wind speed (m/s).

*The value of K , S_1 and S_2:

K=0.43…..from table (A-13)

S_1=0.9…..from table (A-19)

S_2=0.75…..from table (A-20)

V_0=1.4 (m/s) from Palestinian code

And the window is sliding ,then:

L = 4[(1.10+2)*2]

=24.8 m

V_f = 0.43*24.8 $[0.613(0.9*0.75*1.4)^2]^{2/3}$

=7.13 m^3/h

=1.98*10^{-3} m^3/s

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

vo = 0.79 m^3/kg

hi = 48 kJ/kg

ho = 14 kJ/kg

ρo = 1/ vo = 1.282 kg / m^3

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

Through window

$Q_{inf,g}$=0.086 kW

Through door

L =2(1.10+2)

=6.2 m

V_f = 0.43*6.2 $[0.613(0.9*0.75*1.4)^2]^{2/3}$

=1.78 m^3/h
= 4.95*$10^{-4}$$m^3/s$

$Q_{inf,d}$=0.0216 kW

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

$=0.0216+0.086$

$=0.1076$ kW.

Heat gain due to ventilation:

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

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

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

V_f = Room volume $\times$ No. of times the air changes in the hour (2.15)

$$m_f = \frac{V_{f.}}{v_o} = \frac{(5.5*3.12*3)m^3 *(2*2/3)}{0.79(3600)} \quad =0.0364 \text{ kg/s}$$

$$Q_{ventilation} = 0.0244 \times 1000 \times (48 - 14)$$

$$Q_{ventilation} = 0.831\text{kW}$$

The total heat loss from the bedroom is

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

$=0.081 +0.2429+0.594+0.0316+0.1076$

$=1.0571$ kW.

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

$Q_{tot} = 1057.1\times 1.10= 1162.8$ W.

$= 1.1628$ kW.

2.7.4 Total heating load for all spaces

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

Table(2.5): Heating load for each room (W)

	Type of room	Area (m^2)	Q(W)
Ground floor	Office	17	598
	Reception	120	4745
Mzaeen floor	Kitchen	15	278
	Washroom	10	500
	Restaurant	28	246
	Meeting room	84	1594
First floor	Bedroom7	14	1069
	Bedroom8	14	825
	Bedroom9	21	1369
	Bedroom10	14	1178
	Bedroom11	14	735
	Bedroom12	11	595
	Bedroom13	11	533
	Bedroom14	14	573
	Bedroom15	14	1155
Second floor	Bedroom16	14	1369
	Bedroom17	14	825
	Bedroom18	21	1078
	Bedroom19	14	1155
	Bedroom20	14	628
	Bedroom21	11	595
	Bedroom22	11	533
	Bedroom23	14	573
	Bedroom24	14	1178
Third floor	Bedroom25	14	1048
	Bedroom26	14	825
	Bedroom27	21	1369
	Bedroom28	14	1202
	Bedroom29	14	737
	Bedroom30	11	590
	Bedroom31	11	533
	Bedroom32	14	573
	Bedroom33	14	1178
Fourth floor	Bedroom34	14	1048
	Bedroom35	14	825
	Bedroom36	21	1369
	Bedroom37	14	1155
	Bedroom38	14	572
	Bedroom39	11	534
	Bedroom40	11	533
	Bedroom41	14	579
	Bedroom42	14	1178
Roof	Bedroom43	14	948
	Bedroom44	14	726
	Bedroom45	21	1337
	Bedroom46	13	1055
	Bedroom47	14	1111

2.8 Cooling load:

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

To achieve the human comfort conditions it is needed to do some calculation to select the proper equipment to have the conditions that it is needed and the cooling load is the most important load that can helps in selecting the equipment’s that needed correctly. [9]

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 which is located at the wall , Windows , door …… etc. Shown in figure (2.5)

Direct and diffused solar radiation that absorbed by walls and roofs result in raising the temperature of these surfaces. Amount of radiation absorbed by walls and roofs depends upon time of the day, building orientation, types of wall construction and presence of shading. [10]

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

$$Q = UA\,(CLTD)_{corr.} \qquad (2.16)$$

Where:

$(CLTD)_{corr.}$: corrected cooling load temperature difference, ˚C [9]

$$(CLTD)_{corr.} = (CLTD + LM)\,k + (25.5 - T_{in}) + (T_{o,m} - 29.4)\,f \qquad (2.17)$$

Where:

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

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

k: colour adjustment factor .

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

f: attic or roof fan factor.

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

$T_{o,m}$ = (T max + T min) /2 (2.18)

Where**:**

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

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

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

Applying these values in equation (2.18) to obtain the outdoor mean temperature

$T_{o,m}$ = 24 ˚C .

2.8.2 Sample Calculation:

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

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

CLTD = 3˚C

LM = 5

k = 0.83 for permanently light colour roofs.

f = 1 there is no attic or roof fan.

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

= 2.74˚C

$Q_{Roof} = (U_1 A_1 + U_2 A_2)\ (CLTD)_{corr.}$ (2.19)

Q_{Roof} = (0.49 ×12.68 + 0.51 ×3.17) (2.74)

= 21.454 W

Heat gain through sunlit walls (Q wall):

$\dot{Q}_W$ = zero

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

=0.738*4.9576(30-24)

$\dot{Q}_s = Q_{wall}$=21.476W.

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

From the wall around bathroom:

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

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

$Q_{un} = 2.99 \times 9.0792 \times 4$

$= 108.587W$

From North wall

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

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

$Q_{un.,N.}= 2.99 \times 3.2832 \times 4$

$= 39.27W$

$Q_{wall\ un} = 108.587 + 39.27$

$= 147.857\ W$

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

The amount of solar radiation depends upon the following factors [3]:

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:

$$Q_{Glass} = Q_{tr.} + Q_{conv.} \quad (2.20)$$

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) (2.21)

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). [5]

*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. [5]

*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. [5]

SHG in W/m^2 …

For wall in south direction:

A = 4.4 m^2

SHG = 227 W/m^2

SC = 0.57…with interior shading

CLF = 0.68 at 14:00 clock …

$Q_{tr.\,s}$= 4.4× 227 × 0.57 × 0.68

= 387.135W

For wall in west direction:

A = 4.4 m^2

SHG = 678 W/m^2

SC = 0.57… with interior shading

CLF = 0.53 at 14:00 clock …

$Q_{tr.\,w}$= 4.4× 678 × 0.57 × 0.53

= 901.224W.

Q conv. = UA (CLTD) corr. (2.22)

Where**:**

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

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

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

CLTD = 7 ˚C at 14:00 ,clock

k = 1 for glass

f = 1 for glass

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

= 8.1˚C

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

$= 3.2\times8.8\times8.1$

=228.1 W

$Q_{tr.} = Q_{tr.s} + Q_{tr.w} = 387.135 + 901.224 = 1288.36$ W

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

=1288.36+228.1

= 1516.46 W

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

Heat gains due to lights are sensible loads and are calculated by the following equation [5]:

$\dot{Q}_{Lt.}$ = light intensity × A × $(CLF)_{Lt.}$ (2.23)

Where**:**

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

A: floor area = 15.85m^2

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

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

Q Lt. = 25 × 15.85 × 0.82= 324.9W.

Heat gain due to infiltration (Q_f):

As the same way in heating load.

Where**:**

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

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

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

V_o : specific volume (m^3/kg)

v_o = 0.877 (outside the room)

h_{in} = 47.8 kJ/kg

h_{out} = 65 kJ/kg

V_o = 1.4 (m/s) from Palestinian code

V_f =2 m^3/h/m…..from table (A-4)

L= (2W + 2H)(4) for window(double sliding window)

=(2*1.1+2*2)(4)

L_w = 24.8 m

Therefore;

$V_{inf,w}$ = 2(24.8)

= 0.014 m^3/s.

$Q_{Total,w}= (V_{inf,w} / v_o)(h_{out} - h_{in})$ (2.24)

=(0.014/0.877)(1000)(65-47.8)

=270.2W.

$Q_{inf} = Q_{inf,w}$ = 270.2W.

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 [3]:

$Q_{oc.} = Q_{sensible} + Q_{latent}$ (2.25)

$Q_{sensible}$ = heat gain sensible × No. of people × $(CLF)_{oc.}$ (2.26)

Where**:**

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

heat gain sensible = 70W very light work … from table(A-21) [5]

No. of people = 2

$(CLF)_{oc.}$ = 0.84 at 8 hours after each entry into space is obtained from Table (A-6) [5]

Q sensible = 70 × 2× 0.84

= 117.6 W.

Q latent = heat gain latent × No. of people (2.27)

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

$Q_{latent} = 44 \times 2$

= 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:

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

the rate of ventilation =(Ventilation air requirements)(area) (2.28)

=(0.0075)(15.85)

=0.1188 m^3/s

Mass flow rate of ventilation air = rate of ventilation / (v_o) (2.29)

= 0.1188/0.877

=0.1355kg/s.

$Q_{vent} = (m^0)(h_{out} - h_{in})$ (2.30)

=(0.1355)(1000)(65-47.8) =2331.4W.

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

=21.454 + 147.857 +21.476+ 1516.46 + 324.9 + 270.2 + 205.6 + 2331.4

=4840W

=4.840 KW.

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

Q tot = 4.840KW *1.10

= 5.324KW.

2.8.3 Total cooling load for all spaces:

The total cooling load for all spaces and use the rivet software to calculate the load in table (2.6).

Table (2.6) : Cooling Load of each room(W)

	Type of room	Area (m^2)	Q(W)
Ground flower	Office	17	1303
	Reception	120	17244
Mzaeen flower	Kitchen	15	1141
	Washroom	10	1174
	Restaurant	28	4039
	Meeting room	84	10092
First flower	Bedroom7	14	3322
	Bedroom8	14	848
	Bedroom9	21	1439
	Bedroom10	14	5368
	Bedroom11	14	1561
	Bedroom12	11	1634
	Bedroom13	11	1523
	Bedroom14	14	2841
	Bedroom15	14	3413
Second Flower	Bedroom16	14	3344
	Bedroom17	14	848
	Bedroom18	21	1439
	Bedroom19	14	5368
	Bedroom20	14	1565
	Bedroom21	11	1607
	Bedroom22	11	1527
	Bedroom23	14	1667
	Bedroom24	14	3413
Third Flower	Bedroom25	14	3344
	Bedroom26	14	848
	Bedroom27	21	1439
	Bedroom28	14	5321
	Bedroom29	14	2757
	Bedroom30	11	1603
	Bedroom31	11	1527
	Bedroom32	14	1667
	Bedroom33	14	3413
Fourth Flower	Bedroom34	14	3344
	Bedroom35	14	848
	Bedroom36	21	1439
	Bedroom37	14	5368
	Bedroom38	14	1560
	Bedroom39	11	1636
	Bedroom40	11	1527
	Bedroom41	14	1667
	Bedroom42	14	3413
Roof	Bedroom43	14	3225
	Bedroom44	14	1730
	Bedroom45	21	1470
	Bedroom46	13	2932
	Bedroom47	14	3269

2.9 Sample room using revit :

In table (2.7) shows the summary data for sample room :

Table (2.7):Total cooling and heating load calculations for the sample room by rivet software

Space Summary - 28 Room28

Back to summary of spaces

Inputs	
Area (m^2)	14
Volume (m^3)	42.30
Wall Area (m^2)	44
Roof Area (m^2)	16
Door Area (m^2)	3
Partition Area (m^2)	0
Window Area (m^2)	10
Skylight Area (m^2)	0
Lighting Load (W)	50
Power Load (W)	50
Number of People	2
Sensible Heat Gain / Person (W)	73
Latent Heat Gain / Person (W)	45
Infiltration Airflow (L/s)	4.2
Space Type	Dormitory Bedroom
Calculated Results	
Peak Cooling Load (W)	**5,321**
Peak Cooling Sensible Load (W)	5,406
Peak Cooling Latent Load (W)	-85
Peak Cooling Airflow (L/s)	323.7
Peak Heating Load (W)	**1,202**
Peak Heating Airflow (L/s)	92.6

Chapter Three: Fire Fighting System

3.1 Introduction

A firefighting system is probably the most important of the building services, as its aim is to protect human life and property, strictly in that order. Firefighting systems and equipment vary depending on the age, size, use and type of building construction.

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

• Oxidizer to sustain combustion.

• Heat to reach ignition temperature.

• Fuel or combustible material.

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

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

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

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

3.2 Classification of Fire

On the basis of the type of fuel, fires are classified into the following:

- Class A fires are fires in ordinary combustibles such as wood, paper, cloth, rubber, and many plastics.
- Class B fires are fires in flammable liquids such as gasoline, petroleum greases, tars, oils, oil-based paints, solvents, alcohols. Class B fires also include flammable gases such as propane and butane. Class B fires do not include fires involving cooking oils and grease.
- Class C fires are fires involving energized electrical equipment such as computers, servers, motors, transformers, and appliances. Remove the power and the Class C fire becomes one of the other classes of fire.
- Class D fires are fires in combustible metals such as magnesium, titanium, zirconium, sodium, lithium, and potassium.
- Class K fires are fires in cooking oils and greases such as animal and vegetable fats.

Some types of fire extinguishing agents can be used on more than one class of fire. Others have warnings where it would be dangerous for the operator to use on a particular fire extinguishing agent.

3.3 Types of firefighting system

- Fire extinguishers.
- Fire hose reels.
- Fire hydrant systems.
- Automatic sprinkler systems.

3.3.1 Fire extinguishers

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

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

Types of Extinguishers

- Water extinguishers have an effective range of up to 40 feet and discharge for about a minute; however, they are only effective on Class A fires and require some cleanup after use. , firefighters may find it useful to place a finger over the tip to create a "spray" pattern rather than the solid-stream that normally discharges from it.
- Foam fire extinguishers are one of the most common types of fire extinguisher, and are generally used for fires involving flammable solids and liquids. ('class A, B' fires).
- Dry Chemical fire extinguishers extinguish the fire primarily by interrupting the chemical reaction of the fire triangle. Most widely used type of fire extinguisher is the multipurpose dry chemical that is effective on Class A, B, and C fires. This agent also works by creating a barrier between the oxygen element and the fuel element on Class A fires.
- Clean Agent Halogenated or Clean Agent extinguishers include the halon agents as well as the newer and less ozone depleting halocarbon agents. They extinguish the fire by interrupting the chemical reaction and/or removing heat from the fire triangle and clean agent extinguishers are effective on Class A, B and C fires.
- Dry Powder extinguishers are similar to dry chemical except that they extinguish the fire by separating the fuel from the oxygen element or by removing the heat element of the fire triangle. However, dry powder extinguishers are for Class D or combustible metal fires, only. They are ineffective on all other classes of fires.
- Carbon Dioxide fire extinguishers extinguish fire by taking away the oxygen element of the fire triangle and also be removing the heat with a very cold discharge.

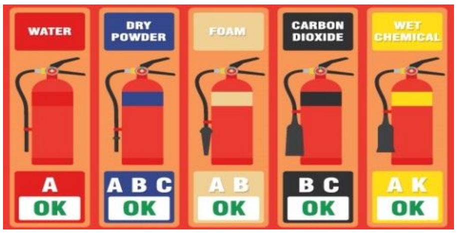


Figure (3.1): Types of Extinguishers

3.3.2. Fire hose reel

Fire hose reels are located at strategic places in buildings to provide a reasonably accessible and controlled supply of water for fire extinguishing. Fire hose reel systems consist of pumps, pipes, water supply and hose reels located strategically in a building, ensuring proper coverage of water to combat a fire. Fire hose reels are intended to give easy access through the fire hose from water supply in order to stamp out fires. Fire hose reels typically come in three main types: grounding, booster and large diameter, all of which feature an increase hose capacity than typical hose reels. [12]

Generally made from canvas or other synthetic materials, fire hoses come in multiple types as well, including booster hoses or collapsible hoses, also known as flat hoses. Fire hoses are intended for use when fire extinguishers fail. [12]

Typical applications that require fire hoses include firefighting and fire rescue operations in hotels, school buildings, shopping malls, houses, warehouses, hospitals and office buildings. Industries that benefit from firehouses include construction, industrial, commercial, retail, residential, agriculture, automotive, military and conservation.

Figure (3.2): Fire hose reel

3.3.3 Fire hose cabinet classes

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

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

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

Class two didn’t need any exp

erience 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.

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).

3.3.4 Fire hydrant system

Fire hydrant systems are installed in buildings to help fire fighters quickly attack the fire. Essentially, a hydrant system is a water reticulation system used to transport water in order to limit the amount of hose that fire fighters have to lay; thus speeding up the fire fighting process.

Fire hydrants are for the sole use of trained fire fighters (which includes factory fire fighting teams). Because of the high pressures, available serious injury can occur if untrained persons attempt to operate the equipment connected to such installations. Fire hydrant systems sometimes include ancillary parts essential to their effective operation such as pumps, tanks and fire service booster connections. These systems must be maintained and regularly tested if they are to be effective when needed. [12]

Figure (3.3): Fire hydrate system

3.3.5 Automatic sprinkler system

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

A sprinkler system consists of a water supply (or supplies) and one or more sprinkler installations; each installation consists of a set of installation main control valves and a pipe array fitted with sprinkler heads. The sprinkler heads are fitted at specified locations at the roof or ceiling, and where necessary between racks, and below shelves.

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

3.3.6 Types of automatic sprinkler system

The four primary systems are the wet pipe system, the dry pipe system, the pre-action system and the deluge system. Some basic information on these systems follows.

1- Wet Pipe System

The wet pipe sprinkler system is, in general, the most cost-effective, the most versatile as far as protection strategies and pipe installation are concerned, and the easiest to maintain. Its cost effectiveness is based on its having fewer components, requiring less maintenance and testing and having fewer design restrictions than any of the other three types of systems. Wet pipe systems are installed where temperatures will not fall below 40°F (4°C) and where one of the design objectives is to put water on a relatively small fire as quickly as possible. [15]

In a wet pipe system, components are arranged in such a manner that, as soon as the heat from a fire operates the heat responsive element of an automatic sprinkler, the water is discharged through the sprinkler to the fire. It is possible to design these systems for fire control, controlling a fire to the room or area of origin until the fire department arrives and extinguishes the fire; fire suppression actually suppressing the fire; or life safety protection as in residential occupancies. The wet pipe system can also include additives such as antifreeze or foam concentrate.

2- Dry Pipe System

When sprinkler systems are required in buildings, or areas of buildings, where the ambient temperature will not be maintained above 40°F (4°C) dry pipe systems are an option. The dry pipe system is more expensive than the wet pipe system; requires more maintenance and testing (weekly, monthly, annually, and over its lifetime); and has additional design requirements beyond those of the basic wet pipe system. [16]

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

When the heat from a fire operates the heat responsive element of an automatic sprinkler, the air in the system must be evacuated through the sprinkler opening to reduce the air pressure in the system holding the clapper of the dry pipe valve in the closed position. When enough air has escaped through the sprinkler, through additional sprinkler actuation as the fire grows, or through quick opening devices that are installed on larger systems, then the water fills the piping, eventually reaching open sprinklers and the fire. This delay of water application allows the fire to grow, creating more fire damage; that needs to be a consideration for both the designer and the owner. The dry pipe system is a fire control system only, but may eventually be appropriate for life safety or residential systems. [15]

3-Pre-action System

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

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

A pre-action system can be designed to operate as a dry system – non-interlocked, or more commonly they are designed to operate in conjunction with a detection system. These include single-interlocked and double-interlocked systems. The pre-action system can be installed in areas or buildings where either wet or dry systems are appropriate based on temperatures, but where accidental discharge of water might be a critical issue, such as in areas that are protecting valuables, irreplaceable articles, freezers, or computer or data centers.

4- Deluge System

Deluge systems are similar to pre-action systems, in most cases utilizing the same valves, pipe, fittings, alarm initiating devices, automatic sprinklers, and detectors, although all of the sprinklers are open and do not include the heat responsive element. Spray nozzles can be used in deluge systems instead of the open automatic sprinklers. The difference between pre-action and deluge systems is that with the sprinklers open at all times, neither air nor water can be maintained in the piping. The deluge system requires a detection system to operate and signal the deluge valve, opening the valve and allowing water to flow through the piping and discharge through all of the sprinklers or nozzles simultaneously. [18]

Deluge systems can be installed in warm or cold very high hazard areas and the primary objective is to put as much water on a fire as is required to contain or control a severe fire hazard as quickly as possible. These systems are utilized where a large amount of water is necessary quickly such as in flammable and combustible dispensing operations, aircraft hangars, and transformers. The deluge systems frequently include foam concentrates. [18]

3.4 Firefighting network accessories

3.4.1 Firefighting network Components:

1-Water source and pumping station :

The main sources of firefighting water are Water Tanks Underground.

2-Pipes :

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

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

3- Valves :

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

3.4.2Firefighting pumps

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

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

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

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

3.5 Types of pumps

1- Horizontal split case pumps:

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

Figure (3.4): Horizontal split case pump

2- Inline fire pumps:

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

Figure(3.5): Inline fire pump

1- 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(3.6): End suction pump

2- 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(3.7): Vertical turbine pump

*In our project we Use three systems:

1-sprinkler system

2-cabinet and fire hydrant

3-Manual extinguishers

3.6 Flow rate calculations

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

3.7 Head estimation

$$\mathbf{H_{pump} = H_R + H_s + H_f} \quad (3.1)$$

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

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

H_s : is the static pressure.

H : is the friction pressure.

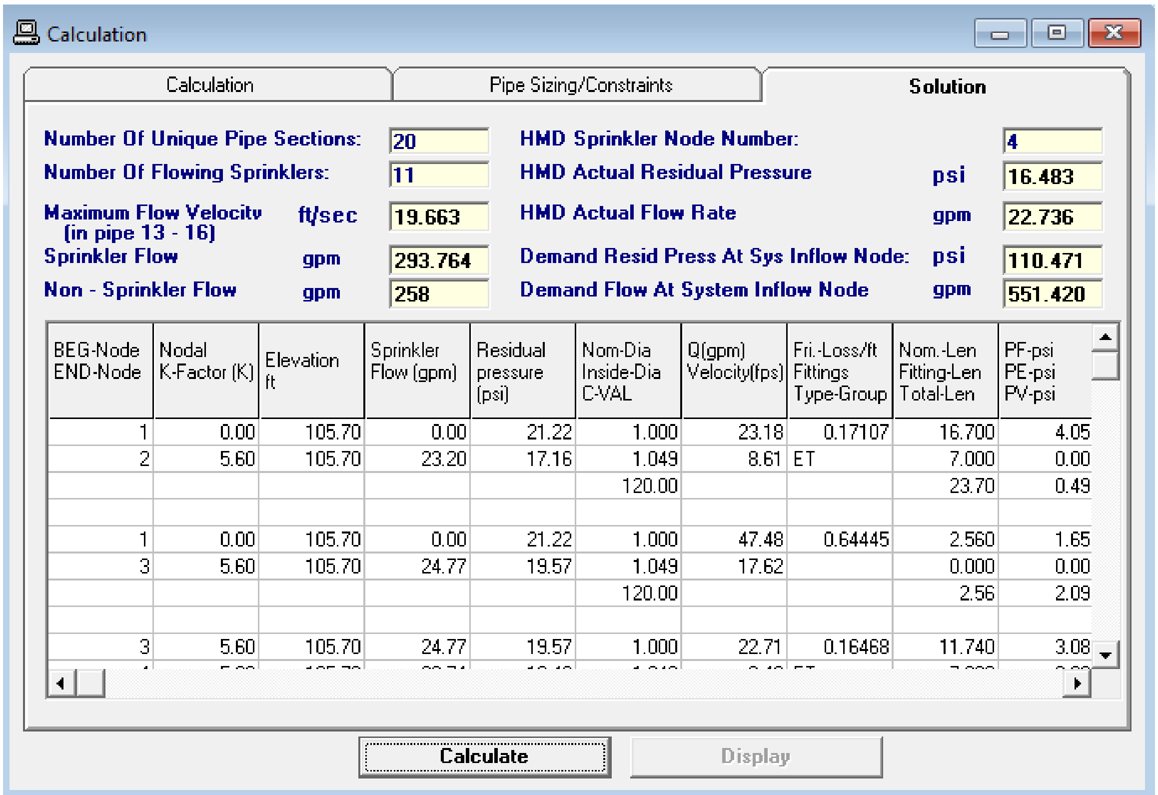
*Static pressure H_s :

for 10.3 m ⟶ 1 bar

32.2m ⟶ X

The Static pressure H_s = 3.12 bar for the total height.

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



Figure(3.8): Elite Fire Fighting program calculations

$$H_{pump} = H_R + H_s + H_f = 110.471 \text{ psi} \qquad (3.2)$$

3.8 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.

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 x **Duration** x **(3.786/1000)** (3.3)

= 551.42 (gal./min.) x 30min x [3.786 (lt/gal) x 1/1000 (m^3/lt)] = 62.63 m^3

= 63 m^3 is added to the water well.

Chapter Four: Plumbing System

4.1 Introduction

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

Plumbing originated during ancient civilizations (such as the Greek, Roman, Persian, Indian, and Chinese cities) as they developed public baths and needed to provide potable water and waste water removal for larger numbers of people. Standardized earthen plumbing pipes with broad flanges making use of asphalt for preventing leakages appeared in the urban settlements of the Indus Valley Civilization by 2700 BC. The Romans used lead pipe inscriptions to prevent water theft. [19]

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

Basic modern plumbing fixtures include toilets, urinals, sinks, bathtubs, showers, laundry tubs, and drinking fountains. In addition, hospitals, laboratories, and industrial buildings require many specialized types of fixtures. Appliances that connected to a plumbing system include dishwashers and laundry washers. Most of these fixtures and appliances require both hot and cold water. Heaters using gas, electricity, boiler water, oil, steam, or solar energy can generate hot water. [19]

Fixtures today are made of impervious materials such as vitreous china, enameled cast iron or steel, stainless steel, and plastic. Piping materials include cast iron, steel, brass, copper, stainless steel, aluminum, plastic, vitrified clay (tile), and concrete. [20]

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

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

4.2 Water supply system

4.2.1 Overview

There are two types of water distribution systems for buildings:

1. Down feed distribution.
2. Up feed distribution system.

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

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

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

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

This section will show the calculation of the total, hot and cold amount of water required for the building by using the water supply fixture unit technique. The cause for selecting this technique is since there is many number of fixture units in the building and that make this technique more accurate. [21]

The design procedure is as follows:

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

4.2.2 Calculation of cold and hot water supply system

4.2.2.1 Calculation of cold and hot water (WSFU) system

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

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

Table (4.1): Number of fixture units for first riser

Floor / Fixture type	Water closet general	Water closet private	Lavatory general	Lavatory private	Shower head	Clothes washer	Kitchen Sink
Ground floor	0	0	0	0	0	0	0
First floor	0	2	4	3	0	4	0
Second floor	0	5	0	5	5	0	0
Third floor	0	5	0	5	5	0	0
Fourth floor	0	5	0	5	5	0	0
fifth floor	0	5	0	5	5	0	0
Roof floor	0	3	0	3	3	0	1
Total	0	23	4	26	23	4	1

Table (4.2): Fixture units load for first riser

Fixture type	No. FU	WSFU	Total WSFU	Cold WSFU	Hot WSFU	Total cold	Total hot
Water closet general	0	5	0	--	--	0	0
Water closet private	23	3	69	--	--	69	0
Lavatory general	4	2	8	2*3/4	2*3/4	6	6
Lavatory private	26	1	26	1*3/4	1*3/4	19.5	19.5
Shower head	23	2	46	2*3/4	2*3/4	34.5	34.5
Clothes washer	4	4	16	4*3/4	4*3/4	12	12
Kitchen sink	1	4	4	4*3/4	4*3/4	3	3
Total	81	--	169	--	--	144	75

We use the (B-1) for estimating demand to calculate the required amount of water :

140 WSFU $\rightarrow$ 53gpm (from table (B-5))

144WSFU $\rightarrow$ X gpm

160 WSFU → 57 gpm

X= 53.8 gpm , For **Cold** water first riser

60 WSFU → 33 gpm (from table (B-5))

75WSFU → X gpm

80 WSFU → 39 gpm

X= 37.5 gpm , For **Hot** water first riser

Tables (4.3 and 4.4) show the total number of fixture units and the total water supply fixture unit (WSFU) for the second riser.

Table (4.3): Number of fixture units for second riser

Floor / Fixture type	Water closet general	Water closet private	Lavatory general	Lavatory private	Shower head	Clothes washer	Kitchen Sink
Ground floor	2	1	2	1	0	0	0
First floor	0	0	0	0	0	0	2
Second floor	0	4	0	4	4	0	0
Third floor	0	4	0	4	4	0	0
Fourth floor	0	4	0	4	4	0	0
fifth floor	0	4	0	4	4	0	0
Roof floor	0	2	0	2	2	0	1
Total	2	19	2	19	18	0	3

Table (4.4): Fixture units load for second riser

Fixture type	No. FU	WSFU	Total WSFU	Cold WSFU	Hot WSFU	Total cold	Total hot
Water closet general	2	5	10	--	--	10	0
Water closet private	19	3	57	--	--	57	0
Lavatory general	2	2	4	2*3/4	2*3/4	3	3
Lavatory private	19	1	19	1*3/4	1*3/4	14.25	14.25
Shower head	18	2	36	2*3/4	2*3/4	27	27
Kitchen sink	3	4	12	4*3/4	4*3/4	9	9
Total	63	--	138			120.25	53.25

We use the (B-1) for estimating demand to calculate the required amount of water :

120 WSFU → 49 gpm (from table (B-5))

120.25 WSFU → X gpm

140 WSFU → 53 gpm

X= 49.05 gpm , For **Cold** water second riser

50 WSFU → 29 gpm (from table (B-5))

53.25 WSFU → X gpm

60 WSFU → 33 gpm

X= 30.3 gpm , For **Hot** water second riser

Table (4.5): Total WSFU and gpm for risers

Riser	Total WSFU CW	Total gpm CW	Total WSFU HW	Total gpm HW
Riser 1st	144	53.8	75	37.5
Riser 2nd	120.25	49.05	53.25	30.3
Total	264.25	77.85	128.25	50.65

4.2.2.2 Pipe sizing calculation

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

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

Where**:**

Static head is to overcome the height.

Friction head is to overcome friction in pipes.

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

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

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

By friction head loss method:

- Static pressure:

As indicated previously that the building consists of nine floors (floor to floor height is 3.84 meters), then as shown in the figure below it appears that the total vertical length from the pump source to the critical fixture (water closet) is 30.4 m.

$$\text{Static pressure} = 30.4 \times \frac{0.433}{0.3048} = 43.19\text{psi} \qquad (4.2)$$

- Friction head:

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

=60-43.19-8= 10.52 psi

Available friction head= 8.81 psi

Total equivalent length.

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

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

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

- For cold water system:

  Total length = 69.9 m.

  Total equivalent length=69.9*1.5*3.28= 344 ft

- For hot water system:

  Total length =69.9 m

  Total equivalent length= 69.9*1.5*3.28 = 344 ft.

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

Friction/100ft =8.81 psi/ (344/100 ft.) = 2.6 (psi/100ft).

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

Table 4.6: Pipe sizing for cold water riser

Section Number	Flow (gpm)	Equivalent length(ft)	Pipe size (in)	Velocity (fps)
1st riser part #1 (From tap off to ground floor)	53.8	60.73	2"	**5.5**
1st riser part #2 (first floor)	48.4	18.9	2"	**5**
1st riser part #3 (second floor)	41.9	18.9	1.5"	**6.5**
1st riser part #4 (third floor)	34.6	18.9	1.5"	**5.5**
1st riser part #5 (fourth floor)	24.5	18.9	1.25"	**5.5**
1st riser part #6 (fifth floor)	13.3	22.13	1"	**4.1**
2st riser part #1 (from tap off to car parking)	49	44.7	2"	**5**
2st riser part #2 (ground floor)	44.9	18.9	1.5"	**6.6**
2st riser part #3 (first floor)	43.4	18.9	1.5"	**6.3**
2st riser part #4 (second floor)	38	18.9	1.5"	**6**
2st riser part #5 (third floor)	31.2	18.9	1.5"	**5.2**
2st riser part #6 (fourth floor)	22.3	18.9	1.25"	**5**
2st riser part #7 (fifth floor)	10.1	58.7	1"	**4**
Main	77.9	78.6	2.5"	**5.5**

Table 4.7: Pipe sizing for hot water riser

Section Number	Flow (gpm)	Equivalent length(ft)	Pipe size (in)	Velocity (fps)
1st riser part #1 (From tap off to ground floor)	37.5	61.1	1.5"	**5.8**
1st riser part #2 (first floor)	31	18.9	1.5"	**5.2**
1st riser part #3 (second floor)	26.4	18.9	1.25"	**5.5**
1st riser part #4 (third floor)	21.1	18.9	1.25"	**5**
1st riser part #5 (fourth floor)	14.6	18.9	1"	**5**
1st riser part #6 (fifth floor)	7.8	22.1	0.75"	**4.2**
2st riser part #1 (from tap off to car parking)	30.3	36.3	1.5"	**5.2**
2st riser part #2 (ground floor)	28.8	18.9	1.5"	**5**

2st riser part #3 (first floor)	26.4	18.9	1.5"	**4.8**
2st riser part #4 (second floor)	22.3	18.9	1.25"	**5.2**
2st riser part #5 (third floor)	17.3	18.9	1.25"	**4.2**
2st riser part #6 (fourth floor)	11.9	18.9	1"	**4.7**
2st riser part #7 (fifth floor)	6.1	60	0.75"	**4**
Main	50.7	86.8	2"	**5.2**

4. 3 Water tank volume

Calculation for the water well volume needed for the hotel :

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

We have 46 room in our hotel:

So (227.125 L/1000)m^3*46= 10.44 m^3 per day.

For 7 days

We need 73.1 m^3

Add 63 m^3 for firefighting

4.4 Head estimation

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

4.5 Pump selection

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

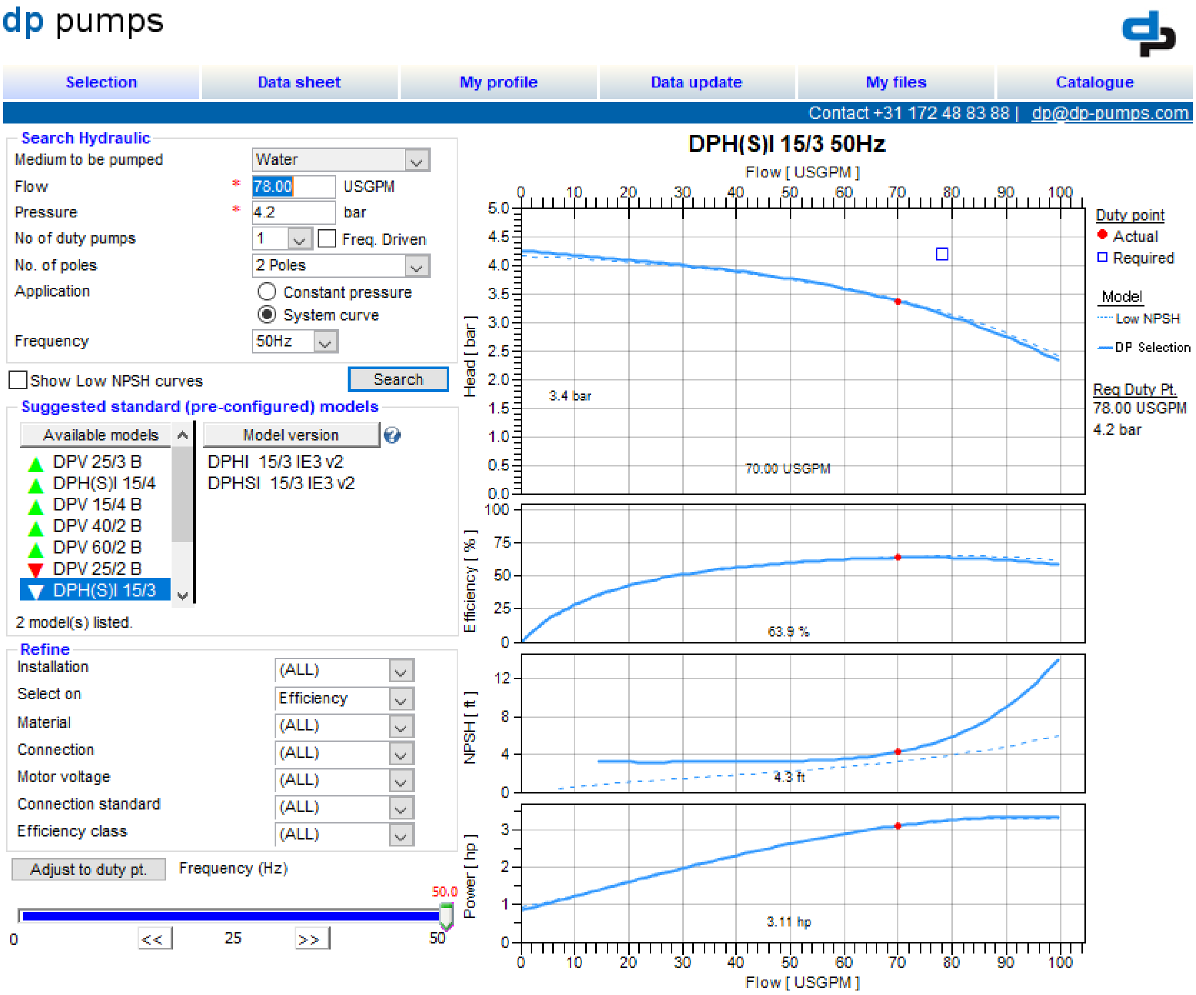


Figure (4.1): Pump data for cold water first and second riser

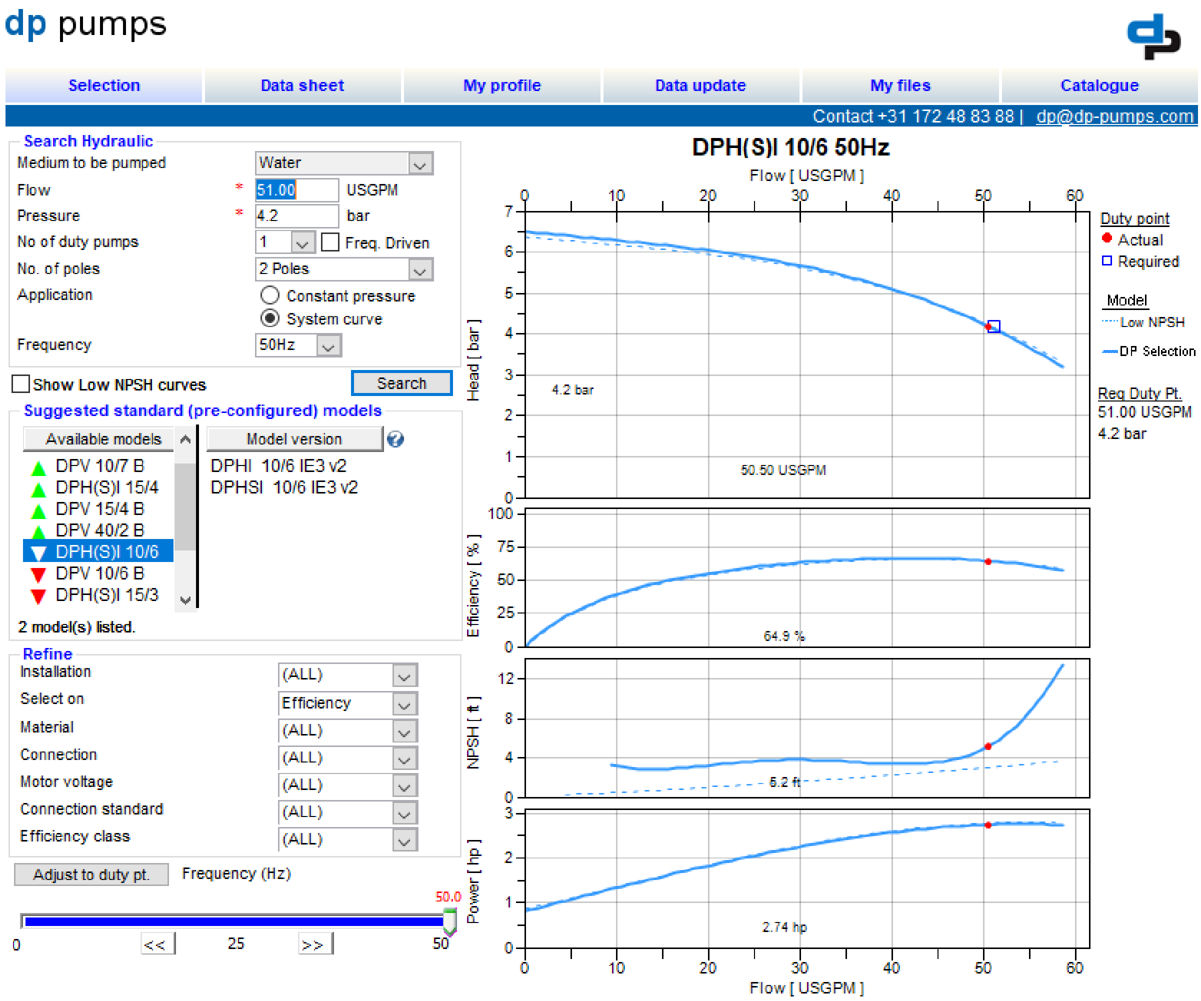


Figure (4.2): Pump data for hot water first and second riser

4.6 pneumatic tanks

pneumatic tanks offer the benefit of providing pressurized water quickly and on-demand, so they do not require the constant use of a pump. In well water applications, they will provide water when a specified pressure range is reached, which prevents the pump from running constantly. When a small amount of water is needed, a pneumatic tank can supply it without the need for starting the pump, making the system more efficient and adaptive. In addition, these tanks can also be used in conjunction with booster pumps to bring water when the system is in a period a shutdown. For irrigation pumps, pneumatic tanks offer a cushion to prevent short cycling of the jockey pump.

At Tanks Direct, we have extensive experience designing and installing pressurized water systems for commercial facilities, including hydro pneumatic tanks. We provide a variety of different types of ASME tanks, fire protection, including chilled water buffer tanks, bladder tanks, expansion tanks, epoxy-lined storage tanks, surge tanks, and blow down tanks. In addition, we can provide you with the accessories that you need for your system, such as booster pumps, water filtration equipment, tank level gauges, and much more.

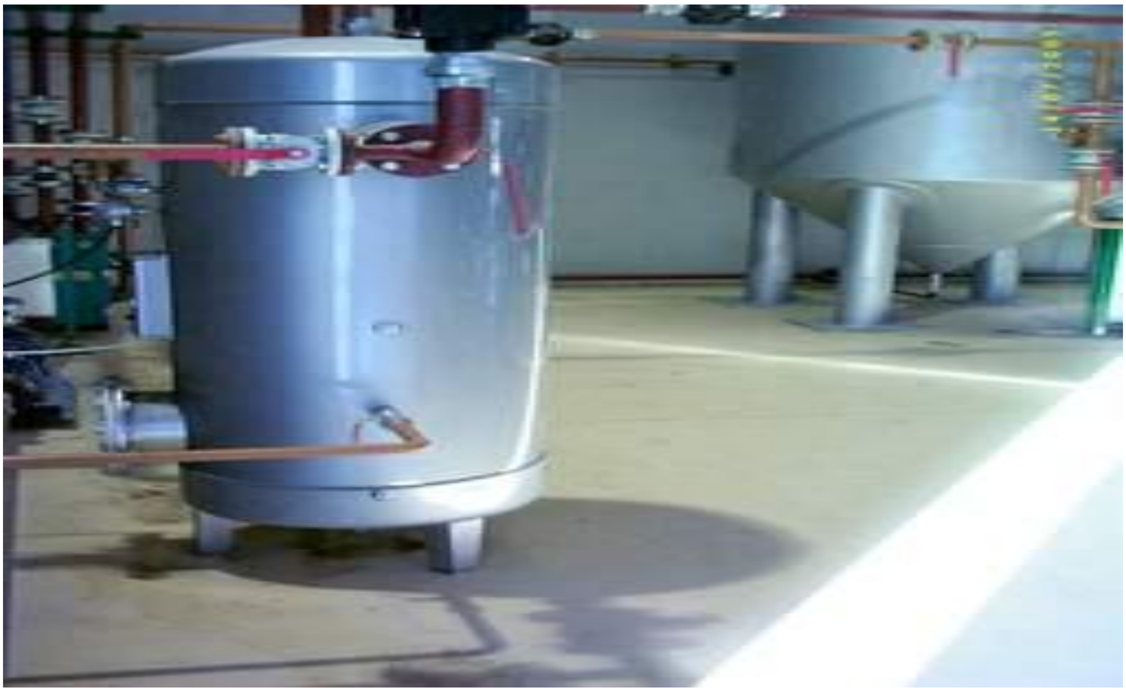


Figure (4.3): pneumatic tanks

4.6.1 Selection for main pneumatic water tank

The total needed for water become pneumatic is 25% of total demand for the every mechanical room & the volume of the tank be calculated from Wessel Company:

Figure (4.4): Selection for main pneumatic water tank

4.7 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

4.7.1 Drainage system components

The main components of drainage system are:

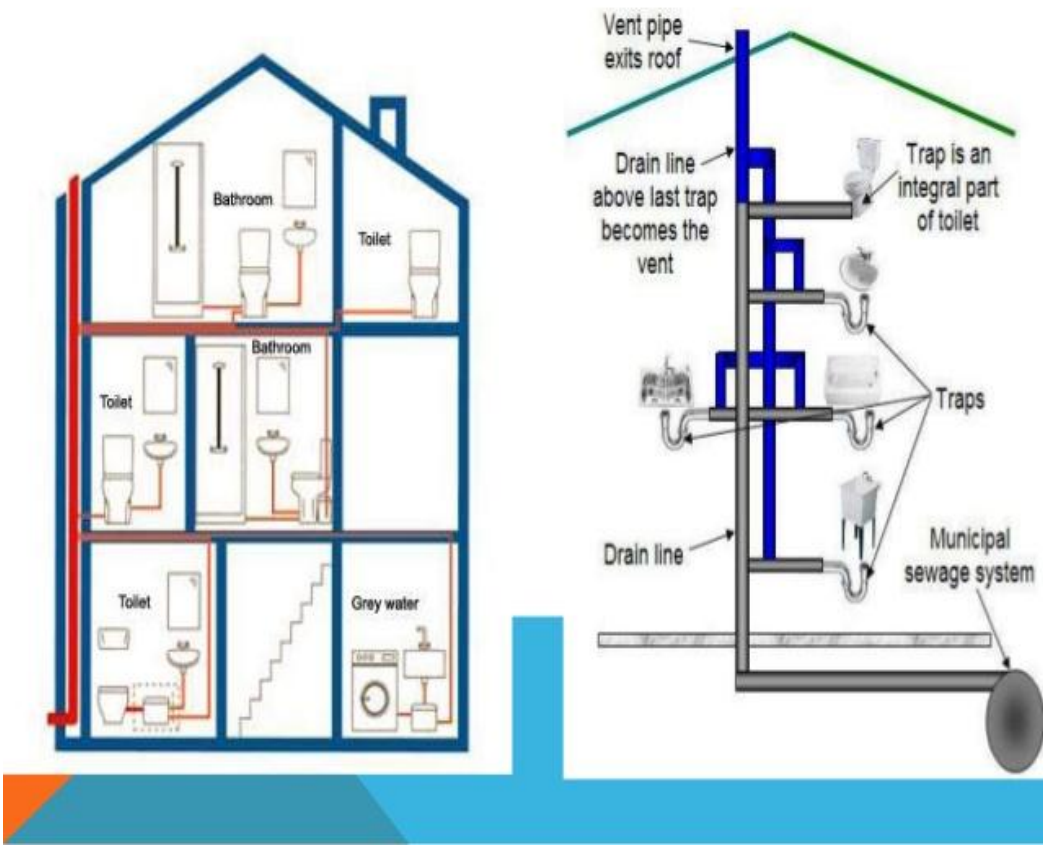


Figure (4.5): Drainage system components

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

4.7.2 Sanitary drainage

Design procedure and pipe sizing

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

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

The recommended velocity for drainage piping:

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

Velocity of water flow through drainage piping depends on:

- Pipe diameter
- Slope

Minimum slope requirements for horizontal drainage piping:

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

Design procedure:

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

4. Choosing the stack pipe diameter by using Table (B-5)
5. Comparing the stack pipe diameter with branch diameter
6. Choosing the building drain pipe diameter by using Table (B-5)

Table (4.8): Sizing of stack 1and 2

Stack			Branch	
Floor	Total DFU	Diameter (in)	Total DFU	Diameter (in)
sixth	13	4	13	4
Fifth	28	4	15	4
fourth	43	4	15	4
Third	58	4	15	4
Second	73	4	15	4
First	73	4	-	-
Ground	73	4	-	-

Table (4.9): Sizing of stack 3 and 4

Stack			Branch	
Floor	Total DFU	Diameter (in)	Total DFU	Diameter (in)
Fifth	14	4	14	4
fourth	28	4	14	4
Third	42	4	14	4
Second	56	4	14	4
First	56	4	-	-
Ground	56	4	-	-

Table (4.10): Sizing of stack 5:

Stack			Branch	
Floor	Total DFU	Diameter (in)	Total DFU	Diameter (in)
sixth	7	4	7	4
Fifth	21	4	14	4
fourth	35	4	14	4
Third	49	4	14	4
Second	63	4	14	4
First	63	4	-	-
Ground	63	4	-	-

Table (4.11): Sizing of stack 6

Stack			Branch	
Floor	Total DFU	Diameter (in)	Total DFU	Diameter (in)
First	8	4	8	4
Ground	21	4	13	4

Table (4.12): Sizing of stack 7:

Stack			Branch	
Floor	Total DFU	Diameter (in)	Total DFU	Diameter (in)
First	19	4	19	4
Ground	19	4	-	-

Table (4.13): Sizing of stack 8:

Stack			Branch	
Floor	Total DFU	Diameter (in)	Total DFU	Diameter (in)
First	6	4	6	4
Ground	10	4	4	2

4.7.3 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.

4.7.4 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.

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:

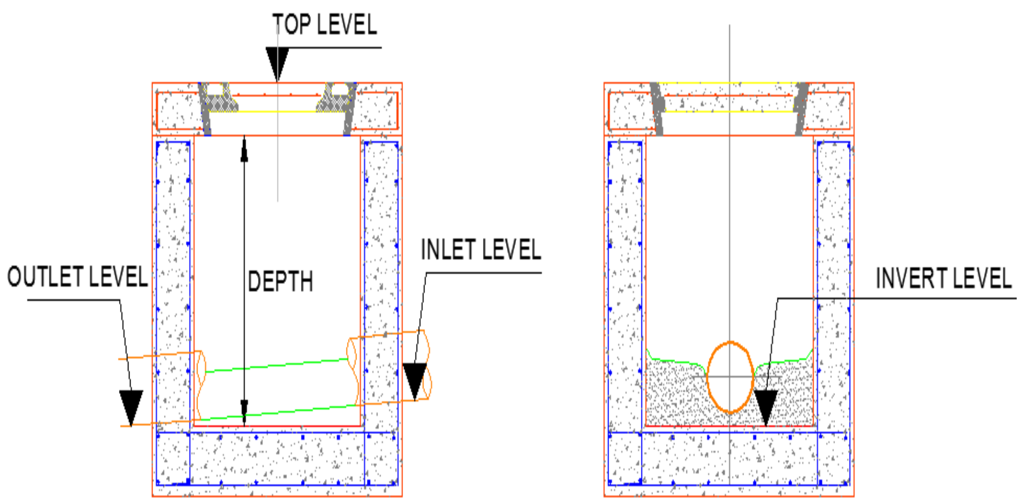


Figure (4.6): Manholes details

Table (4.14): Diameter of manhole according to their depth

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

Chapter five: Air conditioning system

5.1 Introduction

The invention of the components of HVAC systems went hand in hand with the industrial revolution, and companies and inventors worldwide are constantly introducing new methods of modernization, higher efficiency, and system control.

The objective of an HVAC system is to ensure that an indoor environment is both safe and comfortable for humans. Safety here mainly concerns the indoor air quality, meaning that the indoor air should have enough oxygen and be free of noxious gases. Comfort of course is based on human perception, which can vary within bounds. ASHRAE (the American Society of Heating, Refrigeration, and Air-conditioning Engineers), defines comfortable air quality as one “with which a substantial majority (80% or more) of the people exposed do not express dissatisfaction”.[22]

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

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

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

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

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

5.2 Variable refrigerant flow system

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

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

5.3 Variable refrigerant flow description

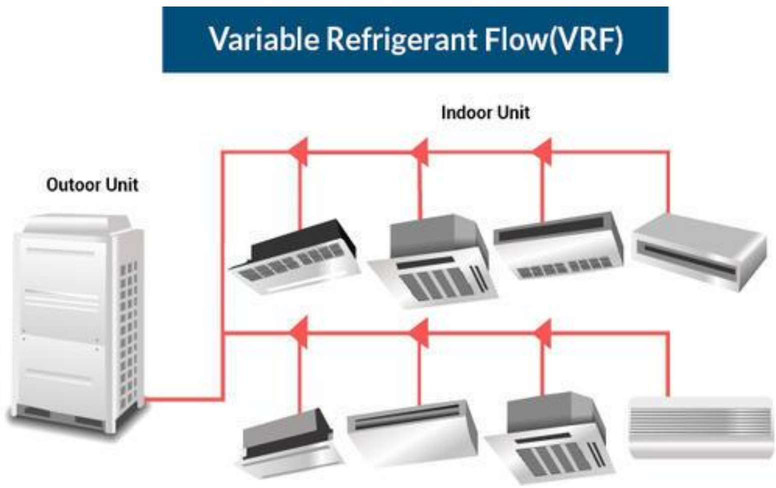


Figure 5.1: VRF system indoor evaporative units [26]

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

5.4 Advantages of a VRF system

1- Control means comfort:

The key to providing comfort is to supply heating or cooling when and where it is required without swings in room temperature. In a VRF system, since the speed of the compressor can be varied, the compressor does not cycle on and off, but operates continuously for longer periods .The required refrigerant flow is supplied to the indoor fan coil and once the set point is reached, the refrigerant flow is adjusted to maintain the room temperature smoothly without fluctuation. In addition to having distinct set points, the indoor unit fan speeds and louver positions can be changed to provide additional comfort in the space.

2- Design flexibility:

One of the major advantages of a VRF system is the flexibility provided by the diversity of the product offering. Multiple types and sizes of fan coils are available to fit any application.

Figure (5.2) shows a sample-zoning layout for a VRF system, combining outdoor and indoor unit to create comfortable conditions within the same building. When selecting a VRF system, keep in mind that not all systems have the same piping capabilities. Systems that offer expanded piping capabilities will maximize the application flexibility provided by the VRF technology. Important considerations when reviewing piping capabilities are:

1-The maximum elevation difference allowed between the highest and lowest indoor units on a single system.

2-The distance allowed from the outdoor unit to the farthest fan coil on the system.

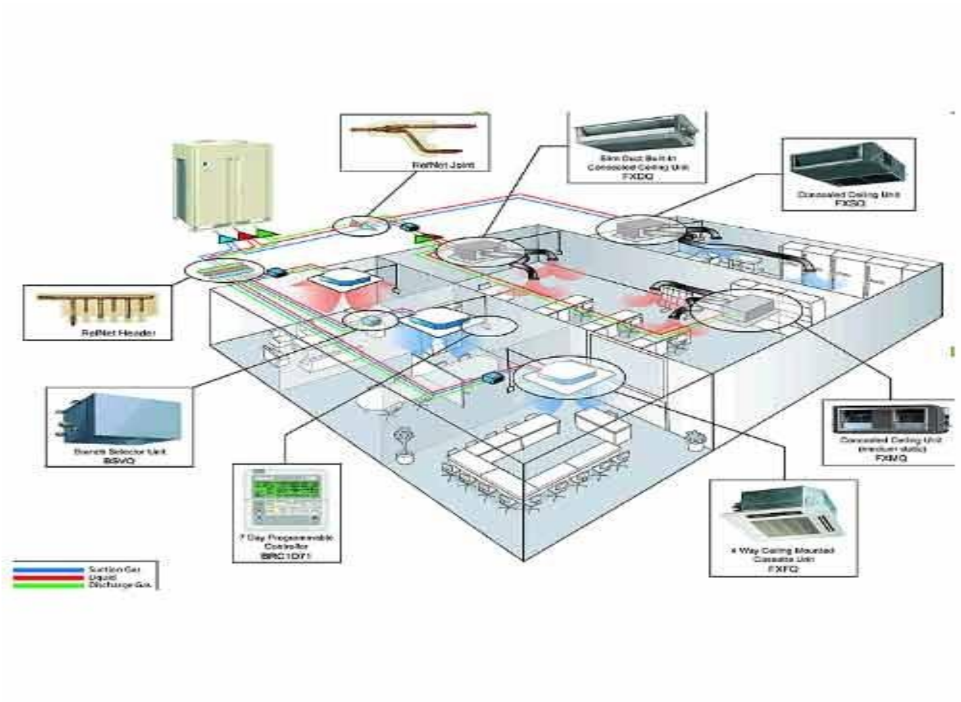


Figure 5.2: Sample zoning layout for a VRF

3- Energy savings:

All VRF systems provide energy savings by varying compressor speed and matching the output of the system as closely as possible to the load. In addition, VRF systems do not experience the same energy losses as systems that move conditioned air through ductwork. However, differences in design in the available outdoor units will influence the efficiency level that is achieved.

4- Cost effective installation:

Depending on the application, the installation of a VRF system can be a cost-effective alternative to traditional systems that require ductwork or large pipe sizes, and pumps and boilers in the case of chilled water systems.

Outdoor units are light in weight and have a small footprint. This means that they will fit in a service elevator, so no crane is required for lifting to a rooftop installation. In some cases, savings on the total construction cost can be achieved since the lightweight unit means that additional support structure in the roof is not required.

5- Comfort:

VRF systems enable wide capacity modulation, 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. [27]

VRF systems are capable of simultaneous cooling and heating. A programmable thermostat can control each individual indoor unit. 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.

6- 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.

7- Ozone friendly refrigerants

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

8- Reliability.

- 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.

5.5 Disadvantages

Many VRF systems provide relatively trouble-free operation with normal maintenance costs. Full life expectancies in our climate are yet to be determined. The manufacturers anticipate life cycles around 25 years with proper maintenance.

Worldwide, there have been several installations and thus some installation problems. Many of the issues encountered have root causes stemming from poor installation or poor maintenance practices. We would stress the importance of following "best practice" refrigeration industry standards for the design, installation, maintenance, and commissioning of these systems.

A few of the issues, or possible issues, with using VRF technology are as follows:

1. 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.
2. Maintenance (cleaning/change of filters) is within the occupied space;
3. Limited air throw which can lead to possible hot/cold spots;
4. Impact on building aesthetics of large building because too many outdoor units will spoil the appearance of the building.

5.6 Types of VRF

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

1- VRF heat pump systems

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

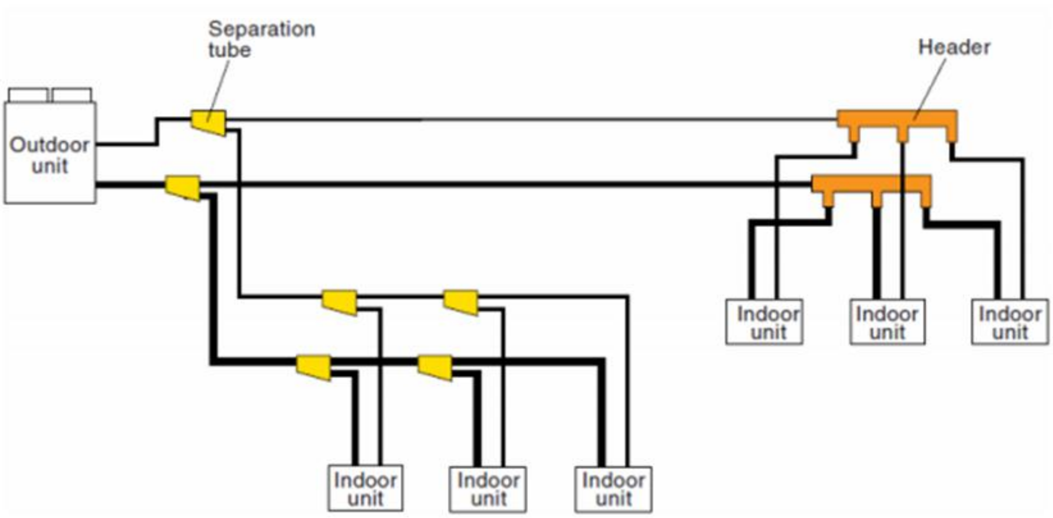


Figure 5.3: VRF heat pump systems [26]

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

2- Heat recovery VRF system

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

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

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

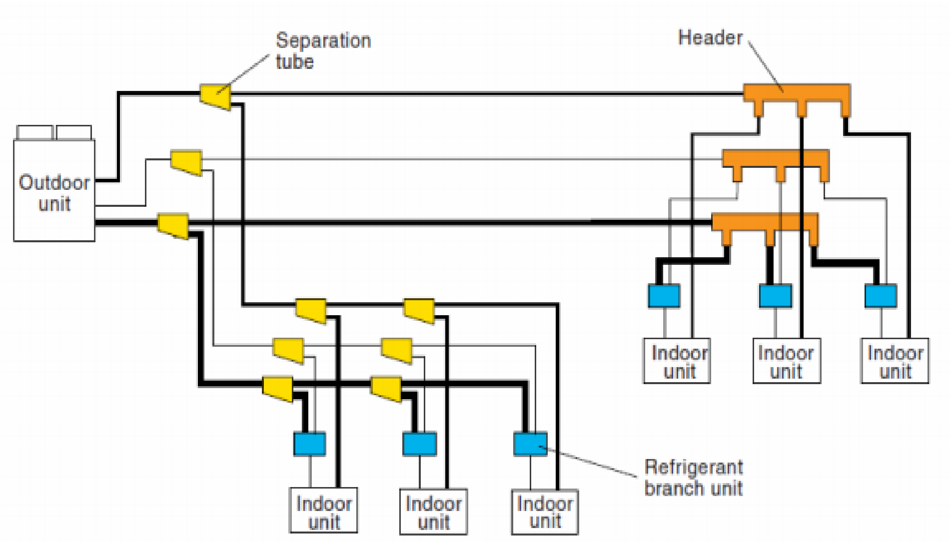


Figure 5.4: Heat recovery VRF system [26]

5.7 VRF technology

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

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

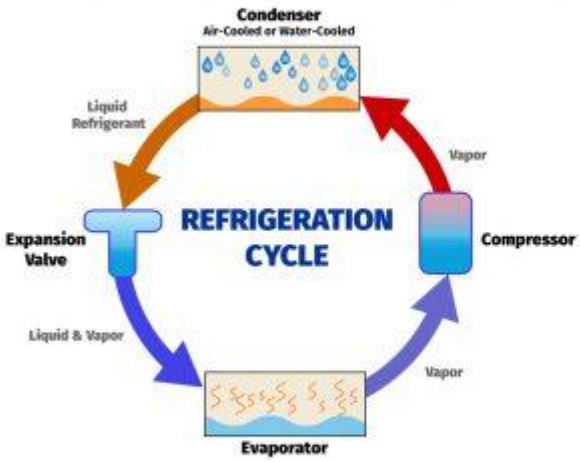


Figure 5.5: Refrigerant cycle

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

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

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

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

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

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

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

5.8 Components of VRF systems

1- Outdoor Units:

Outdoor is two type:

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

Figure 5.6: Outdoor units [25]

2- Indoor units:

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

VRF indoor unit:

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

Figure 5.7: Indoor units

3- Piping network:

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

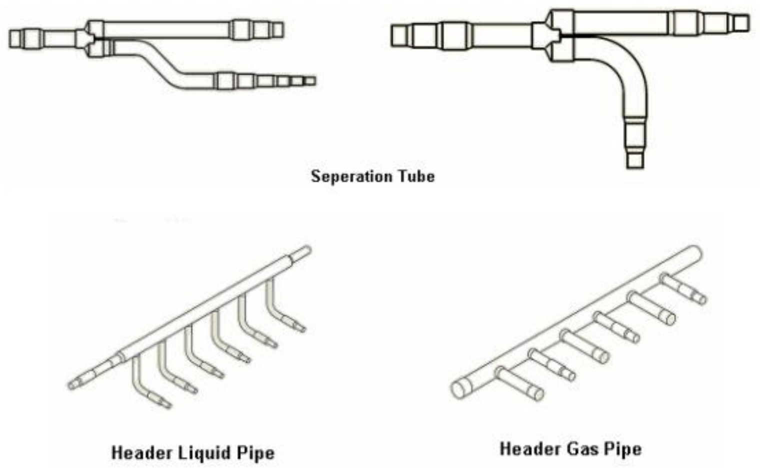


Figure 5.8: Indoor units piping network [26]

4- Insulation:

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

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

5.9 Design considerations

- Space layout

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

And Figure (5.9) shows a typical space layout, with zones specified as requiring heating or cooling and the load reflected in the size and type of the indoor units shown.

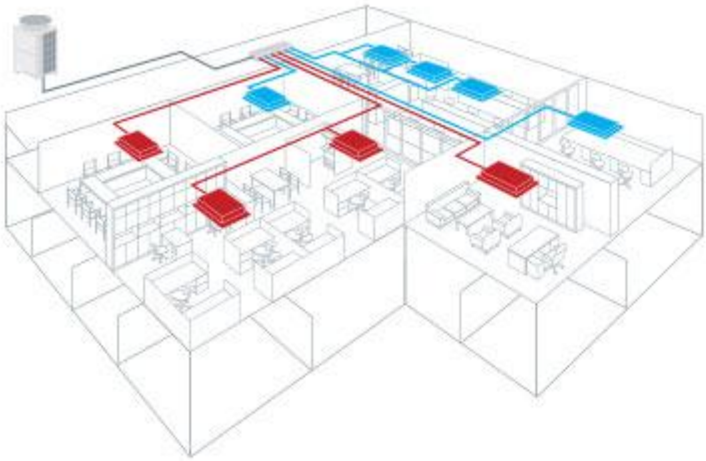


Figure (3.9) Typical VRF system space layout [26]

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

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

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

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

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

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

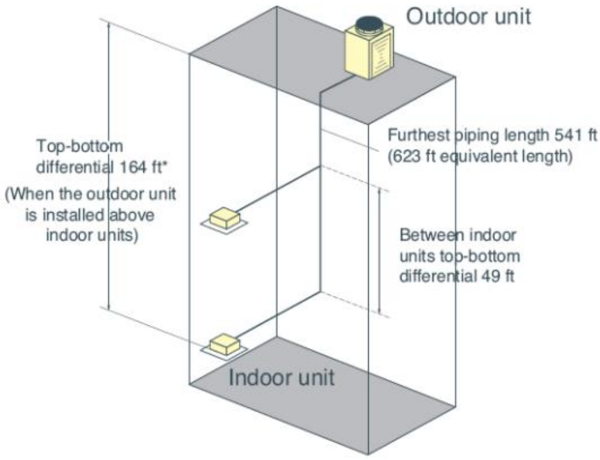


Figure (5.10) Design limits in VRF system [25]

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

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

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

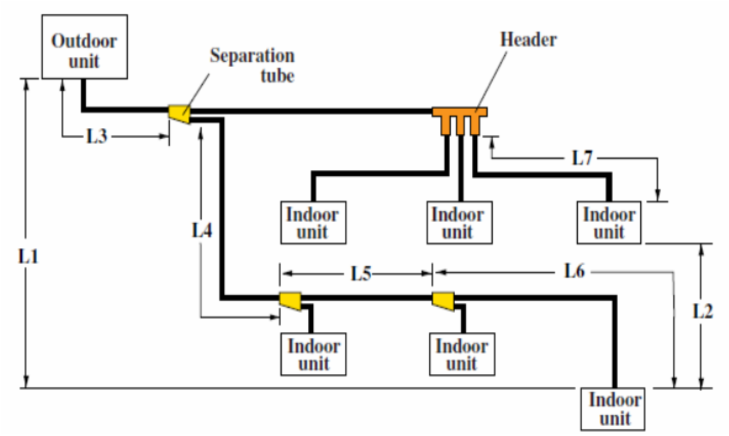

Figure (5.11) Design limits in VRF system [26]

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

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

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

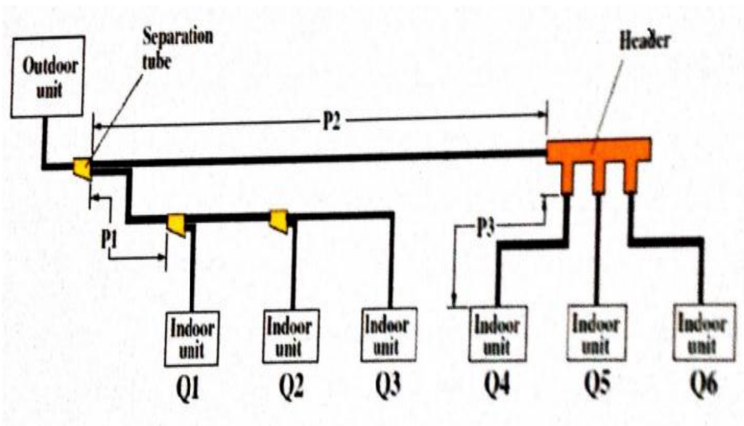

Figure (5.12) Pipe sizing for VRF system [26]

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

➢ Determine the functional and operational requirements by assessing the cooling load and load profiles including location, hours of operation, number/type of occupants, equipment being used, etc.

- Determine the required system configuration in terms of the number of indoor units and the outdoor condensing unit capacity by taking into account the total capacity and operational requirements, reliability and maintenance considerations.

Building a load profile helps determine the outdoor condensing unit compressor capacity. For instance, if there are many hours at low load, it is advantageous to install multiple compressors with at least one with inverter (speed adjustment) feature.
The combined cooling capacity of the indoor sections can match, exceed, or be lower than the capacity of the outdoor section connected to them. But as a normal practice:

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

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

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

5.10 Units Selection

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

Indoor unit:

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

- Ceiling units will only be used for bedrooms, they are flexible in operation and have an attractive and unobtrusive view as shown in the figure (5.13).

Figure (5.13) Ceiling unit [30]

- 4 Way Ceiling Cassette will be used for restaurants, reception hall, meeting room and the rest of the facilities that are characterized by large areas, and these units have been used because they are characterized by regular and good air distribution to large areas and in the form Figure (5.15) we show the shape of this unit.

Figure (5.14) 4 way cassettes unit [30]

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

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

Outdoor unit:

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

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

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

5.11 Selecting refrigerant piping

In these project used Copper Pipes to Connect between all indoor units and all outdoor units in the same system and the figure (5.15) is show the pipe shape.
Refrigerant piping diameter, thickness, and temper is selected according to length, as specified in this section.

Figure (5.15) cupper pipe

In figure (5.16) shows how to calculate pipe diameters:

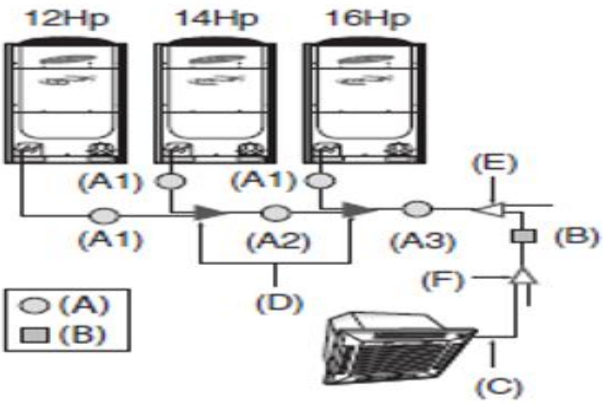

Figure (5.16) calculate pipe diameters [30]

Where:

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

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

A3: Select the main pipe of outdoor units.

Table Table(5.1) shows the required load from each outdoor unit and shows the required pipe diameters.

Table (5.1) Outdoor unit and pipe size [30]

Outdoor unit		Pipe size	
HP	kW	Liquid (mm)	Gas (mm)
12	33.6	12.7	28.58
14	40	12.7	28.58
22	61	15.88	28.58

Table (5.2) shows the required load of each indoor unit and clarifies the required pipe diameters that separate the inner unit.

Table (5.2) Size of pipe between the branch joint and indoor unit

Indoor Unit Type	Indoor Unit model	Pipe size (mm)	
		Liquid	Gas
4 way cassette	AM128FN4DEH	6.35	12.70
Ceiling	AM056FNCDEH	9.52	15.88

5.12 Ventilation

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

There are two ways for Ventilation:

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

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

• The difference between indoor and outdoor temperature;

• Wind.

The bigger the both factors are the more intensive is the air change in rooms. This means that in colder weather conditions the rooms and the building is often over-ventilated and in warmer and windless weather, there is a lack of fresh air. As both of these factors are directly dependent on the external climate, the system is considered to be a non-controllable system. Users of the building cannot change the air volume rate no more than by switching it ON or OFF; this means by opening and closing the exhaust grilles. [31]

•Mechanical or forced ventilation is provided by air movers or fans in the wall, roof or air conditioning system of a building. It promotes the supply or exhaust air flow in a controllable manner.
Mechanical ventilation systems are considered reliable in delivering the designed flow rate, regardless of the impacts of variable wind and ambient temperature. As mechanical ventilation can be integrated easily into air-conditioning, the indoor air temperature and humidity can also be controlled. [32]
Filtration systems can be installed in mechanical ventilation so that harmful microorganisms, particulates, gases, odors and vapors can be removed.

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

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

An air change per hour (ACH) is the most frequently used basis for calculating the required airflow. Air changes per hour are the number of times in one hour an equivalent room volume of air will be introduced into, or extracted from the room space. [5]

Airflow rate per person are generally expressed as liters per person (L/P), and are usually used where fresh air ventilation is required within occupied spaces.
Airflow rates per unit floor area are similar in effect to air changes per hour except that the height of the room is not taken into consideration.
Mechanical ventilation system in this project is just for bathrooms and kitchens.

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

Objectives of ventilation

Ventilation in a building serves to provide fresh and clean air, to maintain a thermally comfortable work environment, and to remove or dilute airborne contaminants in order to prevent their accumulation in the air. Air conditioning is a common type of ventilation system in modern office buildings. It draws in outside air and after filtration, heating or cooling and humidification circulates it throughout the building. A small portion of the return air is expelled to the outside environment to control the level of indoor air Contaminants. [31]

Designing of mechanical ventilation

- Using Air changes per hour.

Step One – Use table 4-6 in a appendix *Air Changes per Hour* identify the required air changes needed for the use of the room.
Step Two - Calculate the volume of the room.
Step Three - Multiply the volume of the room by the required room air changes.
Step Four Divide the answer by 60 minutes per hour to find the required room CFM.
The required CFM is given as;
CFM=Volume of the room *Air Changes per Hour /60 Minutes ……… (5.1)

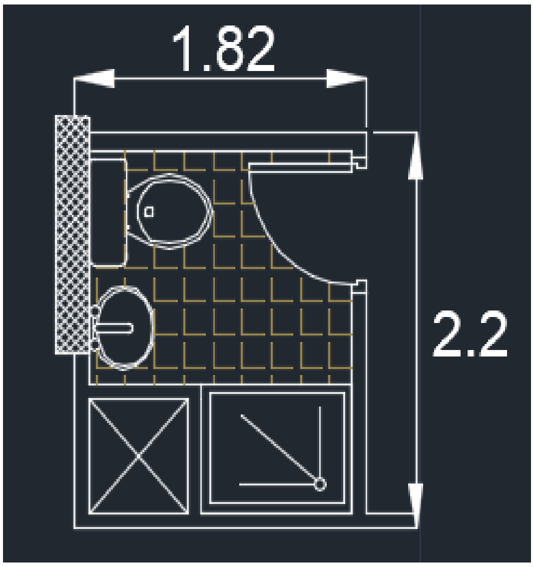

Figure (5.17): bathroom

Sample calculation For bathroom:

Volume = Length* Width * Height (5.2)

Volume=2.2*1.82*3

Volume=12 m^3

Number Air Changes per Hour = 3

Required CFM=12*3*35.3147/60

Required ventilation rate = 21.21 CFM.

Required ventilation rate in =10 liters/sec.

For kitchen

Volume = Length* Width * Height (5.3)

Volume=4.6*3.7*3

Volume=51.06 m^3

Number Air Changes per Hour=2

Required ventilation rate CFM =51.06*2*35.3147/60

Required ventilation rate = 60.1 CFM.

Required ventilation rate =28.34 liters/sec.

Using An airflow rate per person

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

Step Two – estimate number of person in space.

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

ventilation rate= minimum outside air requirements for mechanical ventilation*# of person (5.4)

Sample calculation

For restaurant

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

Ventilation rate=10*58

Required ventilation rate 580liters/sec.

Required ventilation rate =1231 CFM.

An airflow rate per unit floor area method :

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

Step Two – found area of space in secure meter.

Step Three - Multiply area by the minimum outside air requirements L/s/m^2.

ventilation rate= minimum outside air requirements for mechanical ventilation* area (5.5)

Sample calculation

Garage for car parking

Ventilation air requirements for Garage floors 7.5 $L/s/m^2$.

Ventilation rate=297*7.5

Required ventilation rate 2227.5 liters/sec.

Required ventilation rate =4719 CFM.

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Software

AutoCAD 2016.

Revit 2017.

Appendix - A

A-1: Description of wall construction groups

TABLE 9-5 Description of wall construction groups.

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

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

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

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

A-3: Approximate CLTD values for sunlit roofs

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

A-10: Shading coefficient for glass with interior shading

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

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

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

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

Type of Glass	Nominal Thickness, mm	Solar Trans.	Shading Coefficient, $W/m^2 \cdot K$ $h_o = 22.7$	$h_o = 17.0$
Single Glass				
Clear	3	0.84	1.00	1.00
	6	0.78	0.94	0.95
	10	0.72	0.90	0.92
	12	0.67	0.87	0.88
Heat absorbing	3	0.64	0.83	0.85
	6	0.46	0.69	0.73
	10	0.33	0.60	0.64
	12	0.42	0.53	0.58
Double Glass				
Regular	3	—	0.90	—
Plate	6	—	0.83	—
Reflective	6	—	0.20-0.40	—
Insulating Glass				
Clear	3	0.71	0.88	0.88
	6	0.61	0.81	0.82
Heat absorbing*	6	0.36	0.55	0.58

A-12: Solar heat gain factor for sunlit glass

Table (A-3) Solar heat gain factor (SHG) for sunlit glass, W/m^2, for a latitude angle of 32 °N.

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

A-13: Values of infiltration air coefficient for windows

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

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

A-19: Values of the factor S1

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

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

A-20: Values of the factor S2

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

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

A-21: Instantaneous heat gain from occupants

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

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

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

A-25: Latitude- month correction factor LM

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

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

A-26: Minimum outside air requirements for mechanical ventilation

Application	Maximum Occupancy Per 100 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/m^2·°C

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

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

TABLE A(2.5) Overall heat transfer coefficients for wood and metal doors, W/m^2·°C.

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

A-30 Palestinian code

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

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

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

Appendix (B)

B-1: Water supply fixture unit

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

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

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

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

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

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

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

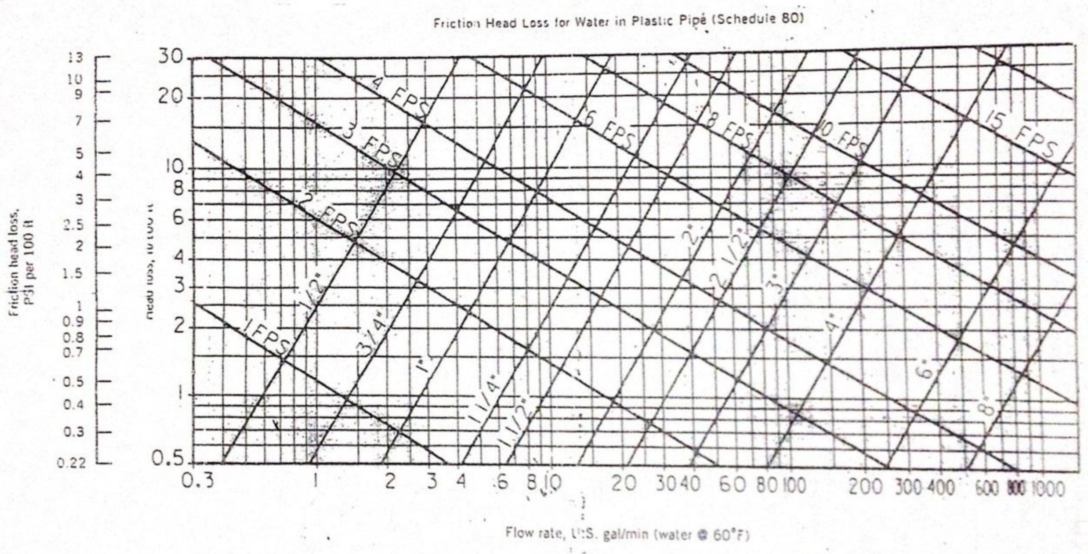
[d] Nominal I.D. pipe size.

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

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

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

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



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

B-3: Minimum pressure required by Typical plumping Fixture

TableA(4.3) Minimum Pressure Required by Typical Plumbing Fixtures

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

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

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

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

Actual Inside Diameter of Pipe, in.	1/16 in./ft Slope		1/8 in./ft Slope 1%		1/4 in./ft Slope 2%		1/2 in./ft Slope	
	Discharge, gpm	Velocity, fps	Discharge, gpm	Velocity, fps	Discharge, gpm	Velocity, fps	Discharge, gpm	Velocity, fps
1 1/4							3.40	1.78
1 3/8					3.13	1.34	4.44	1.90
1 1/2					3.91	1.42	5.53	2.01
1 5/8					4.81	1.50	6.80	2.12
2					8.42	1.72	11.9	2.43
2 1/2			10.8	1.41	15.3	1.99	21.6	2.82
3			17.6	1.59	24.8	2.25	35.1	3.19
4	26.70	1.36	37.8	1.93	53.4	2.73	75.5	3.86
5	48.3	1.58	68.3	2.23	96.6	3.16	137.	4.47
6	78.5	1.78	111.	2.52	157.	3.57	222.	5.04
8	170.	2.17	240.	3.07	340.	4.34	480.	6.13
10	308.	2.52	436.	3.56	616.	5.04	872.	7.12
12	500.	2.83	707.	4.01	999.	5.67	1413	8.02

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

Note: For 1/4 full, multiply discharge by 0.274 and multiply velocity by 0.701. For 1/3 full, multiply discharge by 0.44 and multiply velocity by 0.80. For 3/4 full, multiply discharge by 1.82 and multiply velocity by 1.13. For full, multiply discharge by 2.00 and multiply velocity by 1.00. For smoother pipe, multiply discharge and velocity by 0.015 and divide by n value of smoother pipe.

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B-5: table of estimating demand

Table A(4.2) Table for Estimating Demand

Supply Systems Predominantly for Flush Tanks		Supply Systems Predominantly for Flushometers	
Load, WSFU[a]	Demand, gpm	Load, WSFU[c]	Demand, gpm
6	5	—	—
10	8	10	27
15	11	15	31
20	14	20	35
25	17	25	38
30	20	30	41
40	25	40	47
50	29	50	51
60	33	60	55
80	39	80	62
100	44	100	68
120	49	120	74
140	53	140	78
160	57	160	83
180	61	180	87
200	65	200	91
225	70	225	95
250	75	250	100
300	85	300	110
400	105	400	125
500	125	500	140
750	170	750	175
1000	210	1000	218
1250	240	1250	240
1500	270	1500	270
1750	300	1750	300
2000	325	2000	325
2500	380	2500	380
3000	435	3000	435
4000	525	4000	525
5000	600	5000	600
6000	650	6000	650
7000	700	7000	700
8000	730	8000	730
9000	[illegible]	9000	760
10000	[illegible]	10,000	790

[a] Water Supply Fixture Units

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

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

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

Type of Fixture or Group of Fixtures	*Drainage Fixture Unit Value, dfu*
Automatic clothes washer (2-in. standpipe and trap required, direct connection)	3
Bathtub group consisting of a water closet; lavatory and bathtub or shower stall:	6
Bathtub (with or without overhead shower)[a]	2
Bidet	1
Clinic sink	6
Clothes washer	2
Combination sink-and-tray with food waste grinder	4
Combination sink-and-tray with one 1-in. trap	2
Combination sink-and-tray with separate 1-in. trap	3
Dental unit of cuspidor	1
Dental lavatory	1
Drinking fountain	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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B-7: Horizontal fixtures branches and stacks

Table A(4.5) Horizontal Fixture Branches and Stacks

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

[a] Does not include branches of the building drain.
[b] Not more than two water closets or bathroom groups within each branch interval nor more than six water closets or bathroom groups on the stack.
Note: Stacks shall be sized according to the total accumulated connected load at each story or branch interval and may be reduced in size as this load decreases to a minimum diameter of half of the largest size required.
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Table A(4.6) Building Drains and Sewers[a]

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

[a] On site sewers that serve more than one building may be sized according to the [illegible] current standards and [illegible]
[b] Not over two water closets or two bathroom groups, except that in single family dwellings, not over three water closets or three bathroom groups may be installed.
Source. Reprinted with permission from The National Standard Plumbing [illegible] Heating Cooling Contractors.

يتم الحصول عليه من خلال الكود (Uniform Plumbing Code) **UPC** كما بالصورة التالية .

أيضا يمكن الحصول عليه من كود (American Society for Plumbing Engineers) **ASPE**)

TABLE H 2.1(1)

ESTIMATED WASTE/SEWAGE FLOW RATES[1, 2, 3]

TYPE OF OCCUPANCY	GALLONS PER DAY
1. Airports	15 per employee
	5 per passenger
2. Auto washers	Check with equipment manufacturer
3. Bowling alleys (snack bar only)	75 per lane
4. Camps:	
Campground with central comfort station	35 per person
Campground with flush toilets, no showers	25 per person
Day camps (no meals served)	15 per person
Summer and seasonal	50 per person
5. Churches (Sanctuary)	5 per seat
with kitchen waste	7 per seat
6. Dance halls	5 per person
7. Factories	
no showers	25 per employee
with showers	35 per employee
Cafeteria, add	5 per employee
8. Hospitals	250 per bed
kitchen waste only	25 per bed
laundry waste only	40 per bed
9. Hotels (no kitchen waste)	60 per bed (2 person)
10. Institutions (Resident)	75 per person
Nursing home	125 per person
Rest home	125 per person
11. Laundries, self service	
(minimum 10 hours per day)	50 per wash cycle
Commercial	Per manufacturer's specifications
12. Motel	50 per bed space
with kitchen	60 per bed space
13. Offices	20 per employee

TABLE H 2.1(1) (continued)

ESTIMATED WASTE/SEWAGE FLOW RATES[1, 2, 3]

TYPE OF OCCUPANCY	GALLONS PER DAY
14. Parks, mobile homes	250 per space
Picnic parks (toilets only)	20 per parking space
Recreational vehicles	
without water hook up	75 per space
with water and sewer hook up	100 per space
15. Restaurants cafeterias	20 per employee
toilet	7 per customer
kitchen waste	6 per meal
add for garbage disposal	1 per meal
add for cocktail lounge	2 per customer
kitchen waste disposable service	2 per meal
16. Schools Staff and office	20 per person
Elementary students	15 per person
Intermediate and high	20 per student
with gym and showers, add	5 per student
with cafeteria, add	3 per student
Boarding, total waste	100 per person
17. Service station, toilets	1000 for 1st bay
	500 for each additional bay
18. Stores	20 per employee
Public restrooms, add	1 per 10 square feet of floor space
19. Swimming pools, public	10 per person
20. Theaters, auditoriums	5 per seat
Drive in	10 per space

For SI units: square foot = 0.0929 m², gallon per day = 3.785 L/day

Notes:

[1] Sewage disposal systems sized using the estimated waste/sewage flow rates shall be calculated as follows:

(a) Waste/sewage flow, up to [illegible]500 gallons per day ([illegible]5678 L/day)

Flow x [illegible]5 = septic tank size

(b) Waste/sewage flow, over [illegible]500 gallons per day ([illegible]5678 L/day)

Flow x 0.75 + [illegible]25 = septic tank size

(c) Secondary system shall be sized for total flow per 24 hours.

[2] See Section H 2.

[3] Because of the many variables encountered, it is not possible to set absolute values for waste/sewage flow rates for all situations. The designer should evaluate each situation and, where figures in this table need modification, they should be made with the concurrence of the Authority Having Jurisdiction.

Appendix (C)

C-1: Human comfort

HUMAN COMFORT

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

C-2: Human comfort

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

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

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

C-3: vrf in door unit Samsung

2-1. Indoor units

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

Heat pump Samsung

Heat Pump (Standard)

Model	AM080FXVAGH/EU	AM100FXVAGH/EU	AM120FXVAGH/EU	AM140FXVAGH/EU	AM160FXVAGH/EU	AM180FXVAGH/EU	AM200FXVAGH/EU	AM220FXVAGH/EU	AM240HXVAGH/EU	AM260HXVAGH/EU
AM080FXVAGH/EU	1									
AM100FXVAGH/EU		1								
AM120FXVAGH/EU			1							
AM140FXVAGH/EU				1						
AM160FXVAGH/EU					1					
AM180FXVAGH/EU						1				
AM200FXVAGH/EU							1			
AM220FXVAGH/EU								1		
AM240HXVAGH/EU									1	
AM260HXVAGH/EU										1
AM280HXVAGH1EU			1		1					
AM300HXVAGH1EU			1			1				
AM320HXVAGH1EU			1				1			
AM340HXVAGH1EU			1					1		
AM360HXVAGH1EU				1				1		
AM380HXVAGH1EU					1			1		
AM400HXVAGH1EU				1						1
AM420HXVAGH1EU							1	1		
AM440HXVAGH1EU								2		
AM460HXVAGH1EU			2					1		
AM480HXVAGH1EU			1	1				1		
AM500HXVAGH1EU			1		1			1		
AM520HXVAGH1EU			1			1		1		
AM540HXVAGH1EU			1				1	1		
AM560HXVAGH1EU			1					2		
AM580HXVAGH1EU				1				2		
AM600HXVAGH1EU					1			2		
AM620HXVAGH1EU						1		2		
AM640HXVAGH1EU							1	2		
AM660HXVAGH1EU								3		
AM680HXVAGH1EU			2					2		
AM700HXVAGH1EU			1	1				2		
AM720HXVAGH1EU			1		1			2		
AM740HXVAGH1EU			1			1		2		
AM760HXVAGH1EU			1				1	2		
AM780HXVAGH1EU			1					3		
AM800HXVAGH1EU				1				3		

C-5: Size of pipe A

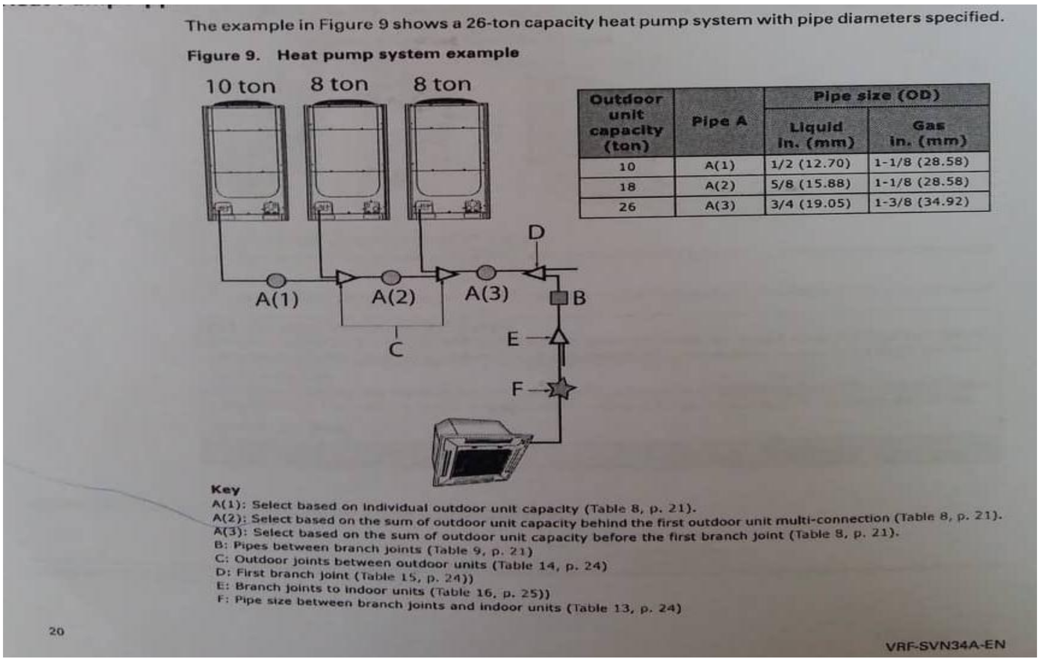
The example in Figure 9 shows a 26-ton capacity heat pump system with pipe diameters specified.

Figure 9. Heat pump system example

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

Key

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

20 VRF-SVN34A-EN

C-6: Size of pipe F

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

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

C-7: Size of pipe E

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

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

C-8: Size of pipe B

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

Table 9. Pipe size between branch joints (B)

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

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

C-9: vrf in door unit samsung

Heat Pump (Standard)

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

BILL OF QUANTITIES

Itom NO	DISCRIPTION	Unit	Quality	Price/ Unit
1	**VRF**			
1.1	**Indoor Units**			
1.1.1	Ceiling VRF indoor units. Price includes all required electrical and gas connections, and operating perfectly. Price includes hangers, isolating valves, and electrical connection to power source. All connections and installation should be executed according to manufacturer instructions. Selection to be based on medium speed, external air pressure of 0.25 ", indoor temperature of 24 C and outdoor temperature of 30 C (summer) 4.7 C (winter)			
1.1.1.1	nominal capacity 5.6	**NO.**	20	
1.1.1.2	nominal capacity 4.1		3	
1.1.2	4-way cassette VRF indoor units. Price includes all required electrical and gas connections, and operating perfectly. Price includes hangers, isolating valves, and electrical connection to power source. All connections and installation should be executed according to manufacturer instructions. Selection to be based on medium speed, external air pressure of 0.25 ", indoor temperature of 24 C and outdoor temperature of 31.9 C (summer) 5.7 C (winter)			
1.1.2.1	nominal capacity 9	**NO.**	4	
1.1.2.2	nominal capacity 11.2	**NO.**	5	
1.1.2.3	nominal capacity 12.8	**NO.**	6	
1.2	**Out Door**			
1.2.1	AM120FXVA GH/EU	**NO.**	**2**	
1.2.2	AM120FXVA GH/EU	**NO.**	**2**	
1.2.3	AM120FXVA GH/EU	**NO.**	**2**	
1.3	**Piping network**			
	Supply and install drain and insulated copper pipes for refrigerant 410 between indoor units and outdoor unit with sizes according to manufacturer instructions and calculations. Price includes all required fittings, hanging, insulation and digging.			
1.3.2	9.52mm	m	102	
1.3.3	12.7mm	m	132	
1.3.4	15.88mm	m	200	
1.3.5	19.05mm	m	157	
1.3.6	22.22mm	m	113	
1.3.7	28.58mm	m	130	
1.3.8	34.92mm	m	65	

1.3.9	41.28mm	m	47	
1.4	**Accessories**			
1.4.1	Refnet Joint	No.	38	
1.4.2	Refrigerant Amount (R410 A)	Kg	160	
2	**VENTLATION**			
	Centrifugal Exhaust Fans set (one duty and one stand-by), complete as per drawings and specifications.			
2.1	100 cfm 0.8bar	No.	1	
2.2	200 cfm 0.8 bar	No.	6	
2.3	400 cfm 0.8 bar	No.	4	
3	**Water System**			
3.1	**Pumps**			
	Supply, install, test & commission water pump set including motor, interconnecting pipe work, complete with all valves, vents, manifolds, gauges, control panel, level switches, pressure vessel & frequency inverter etc., as per specifications and drawings. 4.2 bar and 78 gpm for cold water 4.2 bar and 51 gpm for hot water			
3.1.1	**L.P.** (Lifting pumps set /2 pumps)	SET	1	
3.1.2	**C.W.P.-1** (Set/2 booster pump) with	SET	1	
3.1.6	**H.W.P** (Set/2 (Directly feeds floors with hot water)	SET	1	
3.2	**Pipes**			
3.2.1	Galvanized steel pipes to BS1387 of various sizes for domestic cold and hot water above false ceiling, in walls, etc. Including fittings, supports, expansion loops, thermal insulation cladding of all external and trenches pipes.			
3.2.1.1	20 mm dia pipe (3/4")	m	25	
3.2.1.2	25 mm dia pipe (1")	m	36.16	
3.2.1.3	32 mm dia pipe (11/4")	m	34.56	
3.2.1.4	40 mm dia pipe (1 1/2")	m	70	
3.2.1.5	50 mm dia pipe (2")	m	64.35	
3.2.1.6	65 mm dia pipe (2 1/2")	m	24	
3.2.2	Pex pipes to BS1387 of various sizes for domestic cold and hot water above false ceiling, in walls, etc. Including fittings, supports, expansion loops, thermal insulation cladding of all external and trenches pipes.	ML	320	
3.2.2.1	16 mm dia pipe	m	580	
3.3	**Water Manifolds**			
	Supply, install, test and commission wall hung type steel hot and cold water copper manifolds 16 mm dia outlets. The unit price shall include plug and washer, adaptors with O- rings, brackets, drain cocks, isolating ball valves with T-handle on all outlets, automatic air vent on each manifold, and all accessories and works required to complete the work as shown in the drawings and engineers instructions.			
3.3.1	25 mm dia collector, 8 outlets (average)	No.	51	
4	**Firefighting System**			
4.1	Fire hose reel cabinet (double compartment) including isolating valve with SS304 fully recessed cabinet, 19 mm dia x 25 m rubber hose, ABC 6 kg powder extinguisher and 4.5 kg CO_2 extinguisher.	No.	9	

4.2	Black seamless steel pipe.			
4.2.1	25mm dia pipe (1")	ML	530	
4.2.2	31.25 mm dia pipe (1 1/4")	ML	440	
4.2.3	37.5 mm dia pipe (1 1/2")	ML	210	
4.2.4	mm dia pipe (2")	ML	140	
4.2.5	mm dia pipe(2.5")	ML	90	
2.4.6	mm dia pipe(3")	ML	55	
2.4.7	mm dia pipe(4")	ML	40	
4.3	**Pumps** Supply, install, test and commission fire pumps set, complete with all components including duty pump, split case (electric driven), emergency pump (diesel), jockey pump, centrifugal (electric driven). Price shall include electric control panels, pressurized tank, cork and foundation bed, controllers, accessories for all pumps including wiring connections, all components, water measuring devices including flow meter and sensor, pressure gauges, relief valves, gate valves, check valves etc., all electrical works needed to complete the work according to engineer's instructions. 552 gpm and 7.7 bar			
4.3.1	Electrical pump :552 **gpm, 7.7 bar**	No.	1	
4.3.2	Diesel pump : 552**gpm, 7.7 bar**	No.	1	
4.3.3	Jockey pump 180 gpm, 2.5 bar	No.	1	
4.4	**Fire Extinguisher**			
4.5	K-type dry powder fire extinguishers.	No.	18	
4.6	CO_2 fire extinguishers.	No.	4	
4.7	Self-automatic extinguisher.	No.	6	
4.8	Siamese connection assembly complete with non-return valves. Outlet of 100m dia, and inlet of 65mm dia.	No.	1	
4.9	Supply and install landing valve, complete with fire hose rack.	No.	10	
4.10	Supply and install clean agent system with all accessories such as valves, control, nozzles, etc. All complete as per detailed specifications and drawings.	Set	18	
4.11	Supply and install Fire hydrant, pedestal type and maintain stand spot fitted with 75mm twin faced flanged fire hydrant, complete with isolating valve, an automatic shut-off valve, complete with all necessary mechanical fittings.	No.	9	
4.12	Supply and install Fire hydrant Cabinet, complete with all needed equipment's.,	No.	9	
4.13	Supply, lift into position, install, test, set to work, and commission sprinkler head as following and as per drawings Sprinkler head pendent recessed center link type, Part No. 13577W/B (½ Inch)56 diameter -ORIFICE 15 mm (½ Inch) NPT male connection bronze finish UL/FM approved.	No.	190	
4.14	Supply and install fire system for kitchen consists of 6 nozzles, heat detector sense fire and activate the wet chemical cylinder and wet chemical cylinders all according to drawings and specifications.	Set	1	
5	**Drainage System**			
5.2	**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	No.	46	

	drawings and as per engineer's instructions. Price shall include hand spray hose (connected to domestic cold water), holding paper, and paper basket.			
5.3	**Shower Tray**			
5.3.1	Supply install and test shower tray (80cmx80cm) White Vitreous China connected to domestic cold and hot water supply and drainage network and all fittings and works required to complete the work as per drawings and as per engineer's instructions. Price shall include chrome plated shower mixer, chrome plated hand shower completes with flexible hose 150 cm long and chrome plated shower hanger, Pax pipes, 2" and 4" UPVC pipes needed to connect the tray to the nearest main drainage and supply it with water, Single robe/clothes hook with concealed mounting type	No.	41	
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.	4	
5.5	**Lavatory**			
5.5.1	Supply and install laboratory molded sink 46x46 cm made of anti-corrosion polypropylene with high resistance to acids, alkaline and base chemicals. Price shall include incorporated overflow, complete with threaded drainpipe, made as a single piece without joints. All according to drawings and specifications and as per engineer's instructions	No.	50	
5.6	**UPVC Pipes**			
	Supply, install, and test UPVC pipes and fittings for waste, soil, and rain water drainage services. Price includes all kinds of digging in concrete slabs and walls, supports, hangers and all rubber joints and sealants, syphon and connection to floor drain and flexible connections and all types of fittings. All done according to drawings, specifications and engineer's instructions.			
5.6.1	110 mm dia. (4")	m	330	
5.6.2	150 mm dia. (6")	m	38	
5.6.3	200 mm dia (8")	m	10	
5.6.4	50 mm dia. (2")	m	285	
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.	58	
5.7.2	***FD-HDPE*** and with chromium plated cover, mesh and all accessories needed	No.	44	
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.		49	

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.	2	
5.9.2	100 mm dia. (3")	No.	2	
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")	m	53	
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.	1	
5.11.3	Depth 140 cm - 250 cm. Dia 100 cm	No.	2	
5.11.4	Depth 250 cm - ∞ cm, Dia 120 cm	No.	5	