Palestine Polytechnic University

College of Engineering and Technology

Mechanical Engineering Department

Graduation Project

Design and Documentation of a Mechanical system for a residential building in Hebron

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Abstract

This project aims to design mechanical systems that will serve the residential building which is located at Al-Haras street, Hebron. The project is going to provide an integrating mechanical service to that building in regard to the air conditioning, fire fighting and plumbing systems.

The building consists of four floors as well as a basement. Each floor has an area of about 1300 m^2 on which seven apartments are constructed.

The selected system for air conditioning in the building is Variable Refrigerant Flow (VRF) type DVM plus 4 because of its high performance (efficiency) and it is environmental friendly.

The selected systems for firefighting are extinguishers, and fire hose cabinets.

Also, Jockey pump is used in order to rise the head.

يهدف هذا المشروع إلى تصميم أنظمة ميكانيكية لخدمة المبنى السكني الواقع في شارع الحرس، الخليل. حيث سيوفر المشروع خدمة ميكانيكية متكاملة لهذه البناية من حيث نظام التكييف و التبريد، نظام اطفاء الحريق، و نظام تزويد المياه و تصريفها من المبنى.

تتألف العمارة السكنية من أربع طوابق بالاضافة إلى طابق تسوية . مساحة الطابق الواحد ما يقارب 1300 متر مربع، و كل طابق يضم بداخله سبع شقق.

كان النظام المستخدم للتكييف و التدفئة في العمارة نظام ذو كفاءة عالية و ذو تأثير ايجابي على البيئة (لا يضر بالبيئة) و يسمى النظام ب:

Variable refrigerant flow (VRF) type DVM plus 4.

كما و تم اختيار طفايات الحريق بالاضافة إلى كابينة إطفاء الحريق في نظام إطفاء الحريق للمبنى.

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Chapter1

Introduction

1.1 Introduction

Residential buildings have special importance in Palestine due to the rapid increase in population growth, and lack of land owned by citizens especially as most of the land is being confiscated by Israeli occupation. In addition, Israeli imposed restrictions prevent Palestinians from building freely in their own lands. Therefore, the phenomenon of having many floor residential building's has become a common solution to end this suffering.

Based on the above, the present project proposes a complete mechanical design and documentation for one of these residential buildings that are designed to provide up-to-date facilities needed to guarantee a decent life for Palestinian families.

The main objectives of this project are:

1- To calculate, design, and document heating, ventilation and air conditioning system.

2- To calculate, design, and document the plumping system (Sanitary drainage and water supply system).

3- To calculate, design, and document fire fighting system.

4- To select the required equipment.

5- To prepare the required mechanical drawings for the mechanical systems.

6- To prepare the bill of quantity (BOQ).

Project benefits and justification are:

1- It will create sufficient experiences for the project team.

2- Provide the opportunity to review the mechanical systems.

1.2 Project description

The Residential building under consideration is located at al-Haras in Hebron city. It is approximately 150 m far away from the main street. A person can reach the building by using a shortcut street with a width of 4 m.

Figure (1.1): Project location

It consists of four floors as well as a basement. Each floor has an area of about 1300 m^2 on which seven apartments are constructed.

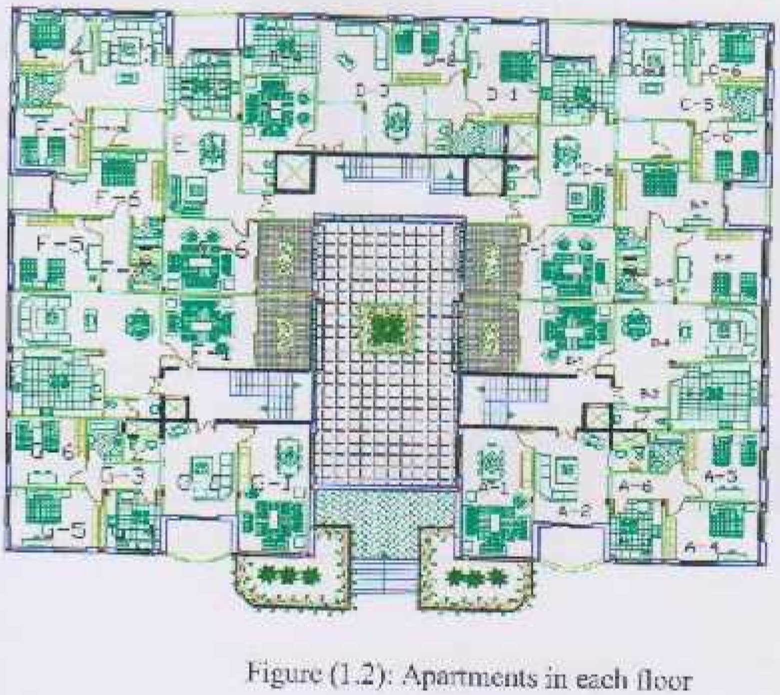


Figure (1.2): Apartments in each floor

1.3 Methodology and project tools

A scientific research method will be adopted in conducting this project. Besides, the theoretical framework of the project will be collected from different scientific reference books, scientific journals, online sources, library, and engineering offices which are involved in this field. Ultimately, the basic principles of design acquired from the above mentioned sources will be definitely implemented on the current project.

1.4 Time Table

Table (1.1): Time table for the first semester

week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
... of the project	■	■														
... about information		■	■	■												
... for previous projects		■	■	■	■	■										
... Load calculation			■	■	■	■										
... load calculation							■	■	■	■						
... supply system											■	■	■			
... drainage system											■	■	■			
... fighting system													■	■		
... documentation			■	■	■	■	■	■	■	■	■	■	■	■	■	
... project																■

Table (1.2): Time table for the second semester

week / task	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Editing and modifying																
Design the HVAC system																
Design the plumping system																
Design the fire fighting system																
Selection and drawing the relevant systems																
Doing bill of quantity table																
Project documentation																
Printing project																

1.5 Project content

Chapter one: Introduction

It includes overview, project objectives, and time table.

Chapter two: Cooling and heating load calculation

It includes a sample calculation of heating and cooling loads for one room in details, and the loads of the other rooms.

Chapter Three: Plumping system

It includes the calculation of water supply system (Total amount of required water), and the drainage system.

Chapter Four: Fire fighting system

It includes general introduction, selection.

Chapter Five: Variable Refrigerant Flow System

It includes a brief introduction, selection of indoor and outdoor units, and ventilation in the basement and kitchens and bathrooms.

Chapter 2

Cooling and heating Load

2.1 Human Comfort

Thermal and atmospheric conditions in an enclosed space are usually controlled in order to ensure the health and comfort of occupants and to ensure the proper functioning of sensitive electronic equipment, such as computers, or certain manufacturing processes that have a limited range of temperature and humidity tolerance.

2.2 Comfort Conditions

Comfort is best defined as the absence of discomfort while thermal comfort is the condition of minimal stimulation of the skin's heat sensors and the heat sensing portion of the brain.

The factors that affect humans are:

1- Temperature of air.

2- Humidity of air.

3- Air motion.

4- Odors

2.3 Cooling Load

The cooling load is the rate at which heat energy must be removed from a space in order to maintain a given inside design condition. Heat gain of a given space or its cooling load can be removed by means of cooling equipment which supply cold air to space in adequate amounts to maintain a given inside design temperature.

2.3.1 Cooling Load Sources

The cooling load of a given space consists of the following heat gains:

1- Heat gains that are transmitted through shaded building structures such as walls, floors, and ceilings that are adjacent to unconditioned spaces.

2- Heat gains due to solar effects which include:

a- Solar radiation transmitted through glass into the air conditioned space and absorbed by inside space surface and furniture.

b- Solar radiation absorbed by walls, glass windows, glass doors, and roofs that are exposed to solar radiation.

3- Sensible and latent heat gains brought into the space as a result of infiltration of air through windows and doors.

4- Sensible heat produced in the space by lights, appliances, motors and other miscellaneous heat gains.

5- Latent heat produced from cooking, hot baths, or any other moisture producing equipment.

6- Sensible and latent heat gains due to occupants.

2.3.2 Cooling and heating Load Calculation

The calculation of the cooling and the heating load for the building begins by taking sample (see figure (2.1)), it will show all the cooling and the heating load sources gradually. The same principle can be adopted when calculating loads for other rooms.

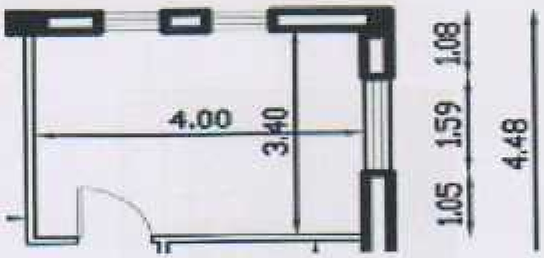


Figure (2.1): Sample selected for the purpose of calculation

Before starting the calculation of these loads some values and information must be prepared.

2.3.2.1 Overall heat transfer coefficient for various sections in the building

The general equation to calculate the overall heat transfer coefficient is:

$$U = \frac{1}{\frac{1}{h_{fin}} + \sum_{m=1}^{n} \frac{\Delta X}{k_m} + \frac{1}{h_{fout}}} \quad \text{--- eq. (2.1)}$$

Where:

U: overall heat transfer coefficient (W/m^2.°C).

h_{fin}: Inside convection heat transfer coefficient (W/m^2.°C).

h_{fout}: Outside convection heat transfer coefficient (W/m^2.°C).

Δx: thickness of each layer in the constructions (m).

k_m: Thermal conductivity of each layer in the construction (W/m.°C).

1- For outside walls:

Table (2.1): Outside walls construction

Number	Material	ΔX(m)	R_{th} (m^2.°C/W)
1	Stone	0.07	0.041
2	Concrete	0.2	0.114
3	Insulation polystyrene	0.03	0.5
4	Plaster cement	0.03	0.025

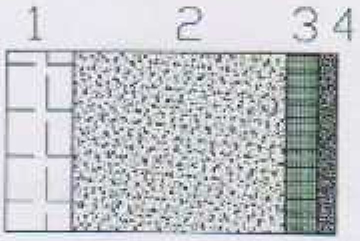


Figure (2.2): Outside wall construction

$$U = \frac{1}{\frac{1}{h_{fin}} + \sum_{m=1}^{n} \frac{\Delta X}{k_m} + \frac{1}{h_{fout}}} \quad \text{--- eq. (2.1)}$$

$$= \frac{1}{0.076+0.041+0.114+0.5+0.025+0.015} = 1.29 W/m^2.^{\circ}C$$

2- For inside walls:

Table (2.2): Inside wall construction

Number	Material	ΔX(m)	R_{th} ($m^2.^{\circ}C/W$)
1	Plaster	0.02	0.025
2	Cement Brick	0. 1	0.078
3	Plaster	0.02	0.025

Figure (2.3): Inside wall construction

$$U = \frac{1}{\frac{1}{h_{f\,in}} + \sum_{m=1}^{n} \frac{\Delta X}{k_m} + \frac{1}{h_{f\,out}}} = \frac{1}{0.05+0.025+0.078+0.025+0.029} = 3.3 W/m^2.^{\circ}C$$

3- For ceiling

Table (2.3): Ceiling construction

Material	Thickness (m)	k(W/m.°C)
Asphalt	0.02	0.7
Concrete	0.05	1.75
Polystyrene	0.05	0.03
Concrete	0.06	1.75
Brick	0.18	0.95
Plaster	0.02	1.2

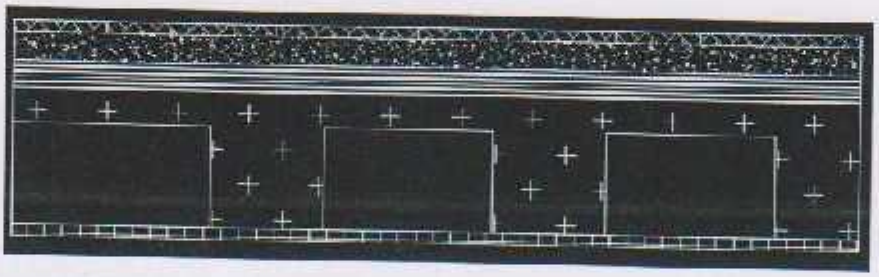


Figure (2.4): Ceiling construction

$$U_{ceiling,1} = \sum \frac{1}{R_{th}} = \frac{1}{\frac{1}{h_{f\,in}} + \sum_{m=1}^{n} \frac{\Delta X}{k_m} + \frac{1}{h_{f\,out}}} = 0.456\ W/m^2.^{\circ}C.$$

$$U_{ceiling,2} = \sum \frac{1}{R_{th}} = \frac{1}{\frac{1}{h_{f\,in}} + \sum_{m=1}^{n} \frac{\Delta X}{k_m} + \frac{1}{h_{f\,out}}} = 0.475\ W/m^2.^{\circ}C.$$

4- For floor, doors and windows:

-Window:

Glass and gap values are from the Palestinian code.

Table (2.4): Window construction

Material	Δx(m)	k (W/m.°C)
Glass	0.005	0.96
Gap	0.006	0.024
Glass	0.005	0.96

U_{window} = 0.38 W/m^2.°C.

-Door: $U_{door} = 2.4\ W/m^2.°C$

-Floor: $U_{floor} = 1.52\ W/m^2.°C$

2.3.2.2 Inside and outside design values

Table (2.5): Inside and outside design values

Properties	Values
Outdoor temperature (T_o), cooling	30 °C
Outdoor temperature (T_o), heating	4.7 °C
Day of calculation	20August
Outdoor enthalpy (h_{out}), heating	13 kJ/kg
Outdoor enthalpy (h_{out}), cooling	70.6 kJ/kg
Indoor enthalpy (h_{in}), heating	48 kJ/kg
Indoor enthalpy (h_{in}), cooling	34 kJ/kg
Outdoor design relative humidity, heating	71.1%
Inside design relative humidity	50%

2.3.2.3 Recommended temperatures for residential buildings

From Palestinian code for Residential building:

Table (2.6): Recommended temperatures

Room	Temperature (°C)
Bathroom	22
Bedroom	18
corridors	16
Salon	20

The Bathroom is unconditioned space, for unconditioned space temperature can be calculated in summer by using this equation:

$T_{Un} = T_{in} + \frac{2}{3} \times (T_{Surr} - T_{in})$ --- eq. (2.2)

Where:

T_{Un}: Is the unconditioned space temperature (°C).

T_{in}: Is the inside temperature (°C).

T_{Surr}: Is the surrounding temperature (°C).

Then:

$T_{Un} = 18 + \left(\frac{2}{3}\right) \times (30 - 18) = 26\ °C$.

2.3.2.4 Cooling load calculation

1- Heat gains that are transmitted through shaded building structures

The calculation of this type of heat gain can be obtained by using the following relation for heat transmission through the walls:

$Q = U \times A \times \Delta T$ --- eq. (2.3)

Where:

Q: Heat flow through the walls, ceiling, floor, by conduction (W).

U: Overall heat transfer coefficient ($W/m^2.°C$).

A: is the effective area that heat transmitted through it (m^2).

ΔT: The total equivalent temperature difference (°C).

Table (2.7): Heat gain transmitted through shaded building structures

Surface	Area (m^2)	U ($W/m^2.C$)	ΔT (C)	Q (W)
Wall1	7.75	1.3	12	128.3
Wall2	9.4	1.3	12	146.64
Wall3	9.38	3.3	9.3	287.63
Wall4	9.3	3.6	0	0
Ceiling	13.6	1.5	12	244.8
Floor	13.6	1.53	0	0
Window1	1.6	0.38	12	7.29
Window2	0.8	0.38	12	3.6
Window3	0.8	0.38	12	3.6
Door	1.8	2.4	-2	-8.64

2- Heat gain through sunlit walls and roofs

The calculation of this type of heat gain can be obtained by using the following relation for heat transmission through the walls:

Q= U×A ×(CLTD) corr --- eq. (2.4)

Where:

Q: Heat flow through the walls, ceiling, floor, by conduction (W).

U: Overall heat transfer coefficient ($W/m^2.°C$).

A: is the effective area that heat transmitted through it (m^2).

(CLTD) corr: The total equivalent temperature difference which takes into account the increase of the wall temperature due to absorption of solar radiation, and is called cooling load temperature difference (CLTD), the value of CLTD extracted from Table (A-3) needs to be corrected, so that the actual value is found for different cases, and hence it will be called corrected CLTD and can be calculated from the following equation:

(CLTD) corr = (CLTD+LM) k + (25.5-T_i) + ($T_{o,m}$ - 29.4) f --- eq. (2.5)

Where:

LM: latitude correction factor which can be obtained from Table (A-25) from reference for horizontal and vertical surfaces.

k: Color adjustment factor such that k=1.0 for dark colored roof, and k=0.5 for permanently light colored roofs.

(25.5-Ti) : a correction factor for indoor design temperature where Ti is the room design temperature °C.

($T_{o,m}$ −29.4): A correction factor for outdoor mean temperature.

It is related to the outdoor design temperatureT_o, according to the relation:

$T_{o,m} = T_o - \frac{DR}{2}$ --- eq. (2.6)

DR: The daily temperature range which equal to the difference between the average maximum and average minimum temperature for the wormiest month of the summer season.

f: Roof fan factor such that f =1.0 if there is no attic or roof fan and f =1 if there is not an attic or roof fan.

For equation (2.5):

k = 0.83 for walls, k= 1 for roof, f =1

$T_{o,m} = T_o - \frac{DR}{2}$ --- eq.(2.6)

= 30 – 12/2= 24 °C.

The wall group is group F; Block+ Air space insulation.

Table (2.8): Heat gains for walls and roof

Wall	CLTD(°C)	LM	$(CLTD)_{corr.}$(°C)	Q(W)
North	3	-0.5	4.475	53.138
West	5	-0.5	5.83	81.445
Roof	20	0	22.1	426.79

3- Heat gain through glass

Solar radiation which falls on glass has three components which are:

1- Transmitted component:

It represents the largest component, which is transmitted directly into the interior of the building or the space.

2-Absorbed component:

This component is absorbed by the glass itself and raises its temperature.

3-Reflected component:

This component is reflected by glass to the outside of the building.

The amount of solar radiation that can be transmitted through glass depends upon the following factor:

1- Type of glass (single, double or insulating glass) and availability of inside shading.

2- Hour of the day, day of the month, and month of the year.

3- Orientation of glass area (North, Northeast, East orientation, etc.).

4- Solar radiation intensity and solar incident angle.

5- Latitude angle of the location.

A- Transmission heat gain

The transmitted cooling load can be calculated from the relation:

$Q_{tr} = A \times SHG \times SC \times CLF$ --- eq. (2.7)

Where:

1- Solar heat factor (SHG); is a factor represents the amount of solar energy from table (A-12).

2- Shading coefficient (SC); this factor accounts for different shading effects of the glass wall or widow and can be extracted from special tables for single and double glass without inside shading or for single and double glass as well as for insulating glass with internal shading from Table (A-10), or (A-11).

3- Cooling load factor (CLF): 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.

Table (2.9): Heat gain from solar transmitted through glass

Surface	SHG	SC	CLF	Q_{tr} (W)
North	117	0.83	0.18	27.95
West1	445	0.84	0.09	26.9
West2	445	0.84	0.09	26.9

B - Convection heat gain

The value of the convection heat gain by the glass can be calculated from the equation:

$Q_{conv.} = U \times A \times (CLTD)_{corr.}$ --- eq. (2.8)

Where:

CLTD is the temperature difference for the glass and can be extracted from Table (A-7). Its designed for inside room temperature of 25.5°C and outside mean temperature of 29.4°C.If Ti and To,m are different from 25.5°C and 29.4°C, then a correction must be added to the value of CLTD.

Table (2.10): Convection heat gain

Orientation	Window	U ($W/m^2.°C$)	A (m^2)	$CLTD_{corr.}$ (°C)	$Q_{conv.}$ (W)
North	1	0.38	1.6	8	4.864
West	2	0.38	0.8	8	2.432
West	3	0.38	0.8	8	2.432

4 - 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:

$Q_{oc.} = Q_{Sensible} + Q_{Latent}$ --- eq. (2.9)

$Q_{Sensible}$ = heat gain sensible × No. of people × (CLF) oc. --- eq. (2.10)

Where: (CLF) oc.: cooling load factor due to occupants.

Heat gain sensible = 70 very light work … from Table A(21)

No. of people = 3

(CLF) oc. = 0.89 at 9 hours after each entry into space is obtained from Table A (6)

$Q_{Sensible} = 70 \times 3 \times 0.89$

= 186.9 W

Q_{Latent} = heat gain latent × No. of people --- eq. (2.11)

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

$Q_{Latent} = 44 \times 3$

= 132 W

$Q_{oc.} = 186.9 + 132 = 318.9$ W

= 0.3189 kW

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

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

$Q_{Lt.}$ = light intensity × A × (CLF) Lt. --- eq. (2.12)

Where:

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

A: floor area = 13.6 m^2.

(CLF)Lt.: cooling load factor for lights.

(CLF)Lt. = 0.84 ... from Table A (5)

Q Lt. = 30 × 13.6 × 0.84

= 342.72 W.

= 0.3427 kW.

6- Heat gain due to infiltration

Using the air crack age method to calculate the heat gain due to infiltration is showed in the following equation:

$Q_{inf.} = \frac{\dot{V}}{v_o}(h_o - h_i)$ --- eq. (2.13)

Where:

$\dot{V}$ = k×L[0.613($s_1 \times s_2 \times$ v) ^{2}]^(2/3) --- eq. (2.14)

k: The infiltration air coefficient.

L: The crack length in meter (m).

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: measured wind speed (m/s) , from the Palestinian code 1.4m/s.

h: is the outside and the inside enthalpy respectively.

v_o: is the specific volume.

$Q_{inf.}$ From windows

$\dot{V}$ = k×L[0.613($s_1 \times s_2 \times$ v) ^{2}]^(2/3) --- eq. (2.14)

Where:

K: Infiltration air Coefficient, from Table A (13), K for double glass Aluminum is 0.45 W/ m. °C.

L= 4× ([(1.6×1) + (0.8×2)] = 12.8 m .

S_1: Factor depends on the topography of location =1, Table (A19)

S_2: Factor depends on the height building = 0.95, Table (A20)

v: The measured wind speed

$\dot{V}$= 28.75 m³/h.

$Q_{inf.}$ Windows = 132.7 W

$Q_{inf.}$ From door

K: Infiltration air Coefficient, from Table A13, K for double glass Aluminum is 0.65 W/ m. °C.

L=1.8 m

$Q_{inf.}$ Door = 4.055 W.

Table (2.11): The total $Q_{inf.}$ due to door and windows

Loads	Q_{inf} (W)
Windows	132.7
Door	4.055

7- 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:

$Q_{vent.} = \dot{m} \times C_{p_{air}} \times (T_o - T_{in})$ --- eq. (2.15)

Where:

$\dot{m}$: mass flow rate of ventilation air (kg/s).

$\dot{m} = \frac{Rate\ of\ ventilation\ air}{v_o}$ --- eq. (2.16)

Rate of ventilation = Room Area × Requirement outside ventilation air --- eq. (2.17)

= 4×3.4×5 = 68 L/s = 0.068 m^3/s.

v_o = 0.84 m^3/kg.

$\dot{m}$ = 0.0809kg/s.

$C_{p_{air}}$: Specific heat of air, $C_{p_{air}}$ = 1.005 kJ/kg.°C.

$Q_{vent.}$ = 0.0809×1.005 × (30-18) = 0.975 kW.

Table (2.12): The total cooling load for the sample

Type of Q	Q(W)
Q_{gain}	813.22
$Q_{walls,ceiling}$	561.373
Q glass	91.478
Q oc.	318.9
Q l.t.	342.72
$Q_{inf.}$	136.7
$Q_{vent.}$	975

Q tot = 3239.39 W.

For all the apartments in the floor, the total cooling load is illustrated:

Table (2.13): Apartment A, B

Apartment A	Q(kW)	Apartment B	Q(kW)
A-1	6.483622	B-1	4.345788
A-2	6.756617	B-2	1.560728
A-3	2.275407	B-3	4.445642
A-4	4.126177	B-4	4.567966
A-5	3.643991	B-5	1.204773
A-6	3.979857	B-6	4.567966
-	-	B-7	4.974208
Total	27.26567	Total	25.66707

Table (2.14): Apartment C, D

Apartment C	Q(kW)	Apartment D	Q(kW)
C-1	4.345788	D-1	5.05997
C-2	4.69392	D-2	3.256707
C-3	3.757739	D-3	6.858719
C-4	4.654856	D-4	2.90463
C-5	0.625856	D-5	3.476435
C-6	3.069384	-	-
C-7	3.168688	-	-
Total	24.31623	Total	21.55646

Table (2.15): Apartment E, F

Apartment E	Q(kW)	Apartment F	Q(kW)
E-1	4.557992	F-1	4.3346
E-2	3.344726	F-2	4.252
E-3	4.716921	F-3	4.252
E-4	3.107751	F-4	1.204773
E-5	3.387607	F-5	4.567966
E-6	4.30276	F-6	4.457829
Total	23.41776	Total	23.06917

Table (2.16): Apartment G

Apartment G	Q(kW)
G-1	6.60387
G-2	6.7772
G-3	0.924116
G-4	3.965938
G-5	3.965938
G-6	3.681794
Total	25.91885

Table (2.17): Total cooling load for each floor

Floor	Q(kW)
Ground Floor	141.089
First Floor	132.421
Second Floor	132.4126
Third Floor	171.213

Total cooling load in the building = 577.1356kW.

2.3.2.5 Heating load calculation

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

1- Heat loss through all exposed walls, ceiling, floor, windows, doors, and walls between a heated space and an unheated space.

2- Heat load required to warm outside cold air infiltrated to heated space through cracks of windows and doors, and outside cold air infiltrated due to opening and closing of doors.

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

Heat loss calculations

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

$$\dot{Q} = A \times U \times (T_i - T_o) \text{ ---- } \quad \text{eq. (2.18)}$$

Where:

$\dot{Q}$: is the heat transfer rate.

A: is the area of the layer which heat flows through it.

ΔT: is the difference between the inside and outside temperatures.

U: is the overall heat transfer coefficient.

1 - Rate of heat transfer from external walls

$Q_{ex.wall} = U_{ex.wall} \times A_{ex.wall} \times (T_{in} - T_{sur})$ --- eq. (2.19)

2 - Rate of heat transfer from the internal walls

$Q_{in,walls} = U_{in,walls} \times A_{in,walls} \times (T_{in} - T_{un/space})$ --- eq. (2.20)

For the internal wall which appears between the sample room and the bath roomT_{sur} -

$T_{un/space} = 18 + \left(\frac{2}{3}\right) \times (18 - 4.7) = 9.14$ °C.

3 - Rate of heat loss transfer from the ceiling

From table (2.3) and figure (2.4) the construction of the ceiling is known, then by using equation(2.21). we can determine the rate of heat transfer for the room from the ceiling as follows:

$Q_{ceiling} = U_{ceiling} \times A_{ceiling} \times (T_{in} - T_{sur.})$ --- eq. (2.21)

4 - Heat loss due to infiltration

Infiltration is the leakage of the outside air through cracks or clearances around the windows and doors. As shown before in the cooling load calculation:

Table (2.18): The total Q_{inf} due to door and windows

Loads	Q_{inf} (W)
Windows	132.7
Door	4.055

5 -Heat loss due to ventilation

The ventilation is used for maintaining a healthy indoor air by introducing a fresh air from outside of the building.

$\dot{V}_v = 3 \times (3.8 \times 2.75 \times 4) = 125.4\, m^3/h = 0.035\, m^3/s.$

$$\dot{m}_f = \frac{0.035}{0.98} = 0.039\ \text{kg/s}.$$

$$\dot{Q}_{ventilation} = 0.039 \times 1000 \times (48 - 13) = 1365\, W$$

Table (2.19): Heat loss through shaded building structures

Surface	Area(m^2)	U($W/m^2.C^o$)	ΔT(C^o)	Q(W)
Wall 1	7.75	1.3	13.3	133.9975
Wall 2	9.4	1.3	13.3	162.526
Wall 3 in	9.38	3.3	8.86	274.2524
Wall4 in	9.3	3.6	0	0
Ceiling	13.6	1.5	13.3	271.32
Floor	13.6	1.53	0	0
Window 1	1.6	0.38	13.3	8.0864
Window 2	0.8	0.38	13.3	4.0432
Window 3	0.8	0.38	13.3	4.0432
Door in	1.8	2.4	2	8.64
-	-	-	Total	866.9087

Table (2.20) Total heat loss from the sample

Type of loss	Q(W)
$Q_{ventilation}$	1365
$Q_{inf.}$	136.755
Q_{loss}	866.9087
Total	2368.664

Table (2.21): Total heat loss from apartment A, B

Apartment A	Q(kW)	Apartment B	Q(kW)
A-1	5.001545	B-1	0.93632
A-2	5.212136	B-2	1.21296
A-3	1.755276	B-3	3.429422
A-4	3.182983	B-4	3.523784
A-5	2.811019	B-5	0.93632
A-6	3.093048	B-6	3.523784
-	-	B-7	3.837164

Table (2.22): Total heat loss from apartment C, D

Apartment C	Q(kW)	Apartment D	Q(kW)
C-1	3.37744	D-1	3.903322
C-2	3.648	D-2	2.512263
C-3	2.898765	D-3	5.290899
C-4	3.590813	D-4	2.240667
C-5	0.4864	D-5	2.7018
C-6	2.36776	-	-
C-7	2.444364	-	-

Table (2.23): Total heat loss from apartment E, F

Apartment E	Q(kW)	Apartment F	Q(kW)
E-1	2.7018	F-1	3.368746
E-2	2.580162	F-2	3.429422
E-3	3.63869	F-3	3.280044
E-4	2.397357	F-4	0.93632
E-5	2.613241	F-5	3.523784
E-6	3.344	F-6	3.438823

Table (2.24): Total heat loss from apartment G

Apartment G	Q(kW)
G-1	5.094305
G-2	5.228014
G-3	0.7182
G-4	1.847984
G-5	3.059372
G-6	2.84018

Table (2.25): Total heat loss from each floor

Floor	Q(kW)
Ground Floor	95.27761
First Floor	91.488
Second Floor	91.466
Third Floor	103.65

Total heating load of the building is 381.88kW.

Chapter 3

Plumping system

3.1 Introduction

There are two main functions of using plumping systems:

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

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

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

In the project up feed distribution system will be used for both cold and hot water systems. Fixture units at the building are designed for private uses, flush tanks used for water closets because it needs low pressure, steel pipes will be used for hot and cold water systems, seven risers will be used for cold and hot water supply systems, riser No. 1.0 is identical to risers No. 3.0, 4.0, 5.0, 7.0, While riser No.2.0 is identical to riser No. 6.0. The critical fixture unit in the system is the kitchen sink fixture unit which is located at the fourth floor of the building.

3.2 Water Supply system

3.2.1 Introduction

The main objective of water supply system is to provide the building with the needed amount of water for daily use, such as drinking, cooking, washing and flushing, fire fighting, bathing, and irrigation.

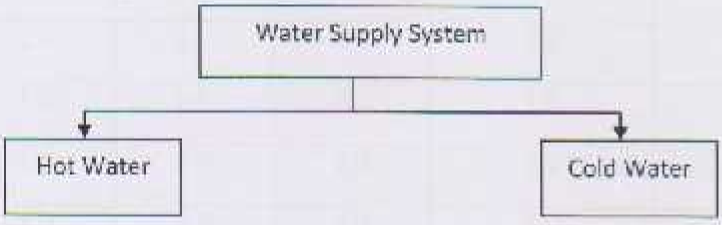


Figure (3.1): Water supply system

3.2.2 Design procedure

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

3.2.3 Calculation of hot and cold water supply system

3.2.3.1 Water supply fixture units load (WSFU)

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

3.2.3.1.1 Total WSFU for the first riser

Tables (3.1, 3.2) below shows the total numbers of fixture units and the total water supply fixture unit (WSFU) for the first riser.

Table (3.1): Total number of fixture units of the first riser in each floor

Fixture type / Floor	Kitchen sink	Lavatory	Water closet	bathtub	Bidet
Ground floor	1.0	2.0	2.0	1.0	1.0
First floor	1.0	2.0	2.0	1.0	1.0
Second floor	1.0	2.0	2.0	1.0	1.0
Third floor	1.0	2.0	2.0	1.0	1.0
Total	4.0	8.0	8.0	4.0	4.0

The figure 3.2 shows the first riser diagram

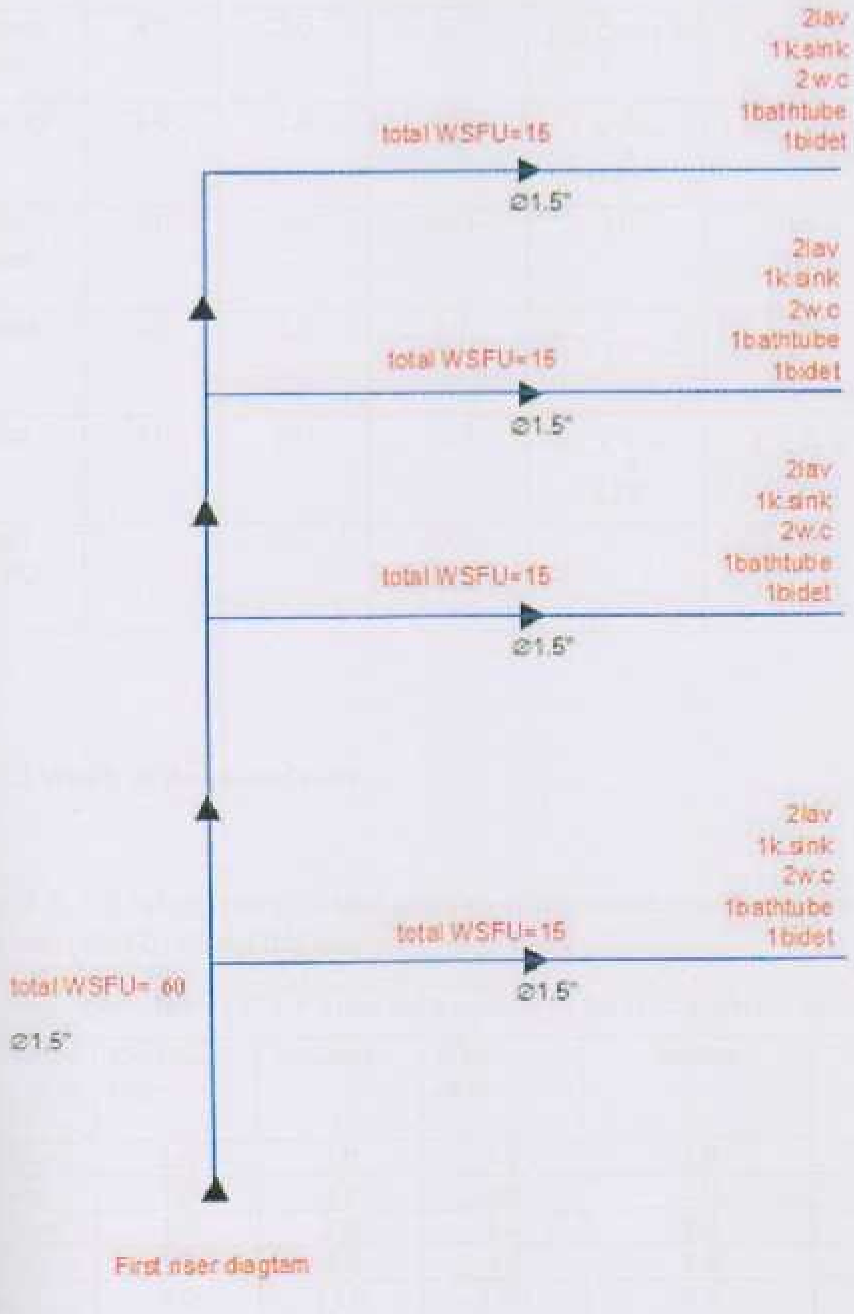


Figure (3.2): First riser diagram

Table (3.2): Total WSFU of the first riser

Fixture Type	No .OF FU	WSFU	Total WSFU	Cold WSFU	Hot WSFU	Total Cold	Total Hot
Kitchen sink	4.0	2.0	8.0	$2 \times \frac{3}{4} = 1.5$	$2 \times \frac{3}{4} = 1.5$	6.0	6.0
Lavatory	8.0	1.0	8.0	$1 \times \frac{3}{4} = 0.75$	$1 \times \frac{3}{4} = 0.75$	6.0	6.0
Water closet	8.0	3.0	24.0	3.0	0.0	24.0	0.0
bathtub	4.0	2.0	8.0	$2 \times \frac{3}{4} = 1.5$	$2 \times \frac{3}{4} = 1.5$	6.0	6.0
Bidet	4.0	3.0	12.0	$3 \times \frac{3}{4} = 2.25$	$3 \times \frac{3}{4} = 2.25$	9.0	9.0
Total WSFU	-	-	60.0	-	-	51.0	27.0

3.2.3.1.2 WSFU at the second riser

Tables (3.3, 3.4) below shows the total numbers of fixture units and the total water supply fixture unit (WSFU) for the first riser.

Table (3.3): Fixture units number of the second riser in each floor

Fixture type / Floor	Kitchen sink	Lavatory	Water closet	bathtub	Bidet
Ground floor	1.0	3.0	3.0	2.0	0.0
First floor	1.0	3.0	3.0	2.0	0.0
Second floor	1.0	3.0	3.0	2.0	0.0
Third floor	1.0	3.0	3.0	2.0	0.0
Total	4.0	12.0	12.0	8.0	0.0

Figure 3.3 shows the second riser diagram

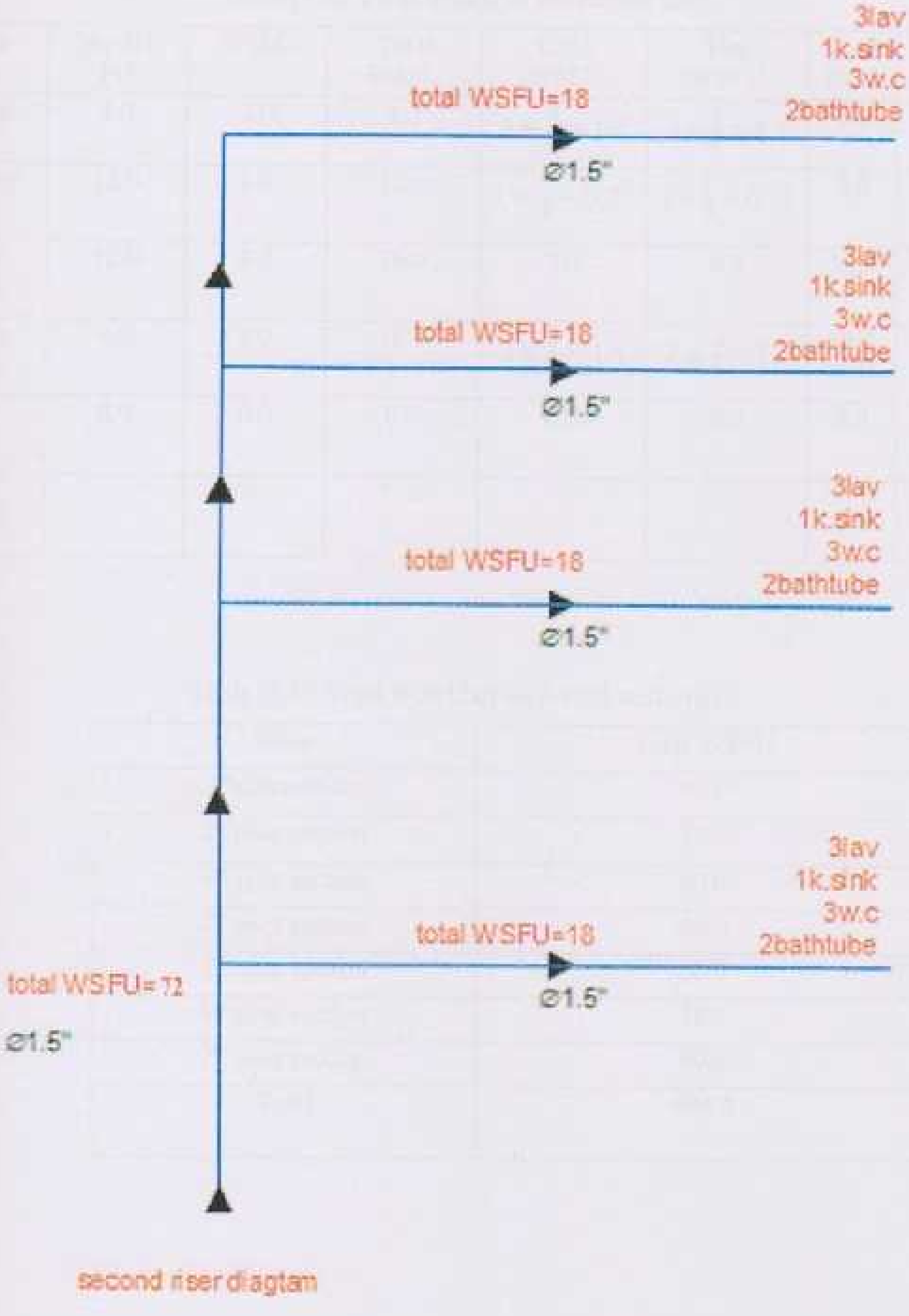


Figure (3.3): Second riser diagram

Table (3.4): Total WSFU of the second riser

Fixture Type	No .OF FU	WSFU	Total WSFU	Cold WSFU	Hot WSFU	Total Cold	Total Hot
Kitchen sink	4.0	2.0	8.0	$2 \times \frac{3}{4} = 1.5$	$2\times \frac{3}{4} - 1.5$	6.0	6.0
Lavatory	12.0	1.0	12.0	$1 \times \frac{3}{4} = 0.75$	$1\times \frac{3}{4} = 0.75$	9.0	9.0
Water closet	12.0	3.0	36.0	3.0	0.0	36.0	0.0
bathtub	8.0	2.0	16.0	$2 \times \frac{3}{4} = 1.5$	$2 \times \frac{3}{4} = 1.5$	12.0	12.0
bidet	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total WSFU	-	-	72.0	-	-	63.0	27.0

Table (3.5): Total WSFU of each cold water riser

Riser	Total WSFU
1strisersection	60.0
2ndriser section	72.0
3rd riser section	60.0
4th riser section	60.0
5th riser section	60.0
6th riser section	72.0
7th riser section	60.0
Total	444.0

3.2.4 Pipe Sizing

In order to calculate the size of each pipe in the water supply system, friction head must be calculated by using the up-feed distribution system equation:

Main pressure (pump pressure) = Static head + Pipe friction + Flow pressure eq. (3.1)

Where:

Static head; is to overcome the height from the source to the critical fixture unit outlet.

Pipe friction; caused by the friction of the moving water inside pipes.

Flow pressure; to overcome the minimum flow pressure, and to impart kinetic energy to the water.

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 (kitchen sink) is 8.0 psi.
2- It is indicated that main pressure (pump pressure) is 50.0 psi.
3- The estimated water meter loss is 5.0 psi

Static pressure:
As indicated previously that the building consists of four floors and basement (floor to floor height is 3.0 meters) , then as shown in the figure below it appears that the total vertical length from the pump source to the critical fixture (Kitchen sink) is 13.30 m.
The figure (3.4) shows the static head of the building

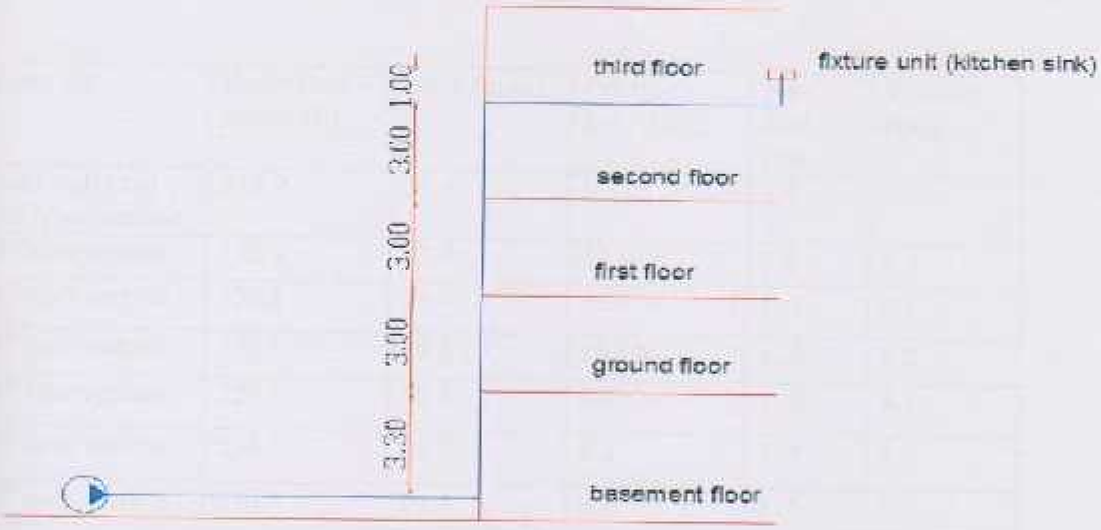


Figure (3.4): Static head of the building

Static pressure $= 13.3 \times \frac{0.433}{0.33} = 17.5$ psi eq. (3.2)

By using the above equation, the pipe friction can be calculated by moving some terms from right to lift to get the following equation:

Pipe friction = Main pressure (pump pressure) - Static head - Flow pressure eq. (3.3)
$= 50.0 - 17.5 - 8.0 = 24.5$ psi

The estimated water meter loss is 5.0 psi, so:

Friction head= Pipe friction – Water meter loss
$= 24.5 - 5.0 = 19.5$ psi eq. (3.4)

On the other hand, One more thing must be calculated which is the total equivalent length (TEL). It appears from the mechanical drawings that the length of the first riser is 47.07 meter.

TEL= $\frac{Total\ length\ (m) \times 1.5}{0.33}$ $= 47.07 \times 1.5 / 0.33 = 213.9$ ft. eq. (3.5)

Uniform design friction loss $= \frac{19.5 \times 100}{213.9} = 9.11 \ \frac{psi}{100ft}$ eq. (3.6)

Table (3.6): Pipe sizing of cold water risers

Riser No.	Equivalent length (ft)	Flow (gpm)	Friction (psi/100ft)	Pipe size (in)	Velocity (fps)
cold water tap to 1st riser section	213.9	29.4	9.11	1.5	5.6
2nd riser section	176.8	33.9	11.0	1.5	6.3
3rd riser section	156.8	29.4	12.4	1. 5	6.8
4th riser section	192.1	29.4	10.15	1. 5	5.8
5th riser section	229.1	29.4	8.5	1. 5	5.5
6th riser section	234.7	33.9	8.3	1. 5	5.2
7th riser section	286.3	29.4	6.8	1. 5	5.0

According to the above table, the main pipe diameter for each riser in the cold water supply system is 1.5″.

Table (3.7): Pipe sizing of hot water risers

No of riser	Equivalent length (ft)	Flow (gpm)	Friction (psi/100ft)	Pipe size (in)	Velocity (fps)
... water tap ... riser section	213.9	18.2	9.11	1.25	5.3
... riser section	176.8	18.2	11.0	1.25	5.5
... riser section	156.8	18.2	12.4	1.25	5.7
... riser section	192.1	18.2	10.15	1.25	5.3
... riser section	229.1	18.2	8.5	1.25	5.1
... riser section	234.7	18.2	8.3	1.25	5
... riser section	286.3	18.2	6.8	1.25	4.8

According to the above table, the main pipe diameter for each riser in the hot water supply system is 1.25″.

Calculation for the main pipe diameter

The total water supply fixture unit for hot water risers equal 189WSFU and for cold water risers equal 381WSFU.

The total demand for cold water equals 101.2 GPM and the total demand for hot water equals 62.8 GPM, and the water tank is about 214 m^3 as shown in drawings.

The friction loss is 9.11 psi/100ft

So the pipe diameter of the main pump is 4.0".

Figure (3.5) shows hot and cold water riser :

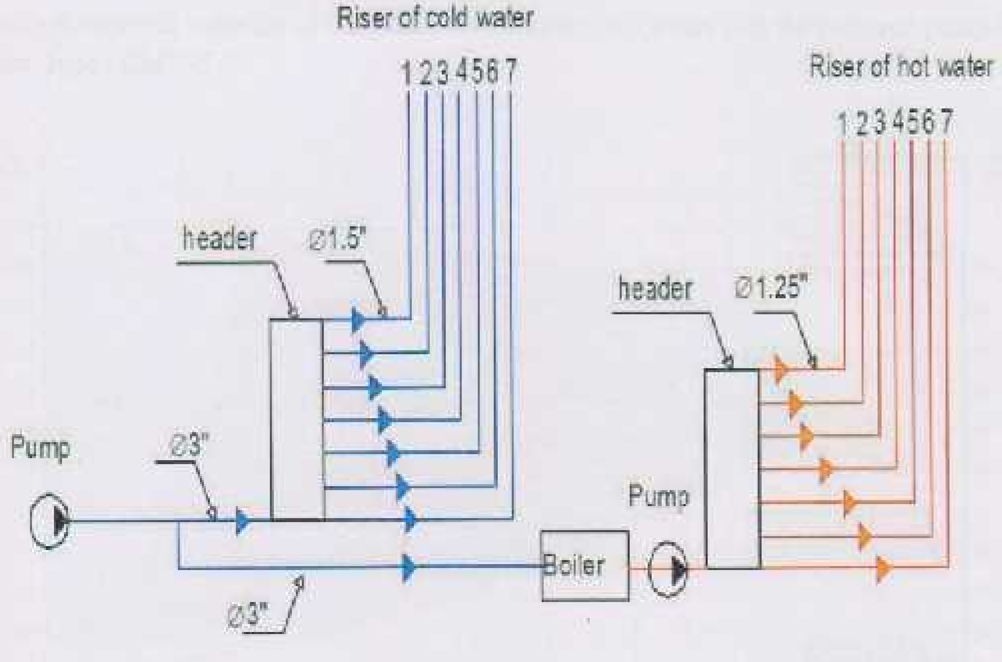


Figure (3.5): Hot and cold water risers

3.2.5 Pump selection

Pumps selection depends on two main properties and these properties are: head (H) and flow rate (Q). Starting selection with:

1- Cold water pump

By converting GPM to m^3/hour, the 101.2 GMP from all the cold water risers equals 22.98 m^3/hour.

Total flow rate = 22.98 m^3/hour.

Head = 2.6 bar (Height of the building = 16 m by dividing this value by 10 it equals 1.6, adding 1 bar for fitting losses it equals 2.6 bar.).

Using the special software of GRUNDFOS company it appears that the required pump is from type : CME25-2

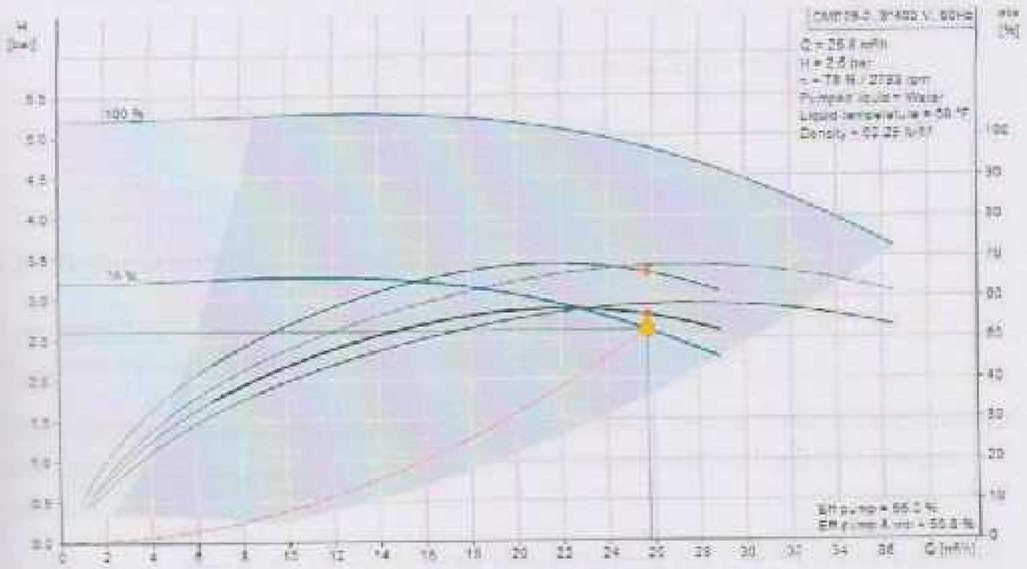


Figure (3.6): Cold water pump characteristic curve

2- Hot water pump

The same procedure in the cold pump selection was used but with flow rate 189WSFU which equals 62.8 GPM.

Total flow rate = 14.2 m^3/hour.

Head = 2.6 bar.

Using the special software of GRUNDFOS company it appears that the required pump is from type: CME15-3

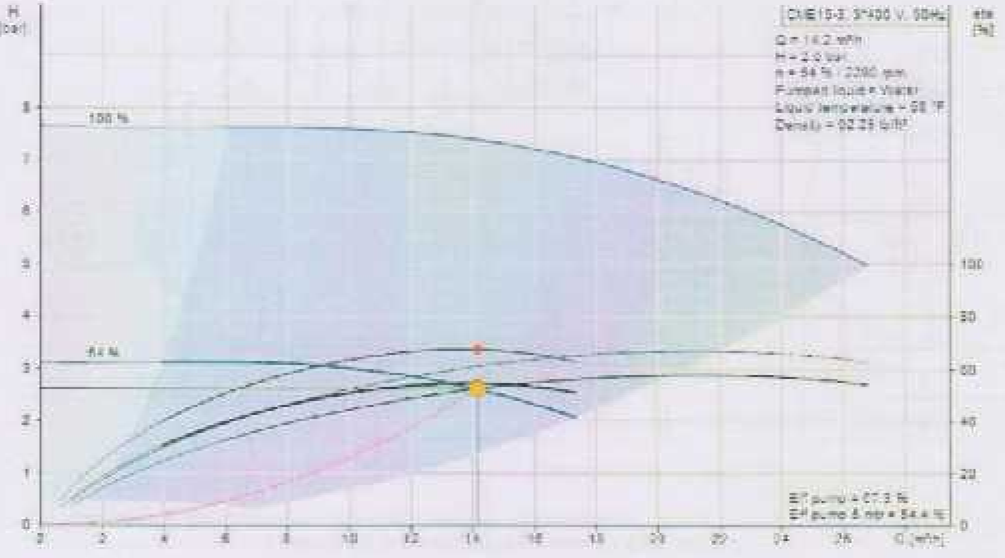


Figure (3.7): Hot water pump characteristic curve

3.2.6 Boiler calculation and selection

According to the total consumption of hot water demand in the building (which is calculated by using WSFU method) Boiler type selected: THW-I NT E

The boiler consists of a cylindrical shell, two head plates, centric flame tube including the back flue gas turning chamber with water cooled finned tube wall and two flue gas passes.

It differs than other boilers because of its high efficiency (up to 95% can be achieved), and its thermal insulation (the boiler is fully insulated) , ...etc.

Figure (3.8) below shows a sectional view of the boiler:

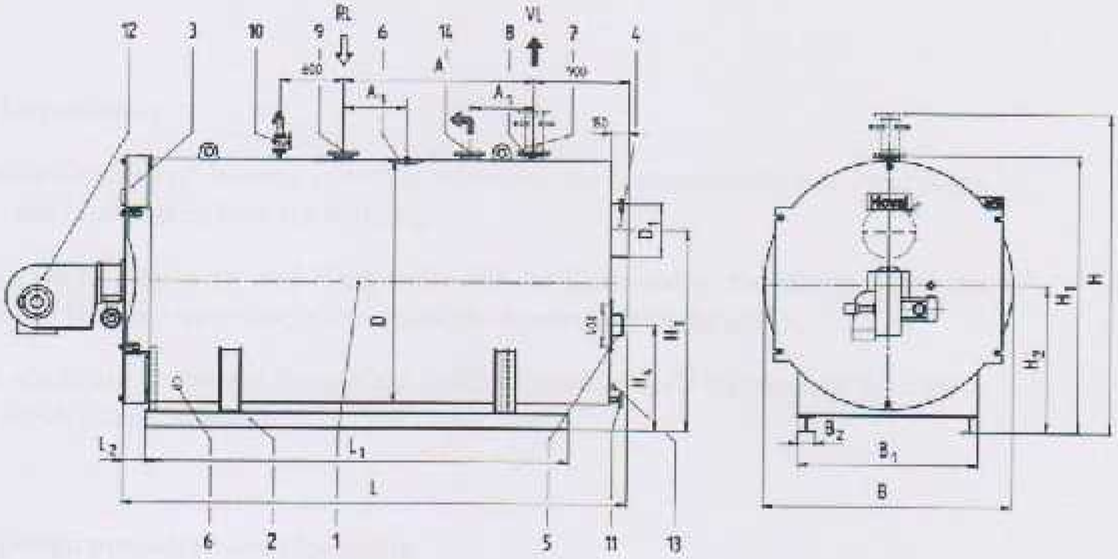


Figure (3.8): sectional view of the boiler

Where:

1- Boiler (with flue gas collector)	8- Boiler outlet nozzle
2- Boiler base	9- Return flow nozzle
3- Hinged door	10- Safety valve nozzle
4- Flue gas outlet	11- Drain nozzle
5- Explosion flap and door opening	12- Burner
6- Inspection opening	13- Condensate drain nozzle
7- Boiler outlet armature tube	14- Return heat up

3.2.7 Expansion tank calculation

To get the right expansion tank for the systems, the flow rate of the pumps multiplied by the number thirty to get the actual GPM.

For cold water system: 101.2 GPM × 30 = 3036 GPM, the result is 182.16 m^3.

For hot water system: 62.8 GPM × 30 = 1884 GPM, the result is 133.04 m^3.

3.3 Sanitary Drainage System

3.3.1 Introduction

The main objective of drainage system is to carry all the contaminated waste water (Grey water, and black water) from the building.

Separation of gray water and black water will be illustrated in the drawings and the manholes. The gray water stacks are 17, and the black water stacks are 15.

These stacks are distributed through the building external walls and through the service areas which called "Manawer".

3.3.2 Design procedure and pipe sizing

3.3.2.1 Design Procedure

Step 1: To determine the drainage fixture unit (dfu) for each fixture unit.

Step 2: To determine the total sum of drainage fixture unit (dfu) in each branch.

Step 3: To determine the number of branches of each stack.

Step 4: To determine the required pipe size of each horizontal branch in each stack.

Step 5: To determine the required pipe size of each vertical stack.

Step 6: To determine the required pipe size of the building drain based on the recommended velocity and slope.

3.3.2.2 Pipe Sizing

In order to determine the diameter of each branch and each stack and each building drain, tables A23, A24 must be used.

Figures below show the pipe sizing of each stack in the building where:

For black water stacks, stack No.1 which is illustrated below is identical to stacks 3,4,5,7,9,11,12,13,15, stack No.2 is identical to stacks 6, 10, 14, and stack 8 is different than the others.

Sizing of stack 1

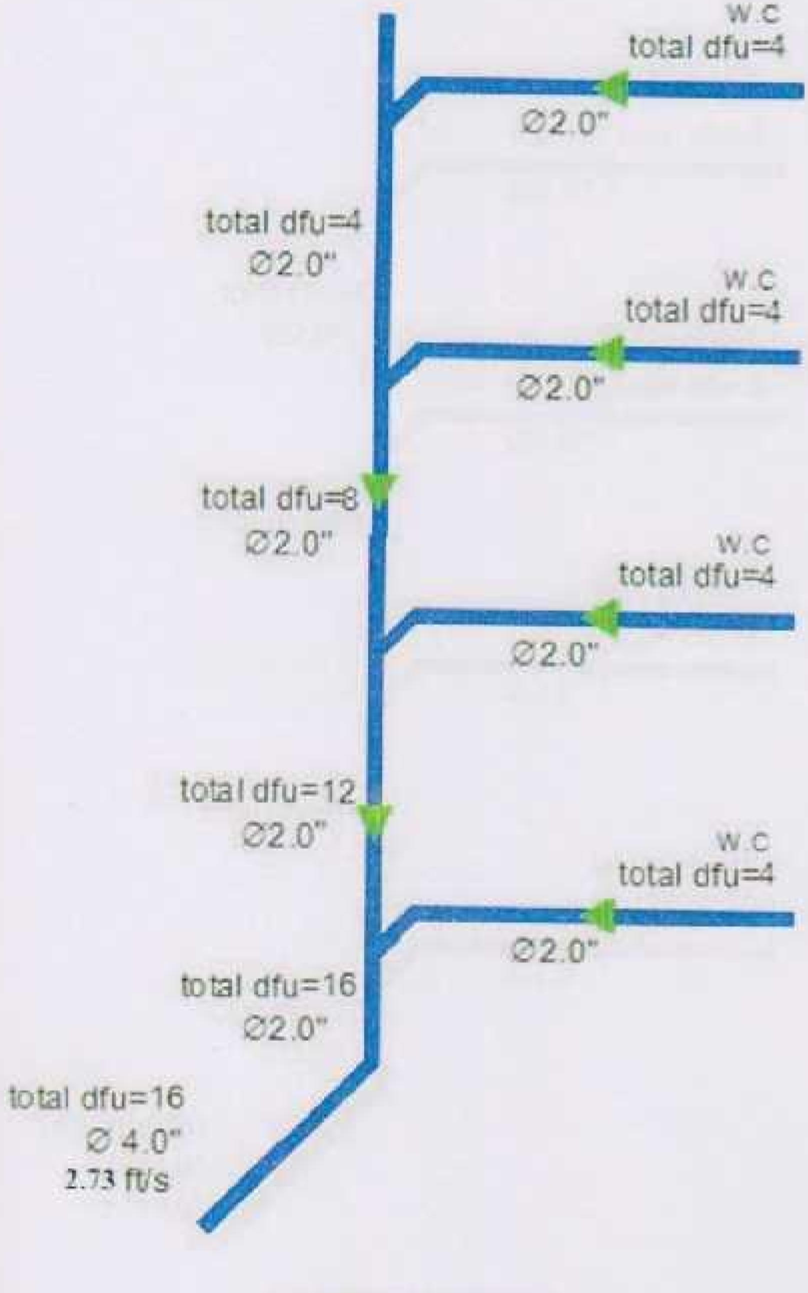


Figure (3.9): Sizing of stack1 , black water

Sizing of stack 2

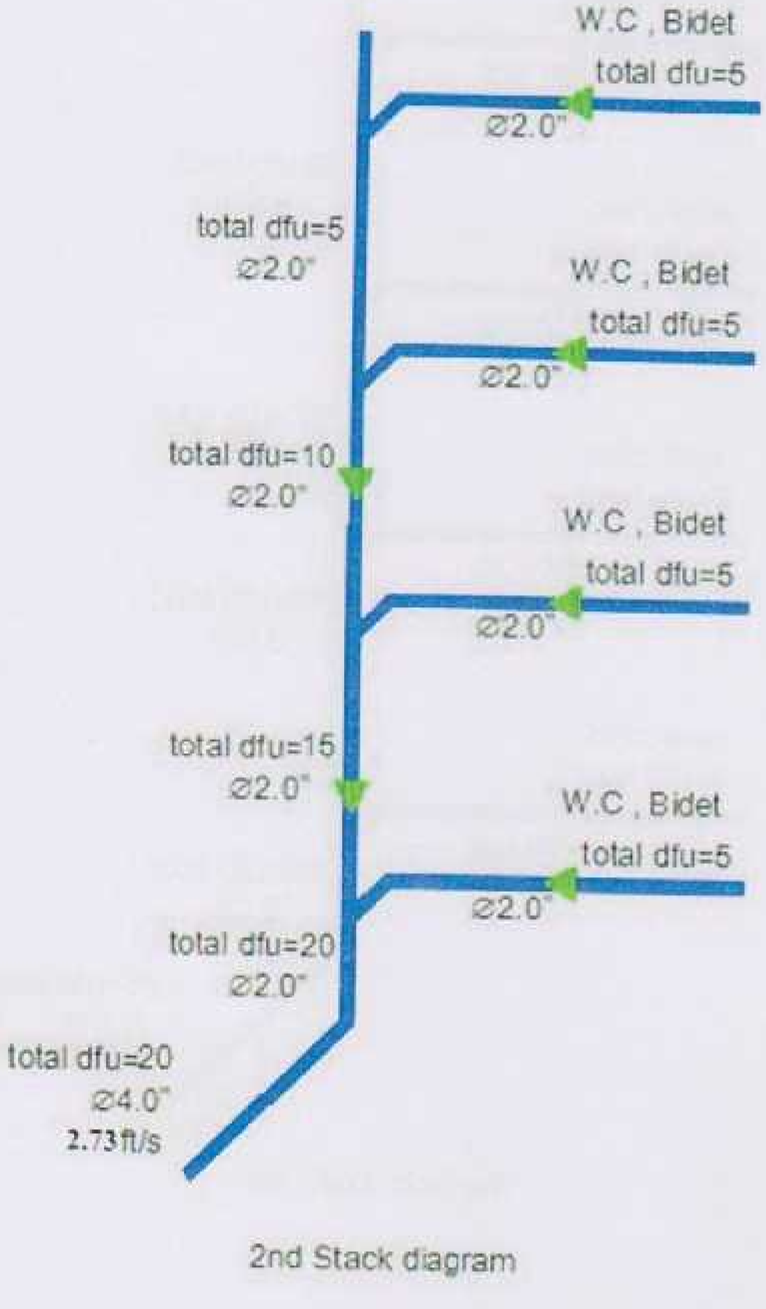


Figure (3.10): Sizing of stack 2, black water

Sizing of stack 8

Figure (3.11): Sizing of stack 8, black water

For grey water stacks, stack No.1 is identical to stacks 7, 11, 17, stack No.2 and No.16 are similar, stack No.3 and No.15 are similar, stack No.4 and No.14 are similar, stack No.5 and No.13 are similar, stack No.6 and No.12 are similar, stack No.8 and No.10 are similar, and finally stack No.9 is different than the others.

Sizing of stack 1

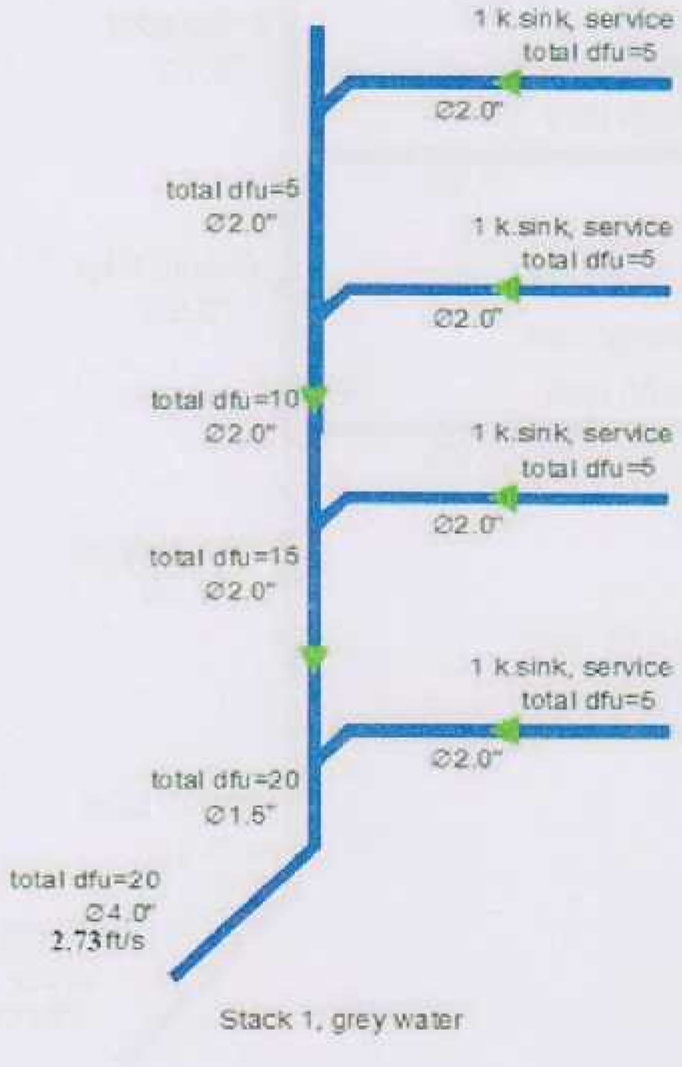


Figure (3.12): Sizing of stack 1, grey water

Sizing of stack 2

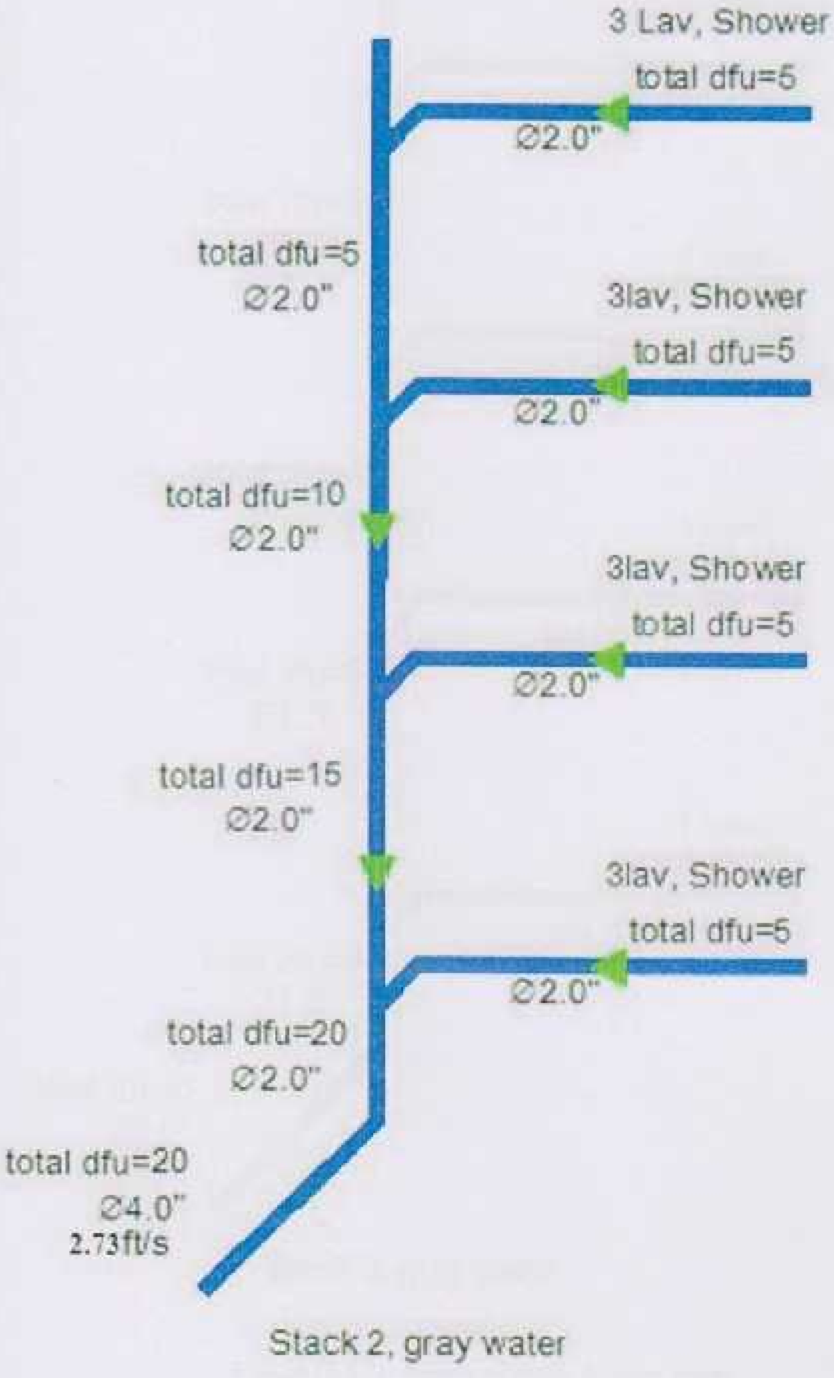


Figure (3.13): Sizing of stack 2, grey water

Sizing of stack 3

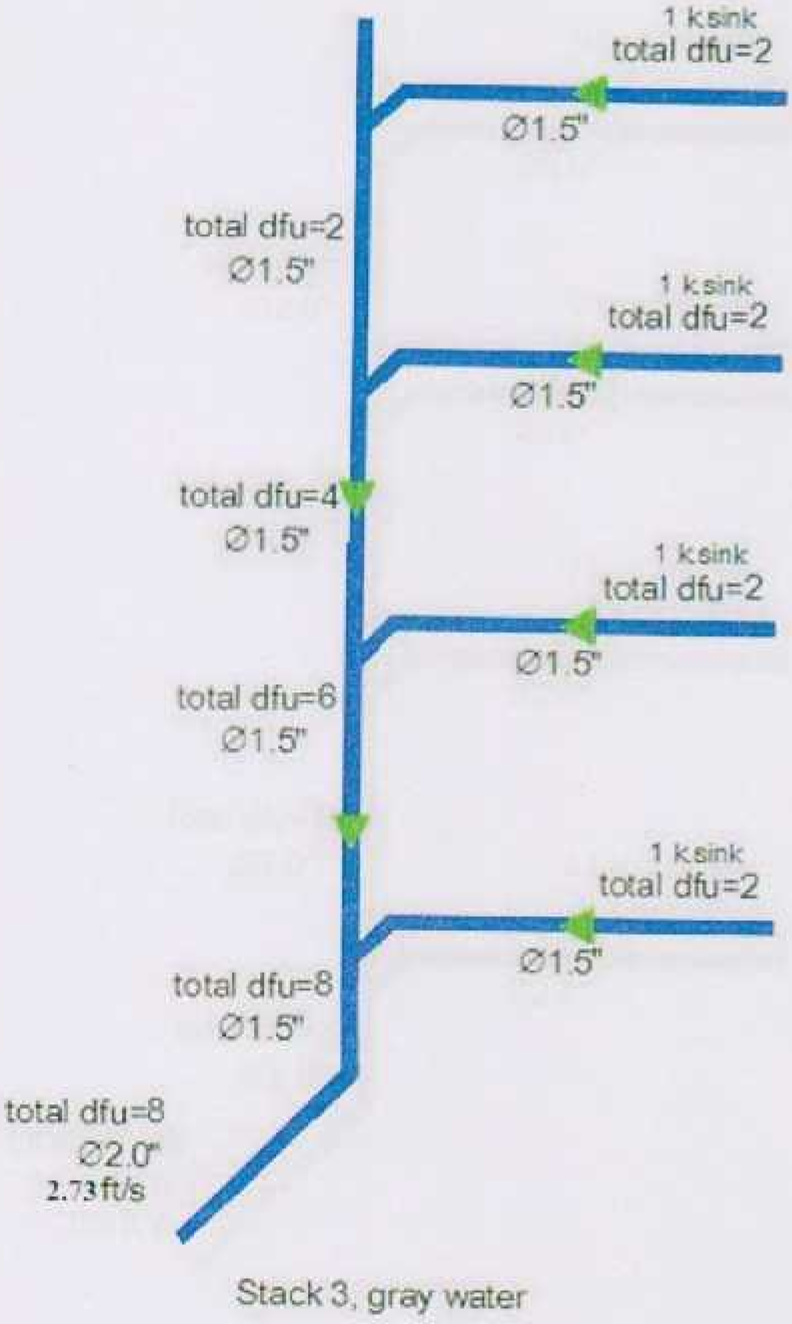


Figure (3.14): Sizing of stack 3, grey water

Sizing of stack 4

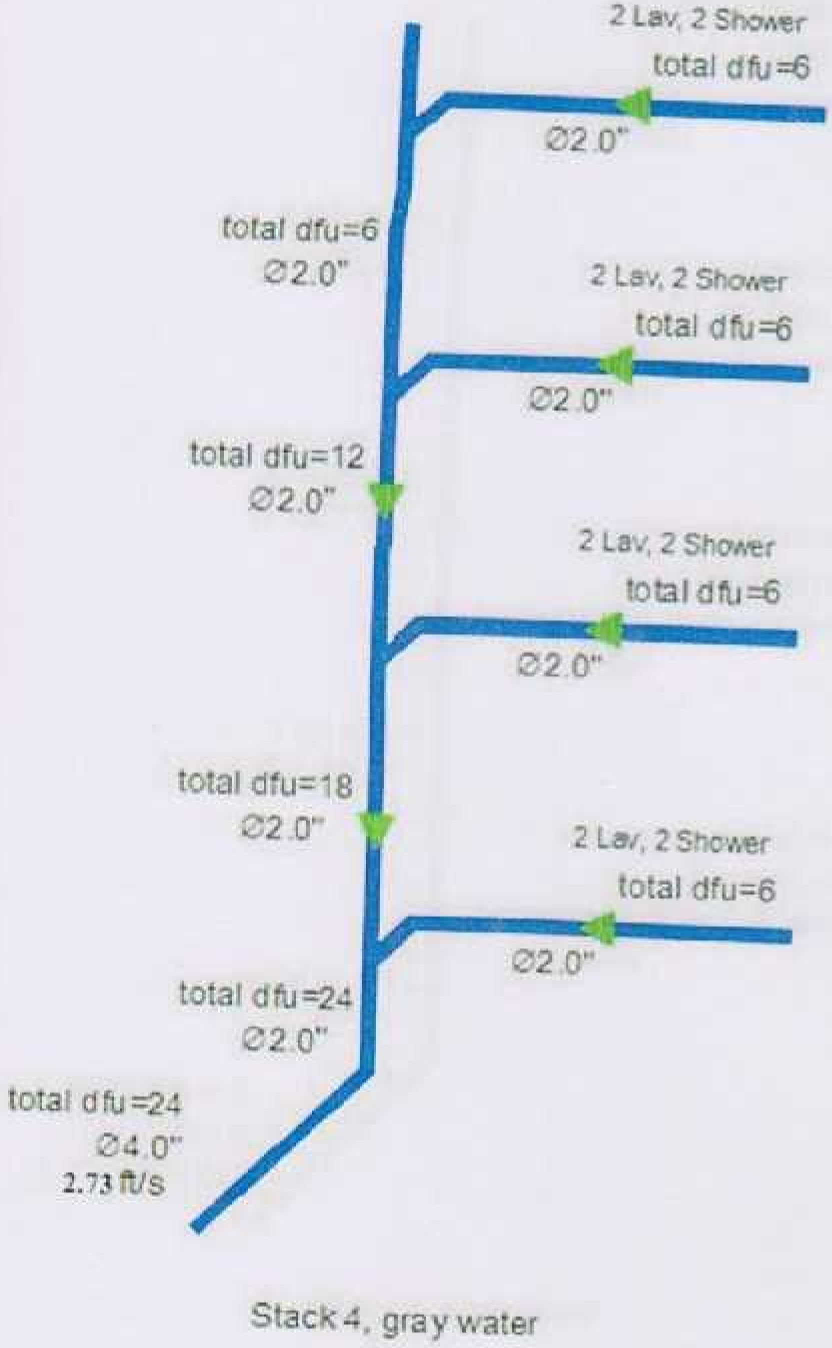


Figure (3.15): Sizing of stack 4, grey water

Sizing of stack 5

Figure (3.16): Sizing of stack 5, grey water

Sizing of stack 6

Figure (3.17): Sizing of stack 6, grey water

Sizing of stack 9

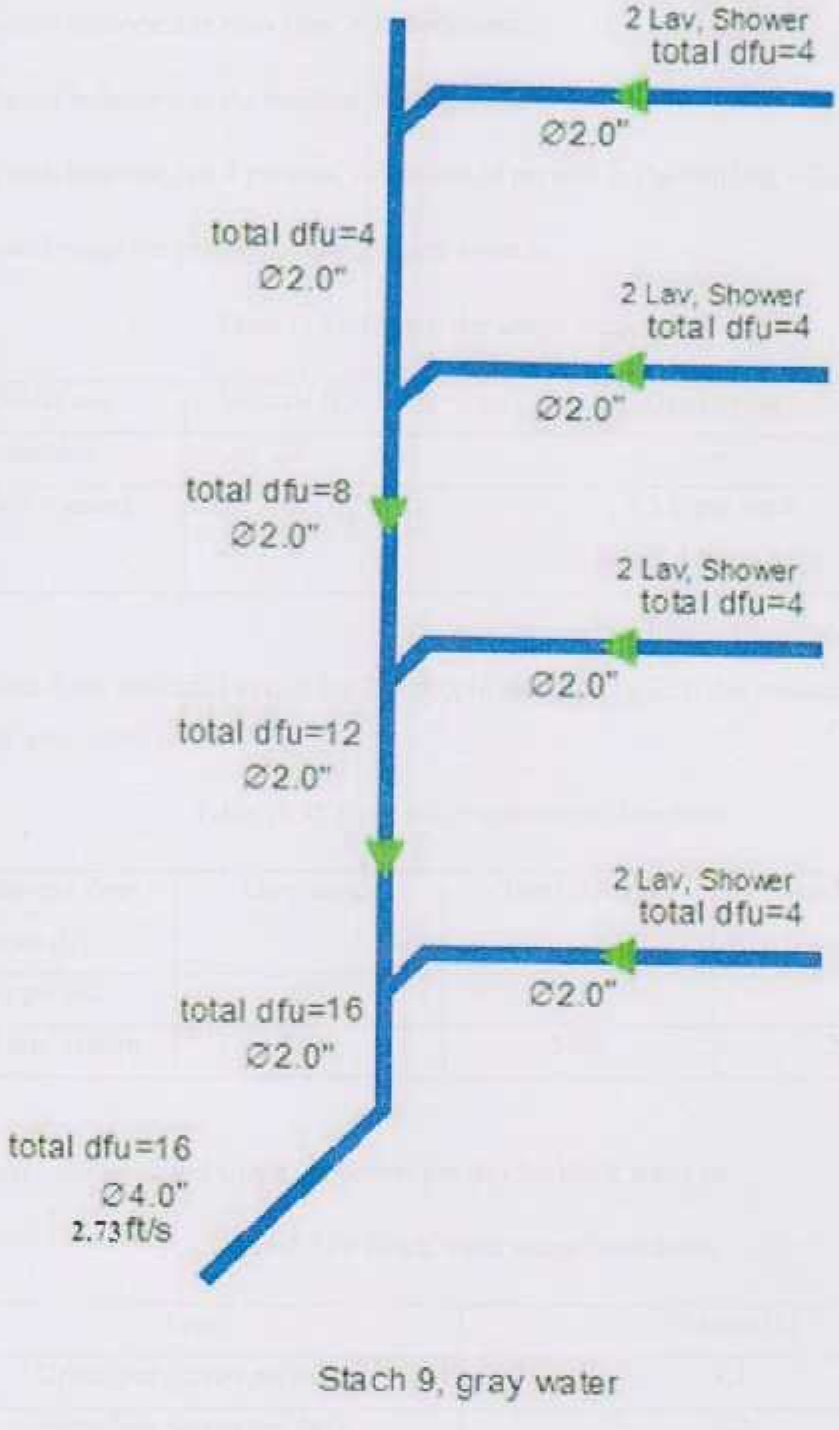


Figure (3.19): Sizing of stack 9, grey water

3.3.3 Calculating the volume of tanks for the sanitation system

Number of bedrooms in each floor = 14 bedrooms.

Number of bedrooms in the building = 56 bedrooms.

Note: each bedroom has 4 persons, so number of persons in the building = 224 person.

Estimated usage per person per day for grey water is:

Table (3.8): Grey water usage breakdown

Water use	Volume (L)	Description
Bathing	20	---
Hand washing	6	1.5 L per wash About 4 times a day

Based on these estimated usages for 224 people using the facility, the volumetric flow rate for grey water is:

Table (3.9): Grey water volumetric flow rates

Volumetric flow rates (Q)	Grey water	Total (L/day)	Total (L/hour)
Per person	26	26	1.08
Total into system	5824	5824	242.66

Similarly, the estimated usage per person per day for black water is:

Table (3.10): Black water usage breakdown

Type	Volume (L)
Urine (per person per day)	1.1
Feces (per person per day)	0.2
Water (per flush)	4.28

Because the facility will only been opened during the day, calculations are based on an estimation of 2 flushes per person per day.

The following volumetric flow rates for black water below is for an estimation of 224 people using the facility

Table (3.11): Black water volumetric flow rates

Volumetric flow rates (Q)	Black water	Total (L/day)	Total (L/hour)
Per person	9.86	9.86	0.41
Total into system	2208.64	2208.64	92.02

According to several studies, the hydraulic retention time (HRT) of ten hours is accurate and can be used to calculate the volume of the two tanks needed.

V = Q ×HRT   eq. (3.7)

For grey water:

V = 242.66 L/hour × 10 hour = 2426.6 L = 2.4266m^3.

For black water:

V = 92.02L/hour × 10 hour = 920.2 L = 0.9202m^3.

In order to account for any changes in population or an increase in usage, a safety factor will be used.

The original volume calculations are the minimum volume needed to handle the specified flow rates. For these purposes, a minimum of a 45% safety factor will be used. The volume of the tank will be calculated:

For grey water: 2.4266m^3 + (2.4266 × 0.45) = 3.518m^3.

For black water: 9.202 m^3 + (9.202×0.45) = 1.33429m^3.

3.3.4 Manholes

Manholes in this project are: grey water manholes and black water manholes.

For grey water manholes:

Table (3.12): Grey water manholes

Manhole No.	Tope level (m)	Depth (cm)	Cover type
M.H1	0.0	60	Concrete
M.H2	0.0	70	Concrete
M.H3	0.0	88	Concrete
M.H4	0.0	106	Concrete
M.H5	0.0	126	Concrete
M.H6	0.0	146	Concrete
M.H7	0.0	165	Concrete
M.H8	0.0	153	Concrete
M.H9	0.0	144	Concrete
M.H10	0.0	131	Concrete
M.H11	0.0	111	Concrete
M.H12	0.0	88	Concrete
M.H13	0.0	73	Concrete
M.H14	0.0	60	Concrete

For black water manholes:

Table (3.13): Black water manholes

Manhole No.	Tope level (m)	Depth (cm)	Cover type
M.H1	0.0	60	Concrete
M.H2	0.0	77	Concrete
M.H3	0.0	93	Concrete
M.H4	0.0	105	Concrete

Manhole No.	Tope level (m)	Depth (cm)	Cover type
M.H5	0.0	116	Concrete
M.H6	0.0	133	Concrete
M.H7	0.0	147	Concrete
M.H8	0.0	163	Concrete
M.H9	0.0	183	Concrete
M.H10	0.0	196	Concrete
M.H11	0.0	214	Concrete
M.H12	0.0	183	Concrete
M.H13	0.0	163	Concrete
M.H14	0.0	148	Concrete
M.H15	0.0	132	Concrete
M.H16	0.0	116	Concrete
M.H17	0.0	104	Concrete
M.H18	0.0	92	Concrete
M.H19	0.0	76	Concrete
M.H20	0.0	60	Concrete

Chapter 4

Fire fighting system

4.1 Introduction

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

1- Fuel (combustible substances).

2- Air (Oxygen).

3- Heat (Source of ignition).

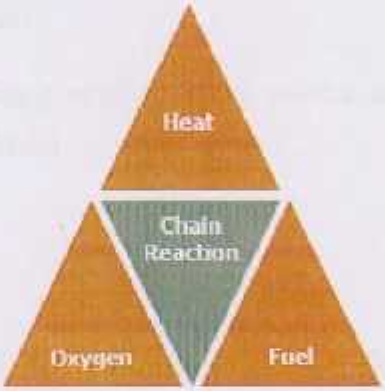


Figure (4.1): Fire ignition components

Fire work is divided into three sections for engineer:

1- Architect engineer; it is specialized in acting fire safety.

2- Electrical engineer; it is specialized in fire alarm.

3- Mechanical engineer; it is specialized in firefighting.

Also in design for firefighting system (NFPA) code can be dependent, national fire protection association or (LPC) British standard.

4.2 Fire classification

Fire classified as follows:

Class A fires: fires in ordinary combustible materials, including cellulosic such as wood, cloth, and paper as well as rubber and many plastics.

Class B fires: fires in flammable liquids, combustible liquids, petroleum greases, tar; oil, oil-based paints, solvents, lacquers, alcohols, and flammable gases.

Class C fires: fires that involve energized electrical equipment.

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

Class K fires: fires in cooking appliances that involve combustible cooking media (vegetable or animal oils and fats)

4.3 Fire signature

A fire signature is any fire effect (smoke, heat, light, etc.) that can be sensed by a fire detector. The amount of heat released by a fire varies in accordance with the type of combustible, arrangement of the combustible, availability of oxygen, and numerous other factors.

The types of occupancies for protection by fire extinguishers are:

1. Light (low) hazard occupancy

Defined as a room, space, or enclosure where the quantity and combustibility of class A combustible and class B flammables are considered to be low (less than 1 gallon), the buildings or rooms occupied as offices, class rooms, churches, assembly halls, and guestroom areas of hotels and motels be classified as a light (low) hazard occupancy.

2. Ordinary (moderate) hazard occupancy

Defined as a room, space, or enclosure where the quantity and combustibility of class A combustibles and class B flammables (1 to 5 gallon maximum) is considered to be moderate, and where fires of moderate heat release are expected, the rooms or building should be classified as ordinary(moderate) hazard occupancy when the following are encountered: dining areas, mercantile shops(shoe store or supermarket) and associated storage, light manufacturing , research operations, auto showrooms, parking garages and workshop or support service areas (kitchens, storages areas) of light hazard occupancies.

3. Extra (high) hazard occupancy

Defined as a room, space, or enclosure where the combustibility of contents is of the storage, handling, or manufacturing of class A combustible material in which the quantity of class A material is high, or where large amounts of class B flammables (more than 5 gallons) are present, and where rapidly developing fires with high rates of heat release are expected. It could consist of wood working, vehicle repair, air craft and boat servicing, cooking.

4.4 Classification of firefighting systems

Firefighting systems are classified to:

1- Water system.

2- Gas system.

3- Foam system.

4.4.1 Water firefighting system

It is the system which mainly depends on water to protect from fire, and it is the most common use in buildings and factories, also water system can classified to manual

And automatic systems as following:

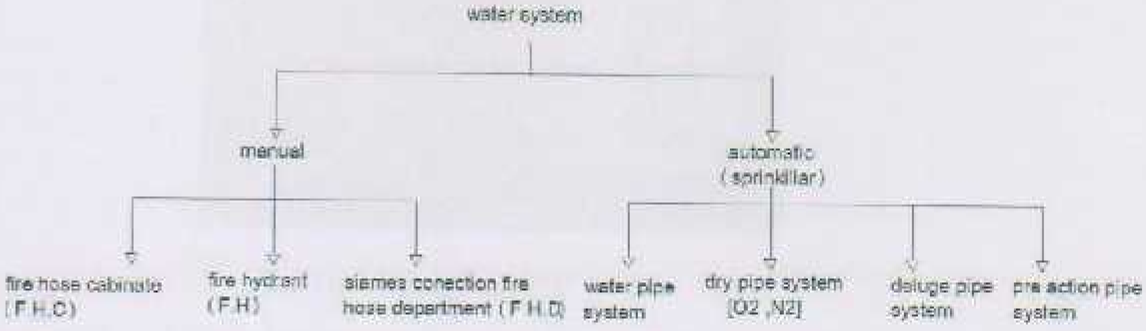


Figure (4.2): Water system firefighting classification

For the Manual system, it consists of three types of fire system divided to:

1- Fire hose cabinet

Fire hose cabinet is located at the following places:

A- Exit stairs.

B- Entrance of buildings.

C- Garages entrance.

D- Wherever travel distance exceeded 36 meter from another fire hose cabinet.

4.4.1.1 Fire hose cabinet

Figure (4.3): Fire hose cabinet

It consists of : 1) Cabinet (wall mounted-recessed), there are three types of cabinets:

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

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

C- Recessed: be inside the entire wall.

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

3) Hose (30 meter).

4) Discharge nozzle.

5) Fire extinguisher (optional).

4.4.1.2 Fire hose cabinet classes

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

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

2) Class 2: standpipe system provides 38-mm (1½-in.) hose stations to supply water for use primarily by the building occupants or by the fire department during initial response.

System limitations are pressure reach 4.5 bars, flow rate 100 gpm, 30m travel distance and located corridors, theaters, colleges and near elevators.

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

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

4.4.1.3 Technical specifications of fire hose cabinet

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

- The maximum pressure at any point in the system at any time shall not exceed 24.1 bar (350 psi).
- Maximum Residual Pressure for (1½-in.) Diameter 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 of4.5 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).
- Hose stream demand and water supply duration requirement for hydraulic calculation system as in the NFPA14 code.

4.4.2 Fire extinguishers

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

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

4.4.2.1 Types of Portable Fire Extinguishers

1- Water extinguishers.

2- Water sprays water extinguishers.

3- Antifreeze solution extinguishers.

4- Foam fire extinguishers, hand and wheeled.

5- Carbon dioxide extinguishers.

6- Clean agent extinguishers.

7- Dry and wet chemical extinguishers, hand and wheeled.

4.4.2.2 Selection of extinguishers

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

4.4.2.2.1 Carbon dioxide extinguishers

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

The cylinders for CO_2Fire Extinguishers are seamless and extruded from high grade Chrome Molybdenum Steel or Manganese Steel or Carbon Steel. Carbon Dioxide is discharged as a white cloud of snow which throttles a fire by eliminating the oxygen.

Designed to protect areas where class B (flammable liquids and gases) or Electrical class of fires could occur.

Carbon dioxide is 1.5 heavier than air, so it forces oxygen out of a room or significantly reduces the *concentration of oxygen at breathing level.*

4.5 Firefighting pumps

A continuous water and pumping station supply should always be available and ready to fight fire, the following three pumps should be connected to a suction header (from water tank), and discharged to a discharge header (to firefighting network)[8].

Pumping stations should include:

1. Electrical firefighting pump.

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

Diesel pump works if:

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

3. Jockey Pump: works 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.

4.5.1 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 (4.4): 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 (4.5): Inline fire pump

3- 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 inline pumps .The one pump application where it is used is small diesel driven applications 500 GPM or l less.

Figure (4.6): End suction pump

4- 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 (4.7): Vertical turbine pump

4.5.2 Flow rate calculations

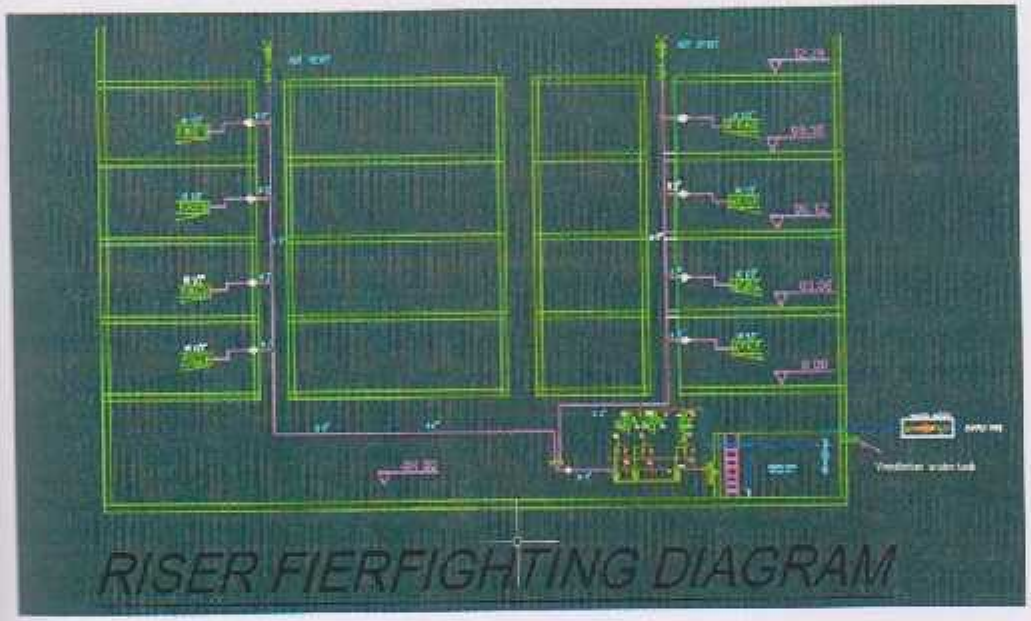


Figure (4.8): Firefighting riser diagram

4.5.3 Flow rate and head calculations

There are two main factors in GPM calculations:

1. Area calculation

2. Standpipe calculation

The standpipe calculation is the selected calculation, so according to NFPA 14 states that the

GPM required for the first standpipe is 500 GPM

Each additional standpipe requires 250 GPM with a maximum GPM of 1000 GPM

If a building has 2 standpipes the pump GPM would be 750 GPM, 500 GPM for the first and 250 for the second.

If a building has 3 standpipes the pump GPM would be 1000 GPM, 500 GPM, 250 for the second, and 250 for the third.

Any building with more standpipes would be 1000 GPM as that is the maximum allowable by code.

So, this building need 500 GPM according to code, with two standpipes the amount of flow rate equal to 750 GPM.

Flow rate calculation:

= No of FHC * 250 GPM for each FHC

2*250 = 500 GPM

Pressure head calculation:

$H_{Pump} = H_{St.} + H_{Res.} + H_f$ eq (4.1)

H_{Pump}= the pressure of the pump.

$H_{Res.}$ = the residential building FHC = 4.5bar.

H_f = the friction head.

$$H f = \frac{4.5 * Q^{1.85}}{C^{1.85} * D^{4.85}} = \frac{4.5 * 500^{1.85}}{120^{1.85} * 0.101^{4.85}}$$

= 1 bar

$H_{St.}$= the static head.

$H_{St.}$= 4+3+3+3+1.5= 14.5 m = 1.4 bar.

So:

H_{Pump}= 4.5 + 1.4 + 1 = 7 bar.

4.5.4 Pump selection

Total flow rate 500 GPM equal to 113.5 m^3/h and amount of head 7 bars.

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

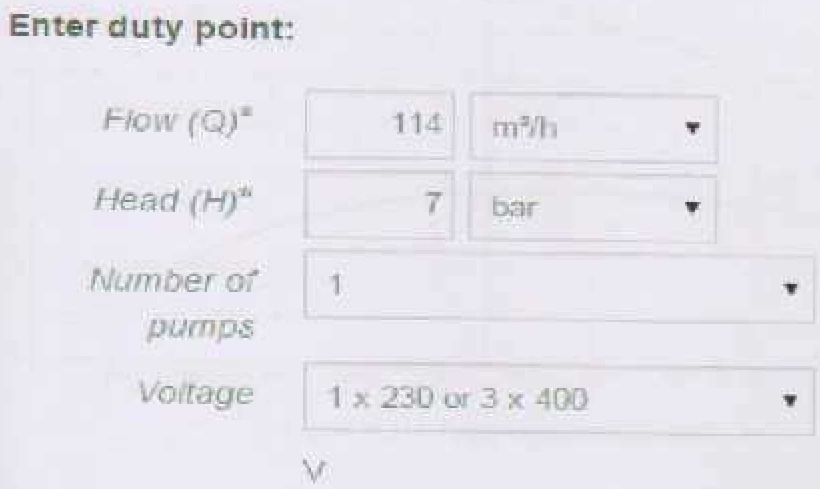


Figure (4.9): Pump's details

Pump type: HS 100-80-242 5/1-F-A-BBVP – 96793691

Figure (4.10): Pump's photo

Pump characteristic curves:

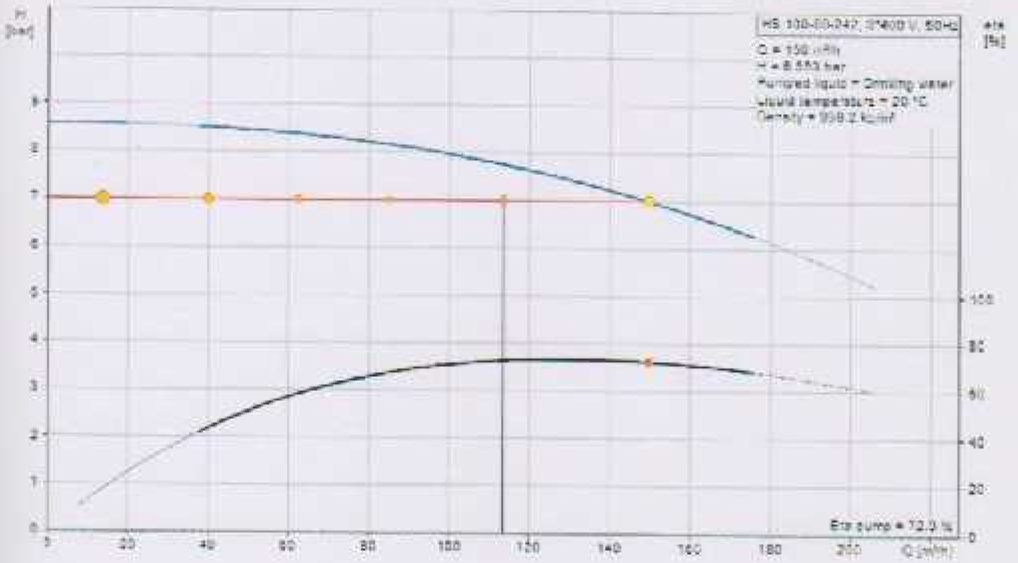


Figure (4.11): Pump characteristic curve

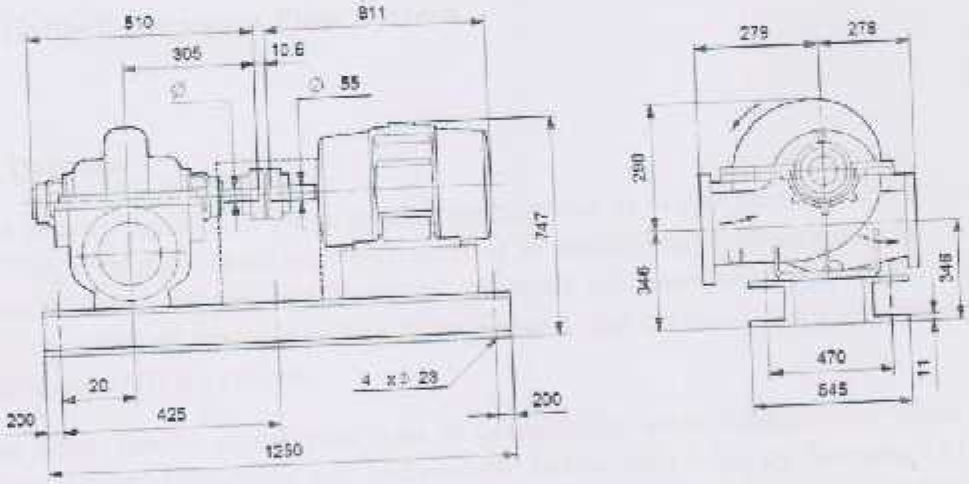


Figure (4.12): Pump dimensional drawing

Chapter 5

Variable Refrigerant Flow System

5.1 Overview

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

The digital variable multisystem is an air conditioning system configuration where there is one outdoor condensing unit and multiple indoor units using by Samsung CO. The term DVM 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.

5.2 Digital variable multisystem description

DVM systems are similar to the multi-split systems which connect one outdoor section to several evaporators. DVM 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 thermostat 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.

The modern DVM technology uses an inverter-driven scroll compressor and permits as many as 48 or more indoor units to operate from one outdoor unit (varies from manufacturer to manufacturer). The inverter scroll compressors are capable of changing the speed to follow the variations in the total cooling/heating load as determined by the suction gas pressure measured on the condensing unit.

5.3 Types of DVM

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

1) Heat pump systems

DVM heat pump systems permit heating or cooling in all of the indoor units but not operate simultaneous heating and cooling. When the indoor units are in the cooling mode they act as evaporators, when they are in the heating mode they act as condensers.

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

2) Energy recovery (Heat Recovery DVM system (DVM-HR))

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

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

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

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

This project deals with DVM plus 4 heat pump systems.

5.4 DVM plus 4 heat pump components

DVM plus 4 heat pump systems consists of some components:

1- Outdoor unit.

2- Indoor unit.

3- Joint indoor/ indoor.

4- Pipe and branch.

1- Outdoor unit

The specification technical data for outdoor unit shown used R-410A as a refrigerant, and depends on type of outdoor unit

1- Individual unit.

2- Combination unit.

Selection of outdoor unit should specify the mode (HP, HR) and nominal cooling and heating capacity.

2- Indoor unit

DVM plus 4 has many types of indoor units:

1- Ceiling mounted.

2- Wall mounted.

3- Cassette type:
A- One way cassette.
B- Two way cassette.
C- 4 way cassette.

4- Ducted type:
A- Slime ducts.
B- MSP ducts "medal static pressure ducted unites ".
C-HSP ducts "high static pressure ducted unites ".

3- Joint indoor/ outdoor

The DVM plus 4 has many types of branches:

A- Separation type: Connection between two units.

1- Branch joint outdoor unit's multi connection (D) Selection according to outdoor capacity.

2- First branch joint (E)
Selection according to outdoor total capacity.

3- Branch joint between indoor (F)
selection size according to the capacity sum of indoor units which are connected below the pipe.

B- Header: Connected with more indoor units

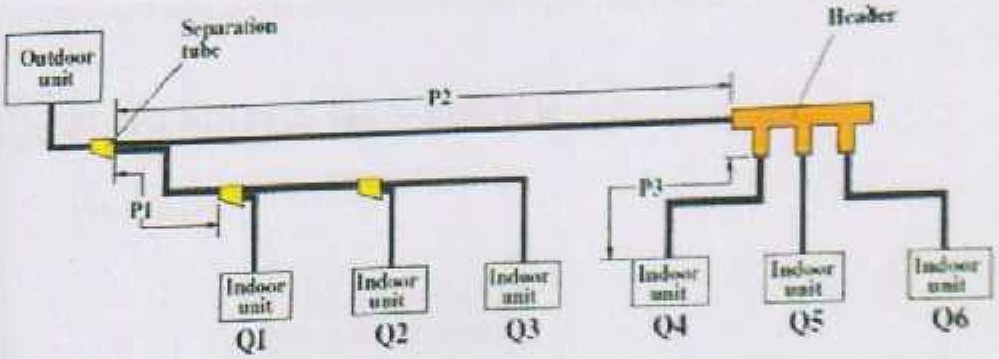


Figure (5.1): Header and Separation tubes

4-Pipe and branch:

The specification technical data for piping work have two types:

1- Outdoor pipe sizing depend on the capacity of the outdoor unit.

2- Indoor pipe sizing depend on the capacity load indoor unit.

3- The distance between the lowest level indoor unit and highest level indoor below15 m.

DVM plus 4 have three types of pipe:

A- Pipe for outdoor unit depends on the capacity of each outdoor capacity and the main pipe depends on the total of all outdoor units.

B- Pipe connects with two branches and depends on the total capacity of the indoor unit zoon, and has name (B).

C- Pipe connection between branch and indoor unit depend on the capacity indoor unit just, and has name (C).

5.5 Selection of the indoor unit in the project

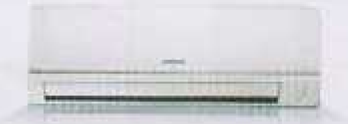
In the project two types of indoor units is used:

1- Wall mounted:

Wall mounted used in this project is "Neo Fort and Neo Fort E ".

10 Neo Forte & Neo-Forte E

10-1. Features



Multi filter system is composed deodorizing filter to keep air clean and fresh. The Wall mounted type is AVXWNH036E, the operation sound level (23-36) dB .

(3) AVXWNH036E*

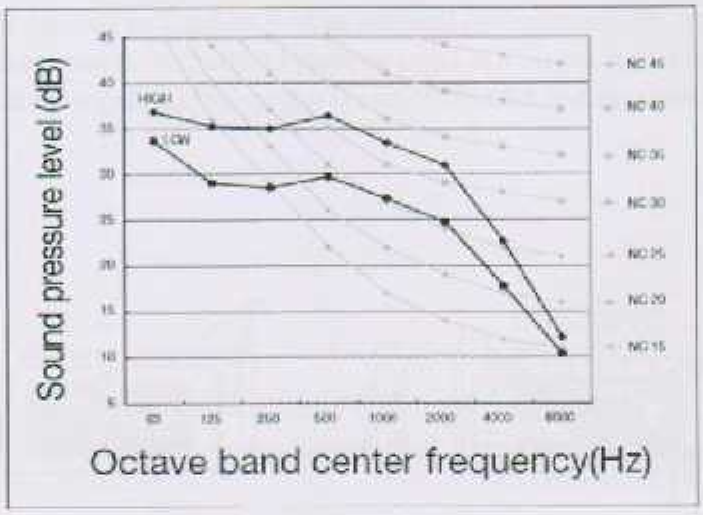
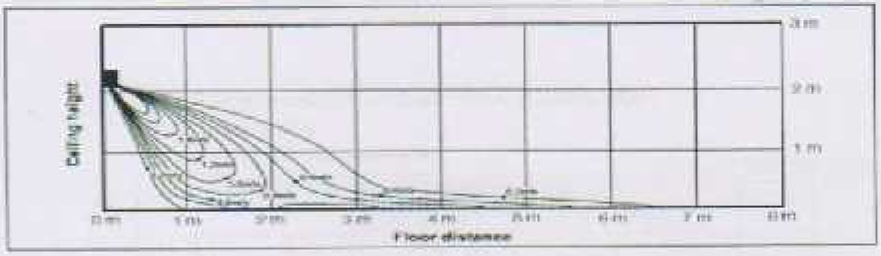


Figure (5.2): Sound pressure level

1) AVXWNH036E*, ND036QHXE*

(1) Cooling air velocity distribution

◆ Discharge angle : 60°



(2) Cooling temperature distribution

◆ Discharge angle : 60°

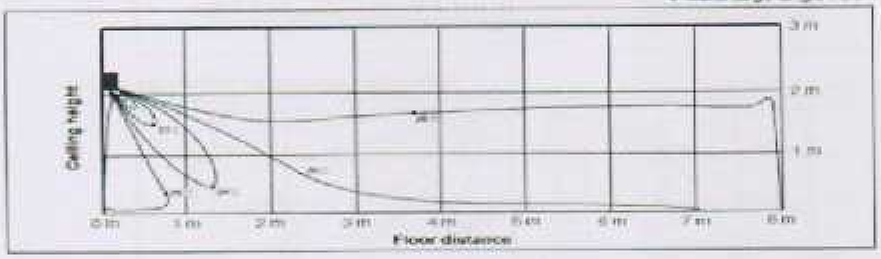
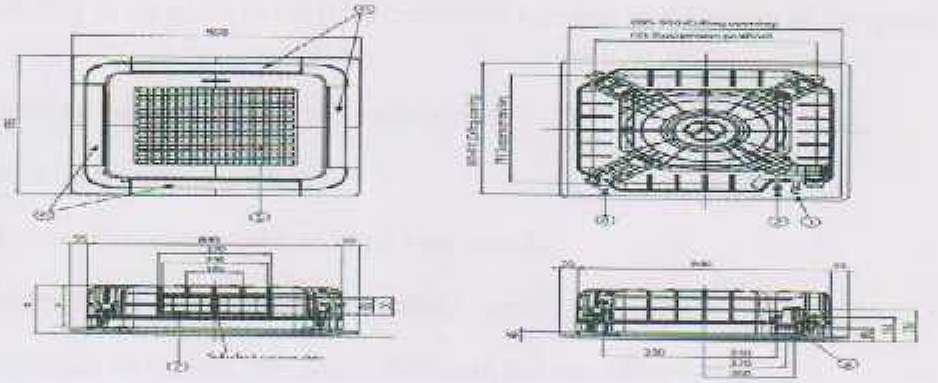


Figure (5.3): Cooling temperature distribution VS

Cooling air velocity distribution of AVXWNH036E

2- 4way cassette S:

4 way cassette S depends on interiors look or personal performance. this type (cassette) controlled by using remote controller to opening angel of 4 blades can be individual set at the same or different angel , and the model is NO0904HXEA and the sound level (28-32) dB .



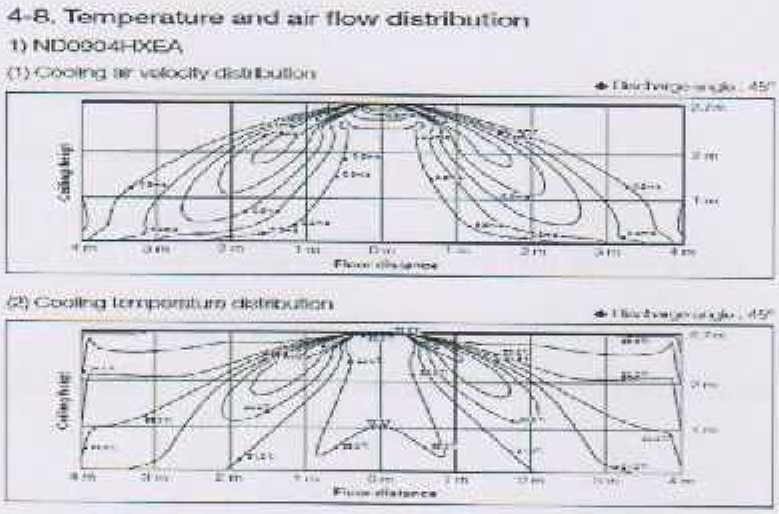


Figure (5.4): Cooling temperature distribution VS

Cooling air velocity distribution of NO0904HXEA

5.6 Design of DVM plus 4 system

1- Take a design outdoor temperature 31 C and wet bulb temperature 14 C.

2- Load calculation "cooling, heating".

3- Selection indoor unit using capacity table.

4- Calculation outdoor unit capacity by:
- capacity ratio 130%.
- Total required indoor capacity.

5- Outdoor unit = total required indoor capacity / capacity ratio 130%.

6- Referring to the tables to see if the capacity is accepted and covering all the space or not.

7- Determine the size pipe for each outdoor unit.

8- Determine the main pipe size.

9- Determine the outdoor joint and first joint branch.

10- Determine the pipe size and joint connect them.

11- Additional refrigerant charging to the length and size of liquid pipe.

12- Main pipe 1 size increment.

5.7 Sample calculation:

The sample calculation is **Apartment A**, where:

1- Cooling load as the required capacity.
2- Selection of indoor units using capacity table depends on the required capacity.

The Selected indoor units are: 4 way cassette S and wall mounted from capacity table.

Table (5.1): Indoor units' specification

Name	Model	Quantity	Required capacity (kW)	Actual capacity	Nominal capacity
FCU(A-1)	O45	4	2.2	3.1	4.5
FCU(A-2)	112	4	6.77	7.7	11.2
FCU(A-3)	112	4	6.4	7.7	11.2
WM(A-1)	O71	4	4.12	4.7	7.1
WM(A-2)	O56	4	3.6	4.7	5.6
		indoor unit =	23.09		
		total indoor unit =	92.36		

The total required capacity for the floor – 23.09 kW

The total required capacity for the zoon " 4 floor " = 92.36 kW

Outdoor unit = total required indoor capacity / capacity ratio 130% eq(5.1)

$= 92.36/1.3 = 72.8$ kW

From the total required capacity for the zoon " 4 floor " the outdoor unit is combination from two outdoor units " 12 , 14 " HP.

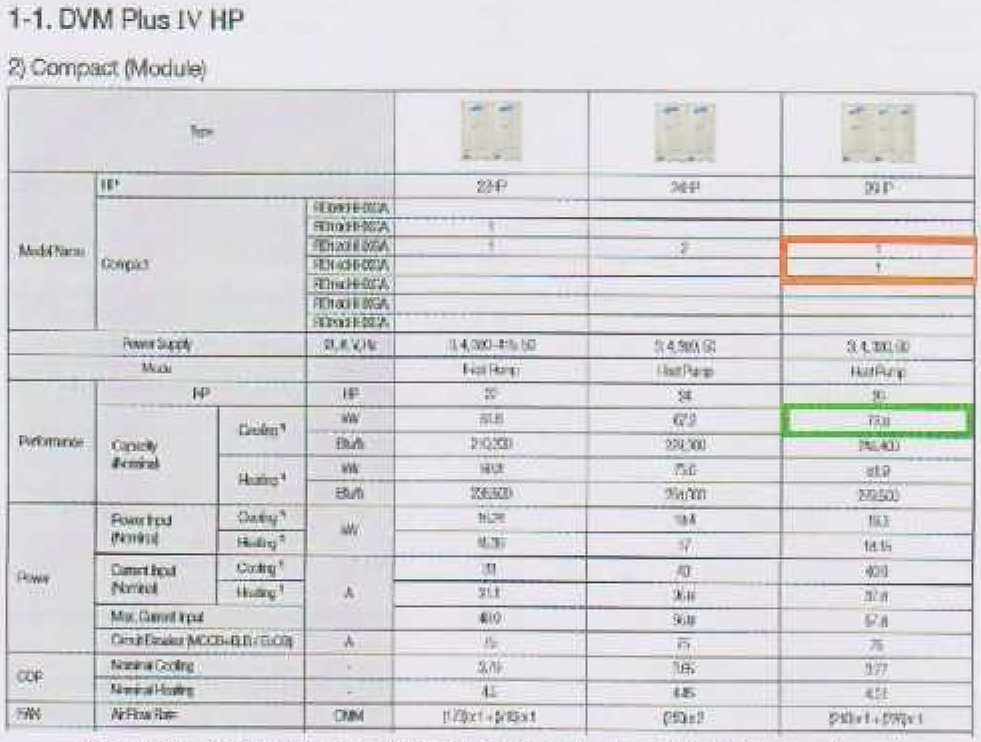


Figure (5.5): Outdoor unit selection depending on the indoor unit

And the actual outdoor from table capacity = 36 HP

1-1. Compact model

15) 36HP | Cooling

TC : Total Capacity PI : Power input

Combination % (Capacity index)	Outdoor Temperature(°C)	Indoor temperature (°C WB)													
		14.0 °C		16.0 °C		18.0 °C		19.0 °C		20.0 °C		22.0 °C		24.0 °C	
		TC	PI	TC	PI	TC	PI	TC	PI	TC	PI	TC	PI	TC	PI
		kW	kW	kW	kW	kW	kW	kW	kW	kW	kW	kW	kW	kW	kW
100%	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Figure (5.6): Outdoor actual unit

Table (5.2): Outdoor units

Outdoor units =	(20 HP , 14 HP)
Actual outdoor =	34 HP

3- Determine the pipe size for each outdoor unit

Table (5.3): Pipe sizing of outdoor units

Outdoor unit	Liquid size	Gas size
12 HP	1/2"	1"
14 HP	1/2"	1"

Outdoor unit	Pipe size (O.D. mm), (A)		Oil balancing pipe size
	Liquid	Gas	
8HP	Ø9.52	Ø19.05	Ø6.35
10HP		Ø22.23	
12HP	Ø12.70	Ø25.40	
14HP			
16HP		Ø28.58	
18HP	Ø15.88		
20HP			
22HP			
24HP			
26~30HP	Ø19.05	Ø31.75	
32~34HP			
36~48HP		Ø38.10	
50~60HP	Ø22.23	Ø44.45	

Figure (5.7): Outdoor unit catalog

The main pipe size for 26 HP (L = 3/4'', g = 1.1/4'')

The first joint for outdoor unit is MXJ-T3819K

The first joint branch is MXJ-YA3119K

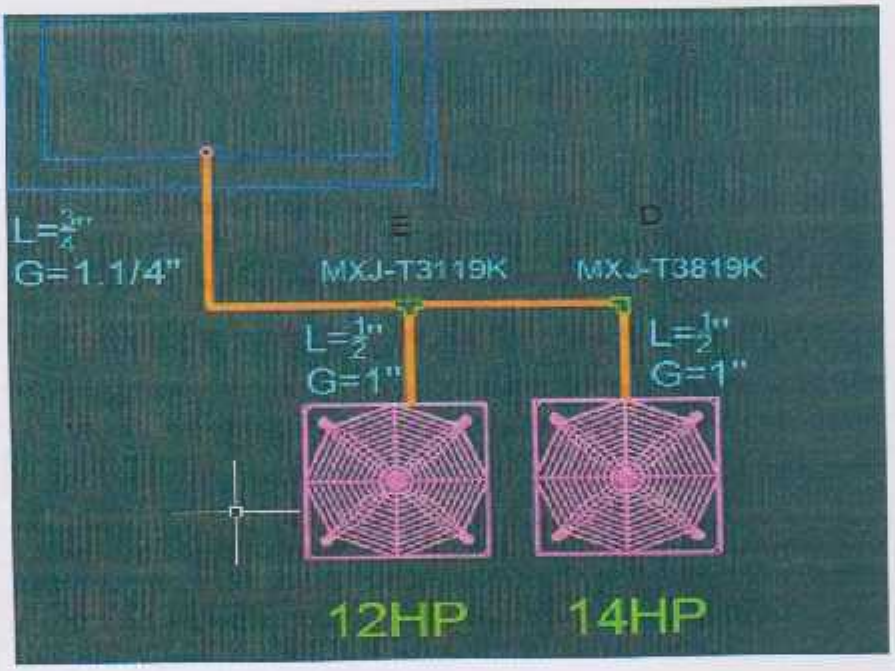


Figure (5.8): Outdoor units' joints

The total refrigerant of the zone depends on the length and the size of the liquid pipe.

Additional refrigerant charging

■ Additional refrigerant has to be charged according to the length and size of liquid pipe.

Liquid pipe size (O.D. mm)	Additional refrigerant charging (kg/m)
ø6.35	0.02
ø9.52	0.06
ø12.70	0.125
ø15.88	0.18
ø19.05	0.27
ø22.23	0.35
ø25.40	0.52

Figure (5.9): Additional refrigerant charging

Table (5.4): Additional refrigerant added to the system

Pipe Name	Liquid size	Gas size	Length (L, G) m	Additional Refrigerant (L) kg/m	Additional (kg)	Quantity (L, G) pipe	Total Length (L, G) pipe m
B1	3/8"	3/4"	1.95	0.06	0.117	4	7.8
B2	3/8"	7/8"	2.3	0.06	0.138	4	9.2
B3	3/8"	7/8"	0.5	0.06	0.03	4	2
B4	3/8"	7/8"	1	0.06	0.06	4	4
C1	3/8"	5/8"	0.7	0.06	0.042	4	2.8
C2	3/8"	5/8"	3.93	0.06	0.235	4	15.72
C3	1/4"	1/2"	2.5	0.02	0.05	4	10
C4	1/4"	1/2"	1.5	0.02	0.03	4	6
B1	3/8"	3/4"	1.95	0.06	0.117	4	7.8
B2	3/8"	7/8"	2.3	0.06	0.138	4	9.2
B3	3/8"	7/8"	0.5	0.06	0.03	4	2

Joints of indoor units in the table below

Table (5.5): Indoor units' joints

Name	Joint	Quantity
F1	MXJ-YA2512k	4
F2	MXJ-YA1509k	12

Where: F1: between (15 – 40) kW.
F2: below 15 kW.

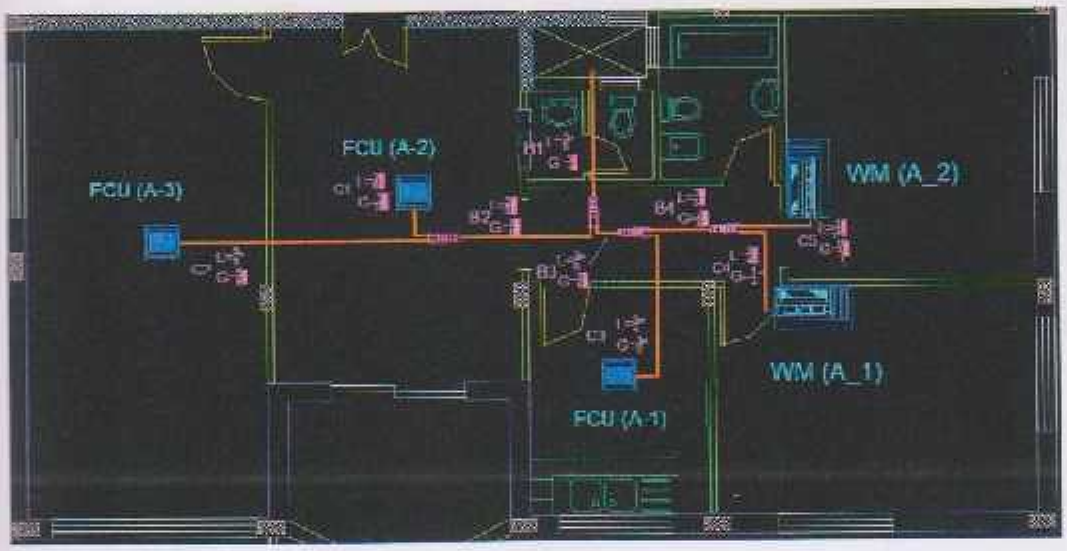


Figure (5.10): Indoor units' distribution

Main pipe 1 size increment

When the equivalent pipe length from outdoor unit to the farthest indoor unit between (45-90) m the main pipe (both liquid and gas pipe) has increase 1 size.

The distance between outdoor to farthest indoor unit is 22.41 m.

No need to increase the main pipe size.

For the rest of the apartments:

Apartment B

Table (5.6): Indoor units' specification

Name	Model	Quantity	Required capacity (kW)	Actual capacity	Nominal capacity
FCU(B-1)	O71	4	4.56	4.9	7.1
FCU(B-2)	O71	4	4.3	4.9	7.1
FCU(B-3)	O71	4	4.44	4.9	7.1
WM(B-1)	O71	4	4.5	4.7	7.1
WM(B-2)	O71	4	4.45	4.7	7.1
		indoor unit =	22.25		
		total indoor unit =	89		

Table (5.7): Outdoor units

Outdoor units =	(12HP, 12HP)
Actual outdoor =	32

Table (5.8): Pipe sizing of outdoor units

Outdoor unit	Liquid size	Gas size
12 HP	1/2"	1"
12 HP	1/2"	1"

Table (5.9): Additional refrigerant added to the system

Pipe Name	Liquid size	Gas size	Length (L, G) m	Additional Refrigerant (L) kg/m	Additional (kg)	Quantity (L, G) pipe	Total Length (L, G) pipe m
B1	3/8"	3/4"	0.58	0.06	0.0348	4	2.32
B2	3/8"	7/8"	1.5	0.06	0.09	4	6
B3	3/8"	7/8"	1.93	0.06	0.1158	4	7.72
B4	3/8"	7/8"	0.5	0.06	0.03	4	2
C1	3/8"	5/8"	2	0.06	0.12	4	8
C2	3/8"	5/8"	5	0.06	0.3	4	20
C3	1/4"	5/8"	5	0.02	0.1	4	20
C4	1/4"	5/8"	0.64	0.02	0.0128	4	2.56
C5	1/4"	5/8"	2.2	0.02	0.044	4	8.8

Table (5.10): Indoor units' joints

Name	Joint	Quantity
F1	MXJ-YA2512k	4
F2	MXJ-YA1509k	12

Apartment C

Table (5.11): Indoor units' specification

Name	Model	Quantity	Required capacity (kW)	Actual capacity	Nominal capacity
FCU(C-1)	O71	4	4.6	4.9	7.1
FCU(C-2)	O71	4	4.34	4.9	7.1
FCU(C-3)	O71	4	3.37	4.9	7.1
FCU(C-3)	O71	4	4.65	4.9	7.1
WM(C-1)	O71	4	3.06	3.9	7.1
WM(C-2)	O71	4	3.16	3.9	7.1
		indoor unit =	18.53		
		total indoor unit =	74.12		

Table (5.12): Outdoor units

Outdoor units =	(12 HP , 10 HP)
Actual outdoor =	26HP

Table (5.13): Pipe sizing of outdoor units

Outdoor unit	Liquid size	Gas size
12 HP	1/2"	1"
10 HP	3/8"	7/8"

Table (5.14): Additional refrigerant added to the system

Pipe Name	Liquid size	Gas size	Length (L, G) m	Additional Refrigerant (L) kg/m	Additional (kg)	Quantity (L, G) pipe	Total Length (L, G) pipe m
B1	3/8"	3/4"	1	0.06	0.06	4	4
B2	3/8"	7/8"	3.15	0.06	0.189	4	12.6
B3	3/8"	7/8"	1.8	0.06	0.108	4	7.2
B4	3/8"	7/8"	3.4	0.06	0.204	4	13.6
B5	3/8"	5/8"	1.26	0.06	0.0756	4	5.04
C1	3/8"	5/8"	3.5	0.06	0.21	4	14
C2	3/8"	5/8"	0.9	0.06	0.054	4	3.6
C3	1/4"	5/8"	0.4	0.02	0.008	4	1.6
C4	1/4"	5/8"	1.4	0.02	0.028	4	5.6
C5	1/4"	3/4"	2	0.02	0.04	4	8
C6	1/4"	7/8"	3	0.02	0.06	4	12

Table (5.15): Indoor units' joints

Name	Joint	Quantity
F1	MXJ-YA2512k	4
F2	MXJ-YA1509k	12

Apartment D

Table (5.16): Indoor units' specification

Name	Model	Quantity	Required capacity (kW)	actual capacity (kW)	Nominal capacity
FCU(C-1)	O56	8	3.34	3.9	5.6
FCU(C-2)	O45	4	2.9	3.1	4.5
FCU(C-3)	O56	4	3.4	3.9	4.5
WM(C-1)	O35	8	5.05	2.5	3.5
WM(C-2)	O56	4	3.4	3.9	5.6
		indoor unit =	18.09		
		total indoor unit =	72.36		

Table (5.17): Outdoor units

Outdoor units –	(20 HP)
Actual outdoor =	26HP

Table (5.18): Pipe sizing of outdoor units

Outdoor unit	Liquid size	Gas size
20 HP	5/8"	1.1/8"

Table (5.19): Additional refrigerant added to the system

Pipe Name	Liquid size	Gas size	Length (L, G) m	Additional Refrigerant (L) kg/m	Additional (kg)	Quantity (L, G) pipe	Total Length (L, G) pipe m
B1	3/8"	3/4"	0.8	0.06	0.048	4	3.2
B2	3/8"	7/8"	2.3	0.06	0.138	4	9.2
B3	3/8"	7/8"	0.94	0.06	0.0564	4	3.76
B4	3/8"	7/8"	2.8	0.06	0.168	4	11.2
B5	3/8"	7/8"	1.72	0.06	0.1032	4	6.88
B6	3/8"	7/8"	3.04	0.06	0.1824	4	12.16
C1	3/8"	5/8"	1.3	0.06	0.078	4	5.2
C2	3/8"	5/8"	3.5	0.06	0.21	4	14
C3	1/4"	1/2"	1.2	0.02	0.024	4	4.8
C4	1/4"	1/2"	2.2	0.02	0.044	4	8.8
C5	1/4"	1/2"	2	0.02	0.04	4	8
C6	1/4"	1/2"	2.6	0.02	0.052	4	10.4
C7	1/4"	1/2"	2.4	0.02	0.048	4	9.6
				additional gas	1.192		
				total additional gas	4.768		

Figure (5.20): Indoor units' joints

Name	Joint	Quantity
F1	MXJ-YA2512k	4
F2	MXJ-YA1509k	20

Apartment E

Table (5.21): Indoor units' specification

Name	Model	Quantity	Required capacity (kW)	actual capacity (kW)	Nominal capacity
FCU(C-1)	O71	4	4.6	4.9	7.1
FCU(C-2)	O71	4	4.34	4.9	7.1
FCU(C-3)	O71	4	3.37	4.9	7.1
FCU(C-3)	O71	4	4.65	4.9	7.1
WM(C-1)	O71	4	3.06	3.9	7.1
WM(C-2)	O71	4	3.16	3.9	7.1
		indoor unit =	18.53		
		total indoor unit =	74.12		

Table (5.22): Outdoor units

Outdoor units =	(12 HP , 10 HP)
Actual outdoor =	26HP

Table (5.23): Additional refrigerant added to the system

Pipe Name	Liquid size	Gas size	Length (L, G) m	Additional Refrigerant (L) kg/m	Additional (kg)	Quantity (L, G) pipe	Total Length (L, G) pipe m
B1	3/8"	3/4"	2.27	0.06	0.1362	4	9.08
B2	3/8"	7/8"	1.5	0.06	0.09	4	6
B3	3/8"	7/8"	4	0.06	0.24	4	16
B4	3/8"	7/8"	3.34	0.06	0.2004	4	13.36
B5	3/8"	7/8"	1.26	0.06	0.0756	4	5.04
C1	3/8"	5/8"	0.9	0.06	0.054	4	3.6
C2	3/8"	5/8"	5.5	0.06	0.33	4	22
C3	1/4"	1/2"	0.5	0.02	0.01	4	2
C4	1/4"	1/2"	1.5	0.02	0.03	4	6
C5	1/4"	1/2"	2.31	0.02	0.0462	4	9.24
C6	1/4"	1/2"	3	0.02	0.06	4	12

Table (5.24): Indoor units' joints

Name	Joint	Quantity
F1	MXJ-YA2512k	4
F2	MXJ-YA1509k	12

Apartment F

Table (5.25): Indoor units' specification

Name	Model	Quantity	Required capacity (kW)	Actual capacity (kW)	Nominal capacity
FCU(F-1)	O71	4	4.56	4.9	7.1
FCU(F-2)	O71	4	4.3	4.9	7.1
FCU(F-3)	O71	4	4.2	4.9	7.1
WM(F-1)	O71	4	4.5	4.7	7.1
WM(F-2)	O71	4	4.45	4.7	7.1
		indoor unit =	22.01		
		total indoor unit =	88.04		

Table (5.26): Outdoor units

Outdoor units =	(12HP, 12HP)
Actual outdoor =	32

Table (5.27): Pipe sizing of outdoor units

Outdoor unit	Liquid size	Gas size
12 HP	1/2"	1"
12 HP	1/2"	1"

Figure (5.28): Indoor units' joints

Name	Joint	Quantity
F1	MXJ-YA2512k	4
F2	MXJ-YA1509k	12

Table (5.29): Additional refrigerant added to the system

Pipe Name	Liquid size	Gas size	Length (L, G) m	Additional Refrigerant (L) kg/m	Additional (kg)	Quantity (L, G) pipe	Total Length (L, G) pipe m
B1	3/8"	3/4"	0.58	0.06	0.0348	4	2.32
B2	3/8"	7/8"	1.5	0.06	0.09	4	6
B3	3/8"	7/8"	1.93	0.06	0.1158	4	7.72
B4	3/8"	7/8"	0.5	0.06	0.03	4	2
C1	3/8"	5/8"	2	0.06	0.12	4	8
C2	3/8"	5/8"	5	0.06	0.3	4	20
C3	1/4"	5/8"	5	0.02	0.1	4	20
C4	1/4"	5/8"	0.64	0.02	0.0128	4	2.56
C5	1/4"	5/8"	2.2	0.02	0.044	4	8.8
				additional gas	0.8474		
				total additional gas	3.3896		

Apartment G

Table (5.30): Indoor units' specification

Name	Model	Quantity	Required capacity (kW)	actual capacity (kW)	Nominal capacity
FCU(G-1)	O45	4	1.9	3.1	4.5
FCU(G-2)	112	4	6.77	7.7	11.2
FCU(G-3)	112	4	6.6	7.7	11.2
WM(G-1)	O71	4	3.89	4.7	7.1
WM(G-2)	O56	4	3.6	4.7	5.6
		indoor unit =	22.76		
		total indoor unit =	91.04		

Table (5.31): Outdoor units

Outdoor units =	(12 HP , 14 HP)
Actual outdoor =	34 HP

Table (5.32): Pipe sizing of outdoor units

Outdoor unit	Liquid size	Gas size
12 HP	1/2"	1"
14 HP	1/2"	1"

Figure (5.33): Indoor units' joints

Name	Joint	Quantity
F1	MXJ-YA2512k	4
F2	MXJ-YA1509k	12

Table (5.34): Additional refrigerant added to the system

Pipe Name	Liquid size	Gas size	Length (L, G) m	Additional Refrigerant (L) kg/m	Additional (kg)	Quantity (L, G) pipe	Total Length (L, G) pipe m
B1	3/8"	3/4"	1.95	0.06	0.117	4	7.8
B2	3/8"	7/8"	2.3	0.06	0.138	4	9.2
B3	3/8"	7/8"	0.5	0.06	0.03	4	2
B4	3/8"	7/8"	1	0.06	0.06	4	4
C1	3/8"	5/8"	0.7	0.06	0.042	4	2.8
C2	3/8"	5/8"	3.93	0.06	0.2358	4	15.72
C3	1/4"	1/2"	2.5	0.02	0.05	4	10
C4	1/4"	1/2"	1.5	0.02	0.03	4	6
C5	1/4"	1/2"	1.08	0.02	0.0216	4	4.32
				additional gas	0.7244		
				total additional gas	2.8976		

5.8 Mechanical ventilation

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

There are two ways for Ventilation:

1- "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 often unreliable.

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

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

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

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

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

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

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

5.8.1 Purposes of ventilation

Ventilation in a building serves to provide fresh and clean air, to maintain a thermally comfortable work environment, and to remove or dilute airborne contaminants in order to prevent their accumulation in the air. Air conditioning is a common type of ventilation system in modern office buildings. It draws in outside air and after filtration, heating or cooling 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.

5.8.2 Designing of mechanical ventilation

Steps of designing mechanical ventilation:

1. Calculate the required ventilating rate of air by using "Ventilation Rates Calculator" Software.

2. Calculate the volume of the room in (m^3).

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

5.8.3 Sample calculation

Using bathroom:

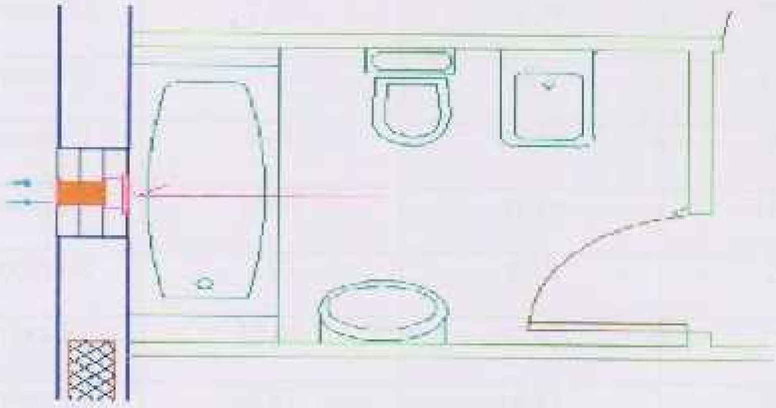


Figure (5.11): Bathroom layout

The volume is $13.23m^3$.

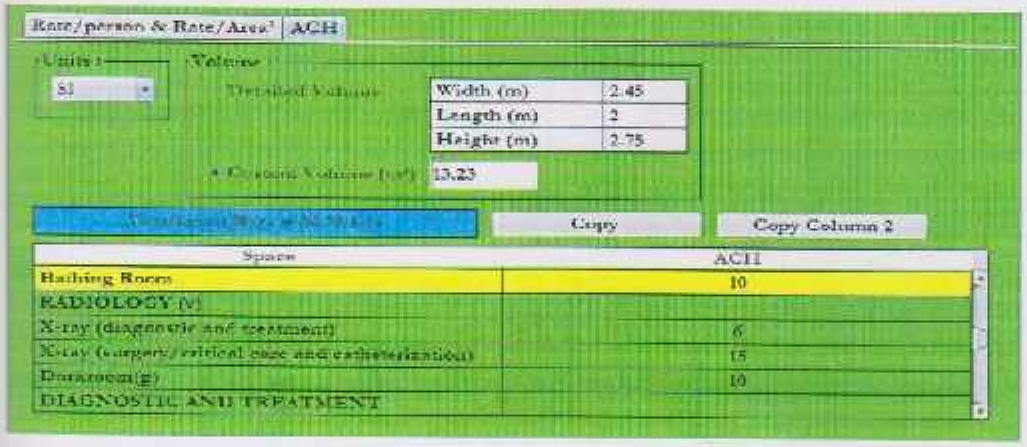


Figure (5.12): Ventilation rates calculator

Table (5.34): Ventilation rates for bathrooms

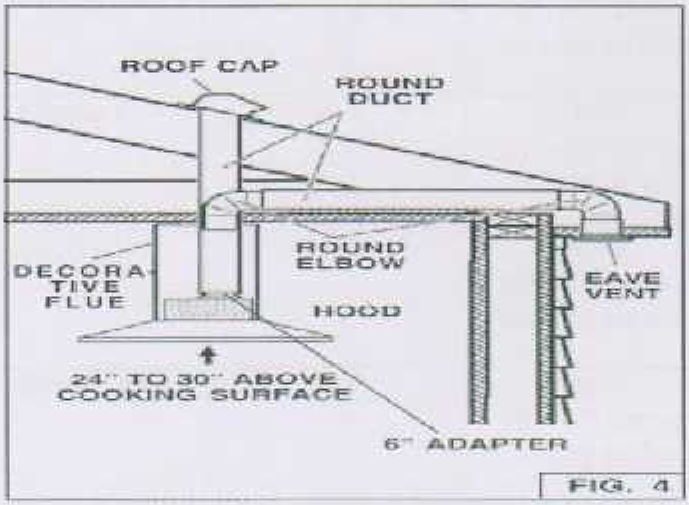
Room	Volume (m^3)	Ventilating Rate	
		(L/S)	(m^3/h)
Bath room A1	13.02	36.17	130.2
Bath room A2	3.88	10.78	38.88
Bath room B1	5.47	15.19	54.68
Bath room B2	7.26	20.17	72.61
Bath room B3	7.70	21.39	77.00
Bath room C1	13.14	36.5	131.4
Bath room C2	9.61	26.69	96.08
Bath room D1	15.07	41.86	150.69
Bath room D2	2.97	8.25	29.7
Bath room E1	13.47	37.42	134.7
Bath room E2	5.87	16.31	58.71
Bath room F1	5.59	15.53	55.90
Bath room F2	7.26	20.17	72.61
Bath room F3	7.7	21.39	77.0
Bath room G1	12.92	35.89	129.2
Bath room G2	3.88	10.78	38.80

Using domestic fan to ventilate bathrooms:

1- Domestic fans for ventilation of bathrooms, toilets and storage rooms can be wall or window mounted and in some cases duct mounted.

2- The used type of fans for ventilation in bathrooms is BF-W100 axial fan.

For kitchen the use of hood fan is installed.



Figure(5.13): Ventilation in kitchen

Table (5.35): Ventilation rates for kitchens

Room	Volume (m^3)	Ventilating
Kitchen A	27.72	Hood 30"- 40" above cooking surface
Kitchen B	54.05	Hood 30"- 40" above cooking surface
Kitchen C	40.7	Hood 30"- 40" above cooking surface
Kitchen D	35.84	Hood 30"- 40" above cooking surface
Kitchen E	40.7	Hood 30"- 40" above cooking surface
Kitchen F	54.05	Hood 30"- 40" above cooking surface
Kitchen G	28.11	Hood 30"- 40" above cooking surface

For basement, Explosion proof centrifugal fans and Jet fans is used to ventilate the basement floor.

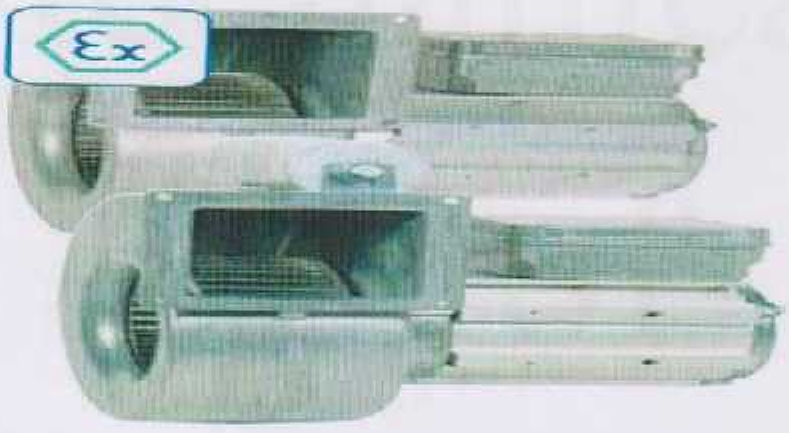


Figure (5.14): Explosion proof centrifugal fans

Figure (5.15): Jet fans

Mechanical Bill of Quantity

Bill No. (1): MECHANICAL WORKS

Item No.	Description	Unit	Qty.	Unit Rate (Shekel)	Amount (Shekel)
1.0	**Preamble** This section shall be read in conjunction with the general, particular mechanical technical specifications, mechanical drawings and invitation to bid conditions. 1-The unit price for all items in this section shall include for supply, installation, connecting, testing, and commissioning, unless otherwise specifically mentioned or instructed by the engineer. 2-All civil and finishing works related to concerned item shall be included in the unit price. 3- In case of conflict between contract documents, please refer to the engineer for clarification. 4- Responsibility of contactor is to ensure that all works are in conformity with international stated codes and local regulation. 5- Quantities, include in this bill of quantities is for guidance, the contractor shall check and verify all quantities.				

Item No.	Description	Unit	Qty.	Unit Rate	Amount
1.1	**Water Supply**				
1.1.1	**Water Supply Pump Set For hot water** Supply, install, test and commission water supply pump set (factory assembled), one duty, one stand-by. The unit price shall include pressure vessel, electric control panel, electrical wiring, galvanized steel frame, inertia base, vibration isolators, concrete base and all required valves and Fittings as detailed on the drawings. Flow rate 14.2 m^3/hour, Head 2.6 Bar.	No.	2	5000	10000
1.1.2	**Water Supply Pump Set For cold water** Supply, install, test and commission water supply pump set (factory assembled), one duty, one stand-by. The unit price shall include pressure vessel, electric control panel, electrical wiring, galvanized steel frame, inertia base, vibration isolators, concrete base and all required valves and Fittings as detailed on the drawings. Flow rate 25.8 m^3/hour, Head 2.6 Bar.	No.	2	5000	10000
1.1.3	**Expansion tank** Supply and install expansion tank "Elbi type" at each hot and cold water systems with 200 litter capacity. Expansion Tank (closed type). The unit price shall include gate valve, double check valve, safety valve, drain valve.	No.	2	2200	4400
1.1.4	**Galvanized Steel Pipes & Fittings** Supply, install, test and commission galvanized steel pipe work to ASTM-A53 Grade "A", for domestic hot and cold water supply pipe work up to the water outlet. The unit price shall include valves, expansion joints, pressure regulators, air vents, fittings and all accessories and works required to complete the work as shown on drawings, specifications and P.M. instructions.				
A.	Diameter 1.5"	ML	155	360	55800
B.	Diameter 1.25"	ML	158	280	44240

Item No.	Description	Unit	Qty.	Unit Rate	Amount
1.1.5	**Polyethylene (PEX) Distribution Pipes** Supply, install, test and commission Cross-linked polyethylene (PEX) pipes to DIN 16892/3, 20 bar working pressure, for cold and hot water distribution from metal water pipes to sanitary fixtures, complete with sleeves and service valve for each connection. The unit price shall include rubber ring seal, brass elbow/adapter inside PVC termination box built in wall for connection with the sanitary fixtures, dielectric unions, excavation, bedding, back filling, chasing in wall and all works required as shown on drawings, specifications and P.M. instructions. 16 mm O.D. x 2.2mm thick, sleeve 25 mm diameter	ML	2400	16	38400
1.1.6	**Water Meter** Supply, install, test and commission water meter with total riser, 2" diameter, including air vent, check valve, strainer, two gate valves, connection to municipality's potable water supply network, fittings, and all accessories and works required to complete the work as shown on the drawings and as per the preamble, specifications and the Supervision engineer's requirements.	No.	1	150	150
1.1.7	**Water Collector** Supply and install hot and cold water collector's type GIACOMINI or E.A With all its accessories and its suspension bolts and beams.				
A.	$1\frac{1}{2}$'' cold water collector	EYE	260	60	15600
B.	$1\frac{1}{4}$'' hot water collector	EYE	128	50	6400

Item No.	Description	Unit	Qty.	Unit Rate	Amount
1.2	**Sanitary Drainage**				
1.2.1	**Water closet** Supply, install, test and commission of floor mounted, white color, porcelain, siphon jet water closet with an elongated bowl, seat with open front and click hinge and carrier or equivalent including necessary accessories, 9 Litters capacity cistern, valves, fittings, 13mm stop angle valves, chrome plated 13mm hose, heavy duty side 1m length, 13mm chrome plated hand shower, connection to drainage and water systems as per drawings, specifications and related codes.	No.	64	600	38400
1.2.2	**Sink** Supply, install, test and commission of glazed porcelain basin sink white size 20×40 × 60-cm excellent water mixer chrome the price shall include plastic siphon and the drain to the nearest floor drain and all that is required for installation and installation according to plans and specifications and instructions of the supervising engineer.	No.	28	300	8400
1.2.3	**Lavatory** Supply and install porcelain wall hung semi pedestal lavatory European type class A, size (45*55-cm), complete with all fittings, valves, waste pipes to nearest floor trap, taps (mixer) (class A and approved by Palestine standard institution), connection to water distribution, traps, with soap holder and any other necessary parts as specification and as directed by Eng. Price including supplying and installing 40*60-cm Aluminum framed mirror.	No.	64	200	12800
1.2.4	**Bidet** Supply and install a white colored porcelain water closet bidet with dimensions 57*37-cm.	No.	20	1000	20000
1.2.5	**Shower** Supply and install a fiber glass shower with a traditional rain can shower head riser shower	No.	36	800	28800

	system.				
Item No.	**Description**	**Unit**	**Qty.**	**Unit Rate**	**Amount**
1.2.6	**Floor Drain** Supply, install, test and commission of 4'' chrome plated threaded 15*15-cm cast brass cover, multi inlet adjustable with trap floor drain. Including floor cleanout plug, HDPE siphon or equivalent and necessary accessories, connections with fixtures and main drain pipes. As per drawings, specifications, and related codes.	NO.	168	100	16800
1.2.7	**Clean out** Supply, install, test and commission of the following HDPE or equivalent, non adjustable 15*15-cm stainless steel cover, and floor clean out with gas and water tightness ABS plug and necessary accessories as per drawings, specifications, and related codes.	No.	132	100	13200
1.2.8	**Vertical and horizontal UPVC pipe** Supply, install UPVC pipes and fittings similar to local made P.S SN 8. The rate shall include all needed connections and all types of fittings caps, all done according to drawings, specifications, and the approval of the supervision engineer.				
A.	Diameter 2''	ML	300	20	6000
B.	Diameter 4''	ML	350	30	10500
C.	Diameter 6''	ML	240	90	21600
1.2.9	**Manholes** Supply and install PRE-CAST concrete manholes of 15 cm thick walls and base with heavy duty cast iron covers and frames of 25 tons load strength with all necessary excavation back filling as specified to the required depth with steps of galvanized pipe ½'' benching and connecting it to main city manholes as shown in drawing and in accordance to specifications and approval engineers.	No.	34	1800	61200

Item No.	Description	Unit	Qty.	Unit Rate	Amount
1.3	**Fire Fighting** Supply and install galvanized steel pipes to ASTM-A53 grade "A" schedule 40 for firefighting system pipe work, inside building. The unit price shall include valves, fittings, and all accessories and works required to complete the work and as specifications, and the supervision of engineer's requirements.				
A.	Diameter 2''	ML	480	120	57600
B.	Diameter 4''	ML	132	100	13200
1.3.1	**Fire fighting pump set** Supply, install, test and commission firefighting pump set (factory assembled), composed on one electric on duty pump, one stand-by Diesel pump, jockey pump, and automatic control panel. The unit price shall include pressure vessel, electric control panel, electrical wiring, galvanized steel frame, inertia base, vibration isolators, concrete base, piping from water reservoir to delivery header outlet complete with test lines, and all required valves and fittings as detailed on the drawings, specifications and P.M. instructions. Flow rate 113.5 m^3/hour, Head 7 Bar.	No.	1	13000	13000
1.3.2	**Fire Extinguisher** Supply and install portable fire extinguisher of 6 Kg. CO2 capacity each in location as decided by the engineer. The installation shall be complete with brackets and it should be in accordance with the civil defense specification.	No.	28	300	8400
1.3.3	**Fire Hose Reel Cabinets** Supply, install, test and commission fire hose reel cabinets to complete with 20 meters long $1\frac{1}{2}$'' diameter rubber hose of 16 bar working pressure. The unit price shall include hose cabinet, pressure reducing valve, globe valve and automatic swinging recessed type cabinet as detailed on drawings and as the specifications and the supervision engineer's requirements.	No.	16	1000	16000

Item No.	Description	Unit	Qty.	Unit Rate	Amount
1.4	**Air conditioning VRF system** Supply, install, test and commission of the following spilt unit, ceiling mounted cassette and wall mounted type indoor unit, complete with electrical connections, insulated PVC drained pipe, indoor/ outdoor hanging supports and insulated copper pipes with necessary Accessories. As per drawings and related Codes.				
A.	Wall mounted type	No.	60	6700	402000
B.	Cassette type	No.	96	5600	537600
1.4.1	**VRF Outdoor Unit** Supply, install, test and commission of outdoor units including all accessories, fittings, valves, and It must be Factory made and assembled. Refrigerant gas to be of zero Ozone depletion potential (ODP) as R410A. All as per Sanyo, Daikin,Samsung or EA.				
A.	**10 HP outdoor unit**	No.	2		
B.	**12 HP outdoor unit**	No.	8		
C.	**14 HP outdoor unit**	No.	2		
D.	**20 HP outdoor unit**	No.	1		
1.6	**Ventilation**				
1.6.1	**Exhaust Fans** Supply, install, connect, test and commission of domestic fan for bathrooms, hood for kitchen, explosion proof centrifugal fan and jet fans for basement.				
A.	Domestic fan	No.	64	800	51200
B.	Hood	No.	28	2500	70000
C.	Explosion proof centrifugal fan	No.	8	12000	96000
D.	Jet fan	No.	2	900	1800
1.7	**Boiler** Supply, install, and connect hot water industrial boiler from type THW-I NT E with high efficiency and flow rate 241.5 L\hour.	No.	1	14000	14000
				Total cost	1703490

Appendix

A

A1: Description of wall construction groups

TABLE 9-5 Description of wall construction groups.

Group No.	Description Of Construction	U_o, $W/m^2 \cdot °C$
	101.6 mm Face Brick + (Brick)	
C	Air space + 101.6 mm face brick	2.033
D	101.6 mm common brick	2.356
C	25.4 mm insulation or air space + 101.6 mm common brick	0.987-1.709
B	50.6 mm insulation + 101.6 mm common brick	0.630
B	203.2 mm common brick	1.714
A	Insulation or air space + 203.2 mm common brick	0.874-1.379
	101.6 mm Face Brick + (H.W. Concrete)	
C	Air space + 50.8 mm concrete	1.987
B	50.8 mm insulation + 101.6 mm concrete	0.658
A	Air space or insulation + 203.2 mm or more concrete	0.625-0.636
	101.6mm 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

A2: 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.

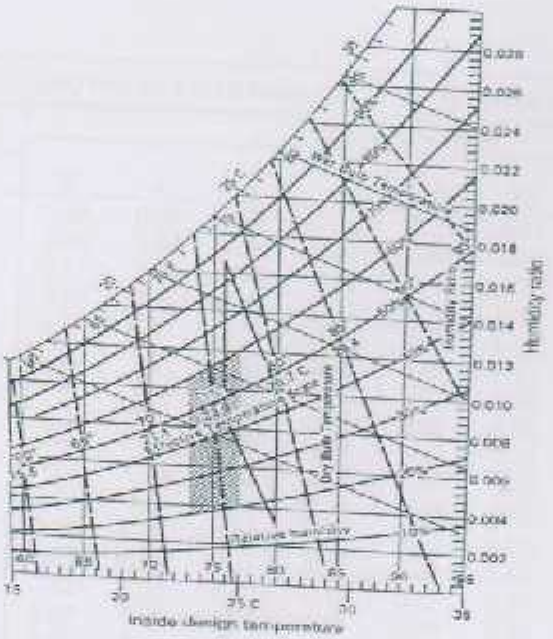
Solar Time	Wall construction											
	Light				Medium				Heavy			
	N	E	S	W	N	E	S	W	N	E	S	W
8:00	—	16	—	—	—	—	—	—	—	—	—	—
9:00	—	20	—	—	—	6	—	—	—	—	—	—
10:00	—	21	2	—	—	11	—	—	—	—	—	—
11:00	—	18	7	—	—	14	—	—	—	3	—	—
12:00	—	12	12	—	—	15	—	—	—	5	—	—
13:00	2	9	15	5	—	14	5	—	—	7	—	—
14:00	3	7	16	13	—	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

A3: 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

A4: Inside design temperature



A5: cooling load factor (CLF), for lights

Table (A-8) Cooling load factor (CLF), for lights [3]

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

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

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

A6: Cooling load factor due to occupants (CLF). for sensible gain

Table (A-6-2) Cooling load factor due to occupants (CLF)..., for sensible heat gain.[a]

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

A7: 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

A8: 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	0.37	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

A9: 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

A10: 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 – Medium	Venetian Blinds – Light	Roller Shade – Opaque – Dark	Roller Shade – Opaque – White	Roller Shade – Translucent – 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	—	—

A11: 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, $W/m^2 \cdot K$ $h_o = 22.7$	Shading Coefficient, $W/m^2 \cdot K$ $h_o = 17.0$
Single Glass				
Clear	3	0.84	1.00	1.00
	6	0.78	0.94	0.95
	10	0.72	0.90	0.92
	12	0.67	0.87	0.88
Heat absorbing	3	0.64	0.83	0.85
	6	0.46	0.69	0.73
	10	0.33	0.60	0.64
	12	0.42	0.53	0.58
Double Glass				
Regular	3	—	0.90	—
Plate	6	—	0.83	—
Reflective	6	—	0.20-0.40	—
Insulating Glass				
Clear	3	0.71	0.88	0.88
	6	0.61	0.81	0.82
Heat absorbing*	6	0.36	0.55	0.58

A12: 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

A13: 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

A14: Infiltration rates due to door opening

TABLE 6–5 Infiltration rates due to door opening, m³ per passage.[4]

№ of Passage per Hour	Doors in One Wall Only			Doors in more than One Wall		
	Single Swing	Vestibule Swinging Doors	Revolving Doors	Single Swing	Vestibule Swinging Doors	Revolving Doors
300	4.757	3.540	1.359	3.115	2.350	0.850
500	4.757	3.540	1.303	3.115	2.350	0.821
700	4.757	3.540	1.218	3.115	2.322	0.765
900	4.757	3.540	1.104	3.087	2.322	0.708
1,100	4.757	3.540	0.935	3.087	2.322	0.651
1,200	4.757	3.540	0.850	3.058	2.322	0.595
1,300	4.757	3.540	0.793	3.058	2.322	0.538
1,400	4.757	3.540	0.708	3.058	2.294	0.510
1,500	4.757	3.540	0.651	3.058	2.294	0.481
1,600	4.729	3.540	0.595	3.058	2.294	0.453
1,700	4.616	3.511	0.538	3.030	2.294	0.425
1,800	4.502	3.455	0.510	2.973	2.265	0.396
1,900	4.418	3.398	0.481	2.945	2.265	0.368
2,000	4.304	3.341	0.453	3.832	2.237	0.340

A15: Table for estimating demand

Table (P-1): Table for Estimating Demand

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

A16: fixture units

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	2	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*
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:

A17: Approximate discharge rates and velocities in sloping drains flowing half full

Table (P-2) Approximate Discharge Rates and Velocities* in Sloping Drains Flowing Half Full†

Actual Inside Diameter of Pipe, in.	1/16 in./ft Slope		1/8 in./ft Slope		1/4 in./ft Slope		1/2 in./ft slope	
	Discharge, gpm	Velocity, fps	Discharge, gpm	Velocity, fps	Discharge, gpm	Velocity, fps	Discharge, gpm	Velocity, fps
1¼							3.40	1.78
1⅜					3.13	1.34	4.44	1.90
1½					3.91	1.42	5.53	2.01
1⅝					4.81	1.50	6.80	2.12
2					8.42	1.72	11.9	2.43
2½			10.8	1.41	15.3	1.99	21.6	2.82
3			17.6	1.59	24.8	2.25	35.1	3.19
4	26.70	1.36	37.8	1.93	53.4	2.73	75.5	3.86
5	48.3	1.58	68.3	2.23	96.6	3.16	137.	4.47
6	78.5	1.78	111.	2.52	157.	3.57	222.	5.04
8	170.	2.17	240.	3.07	340.	4.34	480.	6.13
10	308.	2.52	436.	3.56	616.	5.04	872.	7.12
12	500.	2.83	707.	4.01	999.	5.67	1415.	8.02

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

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

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

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A18: Horizontal fixture branches and stacks

Table (P-3) Horizontal Fixture Branches and Stacks

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

*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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A19: 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

A20: 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

A21: 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.

A22: Minimum pressure required by typical plumbing fixtures

Table 9.2 Minimum Pressure Required by Typical Plumbing Fixtures

Fixture Type	Minimum Pressure, psi
Sink and tub faucets	8
Shower	8
Water closet—tank type	8
Flush valve—urinal	15
Flush valve—siphon pedestal	
Floor mounted	15
wall-mounted[a]	20
Flush valve—blowout bowl	
Floor mounted	25
wall-mounted	25
Garden hose	
½-in. sill cock	15
¾-in. sill cock	30
Drinking fountain	15

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

Table 9.3 Recommended Flow Rates for Typical Plumbing Fixtures

Fixture Type	Flow, gpm
Lavatory	3
Sink	4.5
Bathtub	6
Laundry tray	5
Shower	3–10
Water closet	
tank type	3
flush valve[a]	15–40
Urinal flush valve	15
Garden hose	
½-in. sill cock	3½
¾-in. sill cock	5
Drinking fountain	¾

Source: Data collected from various sources.

[a] Wide range of flows depends on fixture.

Table 9.5 Demand at Individual Water Outlets

Type of Outlet	Demand, gpm
Ordinary lavatory faucet	2.0
Self-closing lavatory faucet	2.5
Sink faucet, ⅜ or ½ in.	4.5
Sink faucet, ¾ in.	6.0
Bath faucet, ½ in.	5.0
Shower head, ½ in.	5.0
Laundry faucet, ½ in.	5.0
Ballcock in water closet flush tank	3.0
1-in. flush valve (25 psi flow pressure)	35.0
1-in. flush valve (15 psi flow pressure)	27.0
¾-in. flush valve (15 psi flow pressure)	15.0
Drinking fountain jet	0.75
Dishwashing machine (domestic)	4.0
Laundry machine (8 or 16 lb)	4.0
Aspirator (operating room or laboratory)	2.5
Hose bibb or sill cock (½ in.)	5.0

Source: Data reproduced with permission from the National Standard Plumbing Code, published by the National Association of Plumbing, Heating, Cooling Contractors.

Table 9.4 Table for Estimating Demand

Supply Systems Predominantly for Flush Tanks		Supply Systems Predominantly for Flushometers	
Load, WSFU[a]	Demand, gpm	Load, WSFU[a]	Demand, gpm
6	5	—	—
10	8	10	27
15	11	15	31
20	14	20	35
25	17	25	38
30	20	30	41
40	25	40	47
50	29	50	51
60	33	60	55
80	38	80	62
100	44	100	65
120	49	120	74
140	53	140	77
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	210
1250	240	1250	240
1500	270	1500	270
1750	300	1750	300
2000	325	2000	325
2500	380	2500	380
3000	435	3000	435
4000	525	4000	525
5000	600	5000	600
6000	650	6000	650
7000	700	7000	700
8000	730	8000	730
9000	760	9000	760
10000	[illegible]	10000	[illegible]

[a] Water supply fixture units.

Source: Reproduced with permission from the National Standard Plumbing Code, published by the Na[illegible]

A23: Drainage fixture unit values for various plumping fixtures

Table 10.2 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
Bathroom group consisting of a water closet, lavatory and bathtub or shower stall	4
Bathtub (with or without overhead shower)*	2
Bidet	1
Clinic sink	6
Clothes washer	2
Combination sink and tray with food waste grinder	4
Combination sink-and-tray with one 1½-in. trap	2
Combination sink-and-tray with separate 1½-in. trap	3
Dental unit or cuspidor	1
Dental lavatory	1
Drinking fountain	½
Dishwasher, domestic	2
Floor drains with 2-in. waste	3
Kitchen sink, domestic, with one 1½-in. trap	2
Kitchen sink, domestic, with food waste grinder	2
Kitchen sink, domestic, with food waste grinder and dishwasher 1½-in. trap	3
Kitchen sink, domestic, with dishwasher 1½-in. trap	3
Lavatory with 1¼-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	3
Water closet, private	4
Water closet, general use	6
Fixtures not already listed	
trap size 1¼ in. or less	1
trap size 1½ in.	2
trap size 2 in.	3
trap size 2½ in.	4
trap size 3 in.	5
trap size 4 in.	6

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

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Table 10.3 Minimum Size of Nonintegral Traps

Plumbing Fixture	*Trap Size, in.*
Bathtub (with or without overhead shower)	1½
Bidet	1¼
Clothes washing machine standpipe	2
Combination sink and wash (laundry) tray	1½
Combination sink and wash (laundry) tray with food waste grinder unit*	1½
Combination kitchen sink, domestic, dishwasher, and food waste grinder	1½
Dental unit or cuspidor	1¼
Dental lavatory	1¼
Drinking fountain	1¼
Dishwasher, commercial	2
Dishwasher, domestic (nonintegral trap)	1½
Floor drain	2
Food waste grinder, commercial	2
Food waste grinder, domestic	1½
Kitchen sink, domestic, with food waste grinder unit	1½
Kitchen sink, domestic	1½
Kitchen sink, domestic, with dishwasher	1½
Lavatory, common	1¼
Lavatory (barber shop, beauty parlor or surgeon's)	1½
Lavatory, multiple type (wash fountain or wash sink)	1½
Laundry tray (1 or 2 compartments)	1½
Shower stall or drain	2
Sink (surgeon's)	1½
Sink flushing rim type (flush valve supplied)	3
Sink (service type with floor outlet trap standard)	3
Sink (service trap with P trap)	2
Sink, commercial (pot, scullery, or similar type)	2
Sink, commercial (with food grinder unit)	2

*Separate trap required for wash tray and separate trap required for sink compartment with food waste grinder unit.

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A24: Horizontal fixture branches and stacks, building drains and sewers

Table 10.4 Horizontal Fixture Branches and Stacks

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

*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 10.5 Building Drains and Sewers*

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

*On site sewers that serve more than one building may be sized according to the [illegible] standards and requirements of the administrative [illegible]
[b]Not over two water closets or two bathroom groups, except that in single family dwellings, not over three water closets or three bathroom groups may be installed.
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A25: 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

References

1- Heating and air conditioning for residential buildings.

2- Heating ventilation and air conditioning analysis and design, 4th edition.

2- Nguyen, Huong, Turgeon, Scott and Matte, Joshua. (2010). " The Anaerobic Baffled Reactor: A study of the wastewater treatment process using the anaerobic baffled reactor.".