Palestine Polytechnic University

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

Graduation Project

Design of Mechanical Systems for the Bank of Palestine - Asira Office

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Special thanks

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I believe that this work would not be accomplished without their inspiration.

إهداء

الى من كانت دعواتها صدى في أذني ورحمة على قلبي وتخفيفاً من مكابدتي

الى أمي

الى من كانت يداه مبسوطتان لإسعادي ولإنجاحي

الى أبي

الكلمات عاجزة عن وصف حبي لها ، فهي تقف إلى جانبي في كل خطوة وحريصة على دعمي

ومساندتي باستمرار. هي حب حياتي

الى زوجتي

الى الشموخ التي أنارت لي دروب العلم والمعرفة منذ طفولتي حتى تخرجي

الى أساتذتي

الى فاتنتي المدللة الساكنة في قلبي الكبير، أعطتني معنى الحياة أهزوجة جوهرية تملئ الدنيا حنين

الى ابنتي الصغيرة سيلين

Abstract

It is known that the thermal science topics is the most important topics in the Department of Mechanical Engineering due to their content on the principles and characteristics of the heat transfer and thermodynamics processes and dynamic factors affecting in those subjects. The process of studying and accounts in the heating and air conditioning, refrigeration depending on those topics and the basis of the calculations and design of mechanical systems operations. As this project talks about the design of mechanical systems of the Bank of Palestine branch of Asira (design of heating and air-conditioning system and the extension of the water and sewage system. Where the building consists of one floor with approximated area of 340 square meters.

In this project, air conditioning system type (VRF) is used since it is efficient and economic .

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CHAPTER ONE

1.1 Introduction

Due to hot summer and cold winter, and sometimes the extreme weather in Nablus, air conditioning system must be installed in each building in order to people feel comfortable.

Heating and cooling loads are the measure of energy needed to be added or removed from a building by the HVAC system to provide the desired level of comfort within a building. And the calculation results will have a direct impact on first construction costs along with the operating energy efficiency, occupant comfort, indoor air quality, and building durability.

The air conditioning system used in this project is the variable refrigerant flow, because its frugality energy, expenses, efficiency, and control.

1.2 Project importance

- In order to achieve all means for human comfort.
- Improving the efficiency of heating and air conditioning system used in the bank by replacing it with the VRF system .

1.3 Project objectives

- To design the mechanical services for the building .
- Design variable refrigeration flow (VRF) air conditioning system for the bank.
- Achieve graduation requirements .

1.4 Key words

- VRF: Variable Refrigeration flow.
- WSFU: water supply fixture unit used for calculation of maximum water demand for the building.
- DFU: Drainage fixture unit used for the calculation and design of drainage system.

1.5 Related studies

- Radio and television building in Ramallah.
- Industrial administration building in Jericho.
- Culture Palace in Ramallah.

1.6 Time table

The tasks and time tables for the first and second semesters are shown below :

Table 1.1: Tasks description

Task ID	Task Description
T1	Choosing the building plane
T2	Review of previous project
T3	Overall heat transfer coefficient calculation for wall, ceiling, floor, and windows
T4	Heating and cooling loads calculation
T5	Documentation
T6	Water supply system calculation
T7	Drainage system calculation
T8	Design of VRF system
T9	Design of plumbing system
T10	Design of fire fighting system
T11	Bill of quantity tables
T12	Printing

Table 1.2: Time table

1^{st} semester															
Task/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
T1	■	■	■												
T2			■	■	■	■	■	■	■	■	■	■			
T3				■	■										
T4					■	■	■	■	■	■	■				
T5														■	■
2^{st} semester															
Task/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
T6	■	■													
T7			■	■											
T8					■	■	■								
T9								■	■						
T10										■	■				
T11												■	■	■	
T12														■	■

CHAPTER TWO

Heating and Cooling Loads
Design Conditions

2.1 Overview

This talks about selection of the design conditions that fit to this type of building and that fit with the region that included this building depending on the Palestinian code and some tables that relate to this object.

2.2 Thermal Comfort Criteria for Inside Design Condition

The inside design conditions refer to temperature, humidity, air speed and quality of inside air that will induce comfort to occupants of the space at minimum energy consumption. There are several factors that control the selection of the inside design conditions and expenditure of energy to maintain those conditions:

1- The outside design conditions.

2- The period occupancy of the conditioned space.

3- The level of activity of occupants in the conditioned space.

2.3 ASHRAE comfort chart

ASHRAE is an abbreviation for the American Society of Heating Refrigerating and Air conditioning Engineers. Its Standard Thermal Environmental Conditions for Human Occupancy describes the combinations of indoor space conditions and personal factors necessary to provide comfort in the effective way. There are no static rules that indicate the best atmospheric condition for making all the individual comfortable because human comfort is affected by several factors such as health, age, clothing, etc.[1]

Comfort conditions are obtained as result of tests for which people are subjected to air at various combinations of temperatures and relative humidities. The results of such tests indicate that a person will feel just about as cool at 24℃ and 60% relative humidity between 30% and 70% indicated that 98% of people feel comfortable when the temperature and relative humidity combinations fall in comfort zone such as that indicated in the ASHRAE comfort chart of Fig 2.1

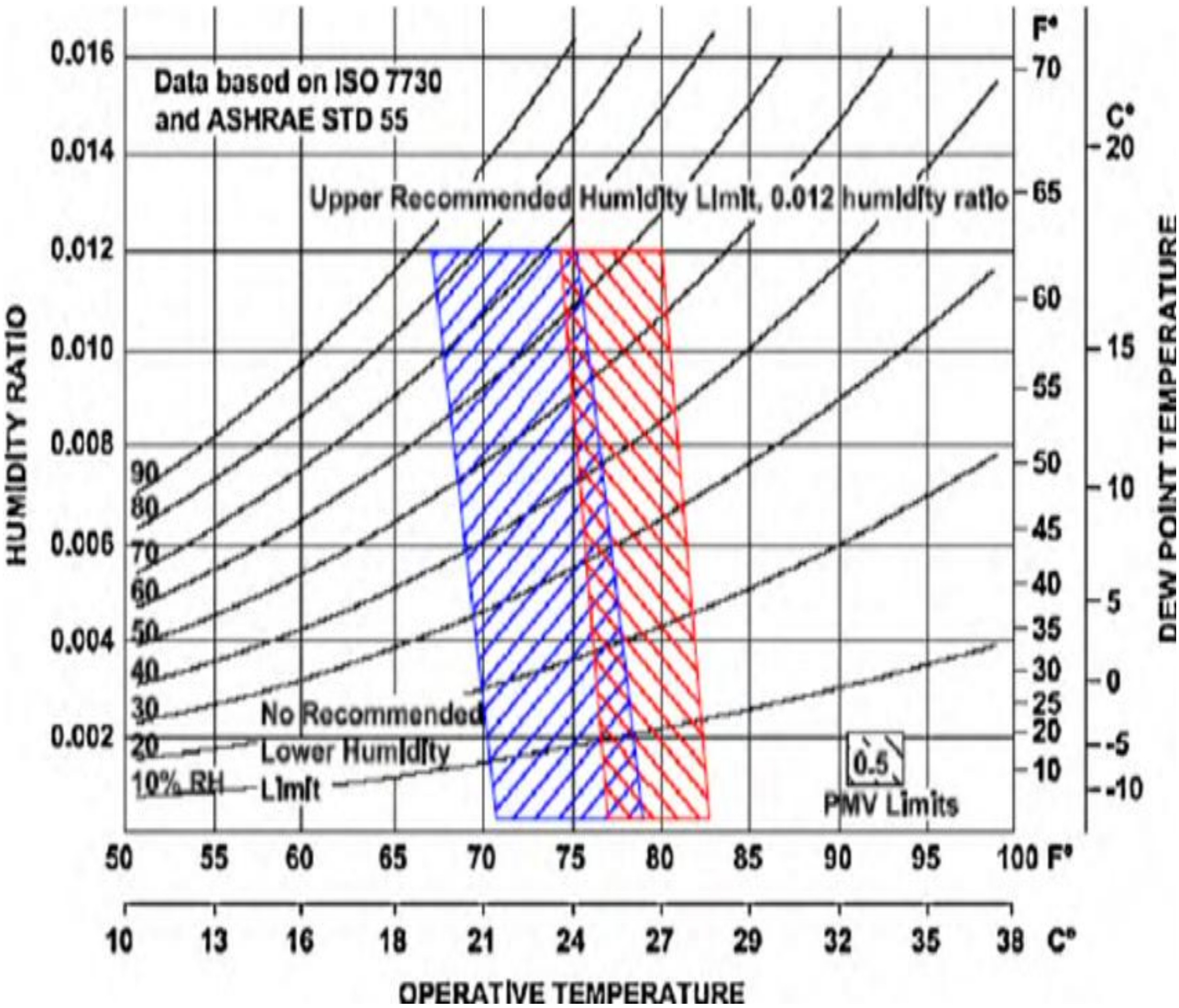


Figure 2.1 ASHRAE human comfort chart [1]

Inside design condition

T_{in} = 24 ˚C

$T_{s.in}$ = 26 °C in summer

$T_{s.in}$ = 17 °C in winter

$\emptyset_{in}$ = 50 % in summer

$\emptyset_{in}$ = 35 % in winter

v_{in}= 0.23 m/s

Where:

T_{in}: inside comfort design temperature.

$T_{s.in}$: inside surface wall temperature.

$\emptyset_{in}$: inside relative humidity.

v_{in}: inside air velocity.

Outside Design Conditions

T_{out} = 31.9 °C in summer

T_{out} = 5.7 °C in winter

$T_{s.out}$ = 28.5 °C in summer

$T_{s.out}$ = 9 °C in winter

$\emptyset_{out}$ = 61.9 % in summer

$\emptyset_{out}$ = 69.7 % in winter

v_{out} = 12.4 m/s in summer

v_{out}= 9.5 m/s in winter

Where:

T_{out}: outside design temperature.

$T_{s.out}$: outside surface wall temperature.

$\emptyset_{out}$: outside relative humidity.

v_{out}: outside air velocity.

- **Convection Heat Transfer Coefficient**

There are two ways to transfer heat by convection:

i. Forced convection.

ii. Free convection.

- Steps to calculate the forced heat transfer coefficient (h_o):

1. $T_f = (T_s + T_\infty)/2$ (2.1)

Where:

T_f : film temperature, k

T_s : surface wall temperature, k

T_∞: ambient temperature, k

2. Calculate the fluid properties v, P_r & k … from Table (A-1)

Where:

v: viscous force, m^2/s

P_r : Prandtl number

k: thermal conductivity, $W/m.K$

3. $R_e = (v \times L)/\nu$ (2.2)

If $R_e < (5 \times 10^5)$ … Laminar flow

If $R_e \geq (5 \times 10^5)$ … Turbulent flow

Where:

R_e: Reynolds number

L: reference length, m

4. $N_u = 0.66\ R_e 0.5\ P_r\ (\frac{1}{3})$ … Laminar flow (2.3)

$N_u = 0.037\ R_e 0.8\ P_r \left(\frac{1}{3}\right)$ … Turbulent flow (2.4)

Where:

Nu: Nusslet number

$h = (N_u \times k)/L$ (2.5)

- Steps to calculate the free transfer coefficient (h_i):

1. $T_f = (T_s + T_\infty)/2$
2. Calculate the fluid properties ν, P_r & k
3. $G_r = g\beta(T_s + T_\infty)L_3/\nu_2$ (2.6)

$\beta = (1/\ T_f)$ (2.7)

Where:

G_r: Grashof number

g: gravitational acceleration , m^2/s

β: coefficient of volume expansion, k^{-1}

4. $R_a = G_r * P_r$ (2.8)

If $R_a \leq 109$ … Laminar flow (2.9)

If $R_a > 109$… Turbulent flow (2.10)

Where:

Ra: Rayleigh Number

5. For Laminar flow:

$$\overline{Nu}_L = 0.68 + \frac{0.670\ Ra_L^{1/4}}{\left[1 + (0.492/\text{Pr})^{9/16}\right]^{4/9}}$$ (2.11)

6. For Turbulent flow:

$$\overline{Nu}_L = \left\{0.825 + \frac{0.387\ Ra_L^{1/6}}{\left[1+\left(0.492/Pr\right)^{9/16}\right]^{8/27}}\right\}^2 \qquad (2.12)$$

♦ Calculate the external convection heat transfer coefficient at heating load (h_o):

$T_f = (T_s + T_\infty)/2$ … From equation (2.1)

$T_f = \frac{9+5.7}{2} = 7.35°C + 273.15 = 280.5\ K$

Using interpolation to find of the fluid properties ν, P_r & k:

- ν = 14.15*10^{-6} m^2/s
- P_r = 0.71207
- k = 24.74*10^{-3} $W/m.k$

L = 3 m

$R_e = (v \times L)/\nu$ … From equation (2.2)

$R_e = (9.5 \times 3)/(14.15 \times 10^{-6}) = 2014134.276$ = (9.5*3)/ (14.15*10^{-6}) = 2014134.276 »»» Turbulent flow

$N_u = 0.037\ R_e 0.8\ P_r \left(\frac{1}{3}\right)$ … Turbulent … From equation (2.4)

$N_u = 0.037(2014134.276)^{0.8}(0.71207)^{(1/3)} = 3650.172$

$h = (N_u \times k)/L$ … From equation (2.5)

$h_o = \frac{3650.172 \times 24.74 \times 10^{-3}}{3} = 30.1\ W/m^2.\ ^\circ C$

♦ Calculate the internal convection heat transfer coefficient at heating load (h_i):

$T_f = (T_s + T_\infty)/2$ … From equation (2.1)

$T_f = \frac{17+24}{2} = 20.5°C + 273.15 = 293.65\ K$

Using interpolation to find of the fluid properties ν, Pr & k:

- ν = 15.32485*10^{-6} m^2/s
- Pr = 0.708651
- k = 25.792*10^{-3} $W/m.k$

$\beta = (1/\ T_f)$ … From equation (2.7)

$\beta = \left(\frac{1}{293.65}\right) = 3.40^{-3}\ K^{-1}$

3. $G_r = g\beta(T_s + T_\infty)L_3/\nu_2$ … From equation (2.6)

$G_r = [9.81 \times 3.40 \times 10^{-3}(24 - 17) \times 3^3]/[15.324 \times 10^{-6}]^2 = 2.6885 \times 10^{10}$

$R_a = G_r * P_r$ … From equation (2.8)

$R_a = 2.6885 \times 10^{10} \times 0.70861 = 1.90 \times 10^{10}$ »»» Turbulent flow

$N_u = \{0.825 + \frac{\mathbf{0.387\ R_a{}^{1/6}}}{[1+(0.492/P_r)^{9/16}]^{8/27}}\}^2$ … From equation (2.12)

$N_u = [0.825 + ((0.387(1.90 \times 10^{10})^{(1/6)})/((1 + \left(\frac{0.492}{0.708651}\right)^{(9/16)}\right))^{(8/27)}]^2 = 309.36$

$h_i = (N_u \times k)/L$ … From equation (2.5)

$h_i = (309.36 \times 25.792 \times 10^{-3})/3 = 2.66\ W/m^2.°C$

because there is an error in the value of h_i, take h_i = 5 $W/m^2.°C$

- Calculate the external convection heat transfer coefficient at cooling load (h_o):

$T_f = (T_s + T_\infty)/2$ … From equation (2.1)

$$T_f = \frac{31.9+29}{2} = 30.45°C + 273.15 = 303.6\ K$$

Using interpolation to find of the fluid properties ν, Pr & k:

- ν= 16.25216*10^{-6} $m^2.s$
- P_r = 0.706496
- k= 26.5664*10^{-3} $W/m.k$

L= 3 m

$R_e = (v \times L)/\nu$ … From equation (2.2)

$R_e = (12.4 \times 3)/(16.25 \times 10^{-6})$= 2288926.158 »»» Turbulent flow

$N_u = 0.037\ R_e 0.8\ P_r \left(\frac{1}{3}\right)$ … Turbulent … From equation (2.4)

$N_u = 0.037(2288926.518)^{0.8}\ (0.76496)^{1/3} = 4032.84$

$h_o = (N_u \times K)/L$ … From equation (2.5)

$$h_o = \frac{4032.84 \times 26.5664 \times 10^{-3}}{3} = 35.712\ W/m^2.°C$$

- Calculate the external convection heat transfer coefficient at heating load (h_i):

$T_f = (T_s + T_\infty)/2$ … From equation (2.1)

$T_f = \frac{26+24}{2} = 25°C + 273.15 = 298.15\ K$

Using interpolation to find of the fluid properties ν, Pr & k:

- ν = 15.72535*10^{-6} m^2/s
- P_r= 0.707481
- k = 26.152*10^{-3} $W/m.k$

$\beta = (1/T_f)$ … From equation (2.7)

$\beta = \left(\frac{1}{298.15}\right) = 3.354 \times 10^{-3} \mathrm{K}^{-1}$

3. $G_r = g\beta(T_s + T_\infty)L_3/\nu_2$ … From equation (2.6)

$G_r = [9.81 \times 3.354 \times 10^{-3} \times (26-24) \times 3^3]/[15.72535 \times 10^{-6}]^2 = 71858941$

$R_a = G_r * P_r$ … From equation (2.8)

$R_a = 71858941 \times 0.707481 = 5083257310$ »»» Turbulent flow

$N_u = \{0.825 + \frac{0.387\, {R_a}^{1/6}}{[1+(0.492/P_r)^{9/16}]^{8/27}}\}^2$ … From equation (2.12)

$N_u = [0.825 + ((0.387(5083257310)^{1/6})/((1 + (0.492/0.707481)^{9/16}))^{8/27}]^2$

$= 203.74$

$h_i = (N_u \times K)/L$ … From equation (2.5)

$h_i = \frac{203.74 \times 26.152 \times 10^{-3}}{3} = 1.776\ W/m^2.°\mathrm{C}$

h_o = 35.71 $W/m^2.°\mathrm{C}$

h_i = 1.77 $W/m^2.°\mathrm{C}$

Note: Because there is an error in the values of ho and hi, these values are obtained from tables (A-20) and (A-21).

Wall horizontal construction materials = 0.12 $m^2.°\mathrm{C}/w$

Ceiling upward construction materials = 0.10

From Table (A-21) inside resistance, Ro less than 0.5 - 5 m/s

Wall construction materials = 0.06 $m^2.°\mathrm{C}/w$

Ceiling upward construction materials = 0.04

$h_i = \frac{1}{Ri}$ (2.13)

$h_{i\ .wall} = \frac{1}{0.12}$ =*8.33* $W/m^2.°\mathrm{C}$

$h_{i\ .cieling} = \frac{1}{0.10}$ =*10* $W/m^2.°\mathrm{C}$

$h_o = \frac{1}{Ro}$ (2.14)

$h_{o\ .wall} = \frac{1}{0.06}$ =*16.66* $W/m^2.°\mathrm{C}$

$h_{o\ .cieling} = \frac{1}{0.04}$ =*25* $W/m^2.°\mathrm{C}$

2.4 Overall Heat Transfer Coefficient

The overall heat transfer coefficient depends on the layers that the wall, floor and roof consist of and the inside and outside convection heat transfer coefficients .

Over all heat transfer coefficient can be calculated by applying the following equation:

$$U=\frac{1}{\frac{1}{hi}+\sum\frac{\Delta x}{k}+\frac{1}{ho}} \qquad (2.15)$$

Δx: The layer thickness (m^2)

k: The thermal conductivity ($W/m.k$)

h_i: convection coefficients (surface conductance)of inside wall, floor, or ceiling(hi(wall) =8.33 $W/m^2.$°C) and hi (ceiling) = 10 $W/m^2.$°C) from table (A-20) .

h_o: convection coefficients (surface conductance)of outside wall, floor, or ceiling(ho wall =16.66 $W/m^2.$°C) and(ho ceiling = 25$W/m^2.$°C) .

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

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

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

The amount of load either heating or cooling (from walls, doors… etc) is directly proportional to the value of the U. [1]

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

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

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

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

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

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

The construction of layers is different from wall to wall so. Table (2.1) shows the sections for the construction layers in the building for each combination.

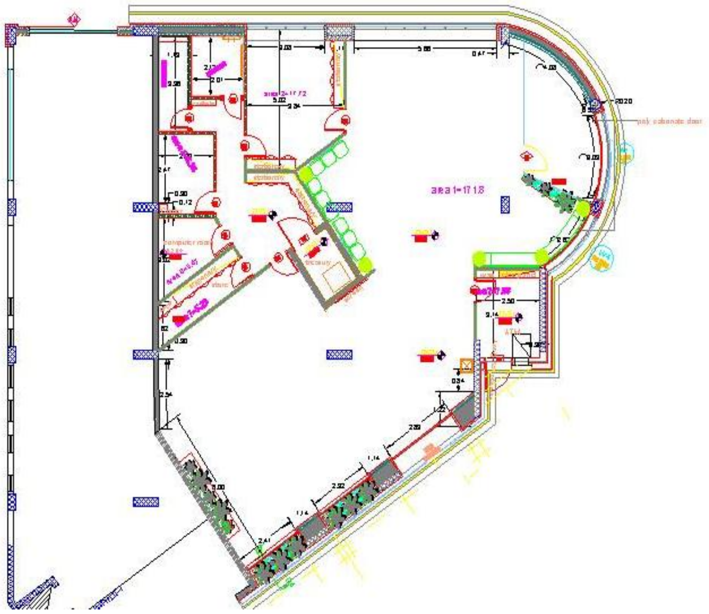
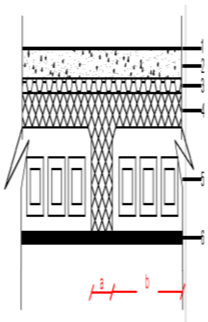
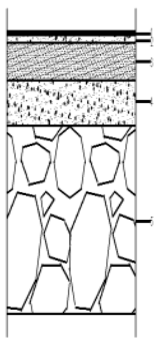
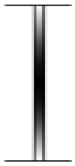
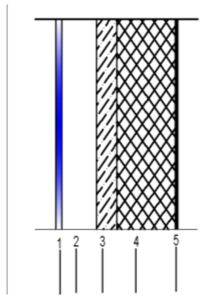
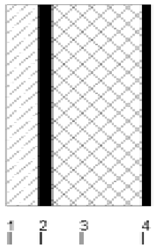
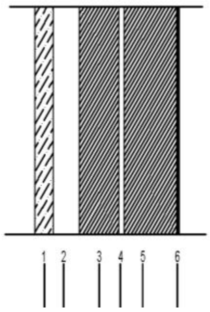
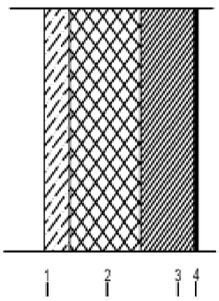
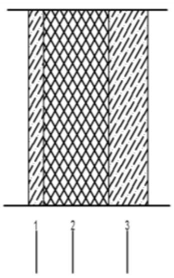
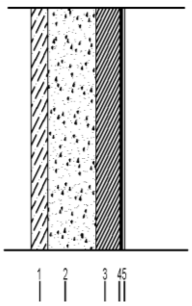
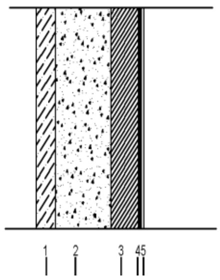
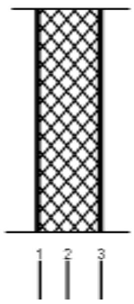


Figure 2.2 Bank of Palestine sketch

Table 2.1 : Over all heat transfer coefficients for typical ceiling, wall, floor, door, window construction .

	Construction detail	Construction material	Material Thickness (m)	Thermal Conduction $(W/m℃)$	U $W/m^2.℃$
Ceiling		1. Asphalt 2. Concrete 3. Polystyrene 4. Rain forced Concrete 5. Hollow brick 6. Plaster	0.003 0.05 0.025 0.06 0.18 0.02	0.81 1.75 0.034 0.88 0.95 1.2	0.868 1.186
Floor		1. Tiles 2. Concrete 3. Mortar 4. Sand 5. Rocks	0.01 0.12 0.02 0.1 0.5	1.20 1.75 1.2 0.7 1.05	1.23

Glass wall		1. Glass	0.02	1.4	5.15
North wall		1. Glass 2. Air gab 3. Stone 4. Rain forced concrete 5. Plaster	0.20 0.12 0.07 0.20 0.02	1.4 0.024 2.60 0.88 1.2	0.182
North wall ATM		1. Stone 2. Mortar 3. Rain forced concrete 4. Plaster	0.07 0.03 0.2 0.01	2.60 1.2 0.88 1.2	2.14
North Wall (Manager)		1. Stone 2. Air gab 3. Brick 4. Air gab 5. Brick 6. Plaster	0.07 0.10 0.15 0.02 0.20 0.01	2.60 0.024 0.95 0.024 0.95 1.2	0.180
North column (Manager)		1. Stone 2. Rain forced concrete 3. Brick 4. Plaster	0.07 0.2 0.15 0.01	2.60 0.88 0.95 1.2	1.66
West column		1. Stone 2. Rain forced concrete 3. Stone	0.07 0.30 0.18	2.60 0.88 1.7	1.74

West Wall (W.C)		1. Stone 2. Concrete 3. Brick 4. Mortar 5. Tiles ceramic	0.10 0.20 0.10 0.01 0.03	2.60 1.75 0.95 1.2 1.2	2.12
South Wall		1. Plaster 2. Brick 3. Plaster	0.01 0.15 0.01	1.2 0.95 1.2	2.82
South Column		1. Plaster 2. Reinforced concrete 3. Plaster	0.01 0.30 0.01	1.2 0.88 1.2	1.86

- Calculation of overall heat transfer coefficient for walls, partition, ceiling and floor:

$$U= \frac{1}{Rth} = \frac{1}{Rin+ \sum\frac{\Delta x}{k} + Rout} \quad (2.15)$$

$$U=\frac{1}{\frac{1}{hi}+\sum\frac{\Delta x}{k}+\frac{1}{ho}}$$

Where:

Δx: the thickness of the wall.

R_{in}: inside film resistance.

R_{out}: Outside film resistance.

- **For ceiling**

Because of its construction, the ceiling is divided in to two overall heat transfer coefficient on with brick and the other without R_{in} and R_{out} for the ceiling are 0.10 and 0.04 respectively from tables (A-20) and (A-21).

$$U_1 = \frac{1}{R_{in} + \frac{\Delta x\ asph}{k\ asph} + \frac{\Delta x\ conc}{k\ conc} + \frac{\Delta x\ poly}{k\ poly} + \frac{\Delta x\ conc}{k\ conc} + \frac{\Delta x\ brick}{k\ brick} + \frac{\Delta x\ plaster}{k\ plaster} + R_{out}} \quad (2.16)$$

$$U_1 = \frac{1}{0.10 + \frac{0.003}{0.81} + \frac{0.05}{1.75} + \frac{0.025}{0.034} + \frac{0.06}{1.75} + \frac{0.18}{0.95} + \frac{0.025}{1.2} + 0.04}$$

U_1 = 0.868 W/m^2.˚C

With brick U_2 =1.039 W/m^2.˚C

$$U_2 = \frac{1}{0.10 + \frac{0.003}{0.81} + \frac{0.05}{1.75} + \frac{0.025}{0.034} + \frac{0.06}{1.75} + \frac{0.025}{1.2} + 0.04}$$

Without brick U_2= 1.0388 W/m^2.˚C

- **For floor :**

$$U = \frac{1}{R_{in} + \frac{\Delta x\ tiles}{k\ tiles} + \frac{\Delta x\ concrete}{k\ concrete} + \frac{\Delta x\ mortar}{k\ mortar} + \frac{\Delta x\ sand}{k\ sand} + \frac{\Delta x\ rocks}{k\ rocks}} \quad (2.17)$$

$$U = \frac{1}{0.10 + \frac{0.01}{1.20} + \frac{0.12}{1.75} + \frac{0.02}{1.2} + \frac{0.1}{0.7} + \frac{0.5}{1.05}}$$

U = 1.23 W/m^2.˚C

- **Wall east glass, east wall, north wall, manager wall, and west wall**

$$U1 = \frac{1}{R_{in} + \frac{\Delta x\ glass}{k\ glass} + R_{out}} \quad (2.18)$$

$$U1 = \frac{1}{0.12 + \frac{0.02}{1.4} + 0.06}$$

= 5.15 W/m^2.˚C

- **For external door glass (waiting room)**
  - **East door**

$$U_{glass\ door} = \frac{1}{R_{in} + \frac{\Delta x\ glass}{k\ glass} + R_{out}} \quad (2.19)$$

$$U = \frac{1}{0.12 + \frac{0.02}{1.4} + 0.06}$$

= 5.15 W/m^2.˚C

- **For external wall (waiting room)**
    - ✦ **North wall**

$$U = \frac{1}{R_{in}+\frac{\Delta x\, glass}{k\, glass}+\frac{\Delta x\, air\, gab}{k\, air\, gab}+\frac{\Delta x\, stone}{k\, stone}+\frac{\Delta x\, rain}{k\, rain}+\frac{\Delta x\, plaster}{k\, plaster}+R_{out}} \tag{2.20}$$

$$U = \frac{1}{0.12+\frac{0.02}{1.4}+\frac{0.12}{0.024}+\frac{0.07}{2.60}+\frac{0.20}{0.88}+\frac{0.03}{1.2}+0.06}$$

= 0.182 W/m^2.˚C

- **For external walls (ATM room)**
    - ✦ **North wall**

$$U = \frac{1}{R_{in}+\frac{\Delta x\, stone}{k\, stone}+\frac{\Delta x\, morter}{k\, morter}+\frac{\Delta x\, rein}{k\, rein}+\frac{\Delta x\, plaster}{k\, plaster}+R_{out}} \tag{2.21}$$

$$U = \frac{1}{0.12+\frac{0.07}{2.60}+\frac{0.03}{1.2}+\frac{0.2}{0.88}+\frac{0.01}{1.2}+0.06}$$

= 2.14 W/m^2.˚C

- **For external walls (Manager)**
    - ✦ **North wall**

$$U = \frac{1}{R_{in}+\frac{\Delta x\, stone}{k\, stone}+\frac{\Delta x\, air\, gab}{k\, air\, gab}+\frac{\Delta x\, brick}{k\, brick}+\frac{\Delta x\, air\, gab}{k\, air\, gab}+\frac{\Delta x\, brick}{k\, brick}+\frac{\Delta x\, plaster}{k\, plaster}+R_{out}} \tag{2.22}$$

$$U = \frac{1}{0.12+\frac{0.07}{2.60}+\frac{0.10}{0.024}+\frac{0.15}{0.95}+\frac{0.02}{0.024}+\frac{0.15}{0.95}+\frac{0.01}{1.2}+0.06}$$

= 0.180 W/m^2.˚C

- **For external manager north column**

$$U= \frac{1}{R_{in}+\frac{\Delta x\, stone}{k\, stone}+\frac{\Delta x\, rein}{k\, rein}+\frac{\Delta x\, brick}{k\, brick}+\frac{\Delta x\, plaster}{k\, plaster}+R_{out}} \tag{2.23}$$

$$U= \frac{1}{0.12+\frac{0.07}{2.60}+\frac{0.2}{0.88}+\frac{0.15}{0.95}+\frac{0.01}{1.2}+0.06}$$

= 1.66 W/m^2.˚C

- **For external walls (waiting room)**
    - ✦ **West Column**

$$U = \frac{1}{R_{in}+\frac{\Delta x\, stone}{k\, stone}+\frac{\Delta x\, rein}{k\, rein}+\frac{\Delta x\, stone}{k\, stone}+R_{out}} \tag{2.24}$$

$$U = \frac{1}{0.12+\frac{0.07}{2.60}+\frac{0.30}{0.88}+\frac{0.7}{2.60}+0.06}$$

$= 1.74\ W/m^2.^\circ C$

- **For external walls (W.C)**
  - ✦ **West wall**

$$U1= \frac{1}{R_{in}+\frac{\Delta x\ stone}{k\ stone}+\frac{\Delta x\ concrete}{k\ concrete}+\frac{\Delta x\ brick}{k\ brick}+\frac{\Delta x\ morter}{k\ morter}+\frac{\Delta x\ tiles\ seramic}{k\ tiles\ seramic}+R_{out}} \quad (2.25)$$

$$U1= \frac{1}{0.12+\frac{0.10}{2.60}+\frac{0.20}{1.75}+\frac{0.10}{0.95}+\frac{0.01}{1.2}+\frac{0.03}{1.2}+0.06}$$

$= 2.12\ W/m^2.^\circ C$

- **For external walls (W.C, Kitchen, computer room, stationary, waiting room)**
  - ✦ **South wall**

$$U1= \frac{1}{R_{in}+\frac{\Delta x\ plaster}{k\ plaster}+\frac{\Delta x\ brick}{k\ brick}+\frac{\Delta x\ plaster}{k\ plaster}+R_{out}} \quad (2.26)$$

$$U1= \frac{1}{0.12+\frac{0.01}{1.2}+\frac{0.15}{0.95}+\frac{0.01}{1.2}+0.06}$$

$= 2.82\ W/m^2.^\circ C$

- **For external manager west column**

$$U1= \frac{1}{R_{in}+\frac{\Delta x\ plaster}{k\ plaster}+\frac{\Delta x\ rein}{k\ rein}+\frac{\Delta x\ plaster}{k\ plaster}+R_{out}} \quad (2.27)$$

$$U1= \frac{1}{0.12+\frac{0.01}{1.2}+\frac{0.30}{0.88}+\frac{0.01}{1.2}+0.06}$$

$= 1.86\ W/m^2.^\circ C$

- **Window**

  $U=5.6\ W/m^2.^\circ C$ from table (A-4)

- **Door steel (Fiber core)**

  $U=3.3\ W/m^2.^\circ C$ from table (A-5)

- **Door wood 25mm – without storm door**

  $U=3.6\ W/m^2.^\circ C$ from table (A-5)

2.5 Area Calculations

- **For the waiting room and customer service and teller:**

$A_{\ wall\ glass} = 22.35 \times 3 = 67.05\ m^2$

$A_{north\ wall} = 0.84 \times 3 = 2.52\ m^2$

$A_{north\ coulmn} = 0.59 \times 3 = 1.77\ m^2$

$A_{north\ coulmn\ (manager)} = 0.52 \times 3 = 1.56\ m^2$

$A_{north\ wall\ (manager)} = 4.08 \times 3 = 12.24\ m^2$

$A_{west\ coulmn\ 1} = 0.47 \times 3 = 1.41\ m^2$

$A_{west\ coulmn\ 2} = 0.47 \times 3 = 1.41\ m^2$

$A_{south\ coulmn} = 0.30 \times 3 = 0.9\ m^2$

$A_{south\ wall} = 8.54 \times 3 = 25.62\ m^2$

$A_{ceiling} = 171.8\ m^2$

- **For the ATM room**

$A_{east\ wall\ \ ATM} = 1.6 \times 3 = 4.8\ m^2$

$A_{external\ door\ ATM} = 0.90 \times 2 = 1.8\ m^2$

$A_{north\ wall\ \ ATM} = 3.14 \times 3 = 9.42\ m^2$

$A_{ceiling} = 2.50 \times 3.14 = 7.85\ m^2$

- **For the back office**

$A_{ceiling} = 17.72\ m^2$

$A_{coulumn} = 0.7 \times 3 = 2.1\ m^2$

$A_{glass\ wall} = 3.08 \times 3 = 9.24\ m^2$

- **For the W.C 1**

$A_{\ wall} = 2.01 \times 3 = 6.03\ m^2$

$A_{ceiling} = 2.01 \times 2.12 = 4.26\ m^2$

- **For the W.C 2**

$A_{\ wall\ west} = 1.13 \times 3 = 3.39\ m^2$

$A_{\ wall\ south} = 3.36 \times 3 = 10.08\ m^2$

$A_{ceiling} = 3.36 \times 1.13 = 3.8\ m^2$

- **For the kitchen**

$A_{wall\ south} = 2.59 \times 3 = 7.77\ m^2$

$A_{coulumn} = 0.30 \times 3 = 0.9\ m^2$

$A_{ceiling} = 2.89 \times 2.20 = 6.36\ m^2$

- **For the computer room**

$A_{ceiling} = 5.47\ \mathrm{m}^2$

$A_{wall\ south} = 2.02 \times 3 = 9.06\ m^2$

- **For the stationary**

$A_{ceiling} = 5.24\ \mathrm{m}^2$

$A_{wall\ south} = 1.62 \times 3 = 4.86\ m^2$

2.6 Heating load

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

The heat loss is divided in to tow groups:

- The heat transmission losses through the confining walls, floor, ceiling, glass or other surfaces.
- The infiltration losses through cracks and openings, or heat required to warm outdoor air used for ventilation.

Normally, the heating loud is estimated for winter design temperature usually occurring at night, therefore, internal heat gain is neglected except for theaters, assembly halls, industrial plant and commercial building.

Internal heat gain is the sensible and latent heat emitted within an internal space by the occupants, lighting, electric motors, electric equipment, etc.[2]

2.6.1 Heating load calculation

The general procedure for calculating the total heating load is:

1. Select the design outdoor air conditions of temperature, humidity, and wind speed and its direction.

2. Select the comfort design indoor conditions of temperature and relative humidity that must be maintained in the heated space.

   ΔT = T_{in} - T_{out}

3. Estimate temperature in adjacent unheated spaces, if any

   ΔT_{adj} = 0.5 (T_{in} - T_{out}) (2.28)

4. Compute the overall heat transfer coefficients for all exposed surfaces of the building through which heat losses are to be calculated.
5. Determine all surface areas through which heat is lost.
6. Compute the heat loss for each type of walls, floor, ceiling or roof, doors, windows, etc. by using this equation

   $\dot{Q}$ = UA (T_{in} – T_{out}) (2.29)

   Where:

   $\dot{Q}$: rate of heat transfer (W)

   U: overall heat transfer coefficient .

   A: heat transfer area (m^2)

   T_{in}: inside design temperature .

   T_{out}: outside design temperature

7. Compute heat loss from bellow-grade walls and floor, if any.
8. Calculate the infiltration air rate and compute the resulting heating load due to infiltration.
9. Assume a safety factor value of 10 to 15% to account for emergency loads.
10. The sum of all the above heat losses for all rooms represents the total heating load of the building.[4]

- **Inside and outside condition**

  The inside and outside condition are obtained from Palestinian code as shown in the following table (2.2):

Table 2.2: Inside and outside design conditions:[5]

Property	Inside design condition		Outside design condition	
	Summer	Winter	Summer	Winter
Temperature (˚C)	24	26	31.9	5.7
Relative humidity (%)	50	35	61.9	69.7
Wind speed (m/s)	….	….	1.5	1.5

- **Sample Calculation**

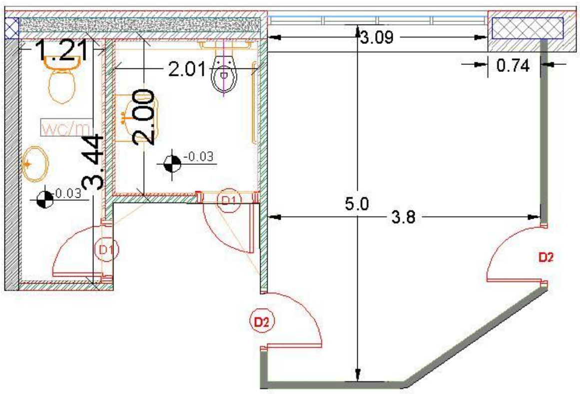


Figure 2.3: Dimension of back office and W.C:

- **Calculation of the heat loss from the back office**

In the last floor as a sample :

The height of the room = 3m

The height of the window = 3m

Heat loss through ceiling Q_c

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

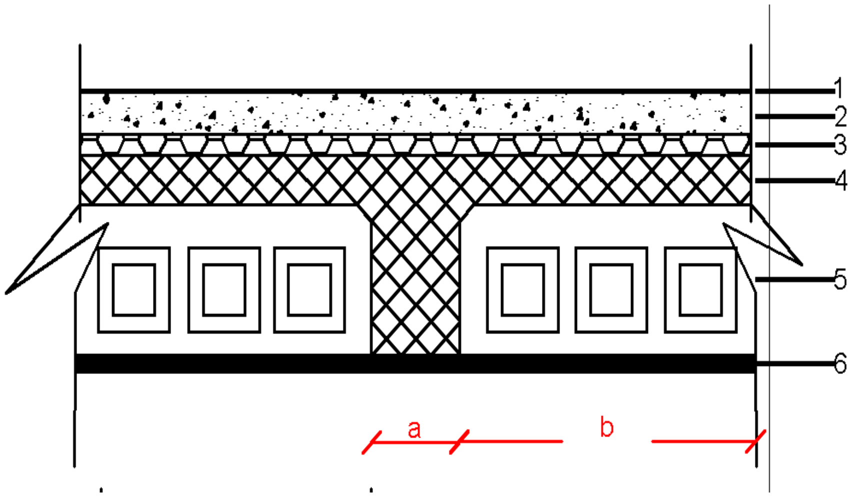


Figure 2.4 : Over all heat transfer coefficients for ceiling

The area A1 is equal to: $A_1 = \frac{4}{5}$ Ac = $\frac{4}{5}$ (17.72) = 14.17m^2

And the area A2 is equal to: $A_2 = \frac{1}{5}$ Ac = $\frac{1}{5}$ (17.72) = 3.54m^2

$$Qc = (U_1 A_1 + U_2 A_2)(T_i - T_o) \qquad (2.30)$$

$Q_c = (U_1 A_1 + U_2 A_2)(T_i - T_o)$

$U_1 =$ 0.868 W/m^2.°C in Table (2,1)

U_2 = 1.186 W/m^2.°C…. From table (2,1)

$Q_c = (0.868 \times 14.17 + 1.186 \times 3.54)$ (24 – 5.7) = 302 W.

- **Heat loss through floor (Q_{floor}) :**

The area (floor) A is equal to: $A_{floor} = 17.72\ m^2$

$$Q_{floor} = (U_f A_f) \times (T_i - T_o) \qquad (2.31)$$

U_{floor} = 1.23 W/m^2.°C …. From table (A-22)

Q_{floor}= (1.23 × 17.72)×(24 – 13.7) = 224.5 W.

- **Heat loss through west column (Q $_w$):**

The external wall area is:

And the area (column) A is equal to: A= (0.7×3)= 2.1 m^2

$Q_{column} = (U_c A_c)(T_i - T_o)$

U_{column} = 1.74 W/m^2.°C

Q_{column}= (1.74 × 2.1) (24 – 5.7) = 66.9 W.

- **The area (window) A is equal to:**

A= (0.7737 × 1)= 0.7737 m^2

$Q_w = (U_w A_w)(T_i - T_o)$

U_w = 5.6 W/m^2.°C

Q_w = (5.6 × 0.7737) (24 – 5.7) = 79.28 W

- **The area (glass wall) A is equal to:**

A= (3.08 − 0.7737) × 3= 6.91 m^2

$Q_w = (U_w A_w)(T_i - T_o)$

U_w = 5.6 W/m^2.°C

Q_w = (5.6 × 6.91) (24 – 5.7) = 708.14 W

- **Heat loss through infiltration ($\dot{Q}_{inf}$) :**

Due to leakages in the building construction, opening and closing of doors, etc. the air in the building shifts. As a rule of thumb the number of air shifts is often set to *0.5* per hour. The value is hard to predict and depend on several variables - wind speed, difference between outside and inside temperatures, the quality of the building construction etc.[3] The total heat load due to infiltration is given by the equation:

$$Q_{inf.g} = \left(\frac{1250}{3600}\right) V_f \,(T_i - T_o) \qquad (2.32)$$

T_i : inside design temperature

T_o: inside design temperature

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

$$V_f = K \times L\ (0.613(S1\ S2V_o)^2]^{2/3} \qquad (2.33)$$

Where:

K = the infiltration air coefficient.

L: The crack length in meter.

$S1$: Factor that depends on the topography of the location of the building.

$S2$: Coefficient that depends on the height of the building.

V_o: Measured wind speed (m/s).

The value of K, $S1$ and S2 is obtained from tables (A-6), (A-7) and (A-8) respectively.

K =0.60 …. From table (A-6)

$S1$=1 …. From table (A-7)

$S2$=0.72 …. From table (A-8)

V_o= 1.5 (m/s)…[5]

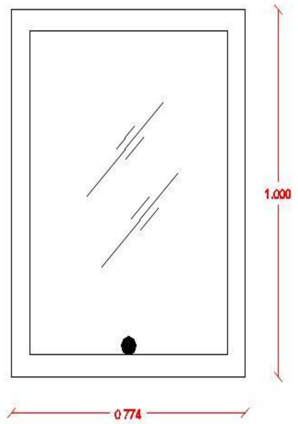


Figure (2.5): Dimensions of window

And the window as shown in Figure (2.4) ,then:

L = [(0.7737× 2) + (2×1)] = 3.55m (2.34)

V_f = (0.60*3.55 (0.613(1*0.72*1.5) ^{2}) $^{(2/3)}$

= 1.70 m^3/h

T_i= 24 °C

h_o = 5.7 °C

$Q_{inf.g=}\ \left(\frac{1250}{3600}\right) 1.70\ (24-5.7)\ = 10.8\ W$

The total heat loss from the back office is:

$Q_{tot=}$ Qc + $Q_{floor} + Q_{column} + Q_{glass\ wall} + Q_w + Q_{inf.g}\ =$

Q_{tot} = 302 + 224.5 + 66.9 + 708.14 + 79.28 + 10.8 = 1391.62 W

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

$Q_{tot}\ =\ 1391.62\ \times 1.1 =\ 1531\ W$.

- **Calculation the heat loss from W.C 1:**

$A_{ceiling}\ =\ 2.01 \times 2.12 = 4.26\ m^2$

Q_c= $(U_1\,A_1 +\ U_2\,A_2\,)(\,T_i\ - T_o)$

U_1 = 0.868 W/m^2.°C

U_1 = 1.186 W/m^2.˚C

The area1 is equal to: A1= $\frac{4}{5}$ Ac = $\frac{4}{5}$ (4.26) = 3.40m^2

And the area 2 is equal to: A2= $\frac{1}{5}$ Ac = $\frac{1}{5}$ (4.26) = 0.85m^2

Q_c = (0.868× 3.40 + 1.186× 0.85) (24 – 5.7) = 72.5 W.

- **Heat loss through floor (Q_{floor}):**

The area (floor) A is equal to: A= $2.01 \times 2.12 = 4.26\ m^2$

$Q_{floor} = (\ U_f\ A_f)\ \times\ (\ T_i\ - T_o)$

U_{floor} = 1.23 W/m^2.˚C

Q_{floor}= (1.23 × 4.26) × (24 – 13.7) = 53.97 W .

- **Heat loss through west walls (Q $_{wall}$) :**

The external wall area is:

The area (wall) A is equal to: A= (2.01 × 3)= 6.03 m^2

$Q_{wall} = (U_w\ A_w\ )(\ T_i\ - T_o)$

U_{wall} = 2.121 W/m^2.˚C

Q_w = (2.121 × 6.03) (24 – 5.7) = 234 W

- **Heat loss through infiltration ($\dot{Q}_{inf}$) :**

$$Q_{inf.g=}\ (\frac{1250}{3600})V_f\ (T_i - T_o)$$

$V_f\ = K\ \times L$ (0.613(S1 S2V_o)^2] $^{2/3}$

The value of K, S1 and S2 is obtained from tables (A-6), (A-7) and (A-8) respectively.

K =0.60 …. From table (A-6)

S1=1 …. From table (A-7)

S2=0.72 …. From table (A-8)

V_o= 1.5 (m/s)…[5]

And the Suction as shown in Figure (2.4), then:

L= (2× 0.30 + 2 × 0.30) 1.2 m

V_f = (0.60*1.2 (0.613(1*0.72*1.5) ^{2}) $^{(2/3)}$

= 0.5757 m^3/h

T_i= 24 ℃

T_o = 5.7 ℃

$Q_{inf.g=}$ $\left(\frac{1250}{3600}\right) 0.5757\ (24 - 5.7)\ = 3.66\ W$

The total heat loss from the WC.1 is:

$Q_{tot=}$ Qc + $Q_{floor} + Q_{wall} + Q_{inf.g}$ =

Q_{tot} = 72.5 + 53.97 + 234 + 3.66 = 364.2 W

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

$Q_{tot}\ = 364.2\ \times 1.1 =\ 400.6\ W$.

- **Calculation the heat loss from W.C 2:**

$A_{ceiling} =\ 3.36 \times 1.13 = 3.8\ m^2$

$A_{west\ wall}\ =\ 1.13 \times 3 = 3.39\ m^2$

$A_{south\ wall}\ =\ 3.36 \times 3 = 10.08\ m^2$

Q_c= $(U_1\ A_1 +\ U_2\ A_2\ )(\ T_i\ - T_o)$

U_1 = 0.868 W/m^2.˚C

U_1 = 1.186 W/m^2.˚C

The area A1 is equal to: A1= $\frac{4}{5}$ Ac = $\frac{4}{5}$ (3.8) = 3.04m^2

And the area A2 is equal to: A2= $\frac{1}{5}$ Ac = $\frac{1}{5}$ (3.8) = 0.76m^2

Qc = (0.868× 3.04 + 1.186× 0.76) (24 – 5.7) = 64.79 W.

- **Heat loss through floor (Q_{floor}):**

The area (floor) A is equal to: A= $3.36 \times 1.13\ = 3.8\ m^2$

Q_{floor} = $\left(\ U_f\ A_f\right) \times(\ T_i\ - T_o)$

U_{floor} = 1.23 W/m^2.˚C

Q_{floor}= (1.23 × 3.8) × (24 – 13.7) = 23 W.

- **Heat loss through west walls (Q_{wall}):**

The external wall area is:

Q_{wall} = $(U_w\ A_w\ )(\ T_i\ - T_o)$

U_{wall} = 2.121 W/m^2.˚C

$Q_{west\ wall}$ = (2.121 × 3.39) (24 – 5.7) = 131.58W

- **Heat loss through south walls (Q $_{wall}$):**

The external wall area is:

Q_{wall} = (U_w A_w)(T_i $- T_o$)

U_{wall} = 2.82 W/m^2.˚C

$Q_{west\ wall}$ = (2.82 × 3.39)× 0.5 (24 – 5.7) = 87.47W

- **Heat loss through infiltration ($\dot{Q}_{inf}$) :**

$$Q_{inf.g=} \left(\frac{1250}{3600}\right) V_f \ (T_i - T_o)$$

$V_f = K \times L$ (0.613($S1$ S2V_o)^2] $^{2/3}$

The value of K , $S1$ and S2 is obtained from tables (A-6), (A-7) and (A-8) respectively.

K =0.60 …. From table (A-6)

$S1$=1 …. From table (A-7)

$S2$=0.72 …. From table (A-8)

V_o= 1.5 (m/s) … [5]

And the Suction as shown in Figure (2.4) ,then:

L= (2× 0.30 + 2 × 0.30) 1.2 m

V_f = (0.60*1.2 (0.613(1*0.72*1.5) ^{2}) $^{(2/3)}$

= 0.5757 m^3/h

T_i= 24 ℃

T_o = 5.7 ℃

$Q_{inf.g=} \left(\frac{1250}{3600}\right) 0.5757\ (24 - 5.7) = 3.66\ W$

The total heat loss from the back office is:

$Q_{tot=}$ Qc + Q_{floor} + $Q_{west\ wall}$ + $Q_{west\ wall}$ + $Q_{inf.g}$ =

Q_{tot} = 64.8 + 23 + 131.58 + 87.47 + 3.66 = 310.5 W

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

$Q_{tot} = 310.5 \times 1.1 = 341.6\ W$.

Table 2.3: Air system heating calculation

Room name	Area (m^2)	$Q_{ceiling}$ (watt)	$Q_{outside\ wall}$ (watt)	Q_{floor} (watt)	Q_{window} (watt)	Q_{door} (watt)	Q_{inf} (watt)	Heating Load (KW)
Customer service and teller	171.8	2928.9	9895.5	2176.54	115.80	461.16	84.64	17.1
ATM room	7.85	124.7	628.44	99.5	----	108.70	18	0.989
Back office	17.72	302	775.04	224.5	79.28	----	10.8	1.53
WC.1	4.26	72.5	234	53.97	----	----	3.66	0.406
WC.2	3.8	64.79	219.05	23	----	----	3.66	0.342
Kitchen	6.36	108.43	400.1	80.6	----	----	3.66	0.593
Computer room	5.47	111.51	467.55	69.38	----	----	0	0.650
Stationary	5.24	90.18	250.8	66.38	----	----	0	0.407
								$\sum = 22.1$

2.7 Cooling load

2.7.1 Overview

Cooling load is the rate at which sensible and latent heat must be removed from the space to maintain a constant space dry-bulb air temperature and humidity. Sensible heat into the space causes its air temperature to rise while latent heat is associated with the rise of the moisture content in the space. The building design, internal equipment, occupants, and outdoor weather conditions may affect the cooling load in a building using different heat transfer mechanisms. The SI units are watts.

2.7.2 Cooling Load Calculations

The rate at which heat energy must be supplied to a space to maintain a given design condition, is called the heating load .

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

The cooling load is expressed in units of watt (joule per second) or in kilowatt (kW) or in tons refrigerant (T.R) where 1T.R = 3.517 kW . [1]

Sometimes, the metric units of kilocalorie per hour ($K_{cal})h$) are used where 1W = 0.8601 K_{cal}/h .

The CLTD values vary with our of the day and it is function of environmental conditions and building parameters .

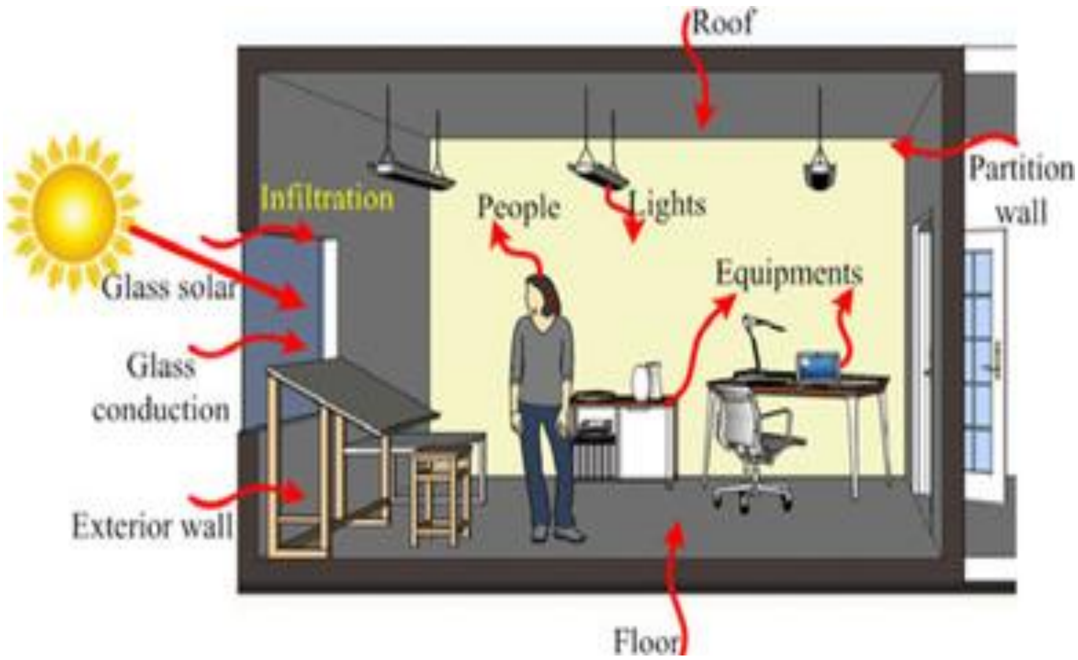


Figure 2.6: Source of cooling load [4]

The heat transfer rate through sunlit walls or sunlit roofs is calculated from the following equation:

$\dot{Q}$ = UA (CLTD) $_{corr.}$ (2.35)

Where:

$(CLTD)_{corr}$: Corrective cooling load temperature difference,℃

$$(CLTD)_{corr} = (CLTD + LM)K + (25.5 - T_{in)} + (T_{o.m} - 29.4)f \quad (2.36)$$

Where:

$(CLTD)$: cooling load temperature difference, ℃

LM: Latitude correction factor.

K: Color adjustment factor.

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

f: Attic or roof fan factor.

$T_{o.m}$: Outdoor mean temperature, ℃

$$T_{o.m} = (T_{max} + T_{\min})/2 \quad (2.37)$$

Where:

T_{max}: Maximum average daily temperature, ℃

$T_{\min}$: Minimum average daily temperature, ℃

T_{max} = 38.5℃ and $T_{\min}$ = 19℃ are obtained …[5]

Applying these values in equation (2.39) to obtain the outdoor mean temperature

$T_{o.m}$ = 28.75℃ .

- **Data analysis**

The following table contains all the inside and outside design conditions needed for the next calculation:

Table (2.4): Outdoor design conditions.[5]

Season	T_{out} ℃	$\emptyset_{out}$ %	h_{out} (KJ/Kg)
Cooling	31.9	61.9	79

Table (2.5): Indoor design conditions.[5]

Season	T_{in} ℃	$\emptyset_{in}$ %	h_{out} (KJ/Kg)
Cooling	24	50	48

- **Sample Calculation:**

Calculation the gain for the ATM in the bank as a sample:

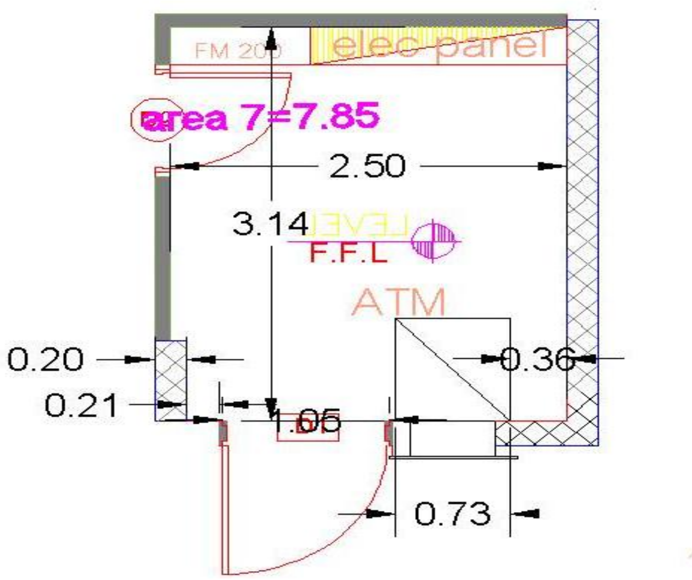


Figure 2.7: The dimension of ATM in bank

- **Heat gain through sunlit roof ($\dot{Q}_{roof}$):**

$CLTD = 14\ ^{\circ}C$ ... from Table (A-10)

LM = 0.5 ... from Table (A-9)

K = 0.83 for permanently light colored roof .

$T_{max} = 38.5℃$ & $T_{min} = 19℃$ …[5]

$T_{o,m} = (38.5 + 19)/2 = 28.75℃$

f = 1 there is no attic or roof fan.

$(CLTD)_{corr} = (14 + 0.5) \times 1 + (25.5 - 24) + (28.75 - 29.4) \times 1 = 12.9$ ℃

$Q_{roof} = ([0.868 \times 7.85 \times \left(\frac{4}{5}\right)] + [1.186 \times 7.85 \times \left(\frac{1}{5}\right)] \times 12.9 = 94.3\ W$

$= 0.0943\ KW$.

- **Heat gain through sunlit floor ($\dot{Q}_{floor}$):**

$(CLTD)_{corr} = (28.75 - (8 - 5.7) = 26.45$ ℃

$Q_{floor} = (\ 1.23 \times 7.85) \times (28.75 - 2.3) = 255.4\ W$

$= 0.2554\ KW$.

- **Heat gain through sunlit door ($\dot{Q}_{door}$):**

$(CLTD)_{corr} = (7 + 0.5) \times 1 + (25.5 - 24) + (28.75 - 29.4) \times 1 = 8.35$ ℃

$Q_{roof} = (3.3\ \times 2.1) \times (8.35) = 57.9W$

$= 0.058\ KW$.

- **Heat gain through sunlit walls ($\dot{Q}_{Wall}$):**

$CLTD$ at 14:00 o'clock … from Table (A-11)

$E = 7$

$N = 3$

$K = 0.65$ for permanent light color walls.

$AN = (3.14 \times 3) = 9.42\ m^2$

$AE = (2.5 \times 3) - (0.90 \times 2) = 4.8\ m^2$

$(CLTD)_{corr.N} = (3 + 0.5) \times 0.65 + (25.5 - 24) + (28.75 - 29.4) \times 1 = 3.125$℃ .

$(CLTD)_{corr.E} = (9 + 0.5) \times 0.65 + (25.5 - 24) + (28.75 - 29.4) \times 1 = 7.025$℃ .

$Q_E = 2.14 \times 4.8 \times 7.025 = 72.16\ W$

$Q_N = 2.14 \times 9.42 \times 3.125 = 62.996\ W$

$Q_{wall} = Q_E + Q_N = 72.16 + 62.996 = 135.16W = 0.1351\ KW$.

- **Heat gain due to lights ($\dot{Q}_{Lt.}$):**

$Q_{lt} = \text{light intensity} \times \text{A} \times (\text{CLF})_{\text{lt}} \times \text{diversity factor} =$ (2.38)

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

$A = floor\ area\ = 7.85\ m^2$

$(\mathrm{CLF})_{\mathrm{lt}} = 0.82$ … from Table (A-17)

diversity factor = 1 … from Table (A-18)

$Q_{lt} = 25 \times 7.85 \times 0.82 \times 1 = 161W = 0.161KW$.

- **Heat gain due to infiltration ($\dot{Q}_f$):**

At the same procedure in heating load

$\mathrm{v}_o = 1.5\ m/s$…[5]

$v_o = 0.88\ m^3/kg$… from psychometric chart

$h_o = 79\ kj/kg$ …from psychometric chart

$h_i = 48\ kj/kg$ …from psychometric chart

$V_f = 0.70 \times 5.8\,(0.613(1 \times 0.72 \times 1.5)^2]^{2/3}$

$= 3.25\ m^3/h$

$Q_f = [(3.25 \times 0.88) \times (79 - 48)]/3600 = 0.0246\ KW$

- **Heat gain due to occupants ($\dot{Q}_{oc.}$):**

$Q_{oc} = Q_{\mathrm{sensible}} + Q_{\mathrm{latent}}$ (2.39)

Q_{sensible} = heat gain sensible × No. of people × $(CLF)_{oc}$ × Diversity Factor (2.40)

Where:

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

heat gain sensible = 71.5 … from Table (A-2)

No. of people = 0

$(CLF)_{oc} = 0.84$ … from Table (A-19)

Diversity Factor = 0.8 … from Table (A-18)

$Q_{\mathrm{sensible}} = 71.5 \times 0.8 \times 0.84 \times 1 = 48\ W$

Q_{latent} = heat gain latent × No. of people × Diversity Factor heat gain latent = 71.5 … from Table [A-2]

$Q_{\mathrm{latent}} = 71.5 \times 1 \times 0.8 = 57.2\ W$

$Q_{oc} = 48 + 57.2 = 105.2\ W = 0.105\ KW$

- **Heat gain due to ventilation (Q_{vn}):**

$Q_{vn} = \dot{m} \times \mathrm{cp}_{\mathrm{air}} \times (\mathrm{T_{in}} - \mathrm{T_{out}})$ (2.41)

Where:

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

cp_{air} : specific heat of air = 1.005 kJ/kg .k

$\dot{m}$ = rate of ventilation air $/v_o$ (2.42)

rate of ventilation air = A_{room} × requirement outside ventilation air

$A_{room} = 7.85\ m^2$

requirement outside ventilation air = $15\ L/s/m^2$ … from Table [A-3]

rate of ventilation air= $7.85 \times 15 = 117.75\ L/s = 0.117\ m^3/s$

v_o = 0.88 m^3/kg

$\dot{m} = 0.117/0.88 = 0.2011$

$Q_{vn=}0.2011 \times 1.005 \times (24 - 5.7) = 3.6985\ W = 0.003698\ KW$.

- **Heat gain due to equipment (Q_{eq}):**

$Q_{eq} = heat\ gain\ due\ to\ computer(ATM)$

$= 1500W$

$= 1.5\ kW$

$Q_{Total} = Q_{roof} + Q_{floor} + Q_{wall} + Q_{door} + Q_{light} + Q_{inf} + Q_{oc.} + Q_{eq}$

$= 0.0943 + 0.2554 + 0.1351 + 0.058 + 0.161 + 0.0246 + 0.094 + 1.5 = 2.32\ kW$

Table 2.6 : Air system cooling calculations for sunlit roof .

Sunlit roof									
Room	CLTD	LM	K	25.5-Tin	Tom-29.4	f	(CLTD) corr	U1A1+U2A2	Q roof [KW]
Customer service and teller	14	0.5	0.83	1.5	-0.65	1	12.9	160	2.064
ATM room	14	0.5	0.83	1.5	-0.65	1	12.9	7.313	0.0943377
Back office	14	0.5	0.83	1.5	-0.65	1	12.9	16.51	0.212979
WC.1	14	0.5	0.83	1.5	-0.65	1	12.9	3.97	0.051213
WC.2	14	0.5	0.83	1.5	-0.65	1	12.9	3	0.0387
Kitchen	14	0.5	0.83	1.5	-0.65	1	12.9	5.925	0.0764325
Computer room	14	0.5	0.83	1.5	-0.65	1	12.9	4.164252	0.053718851
Stationary	14	0.5	0.83	1.5	-0.65	1	12.9	4.881584	0.062972434

Table 2.7 : Air system cooling calculations for floor .

Floor				
Room	A	U	(CLTD) corr	Q light [KW]
Customer service and teller	171.8	1.23	26.45	5.5892553
ATM room	7.85	1.23	26.45	0.255387975
Back office	17.72	1.23	26.45	0.57649362
WC.1	4.26	1.23	26.45	0.13859271
WC.2	3.8	1.23	26.45	0.1236273
Kitchen	6.36	1.23	26.45	0.20691306
Computer room	4.47	1.23	26.45	0.145424745
Stationary	5.24	1.23	26.45	0.17047554

Table 2.8 : Air system cooling calculations for sunlit walls .

Sunlit walls										
Room	CLTD	LM	K	25.5-Tin	Tom-29.4	f	(CLTD) corr	U	A	Q walls [KW]
Customer service and teller										
N	3	0.5	0.65	1.5	-0.65	1	3.125	2.14	2.52	0.0168525
NW	8	0.5	0.65	1.5	-0.65	1	6.375	2.14	12.84	0.1751697
N	3	0.5	0.65	1.5	-0.65	1	3.125	2.14	2.52	0.0168525
S	16	-0.5	0.65	1.5	-0.65	1	10.925	2.82	25.62	0.394656
ATM room										
E	9	0	0.65	1.5	-0.65	1	7.025	2.14	4.8	0.0721608
N	3	0.5	0.65	1.5	-0.65	1	3.125	2.14	9.42	0.06299625
Back office										
W	13	0	0.65	1.5	-0.65	1	9.3	2.12	1.41	0.02779956
WC.1										
W	13	0	0.65	1.5	-0.65	1	9.3	2.12	6.03	0.11888748
WC.2										
W	13	0	0.65	1.5	-0.65	1	9.3	2.12	3.39	0.06683724
S	16	-0.5	0.65	1.5	-0.65	1	10.925	2.82	10.08	0.31054968
Kitchen										
S	16	-0.5	0.65	1.5	-0.65	1	10.925	2.82	7.77	0.239382045
S	16	-0.5	0.65	1.5	-0.65	1	10.925	1.86	0.9	0.01828845
Computer room										
S	16	-0.5	0.65	1.5	-0.65	1	10.925	2.82	9.06	0.27912501
Stationary										
S	16	-0.5	0.65	1.5	-0.65	1	10.925	2.82	1.86	0.05730381

Table 2.9 : Air system cooling calculations for windows .

Windows										
Room	A	SHG	SC	CLF	Q,tr	(CLTD) corr	U	A	Q,conv	Q glass [KW]
Customer service and teller										
NE	15.19	527	0.25	0.74	1481	7	5.6	15.19	595.448	2.076448
W	5.66	678	0.25	0.11	105.53	7	5.6	5.66	221.872	0.327402
Back office										
W	3.08	678	0.25	0.11	57.43	7	5.6	9.24	362.208	0.419638

Table 2.10 : Air system cooling calculations for lights .

Lights					
Room	Light intensity	A	(CLF) lt	Divirsity Factor	Q light [KW]
Customer service and teller	25	171.8	0.82	1	3.5219
ATM room	25	7.85	0.82	1	0.160925
Back office	25	17.72	0.82	1	0.36326
WC.1	25	4.26	0.82	1	0.08733
WC.2	25	3.8	0.82	1	0.0779
Kitchen	25	6.36	0.82	1	0.13038
Computer room	25	4.47	0.82	1	0.091635
Stationary	25	5.24	0.82	1	0.10742

Table 2.11 : Air system cooling calculations for infiltration .

Infiltration			
Room	Vf	L	Q light [KW]
Customer service and teller	9.855	17.608	0.1335
ATM room	3.25	5.8	0.0246
Back office	1.98	3.54	0.015
WC.1	0.6716	1.2	0.005
WC.2	0.6716	1.2	0.005

Table 2.12 : Air system cooling calculations for occupants .

Occupants										
Room	heat gain sensible	No .of people	(CLF)oc	Diversity Factor	Q sensible	heat gain latent	No .of people	Diversity Factor	Q latent	Q oc [KW]
Customer service and teller	71.5	60	0.84	0.8	2882.88	71.5	60	0.8	3432	6.31488
ATM room	71.5	1	0.84	0.8	48.048	71.5	1	0.8	57.2	0.105248
Back office	71.5	10	0.84	0.8	480.48	71.5	10	0.8	514.8	1.05248
WC.1	71.5	1	0.84	0.8	48.048	71.5	1	0.8	57.2	0.105248
WC.2	71.5	1	0.84	0.8	48.048	71.5	1	0.8	57.2	0.105248
Kitchen	71.5	1	0.84	0.8	48.048	71.5	1	0.8	57.2	0.105248
Computer room	71.5	1	0.84	0.8	48.048	71.5	1	0.8	57.2	0.105248
Stationary	71.5	1	0.84	0.8	48.048	71.5	1	0.8	57.2	0.105248

Table 2.13 : Air system cooling calculations for ventilation .

Ventilation							
Room	A room	Out side air	Vo	m	Cp air	ΔT	Q oc [KW]
Customer service and teller	171.8	10	0.88	1.512	1.005	18.3	0.027807948
ATM room	7.85	10	0.88	0.07	1.005	18.3	0.001287405
Back office	17.72	10	0.88	0.201364	1.005	18.3	0.003703379
WC.1	4.26	10	0.88	0.048409	1.005	18.3	0.000890316
WC.2	3.8	10	0.88	0.043182	1.005	18.3	0.000794178
Kitchen	6.36	10	0.88	0.072273	1.005	18.3	0.001329204
Computer room	4.47	10	0.88	0.050795	1.005	18.3	0.000934205
Stationary	5.24	10	0.88	0.059545	1.005	18.3	0.00109513

Table 2.14 : Air system cooling calculations for equipments .

Equipments				
Room	Device	Heat gain[W]	No of device	Q eq. [KW]
Customer service and teller	Computer	500	8	4
ATM room	Automated teller machine	1200	1	1.2
Kitchen	Coffee brewer	290	1	0.29
	Toaster	1760	1	1.76
	Refrigerator (small)	690	1	0.69
	Domestic gas	3630	1	3.63
Computer room	Computer	500	10	5
W.C.2	Water heater	1465	1	1.465

Table 2.15 : Air system cooling calculations for unconditioned walls .

Unconditioned walls				
Room	U	A	ΔT	Q un. [KW]
WC.2	2.82	10.08	5.46	0.155203776
Stationary	2.82	1.86	5.46	0.028638792
Kitchen				
	1.86	0.9	5.46	0.00914004
	2.82	7.77	5.46	0.0424242
Customer service and teller	2.82	25.62	5.46	0.1398852

Table 2.16 : Air system cooling calculations for doors .

Doors				
Room	U	A	ΔT	Q oc [KW]
Customer service and teller	5.6	4.5	8.35	0.21042
ATM room	3.3	2.1	8.35	0.0578655

Table 2.17 : Air system cooling calculations for total heat gain .

Total heat gain	
Room	Q Total [KW]
Customer service and teller	25.9812212
ATM room	2.33480863
Back office	2.66765018
WC.1	0.50627119
WC.2	2.348065996
Kitchen	7.198208295
Computer room	5.675151606
Stationary	0.532058576
$\sum=$	47.24214827

CHAPTER THREE

Variable Refrigerant Flow (VRF) Systems

3.1 Introduction

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

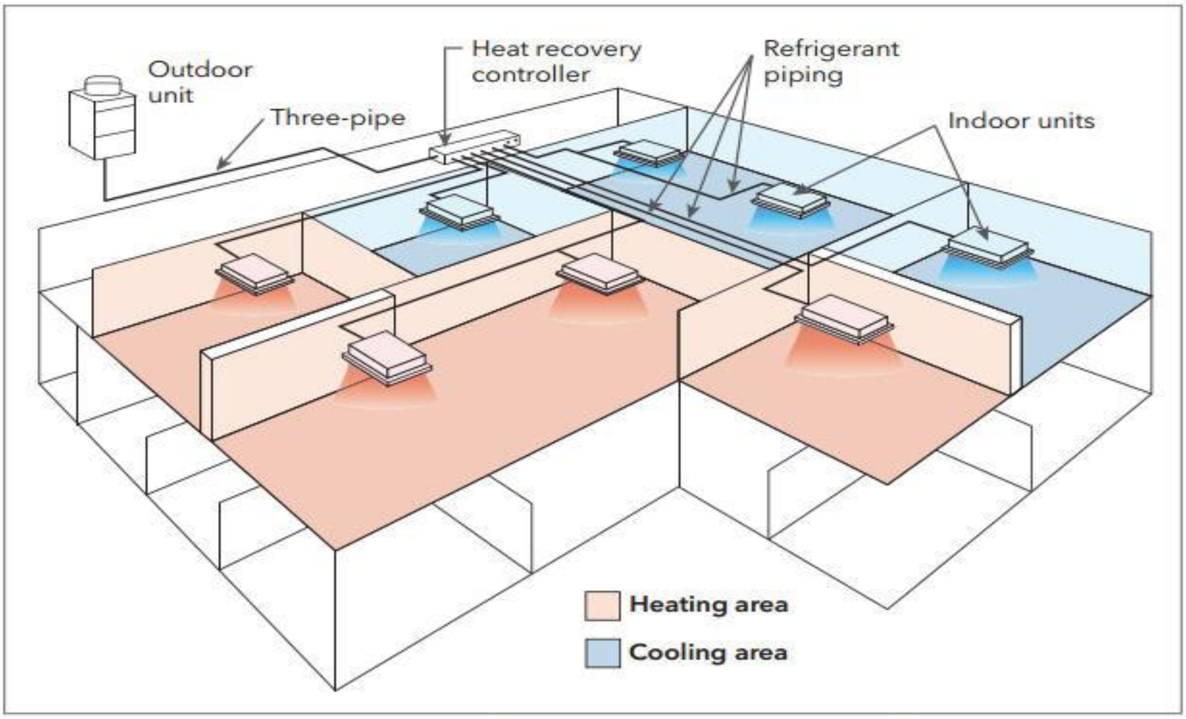
Currently widely applied in large buildings especially in Japan and Europe, these systems are just starting to be introduced in the U.S. The VRF technology/system was developed and designed by Daikin Industries, Japan who named and protected the term variable refrigerant volume (VRV) system so other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

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

3.2 Overview

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

The term VRF refers to the ability of the system to control the amount of refrigerant flowing to each of the evaporators, enabling the use of many evaporators of differing capacities and configurations, individualized comfort control, simultaneous heating and cooling in different zones, and heat recovery from one zone to another. VRF systems operate on the direct expansion (DX) principle meaning that heat is transferred to or from the space directly by circulating refrigerant to evaporators located near or within the conditioned space. Refrigerant flow control is the key to many advantages as well as the major technical challenge of VRF systems. [6]



Variable refrigerant flow systems can deliver cooling to some zones and heating to others, with no reheat needed (an air-source system is shown here).

Figure 3.1 : Variable Refrigerant Flow (VRF) Systems[7]

3.3 Systems Components VRF

- Indoor units
- Outdoor units
- Piping net work
- Control system
- Drain pipes

3.4 Types of VRF

- <u>heat pump systems</u>

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

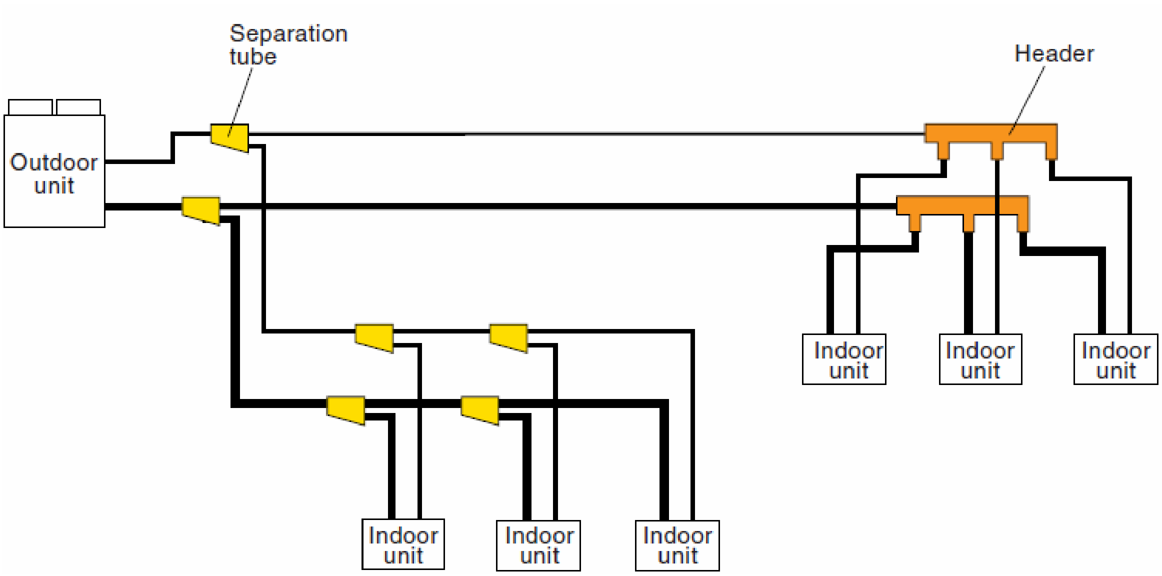


Figure 3.2 : Cooling Type VRF System

- Heat Recovery VRF system (VRF-HR)

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

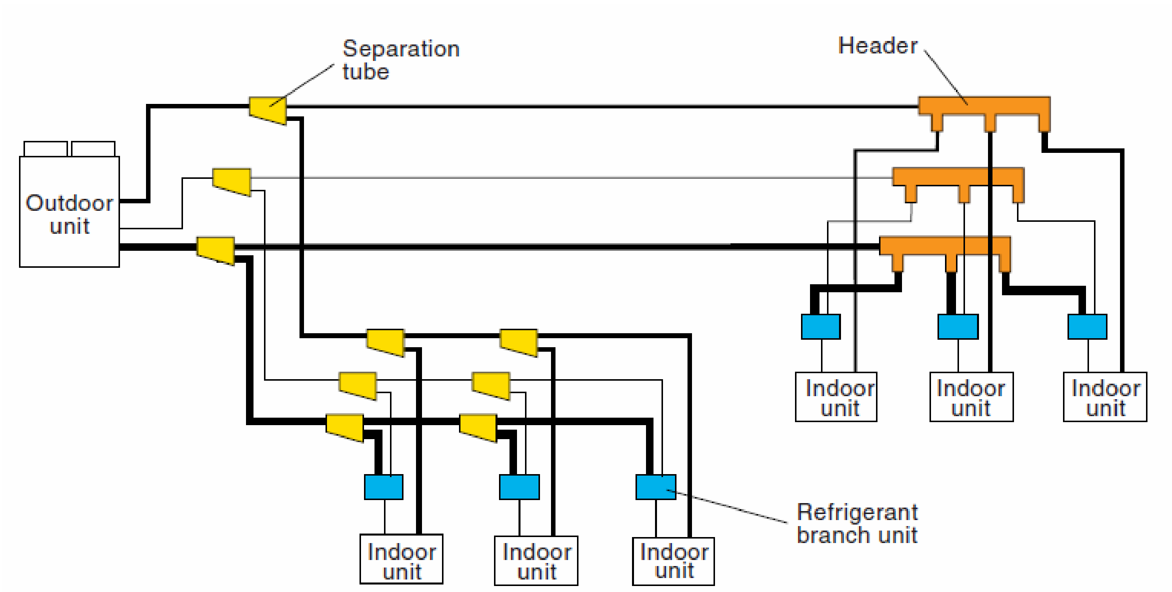


Figure 3.3 : Heat Recovery Type VRF System[8]

3.5 First Costs

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

3.6 VRF advantages and disadvantages

- The main advantage of a variable refrigerant flow system is its ability to respond individually to fluctuations in space load conditions. The user can set the ambient temperature of each room as per his/her requirements and the system will automatically adjust the refrigerant flow to suit the requirement;

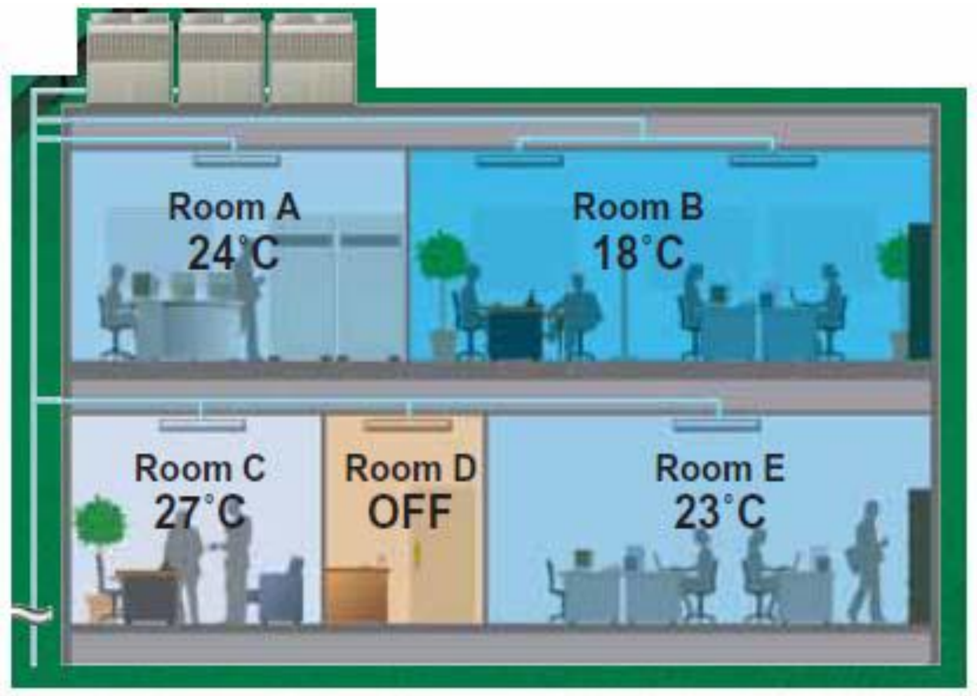


Figure 3.4 : Advantage of a variable refrigerant flow system

- VRF systems enable wide capacity modulation and bring rooms to the desired temperature extremely quickly and keep temperature fluctuations to minimum. The technology offers excellent dehumidification performance for optimal room humidity regardless of outside conditions. Any area in the building will always be exactly at the right temperature and humidity, ensuring total comfort for their occupants;
- VRF systems are capable of simultaneous cooling and heating. Each individual indoor unit can be controlled by a programmable thermostat. Most VRF manufacturers offer a centralized control option, which enables the user to monitor and control the entire system from a single location or via the internet;
- VRF systems can generate separate billing that makes individualized billing easier;
- VRF systems use variable speed compressors (inverter technology) with 10 to 100% capacity range that provides unmatched flexibility for zoning to save energy. Use of inverter technology can maintain precise temperature control, generally within ±1°F.

disadvantages

- very expensive
- Very expensive (construction and installation)
- Potential for Refrigerant leaks
- Because this system new , it need qualified technician .

3.7 Reduced Noise Levels

Indoor and outdoor units are so quiet that they can be placed just about anywhere, providing more flexibility on how to use indoor and outdoor space. Indoor ductless operating sound levels are as low as 27dB(A) and ducted units sound levels are as low as 29dB(A) .

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

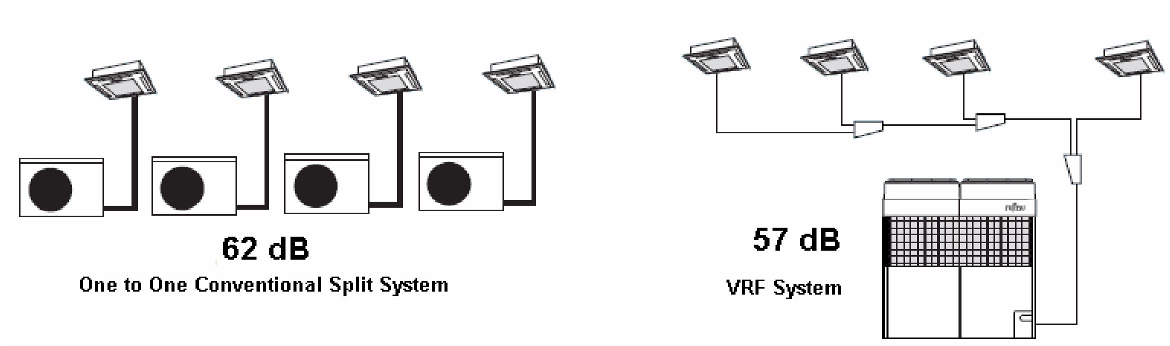


Figure 3.5 : One to one conventional split system (62dB, 57dB)

3.8 Reliability

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

✓ **Indoor Unit**

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

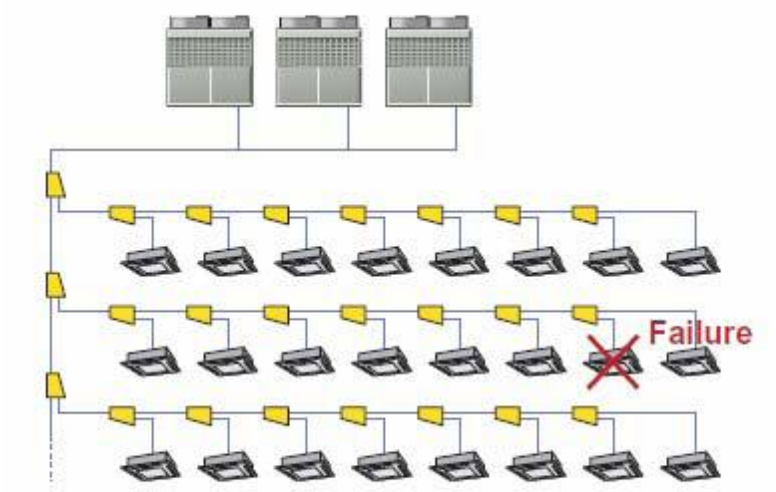


Figure 3.6 : Continuous operation is possible even if trouble occurs at an indoor unit.[6]

✓ **Outdoor Unit**

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

3.9 Aesthetics

Indoor units are available in different capacities and multiple configurations such as wall-mounted, ceiling-mounted cassette suspended, and concealed ducted types. It is possible to provide an assorted arrangement that combine multiple types of indoor sections with a single outdoor section. These provide extreme versatility to the aesthetic requirements of different building types. Outdoor units can be located on roof or hidden space.

Figure 3.7 : Indoor units[9]

3.10 Applications

VRF systems may be a particularly good option for buildings with multiple zones or wide variance heating/cooling loads across many different internal zones. These systems provide individual control and are the most versatile of the multi-split systems. Hotels, schools and office buildings are good examples.

3.11 Availability

1) VRF outdoor units can have cooling and heating capacities from 12,000 Btu/h to 300,000 Btu/h;

2) VRF indoor units can have cooling and heating capacities from 5,000 Btu/h to 120,000 Btu/h;

3) The outdoor unit may support up to 48 indoor evaporator units with capacities that collectively add up to 130% capacity of the condensing unit.

VRF equipment is divided into three general categories: residential, light commercial, and applied:

- Residential equipment is single-phase with a cooling capacity of 65,000 Btu/h or less.
- Light commercial equipment is generally three-phase with cooling capacity greater than 65,000 Btu/h, and is designed for small businesses and commercial properties.
- Applied equipment has cooling capacities higher than 135,000 Btu/h, and is designed for large commercial buildings.

3.12 VRF challenges & limitations

VRF systems are not suitable for all applications. The key challenges include:

✓ **Refrigerant Piping**

A VRF system being the split installation is restricted by distance criteria between the condensing unit and the evaporator. The maximum lengths of refrigerant pipework for a VRF or any other split system is determined by the compressors ability to overcome the pressure drop and for the system to maintain proper oil return. All 'split' systems therefore have a maximum allowable vertical and total refrigeration pipework length. This is a considerable disadvantage compared with hydraulic systems which are pumped; and as the pump may be sized to suit the system, then theoretically, the hydraulic pipework may be run almost infinite distances. It is important that the designer/building owner is aware of these limitations.

Each manufacturer specifies both the size of the pipe work required for their system and the maximum permissible vertical and total refrigerant pipe work runs. **Caution:** Although few manufacturers' literature states that the refrigerant lines can be as long as 500 feet,

when you read the fine print, after the first 'Tee' from the condensing unit, you are limited to 135 feet to the furthest unit.

3.13 Concluding

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

✓ **Salient Features:**

- Refrigerant flow rate is constantly adjusted by an electronic expansion valve in response to load variations as rooms require more or less cooling. Also, if reversible heat pumps are used, the heating output can be varied to match the varying heat loss in a room;
- An expansion valve or control valve can reduce or stop the flow of refrigerant to each indoor unit, thus controlling its output to the room;
- This type of system consists of a number of indoor units (up to 48 and varies per the manufacturer) connected to one or more external condensing units;
- The overall refrigerant flow is varied using either an inverter controlled variable speed compressor, or multiple compressors of varying capacity in response to changes in the cooling or heating requirement within the air conditioned space;
- A control system enables switching between the heating and cooling modes if necessary. In more sophisticated versions, the indoor units may operate in heating or cooling modes independently of others;
- A VRF system uses inverters or scroll compressors. They are efficient and quiet. and are usually hermetically sealed. Small to medium size units may have 2 compressors;
- Refrigeration pipe work up to 500 feet long is feasible;
- Refrigeration pipe work level differences between indoor and outdoor units up to 150 feet is possible;
- Ozone friendly HFC refrigerants; R-410-A and R-407-C are typically used;
- COP's (Coefficient of Performance) may be as high as 3.8;
- Refrigerant liquid lines tend to be about 3/8" in diameter and gas lines about 5/8" to 3/4" in diameter;
- Central control of a VRV system can be achieved by centralized remote controllers.

VRV/VRF technology is based on the simple vapor compression cycle but the system capabilities and limitations must be fully understood and evaluated carefully to determine its suitability. Before working with VRV/VRF systems, it is strongly recommended that manufacturer's product training be undertaken.[10]

3.14 Selection units

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

- **Outdoor unit**

  It was chosen one outdoor units with capacity of individual is 13 Ton .

Table 3.1: Outdoor units for the bank

Outdoor unit	Capacity nominal	External dimension
AM160FXGGH	45 KW	1363× 1887 × 832

- **Indoor unit**

In this project there are three types of indoor units selected, which are split and cassette units and MSP duct . The split unit is used for computer room and ATM room, and the cassette units are used for teller and customer, manager, and kitchen rooms and the MSP duct are used for back office .
The figure below shows the three types of selected units:

Figure 3.8 : Spilt, cassette and MSP duct indoor units [10]

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

Table 3.2 : Indoor units for the bank

Room name	Heating Load (K/W)	Cooling Load (K/W)	Indoor Unit Type	Selection catalog (K/W)	Indoor Unit Name	Dimension (m_m)
Customer service and teller	17.1	25.98	Cassette 4	28.4	AM071KN4DEH	$1093\times 85 \times 1083$
ATM	0.989	2.33	Split	3.51	FTXS25K	289x780x215
Back office	1.53	2.66	MSP Duct	2.8	AM028FNMDEH	$1500\times 280 \times 710$
Kitchen and WC and Stationary	0.593	10.6	Cassette	11.2	AM056KN4DEH	$1093\times 85 \times 1083$
Computers	0.65	5.6	Split	3.51	FTXS60G	290x1,050x250

- **The duct calculation for the Back office :**

  Assumptions

  - Using balanced pressure drop method .
  - $C_p\ of\ air\ = 1\ kJ/kg\,.°C$.
  - Inside design condition $= 24$ °C .
  - Supply design condition $= 31.9$ °C .
  - Air density $\rho = 1.25\ kg/m^3$.
  - Air velocity in the main duct $= 5\, m/s$.

Table 3.3 : Cooling load for back office

Room	Back office
Cooling load	2.667

Where :

$$Q`_s = \rho \times C_p \times V`(T_s - T_i) \quad (3.1)$$

$$= 1.25 \times 1(31.9 - 24)$$

$$V` = \frac{1}{9.87} Q`_s$$

Table 3.4 : The volume for back office

Room	Back office
$V`\ (m^3/s)$	0.270

Therefore, the required total volumetric flow rate of warm supply air V_t is :

$$V_t = \sum V_i \quad (3.2)$$

$$= 0.135 + 0.135 = 0.270\ m^3/s$$

For duct section A-B (main duct) , then $V_{A-B} = 5\, m/s$ and $V`_{A-B} = \ 0.270\ m^3/s$

Therefore from Table (A-34) can obtain that :

$(\frac{\Delta P}{EL})_{A-B} \ \rightarrow$

1.3 Pa/m , and duct diameter is 0.27 m .

Which is constant for all other duct section . Also , since :

$$V` = A \ \times v \quad (3.3)$$

$$A = \frac{0.270}{5} = 0.054\, m^2$$

$$A = \frac{\pi}{4} \times d^2$$

$$d_{A-B} = \sqrt{\frac{4}{\pi}(0.054)} = 0.27\, m \quad (3.4)$$

Similarly, for duct section B-C with flow rate of

V_{B-C} = 0.270 −0.135 = 0.135 m^3/s

and $(\frac{\Delta P}{EL})_{B-C} = (\frac{\Delta P}{EL})_{A-B} \ = 1.3\ Pa/m$, then Table (A-34) gives :

$d_{B-C} = 0.23\, m$ and V_{B-C} 4.2 m/s

Table 3.5 : Indoor units for the back office

Duct section	Volumetric flow rate (m^3/s)	$(\frac{\Delta P}{EL})$ Pa/m	d m	V m/s
A-B	0.270	1.3	0.27	5
B-D	0.135	1.3	0.23	4.2
C-E	0.135	1.3	0.23	4.2

3.15 Mechanical ventilation

Ventilation is the process of supplying and removing air by natural or mechanical means to and from a building. The design of a building's ventilation system should meet the minimum requirements of the building (Ventilating Systems) regulations. [11]

There are two ways for Ventilation:

- Natural ventilation" covers uncontrolled inward air leakage through cracks, windows, doorways and vents (infiltration) as well as air leaving a room (infiltration) through the same routes. Natural ventilation is strongly affected by weather conditions and is often unreliable.
- Mechanical or forced ventilation is provided by air movers or fans in the wall, roof or air conditioning system of a building. It promotes the supply or exhaust air flow in a controllable manner.

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

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

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

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

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

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

3.15.1 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.[11] It draws in outside air and after filtration, heating or cooling and humidification, circulates it throughout the building. A small portion of the return air is expelled to the outside environment to control the level of indoor air Contaminants.

3.15.2 Designing of mechanical ventilation

Steps of designing mechanical ventilation:

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

3.15.3 Sample calculation

Using WC1 and WC2 and kitchen :

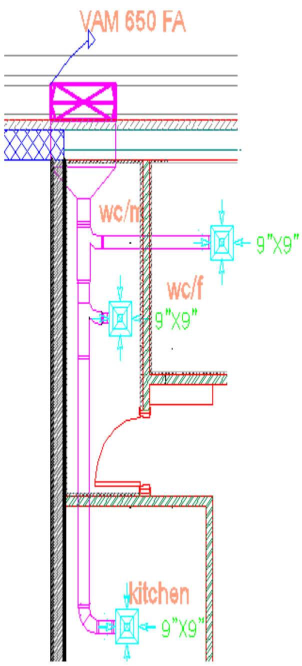


Figure 3.9 : Bathroom layout

- The volume is 12.78 m^3

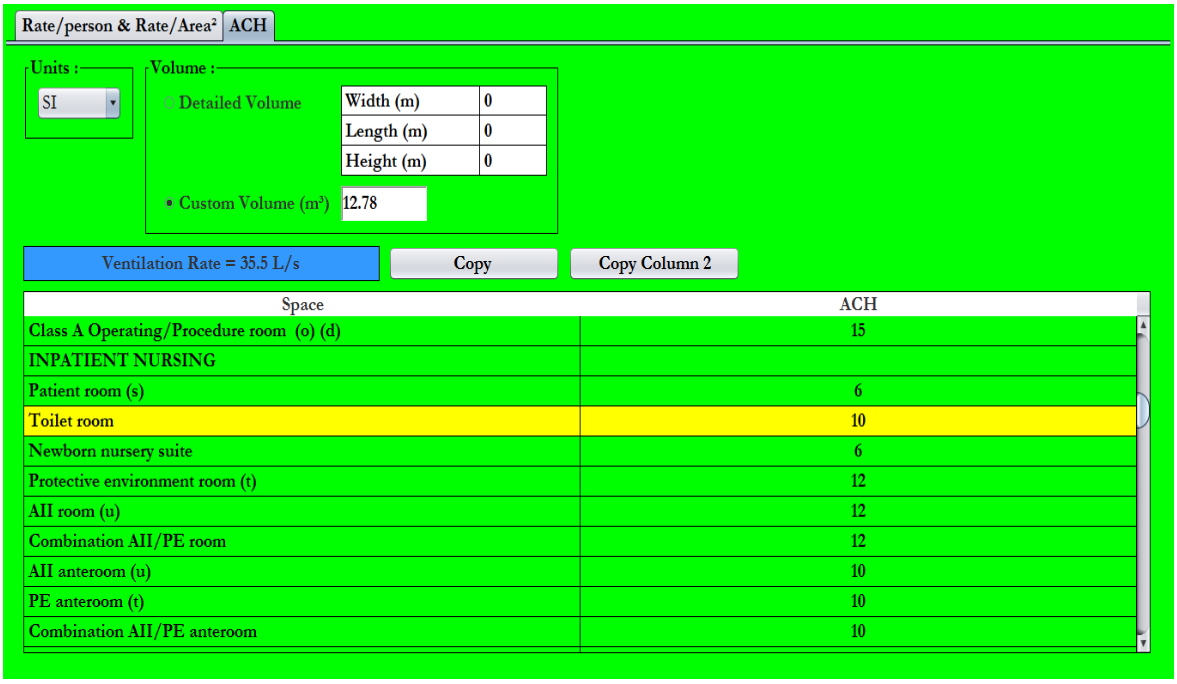


Figure 3.10 : Ventilation rates calculator

Table 3.6 : Ventilation rate

Room	Volume (m^3)	Rate of change air	m^3/h	Ventilation rate	
				(L/s)	(CFM)
Bathroom 1	12.78	12	153.4	35.5	90
Bathroom 2	11.4	12	136.8	31.67	80.5
Kitchen	19.1	16	305.3	79.58	180

- Range of change air from Table (A-35) .

3.15.4 The duct calculation :

Assumptions [6]

- Using balanced pressure drop method .
- C_p of air $= 1$ kJ/kg .°C .
- Inside design condition = 24 °C .
- Supply design condition = 31.9 °C .
- Air density $\rho = 1.25$ kg/m^3.
- Air velocity in the main duct = 5 m/s .

Table 3.7 :Cooling load for WC1,WC2, Kitchen,Customer service and teller

Room	WC1	WC2	Kitchen	Customer service and teller
Cooling load	0.506	2.348	7.19	25.98

Where :

$Q`_s = \rho \times C_p \times V`(T_s - T_i)$

$= 1.25 \times 1(31.9 - 24)$

$V` = \frac{1}{9.87} Q`_s$

Table 3.8: The volume for WC1, WC2, Kitchen

Room	WC1	WC2	Kitchen
$V`\ (m^3/s)$	0.0513	0.238	0.73

Therefore, the required total volumetric flow rate of warm supply air V_t is :

$V_t = \sum V_i$

$= 0.0513 + 0.238 + 0.73 = 1\ m^3/s$

For duct section A-B (main duct) , then $V_{A-B} = 5\, m/s$ and $V`_{A-B} =\ 1\ m^3/s$

Therefore from Table (A-34) can obtain that :

$(\frac{\Delta P}{EL})_{A-B}\ \rightarrow 0.55\ \ Pa/m$, and duct diameter is 0.50 m .

Which is constant for all other duct section . Also , since :

$V` = A\ \times V$

$A = \frac{1}{5} = 0.2\, m^2$

$A = \frac{\pi}{4} \times d^2$

$d_{A-B} = \sqrt{\frac{4}{\pi}(0.2)} = 0.50\, m$

Similarly, for duct section B-C with flow rate of

$V_{B-C} = 1 - 0.0513 = 0.948\, m^3/s$

and $(\frac{\Delta P}{EL})_{B-C} = (\frac{\Delta P}{EL})_{A-B}\ = 0.55\ \ Pa/m$, then Table (A-34) gives :

$d_{B-C} = 0.48\ m$ and V_{B-C} $4.9\ m/s$

Similarly, for duct section C-D with flow rate of $V_{C-D} = 0.948 - 0.238 = 0.71\ m^3/s$ and $(\frac{\Delta P}{EL})_{C-D} = (\frac{\Delta P}{EL})_{B-C} = (\frac{\Delta P}{EL})_{A-B} = 0.55\ Pa/m$, then Table (A-34) gives :

$d_{B-C} = 0.44\ m$ and V_{B-C} $4.6\ m/s$

Table 3.9 : Ventilation rate for WC1, WC2, Kitchen

Duct section	Volumetric flow rate m^3/s	$(\frac{\Delta P}{EL})$ Pa/m	d m	V m/s
A-B	1	0.55	0.50	5
B-C	0.948	0.55	0.48	4.9
C-D	0.71	0.55	0.44	4.6
B-E	0.052	0.55	0.18	2.5
C-F	0.238	0.55	0.28	3.7

Using Customer service and teller :

- The volume is 515.4 m^3

Table 3.10 : Ventilation rate for Customer service and teller

Room	Volume (m^3)	Rate of change air	m^3/h	Ventilation rate	
				(L/s)	(CFM)
Customer service and teller	515.4	6	3092.4	859	1820.12

- **The duct calculation :**

  Assumptions

  - ❖ Using balanced pressure drop method .
  - ❖ $C_p\ of\ air\ = 1\ kJ/kg$.℃ .
  - ❖ Inside design condition = 24 ℃ .
  - ❖ Supply design condition = 31.9 ℃ .
  - ❖ Air density $\rho = 1.25\ kg/m^3$.

❖ Air velocity in the main duct $= 5\, m/s$.

The Cooling load for Customer service and teller 25.98 k_W

Where :

Where :

$Q`_s = \rho \times C_p \times V`(T_s - T_i)$

$= 1.25 \times 1(31.9 - 24)$

$V` = \frac{1}{9.87} Q`_s$

The volume for Customer service and teller 2.63 m^3/s

Therefore, the required total volumetric flow rate of warm supply air V_t is :

$V_t = \sum V_i$ (3.5)

$= 0.4383 + 0.4383 + 0.4383 + 0.4383 + 0.4383 + 0.4383 = 2.63\ m^3/s$

For duct section A-B (main duct) , then $V_{A-B} = 5\, m/s$ and $V`_{A-B} =\ 2.63\ m^3/s$

Therefore from Table (A-34) can obtain that :

$(\frac{\Delta P}{EL})_{A-B} \rightarrow 0.3\ Pa/m$, and duct diameter is 0.84 m .

Which is constant for all other duct section . Also , since :

$V` = A\ \times V$

$A = \frac{2.63}{5} = 0.526\, m^2$

$A = \frac{\pi}{4} \times d^2$

$d_{A-B} = \sqrt{\frac{4}{\pi}(0.526)} = 0.84\, m$

Similarly, for duct section B-C with flow rate of

$V_{B-C} = 2.63 - 0.4383 = 2.1917\ m^3/s$

and $(\frac{\Delta P}{EL})_{B-C} = (\frac{\Delta P}{EL})_{A-B}\ = 0.3\ Pa/m$, then (A-34) gives :

$d_{B-C} = 0.82\ m$ and V_{B-C} 4.8 m/s

Table 3.11: Duct sizing for the Customer service and teller

Duct section	Volumetric flow rate (m^3/s)	$(\frac{\Delta P}{EL})$ Pa/m	d m	V m/s	Duct Length mm (in)	Duct Height mm (in)
A-B	2.63	0.3	0.84	5	500 (20”)	840 (33”)
B-C	1.3151	0.3	0.65	4.2	375 (15”)	650 (25.6”)
C-D	0.8768	0.3	0.55	4	325 (13”)	550 (21.6”)
D-E	0.4385	0.3	0.43	3.2	225 (9”)	430 (13.4”)
B-F	2.63	0.3	0.84	5	500 (20”)	840 (33”)
F-G	2.19	0.3	0.82	4.8	450 (18”)	820 (32”)
G-H	1.7534	0.3	0.73	4.6	400 (16”)	730 (28.7”)
C-R	1.3151	0.3	0.65	4.2	375 (15”)	650 (25.6”)
D-J	0.8768	0.3	0.55	4	325(13”)	550(21.6”)

3.15.5 Rectangular duct :

Assumption

- ❖ The duct aspect ratio (width/height) should not exceed 6:1
- ❖ The allowable height is 200 mm .

For B-C (to explain the way of calculation)

Diameter of duct = 650 mm .

From design tools duct sizer., with H= 200 mm and d= 650 mm then

W= 800 mm

Check aspect ratio = 600:200 → 2: 1 it's ok .

Table 3.12: The dimensions of all duct sections.

Duct section	d (mm)	H (mm)	W (mm)	Aspect ratio
A-B	840	200	1400	7
B-C	650	200	1000	5
C-D	550	200	800	4
D-E	430	200	800	4
B-F	840	200	1400	7
F-G	820	200	1400	7
G-H	730	200	900	4.5
C-R	650	200	900	4.5
D-G	550	200	800	4

Chapter Four
Plumping System

4.1 Introduction

Plumbing is the art and science of installing pipes in buildings, fixtures for bringing in the water supply and removing liquid and waterborne wastes. Plumbing systems are one of the most important parts of building design because it's prevent transmission of disease, hygiene, remove the dirty water and etc.

Plumbing includes many systems in buildings, the figure below shows the details of the plumping systems.[12]

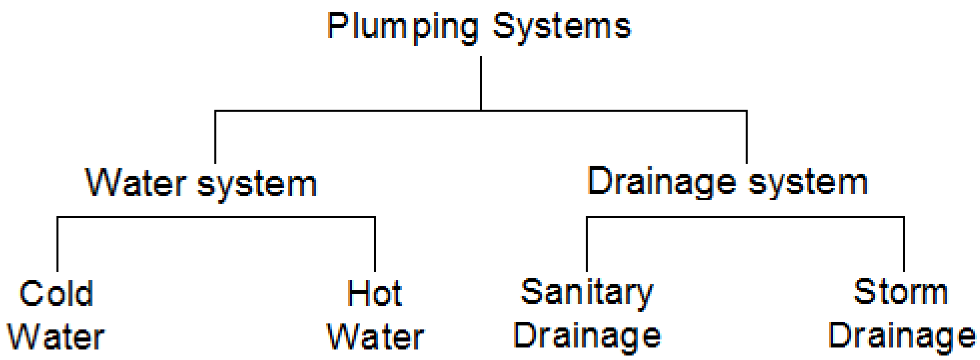


Figure 4.1: Plumping systems

4.2 Water supply system

4.2.1 Overview

There are two type of water distribution system for buildings:

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

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

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

1) The supply of water for the building is received from a city main.

2) Private water supply enters into a pneumatic tank pressurized from approximately 35-60 psi pump.

The main pressure that provides this building is 35 psi.

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

4.2.2 Calculations for hot and cold water

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

The design procedure is as follows:

1) Draw a rise (plumbing section) on this riser show:

- Floor to floor height.
- Run out distance to farthest fixture on each floor.
- Lengths of piping from the service point to the floor take off points.

2) Show the WSFU for each fixture and total fixture unit on each piping run out. Use separate fixture units for hot and cold water.
3) Total the fixture units in each branch of the system. Each hot and cold water riser will require separate diagram and calculation.
4) Show minimum source pressure and the minimum flow pressure required of the most remote outlets.
5) Determine the pressure available for friction head loss from service point to the final outlet.
6) Determine the required pipe size in each section using friction head loss data calculated in step 5 and friction head charts.

4.2.2.1 Sizing of pipes:

To size the pipe, we follow this steps:

1. From Table (A-23); we take the fixture unit & pipe for every fixture type.
2. From table (A-23); we take the flow rate for every fixture.
3. Calculate the total flow at all pipe section.
4. From Table (A-25) , we take the suitable main diameter pipe.
5. From table (A-26) we take the pipe size for every fixture.

In this project, there are several plumbing fixture usage such as Drinking Machine, water closet, lavatories and sink. show the Fixture unit for every fixture:

Table 4.1: Show the fixture unit, the pipe size for every fixture

FIXTURE TYPE	PIPE SIZE	# OF FIXTURE	FIXTURE UNIT COLD	FIXTURE UNIT HOT	TOT. WSFU COLD	TOT. WSFU HOT
LAVATORY	1/2"	2	1.5	1.5	3	3
KITCHEN SINK	1/2"	1	2.25	2.25	2.25	2.25
W.C	3/8”	2	5	0	10	0
DRINKING MACHINE	3/8”	1	0.25	0	0.25	0
TOTAL WSFU					15.5	5.25

Table 4.2: Pipe size used in our work for every fixture.

Fixture	Size
Water Closet	1/2"
Lavatory	1/2"
Collar	1/2"
Sink	1/2"

After we calculate the total Fu, Then from table (A-23) we determine the flow rate for the supply pipe Cold water Q=17.75 gpm & Hot water Q= 9.725 gpm , then from table (A-28) we found the supply pipe size For the hot & cold water.

Under plastic pipe the main cold water diameter = 1" & main hot water diameter = ¾".

Then we calculate the main pipe diameter from supplier:

Also from table (A-28) under Galvanized iron & steel pipe the water supply diameter for the building = 1".

4.2.2.2 Pipe size calculations main supply :

By using the up feed distribution system in which the water is supplied to the building water tank.

Before we calculations should now some information's:

1. The main pressure is equal 35 psi.
2. The friction loss through the water meter equal 8psi by equation
3. The total equivalent length from the source to critically fixture unit is 20 meter &equal 60 feet.
4. The static pressure equal 5 meter equal 16.4 feet & equal 7.12 psi
5. Flow of the total building 1.12 $\frac{\text{liter}}{\text{sec}}$ equal 17.75 US gpm

Main Pressure = Static pressure+ Friction head loss (4.1)

Static pressure $= 5 \times \frac{0.433}{0.304} = 7.12\, psi$

friction head loss = 35-7.12 = 27.88 psi (4.2)

Suppose that the diameter of the water meter is ø $\frac{3}{4}$"

Then: friction head loss water meter 8 psi

Then : friction head loss = 27.88-8 =19.88 psi (4.3)

Equivalent length $= 60 \times 1.5 = 90\ feet$

Uniform design friction loss = $\frac{Availble\ head\ loss}{Equivalent\ length}$ (4.4)

$= \frac{19.88 \times 100}{90} = 22\ \frac{psi}{100ft}$

diameter of the water meter is $ø\,\frac{3}{4}$"

The diameter of the main feeder tube of the building $ø\,\frac{3}{4}$" at 16 psi

and velocity 6.4 .

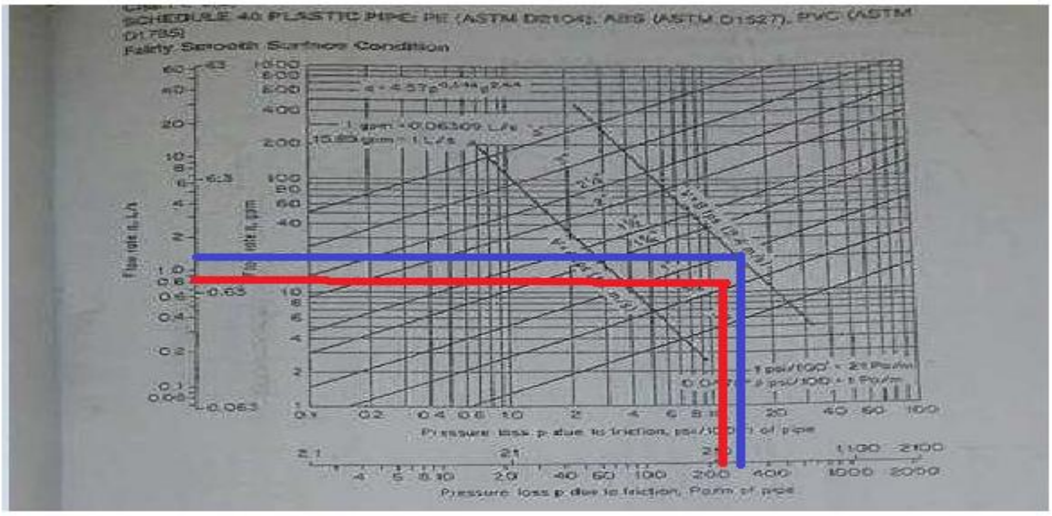


Figure 4.2: Friction head loss for water in commercial steel pipe (schedule 40).

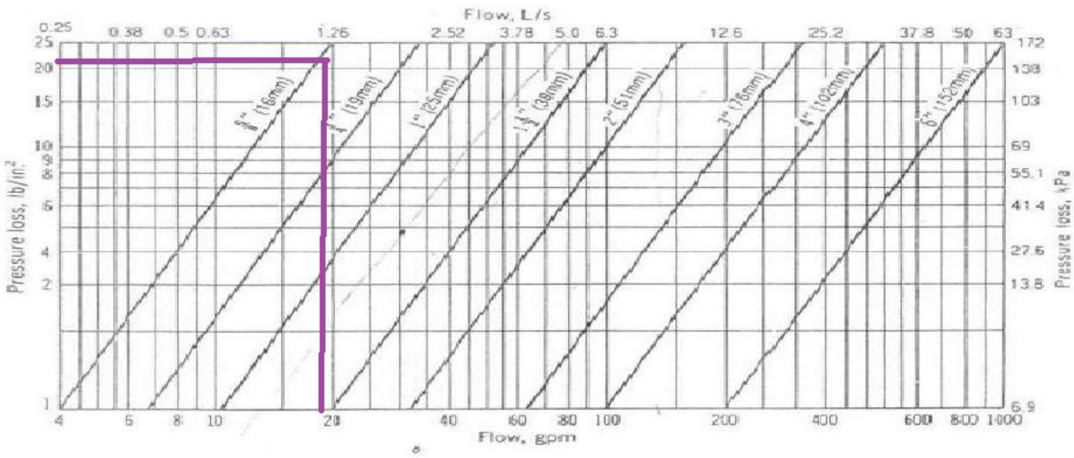


Figure 9.8 Pressure loss (friction head loss) in disk-type water meters. (Reprinted by permission of the American Society of Heating, Refrigerating and Air-Conditioning Engineers, Atlanta, Ga., from the 1993 *ASHRAE Handbook—Fundamentals*.)

Figure 4.3: Pressure loss(friction head loss) in dick type water meter.

4.2.2.3 Pump Selection:

To select the suitable pump we calculate the main pressure of the building by using the following equation:

Main pressure = friction & fitting head + flow pressure - static head (4.5)

Where:

Static head is to overcome the height.

Friction head is to overcome friction in pipes.

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

Static head = γ * height = 9.8 * 3 = 29.4 kPa (4.6)

Flow pressure = 15 Psi = 207 kPa

Then we find the friction & fitting head by using this equation & table (A-27):

First, we divided the pipe line to the section to determine the fitting head, following table show the pressure head done by the fitting & the pipe:

Table 4.3 : Show the value of ΔP for every section

Section	D	Q (gpm)	L (meter)	ΔP/L (kpa/m)	Δp fitting (kpa)
A-B, B-C, C-D	1”	17.75	13.8	0.113	1.8
D-E	1/2"	3	3	1.3	3.9
Total					5.7 kPa

ΔP friction + fitting = 1.8 * ΔP fitting = 1.8 * 5.7 = 10.26 kPa (4.7)

Main pressure (ΔP) = 10.26 + 207 – 29.4 = 188 kPa = 1.88 Bar (4.8)

The required selected pump produced by Marquis Company with model MCP 132 A.

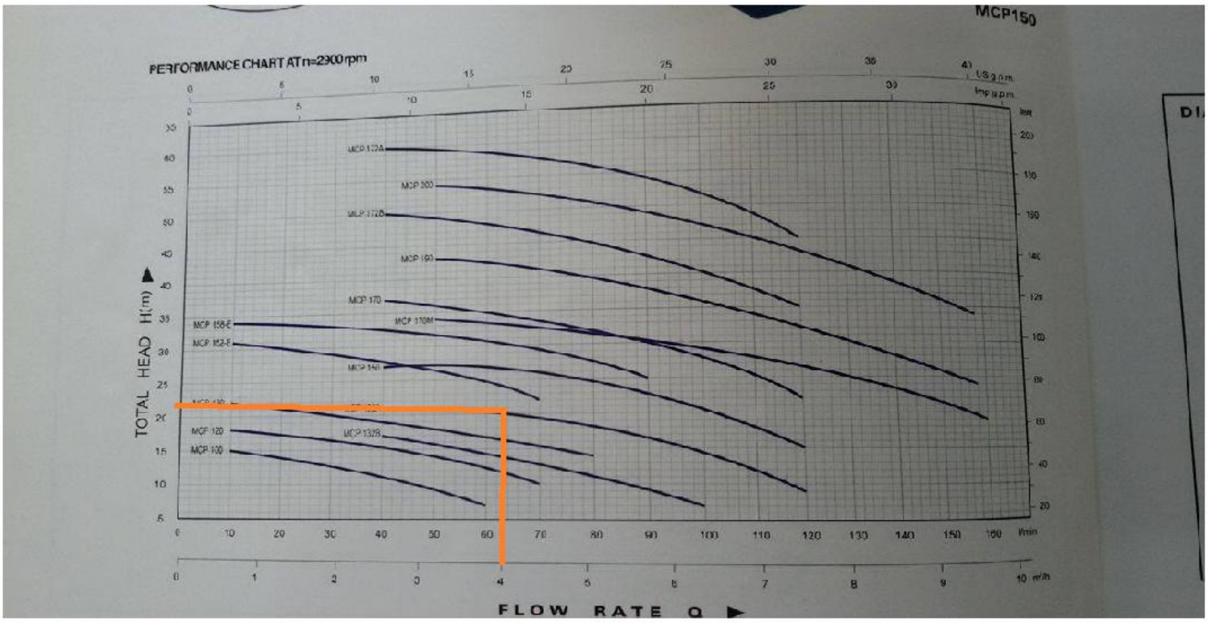


Figure 4.4: Pump characteristic curve

4.3 Water tank volume :

To determine the water tank volume first we convert the flow to L/s:

Q = 17.75*3.8/60 = 1.12 l/s

The tank capacity = flow * 3600/1000 = 1.12 * 3600/1000 = 4 m^3=4000 litter.(4.9)

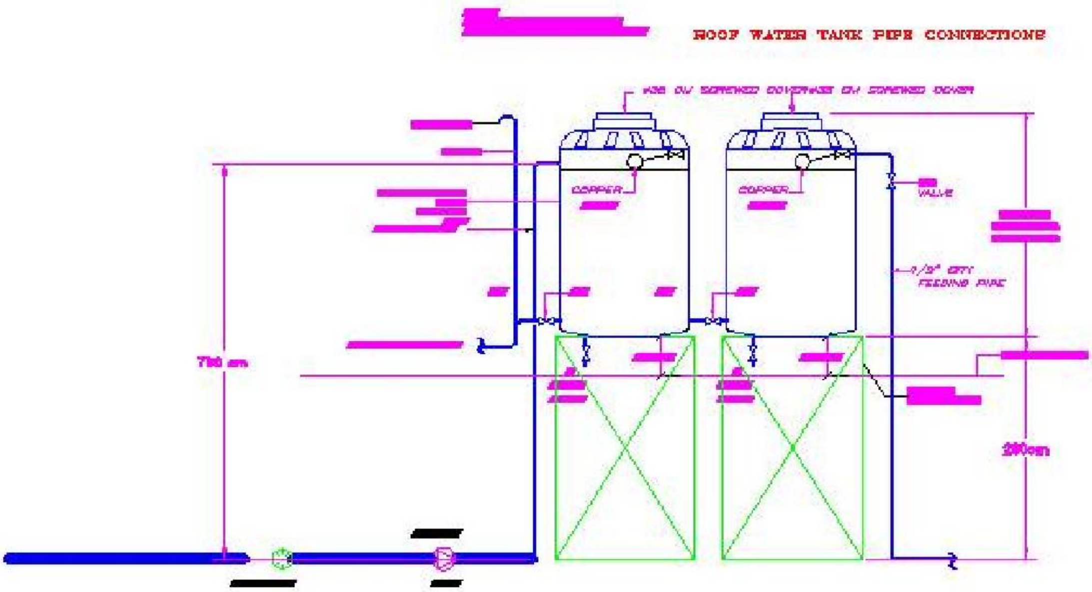


Figure 4.5: Water tank

4.4 Drainage system :

The main objective of drainage system is to carry the waste water from the fixture unit to manhole and from the manhole to the septic tank or to the municipal sewage system.[13]

The provision of drainage systems:

- Sanitary drainage
- Storm drainage

4.4.1 Drainage system components

The main components of drainage system are:

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

4.4.2 Sanitary drainage

4.4.2.1 Design procedure and pipe sizing

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

- o 50% fill in branches (horizontal pipes)

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

The recommended velocity for drainage piping:

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

Velocity of water flow through drainage piping depends on:

- Pipe diameter
- Slope

Minimum slope requirements for horizontal drainage piping:

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

Design procedure:

1. Calculation of the number of DFU for each branch by using Table(A-33)
2. Calculation of the number of DFU for each stack
3. Choosing the branch pipe diameter by using Table (A-31)
4. Choosing the stack pipe diameter by using Table(A-32)
5. Comparing the stack pipe diameter with branch diameter
6. Choosing the building drain pipe diameter by using Table (A-33)

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

4.4.2.2 Pipe sizing for black water:

Pipe size is calculated by using a concept of fixture units (DFU) instead drainage water. This unit takes into account not only the fixtures water use but also its frequency of use, which is the DFU has a built–in diversity factor. This enables us, exactly add DFU of various fixtures to obtain the maximum expected drainage flow.

These tables are built into the fill factors, which are:

- 50% fill in branches (horizontal pipes)

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

The recommended velocity for drainage piping:

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

Velocity of water flow through drainage piping depends on:

- Pipe diameter
- Slope
- Minimum slope requirements for horizontal drainage piping:
- For pipes of diameter ≤ 3" the minimum slope is 1/4”/ft (2%)

Design procedure:

1. Calculation of the number of DFU for each branch by using Table (A-31).
2. Select the required size for every fixture by using Table (A-31).
3. Calculation of the number of DFU for each stack.
4. Choosing the branch pipe diameter by using Table (A-32).
5. Choosing the stack pipe diameter by using Table (A-32).
6. Comparing the stack pipe diameter with branch diameter.
7. Choosing the building drain pipe diameter by using Table (A-32).

To achieve the recommended velocities which are 3 fps in building drain, it will be chosen the slope and flow velocity in building drain by using Table (A-31).

4.4.2.3 Sample calculation:

From Table(A-31) and (A-32) we take the fixture unit of every type fixture, and from table (A-33) we take the size of every fixture; as shown in the following table:

Table 4.4: Sizing & DFU for every fixture.

Fixture	DFU	# of Fixture	Total DFU	Size
Water Closet	6	2	12	3”
Lavatory	2	2	2	$1\frac{1}{2}$”
Collar	1	1	1	2”
Sink	2	1	2	2”
Trap 4”	6	3	18	4”
Total			35	

But the general sizes that used in Palestine work since not produce this size like $1\frac{1}{2}$” are; the size are shown in the following table:

Table 4.5: General size use in Palestine Shops & works.

Fixture	Size
Water Closet	4”
Lavatory	2”
Collar	2”
Sink	3”
Trap 4”	4”

To select the suitable pipe size of the branch, stack & building stake; we follow the following steps (The following size for stack #1):

1. From Table (A-31), we select the require size for any fixture.
2. From Table (A-32). :
   - Under (any Horizontal ….) select the size of branch; for stack 1 pipe branch size =4”.
   - Under (Stack more than 3 – total at one story) select the size of stack; for stack 1 pipe branch size =4”.
3. From Table (A-32), select the size of building drain pipe.

The figure below shows the distribution method of piping:

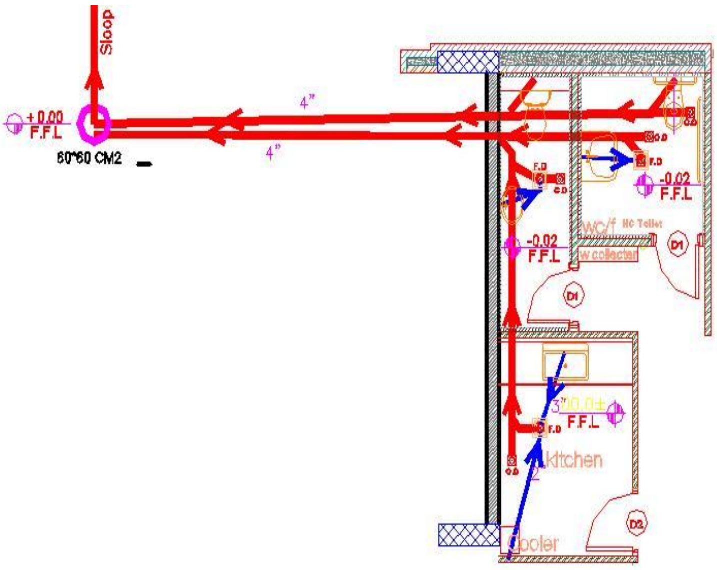


Figure 4.6: Distribution of piping in bathroom

4.4.3 Storm drainage :

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

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

The general rule for the distribution of floor drains (FD):

Every 100 m^2 from roof area needs one 4" FD.

The roof area of this building is 340 m^2, and therefore needs three 4" FD.

4.4.4 Manhole design

The main purpose of the manholes is to carry the water from stacks to various drainage points.

This project contains three types of manhole, which is:

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

Figure 4.7: Manhole design

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

According to the table below, it will be estimated the diameter of the manhole according to their depth

Table 4.6: Diameter of the manhole according to their depth

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

4.4.4.1 Manhole calculation :

The depth of the first manhole is 50 cm, the calculation of the second manhole done according to

The first manhole and so on. The calculations are done by using these equations:

• Depth: (M2 = M1 + (Slope × Distance) + 5 + Level Difference) in cm (4.10)

• Top level: Manholes face level on the ground

• (Invert level = Top level - Depth) in m (4.11)

• Outlet level = - (Depth - 0.05) in m (4.12)

The figure below shows the details of the manholes:

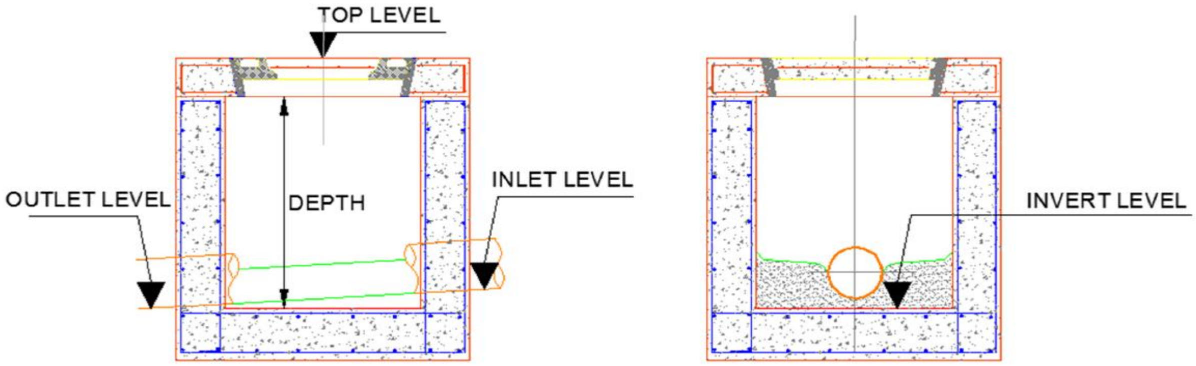


Figure 4.8: Manhole details

Chapter Five

Fire Fighting System

5.1 Introduction

A firefighting system is probably the most important of the building service, as its aim is to protect human life and property strictly in that order, Fire is a chemical reaction involves the rapid oxidation of the combustible materials, also we can divide the causes of fire by four main parts called the fire tetrahedron and the four ignition components are:[14]

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

The following is a description for this component:

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

Air (oxygen) the percentage of the oxygen in natural air is 21% and the percentage which prevents a fire production is to keep more than 16%. Heat it's the main reason to producing a vapor from materials to occurrence of ignition such as heat produces from electrical sources, smoking etc.

Chain chemical reaction, the fire is continues as long as the previous three elements are present correct percentages, and the result of these elements of effective chemicals known as free radicals.

Fire work is divided into three sections for engineer:

1) Architect engineer: It is specialized in acting fire safety.
2) Electrical engineer: it is specialized in fire alarm.
3) Mechanical engineer: it is specialized in firefighting.

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

5.2 Classification of firefighting systems :

Firefighting systems are classified to:

1) Water system.
2) Gas system.
3) Foam system.

5.2.1 Water firefighting system :

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

1) Manual system:

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

a. Fire hose cabinet.

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

b. Fire hydrant.

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

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

2) Automatic system.

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

a. Wet pipe sprinkler system.

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

b. Dry pipe sprinkler system.

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

c. Pre-action sprinkler system.

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

d. Deluge sprinkler system.

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

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

Figure 5.1: Firefighting system

5.2.2 Gas firefighting system :

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

1) Manual system

Fire extinguishers is an active fire protection device used to extinguish or control small fires, often in emergency situations, fire extinguisher consists of a hand-held cylindrical pressure vessel containing an agent which can be discharged to extinguish a fire.

In general fire extinguishers can be water, co2, foam, wet chemical and dry powder extinguisher.

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

2) Automatic system:

Clean agent gases fire extinguisher.

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

These gases are FM-200, NAF 125 (HFC 125), ARGON and CO_2.

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

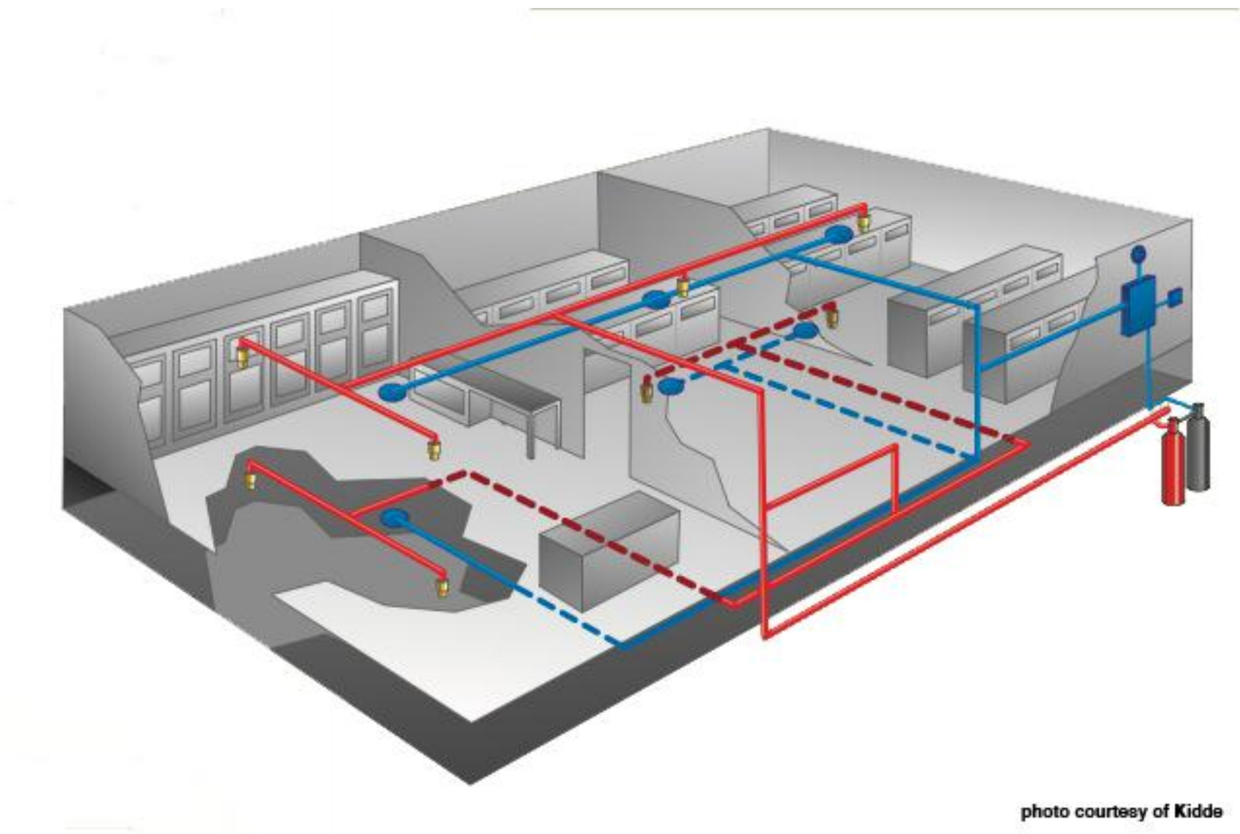


Figure 5.2: Gas firefighting system

5.2.3 Foam firefighting system :

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

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

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

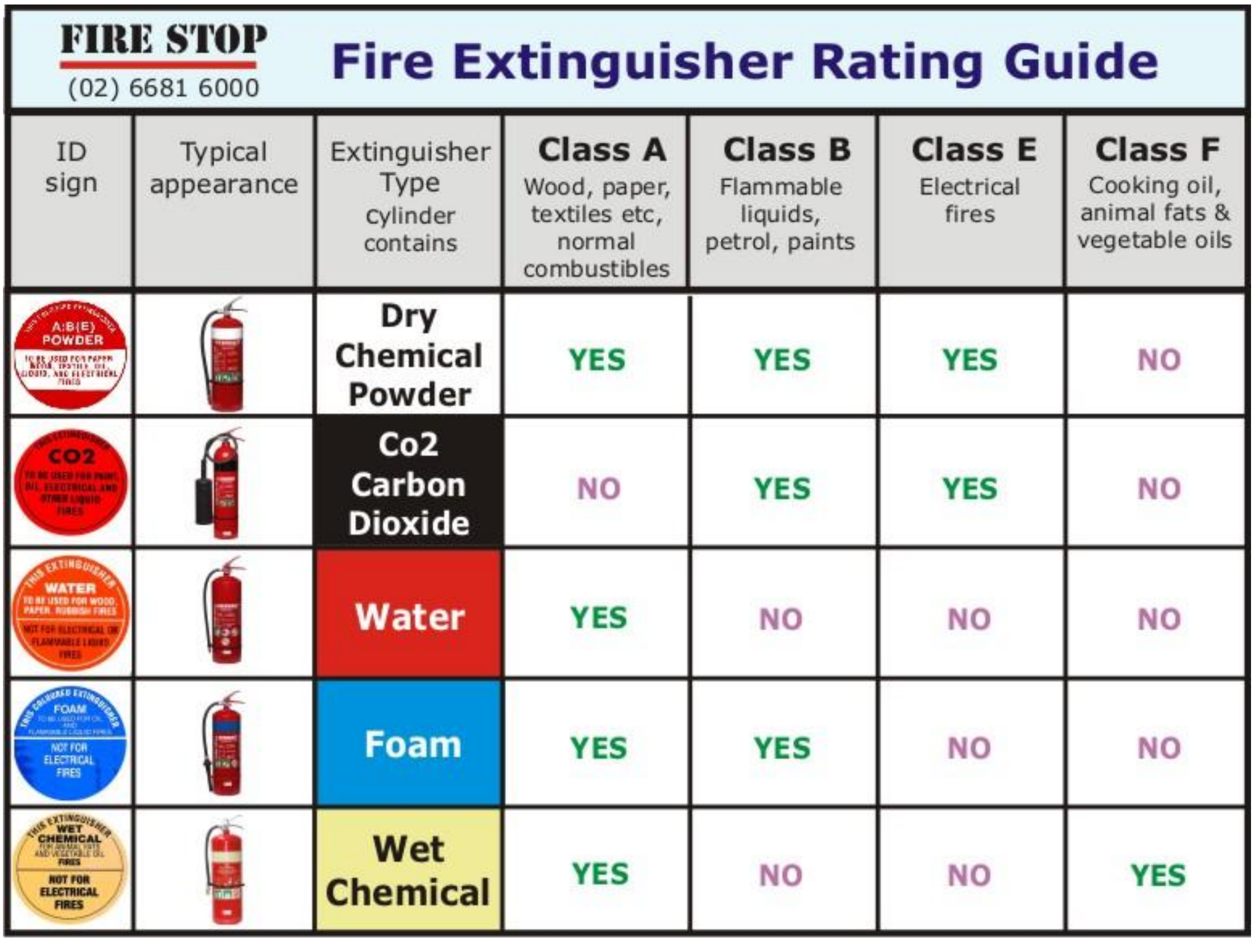
Figure 5.3: Foam firefighting system

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

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

5.2.4 Fire extinguishers :

Fire extinguishers are provided for a "first attack" for fighting measure generally undertaken by the occupants of the building before the first service arrive. It is important that occupants are familiar with extinguisher type to use on fire. Most fires start as a small fire and may be extinguished if the correct type amount of extinguishing agent is applied whilst the fire is controllable.



FIRE STOP (02) 6681 6000

Fire Extinguisher Rating Guide

ID sign	Typical appearance	Extinguisher Type cylinder contains	Class A Wood, paper, textiles etc, normal combustibles	Class B Flammable liquids, petrol, paints	Class E Electrical fires	Class F Cooking oil, animal fats & vegetable oils
		Dry Chemical Powder	YES	YES	YES	NO
		Co2 Carbon Dioxide	NO	YES	YES	NO
		Water	YES	NO	NO	NO
		Foam	YES	YES	NO	NO
		Wet Chemical	YES	NO	NO	YES

Figure 5.4: Fire extinguishers rating guide

5.2.4.1 Type of Portable Fire Extinguishers :

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

5.2.5 Fire hose reel :

Fire hose cabinet should be installed according to NPFA 14 and shown in drawings:

1. Near escape stairs
2. 30m (100ft) length of the pipe which is the distance traveled by the pipeline passing and walls until it reaches the fire place.
3. Next to the main door of the building.
4. Fire house cabinet height above the ground (90-150) cm.

Note: All fire hose cabinet distribution is shown on drawings.

Fire house cabinet includes two types.

- House reel
- House Rack

Figure 5.5: Fire hose cabinet

5.2.6 Fire hydrant system :

Located in the street and it is used in ease that we couldn’t overcome the fire inside the building.

Fire Hydrant should be installed according to NPFA 14.

A pipe with 4" diameter branched into pipes each with 2.5" diameter with flow of 250 gpm .

Figure 5.6: Fire hydrant

5.2.7 Automatic sprinkler system :

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

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

When a sprinkler head operates, the water pressure in the system, activating a alarm which often automatically calls the brigade via a telephone connection.

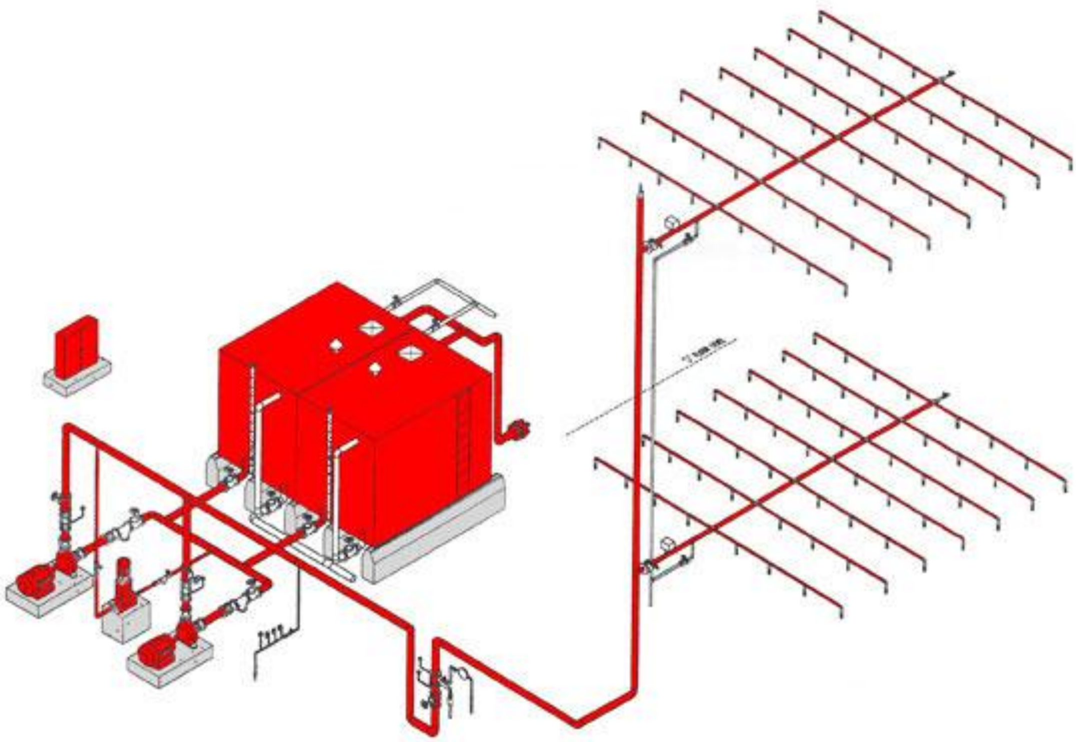


Figure 5.7: Automatic sprinkler system

5.2.8 Smoke sensor :

A smoke detector is a device that senses smoke, typically as an indicator of fire. Commercial security devices issue to a fire pump to open automatically as part a fire of a fire alarm system.

Figure 5.8: Smoke sensor

5.3 Firefighting pumps :

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

Pumping stations should include:

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

   Diesel pump works if:

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

3) Jockey Pump: work to make up the system pressure in case of leakage or during the first seconds of fire.

Pumps are selected to supply the system demands on the basis of three key points relative to their rated flow and rated pressure; most fire pumps are sized to exceed its duty point requirement.

✓ **Types of pumps**

- **Horizontal split case pumps:**

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

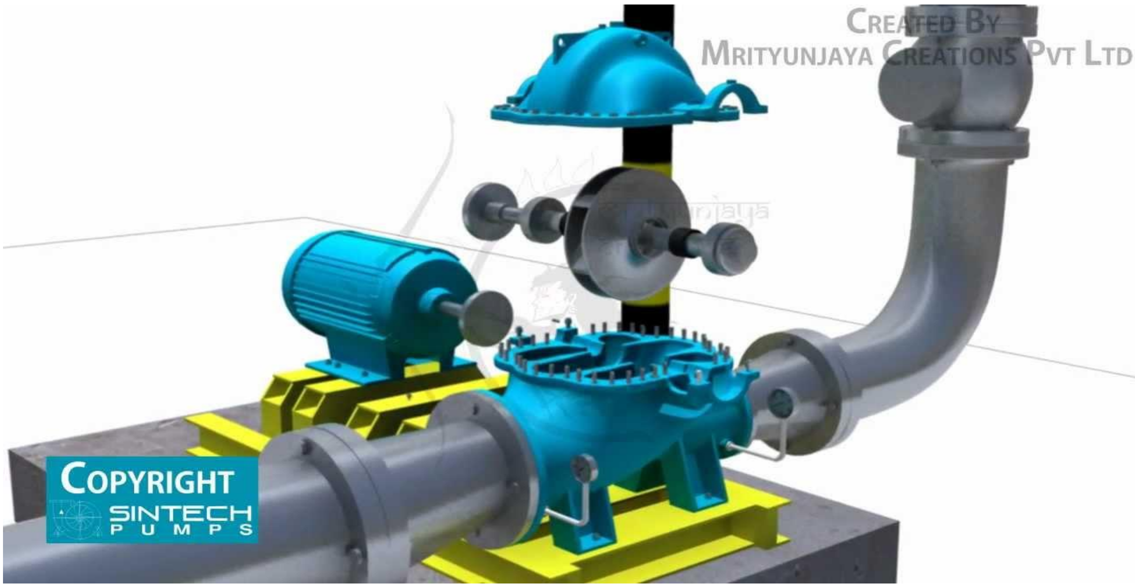


Figure 5.9: Horizontal split case pump

- **Inline fire pumps**

These pumps have expanded in use in the last five years for several reasons, space savings.

Increase in ratings allowable by NFPA 20 from max of 499 GPM, and then to 750 GPM, to today which is unlimited rating. The largest currently available is 1500 GPM, Cost of installation these are typically less expensive to install because there is no base plate that requires grouting.

Figure 5.10: Inline fire pump

- **End suction pumps**

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

Figure 5.11 End suction pump

- **Vertical turbine pumps**

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

Figure 5.12: Vertical turbine pump

5.4 Sizing & Pump Selection :

In this system the material pipe the used in the building is galvanized steel. The main pipe diameter is 2”, the pipe size that for every cabinet equal 1.5”.

In our project we use 2 fire hose reel & 10 fire Extinguishers**.**

- **Pump selection:**

To select the suitable pump we calculate the main pressure of the building by using the following equation:

Main pressure = friction & fitting head + flow pressure - static head (5.1)

Where:

Static head is to overcome the height.

Friction head is to overcome friction in pipes.

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

Static head = Υ * height = 9.8 * 2 = 19.6 kPa (5.2)

Flow pressure = 4.5 Bar = 450 kPa (5.3)

Then we find the friction & fitting head by using this equation & Table (A-27):

First, we divided the pipe line to the section to determine the fitting head, following table show the pressure head done by the fitting & the pipe:

Table 5.1: Show the value of ΔP for every section

SECTION	D	Q (gpm)	L (meter)	ΔP/L (kPa/m)	ΔP FITTING (kPa)
A-B	2”	100	8.7	0.45	3.915
B-C	2”	100	2	0.45	0.9
C-D	2”	100	17.32	0.45	7.8
D-E	1 1/2"	100	12	1.5	18
TOTAL					30.615 kPa

$\Delta P_{\text{friction + fitting}} = 1.8 * \Delta P_{\text{fitting}}$ = 1.8 * 30.615 = 55.12 kPa (5.4)

Main pressure (ΔP) = 55.12 + 450 – 19.6 = 485.52 kPa = 4.85 Bar (5.5)

The required selected pump produced by Marquis Company with model 2MC40/180B.

Fire tank capacity:

Tank capacity = (Q * 3.8 * 60)/1000 = (100 * 3.8 * 60)/ 1000 = 22.8 m^3 (5.6)

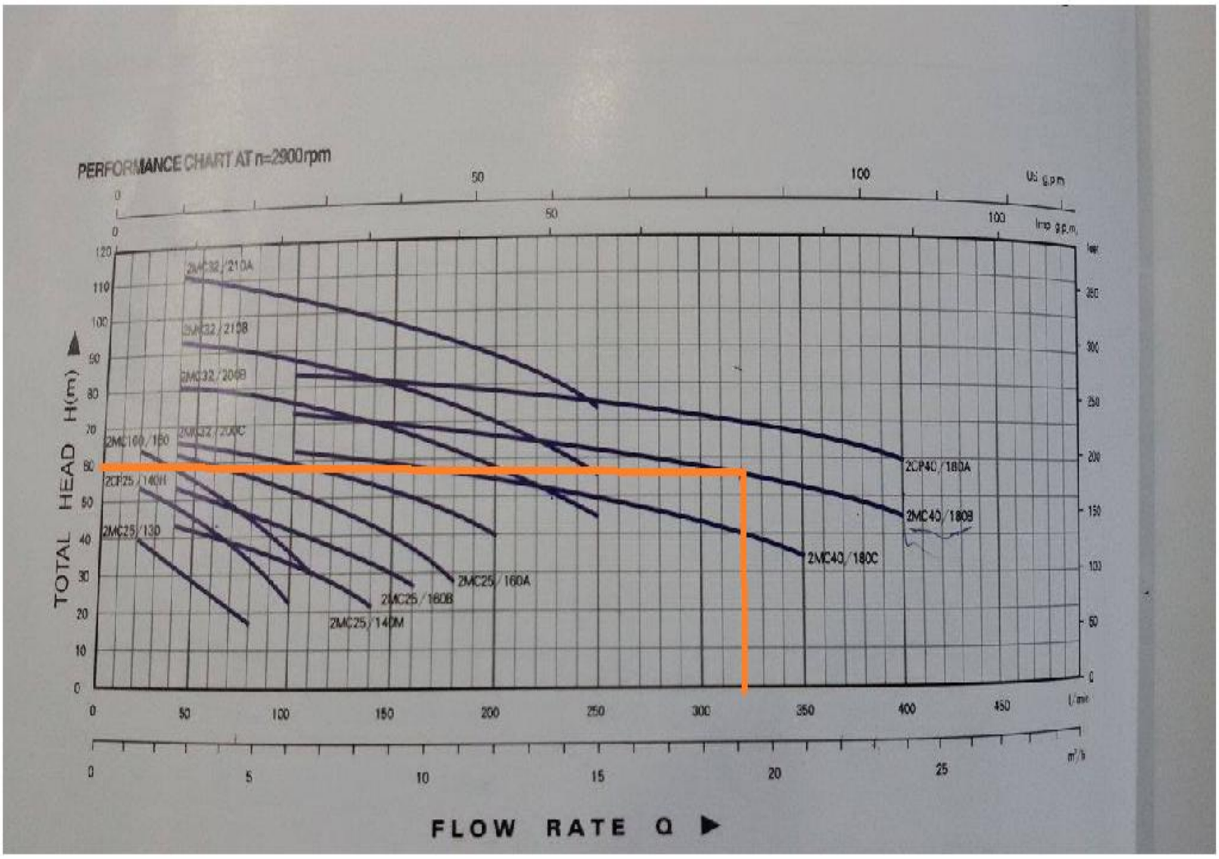


Figure 5.13: Pump characteristic curve

REFERENCES

[1] Mohammad A.Alsaad, Mahmoud A. Hammad,"Heating and Air Conditioning for Residential Building", 4th edition, 1995.

[2] PDHonline Course M196 (4 PDH)
available at: http://www.pdhonline.com/courses/m196/m196content.pdf

[3]The Engineering toolbox
available at: http://www.engineeringtoolbox.com/heat-loss-buildings-d_113.html

[4] Image from Research gate, available at:
https://www.researchgate.net/figure/265597651_fig2_Figure-4-Cooling-load-components

[5] Energy Codes for Buildings Project UNDP/PAPP, "Energy Efficient Building Code", 2004.

[6] A. bahatia. " HVAC - Variable Refrigerant Flow (VRF) Systems", Continuing Education and Development.

[7] Image from seventhwave, available at:
http://www.seventhwave.org/new-technologies/variable-refrigerant-flow-vrf

[8] Image from slide player, available at:
http://slideplayer.com/slide/2760342/

[9] Image from City Multi Minisplits, Available at:
http://allclimatehvac.com/commercial-heating-in-fridley/ductless-split-systems/city-multi-minisplits/

[10] VRF Air Conditioning, Available at:
http://www.arca53.dsl.pipex.com/index_files/vrvrefrig.htm

[11] Heating Ventilation and air condition analysis and design, 4 edition .
http://gbtech.emsd.gov.hk/english/utilize/natural.html

[12] Dicker court. Supply Plumping system , 2 edition , 2013 .
https://plasticpipe.org/pdf/pex_designguide_residential_water_supply.pdf

[13] Sanitary Drainage

http://www.iapmo.org/California%20Plumbing%20Code/Chapter%2007.pdf

[14] City Of Fort Lauderdale (April 2011). Fire Rescue – special operations command .fortlauderdale.gov .
http://www.fortlauderdale.gov/departments/fire-rescue/about-fire-rescue/special-operations-command

Appendix (A)

Bill No. (1): MECHANICAL WORKS

Item No.	Description	Unit	Qty.	UR (NIS)	Amount
1.0	**MECHANICAL WORKS** **Preamble** *-This Section shall be read in conjunction with the general, particular Mechanical technical specifications, Mechanical Drawings and invitation to bid conditions. *-The unit price for all items in this section shall include for supply, Intallation, connecting, testing, and commissioning, unless otherwise specifically mentioned or instructed by the Engineer. *-All Civil and Finishing Works related to the concerned item shall be included in the unit price. *-Preparing of coordinated shop drawings and submitting for engineer approval, coordination with other activities, material storage, removing away from site the remnant of electrical works and handing over the Mechanical works to Mechanical works to the authorized Engineer. *- Flexible PVC suitable size conduits and adaptors to be used for connecting motors to power supply.				

Bill No. (1): MECHANICAL WORKS

Item No.	Description	Unit	Qty.	UR (NIS)	Amount
1.1	**Air Conditioning VRF System** Supply and installation testing and commissioning 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.	2.8 KW (wall mounted type)	No.	1	3000	3000
B.	7.1 KW (cassette type)	No.	4	2500	1000
C.	5.6 KW (cassette type)	No.	2	2000	4000
D,	9x9 grille	No.	2	150	300
1.1.2	**VRF Outdoor Unit** Supply & install, testing and commissioning of, outdoor 14 T.R air source heat pumps consisting of: Factory made and assembled 13 Ton class 2, minimum (HSPF of 8, SEER of 12) modular microprocessor (IGCT) based VFD controlled heat pump for VRF purpose. Including air/air heat exchanger, condenser, compressor and necessary casketing to perform the functions of heating and cooling of air. This to be contained in double wall galvanized steel construction case located on painted steel base with vibration absorbers as per drawings, specifications and AHRI 430, AHRI 410, ASHRAE 51 and AMCA 210 codes. Note: Refrigerant gas to be of zero. Ozone depletion potential (ODP) as R410A. All as per Sanyo, Daikin, Samsung or EA.				

A.	45KW VRF OUT DOOR UNIT	No	1	16000	16000
B.	Copper gas pipe 28mm	ML	45	7	315
C.	Galvanized air duct	area	32.5	4	130
1.1.3	Supply & install, testing and do all commissioning, for outdoor and indoor split unit every split have an $1\frac{1}{4}$ T.R, Price shall include all required electrical connections as per specifications, drawings and related codes.	No.	4	2500	10000
1.2	**Ventilation**				
1.2.1	**Exhaust Fans** Supply, install, and connect, testing and commissioning of, wall mounted exhaust fans with gravity shutter driven by IP 65 electric motors. Price shall include all required electrical connections as pervious specifications, drawings and related codes.	No.			
A.	2000 cfm exhaust fan	No.	1	2000	2000
B.	400 cfm exhaust fan	No.	1	800	800
C,	9x9 grille	No.	9	250	2250
Total Page Carried Forward				**Shekel**	**39795**

Bill No. (1): MECHANICAL WORKS

Item No.	Description	Unit	Qty.	UR (NIS)	Amount
1.2	**Water Supply**				
1.2.1	**Water Supply Pump Set** Supply, install, test and commission water supply pump set (factory assembled), one duty, one stand-by, P54 protection, diaphragm type. The unit price shall include pressure vessel, electric control panel, flow rate $4\ m^3/h$ and head 18 m electrical wiring, galvanized steel frame, inertia base, vibration isolators, concrete base and all required valves and fittings as detailed on the drawings.	No.	2	450	900
1.2.2	**Hot Water Cylinder** Supply, install, test and commission hot water Cylinder, vertical shell & tube storage type, 8 bar working pressure, hydrostatically tested for 1-1/2 times the working pressure. The unit price shall include a thermometer, an ASME rated pressure and temperature relief valve, isolating valves, drain valves, check valve on cold water make-up line, automatic air vent, support.	No.	1	420	420
1.2.3	**Galvanized Steel Pipes & Fittings** Supply, install, test and commission galvanized steel pipe work to ASTM-A53 grade "B", schedule (40) for the 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	ML	10	6	60
1.2.4	**Insulation For Exposed Domestic Hot Water Pipe work** Supply and install rigid fiberglass sections for the domestic hot water pipe work exposed to atmosphere, pipe work inside trenches and in plant and mechanical rooms the unit price shall include joining, taping, end caps, insulated aluminum casings on fittings requiring maintenance, and all accessories and works required to complete the work as shown on the drawings and as per the preamble, specifications & the supervision P.M. requirements.	No.			
A.	25 mm thick for 1"	ML	4	40	160
B.	20 mm thick for $\frac{3}{4}$"	ML	4	30	120

1.2.5	**Cross-Linked 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	ML			

	seal, brass elbow/adapter inside PVC termination box built in wall for connection with the sanitary fixtures, dielectric unions, excavation, bedding, backfilling, chasing in wall and all works required as shown on drawings, specifications and P.M. instructions.				
A.	16 mm thick for $\frac{1}{2}$"	ML	100	5	500
1.2.6	**Water Meter** Supply, install, test and commission water meter with totalize, $\frac{3}{4}$" 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	200	200
1.2.7	**Fittings:** Supply, install, test and commission, water tank, water pump, including air vent, check valve, strainer, 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.			
A.	Air vent 3/8”	No.	3	15	45
B.	1” strainer	No.	1	20	20
C.	Check valve	No.	1	15	15
D.	25mm*1” copper nipple record	No.	1	20	20

E.	½ " copper elbow	No.	8	10	80
F.	Push reducer 1" to 1 ¼ "	No.	1	10	10
G.	Push reducer ¾ " to ½ "	No.	1	10	10
H.	Water pump	No.	1	10	10
1.2.9	**Water Collector** Supply and install hot and cold water collector's type GIACOMINI or E.A				
A.	3 outlet collector ¾ " for hot water	No.	1	30	30
B.	3 outlet collector 1 ¼ " for Cold water	No.	2	50	100
C.	3 outlet collector 1 ¼ " for hot water	No.	1	50	100
1.2.11	**Plastic Water Tanks** Supply and install plastic water tanks made in Palestine each one has a capacity 2000L. The price shall include stand with heavy duty, valves and all fittings needed according to drawings.	No.	2	1050	2100
A.	Size 1000 L (Fire fighting)	No.	1	800	800
Total Page Carried Forward				**Shekel**	**5700**

Bill No. (1): MECHANICAL WORKS					
Item No.	Description	Unit	Qty.	UR (NIS)	Amount
1.3	**Waste and Drainage System**				
1.3.1	**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.	No.			
A.	Diameter 2"	ML	13	4	52
B.	Diameter 4"	ML	65	6	390
1.3.2	**Floor Drain** Supply, install, testing and commissioning of, 4"chrome plated threaded 15x15cm cast brass cover, multi inlet adjustable with trap floor drain. Including, floor clean out plug, HDPE siphon or equivalent and necessary accessories, connections with fixtures and main drain pipes. As be drawings, specifications and related codes.	No.	3	130	390
1.3.3	**Clean Out** Supply, install, testing and commissioning of the following, HDPE or equivalent , non-adjustable 15x15 cm stainless steel cover, and floor clean out with gas and water tightness ABS plug and necessary accessories as per drawings, specifications and related	No.	4	120	480

	codes. (Ø 4")				
1.3.4	**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 of 1/2" benching and connecting it to main city manholes as shown in drawing and in accordance to supervision engineer				
A.	Size 60 cm (inside diameter)	No.	2	950	1900
B.	Size 100 cm (inside diameter)	No.	1	1700	1700
1.3.5	**Sanitary Fixture and Their Accessories**				
1.3.5.1	**laundry** Supply and installation of porcelain wash basin glazed white (from creavit or quivalent) with chrome plated mixer adoption of the supervising engineer) half leg measuring 56 × 45 cm and isolate it from the wall using the Sika Anti-gray color of the rot with water mixer (of the finest international standards, according to the supervising engineer adoption) and Siphon and all chrome-plated The price includes valves angle 13 mm chrome holder soap of the finest varieties mirror 60 × 45 cm with aluminum frame and providing sink series and rubber stopper and all necessary for installation, operation and	No.	1	500	500

	drainage to the nearest packet assembly floor drain , according to the specifications and plans and instructions of the supervising engineer.				
1.3.5.2	A disabled laundry, including all necessary fittings and accessories as shown in the drawings and specifications. (Hydraulic type hydraulic)	No.	1	1000	1000
1.3.5.3	**Water Closet** Supply, install, testing and commissioning of, floor mounted, white color, Porcelain, siphon jet water closet/toilet with an elongated bowl, seat with open front and check hinge, and carrier. or equivalent including necessary accessories, 9-lt capacity cistern, valves, fittings, 13mm stop angle valves, chrome plated 13mm hose, heavy duty side l m length 13mm Chrome plated hand shower, connection to drainage and water systems as per drawings, specifications and related codes.	No	1	700	700
1.3.5.4	Ditto, but for handicapped toilet (hydraulic sliding type),including all necessary fittings and accessories as shown on drawings and in specifications. Price includes supplying and installing 40x60cm mirror.	No.	1	1000	1000
1.3.5.5	**Paper Holder** Supply and installing of: surface mounted satin finish stainless steel,	.	1		

	sanitary napkin disposal or equivalent. Disposal features a flip-up cover, secured to the container by a heavy duty stainless steel piano-hinge. Disposal secured to wall or toilet partition. As per drawings, specifications and the approval of the Engineer.	No.		50	50
1.3.5.6	**Sink (General)** Supply, install, testing and commissioning 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. Counter top Kitchen sink	No.	1	300	300
1.3.5.7	**Faucet** Supply, install, testing and commissioning of, Chrome plated cast brass construction, washer less ceramic disc mixing cartridge, gooseneck spout, with elbow/ wrist/ gear blade control handles or equivalent. including, sockets, copper adaptors, 3/8" angle valves and all necessary accessories, as per drawings, specifications and related codes and RE approval. Single lever Gear control handle faucet.	No.	3	50	150
1.3.5.8	**PVC Pipes** Supply, install, test and commission				

	Cross-linked polyethylene (PEX) pipes to DIN 16892/3, 20 bar working pressure, before and after the pump and from collectors to each water closet according to drawings, 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, backfilling, chasing in wall and all works required as shown on drawings, specifications and P.M. instructions.				
A.	Diameter 25 mm	ML	4	16	64
B.	Diameter 16 mm	ML	100	8	800
Total Page Carried Forward				**Shekel**	**9476**

Bill No. (1): MECHANICAL WORKS

Item No.	Description	Unit	Qty.	UR (NIS)	Amount
1.4	**Fire fighting** Supply and install galvanized steel pipes to ASTM-A53 grade "A" schedule-40 for firefighting system pipework, inside building. The unit price shall include valves, fittings, and all accessories and works required to complete the work and as per preambles, specifications, and the supervision of engineer's requirements.				
A.	Diameter 2”	ML	30	100	3000
B.	Diameter 1 ½ ”	ML	20	70	1400
1.4.1	**Fire Fighting Pump Set** Supply, install, test and commission firefighting pump set(factory assembled), composed of one electric on duty pump, one stand-by electrical 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.	No.	1	450	450

1.4.2	**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	10	300	1800
1.4.3	**Fire Hose Reel Cabinets** Supply, install, test and commission fire hose reel cabinets to, complete with 30 meters long 1 ½" 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 per the specifications and the supervision engineer's requirements.	No.	2	1000	2000
Total Page Carried Forward				**Shekel**	**8650**
Total cost				**Shekel**	**63621**

Table (A-1) : Thermo physical properties of gases at atmospheric pressure .

T (K)	ρ (kg/m^3)	c_p (kJ/kg · K)	$\mu \cdot 10^7$ (N · s/m^2)	$\nu \cdot 10^6$ (m^2/s)	$k \cdot 10^3$ (W/m · K)	$\alpha \cdot 10^6$ (m^2/s)	Pr
Air							
100	3.5562	1.032	71.1	2.00	9.34	2.54	0.786
150	2.3364	1.012	103.4	4.426	13.8	5.84	0.758
200	1.7458	1.007	132.5	7.590	18.1	10.3	0.737
250	1.3947	1.006	159.6	11.44	22.3	15.9	0.720
300	1.1614	1.007	184.6	15.89	26.3	22.5	0.707
350	0.9950	1.009	208.2	20.92	30.0	29.9	0.700
400	0.8711	1.014	230.1	26.41	33.8	38.3	0.690
450	0.7740	1.021	250.7	32.39	37.3	47.2	0.686
500	0.6964	1.030	270.1	38.79	40.7	56.7	0.684
550	0.6329	1.040	288.4	45.57	43.9	66.7	0.683
600	0.5804	1.051	305.8	52.69	46.9	76.9	0.685
650	0.5356	1.063	322.5	60.21	49.7	87.3	0.690
700	0.4975	1.075	338.8	68.10	52.4	98.0	0.695
750	0.4643	1.087	354.6	76.37	54.9	109	0.702
800	0.4354	1.099	369.8	84.93	57.3	120	0.709
850	0.4097	1.110	384.3	93.80	59.6	131	0.716
900	0.3868	1.121	398.1	102.9	62.0	143	0.720
950	0.3666	1.131	411.3	112.2	64.3	155	0.723
1000	0.3482	1.141	424.4	121.9	66.7	168	0.726
1100	0.3166	1.159	449.0	141.8	71.5	195	0.728
1200	0.2902	1.175	473.0	162.9	76.3	224	0.728
1300	0.2679	1.189	496.0	185.1	82	238	0.719
1400	0.2488	1.207	530	213	91	303	0.703
1500	0.2322	1.230	557	240	100	350	0.685
1600	0.2177	1.248	584	268	106	390	0.688
1700	0.2049	1.267	611	298	113	435	0.685
1800	0.1935	1.286	637	329	120	482	0.683
1900	0.1833	1.307	663	362	128	534	0.677
2000	0.1741	1.337	689	396	137	589	0.672
2100	0.1658	1.372	715	431	147	646	0.667
2200	0.1582	1.417	740	468	160	714	0.655
2300	0.1513	1.478	766	506	175	783	0.647
2400	0.1448	1.558	792	547	196	869	0.630
2500	0.1389	1.665	818	589	222	960	0.613
3000	0.1135	2.726	955	841	486	1570	0.536
Ammonia (NH_3)							
300	0.6894	2.158	101.5	14.7	24.7	16.6	0.887
320	0.6448	2.170	109	16.9	27.2	19.4	0.870
340	0.6059	2.192	116.5	19.2	29.3	22.1	0.872
360	0.5716	2.221	124	21.7	31.6	24.9	0.872
380	0.5410	2.254	131	24.2	34.0	27.9	0.869

Table (A-2) : Instantaneous heat gain from occupants in units of watts .

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.

Table (A-3) : Minimum outside air requirements for mechanical ventilation .

Application	Maximum Occupancy Per 100 m²	Ventilation Air Requirements	
		L/s/Person	L/s/m²
Offices:			
Office space	7	10.0	2.5-10.0
Reception areas	60	8.0	3.5-7.5
Telecomm. Centers	60	10.0	—
Conference rooms	50	10.0	—
Public spaces:			
Corridors	—	—	0.25
Public restrooms	100	25.0	—
Locker and dressing rooms	50	7.5-17.5	5-2.5
Smoking lounge	70	30.0	—
Elevators:	—	7.5	5.00
Laundries:			
Commercial laundry	10	13.0	—
Commercial dry cleaner	30	15.0	—
Coin-operated laundries	20	8.0	—
Coin operated dry cleaner	20	8.0	—
Food and beverage services:			
Dining rooms	70	10.0	—
Cafeteria	100	10.0	—
Bars	100	15.0	—
Kitchens	20	8.0	—
Garages, service stations:			
Enclosed parking garage	—	5L/s/car	7.50
Auto repair rooms	—	—	7.50
Factories:	—	—	0.80
Retail stores:			
Basement and street stores	30	2.5-12.5	1.50
Upper floors	20	2.5-12.5	1.00
Storage rooms	15	2.5-12.5	0.75
Dressing rooms	—	3.5-12.5	1.00
Malls	20	2.5-5.0	1.00
Warehouses	5	2.5-5.0	0.25
Smoking lounge	70	30.0	—
Specialty shops:			
Barbers	25	8.0	—
Beauty saloons	25	13.0	—
Reducing saloons	20	8.0	—
Florist	8	8.0	—
Supermarkets	8	8.0	—
Hardware, drugs, fabrics	8	8.0	—
Pet shops	—	—	5.00
Furniture stores	—	—	1.50
Sports:			
Spectator areas	70-150	3.5-17.5	—
Bath, toilets[(2)]	—	10.0	—
Hotels and motels:			
Bedrooms	—	—	7.5-15 L/s/room
Living rooms	—	—	5-10 L/s/room
Bathes	—	—	15-25 L/s/room
Lobbies	30	2.5-7.5	—
Conference rooms	50	3.5-17.5	—
Assembly rooms	120	3.5-17.5	—
Dormitory sleeping areas	20	8.0	—
Gambling casinos	120	15.0	—

Table (A-4) : Overall heat transfer coefficient for windows $W/m^2.°C$

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

Table (A-5) : Overall heat transfer coefficients for wood and metal doors, $W/m^2.°C$

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

Table (A-6) : Values of infiltration air coefficient k , 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

Table (A-7) : Values of the factor S_1

№	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

Table (A-8) : Values of the factor S_2

Class (1) Locations having very high and close obstacles such as capital cities, down town of large cities, etc.

Class (2) Locations having numerous and close obstacles such as small cities, suburbs of large cities, etc.

Class (3) Locations having obstacles whose height less than 10 m such as airports, villages, etc.

Class (4) Locations with obstacles whose height is less than 1.5 m such as desert areas, plains without trees, etc.

Catagory A Structures and buildings whose maximum horizontal or vertical dimension is more than 50 m.

Catagory B Structures and buildings whose maximum dimension (horizontal or vertical) is less than 50 m.

Catagory C Individual structures.

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

Table (A-9) : 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

Table (A-10) : 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

Table (A-11) : 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

Table (A-12) : Solar heat gain factor (SHG) for sunlit glass, W/m^2, for altitude 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

Table (A-13) : 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	—	—

Table (A-14) : 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

Note: Values of the cooling load factors (CLF) of Tables 9–10 and 9–11 for the hours 18:00 to 24:00 may be obtained from McQuiston and Parker, 1994, "*Heating, Ventilating, and Air Conditioning*", 4th ed., Wiley.

Table (A-15) : 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

Table (A-16) : Heat gain rate from miscellaneous appliances, W .

Appliances	Without Hood			With Hood
	Sensible	Latent	Total	All Sensible
Hair dryers (Blower type)	675	120	795	—
Hair dryers (Helmet type)	550	100	650	—
Coffee brewer (electrical)	225	65	290	95
Coffee brewer (gas)	490	210	700	415
Water heater	1,130	335	1,465	—
Coffee urn (electrical)	1,075	350	1,425	440
Coffee urn (gas)	1,460	625	2,085	415
Deep fat fryer (electrical)	820	1,930	2,750	730
Deep fat fryer (gas)	2,080	2,080	4,160	830
Toaster	1,055	705	1,760	440
Domestic gas oven	2,430	1200	3,630	—
Roasting oven	500	320	820	—
Food warmer (gas)	1,550	400	1,950	400
Egg boiler	335	220	555	—
Frying griddle	13,600	7,200	20,800	4,150
Hotplate	1,550	1,060	2,610	780
Neon sign, per meter length	56	—	56	—
Sterilizer	190	350	540	—
Laboratory burner	470	120	590	—
Small copy machine	1,760	—	1,760	—
Large copy machine	3,515	—	3,515	—
Motors:				
400–2,000 W	1,100	—	1,100	—
2,000–15,000 W	2,430	—	2,430	—

Table (A-17) : Cooling load factor $(CLF)_{lt}$, for lights .

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

Table (A-18) : Diversity factor for selected applications .

Application	Diversity Factor	
	Lights	People
Peripheral aras of offices with glazing area of 20%-50%	0.70-0.85	0.7-0.8
Core areas of offices and peripheral areas with less than 20% glazing	0.90-1.00	0.7-0.8
Apartments and hotel bedrooms	0.30-0.50	0.4-0.6
Public rooms in hotels	0.90-1.00	0.4-0.6
Department stores and supermarkets	0.90-1.00	0.8-1.0

Table (A-19) : Cooling load factor due to occupants $(CLF)_{occ}$, for sensible heat gain .

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

Table (A-20) : Inside film resistance R_i

Element	Heat Direction	Material Type	R_i $m^2 \cdot {}^oC/W$
Walls	Horizontal	Construction materials	0.12
		Metals	0.31
Ceilings and floors	Upward	Construction materials	0.10
		Metals	0.21
	Downward	Construction materials	0.15

Table (A-21) : Outside film resistance R_o

Wind Speed		Less than 0.5 m/s	0.5 - 5.0 m/s	More than 5.0 m/s
Element	Material Type	Outside Resistance R_o , $m^2 \cdot °C/W$		
Walls	Construction materials	0.08	0.06	0.03
	Metals	0.10	0.07	0.03
Ceilings	Construction materials	0.07	0.04	0.02
	Metals	0.09	0.05	0.02
Exposed floors	Construction materials	0.09	—	—

Table (A-22) : Overall heat transfer coefficient for floors below grate $W/m^2.°C$

Depth Below Grade, m	Narrowest width of the house, m.			
	6.1	7.3	8.5	9.8
1.22	0.198	0.182	0.153	0.136
1.52	0.182	0.165	0.148	0.131
1.83	0.170	0.153	0.142	0.125
2.13	0.165	0.148	0.131	0.119

Table (A-23) : The fixture unit & pipe for every fixture type.

DEMAND LOAD OF FIXTURES

Fixture	Occupancy	Type of supply control	Load values assigned, water supply fixture units		
			Cold	Hot	Total
Water closet	Public	Flush valve	10		10
Water closet	Public	Flush tank	5		5
Urinal	Public	1" (25.4 mm) flush valve	10		10
Urinal	Public	¾" (19 mm) flush valve	5		5
Urinal	Public	Flush tank	3		3
Lavatory	Public	Faucet	1.5	1.5	2
Bathtub	Public	Faucet	3	3	4
Showerhead	Public	Mixing valve	3	3	4
Service sink	Offices, etc.	Faucet	2.25	2.25	3
Kitchen sink	Hotel, restaurant	Faucet	3	3	4
Drinking fountain	Offices, etc.	⅜" (9.52 mm) valve	0.25		0.25
Water closet	Private	Flush valve	6		6
Water closet	Private	Flush tank	3		3
Lavatory	Private	Faucet	0.75	0.75	1
Bathtub	Private	Faucet	1.5	1.5	2
Shower stall	Private	Mixing valve	1.5	1.5	2
Kitchen sink	Private	Faucet	1.5	1.5	2
Laundry trays (1 to 3)	Private	Faucet	2.25	2.25	3
Combination fixture	Private	Faucet	2.25	2.25	3
Dishwashing machine	Private	Automatic		1	1
Laundry machine [8 lb (3.6 kg)]	Private	Automatic	1.5	1.5	2
Laundry machine [8 lb (3.6 kg)]	Public or general	Automatic	2.25	2.25	3
Laundry machine [16 lb (7.3 kg)]	Public or general	Automatic	3	3	4

Note: For fixtures not listed, loads should be assumed by comparing the fixture with one listed using water in similar quantities and at similar rates. The assigned loads for fixtures with both hot and cold water supplies are given for separate hot and cold water loads and for total load, the separate hot and cold water loads being three-fourths of the total load for the fixture in each case.

Table (A-24) : Estimating demand .

Supply systems predominantly for flush tanks			Supply systems predominantly for Flushometer valves		
Load	Demand		Load	Demand	
Water supply fixture units (WSFU)	gpm	L/s	Water supply fixture units (WSFU)	gpm	L/s
1	3.0	0.19			
2	5.0	0.32			
3	6.5	0.41			
4	8.0	0.51			
5	9.4	0.59	5	15.0	0.95
6	10.7	0.68	6	17.4	1.10
7	11.8	0.74	7	19.8	1.25
8	12.8	0.81	8	22.2	1.40
9	13.7	0.86	9	24.6	1.55
10	14.6	0.92	10	27.0	1.70
12	16.0	1.01	12	28.6	1.80
14	17.0	1.07	14	30.2	1.91
16	18.0	1.14	16	31.8	2.01
18	18.8	1.19	18	33.4	2.11
20	19.6	1.24	20	35.0	2.21

Table (A-25) : Sizing table based on velocity limitation .

Table 6-3*b*

SIZING TABLE BASED ON VELOCITY LIMITATION—SI UNITS

Galvanized Iron and Steel Pipe, Standard Pipe Size

		Velocity = 1.2 m/s				Velocity = 2.4 m/s			
Nominal size, mm	Actual ID, mm	Flow *q*, L/s	Load WSFU (col. A)*	Load WSFU (col. B)†	Friction *p*, Pa/m‡	Flow *q*, L/s	Load WSFU (col. A)*	Load WSFU (col. B)†	Friction *p*, Pa/m‡
12.7	15.8	0.23	1.5		172.3	0.47	3.7		651.5
19.0	20.9	0.42	3.0		126.1	0.84	8.4		472.8
25.4	26.6	0.68	6.1		96.7	1.36	25.3	7.7	361.5
31.8	35.1	1.17	17.5	6.0	71.5	2.34	77.3	23.7	269.0
38.1	40.9	1.60	37.0	9.3	60.9	3.20	132.3	52.0	227.0
50.8	52.5	2.63	93.0	29.8	46.2	5.27	293.0	171.6	176.5
63.5	62.7	3.77	174.0	75.6	37.8	7.54	477.0	361.0	142.9
76.2	77.7	5.80	335.0	209.0	29.4	11.60	842.0	806.0	113.5
102.0	102.3	10.00	688.0	615.0	23.1	20.01	1930.0	1930.0	86.2

* Col. A applies to piping which does not supply flush valves.

† Col. B applies to piping which supplies flush valves.

‡ Friction loss *p*, corresponding to flow rate *q*, for piping having fairly smooth surface condition after extended service applying the formula

$$q = 4.57\, p^{0.546}\, d^{2.64}$$

Table (A-26) :Minimum size of fixture supply pipe .

Table 6-15

MINIMUM SIZE OF FIXTURE SUPPLY PIPES

Fixture or device	Size in	Size mm
Bathtub	½	12.7
Combination sink and laundry tray	½	12.7
Drinking fountain	⅜	9.5
Dishwashing machine (domestic)	½	12.7
Kitchen sink (domestic)	½	12.7
Kitchen sink (commercial)	¾	19.0
Lavatory	⅜	9.5
Laundry tray (1, 2, or 3 compartments)	½	12.7
Shower (single head)	½	12.7
Sink (service, slop)	½	12.7
Sink (flushing rim)	¾	19.0
Urinal [1" (25.4 mm) flush valve]	1	25.4
Urinal [¾" (19.0 mm) flush valve]	¾	19.0
Urinal (flush tank)	½	12.7
Water closet (flush tank)	⅜	9.5
Water closet (flush valve)	1	25.4
Hose bib	½	12.7
Wall hydrant or sill cock	½	12.7

Note: For fixtures not listed in the above table, the minimum size of fixture supply pipes shall be the same as given in the table for comparable fixtures.

Table (A-27) : Friction head loss for water in commercial plastic pipe (schedule 40) .

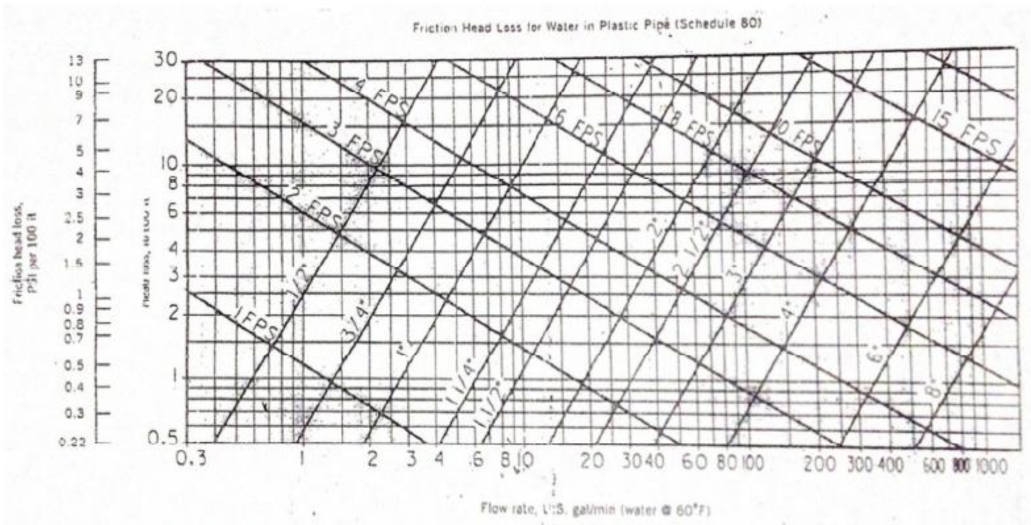


Figure A(4.1) Chart of friction head loss in Schedule 80 plastic pipe for water at 60°F, in feet of water and psi per 100 ft of equivalent pipe length. Pipe sizes are nominal. (Reprinted by permission of the American Society of Heating, Refrigerating and Air-Conditioning Engineers, Atlanta, Georgia,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

Table (A-28) : Friction head loss for water in commercial steel pipe .

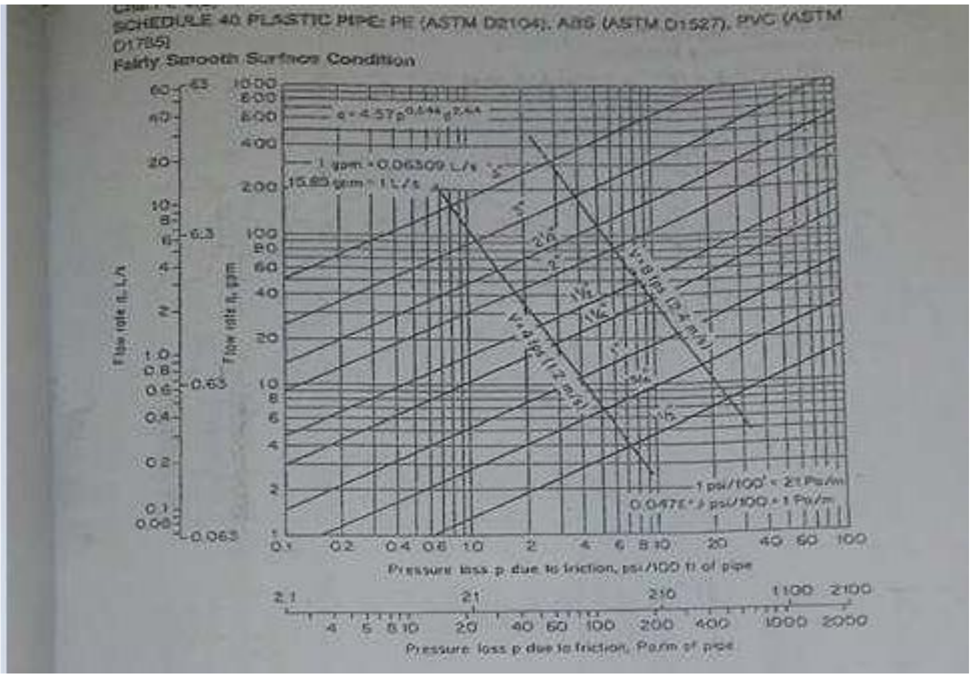


Table (A-29) :Demand at individual water out let.

DEMAND AT INDIVIDUAL WATER OUTLETS

Type of outlet	Demand gpm	Demand L/s
Ordinary lavatory faucet	2.0	0.126
Self-closing lavatory faucet	2.5	0.158
Sink faucet, ⅜" (9.52 mm) or ½" (12.7 mm)	4.5	0.284
Sink faucet, ¾" (19 mm)	6.0	0.378
Bath faucet, ½" (12.7 mm)	5.0	0.315
Shower head, ½" (12.7 mm)	5.0	0.315
Laundry faucet, ½" (12.7 mm)	5.0	0.315
Ball cock in water closet flush tank	3.0	0.189
1" (25.4 mm) flush valve [25 psi (172 kPa) flow pressure]	35.0	2.210
1" (25.4 mm) flush valve [15 psi (103 kPa) flow pressure]	27.0	1.703
¾" (19.0 mm) flush valve [15 psi (103 kPa) flow pressure]	15.0	0.946
Drinking fountain jet	0.75	0.047
Dishwashing machine (domestic)	4.0	0.252
Laundry machine [8 lb (3.6 kg) or 16 lb (7.3 kg)]	4.0	0.252
Aspirator (operating room or laboratory)	2.5	0.158
Hose bib or sill cock, ½" (12.7 mm)	5.0	0.315

Table (A-30) : Pump characteristic curve .

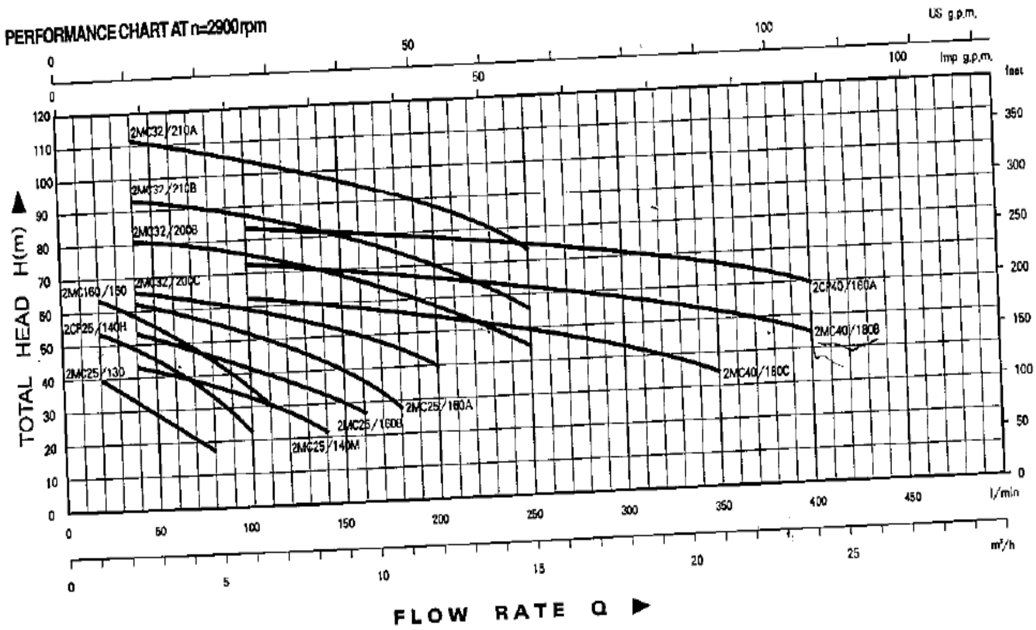


Table (A-31) :Sanitary derange fixture unit values .

SANITARY DRAINAGE FIXTURE UNIT VALUES

Fixture or group	Trap size in	Trap size mm	Fixture units
Residential:			
Automatic clothes washer, domestic	2	50.0	3
Bathroom group consisting of a water closet, lavatory, and bathtub or shower stall:			
Flushometer valve closet			8
Tank-type closet			6
Bathtub (with or without overhead shower)	1½	37.5	2
Bidet	1¼	31.3	1
Dishwasher, domestic	1½	37.5	2
Floor drain	2	50.0	3
Floor drain	3	75.0	5
Floor drain	4	100.0	6
Food waste grinder, domestic	1½	37.5	2
Kitchen sink, domestic	1½	37.5	2
Kitchen sink, domestic, with dishwasher	1½	37.5	2
Kitchen sink, domestic, with food waste grinder	1½	37.5	2
Kitchen sink, domestic, with dishwasher and food waste grinder	2	50.0	2
Kitchen sink and wash (laundry) tray with single 1½-in (37.5-mm) trap	1½	37.5	2
Kitchen sink and wash (laundry) tray with separate 1½-in (37.5-mm) traps	1½	37.5	3
Kitchen sink and wash (laundry) tray with food waste grinder unit	2	50.0	4
Lavatory, common	1¼	31.3	1
Laundry tray (1 or 2 compartments)	1½	37.5	2
Shower stall, single head	2	50.0	2
Sink, bar, private	1½	37.5	1
Water closet, tank-type, trap arm only	3	75.0	4
Public toilet rooms:			
Urinal, pedestal, trap arm only	3	75.0	6
Urinal, pedestal, siphon jet blowout	3	75.0	6
Urinal, stall, washout	2	50.0	4
Urinal, wall [2-in (50-mm) min. waste]	1½	37.5	4
Water closet, Flushometer valve, trap arm only	3	75.0	6

Table (A-32) : Maximum permissible loads for sanitary derange piping in terms of fixture unit .

MAXIMUM PERMISSIBLE LOADS FOR SANITARY DRAINAGE PIPING
In Terms of Fixture Units

Pipe diameter		Any horizontal fixture branch	One stack of 3 stories or less in height	Stacks more than 3 stories in height		Building drain, and building drain branches from stacks — Slope, in/ft (mm/m)			
in	mm			Total for stack	Total at one story	1/16 (5.2)	⅛ (10.4)	¼ (20.8)	½ (41.6
1½*	37.5	3	4	8	2	np	np	np	np
2*	50	6	10	24	6	np	np	21	26
2½*	62.5	12	20	42	9	np	np	24	31
3	75	20†	48‡	72‡	20†	np	np†	42†	50
4	100	160	240	500	90	np	180	216	250
5	125	360	540	1100	200	np	390	480	575
6	150		960	1900	350	np	700	840	1000
8	200			3600	600	1400	1600	1920	2300
10	250			5600	1000	2500	2900	3500	4200
12	300					3900	4600	5600	6700

Table (A-33) : Horizontal fixture branches and stacks .

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

Table (A-34) :Pressure drop ($\frac{\Delta P}{EL}$), for low flow rates of air in galvanized steel duct, based on round duct diameter.

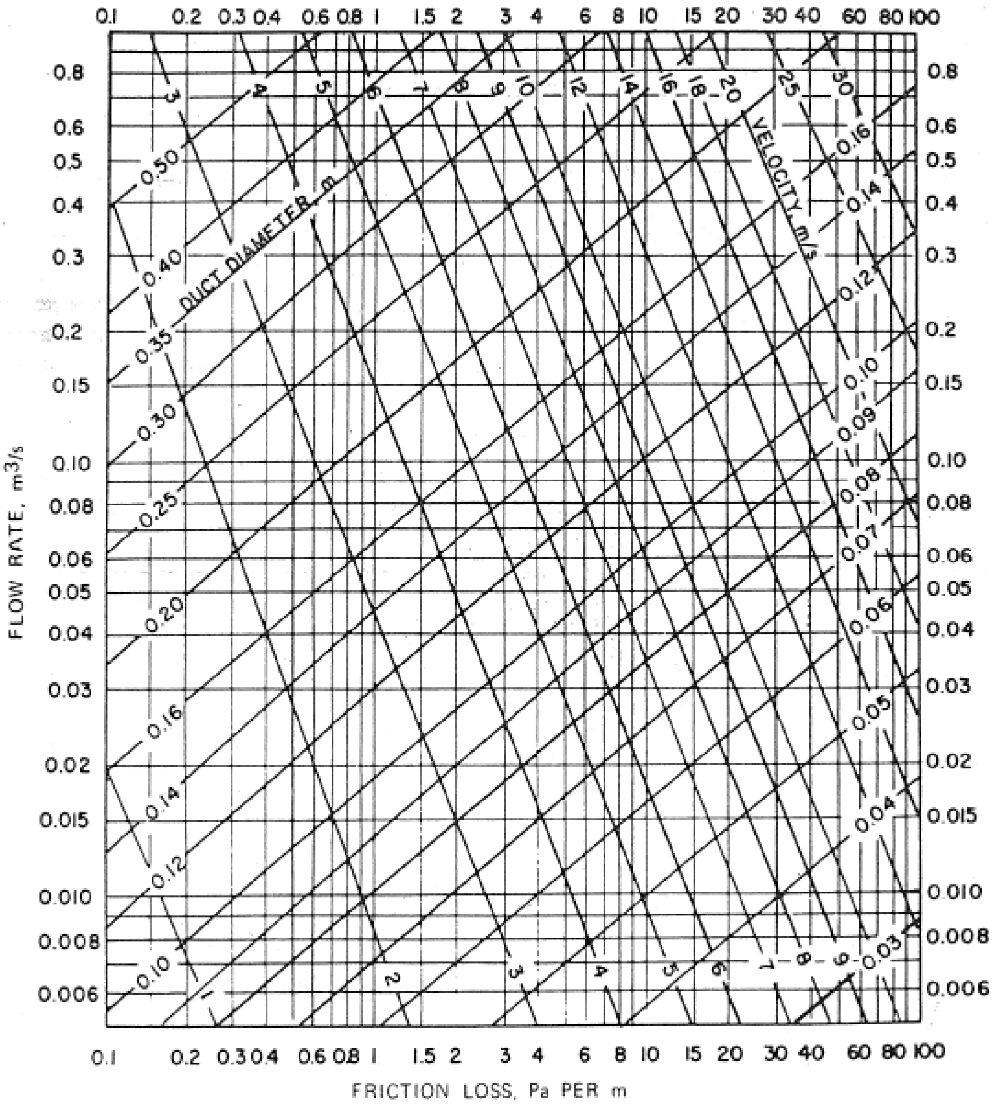


Table (A-34) : Range of change air .

TYPICAL AIR CHANGES PER HOUR TABLE	
Offices	
Business Offices	6-8
Lunch and Break Rooms	7-8
Conference Rooms	8-12
Medical Procedure Offices	9-10
Copy Rooms	10-12
Main Computer Rooms	10-14
Smoking Area	13-15
Restaurants	
Dining Area	8-10
Food Staging	10-12
Kitchens	14-18
Bars	15-20
Public Buildings	
Hallways	6-8
Retail Stores	6-10
Foyers	8-10
Churches	8-12
Restrooms	10-12
Auditoriums	12-14
Smoking Rooms	15-20

APPENDIX B

DVMS LINE UP _Outdoor Unit

DVM S HP Premium, Compact Modulaion																									
			SINGLE										MODULE												
IMAGE	MODEL	CAPACITY	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52
	AM080JXVHGH/EU	8	1																						
	AM100JXVHGH/EU	10		1																					
	AM120JXVHGH/EU	12			1										1	1									
	AM140KXVGGH/EU	14				1											1				1				
	AM160KXVGGH/EU	16					1											1				1			
	AM180KXVGGH/EU	18						1											1				1		
	AM200KXVGGH/EU	20							1						1					1				1	
	AM220KXVGGH/EU	22								1						1	1	1	1	1					1
	AM240KXVGGH/EU	24									1														
	AM260KXVGGH/EU	26										1													
	AM280KXVGGH/EU	28											1												
	AM300KXVAGH/EU	30												1							1	1	1	1	1

DVM S LINE UP & FEATURE _Indoor Unit

CASSETTE

MODEL		4Way S	4Way S (600x600)	Slim 1Way	1Way	2Way	360Cassette
CAPACITY (kW)	1.7		●		●		
	2.2		●	●	●		
	2.8		●	●			
	3.6		●	●			
	4.5	●	●				●
	5.6	●	●		●	●	●
	6.0		●				
	7.1	●			●	●	●
	9.0	●					●
	10.0	●					●
	11.2	●					●
	12.8	●					●
	14.0	●					●
FEATURES	Powerful Airflow	●	●	●	●		●
	Ceiling Dust Prevention	●	●	●	●		●
	Fresh Air Intake	●	●				●
	High Lift-up Drain Pump	●	●	●	●	●	●
	Sub Duct	●	●				

DUCT

MODEL		HSP	MSP	Slim	Duct S	Duct S(AC6000)
CAPACITY	1.7			●		
	2.2			●		
	2.8		●	●		
	3.6		●	●	●	
	4.5		●	●	●	
	5.6		●	●	●	
	7.1		●	●	●	
	9.0		●	●	●	
	11.2	●	●	●	●	
	12.8	●	●	●	●	
	14.0	●	●	●	●	
	18.0					●
	20.0					●
	22.0	●				
	28.0	●				
FEATURES	Pre Filter	●	●	●	●	●
	Easy Filter Cleaning	●	●	●	●	●
	High Lift-up Drain Pump (Optional)	●	●	●	●	●
	Smart Pressure Control	●	●	●	●	●

DVM S LINE UP _Outdoor Unit

DVM S HP Premium

DIGITAL VARIABLE MULTI

- DI(Dual Digital Inverter)
- High Efficiency
- Smart Management
- Flexible Installation
- Comfortable & Reliable Operation
- New Communication Protocol

DVM S HP - Compact

Model Code			DVM S HP	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Power Supply			Φ,#,V,Hz	3,4,380~415,50	3,4,380~415,50	3,4,380~415,50	3,4,380~415,50	3,4,380~415,50	3,4,380~415,50
Mode			-	HEAT PUMP	HEAT PUMP	HEAT PUMP	HEAT PUMP	HEAT PUMP	HEAT PUMP
Performance	HP		HP	8.00	10.00	12.00	14.00	16.00	18.00
	Capacity (Nominal)	Cooling	kW	22.40	28.00	33.60	40.00	45.00	50.40
			Btu/h	76,400	95,500	114,600	136,500	153,500	172,000
		Heating	kW	25.20	31.50	37.80	45.00	50.40	56.70
			Btu/h	86,000	107,500	129,000	153,500	172,000	193,500
Power	Power Input (Nominal)	Cooling[1]	kW	4.58	6.20	7.57	8.89	10.93	10.68
		Heating[2]		4.58	5.80	7.56	9.62	10.75	10.82
	Current Input (Nominal)	Cooling[1]	A	7.40	10.00	12.10	14.30	17.50	17.10
		Heating[2]		7.40	9.40	12.10	15.40	17.20	16.90
	MCA			22.50 (MCA)	26.00 (MCA)	31.00 (MCA)	35.00 (MCA)	35.00 (MCA)	38.00 (MCA)
	MFA		A	30.00	40.00	40.00	45.00	45.00	50.00
COP	Nominal Cooling[1]		-	4.89	4.50	4.44	4.50	4.12	4.72
	Nominal Heating[2]		-	5.50	5.39	5.00	4.68	4.69	5.30
Compressor	Type		-	DC Scroll x 1	DC Scroll x 1	DC Scroll x 1	DC Scroll x 1	DC Scroll x 1	DC Scroll x 2
	Output		kW x n	5.10	(6.30)	6.30	6.50	7.81	6.30x2
	Model Name		-	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Oil	Type	-	PVE	PVE	PVE	PVE	PVE	PVE
		Initial Charge	cc	1100	1100	1100	1100	1400	2200
Fan	Type		-	Propeller	Propeller	Propeller	Propeller	Propeller	Propeller
	Output x n		W	830.0 x 1	830.0 x 1	830.0 x 1	620.0 x 2	620.0 x 2	620.0 x 2
	Air Flow Rate		CMM	175	175	220	255	255	290
			l/s	2,916.67	2,916.67	3,666.67	4,250.00	4,250.00	4,833.33
	External Static Pressure	Max.	mmAq	8.00	8.00	8.00	8.00	8.00	8.00
			Pa	78.45	78.45	78.45	78.45	78.45	78.45
Piping Connections	Liquid Pipe		Φ, mm	9.52	9.52	12.70	12.70	12.70	15.88
			Φ, inch	3/8"	3/8"	1/2"	1/2"	1/2"	5/8"
	Gas Pipe		Φ, mm	19.05	22.22	28.58	28.58	28.58	28.58
			Φ, inch	3/4"	7/8"	1 1/8"	1 1/8"	1 1/8"	1 1/8"
	Discharge Gas Pipe		Φ, mm	-	-	-	-	-	-
			Φ, inch	-	-	-	-	-	-
	Oil Equalizing Pipe		Φ, mm	-	-	-	-	-	-
			Φ, inch	-	-	-	-	-	-
	Installation Limitation	Max. Length	m	300	300	300	300	300	300
		Max. Height	m	110.0	110.0	110.0	110.0	110.0	110.0
Field Wiring	Power Source Wire		mm²	-	-	-	-	-	-
	Transmission Cable		mm²	0.75~1.5	0.75~1.5	0.75~1.5	0.75~1.5	0.75~1.5	0.75~1.5
Refrigerant	Type		-	R410A	R410A	R410A	R410A	R410A	R410A
	Factory Charging		kg	6.00	6.00	6.00	8.40	8.40	8.40
Sound[3]	Sound Pressure		dB(A)	57.0	58.0	61.0	61.0	63.0	65.0
	Sound Power		dB(A)	77.0	79.0	81.0	81.0	83.0	85.0
External Dimension	Net Weight		kg	201.0	201.0	201.0	241.0	255.0	285.0
	Shipping Weight		kg	217.0	217.0	217.0	261.0	275.0	305.0
	Net Dimensions (WxHxD)		mm	880 x 1,695 x 765	880 x 1,695 x 765	880 x 1,695 x 765	1,295 x 1,695 x 765	1,295 x 1,695 x 765	1,295 x 1,695 x 765
	Shipping Dimensions (WxHxD)		mm	940 x 1,887 x 832	940 x 1,887 x 832	940 x 1,887 x 832	1,360 x 1,887 x 832	1,360 x 1,887 x 832	1,360 x 1,887 x 832
Operating Temp. Range	Cooling		°C	-5.0~48.0	-5.0~48.0	-5.0~48.0	-5.0~48.0	-5.0~48.0	-5.0~48.0
	Heating		°C	-20.0~24.0	-20.0~24.0	-20.0~24.0	-20.0~24.0	-20.0~24.0	-20.0~24.0

MSP Duct

- Narrow Width
- Strong and Large Coverage Area
- Silent Operation with the Static Pressure Control
- Easy to Maintain
- New Communication Protocol

MSP Duct

Model Code				AM022FNMDEH	AM028FNMDEH	AM036FNMDEH	AM045FNMDEH	AM056FNMDEH	AM071FNMDEH	AM090FNMDEH	AM112FNMDEH
Power Supply			Ø, #, V, Hz	1,2,220-240,50	1,2,220-240,50	1,2,220-240,50	1,2,220-240,50	1,2,220-240,50	1,2,220-240,50	1,2,220-240,50	1,2,220-240,50
Mode			-	HP/HR	HP/HR	HP/HR	HP/HR	HP/HR	HP/HR	HP/HR	HP/HR
Performance	Capacity (Nominal)	Cooling	kW	2.20	2.80	3.60	4.50	5.60	7.10	9.00	11.20
			Btu/h	7,500	9,600	12,300	15,400	19,100	24,200	30,700	38,200
		Heating	kW	2.50	3.20	4.00	5.00	6.30	8.00	10.00	12.50
			Btu/h	8,500	10,900	13,600	17,100	21,500	27,300	34,100	42,700
Power	Power Input (Nominal)	Cooling	W	80.00	80.00	85.00	125.00	130.00	190.00	240.00	260.00
		Heating	W	80.00	80.00	85.00	125.00	130.00	190.00	240.00	260.00
	Current Input (Nominal)	Cooling	A	0.40	0.40	0.55	1.15	1.10	1.25	1.30	1.17
		Heating	A	0.40	0.40	0.55	1.15	1.10	1.25	1.30	1.17
Fan	Motor	Type	-	Sirocco Fan	Sirocco Fan	Sirocco Fan	Sirocco Fan	Sirocco Fan	Sirocco Fan	Sirocco Fan	Sirocco Fan
		Output x n	W	69 x 1	69 x 1	112 x 1	219 x 1	124 x 1	124 x 1	130 x 1	130 x 1
	Air Flow Rate	H/M/L (UL)	CMM	8.50/7.50/6.30	10.00/9.20/7.50	12.00/10.20/8.80	14.00/12.00/10.50	14.50/13.00/11.50	18.50/17.00/15.50	19.50/18.00/16.50	27.00/25.00/23.00
			l/s	141.67/125.00/105.00	166.67/153.33/125.00	200.00/170.00/146.67	233.33/200.00/175.00	241.67/216.67/191.67	308.33/283.33/258.33	325.00/300.00/275.00	450.00/416.67/383.33
	External Pressure	Min / Std / Max	mmAq	0.00/2.00/6.00	0.00/2.00/6.00	0.00/2.00/6.00	0.00/4.00/8.00	0.00/4.00/8.00	0.00/4.00/8.00	4.00/6.00/8.00	4.00/8.00/12.00
			Pa	0.00/19.61/58.84	0.00/19.61/58.84	0.00/19.61/58.84	0.00/39.23/78.45	0.00/39.23/78.45	0.00/39.23/78.45	39.23/58.84/78.45	39.23/78.45/117.68
Piping Connections	Liquid Pipe		Ø, mm	6.35	6.35	6.35	6.35	6.35	9.52	9.52	9.52
			Ø, inch	1/4"	1/4"	1/4"	1/4"	1/4"	3/8"	3/8"	3/8"
	Gas Pipe		Ø, mm	12.70	12.70	12.70	12.70	12.70	15.88	15.88	15.88
			Ø, inch	1/2"	1/2"	1/2"	1/2"	1/2"	5/8"	5/8"	5/8"
	Drain Pipe		Ø, mm	VP25 (OD 32, ID 25)	VP25 (OD 32, ID 25)	VP25 (OD 32, ID 25)	VP25 (OD 32, ID 25)	VP25 (OD 32, ID 25)	VP25 (OD 32, ID 25)	VP25 (OD 32, ID 25)	VP25 (OD 32, ID 25)
Field Wiring	Power Source Wire		mm²	1.5~2.5	1.5~2.5	1.5~2.5	1.5~2.5	1.5~2.5	1.5~2.5	1.5~2.5	1.5~2.5
	Transmission Cable		mm²	0.75~1.50	0.75~1.50	0.75~1.50	0.75~1.50	0.75~1.50	0.75~1.50	0.75~1.50	0.75~1.50
Refrigerant	Type		-	R410A	R410A	R410A	R410A	R410A	R410A	R410A	R410A
	Control Method		-	EEV INCLUDED	EEV INCLUDED	EEV INCLUDED	EEV INCLUDED	EEV INCLUDED	EEV INCLUDED	EEV INCLUDED	EEV INCLUDED
Sound	Sound Pressure	High / Mid / Low	dB(A)	23.0/21.0/19.0	24.0/22.0/19.0	29.0/27.0/24.0	32.0/30.0/28.0	35.0/33.0/31.0	39.0/35.0/31.0	40.0/37.0/34.0	41.0/40.0/38.0
	Sound Power	Cooling	dB(A)	47.0	48.0	60.0	63.0	66.0	71.0	71.0	72.0
Dimensions	Net Weight		kg	23.50	23.50	23.50	29.00	29.00	29.00	34.00	36.00
	Shipping Weight		kg	28.00	28.00	28.00	33.00	33.00	33.00	39.00	42.00
	Net Dimensions (WxHxD)		mm	900 x 199 x 600	900 x 199 x 600	900 x 199 x 600	900 x 260 x 480	900 x 260 x 480	900 x 260 x 480	1150 x 260 x 480	1150 x 320 x 480
	Shipping Dimensions (WxHxD)		mm	1150 x 280 x 710	1150 x 280 x 710	1150 x 280 x 710	1170 x 340 x 595	1170 x 340 x 595	1170 x 340 x 595	1420 x 340 x 595	1420 x 400 x 595
Panel Size	Panel model		-	-	-	-	-	-	-	-	-
	Panel Net Weight		kg	-	-	-	-	-	-	-	-
	Shipping Weight		kg	-	-	-	-	-	-	-	-
	Net Dimensions (WxHxD)		mm	-	-	-	-	-	-	-	-
	Shipping Dimensions (WxHxD)		mm	-	-	-	-	-	-	-	-
Additional Accessories	Drain pump	Drain pump	- / Model name	MDP-E075SEE3D	MDP-E075SEE3D	MDP-E075SEE3D	MDP-M075SGU3D	MDP-M075SGU3D	MDP-M075SGU3D	MDP-M075SGU1D	MDP-M075SGU1D
		Max. lifting Height / Displacement	mm / liter/h	-	-	-	-	-	-	-	-
	Air Filter		-	-	-	-	-	-	-	-	-

* Product Specifications in the Publication can be changed without a prior notice. Because there is always an ongoing improvement on our product.
* These products contain R410A which is fluorinated greenhouse gas.

360 Cassette

- Cold Draft Free
- Perfect even cooling
- Stylish design
- New communication Protocol

360 Cassette

Type				360 CST (Square)	360 CST (Circle)	360 CST (Square)	360 CST (Circle)	360 CST (Square)	360 CST (Circle)
Model Code				AM045KN4DEH	AM045KN4DEH	AM056KN4DEH	AM056KN4DEH	AM071KN4DEH	AM071KN4DEH
Power Supply			Φ, #, V, Hz	1,2,220-240,50	1,2,220-240,50	1,2,220-240,50	1,2,220-240,50	1,2,220-240,50	1,2,220-240,50
Mode			-	HP/HR	HP/HR	HP/HR	HP/HR	HP/HR	HP/HR
Performance	Capacity (Nominal)	Cooling	kW	4.50	4.50	5.60	5.60	7.10	7.10
			Btu/h	15,400	15,400	19,100	19,100	24,200	24,200
		Heating	kW	5.00	5.00	6.30	6.30	8.00	8.00
			Btu/h	17,100	17,100	21,500	21,500	27,300	27,300
Power	Power Input (Nominal)	Cooling	W	26.00	26.00	30.00	30.00	34.00	34.00
		Heating		26.00	26.00	30.00	30.00	34.00	34.00
	Current Input (Nominal)	Cooling	A	0.18	0.18	0.21	0.21	0.25	0.25
		Heating		0.18	0.18	0.21	0.21	0.25	0.25
Fan	Type		mm²	Turbo Fan	Turbo Fan	Turbo Fan	Turbo Fan	Turbo Fan	Turbo Fan
	Motor	Output x n	W	65 x 1	65 x 1	65 x 1	65 x 1	65 x 1	65 x 1
	Air Flow Rate	H/M/L (UL)	CMM	14.50/13.50/12.50	14.50/13.50/12.50	16.00/14.50/13.50	16.00/14.50/13.50	18.00/16.00/14.00	18.00/16.00/14.00
			l/s	241.67/225.00/208.33	241.67/225.00/208.33	266.67/241.67/225.00	266.67/241.67/225.00	300.00/266.67/233.33	300.00/266.67/233.33
	External Pressure	Min / Std / Max	mmAq	-	-	-	-	-	-
			Pa	-	-	-	-	-	-
Piping Connections	Liquid Pipe		Φ, mm	6.35	6.35	6.35	6.35	9.52	9.52
			Φ, inch	1/4"	1/4"	1/4"	1/4"	3/8"	3/8"
	Gas Pipe		Φ, mm	12.70	12.70	12.70	12.70	15.88	15.88
			Φ, inch	1/2"	1/2"	1/2"	1/2"	5/8"	5/8"
	Drain Pipe		Φ, mm	VP25 (OD 32, ID 25)	VP25 (OD 32, ID 25)	VP25 (OD 32, ID 25)	VP25 (OD 32, ID 25)	VP25 (OD 32, ID 25)	VP25 (OD 32, ID 25)
Field Wiring	Power Source Wire		mm²	1.5~2.5	1.5~2.5	1.5~2.5	1.5~2.5	1.5~2.5	1.5~2.5
	Transmission Cable		mm²	0.75~1.5	0.75~1.5	0.75~1.5	0.75~1.5	0.75~1.5	0.75~1.5
Refrigerant	Type		-	R410A	R410A	R410A	R410A	R410A	R410A
	Control Method		-	EEV INCLUDED	EEV INCLUDED	EEV INCLUDED	EEV INCLUDED	EEV INCLUDED	EEV INCLUDED
Sound	Sound Pressure	High / Mid / Low	dB(A)	33.0/31.0/29.0	33.0/31.0/29.0	34.0/32.0/29.0	34.0/32.0/29.0	36.0/33.0/30.0	36.0/33.0/30.0
	Sound Power	Cooling	dB(A)	50.0	50.0	51.0	51.0	53.0	53.0
Dimensions	Net Weight		kg	21.00	21.00	21.00	21.00	21.00	21.00
	Shipping Weight		kg	25.00	25.00	25.00	25.00	25.00	25.00
	Net Dimensions (WxHxD)		mm	947 x 281 x 947	947 x 281 x 947	947 x 281 x 947	947 x 281 x 947	947 x 281 x 947	947 x 281 x 947
	Shipping Dimensions (WxHxD)		mm	990 x 330 x 990	990 x 330 x 990	990 x 330 x 990	990 x 330 x 990	990 x 330 x 990	990 x 330 x 990
Panel Size	Panel model		-	PC4NUDMAN	PC4NUNMAN	PC4NUDMAN	PC4NUNMAN	PC4NUDMAN	PC4NUNMAN
	Panel Net Weight		kg	3.60	2.70	3.60	2.70	3.60	2.70
	Shipping Weight		kg	6.00	5.10	6.00	5.10	6.00	5.10
	Net Dimensions (WxHxD)		mm	1000 x 66 x 1000	1050 x 94 x 1050	1000 x 66 x 1000	1050 x 94 x 1050	1000 x 66 x 1000	1050 x 94 x 1050
	Shipping Dimensions (WxHxD)		mm	1093 x 85 x 1083	1093 x 85 x 1083	1093 x 85 x 1083	1093 x 85 x 1083	1093 x 85 x 1083	1093 x 85 x 1083
Additional Accessories	Drain pump	Drain pump	- / Model name	-	-	-	-	-	-
		Max. lifting Height / Displacement	mm / liter/h	-	-	-	-	-	-
	Air Filter		-	-	-	-	-	-	-

* Product Specifications in the Publication can be changed without a prior notice. Because there is always an ongoing improvement on our product.
* These products contain R410A which is fluorinated greenhouse gas.

SPECIFICATIONS

INDOOR UNIT					VAM150FA	VAM250FA	VAM350FA	VAM500FA	VAM650FA	VAM800FA	VAM1000FA	VAM1500FA	VAM2000FA
Power input - 50Hz	Heat exchange mode	Nom.	Ultra high/ High/Low	kW	0.116/0.100/0.056	0.141/0.112/0.062	0.194/0.175/0.111	0.212/0.189/0.118	0.380/0.325/0.227	0.451/0.400/0.346	0.469/0.432/0.349	0.864/0.758/0.655	0.953/0.767/0.653
	Bypass mode	Nom.	Ultra high/ High/Low	kW	0.116/0.100/0.056	0.141/0.112/0.062	0.194/0.175/0.111	0.212/0.189/0.118	0.380/0.325/0.227	0.451/0.400/0.346	0.469/0.432/0.349	0.864/0.758/0.655	0.953/0.767/0.653
Power input - 60Hz	Heat exchange mode	Nom.	Ultra high/ High/Low	kW	0.117/0.099/0.056	0.138/0.119/0.062	0.226/0.214/0.120	0.253/0.232/0.125	0.432/0.384/0.251	0.514/0.471/0.408	0.571/0.537/0.419	0.981/0.929/0.754	1.017/1.021/0.779
	Bypass mode	Nom.	Ultra high/ High/Low	kW	0.117/0.099/0.056	0.138/0.119/0.062	0.226/0.214/0.120	0.253/0.232/0.125	0.432/0.384/0.251	0.514/0.471/0.408	0.571/0.537/0.419	0.981/0.929/0.754	1.017/1.021/0.779
Temperature exchange efficieny - 50Hz	Ultra high/High/Low			%	74/74/79	72/72/77	75/75/80	74/74/77		74/74/76	75/75/76.5	75/75/78	
Temperature exchange efficieny - 60Hz	Ultra high/High/Low			%	74/74/80	72/72/77	75/75/81	74/74/78.5	74/74/78	74/74/76	75/75/78		
Enthalpy exchange efficieny - 50Hz	Cooling	Ultra high/High/Low		%	58/58/64	58/58/62	61/61/67	58/58/63		60/60/62	61/61/63	61/61/64	61/61/66
	Heating	Ultra high/High/Low		%	64/64/69	64/64/68	65/65/70	62/62/67	63/63/66	65/65/67	66/66/68		66/66/70
Enthalpy exchange efficieny - 60Hz	Cooling	Ultra high/High/Low		%	58/58/66	58/58/63	61/61/68	58/58/65		60/60/63	61/61/66	61/61/64	61/61/66
	Heating	Ultra high/High/Low		%	64/64/71	64/64/69	65/65/71	62/62/68.5	63/63/68	65/65/68	66/66/71	66/66/68	66/66/70
Operation mode					Heat exchange mode Bypass mode Fresh-up mode								
Heat exchange system					Air to air cross flow total heat (sensible + latent heat) exchange								
Heat exchange element					Specially processed non-flammable paper								
Casing	Material				Galvanised steel plate								
Dimensions	Unit	HeightxWidthxDepth		mm	285x776x525		301x828x816		364x1,004x868		364x1,004x1,156	726x1,514x868	726x1,514x1,156
Weight	Unit			kg	24		33		48		61	132	158
Fan	Type				Sirocco fan								
	Air flow rate - 50Hz	Heat exchange mode	Ultra high/ High/Low	m³/h	150/150/110	250/250/155	350/350/230	500/500/350	650/650/500	800/800/670	1,000/1,000/870	1,500/1,500/1,200	2,000/2,000/1,400
		Bypass mode	Ultra high/ High/Low	m³/h	150/150/110	250/250/155	350/350/230	500/500/350	650/650/500	800/800/670	1,000/1,000/870	1,500/1,500/1,200	2,000/2,000/1,40
	Air flow rate - 60Hz	Heat exchange mode	Ultra high/ High/Low	m³/h	150/150/110	250/250/145	350/350/210	500/500/300	650/650/440	800/800/660	1,000/1,000/800	1,500/1,500/1,200	2,000/2,000/1,40
		Bypass mode	Ultra high/ High/Low	m³/h	150/150/110	250/250/145	350/350/210	500/500/300	650/650/440	800/800/660	1,000/1,000/800	1,500/1,500/1,200	2,000/2,000/1,40
	External static pressure - 50Hz	Ultra high/High/Low		Pa	69/39/20	64/39/20	98/70/25	98/54/25	93/39/25	137/98/49	157/98/78	137/98/49	137/78/59
	External static pressure - 60Hz	Ultra high/High/Low		Pa	98/54/24	98/54/20	142/85/15	147/54/20	162/69/34	225/118/69	196/108/69	206/118/69	196/88/69
Sound pressure level - 50Hz	Heat exchange mode	Ultra high/High/Low		dBA	27 28.5/26 27.5/20.5 21.5	28 29/26 27/21 22	32 34/31.5 33/23.5 26	33 34.5/31.5 33/24.5 26.5	34.5 35.5/33 34/27 28	36 37/34.5 36/31 32	36 37/35 36/31 32	39.5 41.5/38 39/34 36	40 42.5/38 41/35 37
	Bypass mode	Ultra high/High/Low		dBA	27 28.5/26.5 27.5/20.5 21.5	28 29/27 28/21 22	32 34/31 32.5/24.5 26.5	33.5 34.5/32.5 33.5/25.5 27.5	34.5 35.5/34 35/27 28.5	36 37/34.5 36/31 33	36 37/35.5 36/31 32	40.5 41.5/38 39/33.5 36	40 42.5/38 41/35 37
Sound pressure level - 60Hz	Heat exchange mode	Ultra high/High/Low		dBA	28.5/26.5/19	29.5/26/19.5	34.5/32/22	34/31/24	36/33/27	37/35/30		40.5/38/33	41/38/35
	Bypass mode	Ultra high/High/Low		dBA	28/27/20	29/27/20.5	34.5/33/22	35/33/24	35.5/34/27	37/35/31		40.5/38/33	41/38/35
Operation range	Min.			°CDB	-15								
	Max.			°CDB	50								
	Relative humidity			%	80% or less								
Connection duct diameter				mm	100	150		200		250		350	
Piping connections	Drain				-								
Insulation material					Self-extinguishable urethane foam								
Air filter					Multidirectional fibrous fleeces								
Power supply	Phase/Frequency/Voltage			Hz/V	1~/50/60/220-240/220								

(1) Air flow rate can be changed to Low mode or High mode.
(2) Operation sound is measured at 1.5m below the center of the body.
(3) Sound values are measured in an anechoic chamber. Operating sound level generally becomes higher than this value depending on the operating conditions, reflected sound, and peripheral noise.
(4) The noise level at the air discharge port is about 8dB higher than the operating sound of the unit.

Connecting Method

Installing the Y-joint

Install the Y-joint 'horizontally' or 'vertically'.

<Install horizontally>

<Install vertically>

<Using reducer>

- Use connection part of Y-joint or provided reducer by cutting them in accordance with diameter of connecting pipe.
- Make certain 10~15mm or more for reducer which connected with pipe.
- Remove burr on cut part of reducer. It is impossible to connect reducer with pipe if pipe is deformed or reducer is unfinished.

- Keep a minimum distance of 1000mm or more before connecting a branch joint.

<Insertion depth of the connecting pipe>

- Do not insert the pipe deeply into the Y-joint. (Do not insert more than 10mm.)

- Install the Y-joint within ±15° on the horizon or on the vertical.

Installing the Header joint

1. Select the reducer fitted on the diameter of the pipe.

<Liquid side> <Gas side>

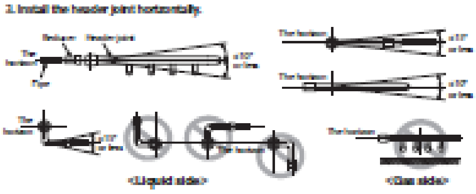
2. Block the reducer that is not used by brazing the cap if the number of connected indoor unit is fewer than header joint holes.

<Liquid side> <Gas side>

Connect the header joint to the pipe by cutting the provided reducer properly.

- Connect the header joint in order respecting the number of the indoor unit.
- Connect the indoor unit as the highest capacity comes first.

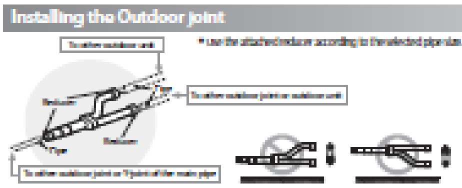
3. Install the header joint horizontally.



<Liquid side> <Gas side>

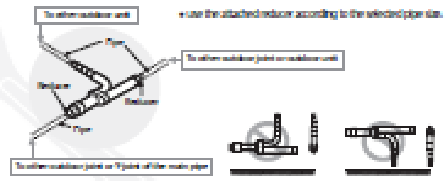
Installing the Outdoor joint

- Use the attached reducer according to the selected pipe size.



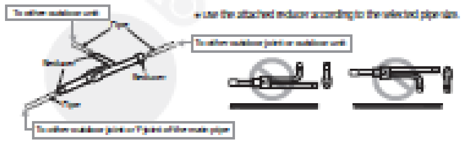
<Liquid side>

- Use the attached reducer according to the selected pipe size.



<Gas side>

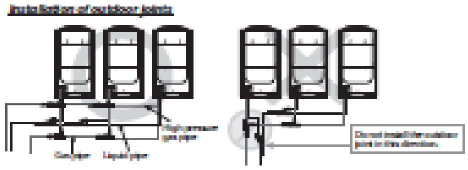
- Use the attached reducer according to the selected pipe size.



<High pressure gas side>

Connect the Outdoor joint to the pipe by cutting the outlet of the Outdoor joint or provided reducer properly.

Installation of outdoor joints

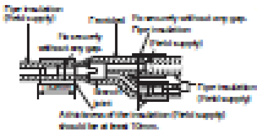


- High pressure gas pipe only applies to the HR product.

Insulating the branch joint

Y-joint & liquid side & gas side of the outdoor unit

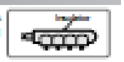
- Attach the insulation provided with a branch joint to the insulation supplied in the field without a gap. Wrap the connected part with an insulation (Field supply) of a thickness of at least 10mm.
- Use an insulation with the heat resisting temperature over 120°C. Wrap the branch joint with an insulation of a thickness of at least 10mm.
- When insulating in high humidity (higher than 30°C, 80%), wrap the supplied insulation with more than 10mm of extra insulation such as Polyethylene Foam or other similar material.
- Wrap the connected part between the Outdoor joint and the gas side of the outdoor unit to prevent it from defrosting. Wrap gas side pipe of the outdoor unit wholly to prevent it from dewing.

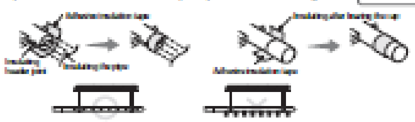


- Attach the adhesive insulation tape to the pipe as shown in the picture after insulating the pipe.

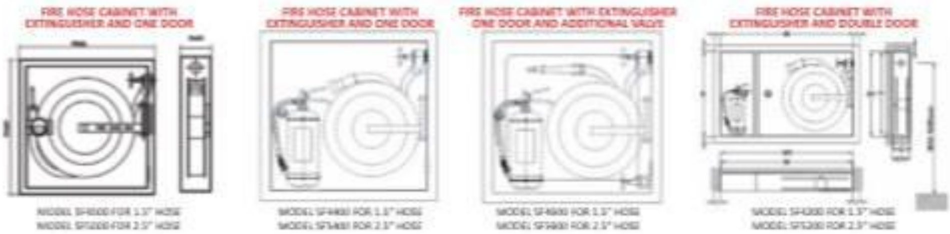
Header joint

- Cover the connected part and fasten the header joint using a cable tie.
- Insulate the header joint and the brazed part and wrap the connected part with an adhesive insulation tape to prevent it from dewing.





1½" SYNTHETIC HOSE CABINET



CABINETS FOR 1½" SYNTHETIC HOSE

MODEL	SIZE OF CABINET			WALL OPENING SIZE		
	WIDTH	HEIGHT	DEPTH	WIDTH	HEIGHT	DEPTH
SF4000	650mm	650mm	150mm	670mm	670mm	160mm
SF4200	900mm	650mm	180mm	920mm	670mm	190mm
SF4400	850mm	650mm	180mm	870mm	670mm	190mm
SF4600	850mm	900mm	220mm	870mm	920mm	230mm

CO_2 EXTINGUISHERS

APPROVED MODELS

MODEL	CAPACITY	FIRE RATING
CD2S	2 kg	34 B
CD2SZ	2 kg	55 B
CD2G	2 kg	21 B
CD5G	5 kg	55 B

STANDARD MODELS

MODEL	CAPACITY	TYPE	DESCRIPTION
CD 2-G	2 kg	Portable	Stored Pressure
CD 5-L	5 Lbs	Portable	Stored Pressure
CD 10-L	10 Lbs	Portable	Stored Pressure
CD 5-G	5 kg	Portable	Stored Pressure
CD 6-G	6 kg	Portable	Stored Pressure
CD 15-L	15 Lbs	Portable	Stored Pressure
TC10	10 kg	Mobile	Stored Pressure
TC20	20 kg	Mobile	Stored Pressure
TC25	25 kg	Mobile	Stored Pressure
TC30	30 kg	Mobile	Stored Pressure
TC45	45 kg	Mobile	Stored Pressure
TC50	50 kg	Mobile	Stored Pressure
TC60	60 kg	Mobile	Stored Pressure

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