Palestine Polytechnic University

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

Graduation Project

Design of Mechanical Systems and Greywater Treatment Facility for a Residential Building in Hebron

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

Supervisor signature

………………………………

Examine committee signature

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Department Head signature

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Dedication

بسم الله الرحمن الرحيم

{يَرْفَعِ اللَّهُ الَّذِينَ آمَنُوا مِنكُمْ وَالَّذِينَ أُوتُوا الْعِلْمَ دَرَجَاتٍ}

صدق الله العظيم

إلهي لا يطيب الليل إلا بشكرك ولا يطيب النهار إلى بطاعتك .. ولا تطيب اللحظات إلا بذكرك .. ولا تطيب الآخرة إلا بعفوك .. ولا تطيب الجنة إلا برؤيتك الله جل جلاله

إلى من بلغ الرسالة وأدى الأمانة .. ونصح الأمة .. إلى نبي الرحمة ونور العالمين ..

سيدنا محمد صلى الله عليه وسلم

إلى من علمني النجاح والصبر

إلى من افتقده في مواجهة الصعاب

ولم تمهله الدنيا لأرتوي من حنانه.. أبي

وإلى من تتسابق الكلمات لتخرج معبرة عن مكنون ذاتها

من علمتني وعانت الصعاب لأصل إلى ما أنا فيه

وعندما تكسوني الهموم أسبح في بحر حنانها ليخفف من آلامي .. أمي

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And, finally, our thanks go to all lecturers & doctors, engineers, and laboratory supervisors in PPU. Their effort and their nice dealing with us improved our characters to become successful engineers in the future.

Abstract

The aim of the project is to design a complete mechanical system for a residential building which is located in Hebron city. This building consists of seven floors with a total area of 2791.6 m^2. These services are certainly designed to verify human comfort.

In this project, air conditioning system type (VRF) is used since it is efficient and economical. Also, gray water is treated in such away to be able to reuse it for flushing tanks and irrigation in order to reduce water consumption and save it.

DP select and ventilation rates calculator programs are used in this project for calculation of flow rate of ventilation and selection of pumps.

يهدف المشروع إلى تصميم نظام ميكانيكي كامل لبناية سكنية تقع في مدينة الخليل مكونة من سبعة طوابق بمساحة اجمالية 2791.6 م^2 ، حيث أن هذه الخدمات يتم تصميمها سعياً لراحة الإنسان.

تم استخدام نظام تكييف من نوع (VRF) في المبنى وذلك لكفاءته العالية وتوفيره للطاقة، كما تم معالجة المياه الرمادية لاستخدامها في صناديق طرد المراحيض وري المزروعات وذلك للترشيد في استهلاك المياه.

تم استخدام عدة برامج مثل : ventilation rates calculator, DP select لحساب كميات التهوية المطلوبة واختيار المضخات.

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Chapter One

Introduction

1.1 Introduction

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

Water in Palestine is little and it is vital for every living thing specially human beings. The daily consumption of water is very high and some of it goes useless. So, in this project, the outlet water that goes from all fixture units except water closet and urinal are treated and reused for toilet flushing which its consumption relative is 35% of the total daily consumption.

Fire safety is very important in all places. Without fire alarms, a lot of things may be lost like people and expensive things. In this case, firefighting system should be installed in the building.

In to the above, numerous systems also used in this building such that sanitary drainage system, water supply system and ventilation system.

1.2 Project objectives

1) To design the mechanical services for the building.
2) To treat the gray water and reuse it.
3) Design variable refrigeration flow (VRF) air conditioning system for the building.
4) Design firefighting system.

1.3 Project importance

1) In order to achieve all means for human comfort.
2) Water conservation and optimum exploitation for gray water which was recycled.
3) To protect people and expensive things from fire.

1.4 Building description

The building site is in Dahiet Al-Zayton. It consists of six floors, each floor contains two apartments , the area of each apartment is 154 m^2 .

1.5 Project outline

The project contains sex chapters, these chapters are arranged as follows:

Chapter one: Introduction
This chapter includes overview about the project, project objectives, building description and time planning.

Chapter two: Heating and Cooling Loads

This chapter consists of the procedures for calculating the heating and cooling load

Chapter three: Variable Refrigerant Flow System

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

Chapter four: Plumping System.

This chapter includes the water distribution calculation, drainage system.

Chapter five: Gray Water Treatment.

This chapter includes procedures of greywater treatment and use it for flushing tank and irrigation.

Chapter six: Firefighting system

This chapter contains the fire extinguishing system

1.6 Time Planning

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

No. of week / Task	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Choosing the project																
Visit the library to collect information																
Reading books																
Put the title																
Writing the introduction and human comfort																

No. of week / Task	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Calculate the heating and cooling load																
Writing HVAC system																
Visit supervisor and takes some notation																
Plumping system calculations																
Writing greywater treatment																
Firefighting																
Writing and printing in a scientific way															`	

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

No. of week / Task	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Design VRV system																
Ventilation system																
Tanks calculation for gray water																
Pumps calculations																
Calculation and distribution of the concrete and steel bar																
Drawing water system																
Drawing drainage system																
Drawing VRV system																
Drawing firefighting system																
Bill of quantity																
catalog																

Chapter Two

Heating and Cooling Loads

2.1 Overview

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

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

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 Inside and outside condition

The inside and outside conditions are obtained from Palestinian code as shown in the following Table [1]:

Table (2.1) Inside and outside design conditions

Property	Inside design condition		outside design condition	
	summer	winter	summer	winter
Temperature (˚C)	24	24	30	4
Relative humidity (%)	45	30	57	72
Wind speed (m/s)	….	….	1.4	1.4

2.4 ASHRAE Comfort Chart

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

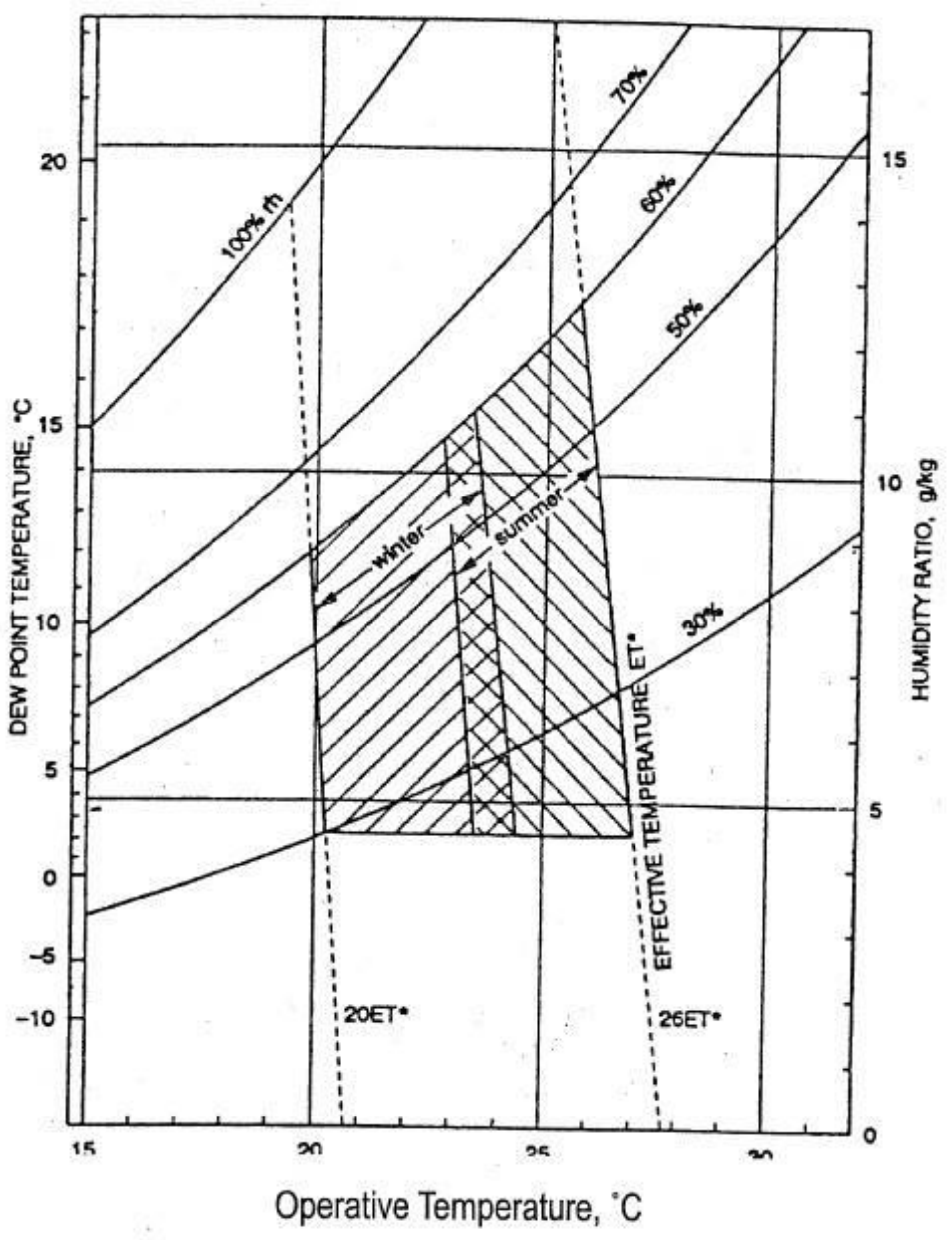


Figure (2.1): Human comfort chart

2.5 Convection Heat Transfer Coefficient

There are two ways to transfer heat by convection[2]:

i. Forced convection.
ii. Free convection.

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

1. $T_f = \frac{Ts + T\infty}{2}$ (2.1)

   Where:

   T_f: film temperature, K
   Ts: surface wall temperature, K
   T_∞: ambient temperature, K

2. Find the fluid properties ν, Pr and k from Table A(2-1)

   Where:

   ν: viscous force, m^2/s
   Pr: Prandtl number
   k: thermal conductivity, W/m.K

3. $Re = \frac{v \times L}{\nu}$ (2.2)

   If $Re < (5\times10^5)$ … Laminar flow
   If $Re \geq (5\times10^5)$ … Turbulent flow

   Where:

   Re: Reynolds number
   L: reference length, m
   ν: kinematic viscosity.

4. $Nu = 0.66\ Re^{0.5}\ Pr^{(1/3)}$ … Laminar flow (2.3)
   $Nu = 0.037\ Re^{0.8}\ Pr^{(1/3)}$ … Turbulent flow (2.4)

   Where:

   Nu: Nusselt number

5. $h = \frac{Nu \times k}{L}$ (2.5)

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

1. $T_f = \frac{Ts + T\infty}{2}$
2. Find the fluid properties ν, Pr and k from Table A(2.1)
3. $Gr = g\beta(T_s - T_\infty)L^3/\nu^2$ (2.6)

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

Where:

Gr: Grashof number[3]

g: gravitational acceleration , m^2/s

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

4. Ra = Gr×Pr (2.8)

   If $Ra \leq 10^9$ … Laminar flow

   If $Ra > 10^9$… Turbulent flow

   Where:

   Ra: Rayleigh Number

5. For Laminar flow:

$$Nu_L = 0.68 + \frac{0.670 Ra^{1/4}}{[1+(0.492/Pr)^{9/16}]^{4/9}} \quad (2.9)$$

For Turbulent flow:

$$Nu_L = [0.825 + \frac{0.387 Ra^{1/6}}{[1+(0.492/Pr)^{9/16}]^{8/27}}]^2 \quad (2.10)$$

6. $h = \frac{Nu \times k}{L}$

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

T_f = (277.15+280.15)/2 = = 278.65 K

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

- $\nu = 13.98985 \times 10^{-6}\ m^2/s$
- Pr = 0.712551
- $k = 24.592 \times 10^{-3}$ W/m.K

L = 3 m

Re = $(12.8 \times 3)/ (13.98985 \times 10^{-6})$ = 2744847.157 »»» Turbulent flow

Nu = $0.037(2744847.157)^{0.8}(0.712551)^{(1/3)}$ = 4676.87

$h_o = (4676.87 \times 24.592 \times 10^{-3})/3 = 38.34\ W/m^2.^{\circ}C$

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

T_f = (285.65+297.15)/2 = 291.4 K

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

- $\nu = 14.9466 \times 10^{-6}\ m^2/s$
- Pr = 0.709756

- $k = 25.452\times10^{-3}$ W/m.K

$\beta = (1/291.4) = 3.4554\times10^{-3}\ K^{-1}$

$Gr = [9.81\times3.4554\times10^{-3*}(20-12.5)\times 3^3]/ [14.9466\times10^{-6}] = 3.0727\times10^{10}$

$Ra = (3.0727\times10^1)(0.709756) = 2.181\times10^{10}$ »»» Turbulent flow

$Nu = [0.825 + ((0.387(2.181\times10^{10})^{(1/6)})/ ((1+ (0.492/0.709756)^{(9/16)}))^{(8/27)}]^2 = 323.02$

$h_i = (323.02\times25.452\times10^{-3})/3 = 2.741$ W/m^2.˚C

The same procedures are used to calculate convection heat transfer coefficient in cooling load:

$h_o = 29.67$ W/m^2.˚C

$h_i = 1.7885$ W/m^2.˚C

Note: Because there is an error in the values of h_o and h_i, these values are obtained from tables A(2.2) and A(2.3).

2.6 Overall Heat Transfer Coefficient

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

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

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

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

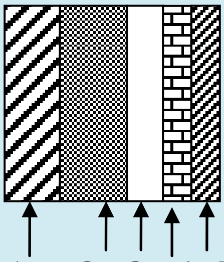
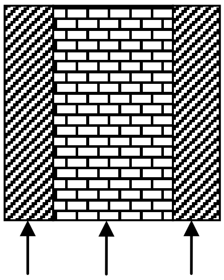
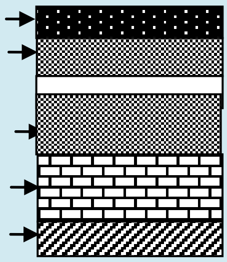
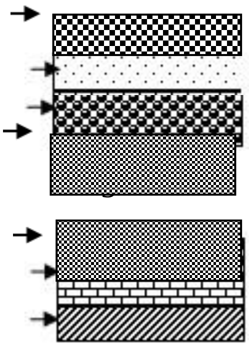
U_{floor} = Overall heat transfer coefficient for the ground of the rooms.

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

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

The construction of layers is different from wall to wall so, Table (2.2) shows the sections for the construction layers in the building for each combination.

Table (2-2) : Sections for constructions

Construction	Construction detail	Construction material
External walls		1- Hard stone 2-Concrete 3-Polystyrene 4- Brick 5- Plaster
Internal walls		1- plaster 2- Block 3- plaster
Ceiling		1- Asphalt mix 2- Concrete 3- Polystyrene 4- Reinforced concrete 5- Hollow brick 6- plaster
Floor		1- Ceramic tiles 2- Mortar 3- Aggregates 4- Concrete 5- Polystyrene 6- Reinforced concrete 7- Hollow brick 8- plaster

The construction of walls, ceilings and floors are chosen as follows tables:

Table (2.3): External walls constructions

Material	ΔX(m)	K(W/m.°C)
Hard stone	0.05	1.7
Concrete	0.15	1.75
Polystyrene	0.03	0.034
Brick	0.07	0.95
Plaster	0.02	1.2

Table (2.4): Internal walls (partition) constructions

Material	ΔX(m)	K(W/m.°C)
Plaster	0.02	1.2
Brick	0.1	0.95
Plaster	0.02	1.2

Table (2.5): Ceiling constructions

Material	ΔX(m)	K(W/m.°C)
Asphalt mix	0.02	0.70
Concrete	0.05	1.75
Polystyrene	0.025	0.034
Reinforced concrete	0.06	1.75
Hollow brick	0.18	0.95
Plaster	0.02	1.2

Table (2.6): Floor constructions

Material	ΔX(m)	K(W/m.°C)
ceramic tiles	0.02	1.10
Mortar	0.02	0.16
Aggregates	0.10	1.05
concrete	0.05	1.75
Polystyrene	0.03	0.034
Reinforced concrete	0.06	1.75
Hollow brick	0.18	0.95
Plaster	0.025	1.20

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

$$U = \frac{1}{\Sigma\, Rth} = \frac{1}{\text{Rin} + \Sigma\frac{\Delta x}{K} + \text{Rout}} \qquad (2.11)$$

Where:

Δx: the thickness of the wall.

R_{in}: inside film resistance.

R_{out}: Outside film resistance.

For walls:

R_{in} and R_{out} for the external walls as 0.12 and 0.06 (m^2/W. °C), respectively from tables A(2.2) and A(2.3)

$$\text{Uout} = \frac{1}{\text{Rin} + \frac{\Delta x_{st.}}{k_{st.}} + \frac{\Delta x_{con.}}{k_{con.}} + \frac{\Delta x_{poly.}}{k_{poly.}} + \frac{\Delta x_{Brick}}{k_{Brick}} + \frac{\Delta x_{plaster}}{k_{plaster}} + \text{Rout}}$$

$$= \frac{1}{0.12+\frac{0.05}{1.7}+\frac{0.15}{1.75}+\frac{0.03}{0.034}+\frac{0.07}{0.95}+\frac{0.02}{1.2}+0.06}$$

= 0.788 (W/m^2. °C).

For ceiling:

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

R_{in} and R_{out} for the ceiling are 0.1 and 0.04 (m^2/W. °C), respectively from tables A(2.2) and A(2.3).

$$U_1 = \frac{1}{\text{Rin}+\frac{\Delta x_{asph.}}{k_{asph.}}+\frac{\Delta x_{conc.}}{k_{conc.}}+\frac{\Delta x_{poly.}}{k_{poly.}}+\frac{\Delta x_{conc.}}{k_{conc.}}+\frac{\Delta x_{Brick}}{k_{Brick}}+\frac{\Delta x_{Plaster}}{k_{Plaster}}+\text{Rout}}$$

$$= \frac{1}{0.1+\frac{0.02}{0.70}+\frac{0.05}{1.75}+\frac{0.025}{0.034}+\frac{0..06}{1.75}+\frac{0.18}{0.95}+\frac{0.025}{1.2}+0.04}$$

= 0.849(W/m^2. °C).

Similarly, U_2 = 0.917(W/m^2. °C)

For partition:

R_{in} = R_{out} = 0.12 (m^2/W. °C) from table A(2.2).

$$Up = \frac{1}{\text{Rin} + 2 \times \frac{\Delta x_{Plaster}}{k_{Plaster}} + \frac{\Delta x_{Brick}}{k_{Brick}} + \text{Rin}}$$

$$= \frac{1}{0.12+2\times\frac{0.02}{1.2}+\frac{0.1}{0.95}+0.12}$$

$= 2.642(\text{W}/m^2.\,°\text{C})$.

For floor:

As the same ceiling, we divided the construction into two parts.

R_{in} = 0.15 (m^2/W. °C), from tables A(3.2)

$$U1 = \frac{1}{\text{Rin} + \frac{\Delta x_{ceramic}}{k_{ceramic}} + \frac{\Delta x_{mortar}}{k_{mortar}} + \frac{\Delta x_{aggregates}}{k_{aggregates}} + \frac{\Delta x_{con.}}{k_{con.}} + \frac{\Delta x_{poly.}}{k_{poly.}} + \frac{\Delta x_{con.}}{k_{con.}} + \frac{\Delta x_{Brick}}{k_{Brick}} + \frac{\Delta x_{Plaster}}{k_{Plaster}}}$$

$$= \frac{1}{0.15+\frac{0.02}{1.1}+\frac{0.02}{0.16}+\frac{0.10}{1.05}+\frac{0.05}{1.75}+\frac{0.03}{0.034}+\frac{0.06}{1.75}+\frac{0.18}{0.95}+\frac{0.02}{1.2}}$$

$= 0.649(\text{W}/m^2.\,°\text{C})$.

Similarly, U_2 = $0.688(\text{W}/m^2.\,°\text{C})$

For window:

From table A(2.4) , $Ug = 3.2$ (W/m^2. °C) for double glass aluminum frame.

For door:

From table A(2.5) , $Ud = 5.8$ (W/m^2. °C) for steel door type.

For un condition :

$$Uun. = \frac{1}{\text{Rin} + 2\times\frac{\Delta x_{Plaster}}{k_{Plaster}} + \frac{\Delta x_{con.}}{k_{conc}} + \text{Rout}}$$

$$= \frac{1}{0.12+2\times\frac{0.02}{1.2}+\frac{0.2}{1.75}+0.06}$$

$= 3.053$ (W/m^2. °C).

2.7 Heating load calculation:

2.7.1 Overview:

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

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

i. Heat loss through all exposed walls, ceiling, floor, windows, doors, and walls between a heated space and an unheated space (partition walls).
ii. Heat load required to warm outside cold air infiltrated to heated space through cracks (clearances) of windows and doors, and outside cold air infiltrated due to opening and closing of doors.
iii. Domestic hot water load.
iv. Miscellaneous loads such as emergency heating loads and safety factor heating load. [1]

2.7.2 Heating Load Calculations

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.
   $\Delta T = T_{in} - T_{out}$
3. Estimate temperature in adjacent unheated spaces, if any.
   $\Delta T_{un} = 0.5\ (T_{in} - T_{out})$ (2.12)
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
   $\dot{Q} = UA\ (T_{in} - T_{out})$ (2.13)
   Where:
   - $\dot{Q}$: rate of heat transfer (W)
   - U: overall heat transfer coefficient ($W/m^2.°C$).
   - A: heat transfer area (m^2)
   - T_{in}: inside design temperature (°C).
   - 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]

2.7.3 Sample Calculation

Figure (2.2) illustrates the dimension of guest room

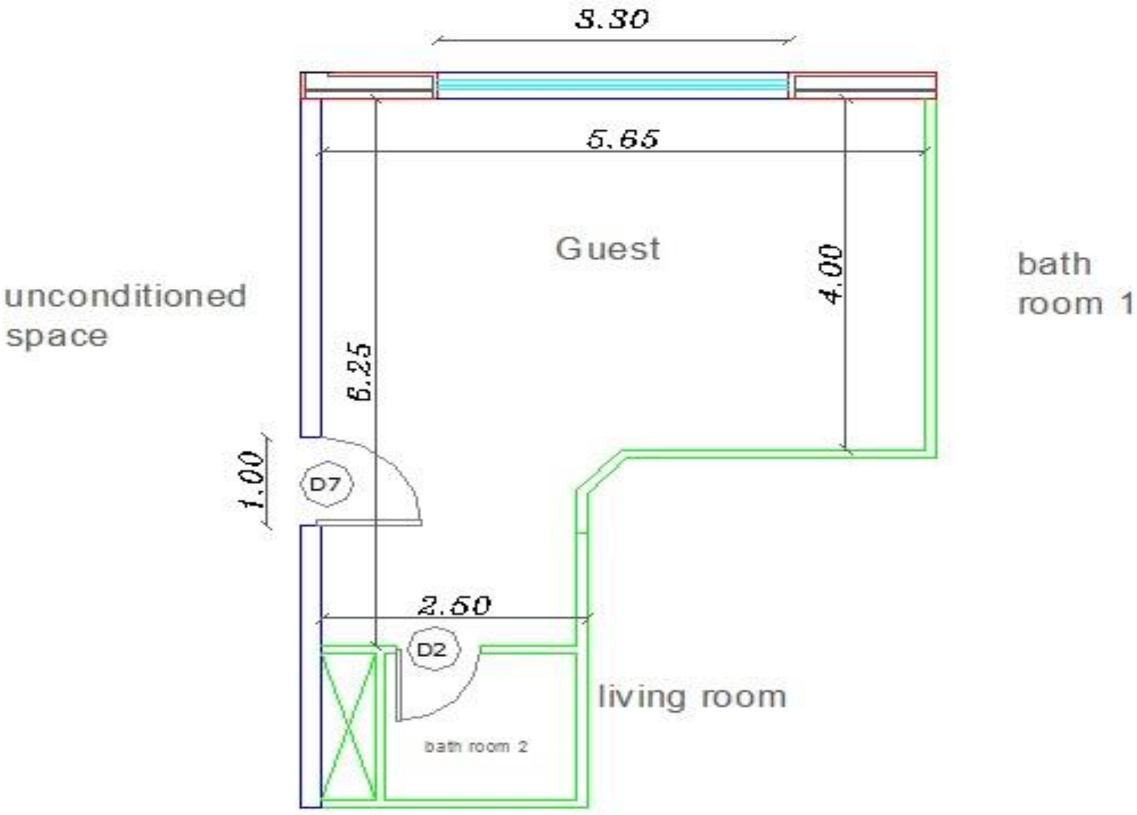


Figure (2.2): Guest room dimensions

Calculation the heat loss from the Guest room in the last floor as a sample :

The height of the room = 3m

The height of the window = 1m

The height of the bath room window = 1.5m

Heat loss through ceiling ($\dot{Q}_c$) :

Because of its construction, the ceiling is divided into two areas which are area A_1 and area A_2 as showing in Figure (2.3).

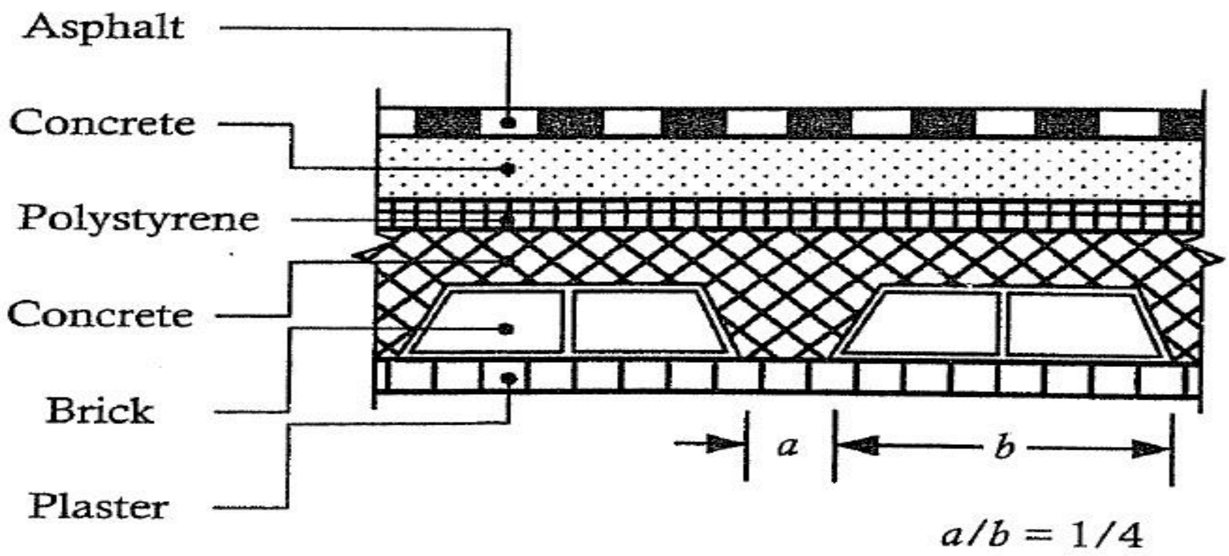


Figure (2.3): Ceiling construction

The area A_1 is equal to:

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

$$= \frac{4}{5}(28.1134)$$

$$= 22.49 \text{ m}^2$$

And the area A_2 is equal to:

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

$$= \frac{1}{5}(28.1134)$$

$$= 5.62 \text{ m}^2$$

$$\dot{Q}_c = U_c A_c (T_i - T_o) \tag{2.14}$$

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

$$\dot{Q}_c = (0.849 \times 22.49 + 0.917 \times 5.62)(24 - 4)$$

$$\dot{Q}_c = 484.95 \text{ W}$$

Heat loss through walls ($\dot{Q}_w$) :

The external wall area is

$A_{w,ex}$ = (5.65×3)-(3.3×1)

=13.65 m^2

The heat loss from external wall is

$\dot{Q}_{w,ex} = (U_{w,ex} A_{w,ex})(T_i - T_o)$

= (0.788× 13.65) (24-4)

= 215.124 W

There are two space beside the guest room are unconditioned, so heat loss from unconditioned walls :

$\dot{Q}_{w,un.} = \dot{Q}_{w,un.1} + \dot{Q}_{w,un.2}$

The unconditioned temperature is calculate by equation (2.12)

$T_{un.} = 0.5 (T_i - T_o)$

= 0.5 (24 - 4)

= 10 °C

The unconditioned area is

$A_{w,un.}$ =(6.25× 3)-(2×1)

=16.75 m^2

$\dot{Q}_{w,un.1} = (U_{un.} A_{w,un.})(T_i - T_{un.})$

= (3.053×16.75)(24-10)

= 715.93 W

$\dot{Q}_{w,un.2} = (U_p A_{p,un})(T_i - T_{un.})$

= (2.642×1.5)(24-10)

= 55.48 W

$\dot{Q}_{w,un.} = \dot{Q}_{w,un.1} + \dot{Q}_{w,un.2}$

= 715.93 + 55.48

= 771.412 W

Now, the total heat loss from walls is

$\dot{Q}_{w,tot} = \dot{Q}_{w,ex} + \dot{Q}_{w,un.}$

$= 215.124 + 771.412$

$= 986.536$ W

Heat loss through windows ($\dot{Q}_g$):

$\dot{Q}_g = U_g A_g (T_i - T_o)$

$=(3.2)(3.3\times 1)(24-4)$

$= 211.2$ W

Heat loss through external door ($\dot{Q}_d$) :

$\dot{Q}_d = U_d A_d (T_i - T_{un.})$

$=(5.8)(2\times 1)(24-10)$

$= 162.4$ W

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

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

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

$$\dot{Q}_{inf.,g} = \frac{\dot{V}f}{vo} (h_i - h_o) \quad (2.15)$$

Where:

hi: Inside enthalpy of infiltrated air in(kJ/kg)

ho: Outside enthalpy of infiltrated air in (kJ/kg)

$\dot{V}f$: The volumetric flow rate of infiltrated air in (m^3/s)

vo : Specific volume in(m^3/kg)

$$\dot{V}f = K \times L \; [0.613 \, (S_1 \times S_2 \times V_o)^2 \,]^{2/3} \quad (2.16)$$

Where :

K = the infiltration air coefficient.

L: the crack length in meter.

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

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

V_O: measured wind speed (m/s)

The value of K, S_1 and S_2 is obtained from tables A(2.6), A(2.7) and A(2.8) respectively.

K =0.43

S_1 =0.9

S_2 =0.75

V_O= 1.4 (m/s)   from Palestinian code

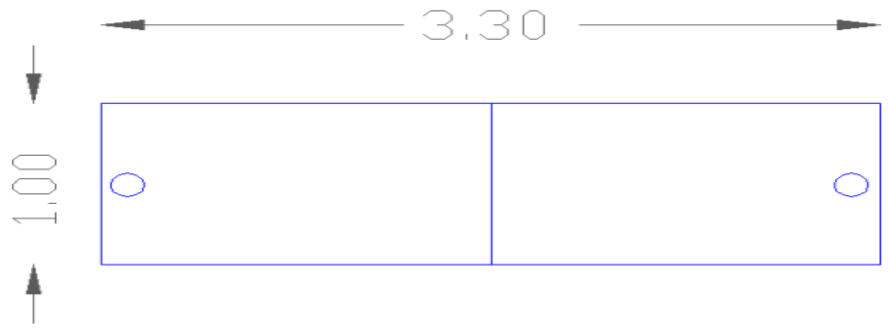


Figure (2.4): Sliding window

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

L = [(3.3× 2) + (3×1)]

= 9.6 m

Therefore ;

$\dot{V}f$ = (0.43) (9.6) [0.613(0.9 × 0.75 × 1.4)^2] $^{2/3}$

= 2.76 m^3/h

= 7.67× 10^{-3} m^3/s

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

v_o = 0.7889 m^3/kg , h_i = 40.6 kJ/kg , h_o = 13.1 kJ/kg

ρ_o = 1/ v_o = 1.267 kg / m^3

The total heat loss due to infiltration is calculated by equation (2.15) as follows:

Through window

$\dot{Q}_{inf.,g} = \rho_o \dot{V}f\ (h_i - h_o)$

$= (1.267)(\ 7.67\times 10^{-3}\ )(24 - 4)$

= 0.0267kW

= 26.7 W

Through door

$\dot{Q}_{inf.,d} = \frac{\dot{V}f}{vo}(h_i - h_o)$

$\dot{V}f = K \times L\ [0.613\ (S_1\times S_2\times v_\circ)^2\ ]^{2/3}$

L = [(2× 2) + (2×1)]

= 6 m

Therefore ;

$\dot{V}f = (0.43)\ (6)\ [0.613(\ 0.9 \times 0.75 \times 1.4)^2\ ]^{2/3}$

= 1.726 m^3/h

= 4.79×10^{-4} m^3/s

$\dot{Q}_{inf.,d} = \rho_o \dot{V}f\ (h_i - h_o)$

$= (1.267)(\ 4.79\times 10^{-4}\ )(24 - 14)$

= 0.01667 kW

= 16.67 W

$\dot{Q}_{inf.,tot} = \dot{Q}_{inf.,g} + \dot{Q}_{inf.,d}$

= 26.7 + 16.67

$= 43.37$ W

The total heat loss from the guest room is

$$\dot{Q}_{tot} = \dot{Q}_{w,tot} + \dot{Q}_{c} + \dot{Q}_{g} + \dot{Q}_{d} + \dot{Q}_{inf.,tot}$$

$$= 986.536 + 484.95 + 211.2 + 162.4 + 43.37$$

$$= 1888.45 \text{ W}$$

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

$\dot{Q}_{tot} = 1888.45 \times 1.1 = 2077.30$ W.

Heating Load Summary is listed in the following table:

Table (2.7): Heating load for each flat in the building

Flat No.	Heating Load (kW)	Flat No.	Heating Load (kW)
1	7.6157	7	5.5799
2	7.6157	8	5.5799
3	5.5799	9	5.5799
4	5.5799	10	5.5799
5	5.5799	11	7.8891
6	5.5799	12	7.8891

The total heating load for the building = 75.6488 kW

2.8 Cooling Load calculation:

2.8.1 Overview

Cooling load is the rate at which heat energy must be removed from a space in order to maintain a given inside design condition. Figure (2.5) shows the source of cooling load.

The cooling load of a building consists of the following heat gains [1]:

i. Heat gains that are transmitted through shaded building structures such as walls, floors and ceilings and that adjacent to unconditioned space. The heat transmitted in this case is caused by temperature difference that exists on both sides of the structure. This heat gain is calculated by using this equation:

$$Q = UA\,(T_{out} - T_{in}) \tag{2.17}$$

ii. Heat gains due to solar effects which include:
   a. Solar radiation transmitted through the glass into the air conditioned space and absorbed by inside space surfaces and furniture.
   b. Solar radiation absorbed by walls, glass windows, glass doors, and roofs that are exposed to solar radiation.

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

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

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

vi. Sensible and latent heat gains due to occupants.

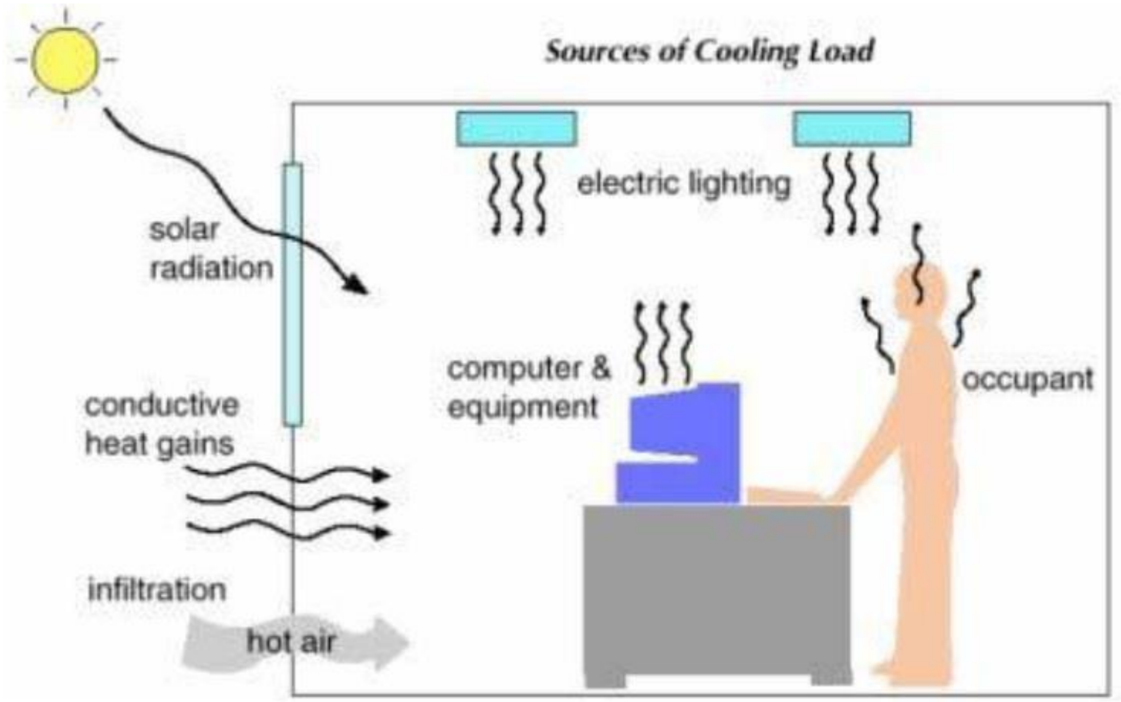


Figure (2.5): Source of cooling load

2.8.2 Cooling Load Calculations:

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

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

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

Where:

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

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

Where:

CLTD: cooling load temperature difference, ˚C
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, ˚C

$T_{o,m} = (T_{max} – T_{min})\ /2$ (2.18)

Where:

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

T_{max} = 36.1 ˚C and $T_{min\ =}$ 13.7 ˚C are obtained from Palestinian Code.

Applying these values in equation (3.18) to obtain the outdoor mean temperature

$T_{o,m}$ = 24.9 ˚C.

2.8.3 Sample Calculation:

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

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

CLTD = 14 ˚C from Table A (2.9)

LM = 0.5 from Table A(2.10)

k = 0.5 for permanently light colored roofs.

f = 1 there is no attic or roof fan.

$(CLTD)_{corr.}$ = (14 + 0.5) 0.5 + (25.5 - 24) + (24.9 - 29.4) 1

$= 4.25^\circ C$

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

$\dot{Q}_{Roof} = (0.849 \times 22.49 + 0.917 \times 5.62)(4.25)$

$= 103.05$ W

$= 0.103$ kW

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

CLTD at 14:00 o'clock … from Table A(2.11)

N = 0.0

k = 0.83 for permanent medium color walls.

$A_N = (5.65 \times 3)-(3.3) = 13.65\ m^2$

$(CLTD)_{corr., N} = (0.0+0.5)\ 0.83 + (25.5-24) + (24.9-29.4) \times 1$

$= -2.585\ ^\circ C$

$\dot{Q}_{Wall} = \dot{Q}_N = 0.7880 \times 13.65 \times -2.585$

$= -27.80$ W

$= -0.0278$ kW

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

From south wall

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

$= 2.642 \times 1.5 \times 4$

$= 15.582$ W

From east wall

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

$= 3.053 \times 16.75 \times 4$

$= 204.551$ W

$Q_{un} = 15.582 + 204.551$

$= 0.2204$ kW

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

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

1- Transmitted component: it represents the largest component, which is transmitted directly into the interior of the building or the space. This component represents about 42% to 87% of incident solar radiation, depending on the glass transmissibility value.

2- Absorbed component: this component is absorbed by the glass itself and raises its temperature. About 5 to 50% of solar radiation it absorbed by the glass, depending on the absorptive value of the glass.

3- Reflected component: this component is reflected by the glass to the outside of the building. About 8% of the solar energy is reflected back by the glass.

The amount of solar radiation depends upon the following factors:

1- Type of glass (single, double or insulation glass) and availability of inside shading.
2- Hour of the day, day of the month, and month of the year.
3- Orientation of glass area. (North, northeast, east orientation, etc).
4- Solar radiation intensity and solar incident angle.
5- Latitude angle of the location.

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

$$Q_{Glass} = Q_{tr.} + Q_{conv.} \tag{2.20}$$

Where:

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

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

SHC : Solar heat gain factor : this factor represents the amount of solar energy that would be received by floor, furniture and the inside walls of the room and can be extracted from table A(2.12).

SC : Shading coefficient : this factor accounts for different shading effects of the glass wall or window and can be extracted from tables A(2.13) for single and double glass without interior shading or from table A(2.14) for single and double glass as well as for insulating glass with internal shading

CLF : Cooling load factor : this represent the effects of the internal walls, floor, and furniture on the instantaneous cooling load, and can be extracted from table A(2.15) for glass without interior shading or from table A(2.16) for glass with interior shading. [1]

The transmitted cooling load is calculated as follows:

$Q_{tr.} = A\ (SHG)\ (SC)\ (CLF)$ (2.21)

SHG in W/m^2 … from Table A(2.12)

N = 126

SC = 0.4 … reflective double from Table A(2.14)

CLF at 14:00 o'clock … from Table A(2.16)

N = 0.86

$Q_{tr.\ N} = 3.3 \times 126 \times 0.4 \times 0.86$

$= 143.03$ W

$Q_{conv.} = UA\ (CLTD)_{corr.}$ (2.22)

Where:

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

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

$(CLTD)_{corr.}$: is calculated as the same of walls and roofs and the CLTD value for glass is obtained from table A(2.21)

CLTD = 7 ˚C at 14:00 o'clock

k = 1 for glass

f = 1 for glass

$Q_{conv.\ N} = 47.52$ W

$Q_{Glass} = 143.03 + 47.52$

$= 190.55$ W

$= 0.1906$ kW

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

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

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

Where:

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

A: floor area = 28.11 m^2

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

$(CLF)_{Lt.}$ = 0.84 … from Table A(2.17)

$Q_{Lt.}$ = 30 × 28.11 × 0.84

= 708.37 W

= 0.708 kW

Heat gain due to infiltration (Q_f):

As the same way in heating load

$$\dot{Q}_{inf.,g} = \frac{\dot{V}f}{vo} (h_o - h_i) \quad (2.24)$$

Where:

hi: Inside enthalpy of infiltrated air in(kJ/kg)

ho: Outside enthalpy of infiltrated air in (kJ/kg)

$\dot{V}f$: The volumetric flow rate of infiltrated air in (m^3/s)

vo : Specifics volume in(m^3/kg)

$$\dot{V}f = K \times L \;[0.613\,(S_1 \times S_2 \times V_o)^2\,]^{2/3} \quad (2.16)$$

Where :

K = the infiltration air coefficient.

L: the crack length in meter.

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

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

V_o: measured wind speed (m/s)

The value of K, S_1 and S_2 is obtained from tables A(2.6), A(2.7) and A(2.8) respectively.

$K = 0.43$

$S_1 = 0.9$

$S_2 = 0.75$

$V_O = 1.4$ (m/s)   from Palestinian code

And the window is sliding as figure (2.3), then :

$L = [(3.3\times 2) + (3\times1)]$

$= 9.6$ m

Therefore ;

$\dot{V}f = (0.43)\ (9.6)\ [0.613(0.9 \times 0.75 \times 1.4)^2\ ]^{2/3}$

$= 2.76\ m^3/h$

$= 7.67\times 10^{-3}\ m^3/s$

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

$v_o = 0.7889\ m^3/kg$, $h_i = 47.79$ kJ/kg , $h_o = 69.06$ kJ/kg

$\rho_o = 1/ v_o = 1.267\ kg / m^3$

$\dot{Q}_{inf.,g} = \rho_o \dot{V}f\ (h_i - h_o)$

$= (1.267)(7.67\times 10^{-3})(69.06 - 47.79)$

$= 0.02066$ kW

$\dot{Q}_{inf.,d} = \frac{\dot{V}f}{vo}\ (h_o – h_i)$

$\dot{V}f = K \times L\ [0.613\ (S_1\times S_2\times v_\circ)^2\ ]^{2/3}$

$L = [(2\times 2) + (2\times1)]$

$= 6$ m

Therefore ;

$\dot{V}f = (0.43)\ (6)\ [0.613(0.9 \times 0.75 \times 1.4)^2\ ]^{2/3}$

$= 1.726\ m^3/h$

$= 4.79\times 10^{-4}\ m^3/s$

$\dot{Q}_{inf.,d} = \rho_o \dot{V} f\ (h_i - h_o)$

$= (1.267)(4.79\times10^{-4})(69.06 - 47.79)$

$= 0.01667$ kW

$\dot{Q}_{inf.,tot} = \dot{Q}_{inf.,g} + \dot{Q}_{inf.,d}$

$= 0.0336$ kW

Heat gain due to occupants ($Q_{oc.}$):

Sensible and latent heat gains from occupants must be removed from the conditioned space. The heat gain due to occupants is the following:

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

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

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

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

No. of people = 6

$(CLF)_{oc.}$ = 0.89 at 9 hours after each entry into space is obtained from Table A(2.19)

$Q_{sensible} = 70 \times 6 \times 0.89$

$= 373.8$ W

Q_{latent} = heat gain latent × No. of people (2.27)

heat gain latent = 44… very light work from Table A(2.18)

$Q_{latent} = 44 \times 6$

$= 264$ W

$Q_{oc.} = 373.8 + 264$

$= 637.8$ W

$= 0.6378$ kW

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

Mechanical ventilation is required for places in which the inside air is polluted due to activities that place in these spaces as factories, restaurants, closed parking areas, etc. The amount of outside fresh air recommended for mechanical ventilation for different applications is listed in Table A(2.20). The sensible and total cooling loads required to cool the ventilated air to the inside room temperature is calculating by the following equation:

$$\dot{Q}_{vn.} = \dot{m} \times Cp_{air} \times (T_{out} - T_{in}) \qquad (2.28)$$

Where:

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

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

$$\dot{m} = \frac{\text{rate of ventilation air}}{\text{vo}} \qquad (2.29)$$

rate of ventilation air = A_{room} × requirement outside ventilation air (2.30)

$A_{room} = 28.11\ m^2$

requirement outside ventilation air = 10 L/s/m^2 … from Table A(2.20)

rate of ventilation air = 28.11 × 10

= 281.1 L/s

= 0.2811 m^3/s

$v_o = 0.879 m^3/kg$

$\dot{m}$ = 0.2811/0.879

= 0.319 kg/s

$Q_{vn.}$ = 0.319 × 1.005 × (30 - 24)

= 1.92 W

= 0.0019 kW

The total heat loss from Guest Room is:

$$Q_{Tot} = Q_{Roof} + Q_{Wall} + Q_{un.} + Q_{Glass} + Q_{Lt} + Q_f + Q_{oc.} + Q_{vn.} \qquad (2.31)$$

= 0.1030 -0.0278 + 0.2204 + 0.1906 + 0.3542 + 0.0336 + 0.6378 + 0.0019

= 1.56 kW

Cooling Load Summary is listed in the following table:

Table (2.8): Cooling load for each flat in the building

Flat No.	Cooling Load (kW)	Flat No.	Cooling Load (kW)
1	10.3842	7	13.3287
2	10.2634	8	13.2777
3	13.3287	9	13.3287
4	13.2777	10	13.2777
5	13.3287	11	10.1697
6	13.2777	12	10.0489

The total cooling load for the building = 147.2918 kW

Chapter Three

Variable Refrigerant Flow System

3.1 Variable Refrigerant Flow System

3.1.1 Overview

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

Variable refrigerant flow (VRF) is an air conditioning 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.

3.1.2 Variable refrigerant flow description

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

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

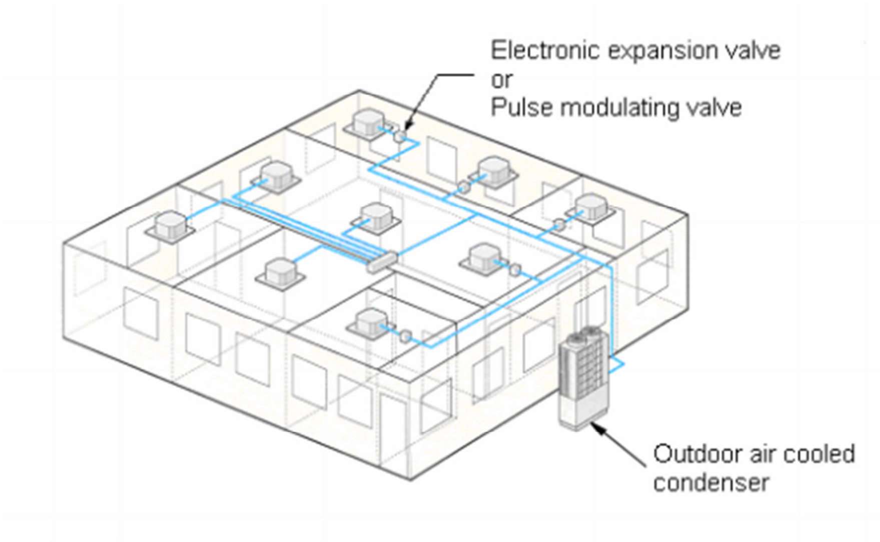
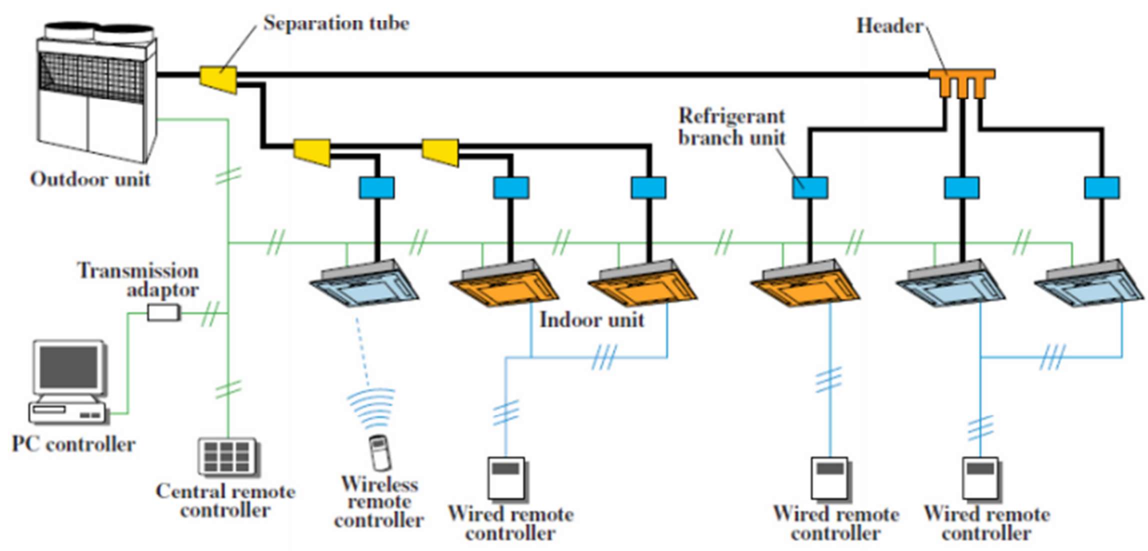


Figure (3.1): VRF System with multiple indoor evaporate units

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

Refrigerant piping runs of more than 200 ft are possible, and outdoor units are available in sizes up to 240,000 Btu/ h (60478.98 kW).

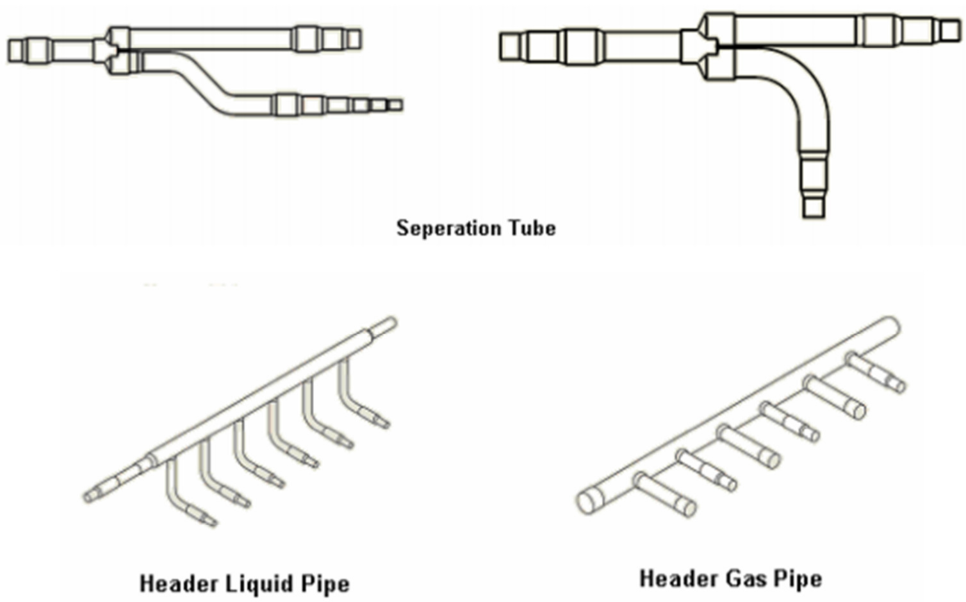
A schematic VRF arrangement is indicated below:



[9] Figure (3.2): A schematic VRF arrangement

VRF systems are engineered systems and use complex refrigerant and oil control circuitry. The refrigerant pipe-work uses a number of separation tubes and/or headers (refer schematic figure above).

A separation tube has 2 branches whereas a header has more than 2 branches. Either of the separation tube or header, or both, can be used for branches. However, the separation tube is never provided after the header because of balancing issues.



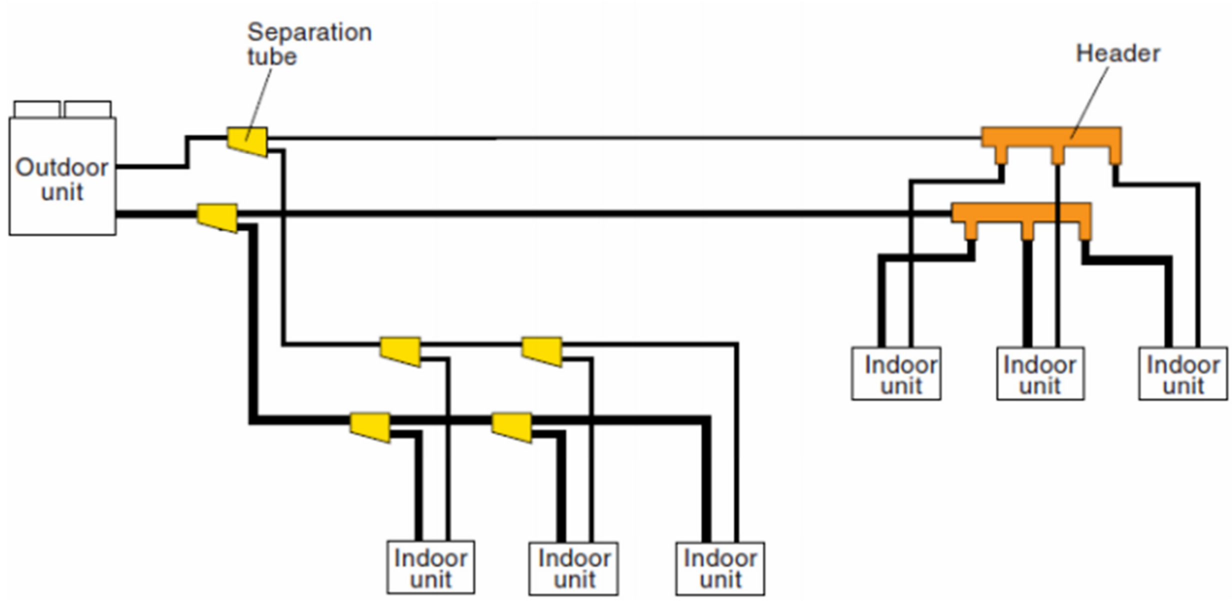
[9] Figure (3.3): Separation and header tubes

3.1.3 Types of VRF

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

<u>VRF heat pump systems</u>

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



[9] Figure (3.4): VRF heat pump systems

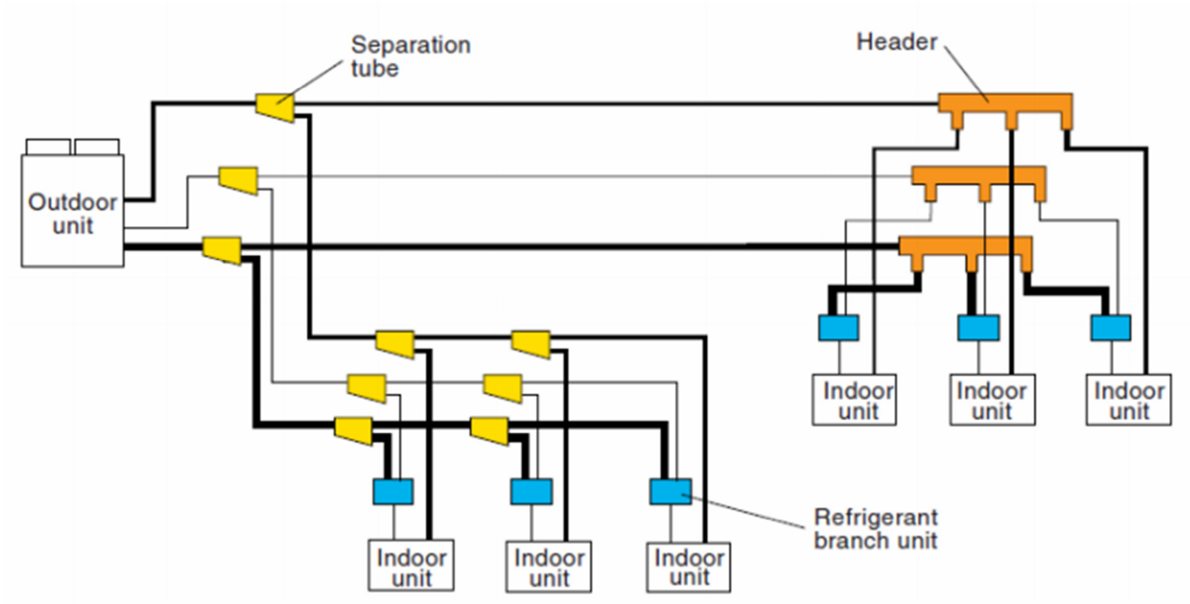
VRF heat pump systems are effectively applied in open plan areas, retail stores, cellular offices and any other areas that require cooling or heating during the same operational periods.

Heat Recovery VRF system (VRF-HR)

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

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

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



[9] Figure (3.5): Heat recovery type VRF system

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

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

This project deals with VRF heat pump systems.

3.1.4 Refrigerant modulation in a VRF system

VRV/VRF technology is based on the simple vapor compression cycle (same as conventional split air conditioning systems) but gives you the ability to continuously control and adjust the flow of refrigerant to different internal units, depending on the heating and cooling needs of each area of the building. The refrigerant flow to each evaporator is adjusted precisely through a pulse wave electronic expansion valve in conjunction with an inverter and multiple compressors of varying capacity, in response to changes in the cooling or heating requirement within the air conditioned space. [9]

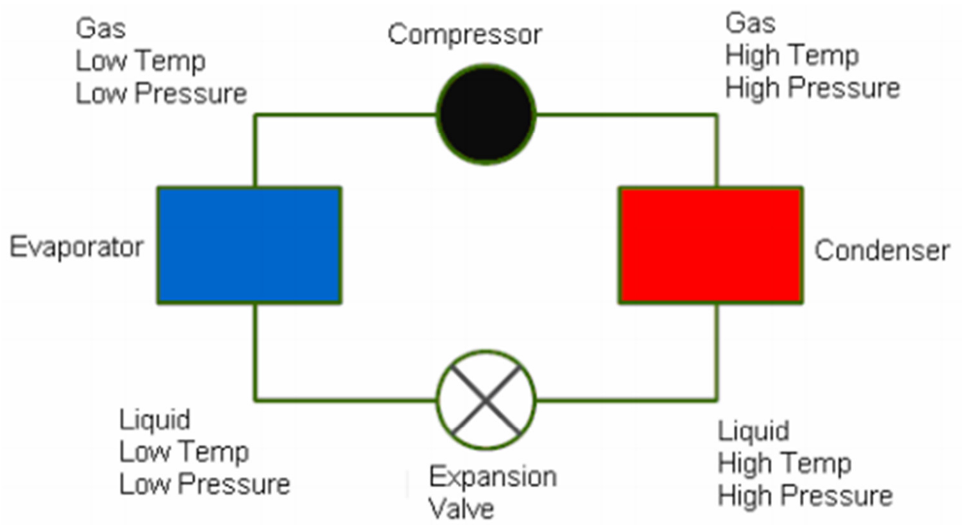


Figure (3.6): Basic refrigeration cycle

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

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

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

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

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

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

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

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

3.1.5 Design considerations for VRF system

Deciding what HVAC system best suits your application will depend on several variables such as building characteristics, cooling and heating load requirements, peak occurrence, simultaneous heating and cooling requirements, fresh air needs, accessibility requirements, minimum and maximum outdoor temperatures, sustainability, and acoustic characteristics. [9]

Building Characteristics

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

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

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

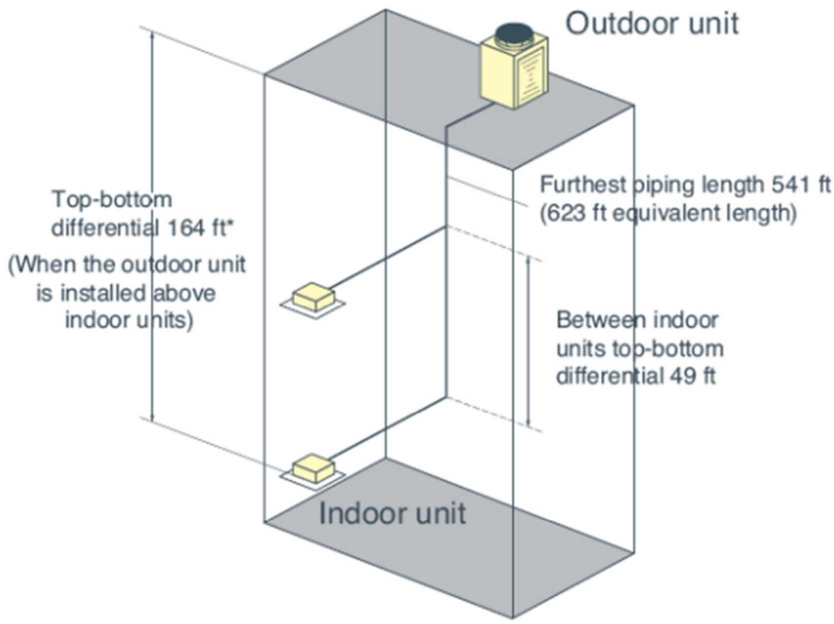
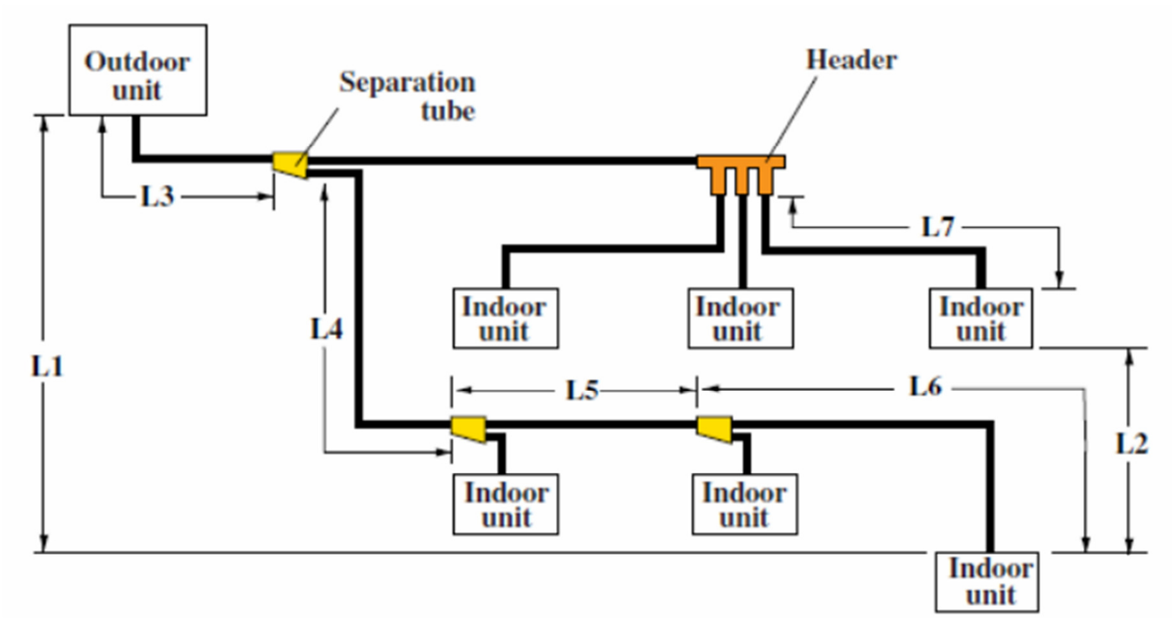


Figure (3.7): Design limits in VRF system

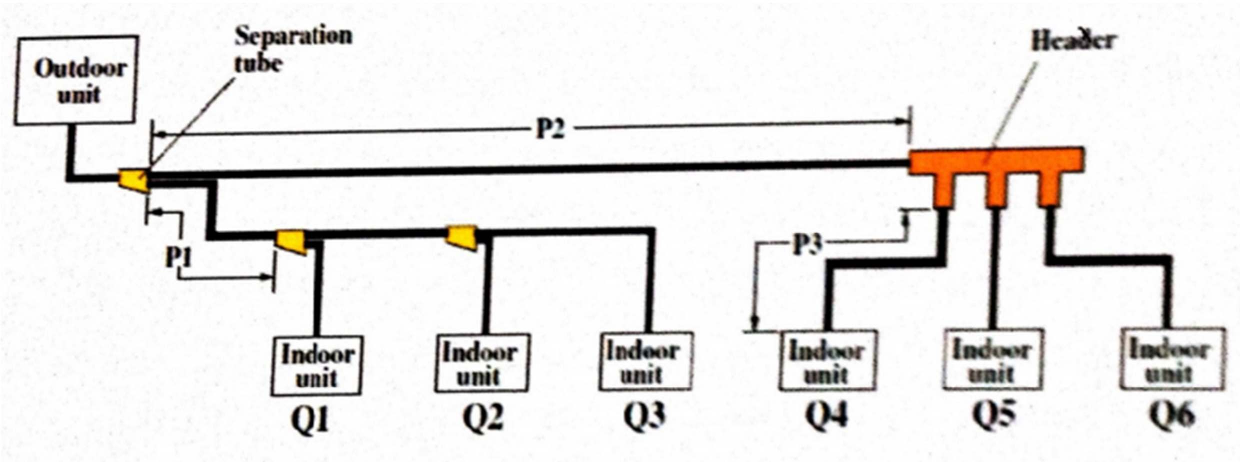
As stated, the refrigerant piping criteria varies from manufacturer to manufacture, for example for one of the Japanese manufacturer (Fujitsu), the system design limits are:



[9] Figure (3.8): Design limits in (Fujitsu) VRF system

- L1: Maximum height difference between outdoor unit and indoor unit = 50m
- L2: Maximum height difference between indoor unit and indoor unit = 15m

- L3: Maximum piping length from outdoor unit to first separation tube = 70m
- [L3+L4+L5+L6]: Maximum piping length from outdoor unit to last indoor unit = 100m
- L6 & L7: Maximum piping length from header to indoor unit = 40m
- Total piping length = 200m (Liquid pipe length)



[9] Figure (3.9): Pipe sizing for VRF system

- Size of P1: Depends on the total capacity of (Q1+Q2+Q3)
- Size of P2: Depends on the total capacity of (Q4+Q5+Q6)
- Size of P3: Depends on the total capacity of (Q4)

Building Load Profile

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

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

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

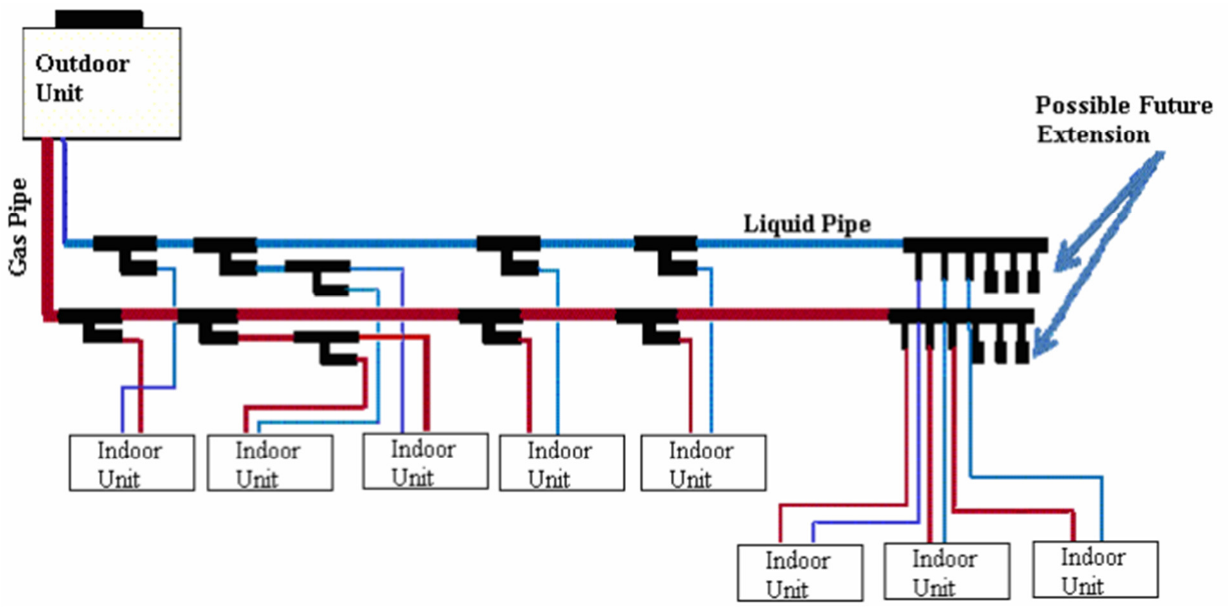
The combined cooling capacity of the indoor sections can match, exceed, or be lower than the capacity of the outdoor section connected to them. But as a normal practice:

- The indoor units are typically sized and selected based on the greater of the heating or cooling loads in the zone it serves, i.e. maximum peak load expected in any time of the year.
- The outdoor condensing unit is selected based on the load profile of the facility which is the peak load of all the zones combined at any one given time. The important thing here is that it is unlikely that all zones will peak at a given time so an element of diversity is considered for economic sizing. Adding up the peak load for each indoor unit and using that total number to size the outdoor unit will result in an unnecessarily oversized condensing unit. Although an oversized condensing unit with multiple compressors is capable of operating at lower capacity, too much over sizing sometimes reduces or ceases the modulation function of the expansion valve. As a rule of thumb, an engineer can specify an outdoor unit with a capacity anywhere between 70% and 130% of the combined capacities of the indoor units.

Sustainability

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

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



[9] Figure (3.10): Pipe work schematic

Other sustainability factors include:

- Use of non-ozone depleting environment-friendly refrigerants such as R 410a

- Opting for heat pump instead of electrical resistance heating in areas demanding both cooling and heating.

Heat pumps offer higher energy efficiency.

Simultaneous Heating and Cooling

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

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

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

First Costs

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

3.1.6 Advantages of VRF system

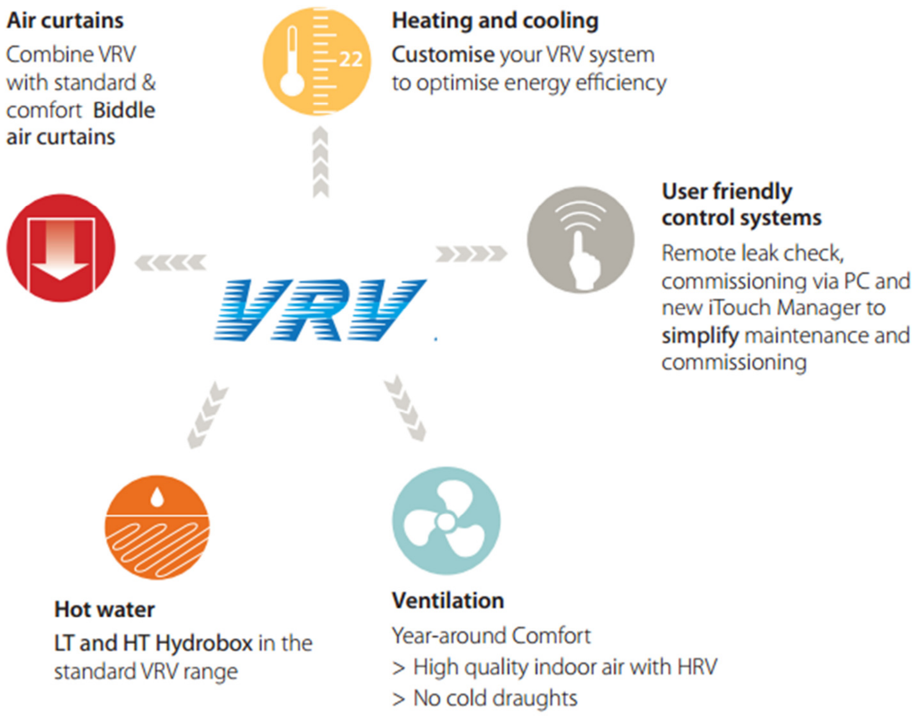


Figure (3.11): VRV provides a total solution for integrated climate control

VRF systems have several key benefits, including:

1. Installation Advantages.
   VRF systems are lightweight and modular. Each module can be transported easily and fits into a standard elevator.
2. Design Flexibility.
   A single condensing unit can be connected to many indoor units of varying capacity (e.g., 0.5 to 4 tons [1.75 to 14 kW]) and configurations (e.g., ceiling recessed, wall mounted, floor console). Current products enable up to 20 indoor units to be supplied by a single condensing unit. Modularity also makes it easy to adapt the HVAC system to expansion or reconfiguration of the space, which may require additional capacity or different terminal units.
3. Maintenance and Commissioning**.**
   VRF systems with their standardized configurations and sophisticated electronic controls are aiming toward near plug-and-play commissioning.
4. Comfort.
   Many zones are possible, each with individual set point control. Because VRF systems use variable speed compressors with wide capacity modulation capabilities, they can maintain precise temperature control, generally within ±1°F (±0.6°C), according to manufacturers' literature.

5. Energy Efficiency.
   The energy efficiency of VRF systems derives from several factors. The VRF essentially eliminates duct losses, which are often estimated to be between (10-20) percent of total airflow in a ducted system. VRF systems typically include two to three compressors, one of which is variable speed, in each condensing unit, enabling wide capacity modulation. This approach yields high part-load efficiency, which translates into high seasonal energy efficiency, because HVAC systems typically spend most of their operating hours in the range of 40% to 80% of maximum capacity.
6. Refrigerant piping runs of more than 200 feet (60.96 m) are possible and outdoor units are available in sizes up to 240,000 Btu/ h (60478.98 kW).

3.1.7 Selection units

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

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

Outdoor unit

It was chosen three outdoor units with capacity of individual is 14 Ton (AM168FXVAFH/AA)

Indoor unit

In this project there are two types of indoor units selected, which are split and cassette units. The split unit is used for bedrooms, and the cassette units are used for guest rooms, living rooms, and kitchen.

The figure below shows the two types of selected units:

[10] Figure (3.12): Spilt and cassette indoor units

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

Table (3.1): Indoor units for first floor

Room Name	Heating Load (Kw)	Cooling Load (Kw)	Indoor Unit Type	Indoor Unit Name	Dimension (Mm)
A-Master Bedroom	0.91	1.74	Split	AM007FNTDCH/AA	825×285×189
A-Bedroom 1	0.60	0.88	Split	AM007FNTDCH/AA	825×285×189
A-Bedroom 2	1.04	1.20	Split	AM007FNTDCH/AA	825×285×189
A-Guest Room	2.16	1.96	Cassette	AM009FNNDCH/AA	575×250×575
A-Living Room	1.13	2.23	Cassette	AM009FNNDCH/AA	575×250×575
A-Kitchen	1.04	1.50	Cassette	AM009FNNDCH/AA	575×250×575
B-Master Bedroom	0.91	1.65	Split	AM007FNTDCH/AA	825×285×189
B-Bedroom 1	0.60	0.93	Split	AM007FNTDCH/AA	825×285×189
B-Bedroom 2	1.04	1.14	Split	AM007FNTDCH/AA	825×285×189
B-Guest Room	2.16	0.93	Cassette	AM009FNNDCH/AA	575×250×575
B-Living Room	1.13	2.23	Cassette	AM009FNNDCH/AA	575×250×575
B-Kitchen	1.04	1.49	Cassette	AM009FNNDCH/AA	575×250×575

Table (3.2): Indoor units for second, third, fourth, fifth floors

Room Name	Heating Load (Kw)	Cooling Load (Kw)	Indoor Unit Type	Indoor Unit Name	Dimension (Mm)
A-Master Bedroom	0.67	1.74	Split	AM007FNTDCH/AA	825×285×189
A-Bedroom 1	0.40	1.66	Split	AM007FNTDCH/AA	825×285×189
A-Bedroom 2	0.78	0.82	Split	AM007FNTDCH/AA	825×285×189
A-Guest Room	1.75	0.68	Cassette	AM009FNNDCH/AA	575×250×575
A-Living Room	0.70	0.82	Cassette	AM009FNNDCH/AA	575×250×575
A-Kitchen	0.76	1.34	Cassette	AM009FNNDCH/AA	575×250×575
B-Master Bedroom	0.67	1.68	Split	AM007FNTDCH/AA	825×285×189
B-Bedroom 1	0.40	1.57	Split	AM007FNTDCH/AA	825×285×189
B-Bedroom 2	0.78	0.80	Split	AM007FNTDCH/AA	825×285×189
B-Guest Room	1.75	0.68	Cassette	AM009FNNDCH/AA	575×250×575
B-Living Room	0.70	1.46	Cassette	AM009FNNDCH/AA	575×250×575
B-Kitchen	0.76	1.68	Cassette	AM009FNNDCH/AA	575×250×575

Table (3.3): Indoor units for sixth floor

Room Name	Heating Load (Kw)	Cooling Load (Kw)	Indoor Unit Type	Indoor Unit Name	Dimension (Mm)
A-Master Bedroom	0.92	1.72	Split	AM007FNTDCH/AA	825×285×189
A-Bedroom 1	0.64	0.86	Split	AM007FNTDCH/AA	825×285×189
A-Bedroom 2	1.23	1.17	Split	AM007FNTDCH/AA	825×285×189
A-Guest Room	2.10	0.86	Cassette	AM009FNNDCH/AA	575×250×575
A-Living Room	1.23	2.18	Cassette	AM009FNNDCH/AA	575×250×575
A-Kitchen	1.05	1.47	Cassette	AM009FNNDCH/AA	575×250×575
B-Master Bedroom	0.92	1.63	Split	AM007FNTDCH/AA	825×285×189
B-Bedroom 1	0.64	0.91	Split	AM007FNTDCH/AA	825×285×189
B-Bedroom 2	1.23	1.12	Split	AM007FNTDCH/AA	825×285×189
B-Guest Room	2.10	0.91	Cassette	AM009FNNDCH/AA	575×250×575
B-Living Room	1.23	2.18	Cassette	AM009FNNDCH/AA	575×250×575
B-Kitchen	1.05	1.46	Cassette	AM009FNNDCH/AA	575×250×575

3.2 Mechanical ventilation

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

There are two ways for Ventilation:

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

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

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

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

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

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

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

3.2.1 Purposes of ventilation

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

3.2.2 Designing of mechanical ventilation

Steps of designing mechanical ventilation:

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

3.2.3 Sample calculation

Using bathroom:

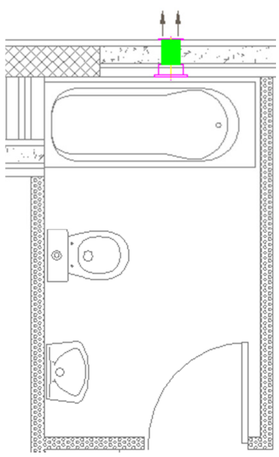


Figure (3.13): Bathroom layout

- The volume is 15.2 m^3
-

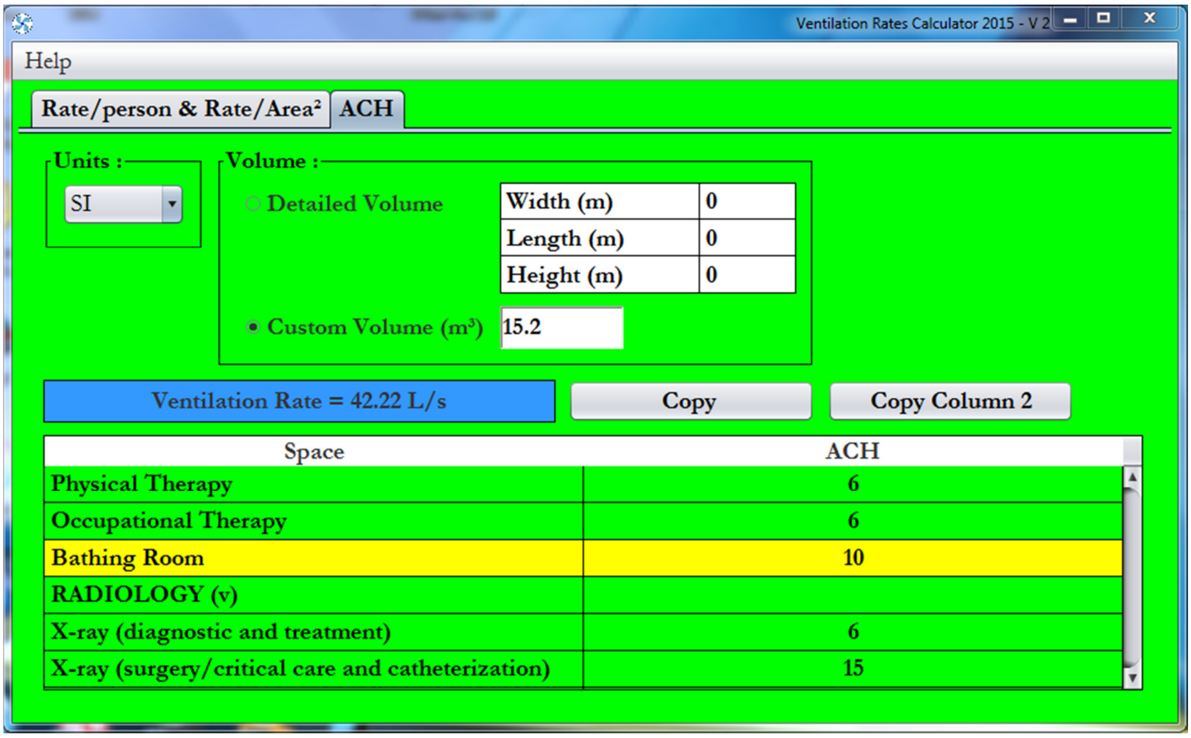


Figure (3.14): Ventilation rates calculator

Table (3.4): Ventilation rate

Room	Volume (m^3)	Ventilating Rate	
		(L/s)	(CFM)
Kitchen	57.8	57.8	122.47
Bathroom 1	15.2	42.22	89.46
Bathroom 2	8.91	24.75	52.44
Bathroom 3	16.74	46.5	98.53

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.

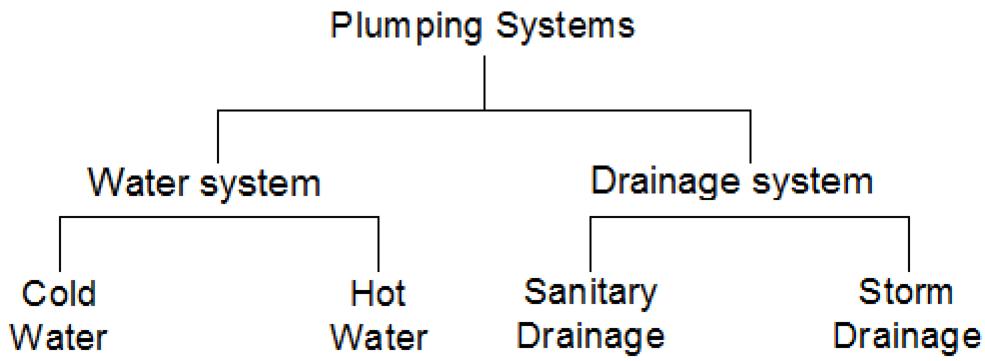


Figure (4.1): Plumping systems

The other part of this chapter is about grey water treatment which means all waste water that is discharged from a building excluding black water. This includes water from showers, bathtubs, sinks, kitchen, dishwashers, laundry tubs, and washing machines.

The main purpose of grey water recycling and treatment is to substitute the precious drinking water in applications which do not require drinking water quality; with grey water recycling it is possible to reduce the amounts of fresh water consumption as well as wastewater production in addition to reducing the water bills.

In water treatment the main process is using the sand filter to achieve the required percentage of recycled water.

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 50 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 Fixture units load for the first riser

For a private, flush tank system, first riser and symmetry floors, using Table A(5.1) has the following:

Table (4.1): Fixture units load

Fixture type	No. FU	WSFU	Tot. WSFU	Cold WSFU	Hot WSFU	Tot. cold	Tot. hot
Kitchen sink	1	2	2	2x3/4=1.5	2x3/4=1.5	1.5	1.5
Lavatory	3	1	3	1x3/4=3/4	1x3/4=3/4	2.25	2.25
Water closet	3	3	9	3	0	9	0
Bathtub	2	2	4	2x3/4=1.5	2x3/4=1.5	3	3
Dishwasher	1	1	1	1	0	1	0
C. washer	1	2	2	2	0	2	0
Total(WSFU)			21			18.75	6.75

The total amount of water supply fixture unit is 21×6 = 126 total fixture unit load so we use the Table (4.2) for estimating demand to calculate the required amount of water which is equal 50 gallon per minute (gpm) using following interpolation.

120 wsfu → 49 gpm
126wsfu → X gpm
140 wsfu → 53 gpm

X=50 gpm

Same calculation for the second riser used on the other side of the building.

4.2.2.2 Sizing of pipes

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

Main pressure = static head + friction head + flow pressure (4.1)

Where:

Static head is to overcome the height.

Friction head is to overcome friction in pipes.

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

Assume that the shower fixture that at the 6th floor is the critical fixture unit, by Table A(4.3) flow pressure = 8psi.

Static pressure:

Six floors with 3.5 m for each one, half meter for the high of fixture unit.

Main pressure = 50 psi.

Pump pressure

So, the equation will be as following:

Friction head = main pressure – static pressure –flow pressure

= 50 – 28.21-8

= 13.79 psi.

Equivalent length = ((1.8 +1.89+21+0.35+10.26+0.5) ×1.5) / 0.33

= 162.72 ft

Friction head loss psi / 100 ft, by the relation

= (13.79 psi × 100 ft) / 162.72 ft

= 8.5 psi/ 100ft

Referring to the Figure A(4.1) and using steel pipes the diameter exactly equal to 1.5" in. and the velocity is 9.2 fps, the following table shows the pipe sizing for all sections of the cold water riser**.**

Table 4.2: Pipe sizing for cold water riser

Section number	Flow (gpm)	Equivalent length(ft)	Pipe size (in)	Friction(psi /100ft)	Velocity (fps)	Section friction (psi)	Cumulative friction (psi)
Pump-1st riser	50	32.7	1.5"	8.5	9.2	2.78	2.78
2nd riser section	42.2	15.9	1.5"	6.5	6.8	1.03	3.81
3rd riser section	37.5	15.9	1.5"	4.4	6.3	0.7	4.51
4th riser section	31.5	15.9	1.5"	3.4	6	0.54	5.05
5th riser section	23.75	15.9	1.5"	2.2	4.1	0.35	5.4
6th riser section	13.25	15.9	1.25"	1.4	3	0.22	5.6
Run out	7	46.6	0.5"	0.6	2	0.28	5.8

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

Table 4.3: Pipe sizing for hot water riser

Section number	Flow (gpm)	Equivalent length(ft)	Pipe size (in)	Friction(psi /100ft)	Velocity (fps)	Section friction (psi)	Cumulative friction (psi)
Hot water tap to 1st riser	25.2	34	1.25"	8.5	7.8	2.89	2.89
2nd riser section	21.87	15.9	1.25 "	3.7	5.3	0.59	3.5
3rd riser section	18.2	15.9	1.25 "	2.8	4.4	0.45	3.9
4th riser section	14.15	15.9	1.25"	1.5	3.2	0.24	4.1
5th riser section	10.1	15.9	1.25"	1	2.5	0.16	4.3
6th riser section	5.56	15.9	1.25"	0.37	1.4	0.06	4.36
Run out	13.25	15.39	0.5"	0.7	2.1	0.03	3.5

The diameter will be select for hot riser is 1.25 in.

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

4. 3 Water tank volume

Water tank volume can be determined by multiplying the amount of gpm by 3 as a factor to ensure the availability of water source.

Then, 100 gpm are the total demand for the building and two risers.

So: 100×3 = 300 gpm.

Converting 300 gpm the result is 82 cubic meters that will the underground tank volume for water building demand.

4.4 Water pump selection

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

4.4.1 Flow rate determination

According to the previews calculation and equation estimation, the total flow rate for the first riser is 50gpm and the same for another one, so by converting 50gpm equal to 11.3$m^{\wedge 3}$/h.

4.4.2 Head estimation

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

Height of the building = 3.5m * 7floors = 24.5 m.

Dividing 24.5 by 10 = 2.4 bar

Adding 1 bar for fittings losses the value is almost 3.5 bar

4.4.3 Pump selection

Using dp-select software and with filling data into brackets as follow [6].

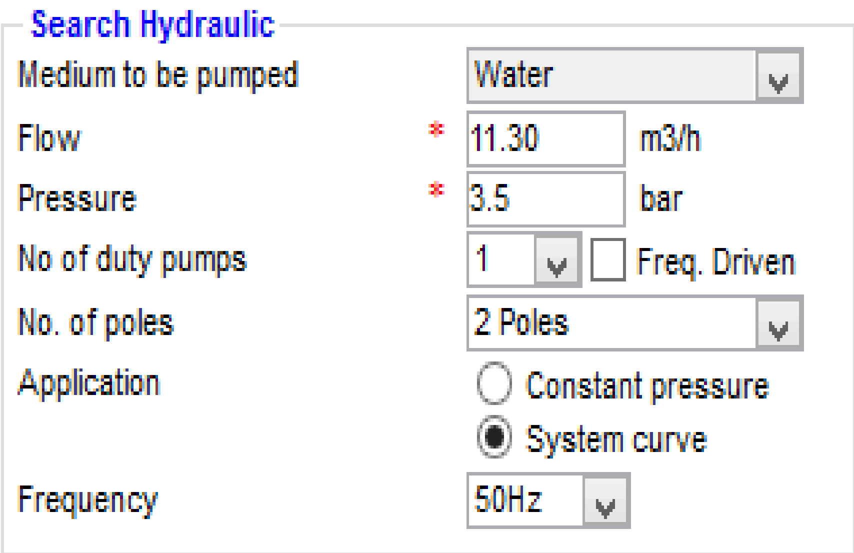


Figure (4.2): Pump data

The pump model selected “DPV 10/5 B”.

The characteristic curves of this pump as follow:

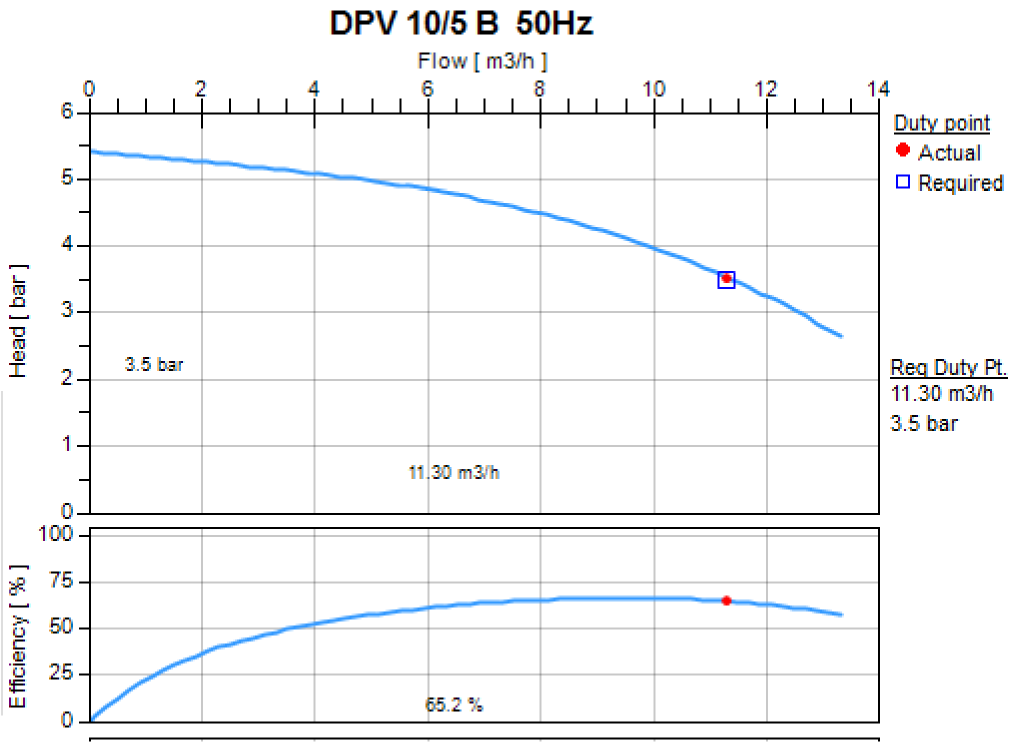


Figure (4.3): Pump characteristic curves

4.5 Drainage system

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

The provision of drainage systems:

- Sanitary drainage
- Storm drainage

4.5.1 Drainage system components

The main components of drainage system are:

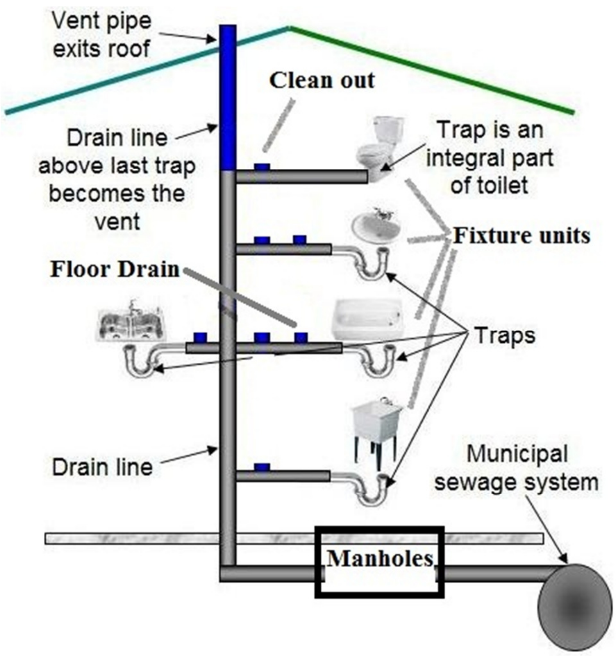


Figure (4.4): Drainage system components

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

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

4.5.2 Sanitary drainage

4.5.2.1 Design procedure and pipe sizing

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

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

The recommended velocity for drainage piping:

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

Velocity of water flow through drainage piping depends on:

- Pipe diameter
- Slope

Minimum slope requirements for horizontal drainage piping:

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

Design procedure:

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

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

4.5.2.2 Pipe sizing for gray water

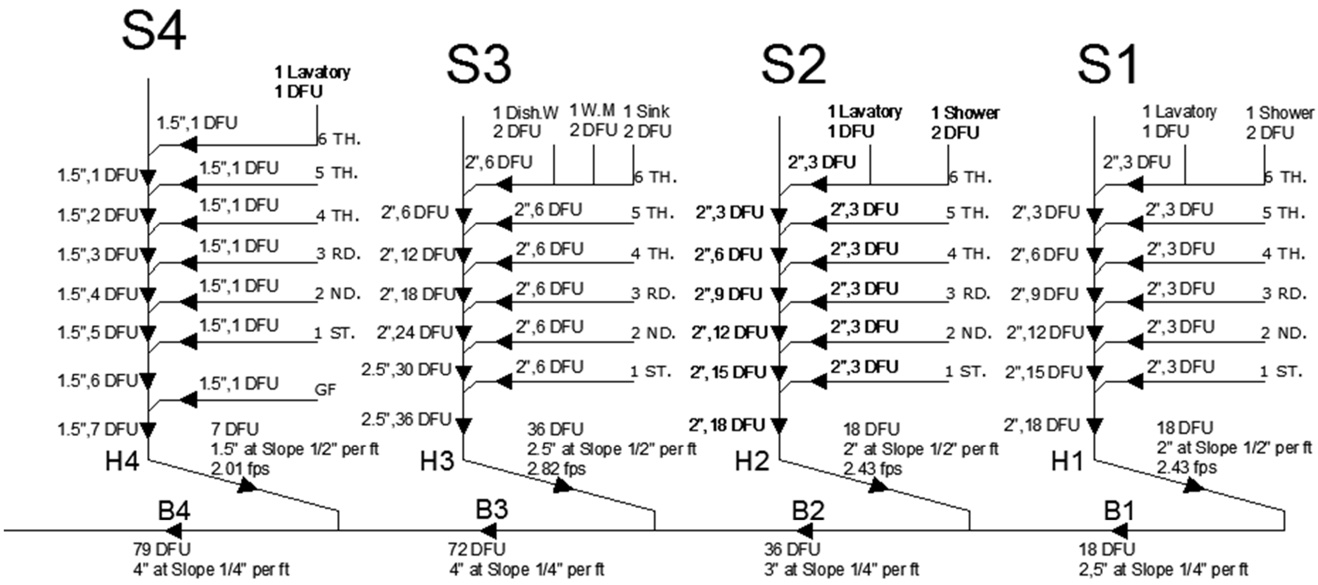


Figure (4.5): Gray water pipe sizing

Table (4.4): Sizing of stack 1

Floor	Stack		Branch	
	Total DFU	Diameter (in)	Total DFU	Diameter (in)
Sixth	3	2	3	2
Fifth	6	2	3	2
Fourth	9	2	3	2
Third	12	2	3	2
Second	15	2	3	2
First	18	2	3	2

Table (4.5): Sizing of stack 2

Floor	Stack		Branch	
	Total DFU	Diameter (in)	Total DFU	Diameter (in)
Sixth	3	2	3	2
Fifth	6	2	3	2
Fourth	9	2	3	2
Third	12	2	3	2
Second	15	2	3	2
First	18	2	3	2

Table (4.6): Sizing of stack 3

Floor	Stack		Branch	
	Total DFU	Diameter (in)	Total DFU	Diameter (in)
Sixth	6	2	6	2
Fifth	12	2	6	2
Fourth	18	2	6	2
Third	24	2	6	2
Second	30	2.5	6	2
First	36	2.5	6	2

Table (4.7): Sizing of stack 4

Floor	Stack		Branch	
	Total DFU	Diameter (in)	Total DFU	Diameter (in)
Sixth	1	1.5	1	1.5
Fifth	2	1.5	1	1.5
Fourth	3	1.5	1	1.5
Third	4	1.5	1	1.5
Second	5	1.5	1	1.5
First	6	1.5	1	1.5
Ground	7	1.5	1	1.5

Table (4.8): Branches of building drain

Branch of building drain	Total DFU	Diameter (in)	Slope (in/ft)	Velocity (ft/s)
H1	18	2	0.5	2.43
H2	18	2	0.5	2.43
H3	36	2.5	0.5	2.82
H4	7	1.5	0.5	2.01

Table (4.9): Building drain

building drain	Total DFU	Diameter (in)	Slope (in/ft)
B1	18	2.5	0.25
B2	36	4	0.25
B3	72	4	0.25
B4	79	4	0.25

4.5.2.3 Pipe sizing for black water

Note: all stacks are the same, because of symmetry.

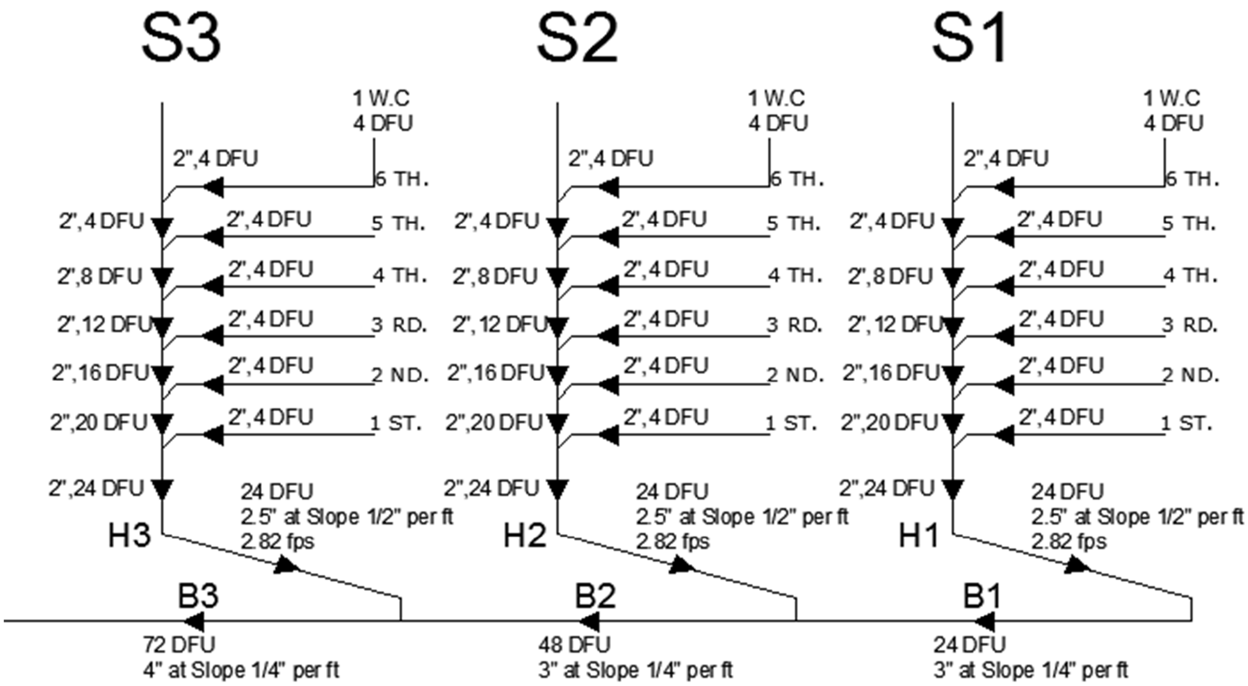


Figure (4.6): Black water pipe sizing

Table (4.10): Sizing of black water stacks

	Stack		Branch	
Floor	Total DFU	Diameter (in)	Total DFU	Diameter (in)
Sixth	4	2	4	2
Fifth	8	2	4	2
Fourth	12	2	4	2
Third	16	2	4	2
Second	20	2	4	2
First	24	2	4	2

Table (4.11): Branches of building drain

Branch of building drain	Total DFU	Diameter (in)	Slope (in/ft)
H1	24	2.5	0.5
H2	24	2.5	0.5
H3	24	2.5	0.5

Table (4.12): Building drain

building drain	Total DFU	Diameter (in)	Slope (in/ft)
B1	24	2.5	0.25
B2	48	3	0.25
B3	72	4	0.25

The diameter of branches and stacks that selected is 4" for both gray and black water.

The figure below shows the distribution method of piping:

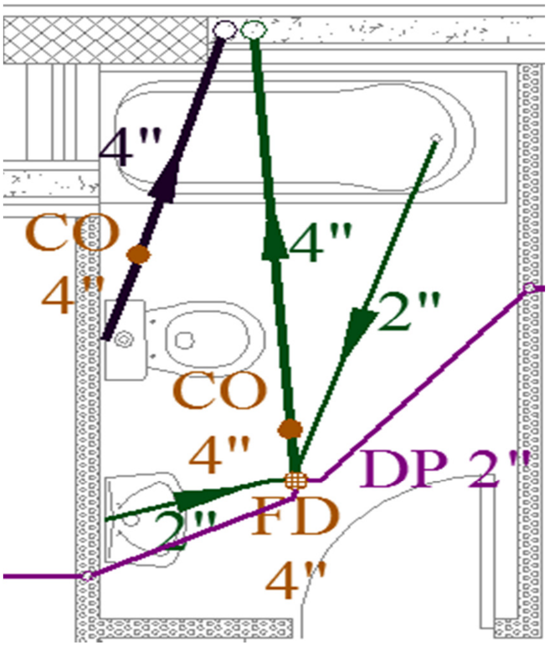


Figure (4.7): Distribution of piping in bathroom

4.5.3 Storm drainage

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

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

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

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

The roof area of this building is 356.3 m^2, and therefore needs three 4" FD.

4.5.4 Manhole design

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

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

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

According to the table below, it will be estimated the diameter of the manhole according to their depth. [11]

Table (4.13): Diameter of the manhole according to their depth

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

4.5.4.1 Manhole calculation

The depth of the first manhole is 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
- Top level: Manholes face level on the ground
- (Invert level = Top level - Depth) in m
- Outlet level = - (Depth - 0.05) in m

The figure below shows the details of the manholes:

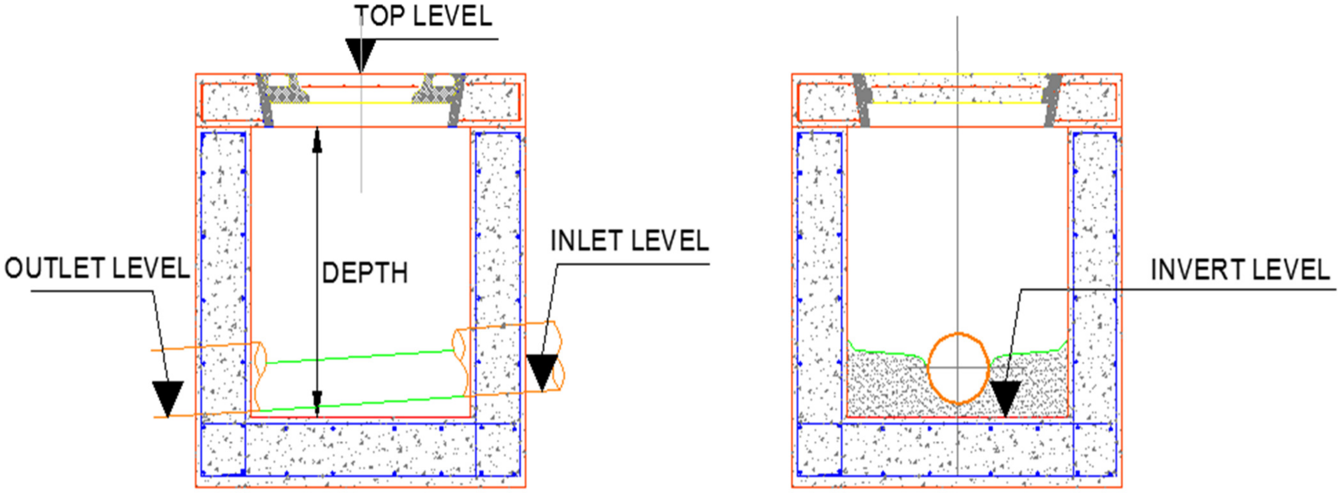


Figure (4.8): Manholes details

The result calculation of the gray water and black water manholes is listed in the tables below:

Table (4.14): Gray water manholes

Manhole No.	Top level (m)	Invert level (m)	Outlet level (m)	Depth (cm)	Dia. Size (cm)	Cover Type
M01	±0.00	-0.50	-0.45	50	60	Concrete
M02	±0.00	-0.64	-0.59	64	60	Concrete
M03	-0.20	-1.25	-1.00	105	80	Concrete
M04	-0.20	-1.59	-1.34	139	80	Concrete
M05	-0.20	-2.94	-2.67	272	125	Concrete
M06	-0.20	-2.59	-2.34	239	100	Concrete
M07	-0.20	-2.27	-2.02	207	100	Concrete
M08	-0.20	-1.94	-1.69	174	100	Concrete
M09	-0.20	-1.59	-1.34	139	80	Concrete
M10	-0.20	-1.25	-1.00	105	80	Concrete
M11	±0.00	-0.64	-0.59	64	60	Concrete
M12	±0.00	-0.50	-0.45	50	60	Concrete

Table (4.15): Black water manholes

Manhole No.	Top level (m)	Invert level (m)	Outlet level (m)	Depth (cm)	Dia. Size (cm)	Cover Type
M01	-0.20	-0.70	-0.45	50	60	Concrete
M02	±0.00	-0.91	-0.86	91	80	Concrete
M03	±0.00	-1.08	1.03	108	80	Concrete
M04	-0.20	-0.70	-0.45	50	60	Concrete
M05	±0.00	-0.91	-0.86	91	80	Concrete
M06	±0.00	-1.08	1.03	108	80	Concrete
M07	±0.00	-1.19	-1.14	119	80	Concrete
M08	±0.00	-1.35	-1.30	135	80	Concrete

Chapter Five

Gray Water Treatment

5.1 Overview

Gray water is all wastewater that is discharged from a house, excluding blackwater (toilet water). This includes water from showers, bathtubs, sinks, kitchen, dishwashers, laundry tubs, and washing machines.

It commonly contains soap, shampoo, toothpaste, food scraps, cooking oils, detergents and hair. Gray water makes up the largest proportion of the total wastewater flow from households in terms of volume. Typically, 50-80% of the household wastewater is gray water. The main difference between gray water and blackwater (sewage) is the organic loading. Sewage has a much larger organic loading compared to gray water.[5]

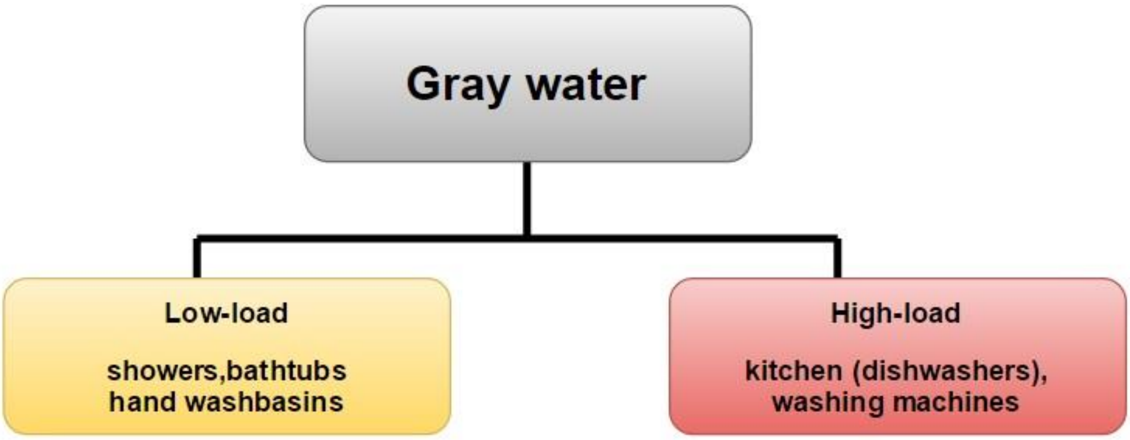


Figure (5.1): Gray water loads

Gray water from baths, showers, washbasins and washing machines has to be collected separately from blackwater, treated and eventually disinfected for reuse as a non-potable water source.

Garden irrigation is commonly applied, whereby gray water can be bucketed or diverted to the garden for immediate use. Advanced systems are also available that collect, filter and treat gray water for indoor use such as toilet flushing or laundry washing.

Laundry washing accounts for 10-30% of the average household water use. Gray water from laundry is easy to capture and with the right choice of laundry products, the treated gray water can be reused for flushing tank or irrigation.

5.2 Gray water quality

The quality of gray water between households, and even within households, varies daily depending on the activities of the household's occupants. In addition, the quality of gray water varies depending on the source of the water , see table (5.1). For most households gray water contains soap, shampoo, toothpaste, shaving cream, laundry detergents, hair, lint, body oils, dirt, grease, fats and chemicals (from soaps, shampoos, cosmetics). The most significant pollutant of gray water is laundry detergent, particularly those high in sodium and phosphorus. Greywater also contains bacteria, parasites and viruses washed from the body and clothes.[5]

Table (5.1) Characteristic of gray water

Water Source	Cloth Washing	Washing Of Utensils	Bathing	Kitchen
Bacteria		✓	✓	✓
Chlorine				
Foam	✓	✓		
Food Particles		✓		✓
Hair			✓	
High PH	✓	✓		
Nitrate	✓			
Odor		✓	✓	✓
Oil &Grease	✓	✓	✓	✓
Organics Matter		✓		✓
Oxygen Demand	✓	✓	✓	✓
Phosphate	✓			
Salinity	✓			
Soaps	✓	✓	✓	✓
Sodium	✓	✓		
Suspended Solids	✓	✓	✓	✓
Turbidity	✓	✓	✓	✓

5.3 Applications of recycled gray water

- Irrigation

Gray water typically breaks down faster than blackwater and has lower levels of nitrogen and phosphorus. However, all gray water must be assumed to have some blackwater-type components, including pathogens of various sorts. Gray water should be applied below the surface where possible (e.g via drip line on top of the soil) and not sprayed, as there is a danger of inhaling the water as an aerosol.

In any gray water system, it is important to avoid toxic materials such as bleaches, bath salts, artificial dyes, chlorine-based cleansers, strong acids/alkali, solvents, and products containing boron, which is toxic to plants at high levels.

- Indoor reuse

Recycled gray water from showers and bathtubs can be used for flushing toilets in most European and Australian jurisdictions and in United States jurisdictions that have adopted the International Plumbing Code.

Such a system could provide an estimated 35% reduction in water use for the average household. The danger of biological contamination is avoided by using:

1) A cleaning tank, to eliminate floating and sinking items
2) An intelligent control mechanism that flushes the collected water if it has been stored long enough to be hazardous; this completely avoids the problems of filtration and chemical treatment

Figure (5.2) summarizes the major possible applications for treated gray water.

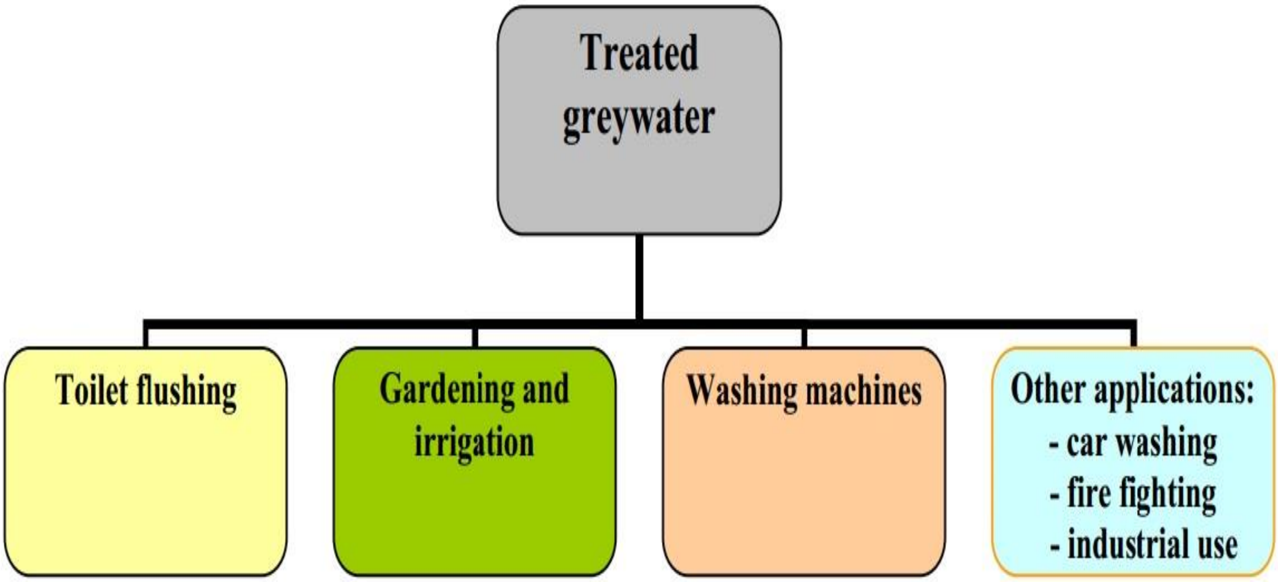


Figure (5.2): Major possible applications for treated gray water.

The advantage of recycling gray water is that it is a large source with a low organic content. To illustrate, gray water represents up to 70% of total consumed water but contains only 30% of the organic fraction and from 9 to 20% of the nutrients. Moreover, in an individual household, it has been established that gray water could support the amount of water needed for toilet flushing and outdoor uses such as car washing and garden watering.

There are studies in British society found the flushing tanks use represent 35% of total domestic water usage whereas gray water from shower, bath, wash basin, laundry and dishwasher correspond to 44%. Figure (5.3) shows the Distribution of domestic water usage in British society.

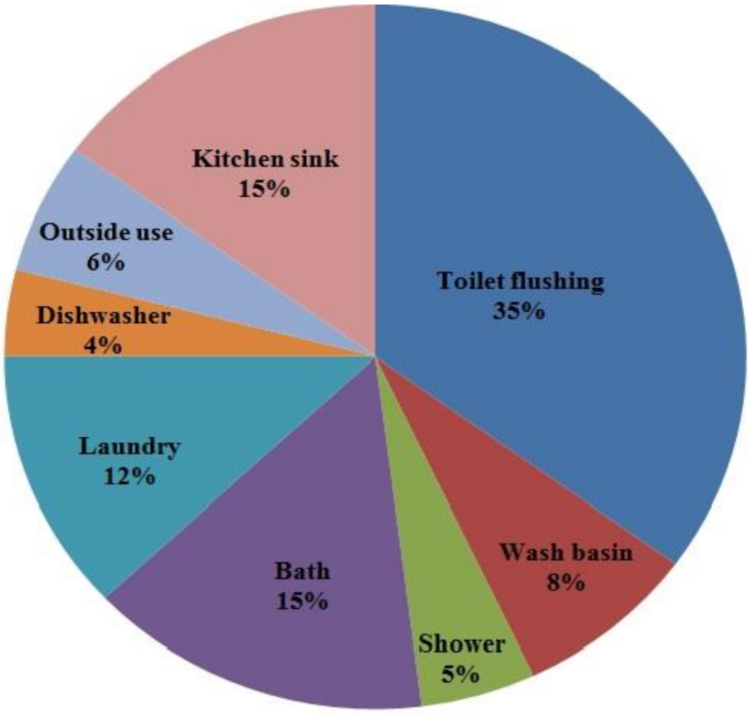


Figure (5.3): Distribution of domestic water usage

5.4 Gray water recycling

The main purpose of gray water recycling is to substitute the precious drinking water in applications which do not require drinking water quality. Non-potable reuse applications include industrial, irrigation, toilet flushing and laundry washing dependent on the technologies utilized in the treatment process. With gray water recycling, it is possible to reduce the amounts of fresh water consumption as well as wastewater production, in addition to reducing the water bills. If gray water is regarded as an additional water source, an increased supply for irrigation water can be ensured which will in turn lead to an increase in agricultural productivity.

Most gray water is easier to treat and recycle than blackwater, because of lower levels of contaminants. If collected using a separate plumbing system from blackwater, domestic gray water can be recycled directly within the home, garden or company and used either immediately or processed and stored. If stored, it must be used within a very short time or it will begin to putrefy due to the organic solids in the water. Recycled gray water of this kind is never safe to drink, but a number of stages of filtration and microbial digestion can be used to provide water for washing or flushing toilets. Some gray water may be applied directly from the sink to the garden or container field, receiving further treatment from soil life and plant roots. Given that gray water may contain nutrients, pathogens, and is often discharged warm, it is very important to store it before use for irrigation purposes, unless it is properly treated first.

When you take a bath, soap, shampoo, and other chemicals end up in the water together with your sweat, dead skin, hair, bacteria, and pathogens. If this cocktail is left in a water-butt for a few hot summers days it will start to smell awful. Vegetables and other edible crops watered with the recycled water could be also be tainted.

Gray water systems that involve storing gray water must treat the gray water to reduce the bacteria and other microorganisms that can multiply in stagnant water. Physical and chemical gray water treatment systems primarily utilize disinfection and filtration to remove contaminants while biological treatment uses aeration and membrane bioreactors.

In terms of treatment plan design, unit processes are classified into five groups or functions:

1) Preliminary treatment : The removal and disintegration of gross solid, the removal of grit and the separation of storm water. Oil and grease are also removed at this stage.
2) Primary (sedimentation) treatment : The first major stage of treatment following preliminary treatment, which usually involves the removal of settleable solids.
3) Secondary (biological) treatment : The dissolved and colloidal organic matter is oxidized by micro-organism.
4) Tertiary treatment : Further treatment of a biological treated effluent to remove remaining suspended solid, bacteria, specific toxic compounds or nutrients to enable the final effluent to comply with a standard more stringent that can be achieved by secondary treatment alone.
5) Sludge treatment : The dewatering, stabilization and disposal of sludge.

Figure (5.4) shows the typical layout of small gray water treatment plant in general .

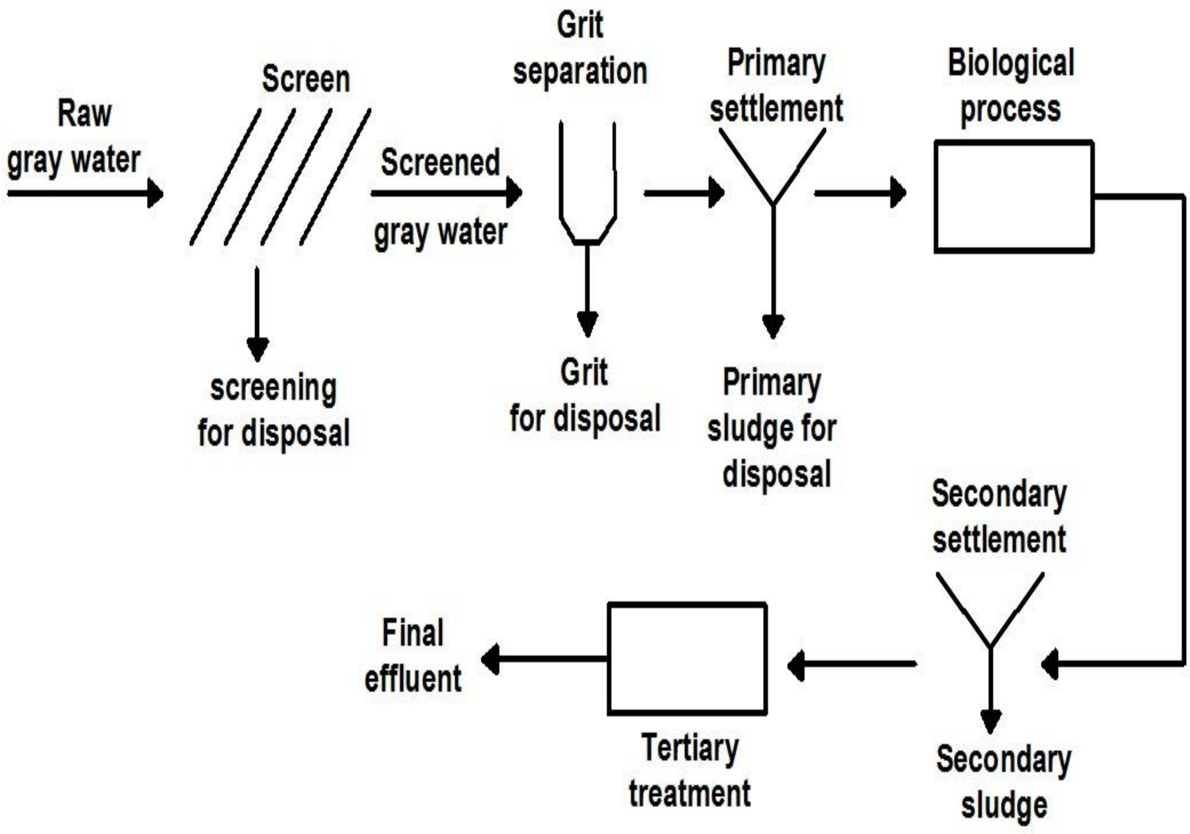


Figure (5.4): Typical layout of small gray water treatment plant.

In this project, the gray water of the building passes through five stages:

1) Stage one: primary settling tank
   The gray water enters in the primary settling tank where any large impurities become sediments .Then the gray water goes to second tank.

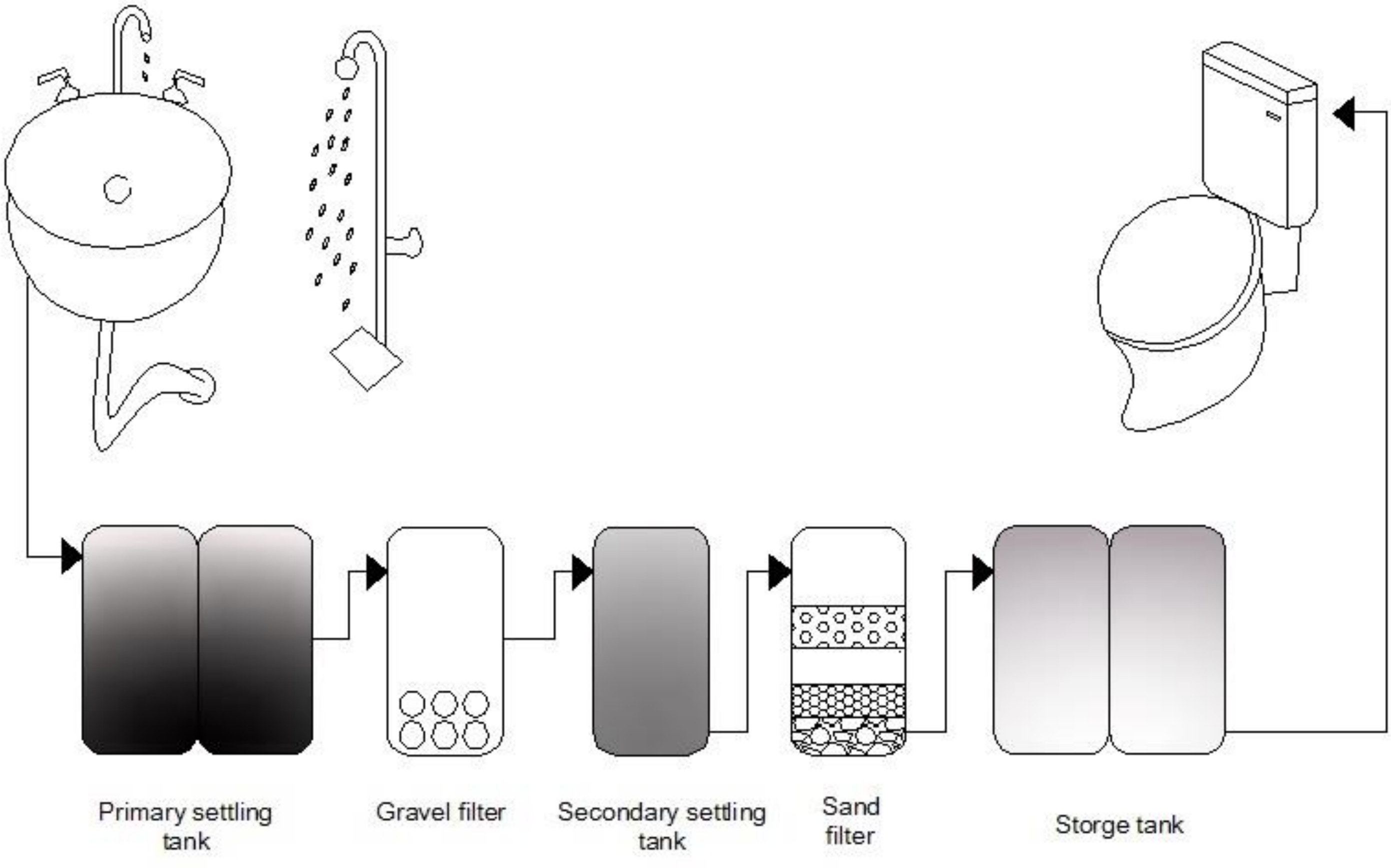
2) Stage two: Gravel filter tank
   This tank consist of gravels which contain bacteria that absorbs the microbes in the gray water. Then the gray water goes to the third tank.

3) Stage three: Secondary settling tank
   In this stage, any residual impurities not sediment in the first tank become sediments. Then the gray water goes to the fourth tank.

4) Stage four: Sand filter tank
   This tank has four materials which are gravel, garnet, sand and coal.
   Gray water passes through the coal then through sand and then through garnet and finally across the gravel. Then the gray water goes to the fifth tank.

5) Stage five: Storage tank

The gray water which goes out from tank four is collected in tank called storage tank to be transported to the building. Figure (5.5) illustrates these five stages .



(Figure 5.5): Gray water stages in the building

The first three tanks are in the garden around the building and the other two tanks are in the roof. Third tank is connecting with a pump which pull the gray water from this tank and put it in the fourth tank. The fourth tank located above the stand to allow the gray water flow under gravity to the fifth tank.

An electrical float valve which is in tank five is connected with the pump. When tank five becomes half full, the electrical float valve will turn on the pump and the pump pull the supernatant of gray water from tank three to tank four and the cycle is repeated.

Over flow pipe is connected in the highest point of tank three to get rid of the extra water that exceeds the capacity of this tank to prevent the gray water from going back to the building. This water which outlet from over flow pipe is connected with a pipe to irrigate the flowers in the garden. The schematic diagram for the flow of gray water in tanks to reach the building is illustrated in figure (5.6). The track of gray water from throughout the system is illustrated in figure (5.7).

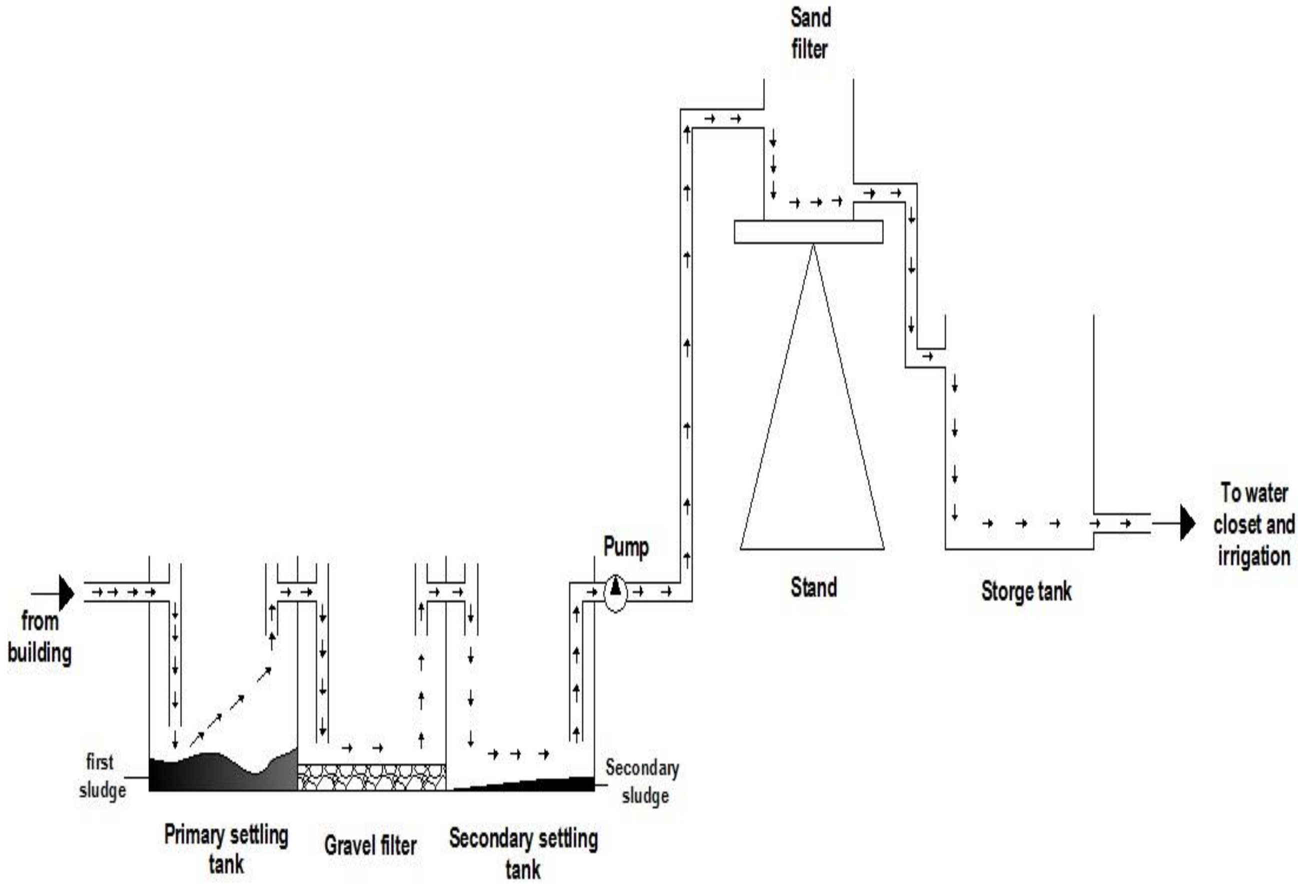


Figure (5.6): Schematic diagram for flow of gray water in the tanks

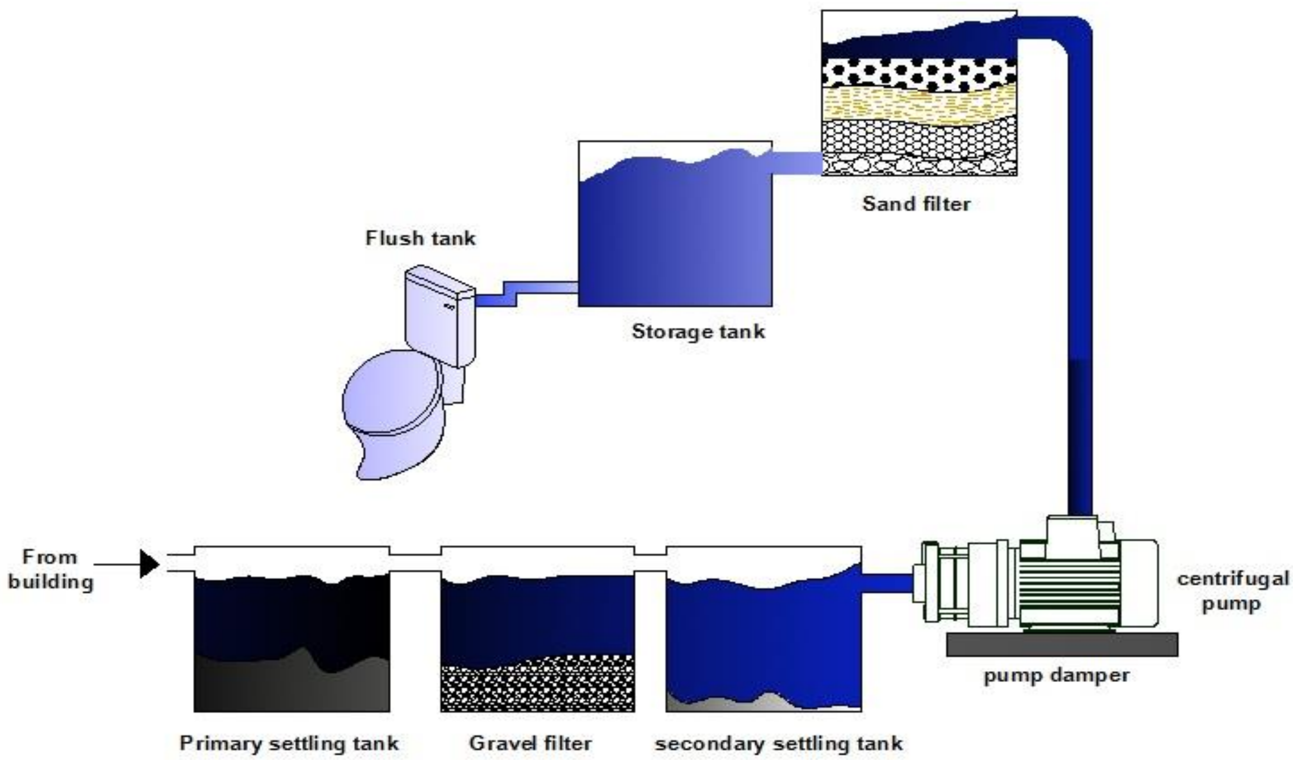


Figure (5.7): Gray water treatment and disinfection plant

5.4.1 Sand filter

As shown in Figure (5.8), sand filter consist of four materials which are gravel, garnet, sand and coal. A sand filter is 1 to 1.5 meters thick. The filtration comes from sand particles that are about 0.35 mm in diameter and fairly uniform. The solids in the water collect mostly on top of the filter and are scraped away at intervals of 1 to 6 months. At this time the sand is cleaned by vigorous flushing with water flowing upward. Sand adsorbs organic compounds on which microorganisms can feed. The highest nutrient concentration is right on the sand granules, so that is where the organisms grow. Microbial growth clogs filters and shortens the interval until cleaning.

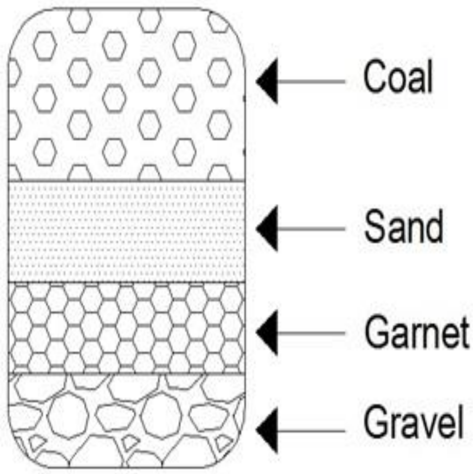


Figure (5.8): Sand filter section

Too much head loss is the signal that cleaning is required. Chlorination kills the microorganisms and keeps the filter going longer. A sand filter removes the tiniest particles from water - even smaller than the gap between the very fine grains of sand in the filter. A slow and constant flow of water through the filter described above leads to biological activity as the top layer of sand traps micro-organisms (e.g. bacteria and viruses). These micro-organisms digest disease-causing pathogens when they too get trapped in the sand. In time a bio-film builds up on top of the sand through which few pathogens can cross.

5.4.2 Oder control

Good design and maintenance practices will reduce odor problems in gray water treatment system without air treatment. However ,the following measures are recommended to minimize odor problems:

1. A minimum slope of 2-3 % should be provided so as to ensure sufficient flow through the system .
2. The closed conduit system should be avoided.
3. Deposited solid should periodically be removed from primary and secondary settling tanks
4. Addition of chemicals such as calcium nitrate.
5. Sand filter media should be periodically replaced.
6. Chlorination also helps in minimizing odors

5.5 Pump selection

5.5.1 Flow rate calculation:

The pump which lifts the supernatant of gray water from tank three to tank four must be selected precisely. In the building there are six floors, each floor has two flats and in each flat there are three water closet which will continuously supplied with the amount of gray water needed from tank 5, so using water supply fixture unit (WSFU) technique, the amount of water needed for all water closets will be :

$$WSFU = \text{No. of flats} \times \text{No. of W.C in each flat} \times \text{unit load for W.C} \quad (5.1)$$

From Table (4.1), the unit load for private use WC is 3 WSFU, so

$$WSFU = 12 \times 3 \times 3$$

$$= 108 \text{ WSFU}$$

Using Table (4.2), the WSFU will be converted to gpm by interpolation which will give 46 gpm. So, the pump flow rate will be:

Q_{pump} = 46 gpm = 2.902 L/s = 2.902×10^{-3} m^3/s = 10.4477 m^3/h.

5.5.2 Head calculation:

To calculate head accurately we must calculate the total head on both the suction and discharge sides of the pump. In addition to the static head we will learn that there is a head caused by resistance in the piping, fittings and valves called friction head, and a head caused by any pressure that might be acting on the liquid in the tanks including atmospheric pressure, called " surface pressure head"

Consider a typical installation of a centrifugal pump as shown in Figure (5.9). The liquid enters at the bottom of the suction pipe through a strainer and the pump operates so as to discharge it to tank 4 by means of the delivery pipe.

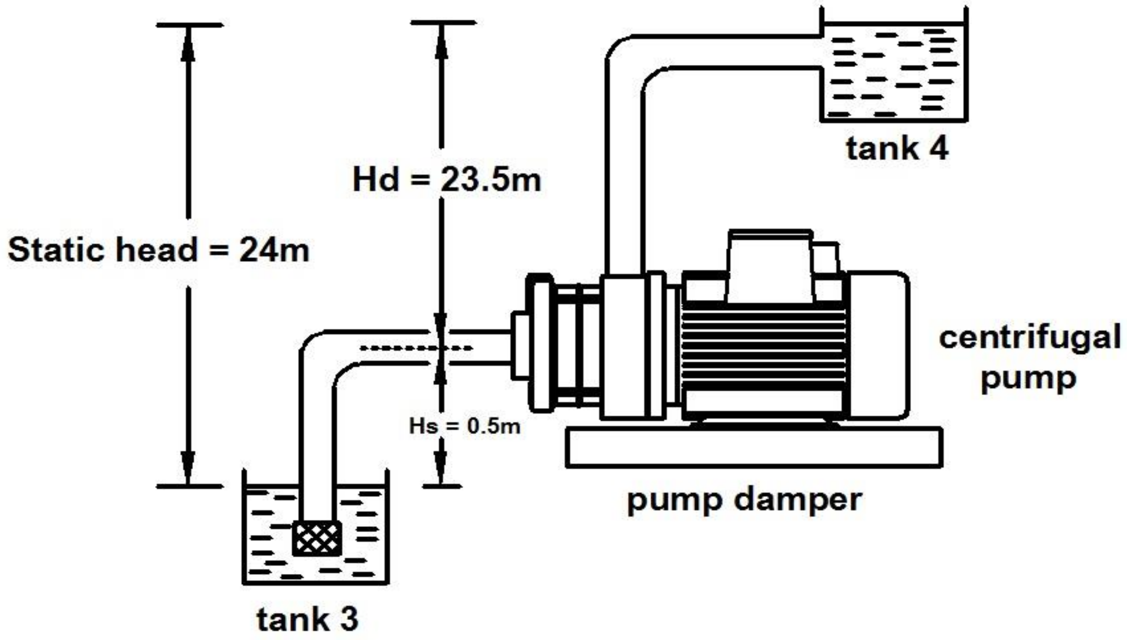


Figure (5.9): Typical installation of a centrifugal pump.

$H_{total} = S.T + h_{L\ major} + h_{L\ minor} + \frac{V^2}{2g}$ (5.2)

Where :

H_{total} : total head [m].

S.T : static head [m].

$h_{L\ major}$: major losses in pipe [m].

$h_{L\ minor}$: minor losses in pipe [m].

$\frac{V^2}{2g}$: velocity head [m].

Static head = $H_s + H_d$ (5.3)

Where :

H_s : suction lift which means, the vertical height from the level of the sump to the center line of the pump.

H_d : delivery lift which means, the vertical height from the center line of the pump to the level in the overhead tank.

Static head = 0.50 + 23.50 = 24 m

$h_{L\ major} = f\left(\frac{L}{D}\right)\frac{V^2}{2g}$ (5.4) where :

f: Friction factor

L: length of pipe [m].

D: inside diameter of pipe [m].

V: velocity of fluid in the pipe [m/s].

Friction factor is obtained from the moody diagram using Reynolds number (Re) and relative roughness factor (R_R).

$$Re = \frac{\rho V D}{\mu} \tag{5.5}$$

Where :

ρ : density of water [kg/m^3]

V: velocity of water in the pipe [m/s].

D: diameter of pipe [m].

μ : dynamic viscosity of water at room temperature [Pa.s]

In the suction side

D = 2 in = 0.0508 m

V = 0.5 m/s and recommended from table A(5-1)

$\mu = 1 \times 10^{-3}$ Pa.s and recommended from table A(5-3)

$$Re = \frac{(1000)(0.5)(0.0508)}{1\times10^{-3}}$$

$$= 25400$$

$$R_R = \frac{k}{d} \tag{5.6}$$

Where:

R_R : relative roughness.

k: pipe inside surface roughness [m].

d: pipe inside diameter [m].

For PVC and plastic pipe, k = 4.25×10^{-6} m and obtained from table A(5-4)

$$R_R = \frac{4.25\times10^{-6}}{0.0508}$$

$= 83.66 \times 10^{-6}$

From moody chart, the friction factor = 0.0246 .

Substituting the values into equation (5.4)

$h_{L\ major} = 0.0246\ (\frac{0.5+1}{0.0508})\frac{1}{(2)(9.81)}$

$h_{L\ major}$ = 0.0370 m.

In the discharge side

D = 1 in = 0.0254 m

V = 1 m/s and recommended from table A(5-2)

$\mu = 1 \times 10^{-3}\ m^2/s$ and recommended from table A(5-3)

$Re = \frac{(1000)(1)(0.0254)}{1\times10^{-3}}$

$= 25400$

Substituting the values into equation (5.6)

$R_R = \frac{4.25\times10^{-6}}{0.0254}$

$= 167.32 \times 10^{-6}$

From moody chart, the friction factor = 0.0248 .

Substituting the values into equation (5.4)

$h_{L\ major} = 0.0248\ (\frac{1+24+1}{0.0254})\frac{1}{(2)(9.81)}$

$h_{L\ major}$ = 1.29 m.

$$h_{L\ minor} = K\frac{V^2}{2g} \quad (5.7)$$

where :

K: minor loss coefficient for the pipe fitting.

The minor loss coefficients for the pipe fittings are listed in the following table:

Table (5.2): Minor loss coefficient for the fittings used in gray water treatment

Type Of Fitting	Minor Loss Coefficient (K)
Foot valve	15
Ball valve	0.05
Check valve	2

In the suction side

There are two fittings in this side, foot valve and ball valve, so

$$h_{L\ minor} = \Sigma K \frac{V^2}{2g} \qquad (5.7a)$$

$$= (15 + 0.05)\frac{0.5\times0.5}{2\times9.81}$$

$$= 0.1917 \text{ m}$$

In the discharge side

There are two fittings in this side, check valve and ball valve, so

$$h_{L\ minor} = \Sigma K \frac{V^2}{2g}$$

$$= (0.05 + 2)\frac{1\times1}{2\times9.81}$$

$$= 0.1044 \text{ m}$$

$$\text{Velocity head} = \frac{V^2}{2g} \qquad (5.8)$$

$$= \frac{1\times1}{2\times9.81}$$

$$= 0.0509 \text{ m}$$

Applying equation (5.2)

H_{total} = 24 + (0.0370 + 1.29) + (0.1917+ 0.1044) + 0.0509

= 25.67 m

The type of pump which is selected is Grundfos as shown in figure (5.10) and the actual duty point is :

Q = 11.7 m^3/h

H = 29.97 m

Figure (5.10): Selected Grundfos pump

5.5.3 Pump cavitation

NPSH is a commercial term mean (net positive suction head) used by the pump manufacturers and indicates the suction head which the pump impeller can produce.

For any pump installation, a distinction is generally made between the required net positive suction head ($NPSH_r$) and the available net positive suction head ($NPSH_a$). The available ($NPSH_a$) depends upon the site conditions and the available equipment. So in order to have a smooth working of the pump (no cavitation), the available ($NPSH_a$) should be more than or equal to the required ($NPSH_r$).

That is the cavitation can be minimized using this equation:

$$(NPSH_a) = \frac{Patm}{\rho g} - H_s - h_{L,tot} - \frac{V^2}{2g} - \frac{P_v}{\rho g} \quad (5.9)$$

Where :

P_{atm} : atmospheric pressure [Pa].

H_s: suction lift [m].

$h_{L,tot}$: Total friction head loss in the suction pipe [m].

V : velocity in the suction pipe [m/s].

P_v : saturated vapor pressure [Pa].

Note : the saturated vapor pressure will be taken at a specified temperature. Since cavitation possibility occurs in summer more than in winter, the temperature used to calculate P_v is taken to be 35 ˚C, so;

$P_v = P_{sat.}$ @35˚C

= 5.63 kPa.

$$(NPSH_a) = \frac{100000}{(1000)(9.81)} - 0.5 - (0.0370 + 0.1917) - \frac{0.5\times0.5}{2\times9.81} - \frac{5630}{(1000)(9.81)}$$

= 8.87 m

From the catalog of the Grundfos pump selected in the appendix , the required net positive suction head ($NPSH_r$) = 3.98 m.

($NPSH_a$) > ($NPSH_r$)

9.21 > 3.98

That mean no cavitation will occur.

The characteristic curves and some information like NPSH, speed of impeller , power and efficiency of the centrifugal pump are shown in the figure (5.11).

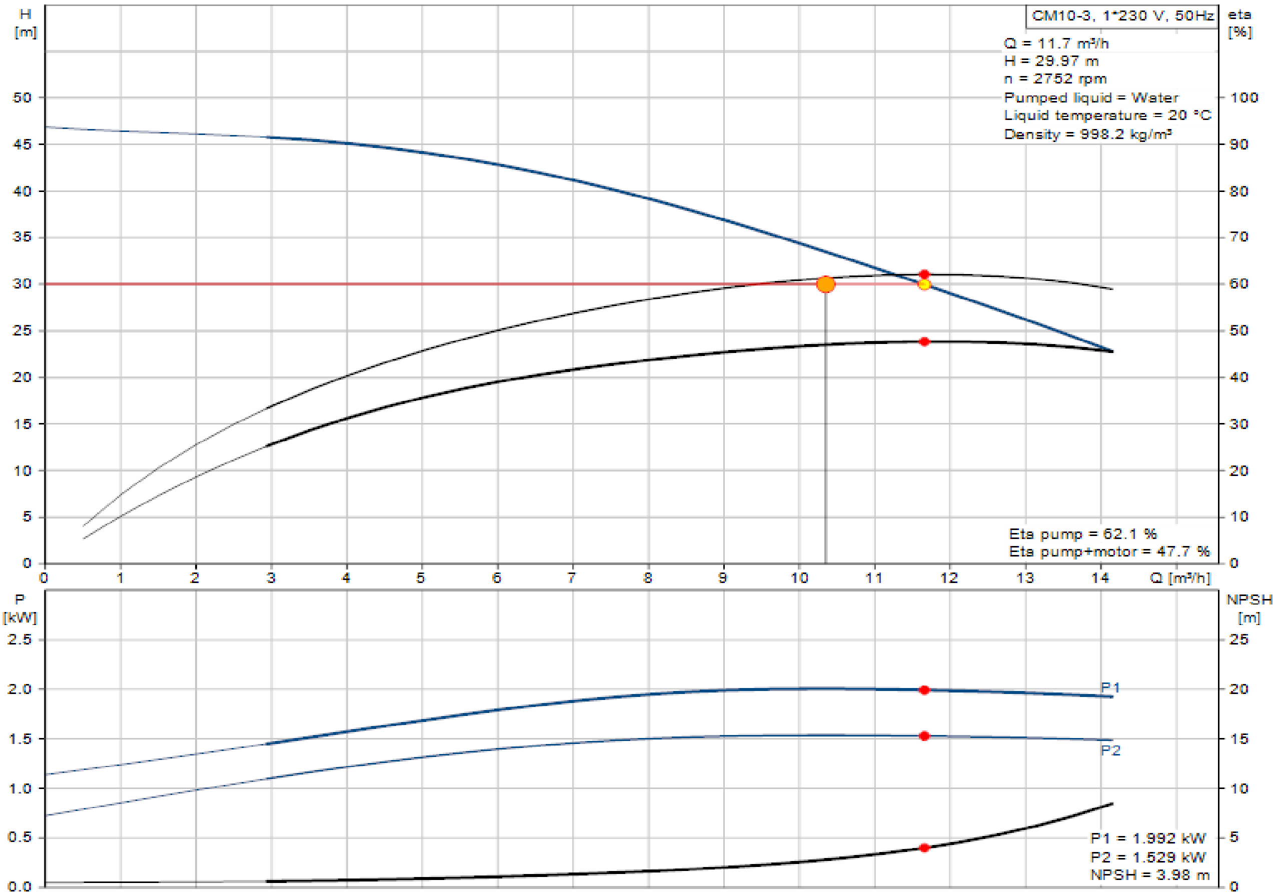


Figure (5.11): Pump characteristic curves

5.6 Tanks calculations

5.6.1 Hydraulic retention time

The hydraulic retention time (HRT), also known as hydraulic residence time or (tau), is a measure of the average length of time that a soluble compound remains in a constructed bioreactor.

Hydraulic retention time is the volume of the aeration tank divided by the influent flowrate:

$$\text{HRT} = \frac{V}{Q_{dis.}} \quad (5.10)$$

Where :

V: the volume of the aeration tank in m^3

Q_{dis}: influent discharge flowrate greywater from the building in m^3/h

Hydraulic retention time (HRT) is usually expressed in hours (or sometimes days) and different from tank to tank, so the HRT for each tank is listed in the table below [5]:

Table (5.3): Hydraulic retention time (HRT) for each tank in the gray water treatment.

Tank NO.	Tank Name	HRT(hour)
1	Primary settling	4
2	Gravel filter	12
3	Secondary settling	12
4	Sand filter	12
5	Storage tank	24

5.6.2 Calculation the volume of the tanks

$$HRT = \frac{V}{Q_{dis.}} \qquad (5.10)$$

$$V = HRT \times Q_{dis.} \qquad (5.10.a)$$

Note: the value of flowrate ($Q_{dis.}$) is constant for the first three tanks (the losses are very small, so can be neglected).

The amount of flowrate (gray water) discharge from the building as shown in Figure (4.5) equal 79 DFU.

Use the conversion of **1 gpm = 2 DFU** to convert this value, so

$Q_{dis.}$ = 39.5 gpm = 8.97142 m^3/h.

For tank 1

$V_1 = (HRT)_1 \times Q_{dis.}$

$= 4 \times 8.97142$

$= 35.885\ m^3$

For tank 2

$V_2 = (HRT)_2 \times Q_{dis.}$

$= 12 \times 8.97142$

$= 107.657\ m^3$

The volume of tank 3 is the same as tank 2 .

$V_3 = V_2 = 107.657\ m^3$

As tank 4 and 5 will be placed on the roof of the building, so not to make an extra heavy weight on the building, the volume of each tank will be chosen as 2000L=2m^3 which is available in the market.

5.6.3 Calculation and distribution of the concrete and steel bar

5.6.3.1 The quantity of concrete

Tank 1,2 and 3 are reinforced concrete ones, with 2m depth for each, so the quantity of concrete of each tank will be as follow:

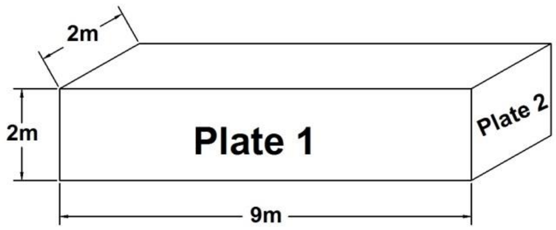


Figure (5.12): dimensions of walls for tank 1

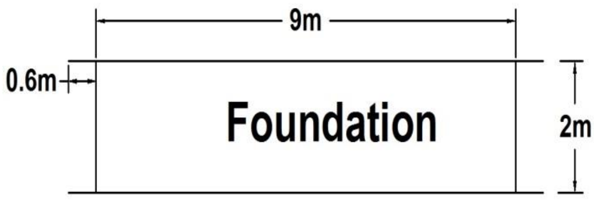


Figure (5.13): dimensions of floor for tank 1

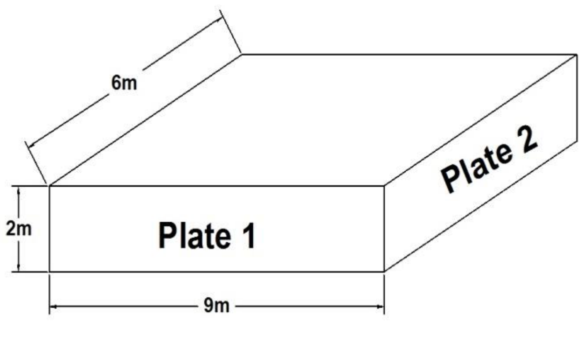


Figure (5. 14): dimensions of walls for tank 2

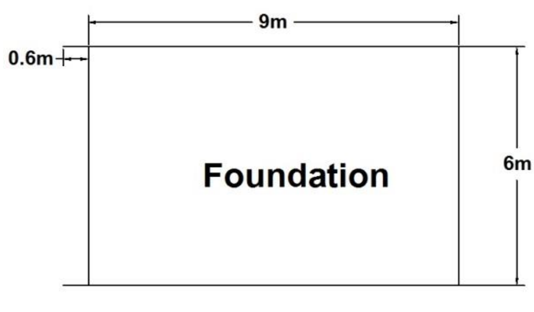


Figure (5.15): dimensions of floor for tank 2

From the recommended of civil engineering, the quantity of concrete for the tanks as follow:

For tank 1

According to figures (5.12) and (5.13);

Quantity of walls for plate 1 = 9 × 2 × 0.3 = 5.4 m^3

Because we have two wall, the quantity of walls = 2 × 5.4 = 10.8 m^3

Quantity of walls for plate 2 = 2 × 2 × 0.3 = 1.2 m^3

Because we have two wall, the quantity of walls = 2 × 1.2 = 2.4 m^3

Total Quantity of walls for tank 1 = 10.8 + 2.4 = 13.2 m^3

Quantity of foundation (floor) = 10.2 × 3.2 × 0.2 = 6.5 m^3

Total quantity of concrete for tank 1 = 13.2 + 6.5 = 19.7 m^3

For tank 2

According to figures (5.14) and (5.15);

Quantity of walls for plate 1 = 9 × 2 × 0.3

= 5.4 m^3

Because we have two wall, the quantity of walls = 2 × 5.4 = 10.8 m^3

Quantity of walls for plate 2 = 6 × 2 × 0.3

= 3.6 m^3

Because we have two wall, the quantity of walls = 2 × 3.6 = 7.2 m^3

Total Quantity of walls for tank 2 = 10.8 + 7.2 = 18 m^3

Quantity of foundation (floor) = 10.2 × 7.2 × 0.2

= 14.7 m^3

Total quantity of concrete for tank 2 = 18 + 14.7 = 32.7 m^3

This is the same quantity for tank 3.

Total concrete quantity = 19.7 + 32.7 + 32.7 = 85.1 m^3

5.6.3.2 The reinforcement of walls

5.6.3.2.1 Vertical bars

For tank 1

Ø12-20

NO. of bars in length = $\frac{9}{0.2} + 1 = 46$

Because we have two faces, we need 92 Ø12-20, where the length of bar = 1.96m

Ø12-20

NO. of bars in width = $\frac{2}{0.2} + 1 = 11$

Because we have two faces, we need 22 Ø12-20, where the length of bar = 1.96m

Total number of bars for tank 1 = 114 bars with diameter 12.

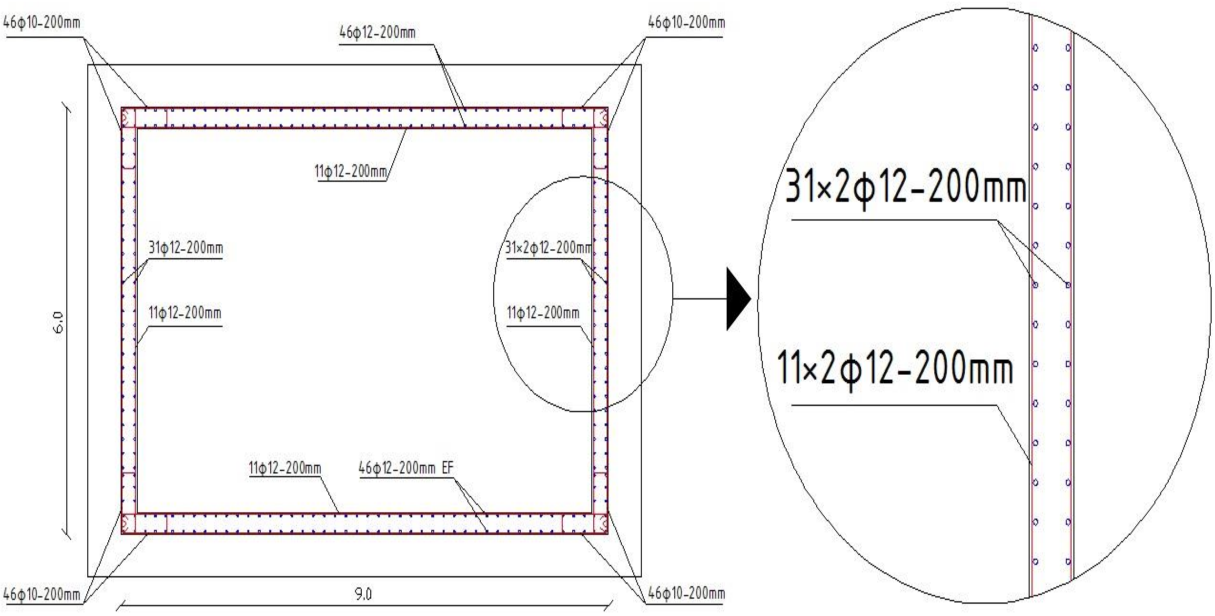


Figure (5.16): section wall for tank 2

For tank 2

Figure (5.16) illustrates the section wall and distribution of vertical bars for this tank .

Ø12-20

NO. of bars in length = $\frac{9}{0.2} + 1 = 46$

Because we have two faces, we need 92 Ø12-20, where the length of bar = 1.96m

Ø12-20

NO. of bars in width = $\frac{6}{0.2}$ + 1 = 31

Because we have two faces, we need 62 Ø12-20, where the length of bar = 1.96m

Total number of bars for tank 2 = 154 bars with diameter 12.

The same calculation for tank 3, so;

Total number of bars for tank 3 = 154 bars with diameter 12.

5.6.3.2.2 Horizontal bars

For tank 1

Ø12-20

NO. of bars = $\frac{2}{0.2}$ + 1 = 11

Because we have two faces, we need 22 Ø12-20

44 Ø12-20, L = 8.96m

44Ø12-20, L = 1.96m

For tank 2

Ø12-20

NO. of bars = $\frac{2}{0.2}$ + 1 = 11

Because we have two faces, we need 22 Ø12-20

44 Ø12-20, L = 5.96m

44Ø12-20, L = 8.96m

For foundation

For tank 1

Ø12-10

NO. of bars = $\frac{10.2}{0.1}$ + 1 = 103

Because we have two faces, we need 206 Ø12-20 , L = 3.16m

Ø12-10

NO. of bars $= \frac{3.2}{0.1} + 1 = 33$

Because we have two faces, we need 33 Ø12-20 , L = 10.16m

For tank 2

Ø12-10

NO. of bars $= \frac{10.2}{0.1} + 1 = 103$

Because we have two faces, we need 206 Ø12-20 , L = 7.16m

Ø12-10

NO. of bars $= \frac{7.2}{0.1} + 1 = 73$

Because we have two faces, we need 146 Ø12-20 , L = 10.16m

For tank 3 , the same calculation of tank 2 so;

206 Ø12-20 , L = 7.16m

146 Ø12-20 , L = 10.16m

The following table summarizes the steel bars needed to the project.

Table (5.4): Steel list

Diameter (mm)	Length (m)	NO.	Weight (Kg)	Total (Kg)
Ø12	1.96	510	0.88× 1.96× 510	879.6
Ø12	8.96	132	0.88× 8.96× 132	1040.8
Ø12	5.96	88	0.88× 5.96× 88	461.5
Ø12	3.16	206	0.88× 3.16× 206	572.8
Ø12	7.16	412	0.88× 7.16× 412	2596
Ø12	10.16	358	0.88× 10.16× 358	3200.8

Total weight of bars = 8751.5 Kg =8.75 ton

5.7 Maintenance requirements for gray water system.

Once a gray water system is installed, it is the homeowner's responsibility to ensure its maintenance for the life of the installation. Gray water system requires regular maintenance, such as cleaning and replacing of filters and periodic clean out of the primary and secondary settling tanks, regular periodic inspection of the sand filter.

The primary and secondary settling tanks on the inlet of the gray water system is important as it removes a variety of materials that may clog the pump or the pipe in the system. If the pipe becomes clogged, less gray water can get to the storage tank.

This maintenance work itself has inherent health risks, just like managing a worm farm or compost bin. Rubber gloves should be worn and thorough washing of hands and clothes should take place immediately afterwards.

Gray water filters will need to be replaced from time to time, and the solids that settle on top of the greywater must be removed regularly.

The following table provides a summary of possible maintenance requirements.

Table (5.5): Maintenance requirements for gray water system[5]

Gray water Device Components	Maintenance Required	Frequency
primary settling tank	Clean out precipitated materials from primary settling tank	Every 6 months
Gravel filter tank	Clean gravel or replace it	Every 4 months
Secondary settling tank	Clean out precipitated materials from Secondary settling tank	Every year
Sand filter	* Clean filter: filter should be removed and cleaned, removing physical contaminants (lint, hair... etc)	Monthly
	* Replace Filter	As recommended by the manufacturer or as required (usually every 6–12 months)
Storage tank	Washed and exposed to the sun	Every two year

5.8 Benefits

Gray water pipe separation is a relatively easy low cost when planned into a new smaller-scale residential construction. Cost and space savings can even be gained by reducing the wastewater treatment system, especially for septic systems.

Other Potential Benefits:

1) Reduces the amount of potable, fresh water used by households.
2) Reduces the flow of wastewater entering sewer or septic systems.
3) Minimizes the amount of harmful chemicals used by homeowners.
4) Supports plant growth without using expensive potable water.
5) Helps recharge groundwater when applied outdoors.
6) Raises public awareness of natural water cycles.
7) Saves money on water bills.

5.9 Sizing of pipes which feeds flush tank

Using down feed distribution system where the water serve the all water closet in the building , and the equation of the flow will be as following:

static head = pipe friction + mini. flow pressure (5.11)

the water closet in the 6^{th} floor is the critical fixture unit, by table A(4.3) flow pressure = 8psi.
Static pressure = 10.3 psi
Applying equation (5.11)
Pipe friction = static head – mini. flow pressure
= 10.3 – 8
= 2.3 psi

length = 3 + 5 + 9 =17m
= 51.51 ft

Because there are fittings in the system, a factor of safety required to cover the losses.
Equivalent length = 1.5 × 51.51
= 77.27 ft

Friction head loss psi / 100 ft, by the relation
= (2.3 psi × 100 ft) / 77.27 ft
= 2.97 psi psi/ 100ft

Referring to the figure A(4.1) and using steel pipes the diameter equal to 1.5" in. and the velocity is 7.1FPS, the following table shows the pipe sizing all sections for the water riser.

Table (5.6): Pipe sizing for water closet riser

Section number	Flow (gpm)	WSFU	Pipe size (in)	Velocity (fps)
Pump-1st riser	46	108	1.5"	7.1
2nd riser section	30.2	54	1. 5"	4.9
3rd riser section	27	45	1. 5"	4.2
4th riser section	22.9	36	1.25"	4.4
5th riser section	18.3	27	1.25"	4
6th riser section	13	18	1"	4.1
Run out	7.5	9	1"	2.6

The diameter will be select in 1.5 in.

Chapter Six

Fire Fighting System

6.1 Introduction

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

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

Figure (6.1): Fire tetrahedron

The following is a description for this component:

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

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

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

Chain chemical reaction, the fire is continues as long as the previous three elements are present correct percentages, and the result of these elements of effective chemicals known as free radicals.[8]

Fire work is divided into three sections for engineer:

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

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

6.2 Classification of firefighting systems

Firefighting systems are classified to:

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

6.2.1 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.

6.2.2 Gas firefighting system

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

1) Manual system

   Fire extinguishers

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

   In general fire extinguishers can be water, co_2, foam, wet chemical and dry powder extinguisher.

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

2) Automatic system

   Clean agent gases fire extinguisher.

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

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

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

6.2.3 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.

6.3 System selection and design

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

6.3.1 Hazard classification

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

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

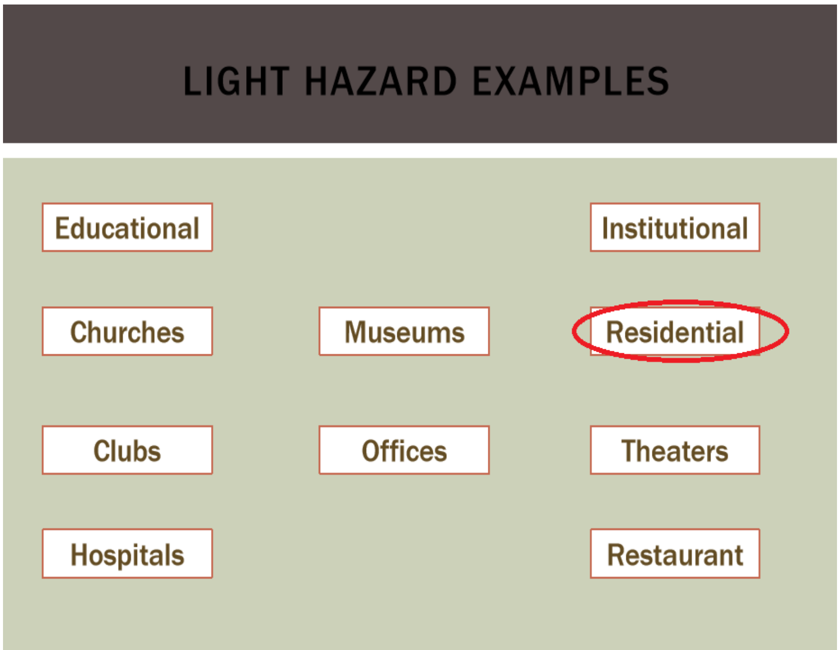


Figure (6.2): Light hazard examples

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

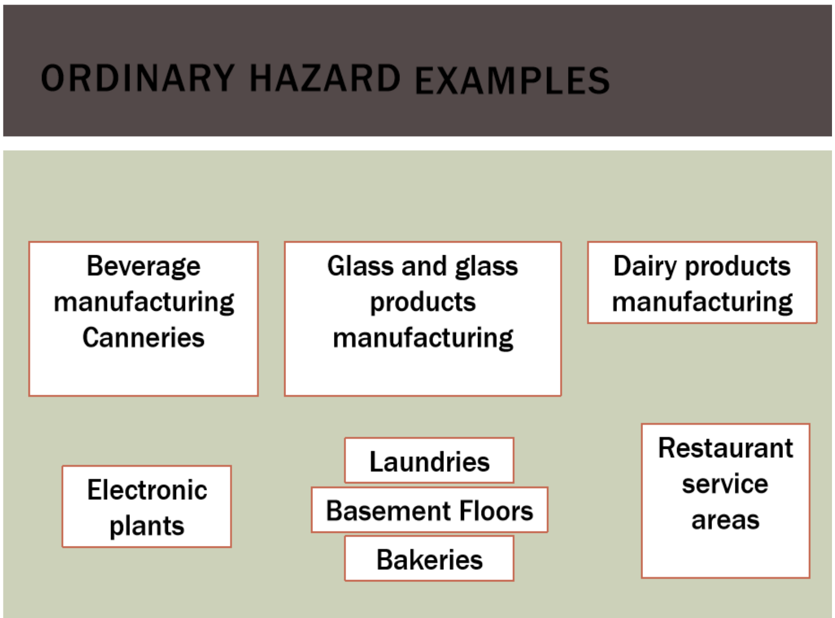


Figure (6.3): Ordinary hazard examples

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

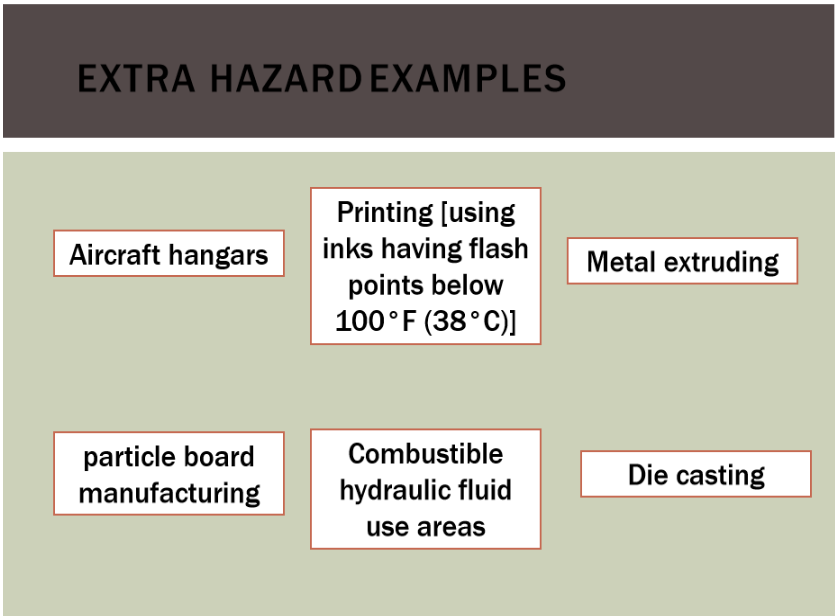


Figure (6.4): Extra hazard examples

So, the system hazard in a residential building is light hazard.

According to the light level of hazard the best appropriate system **is fire house cabinet** and **fire extinguisher** systems.

6.3.2 Firefighting network accessories

6.3.2.1 Firefighting network Components:

1. Water source and pumping station

The main sources of firefighting water are Water Tanks Underground.

2. Pipes
   a) Black steel
   b) Galvanized steel
   c) High density polyethylene
   d) UPVC poly vinyl chloride

Firefighting pipes should be tested after installation at site to ensure durability of the system.

All pipes, fittings, valves and other accessories should be tested at 4 bars above the working pressure for two hours according to the NFPA14 code.

TESTING OF PIPES

10.10.2.2 Hydrostatic Test.

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

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

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

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

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

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

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

Figure (6.5): Testing of pipes

3. Valves

    a) Sectional valves: are used to separate specific parts of the firefighting network for maintenance and repair times and should be automatically supervised.

    b) Drain valve: should be placed at the lowest point of the firefighting network to drain the water network for washing& maintenance of the pipes.

    c) Check valve.

4. Standpipes.

6.3.2.2 Pipes hangers and supports

Referring to the NFPA14 code the hanger's details as follow:

9.1 Hangers.

9.1.1* General.

9.1.1.1 Unless the requirements of 9.1.1.2 are met, types of hangers shall be in accordance with the requirements of Section 9.1.

9.1.1.2 Hangers certified by a registered professional engineer to include all of the following shall be an acceptable alternative to the requirements of Section 9.1:

(1) Hangers shall be designed to support five times the weight of the water-filled pipe plus 250 lb (114 kg) at each point of piping support.

(2) These points of support shall be adequate to support the system.

(3) The spacing between hangers shall not exceed the value given for the type of pipe as indicated in Table 9.2.2.1.

(4) Hanger components shall be ferrous.

(5) Detailed calculations shall be submitted, when required by the reviewing authority, showing stresses developed in hangers, piping, and fittings and safety factors allowed.

Figure (6.6): Pipes hangers

Split ring hanger was selected to support the fire piping system; the rod size that carries the ring hanger is 3/8'' for 4'' pipe riser according to the NFPA14 code.

Table 9.1.2.1 Hanger Rod Sizes

Pipe Size	Diameter of Rod	
	in.	mm
Up to and including 4 in.	⅜	9.5
5 in., 6 in., and 8 in.	½	12.7
10 in. and 12 in.	⅝	15.9

Figure (6.7): Hanger rod sizes

6.3.3 Fire hose cabinet

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

1. Hose reel: it's a rubber hose coiled on the reel her arm؛ it's commonly used by individuals within buildings.
2. Hose rack: Is a cloth-reinforced hose riding on rack often used by Civil defense.

Figure (6.8): Fire hose cabinet

Fire hose cabinet is located at the following places:

1) Exit stairs
2) Entrance of buildings
3) Garages entrance
4) Wherever travel distance exceeded 36 meter from another fire hose cabinet.

6.3.3.1 Fire hose cabinet components

1) Cabinet (wall mounted-recessed), there is three type of cabinet here
   - **a)** Exposed: be prominent from the wall and out of it a distance of 25 cm, and Fund riding on the surface of the wall.
   - **b)** Semi predated: be prominent from the wall a distance of 10 cm, and inside the wall 15 cm.
   - **c)** Recessed: be inside the entire wall.
2) Landing valve, a valve to control the water stream, located inside or outside the building.
3) Hose (30 meter)
4) Discharge nozzle
5) Fire extinguisher (optional)

6.3.3.2 Fire hose cabinet classes

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

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

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

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

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

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

6.3.3.3 Technical specifications of fire hose cabinet

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

- The maximum pressure at any point in the system at any time shall not exceed 24.1 bar (350 psi).
- Maximum Residual Pressure for (1½-in.) Dia F.H.C=6.9 Bar.
- Hydraulically designed standpipe systems shall be designed to provide the water flow rate required at a minimum residual pressure of 4.5 bar (65 psi) at the outlet of the hydraulically most remote 38-mm (1½-in.) hose station.
- Standpipes size shall be at least 100 mm (4 in.) (Main riser).
- Hose stream demand and water supply duration requirement for hydraulic calculation system as in the NFPA14 code:

6.3.4 fire extinguishers

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

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

Figure (6.9) Portable Fire Extinguishers

6.3.4.1 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.

6.3.4.2 Selection of extinguishers

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

6.3.4.3 Carbon dioxide extinguishers

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

The cylinders for CO_2 Fire Extinguishers are seamless and extruded from high grade Chrome Molybdenum Steel or Manganese Steel or Carbon Steel. Carbon Dioxide is discharged as a white cloud of snow which throttles a fire by eliminating the oxygen. Designed to protect areas where class B (flammable liquids and gases) or Electrical class of fires could occur.

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

6.3.5 Firefighting pumps

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

Pumping stations should include:

1. Electrical firefighting pump.

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

Diesel pump works if:

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

3. Jockey Pump: 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.

6.3.5.1 Types of pumps

- Horizontal split case pumps:

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

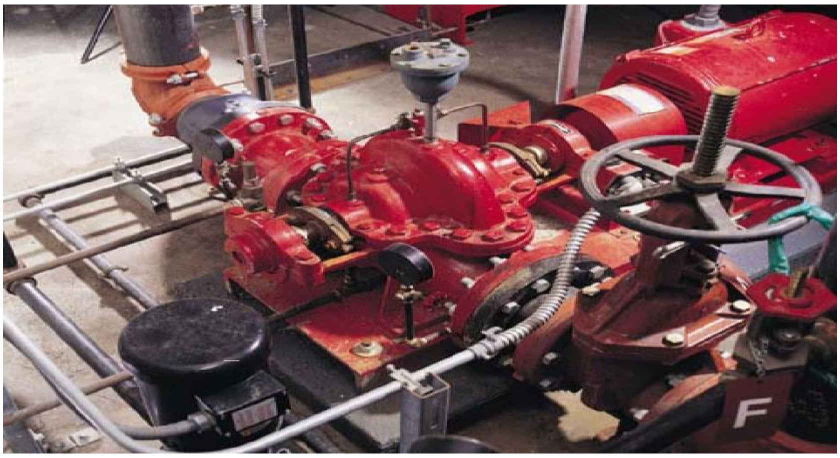


Figure (6.10): Horizontal split case pump

- Inline fire pumps

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

Figure (6.11): Inline fire pump

- End suction pumps

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

Figure (6.12) End suction pump

- Vertical turbine pumps

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

Figure (6.13) Vertical turbine pump

6.3.6 Flow rate calculations

There are two main factors in GPM calculations:

1. Area calculation
2. Standpipe calculation

The standpipe calculation is the selected calculation, so according to NFPA 14 states that the GPM required for the first standpipe is 500 GPM

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

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

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

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

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

6.3.7 Head estimation

With 24.5 meter height of the buildings there are 2.5 bars, adding 4.5 bars for cabinet pressure and 1 bar for loss in fittings, so total head equal 8 bars.

6.3.8 Water tank sizing

Water tank is the main source of water that provides the firefighting network and other systems in the project, size of water tank can be calculated with referring to the NFPA 14 code which mainly depends on the hazard classification and the expectation duration work for the system.

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

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

Figure (6.14): Total gallon and duration

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

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

= 750gpm*30min*(3.785/1000)

=85m^3

6.3.9 Pump selection

Total flow rate 750 GPM equal to 170 m^3/h and amount of head 8 bars.

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

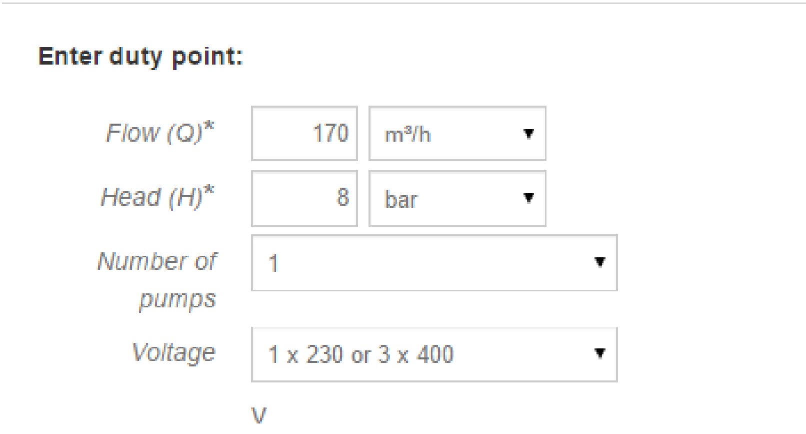


Figure (6.15): Pump details

Pump type: TP 100-960/2 A-F-ADBUE

Pump characteristic curves:

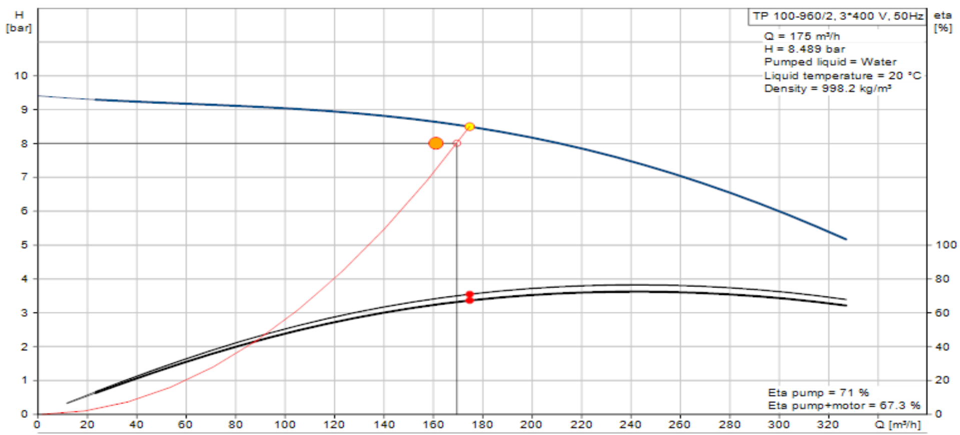


Figure (6.16): Pump characteristic curve

Efficiency & Head curves:

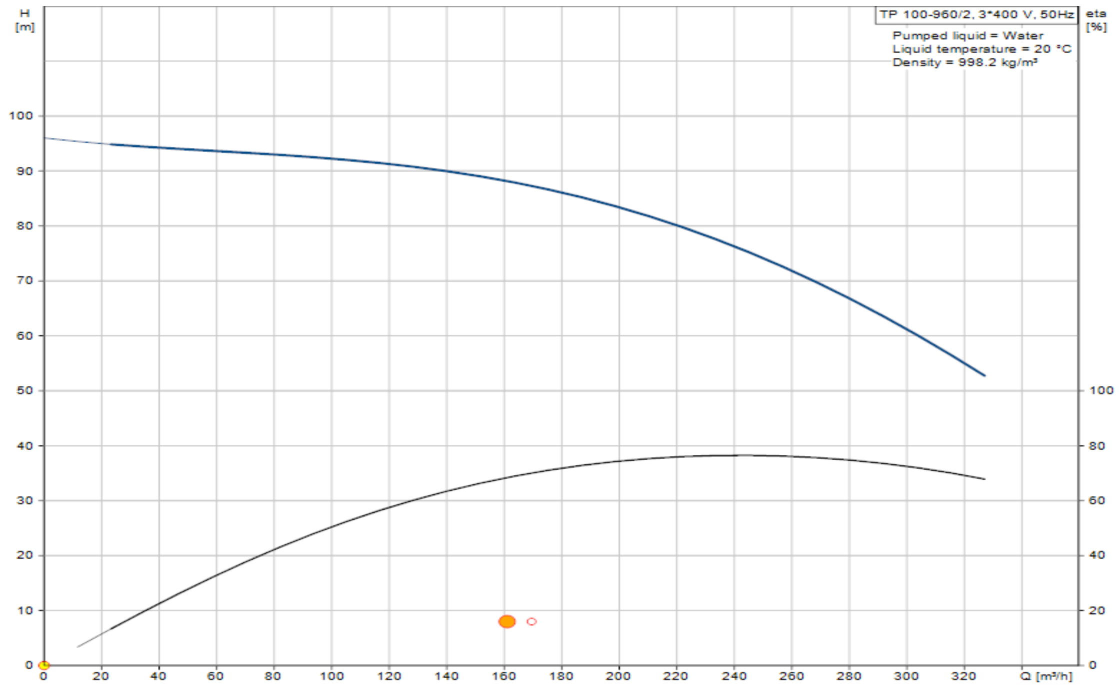


Figure (6.17): Efficiency curve

Figure (6.18): Pump photo

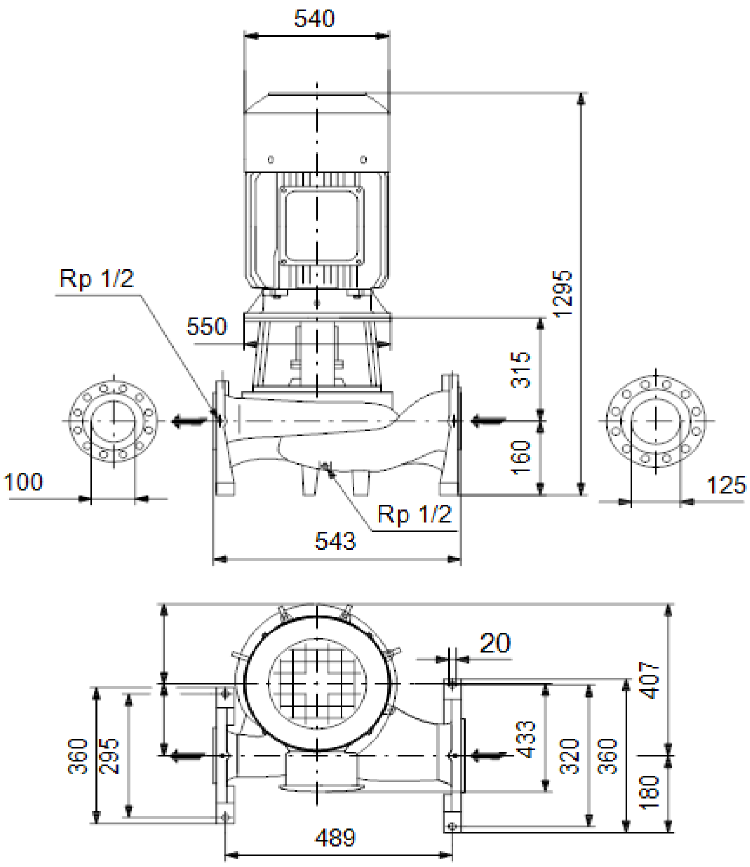


Figure (6.19): Pump dimensional drawing

References

Books:

[1] Heating and air conditioning for residential buildings.

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

[3] Fundamentals of Heat and Mass Transfer, 5 edition.

[4] Heating Ventilation and Air Conditioning Analysis and Design, 4 edition.

[5] Introduction to environmental engineering, fourth edition.

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, installation, 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.				
Total Page Carried Forward				**Shekel**	

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.	7500 BTU/H (wall mounted type)	No.	36	7000	252000
B.	9500 BTU/H (cassette type)	No.	36	5500	198000
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 14 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.	No.	3	17000	51000
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 per specifications, drawings and related codes. 100 CFM tube fan wall mounted	No.	36	200	7200
Total Page Carried Forward				**Shekel**	508200

Bill No. (1): MECHANICAL WORKS

Item No.	Description	Unit	Qty.	UR (NIS)	Amount
1.2	**Water Supply**				508200
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, electrical wiring, galvanized steel frame, inertia base, vibration isolators, concrete base and all required valves and fittings as detailed on the drawings.	No.	2	5000	10000
1.2.2	**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 ½”	ML	30	375	11250
B.	Diameter 1 ¼”	ML	30	300	9000
1.2.3	**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. 32 mm thick for 1 1/4"	No.	25	44	176
Total Page Carried Forward				**Shekel**	30426

Bill No. (1): MECHANICAL WORKS

Item No.	Description	Unit	Qty.	UR (NIS)	Amount
Carried Before				**Shekel**	538626
1.2.4	**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 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. 16 mm O.D. x 2.2mm thick, sleeve 25 mm diameter	ML	2160	16	34560
1.2.5	**Water Meter** Supply, install, test and commission water meter with totalizer, 2" diameter, including air vent, check valve, strainer, two gate valves, connection to municipality's potable water supply network, fittings, and all accessories and works required to complete the work as shown on the drawings and as per the preamble, specifications and the supervision engineer's requirements.	No.	1	300	300
1.2.6	**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.	2	2176	4352
Total Page Carried Forward				**Shekel**	39062

Bill No. (1): MECHANICAL WORKS

Item No.	Description	Unit	Qty.	UR (NIS)	Amount
Carried Before				**Shekel**	577688
1.2.7	**Water Collector** Supply and install hot and cold water collector's type GIACOMINI or E.A				
A.	1 ¼" cold water collector	EYE	144	40	5760
B.	¾" hot water collector	EYE	72	30	2160
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.				
A.	Diameter 2"	ML	318.5	20	6370
B.	Diameter 4"	ML	445	30	13350
C.	Diameter 6"	ML	145	90	13050
1.3.1	**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 per drawings, specifications and related codes.	No.	67	130	8710
1.3.2	**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 codes. (Ø 4")	No.	79	120	9480
Total Page Carried Forward				**Shekel**	58880

Bill No. (1): MECHANICAL WORKS

Item No.	Description	Unit	Qty.	UR (NIS)	Amount
Carried Before				**Shekel**	636568
1.3.3	**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 specifications and approval engineers.				
A.	Size 60 cm (inside diameter)	No.	6	950	7600
B.	Size 80 cm (inside diameter)	No.	10	1450	11600
C.	Size 100 cm (inside diameter)	No.	3	1700	5100
D.	Size 125 cm (inside diameter)	No.	1	1930	1930
1.3.4	**Sanitary Fixture and Their Accessories**				
1.3.4.1	**Lavatory** Supply and installation of porcelain wash basin glazed white (from creavit or equivalent) 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 drainage to the nearest packet assembly floor drain , according to the specifications and plans and instructions of the supervising engineer.	No.	37	200	7400
Total Page Carried Forward				**Shekel**	33630

Bill No. (1): MECHANICAL WORKS

Item No.	Description	Unit	Qty.	UR (NIS)	Amount
Carried Before				**Shekel**	670198
1.3.4.2	**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.	36	600	21600
1.3.4.3	**Paper Holder** Supply and installing of: surface mounted satin finish stainless steel, 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.	36	50	1800
1.3.4.4	**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.	12	300	3600
Total Page Carried Forward				**Shekel**	27000

Bill No. (1): MECHANICAL WORKS

Item No.	Description	Unit	Qty.	UR (NIS)	Amount
	Carried Before			**Shekel**	697198
1.3.4.5	**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.	49	50	2451
1.4	**Gray Water System**				
1.4.1	**Horizontal UPVC pipe** Supply, install, test and commission underground UPVC pipes for grey water system between manholes and fittings similar to local made P.S SN 8. The rate shall include all needed connections and all types of fittings caps, digging and removing dirt, all done according to drawings, specifications and the approval of the supervision engineer. (Ø 6")	ML	3	30	90
1.4.2	**Concrete and Steel** Supply concrete and steel to build manholes of 30 cm thick walls and base with heavy duty cast iron covers and frames of 25 tons load strength with all necessary excavation, backfilling as specified and connecting it to main city manholes as shown in drawing and in accordance to specifications and approval engineers.				
A.	Total concrete quantity	m^3	85.1	300	25530
B.	Steel bars Ø12, L = 1.96, NO. = 510	Ton	0.8796	1500	1319.4
C.	Steel bars Ø12, L = 8.96, NO. = 132	Ton	1.0408	1500	1561.2
D.	Steel bars Ø12, L = 5.96, NO. = 88	Ton	0.4615	1500	692.25
E.	Steel bars Ø12, L = 3.16, NO. = 206	Ton	0.5728	1500	859.2
F.	Steel bars Ø12, L = 7.16, NO. = 412	Ton	2.596	1500	3894
G.	Steel bars Ø12, L = 10.16, NO. = 358	Ton	3.200	1500	4800
	Total Page Carried Forward			**Shekel**	41197

Bill No. (1): MECHANICAL WORKS

Item No.	Description	Unit	Qty.	UR (NIS)	Amount
Carried Before				**Shekel**	738395
1.4.3	**Water Pump** Supply, install, test and commission water pump for gray water system with cast iron body and stainless steel impeller Grundfos factory assembly or E.A. The rate shall include bolts, nuts, concrete slab, foot valve, ball valves, electrical float, check valve and any accessories needed in the suction and discharge line to connect with the network as shown in pump details. Flow rate 10.5 m3/h, Head 30 m	No.	1	5000	5000
1.4.4	**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
1.4.5	**Materials of The Filter** Supply and install the materials of the filter with sackcloth between them.				
A.	Sand	m^3	0.5	115	58
B.	Coal	kg	15	13	195
C.	Gravel	m^3	0.5	41	21
D.	Garnet	m^3	0.5	45	23
1.4.6	**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	43	16	688
B.	Diameter 16 mm	ML	228	8	1824
Total Page Carried Forward				**Shekel**	9909

Bill No. (1): MECHANICAL WORKS

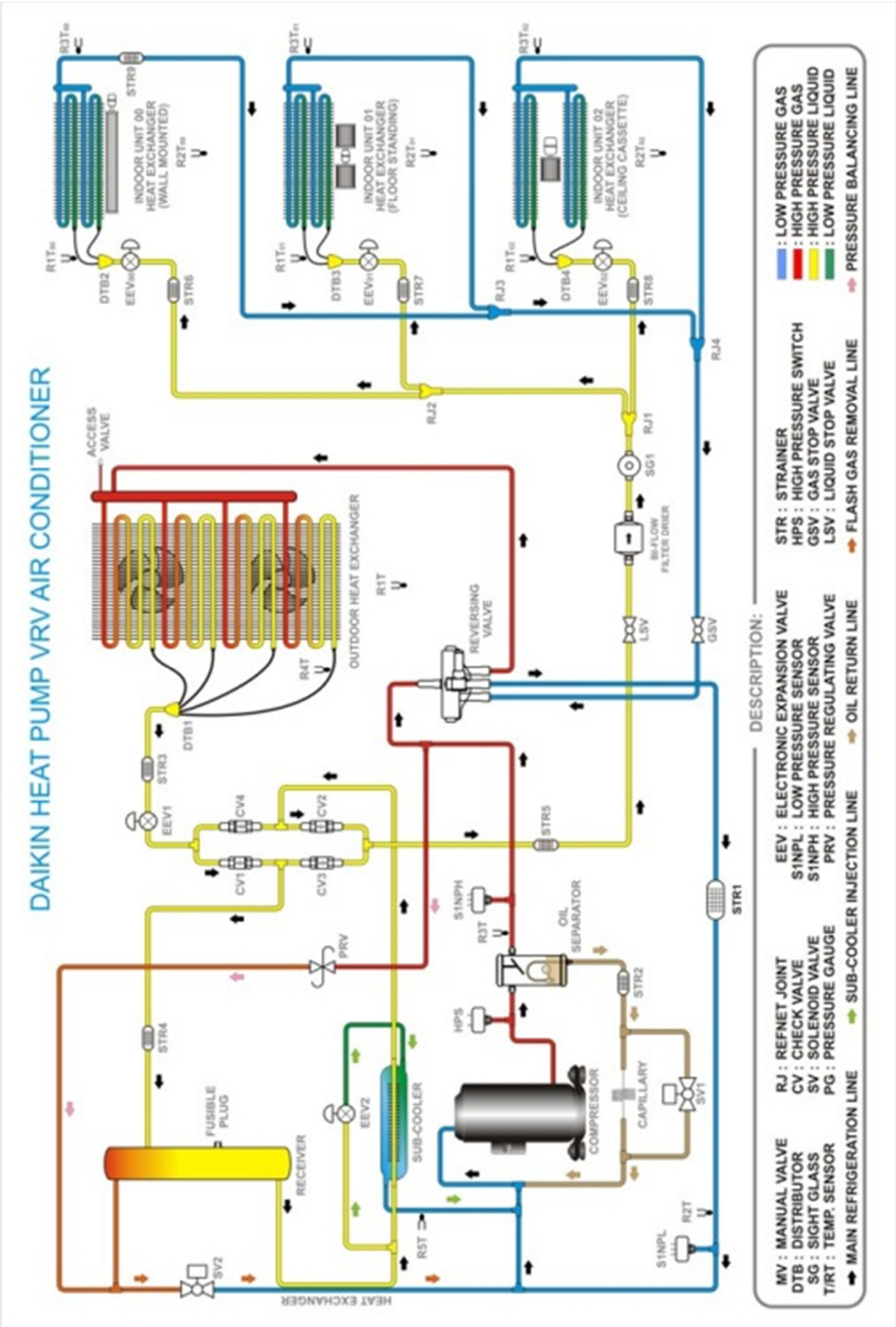
Item No.	Description	Unit	Qty.	UR (NIS)	Amount
Carried Before				**Shekel**	748304
1.4.7	**Water Collectors** Wages and the cost of supplying and installing closet of cold water collectors galvanized iron painted well installed in the walls and all its contents from collectors and Spherical valves with Provisions and connect, valves sub – valve for each output - and links and stalls collectors and hobby Auto and links end (End Piece), all (of the finest international standards and the adoption by the supervising engineer) and the price is the number of openings (eyes) and all what it takes to get the job done, according to the specifications and plans and instructions of the supervising engineer. Diameter 0.5" /16 mm	EYE	36	40	1440
1.5	**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 4”	ML	30	120	3600
B.	Diameter 2”	ML	30	100	3000
1.5.1	**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	10000	10000
Total Page Carried Forward				**Shekel**	18040

Bill No. (1): MECHANICAL WORKS

Item No.	Description	Unit	Qty.	UR (NIS)	Amount
Carried Before				**Shekel**	766344
	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.	20	300	6000
	Drain / Test Valves Supply, install, test and commission 2" Dia. drains & test valves complete with nipple and cap to NFPA requirements.	No.	2	400	800
	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.	14	1000	14000
Total Page Carried Forward				**Shekel**	20800
Total cost				**Shekel**	**787144**

Appendix (B)

Mechanical cycle:



Components:

- Compressor (3-Phase)
- Reversed valve
- Condenser fans (1-Phase)
- Evaporator fans (1-Phase)

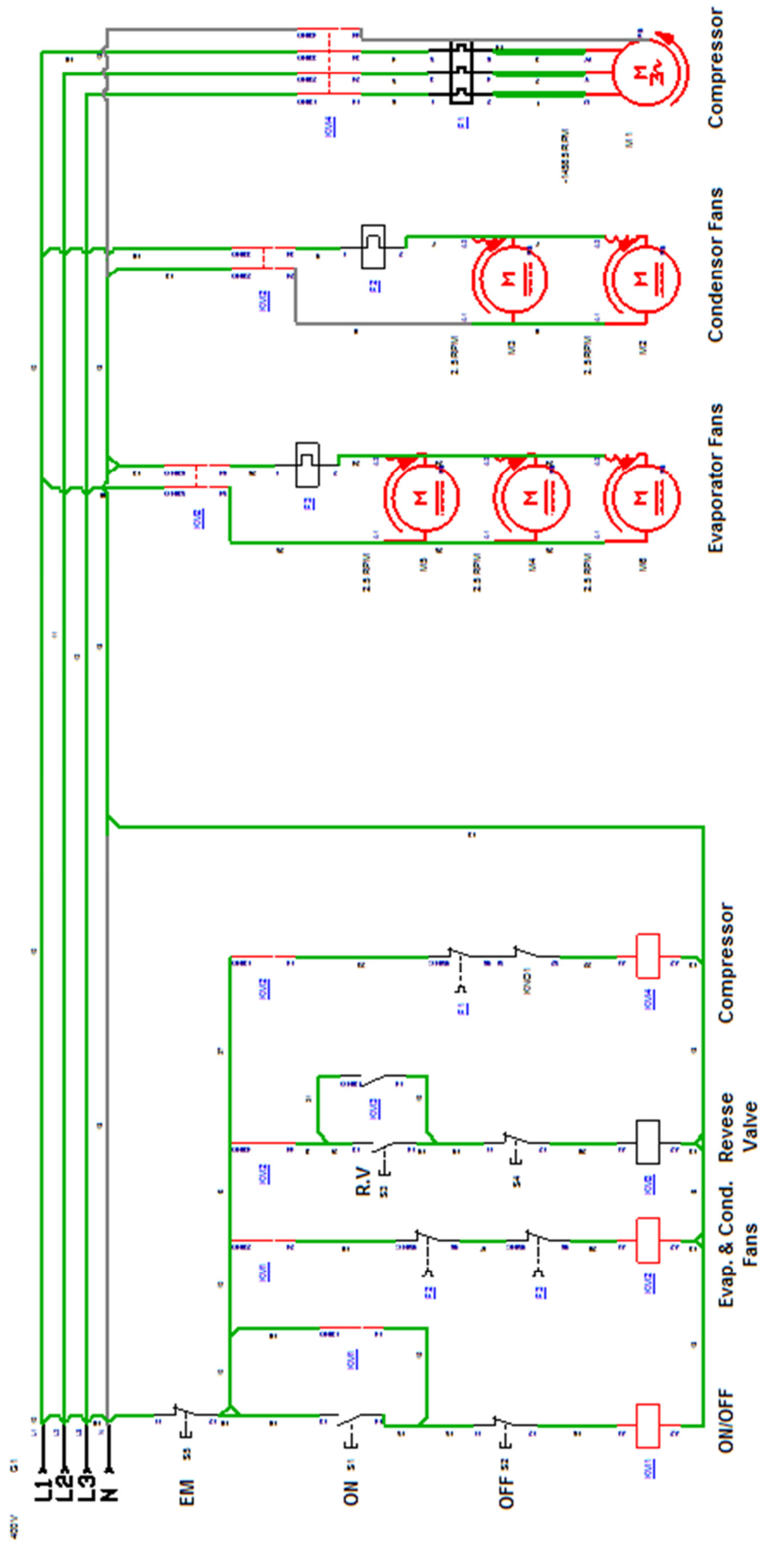
Protections:

- Overload
- High and low pressure for compressor

Operations:

1) Evaporator fans and condenser fans at once
2) Compressor

Control and power circuits:



Appendix (C)

TABLE A(2.1) Thermophysical Properties of Gases at Atmospheric Pressure[a]

T (K)	ρ (kg/m³)	c_p (kJ/kg · K)	$\mu \cdot 10^7$ (N · s/m²)	$\nu \cdot 10^6$ (m²/s)	$k \cdot 10^3$ (W/m · K)	$\alpha \cdot 10^6$ (m²/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

Table A(2.2) Inside film resistance, R_i.

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

Table A(2.3) Outside film resistance, R_o.

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

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

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

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

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

TABLE A(2.6) Values of infiltration air coefficient K[2] for windows.

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

TABLE A(2.7) 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(2.9) 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

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.

TABLE A(2.10) 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(2.8) Values of the factor S_2

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	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

TABLE A(2.11) 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(2.12) Solar heat gain factor (SHG) for sunlit glass, W/m², for a latitude angle of 32 °N.

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

TABLE A(2.13) Shading coefficient (SC) for glass windows without interior shading.[1]

Type of Glass	Nominal Thickness, mm	Solar Trans.	Shading Coefficient, W/m²·K $h_o = 22.7$	$h_o = 17.0$
Single Glass				
Clear	3	0.84	1.00	1.00
	6	0.78	0.94	0.95
	10	0.72	0.90	0.92
	12	0.67	0.87	0.88
Heat absorbing	3	0.64	0.83	0.85
	6	0.46	0.69	0.73
	10	0.33	0.60	0.64
	12	0.42	0.53	0.58
Double Glass				
Regular	3	—	0.90	—
Plate	6	—	0.83	—
Reflective	6	—	0.20-0.40	—
Insulating Glass				
Clear	3	0.71	0.88	0.88
	6	0.61	0.81	0.82
Heat absorbing*	6	0.36	0.55	0.58

TABLE A(2.14) 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	—	—	—	—

TABLE A(2.15) Cooling load factors (CLF) for glass windows without interior shading, north latitudes.

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

(Solar Time, h)

TABLE A(2.16) Cooling Load factors (CLF) for glass windows with interior shading, North latitude.

Fenestration Facing	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

(Solar Time, h)

TABLE A(2.17) Cooling load factor $(CLF)_{Lt}$, for lights.[3]

Number of hours after lights are turned On	Fixture X[c] hours of operation: 10	Fixture X[c]: 16	Fixture Y[c] hours of operation: 10	Fixture Y[c]: 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(2.18) Instantaneous heat gain from occupants in units of Watts[a].

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

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

TABLE A(2.19) Cooling load factor due to occupants $(CLF)_{occ.}$, for sensible heat gain.[5]

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

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

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

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

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

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

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

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

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

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

[d] Nominal I.D. pipe size.

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

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

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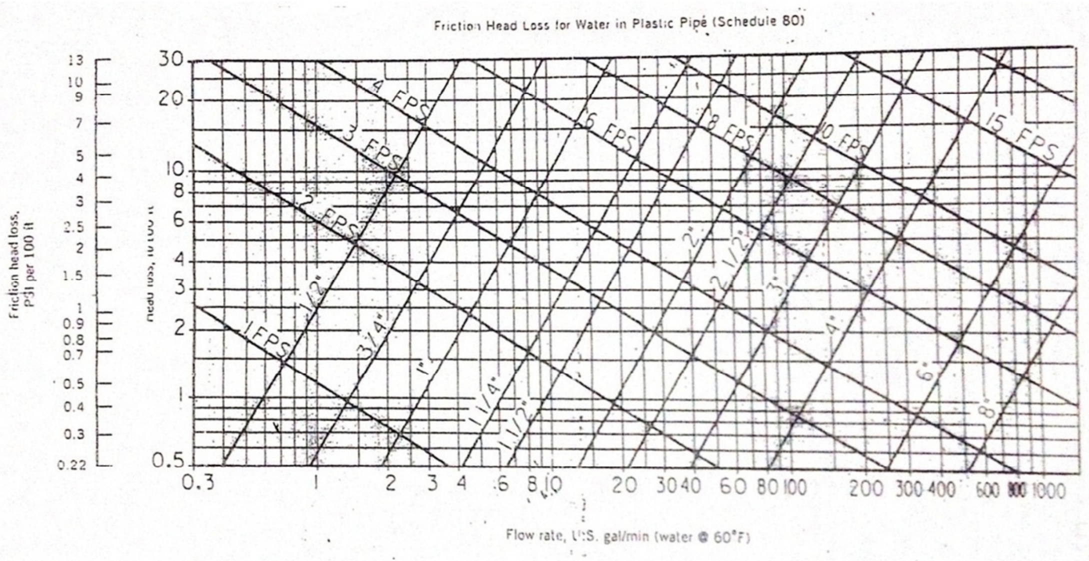

Figure A(4.1) Chart of friction head loss in Schedule 80 plastic pipe for water at 60°F, in feet of water and psi per 100 ft of equivalent pipe length. Pipe sizes are nominal. (Reprinted by permission of the American Society of Heating, Refrigerating and Air-Conditioning Engineers, Atlanta, Georgia,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

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

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

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

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

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

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

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

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Table A(4.2) Table for Estimating Demand

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

[a] Water Supply Fixture Units

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

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

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

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Table A(4.5) Horizontal Fixture Branches and Stacks

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

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

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

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

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

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

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

[b] Not over two water closets or two bathroom groups, except that in single family dwellings, not over three water closets or three bathroom groups may be installed.

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A(5.1)

Capacity problems, cavitation and high power consumption in pumps, are often results of the conditions on the suction side.

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

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

A(5.2)

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

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

A(5.3)

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

*) at room temperature

A(5.4)

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

Appendix (D)

SPECIFICATIONS - OUTDOOR UNITS

DVM S HEAT PUMP (208~230V)

Model Name				AM072FXVAFH/AA	AM096FXVAFH/AA	AM120FXVAFH/AA	AM144FXVAFH/AA
Power Supply			Ø, V, Hz	3, 208-230, 60	3, 208-230, 60	3, 208-230, 60	3, 208-230, 60
Mode			-	HEAT PUMP	HEAT PUMP	HEAT PUMP	HEAT PUMP
Performance	Ton		TON	6.00	8.00	10.00	12.00
	Capacity (Nominal)	Cooling[1]	Btu/h	72,000	96,000	120,000	144,000
		Heating[1]	Btu/h	81,000	108,000	135,000	162,000
	Capacity (Rated)	Cooling	Btu/h	69,000	92,000	114,000	138,000
		Heating	Btu/h	77,000	103,000	129,000	154,000
Power	MCA		A	28	37.8	43	52.6
	MOP		A	35	50	50	70
Compressor	Type		-	SSC Scroll x 1	SSC Scroll x 2	SSC Scroll x 2	SSC Scroll x 2
	Output		kW × n	(4.96)	(4.96x2)	(4.96x2)	(4.96x2)
	Model Name		-	DS-GB052FBVASG x 1	DS-GB052FBVASG x 2	DS-GB052FBVASG x 2	DS-GB052FBVASG x 2
	Oil	Type	-	PVE	PVE	PVE	PVE
		Initial Charge	cc	1100	2200	2200	2200
			fl. oz.	77.77	155.54	155.54	155.54
Fan	Type		-	Propeller	Propeller	Propeller	Propeller
	Output x n		W	400 x 1	620 x 2	620 x 2	620 x 2
	Air Flow Rate		CFM	7,239.78	9,182.16	9,182.16	9,535.32
	External Static Pressure	Max.	mmAq	8.00	8.00	8.00	8.00
			In Wg	0.31	0.31	0.31	0.31
Piping Connections	Liquid Pipe		Ø, mm	9.52	9.52	12.70	12.70
			Ø, inch	3/8	3/8	1/2	1/2
	Gas Pipe		Ø, mm	19.05	22.22	28.58	28.58
			Ø, inch	3/4	7/8	1 1/8	1 1/8
	High Pressure Gas Pipe (for HR)		Ø, mm	-	-	-	-
			Ø, inch	-	-	-	-
	Installation Limitation	Max. Length	m	200(220)	200(220)	200(220)	200(220)
			ft	656(722)	656(722)	656(722)	656(722)
		Max. Height	m	110(40)	110(40)	110(40)	110(40)
			ft	361(131)	361(131)	361(131)	361(131)
Refrigerant	Type		-	R410A	R410A	R410A	R410A
	Factory Charging		kg	5.50	7.40	7.40	8.70
			lbs	12.13	16.31	16.31	19.18
Sound[2]	Sound Pressure		dB(A)	60.0	61.0	61.0	62.0
	Sound Power			81	81	81	83
External Dimension	Net Weight		kg	190.0	278.0	278.0	293.0
			lbs	418.88	612.89	612.89	645.95
	Shipping Weight		kg	206.0	300.0	300.0	312.0
			lbs	454.15	661.39	661.39	687.84
	Net Dimensions (WxHxD)		mm	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
			inch	34.65 x 66.73 x 30.12	50.98 x 66.73 x 30.12	50.98 x 66.73 x 30.12	50.98 x 66.73 x 30.12
	Shipping Dimensions (WxHxD)		mm	948 x 1,912 x 832	1,363 x 1,912 x 832	1,363 x 1,912 x 832	1,363 x 1,912 x 832
			inch	37.32 x 75.28 x 32.76	53.66 x 75.28 x 32.76	53.66 x 75.28 x 32.76	53.66 x 75.28 x 32.76
Operating Temp. Range	Cooling		°F	23.0 ~ 120.0	23.0 ~ 120.0	23.0 ~ 120.0	23.0 ~ 120.0
	Heating		°F	-4.0 ~ 75.0	-4.0 ~ 75.0	-4.0 ~ 75.0	-4.0 ~ 75.0

1) Nominal Capacity is based on (Equivalent refrigerant piping : 25ft , Level differences : 0ft);
- Cooling : Indoor temperature : 80°F DB, 67°F WB / Outdoor temperature : 95°F DB, 75°F WB
- Heating : Indoor temperature : 70°F DB, 60°F WB / Outdoor temperature : 47°F DB, 43°F WB

2) Sound pressure was acquired in a dead room. Thus actual noise level may be different depending on the installation conditions.
3) Specifications are subject to change without prior notice for product improvement.

OUTDOOR UNITS

DVM S HEAT PUMP (208~230V)

Model Name				AM168FXVAFH/AA	AM192FXVAFH/AA	AM216FXVAFH/AA	AM240FXVAFH/AA
Power Supply			Ø, V, Hz	3, 208-230, 60	3, 208-230, 60	3, 208-230, 60	3, 208-230, 60
Mode			-	HEAT PUMP	HEAT PUMP	HEAT PUMP	HEAT PUMP
Performance	Ton		TON	14.00	16.00	18.00	20.00
	Capacity (Nominal)	Cooling[1]	Btu/h	168,000	192,000	216,000	240,000
		Heating[1]	Btu/h	189,000	216,000	243,000	270,000
	Capacity (Rated)	Cooling	Btu/h	161,000	183,000	207,000	228,000
		Heating	Btu/h	180,000	206,000	231,000	258,000
Power	MCA		A	65.8	71	80.6	86
	MOP		A	85	85	105	100
Compressor	Type		-	SSC Scroll x 3	SSC Scroll x 3	SSC Scroll x 3	SSC Scroll x 4
	Output		kW × n	(4.96x2) + (4.96)	(4.96x2) + (4.96)	(4.96x2) + (4.96)	(4.96x2)x2
	Model Name		-	DS-GB052FBVASG x 3	DS-GB052FBVASG x 3	DS-GB052FBVASG x 3	DS-GB052FBVASG x 4
	Oil	Type	-	PVE	PVE	PVE	PVE
		Initial Charge	cc	3300	3300	3300	4400
			fl. oz.	233.32	233.32	233.32	311.09
Fan	Type		-	Propeller	Propeller	Propeller	Propeller
	Output x n		W	620 x 2 + 400 x 1	620 x 2 + 400 x 1	620 x 2 + 400 x 1	(620 x 2) x 2
	Air Flow Rate		CFM	9,182.16 + 7,239.78	9,182.16 + 7,239.78	9,535.32 + 7,239.78	9,182.16 x 2
	External Static Pressure	Max.	mmAq	8.00	8.00	8.00	8.00
			In Wg	0.31	0.31	0.31	0.31
Piping Connections	Liquid Pipe		Ø, mm	15.88	15.88	15.88	15.88
			Ø, inch	5/8	5/8	5/8	5/8
	Gas Pipe		Ø, mm	28.58	28.58	28.58	28.58
			Ø, inch	1 1/8	1 1/8	1 1/8	1 1/8
	High Pressure Gas Pipe (for HR)		Ø, mm	-	-	-	-
			Ø, inch	-	-	-	-
	Installation Limitation	Max. Length	m	200(220)	200(220)	200(220)	200(220)
			ft	656(722)	656(722)	656(722)	656(722)
		Max. Height	m	110(40)	110(40)	110(40)	110(40)
			ft	361(131)	361(131)	361(131)	361(131)
Refrigerant	Type		-	R410A	R410A	R410A	R410A
	Factory Charging		kg	12.90	12.90	14.20	14.80
			lbs	28.44	28.44	31.31	32.63
Sound[2]	Sound Pressure		dB(A)	-	-	-	-
	Sound Power			-	-	-	-
External Dimension	Net Weight		kg	278.0 + 190.0	278.0 + 190.0	293.0 + 190.0	278.0 x 2
			lbs	612.89 + 418.88	612.89 + 418.88	645.95 + 418.88	612.89 x 2
	Shipping Weight		kg	300.0 + 206.0	300.0 + 206.0	312.0 + 206.0	300.0 x 2
			lbs	661.39 + 454.15	661.39 + 454.15	687.84 + 454.15	661.39 x 2
	Net Dimensions (WxHxD)		mm	1,295 x 1,695 x 765 + 880 x 1,695 x 765	1,295 x 1,695 x 765 + 880 x 1,695 x 765	1,295 x 1,695 x 765 + 880 x 1,695 x 765	(1,295 x 1,695 x 765) x 2
			inch	50.98 x 66.73 x 30.12 + 34.65 x 66.73 x 30.12	50.98 x 66.73 x 30.12 + 34.65 x 66.73 x 30.12	50.98 x 66.73 x 30.12 + 34.65 x 66.73 x 30.12	(50.98 x 66.73 x 30.12) x 2
	Shipping Dimensions (WxHxD)		mm	1,363 x 1,912 x 832 + 948 x 1,912 x 832	1,363 x 1,912 x 832 + 948 x 1,912 x 832	1,363 x 1,912 x 832 + 948 x 1,912 x 832	(1,363 x 1,912 x 832) x 2
			inch	53.66 x 75.28 x 32.76 + 37.32 x 75.28 x 32.76	53.66 x 75.28 x 32.76 + 37.32 x 75.28 x 32.76	53.66 x 75.28 x 32.76 + 37.32 x 75.28 x 32.76	(53.66 x 75.28 x 32.76) x 2
Operating Temp. Range	Cooling		°F	23.0 ~ 120.0	23.0 ~ 120.0	23.0 ~ 120.0	23.0 ~ 120.0
	Heating		°F	-4.0 ~ 75.0	-4.0 ~ 75.0	-4.0 ~ 75.0	-4.0 ~ 75.0

1) Nominal Capacity is based on (Equivalent refrigerant piping : 25ft , Level differences : 0ft);
- Cooling : Indoor temperature : 80°F DB, 67°F WB / Outdoor temperature : 95°F DB, 75°F WB
- Heating : Indoor temperature : 70°F DB, 60°F WB / Outdoor temperature : 47°F DB, 43°F WB

2) Sound pressure was acquired in a dead room. Thus actual noise level may be different depending on the installation conditions.
3) Specifications are subject to change without prior notice for product improvement.

SPECIFICATIONS - INDOOR UNITS

4 WAY CASSETTE

Model				AM030FN4DCH/AA	AM036FN4DCH/AA	AM048FN4DCH/AA
Power Supply			Ø, V, Hz	1,208-230,60	1,208-230,60	1,208-230,60
Mode			-	HP/HR	HP/HR	HP/HR
Performance	Capacity (Nominal)	Cooling 1)	Btu/h	30,000	36,000	48,000
			US RT	2.50	3.00	4.00
		Heating 1)	Btu/h	34,000	40,000	54,000
			US RT	2.83	3.33	4.50
Power	Power Input (Nominal)	Cooling 1)	W	65.00	75.00	95.00
		Heating 1)		65.00	75.00	95.00
	Current Input (Nominal)	Cooling 1)	A	0.50	0.56	0.75
		Heating 1)		0.50	0.56	0.75
Fan	Motor	Type	-	Turbo Fan	Turbo Fan	Turbo Fan
		Output x n	W	97 x 1	97 x 1	97 x 1
	Air Flow Rate	H/M/L (UL)	CFM	776.95/688.66/600.37	847.58/776.95/706.32	1,024.16/953.53/847.58
	External Pressure	Min / Std / Max	Pa	-	-	-
Piping Connections	Liquid Pipe		Ø, mm	9.52	9.52	9.52
			Ø, inch	3/8	3/8	3/8
	Gas Pipe		Ø, mm	15.88	15.88	15.88
			Ø, inch	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)
Refrigerant	Type		-	R410A	R410A	R410A
	Control Method		-	EEV INCLUDED	EEV INCLUDED	EEV INCLUDED
Sound	Sound Pressure 2)	High / Mid / Low	dBA	39.0/34.0/30.0	40.0/37.0/33.0	44.0/42.0/39.0
Dimensions	Net Weight		kg	18.50	18.50	18.50
			lbs	40.79	40.79	40.79
	Shipping Weight		kg	23.00	23.00	23.00
			lbs	50.71	50.71	50.71
	Net Dimensions (WxHxD)		mm	840 x 288 x 840	840 x 288 x 840	840 x 288 x 840
			inch	33.07 x 11.34 x 33.07	33.07 x 11.34 x 33.07	33.07 x 11.34 x 33.07
	Shipping Dimensions (WxHxD)		mm	898 x 357 x 898	898 x 357 x 898	898 x 357 x 898
			inch	35.35 x 14.06 x 35.35	35.35 x 14.06 x 35.35	35.35 x 14.06 x 35.35
Panel Size	Panel model		model name	PC4NUSKFN	PC4NUSKFN	PC4NUSKFN
	Panel Net Weight		kg	5.80	5.80	5.80
			lbs	12.79	12.79	12.79
	Shipping Weight		kg	8.40	8.40	8.40
			lbs	18.52	18.52	18.52
	Net Dimensions (WxHxD)		mm	950 x 45 x 950	950 x 45 x 950	950 x 45 x 950
			inch	37.40 x 1.77 x 37.40	37.40 x 1.77 x 37.40	37.40 x 1.77 x 37.40
	Shipping Dimensions (WxHxD)		mm	1005 x 100 x 1005	1005 x 100 x 1005	1005 x 100 x 1005
			inch	39.57 x 3.94 x 39.57	39.57 x 3.94 x 39.57	39.57 x 3.94 x 39.57
Additional Accessories	Drain pump	Drain pump	model name	Built-in	Built-in	Built-in
		Max. lifting Height / Displacement	mm/liter/h	750 / 24	750 / 24	750 / 24
	Air Filter		-	Long life filter	Long life filter	Long life filter

1) Nominal Capacity is based on (Equivalent refrigerant piping : 25ft , Level differences : 0ft);
 - Cooling : Indoor temperature : 80°F DB, 67°F WB / Outdoor temperature : 95°F DB, 75°F WB
 - Heating : Indoor temperature : 70°F DB, 60°F WB / Outdoor temperature : 47°F DB, 43°F WB
2) Sound pressure was acquired in a dead room. Thus actual noise level may be different depending on the installation conditions.
3) Specifications are subject to change without prior notice for product improvement.

INDOOR UNITS

MINI 4 WAY CASSETTE

Model				AM009FNNDCH/AA	AM012FNNDCH/AA
Power Supply			Ø, V, Hz	1,208-230,60	1,208-230,60
Mode			-	HP/HR	HP/HR
Performance	Capacity (Nominal)	Cooling 1)	Btu/h	9,500	12,000
			US RT	0.79	1.00
		Heating 1)	Btu/h	10,500	13,500
			US RT	0.88	1.12
Power	Power Input (Nominal)	Cooling 1)	W	24.00	28.00
		Heating 1)		24.00	28.00
	Current Input (Nominal)	Cooling 1)	A	0.17	0.19
		Heating 1)		0.17	0.19
Fan	Motor	Type	-	Turbo Fan	Turbo Fan
		Output x n	W	65 x 1	65 x 1
	Air Flow Rate	H/M/L (UL)	CFM	353.16/300.19/264.87	370.82/335.50/282.53
	External Pressure	Min / Std / Max	Pa	-	-
Piping Connections	Liquid Pipe		Ø, mm	6.35	6.35
			Ø, inch	1/4	1/4
	Gas Pipe		Ø, mm	12.70	12.70
			Ø, inch	1/2	1/2
	Drain Pipe		Ø, mm	VP25 (OD 32,ID 25)	VP25 (OD 32,ID 25)
Refrigerant	Type		-	R410A	R410A
	Control Method		-	EEV INCLUDED	EEV INCLUDED
Sound	Sound Pressure 2)	High / Mid / Low	dBA	34.0/30.0/26.0	36.0/34.0/31.0
Dimensions	Net Weight		kg	12.00	12.00
			lbs	26.46	26.46
	Shipping Weight		kg	14.00	14.00
			lbs	30.86	30.86
	Net Dimensions (WxHxD)		mm	575 x 250 x 575	575 x 250 x 575
			inch	22.64 x 9.84 x 22.64	22.64 x 9.84 x 22.64
	Shipping Dimensions (WxHxD)		mm	623 x 298 x 653	623 x 298 x 653
			inch	24.53 x 11.73 x 25.71	24.53 x 11.73 x 25.71
Panel Size	Panel model		model name	PC4SUSMEN	PC4SUSMEN
	Panel Net Weight		kg	2.70	2.70
			lbs	5.95	5.95
	Shipping Weight		kg	4.20	4.20
			lbs	9.26	9.26
	Net Dimensions (WxHxD)		mm	670 x 45 x 670	670 x 45 x 670
			inch	26.38 x 1.77 x 26.38	26.38 x 1.77 x 26.38
	Shipping Dimensions (WxHxD)		mm	714 x 106 x 724	714 x 106 x 724
			inch	28.11 x 4.17 x 28.50	28.11 x 4.17 x 28.50
Additional Accessories	Drain pump	Drain pump	model name	Built-in	Built-in
		Max. lifting Height / Displacement	mm/liter/h	750 / 24	750 / 24
	Air Filter		-	Long life filter	Long life filter

1) Nominal Capacity are based on (Equivalent refrigerant piping : 25ft , Level differences : 0ft);
 - Cooling : Indoor temperature : 80°F DB, 67°F WB / Outdoor temperature : 95°F DB, 75°F WB
 - Heating : Indoor temperature : 70°F DB, 60°F WB / Outdoor temperature : 47°F DB, 43°F WB
2) Sound pressure was acquired in a dead room. Thus actual noise level may be different depending on the installation conditions.
3) Specifications are subject to change without prior notice for product improvement.

SPECIFICATIONS

SPECIFICATIONS - INDOOR UNITS

SLIM DUCT

Model				AM024FNLDCH/AA	AM030FNLDCH/AA	AM036FNLDCH/AA	AM048FNLDCH/AA
Power Supply			Ø, V, Hz	1,208-230,60	1,220-240,50	1,208-230,60	1,208-230,60
Mode			-	HP/HR	HP/HR	HP/HR	HP/HR
Performance	Capacity (Nominal)	Cooling 1)	Btu/h	24,000	30,000	36,000	48,000
			US RT	2.00	2.50	3.00	4.00
		Heating 1)	Btu/h	27,000	34,000	40,000	54,000
			US RT	2.25	2.83	3.33	4.50
Power	Power Input (Nominal)	Cooling 1)	W	145.00	95.00	120.00	180.00
		Heating 1)		145.00	95.00	120.00	180.00
	Current Input (Nominal)	Cooling 1)	A	0.98	0.80	1.05	1.40
		Heating 1)		0.98	0.80	1.05	1.40
Fan	Motor	Type	-	Sirocco Fan	Sirocco Fan	Sirocco Fan	Sirocco Fan
		Output x n	W	110 x 1	80 x 1	100 x 1	160 x 1
	Air Flow Rate	H/M/L (UL)	CFM	582.71/529.74/476.77	1,094.80/918.22/812.27	1,200.74/1,024.16/847.58	1,342.01/1,130.11/953.53
	External Pressure	Min / Std / Max	Pa	0.00/9.81/39.23	0.00/9.81/58.84	0.00/29.42/58.84	0.00/29.42/58.84
			in. Wg	0.00/0.04/0.16	0.00/0.04/0.24	0.00/0.12/0.24	0.00/0.12/0.24
Piping Connections	Liquid Pipe		Ø, mm	9.52	9.52	9.52	9.52
			Ø, inch	3/8	3/8	3/8	3/8
	Gas Pipe		Ø, mm	15.88	15.88	15.88	15.88
			Ø, inch	5/8	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)
Refrigerant	Type		-	R410A	R410A	R410A	R410A
	Control Method		-	EEV INCLUDED	EEV INCLUDED	EEV INCLUDED	EEV INCLUDED
Sound	Sound Pressure 2)	High / Mid / Low	dBA	38.0/36.0/33.0	37.0/36.0/34.0	37.0/36.0/34.0	39.0/38.0/36.0
Dimensions	Net Weight		kg	30.00	40.00	40.00	41.50
			lbs	66.14	88.18	88.18	91.49
	Shipping Weight		kg	34.50	47.00	47.00	48.50
			lbs	76.06	103.62	103.62	106.92
	Net Dimensions (W×H×D)		mm	1100 x 199 x 600	1300 x 295 x 690	1300 x 295 x 690	1300 x 295 x 690
			inch	43.31 x 7.83 x 23.62	51.18 x 11.61 x 27.17	51.18 x 11.61 x 27.17	51.18 x 11.61 x 27.17
	Shipping Dimensions (W×H×D)		mm	1350 x 280 x 710	1575 x 370 x 835	1575 x 370 x 835	1575 x 370 x 835
			inch	53.15 x 11.02 x 27.95	62.01 x 14.57 x 32.87	62.01 x 14.57 x 32.87	62.01 x 14.57 x 32.87
Panel Size	Panel model		model name	-	-	-	-
	Panel Net Weight		kg	-	-	-	-
			lbs	-	-	-	-
	Shipping Weight		kg	-	-	-	-
			lbs	-	-	-	-
	Net Dimensions (W×H×D)		mm	-	-	-	-
			inch	-	-	-	-
	Shipping Dimensions (W×H×D)		mm	-	-	-	-
			inch	-	-	-	-
Additional Accessories	Drain pump	Drain pump	model name	MDP-E075SEE3D	MDP-E075SEE3D	MDP-E075SEE3D	MDP-E075SEE3D
		Max. lifting Height / Displacement	mm/liter/h	750 / 24	750 / 24	750 / 24	750 / 24
	Air Filter		-	Long life filter	Long life filter	Long life filter	Long life filter

1) Nominal Capacity is based on (Equivalent refrigerant piping : 25ft , Level differences : 0ft);
- Cooling : Indoor temperature : 80°F DB, 67°F WB / Outdoor temperature : 95°F DB, 75°F WB
- Heating : Indoor temperature : 70°F DB, 60°F WB / Outdoor temperature : 47°F DB, 43°F WB

2) Sound pressure was acquired in a dead room. Thus actual noise level may be different depending on the installation conditions.

3) Specifications are subject to change without prior notice for product improvement.

SAMSUNG VRF SYSTEM - DVM S

INDOOR UNITS

HIGH WALL

Model				AM007FNTDCH/AA	AM009FNTDCH/AA	AM012FNTDCH/AA
Power Supply			Ø, V, Hz	1,208-230,60	1,208-230,60	1,208-230,60
Mode			-	HP/HR	HP/HR	HP/HR
Performance	Capacity (Nominal)	Cooling 1)	Btu/h	7,500	9,500	12,000
			US RT	0.63	0.79	1.00
		Heating 1)	Btu/h	8,500	10,500	13,500
			US RT	0.71	0.88	1.13
Power	Power Input (Nominal)	Cooling 1)	W	37.00	37.00	45.00
		Heating 1)		37.00	37.00	45.00
	Current Input (Nominal)	Cooling 1)	A	0.25	0.25	0.30
		Heating 1)		0.25	0.25	0.30
Fan	Motor	Type	-	Crossflow Fan	Crossflow Fan	Crossflow Fan
		Output x n	W	23 x 1	23 x 1	23 x 1
	Air Flow Rate	H/M/L (UL)	CFM	275.46/240.15/204.83	289.59/254.28/218.96	328.44/293.12/257.81
	External Pressure	Min / Std / Max	Pa	-	-	-
Piping Connections	Liquid Pipe		Ø, mm	6.35	6.35	6.35
			Ø, inch	1/4	1/4	1/4
	Gas Pipe		Ø, mm	12.70	12.70	12.70
			Ø, inch	1/2	1/2	1/2
	Drain Pipe		Ø, mm	ID 18 HOSE	ID 18 HOSE	ID 18 HOSE
Refrigerant	Type		-	R410A	R410A	R410A
	Control Method		-	EEV NOT INCLUDED	EEV NOT INCLUDED	EEV NOT INCLUDED
Sound	Sound Pressure 2)	High / Mid / Low	dBA	31.0/29.0/27.0	31.0/29.0/27.0	37.0/33.0/29.0
Dimensions	Net Weight		kg	8.50	8.50	8.50
			lbs	18.74	18.74	18.74
	Shipping Weight		kg	11.00	11.00	11.00
			lbs	24.25	24.25	24.25
	Net Dimensions (W×H×D)		mm	825 x 285 x 189	825 x 285 x 189	825 x 285 x 189
			inch	32.48 x 11.22 x 7.44	32.48 x 11.22 x 7.44	32.48 x 11.22 x 7.44
	Shipping Dimensions (W×H×D)		mm	904 x 353 x 263	904 x 353 x 263	904 x 353 x 263
			inch	35.59 x 13.90 x 10.35	35.59 x 13.90 x 10.35	35.59 x 13.90 x 10.35
Panel Size	Panel model		model name	-	-	-
	Panel Net Weight		kg	-	-	-
			lbs	-	-	-
	Shipping Weight		kg	-	-	-
			lbs	-	-	-
	Net Dimensions (W×H×D)		mm	-	-	-
			inch	-	-	-
	Shipping Dimensions (W×H×D)		mm	-	-	-
			inch	-	-	-
Additional Accessories	Drain pump	Drain pump	model name	-	-	-
		Max. lifting Height / Displacement	mm/liter/h	-	-	-
	Air Filter		-	Long life filter	Long life filter	Long life filter

1) Nominal Capacity is based on (Equivalent refrigerant piping : 25ft , Level differences : 0ft);
- Cooling : Indoor temperature : 80°F DB, 67°F WB / Outdoor temperature : 95°F DB, 75°F WB
- Heating : Indoor temperature : 70°F DB, 60°F WB / Outdoor temperature : 47°F DB, 43°F WB

2) Sound pressure was acquired in a dead room. Thus actual noise level may be different depending on the installation conditions.

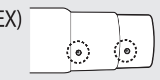
3) Specifications are subject to change without prior notice for product improvement.

INSTALLATION MANUAL

Please read 'Safety Precautions' described in the installation manual of the air conditioner.
- Check the following parts in the package.
- For further information of the piping material and size of the refrigerant pipes, refer to the installation manual of the air conditioner.

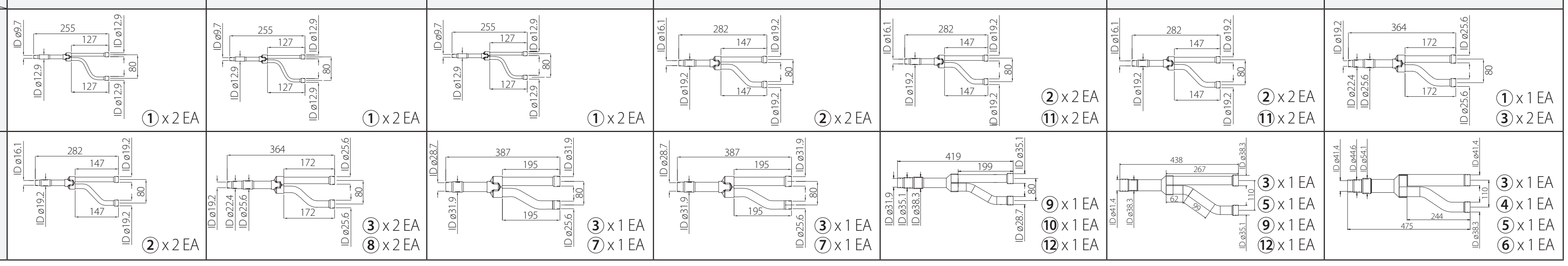
Requirement

- Condensate may occur on the heat insulation surface according to the atmosphere inside of the ceiling.
- If the inside of the ceiling has high temperature or humidity rate is more than 80%, please add proper insulation to prevent water drops.
- The stopper area of the pipe or socket should be spread with a welding material. EX)



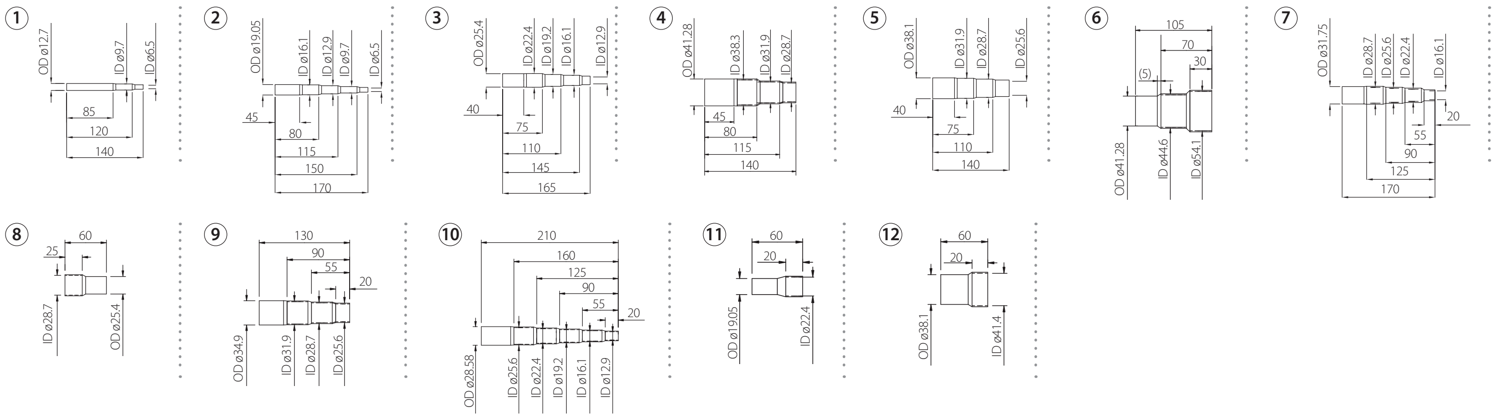
Branch joints

Y-joint



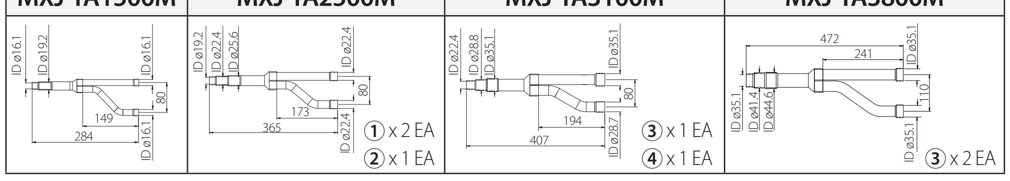
Name \ Model	MXJ-YA1509M	MXJ-YA2512M	MXJ-YA2812M	MXJ-YA2815M	MXJ-YA3419M	MXJ-YA4119M	MXJ-YA4422M
Liquid side	① x 2 EA	① x 2 EA	① x 2 EA	② x 2 EA	② x 2 EA ⑪ x 2 EA	② x 2 EA ⑪ x 2 EA	① x 1 EA ③ x 2 EA
Gas side	② x 2 EA	③ x 2 EA ⑧ x 2 EA	③ x 1 EA ⑦ x 1 EA	③ x 1 EA ⑦ x 1 EA	⑨ x 1 EA ⑩ x 1 EA ⑫ x 1 EA	③ x 1 EA ⑤ x 1 EA ⑨ x 1 EA ⑫ x 1 EA	③ x 1 EA ④ x 1 EA ⑤ x 1 EA ⑥ x 1 EA

Reducer



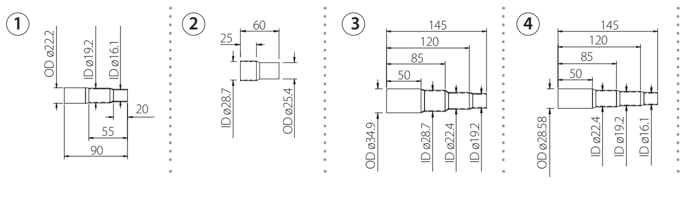
Model name	Total indoor unit's capacities
MXJ-YA1509M	15.0 kW (51 MBH) and below
MXJ-YA2512M	Over 15.0~40.0 kW (51~136 MBH) and below
MXJ-YA2812M	Over 40.0~45.0 kW (136~154 MBH) and below
MXJ-YA2815M	Over 45.0~70.3 kW (154~240 MBH) and below
MXJ-YA3419M	Over 70.3~98.4 kW (240~336 MBH) and below
MXJ-YA4119M	Over 98.4~135.2 kW (336~461 MBH) and below
MXJ-YA4422M	Over 135.2 kW (461 MBH)

Y-joint for *HR* (High pressure gas)



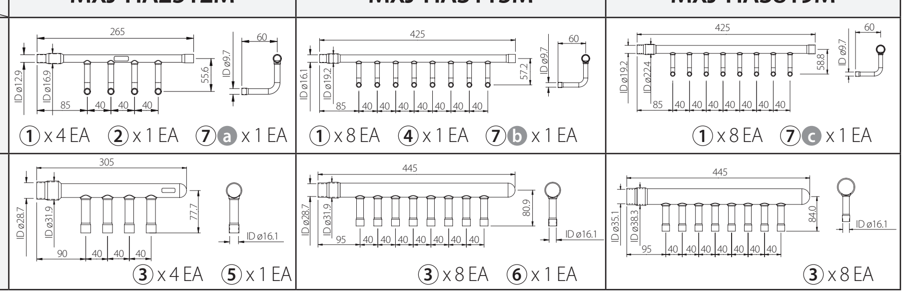
Model			
MXJ-YA1500M	MXJ-YA2500M	MXJ-YA3100M	MXJ-YA3800M
	① x 2 EA ② x 1 EA	③ x 1 EA ④ x 1 EA	③ x 2 EA

Reducer



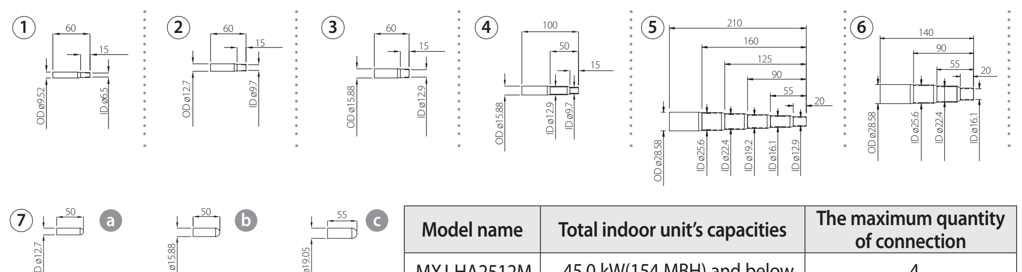
Model name	Total indoor unit's capacities
MXJ-YA1500M	22.4 kW (76 MBH) and below
MXJ-YA2500M	Over 22.4~70.3 kW (76~240 MBH) and below
MXJ-YA3100M	Over 70.3~ 135.2 kW (240~461 MBH) and below
MXJ-YA3800M	Over 135.2 kW (461 MBH)

Header joint



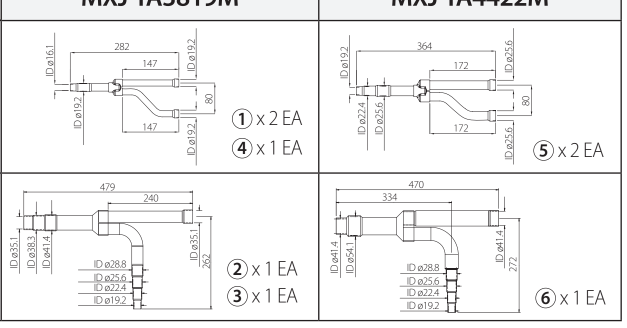
Name \ Model	MXJ-HA2512M	MXJ-HA3115M	MXJ-HA3819M
Liquid side	① x 4 EA ② x 1 EA ⑦ⓐ x 1 EA	① x 8 EA ④ x 1 EA ⑦ⓑ x 1 EA	① x 8 EA ⑦ⓒ x 1 EA
Gas side	③ x 4 EA ⑤ x 1 EA	③ x 8 EA ⑥ x 1 EA	③ x 8 EA

Reducer



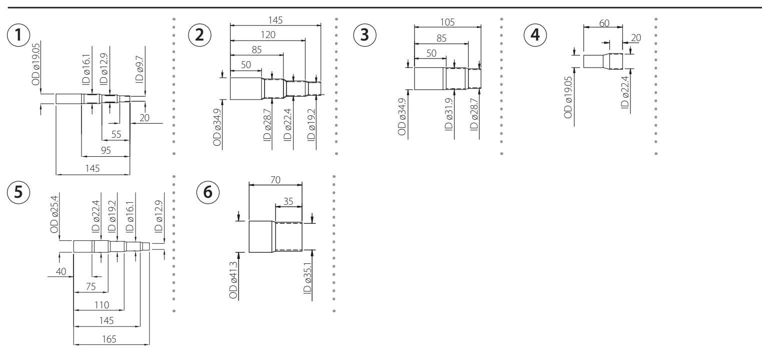
Model name	Total indoor unit's capacities	The maximum quantity of connection
MXJ-HA2512M	45.0 kW(154 MBH) and below	4
MXJ-HA3115M	70.3 kW(240 MBH) and below	8
MXJ-HA3819M	Over 70.3 kW (240 MBH)	8

Outdoor joint



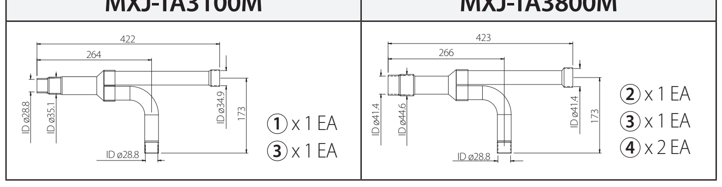
Name \ Model	MXJ-TA3819M	MXJ-TA4422M
Liquid side	① x 2 EA ④ x 1 EA	⑤ x 2 EA
Gas side	② x 1 EA ③ x 1 EA	⑥ x 1 EA

Reducer



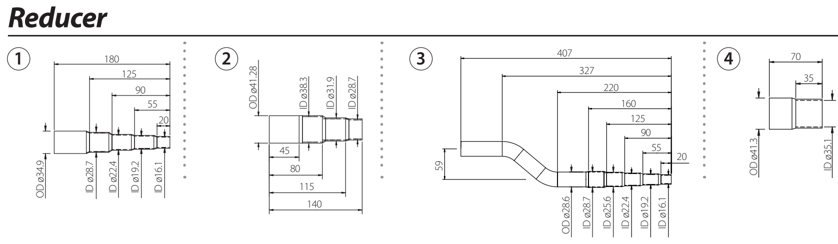
Model name	Total outdoor unit's capacities
MXJ-TA3819M	Below 135.2 kW(48HP, 461.3 MBH)
MXJ-TA4422M	Above 140.2 kW(50HP, 478.4 MBH)

Outdoor joint for *HR* (High pressure gas)



Model	
MXJ-TA3100M	MXJ-TA3800M
① x 1 EA ③ x 1 EA	② x 1 EA ③ x 1 EA ④ x 2 EA

Reducer



Model name	Total outdoor unit's capacities
MXJ-TA3100M	Below 135.2 kW(48HP, 461.3MBH)
MXJ-TA3800M	Above 140.2 kW(50HP, 478.4 MBH)

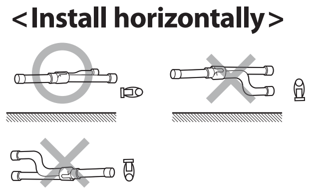
DVM S 유럽향 분기관_MXJ-YA1509M_IM_EN_03340A(2).indd 1 2013-06-10 오후 3:13:54

Connecting Method

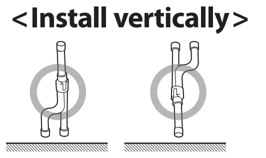
Installing the Y-joint

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

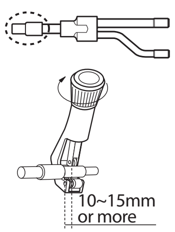
<Install horizontally>



<Install vertically>



<Using reducer>

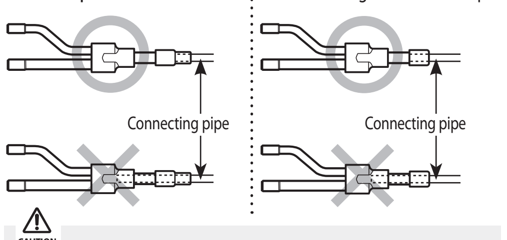


- Use connection part of Y-joint or provided reducer by cutting them in accordance with diameter of connecting pipe.
- Make certain 10~15mm or more for reducer which connected with pipe.
- Remove burr on cut part of reducer. It is impossible to connect reducer with pipe, if pipe is deformed or reducer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

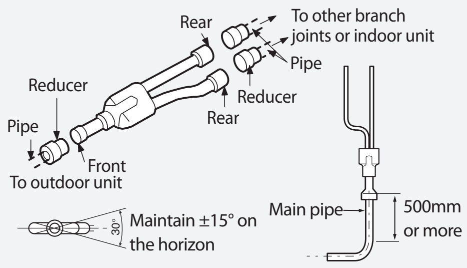
CAUTION
- ◆ ***Keep a minimum distance of 500mm or more before connecting a branch joint.***

<Insertion depth of the connecting pipe>

✳ Basic specification ✳ When cutting the connection part



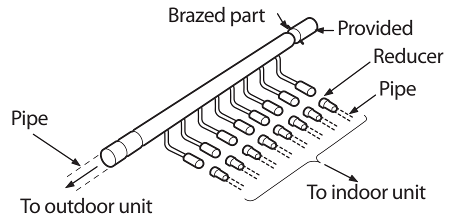
CAUTION
- ◆ ***Do not insert the pipe deeply into the Y-joint. (Do not insert more than 70mm.)***



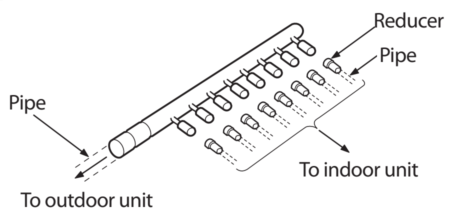
✳ Install the Y-joint within ±15° on the horizon or on the vertical.

Installing the Header joint

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

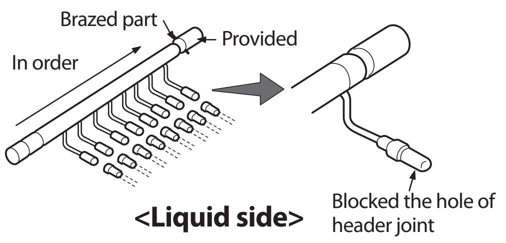


<Liquid side>

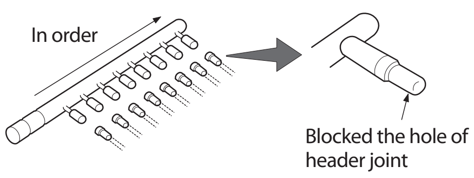


<Gas side>

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.

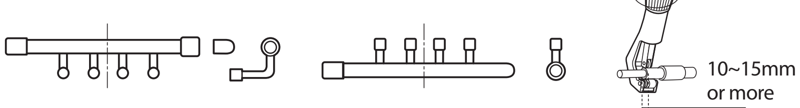


<Liquid side>



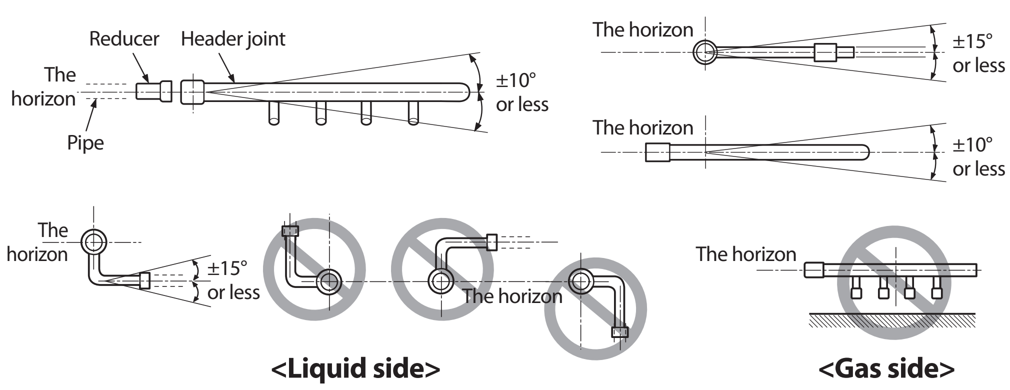
<Gas side>

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



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

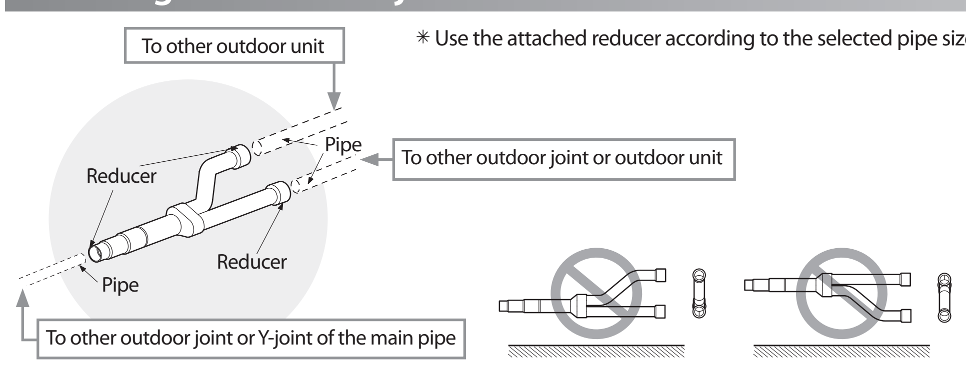
3. Install the header joint horizontally.



<Liquid side> **<Gas side>**

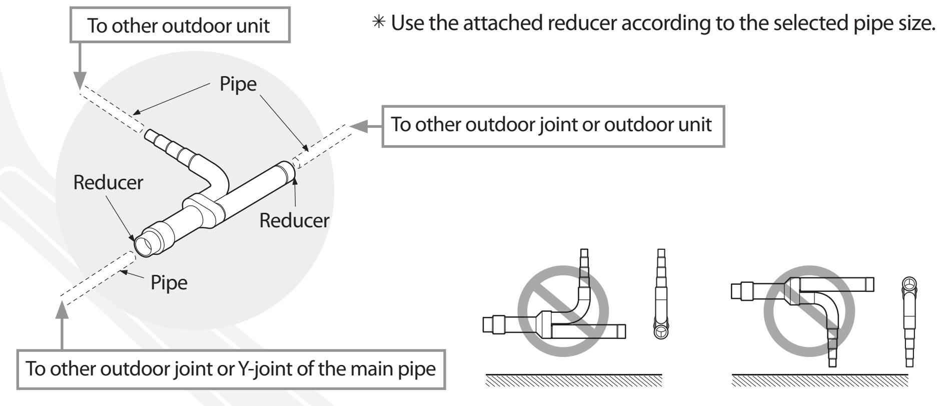
Installing the Outdoor joint

✳ Use the attached reducer according to the selected pipe size.



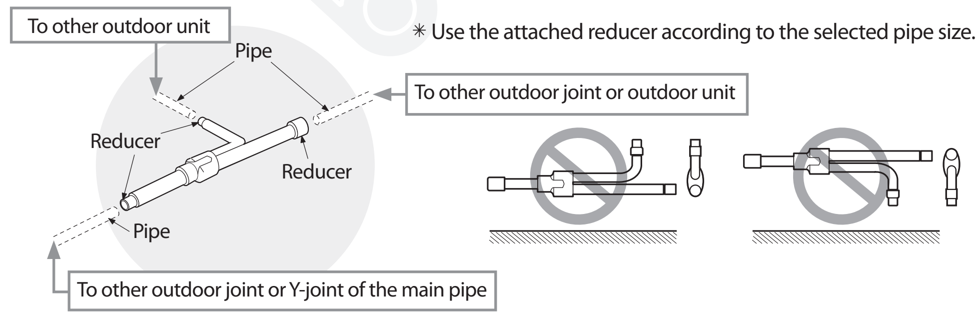
<Liquid side>

✳ Use the attached reducer according to the selected pipe size.



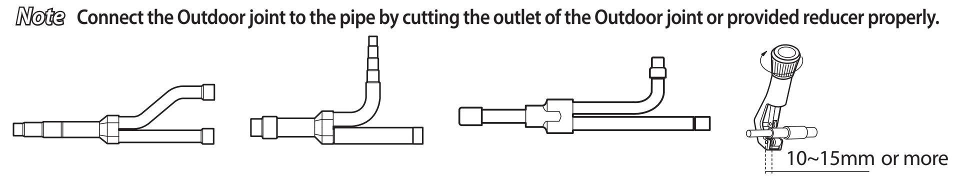
<Gas side>

✳ Use the attached reducer according to the selected pipe size.

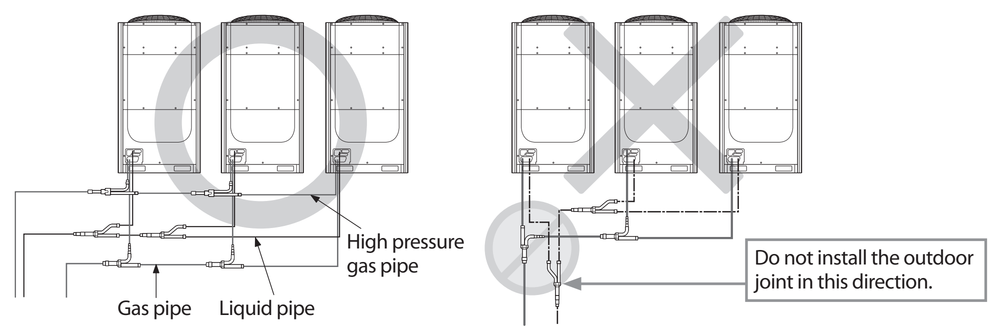


<High pressure gas side>

Note **Connect the Outdoor joint to the pipe by cutting the outlet of the Outdoor joint or provided reducer properly.**



Installation of outdoor joints

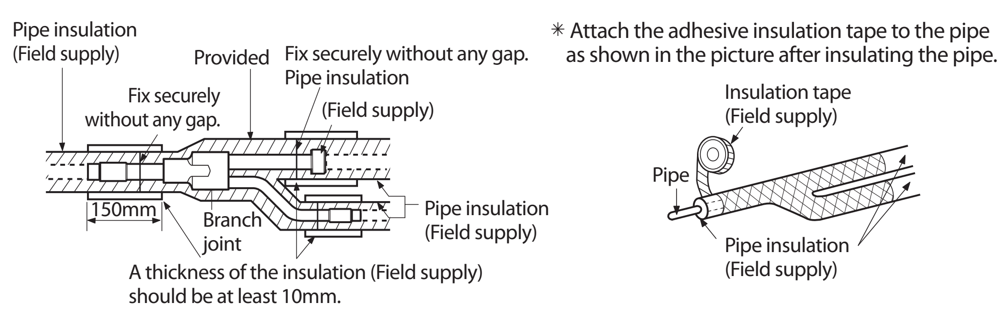


✳ High pressure gas pipe only applies to the HR product.

Insulating the branch joint

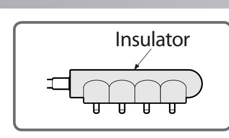
Y-joint & liquid side & gas side of the outdoor unit

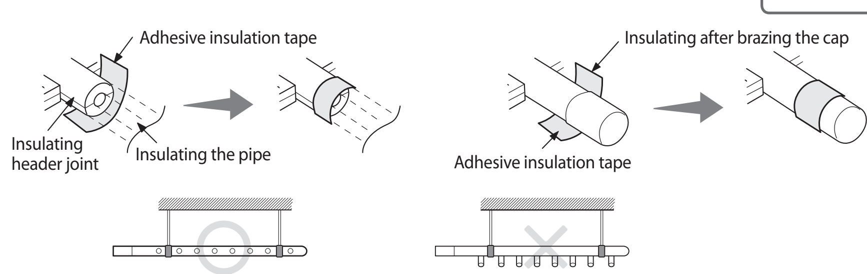
- ◆ Attach the insulation provided with a branch joint to the insulation supplied in the field without a gap. Wrap the connected part with an insulation (Field supply) of a thickness of at least 10mm.
- ◆ Use an insulation with the heat resisting temperature over 120°C. Wrap the branch joint with an 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.



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.





Arc Canopy Rangehood AAS6SE3

2 YEARS WARRANTY

Stainless Steel

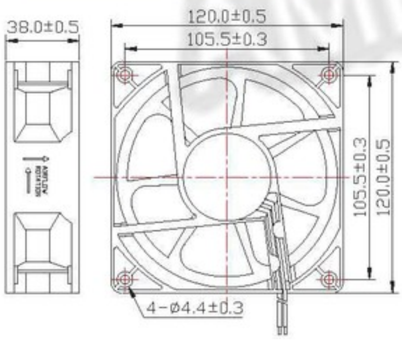
Model Number	AAS6SE3
Brand	Arc
Depth (mm)	500 mm
Minimum Height (mm)	645 mm
Width (mm)	600 mm
Noise when working	57 dB
Warranty	2 Years
Lighting	Halogen
Max Air Flow	700 m3/hr

AV-F12038

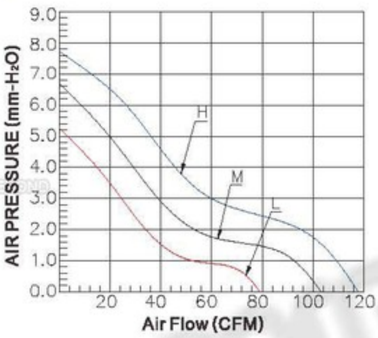
SIZE:
120x120x38mm
construction:
Glass Fiber reinforced plsatic;
Impeller and housing PBT are UL 94V-0 rating
OPERATING TEMPERATURE:
Sleeve bearing -10°C to +70°C
INSULATION RESISTANCE:
10meg Ohm min, at 500 VDC
(between frame and terminal)
DIELECTRIC STRENGTH:
5mA max, at 500 VAC 60Hz one minute
(between frame and terminal)

| Dimensions Drawing

Unit:mm



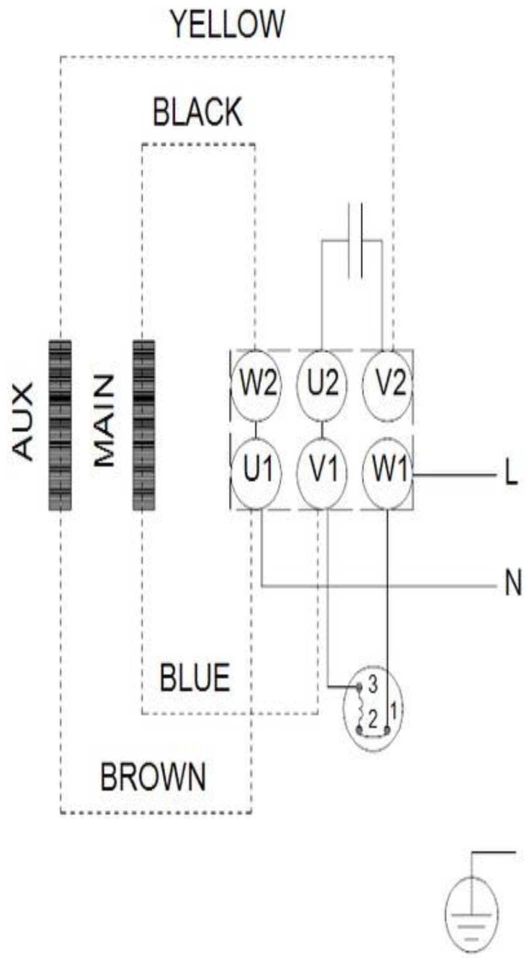
| Characteristic Curves



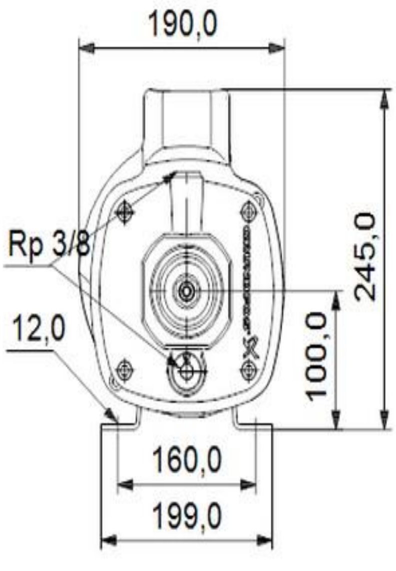
| Specifications

Carton Specifications (Unit: cm):45x25x25 QTY:40pcs GW:9.44Kg

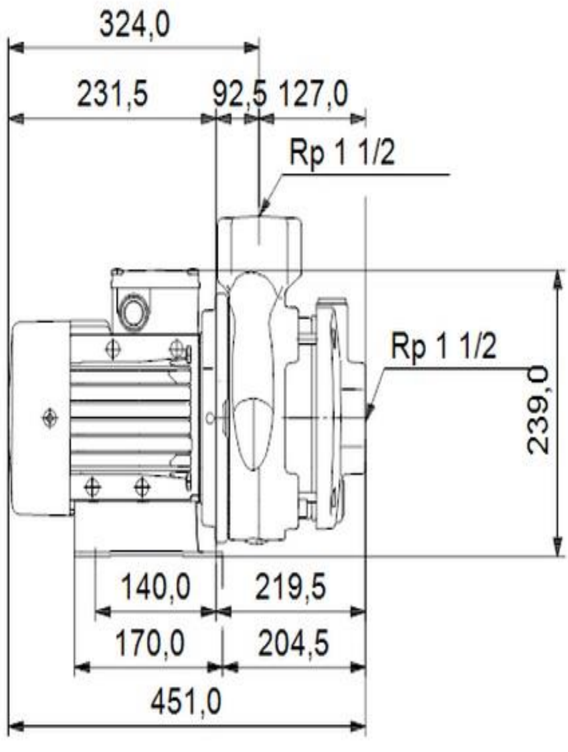
Model	Bearing Type	Rated Voltage	Operation Voltage	Current	Speed	Air Flow	Static Pressure	Noise Level	Weight
		VDC	VDC	A	RPM	CFM	mmH₂O	dBA	g
AV-F12038HS	Sleeve	12	10.8~13.2	1.00	4000	119.49	7.81	44.47	236
AV-F12038MS	Sleeve	12	10.8~13.2	0.45	3000	107.54	6.66	41.51	236
AV-F12038LS	Sleeve	12	10.8~13.2	0.30	2000	79.66	5.26	39.98	236
AV-F12038HB	Ball	12	10.8~13.2	1.00	4000	119.49	7.81	44.47	236
AV-F12038MB	Ball	12	10.8~13.2	0.45	3000	107.54	6.66	41.51	236
AV-F12038LB	Ball	12	10.8~13.2	0.30	2000	79.66	5.26	39.98	236
AV-F12038HS24	Sleeve	24	21.6~26.4	0.75	4000	119.49	7.81	44.47	236
AV-F12038MS24	Sleeve	24	21.6~26.4	0.30	3000	107.54	6.66	41.51	236
AV-F12038LS24	Sleeve	24	21.6~26.4	0.20	2000	79.66	5.26	39.98	236
AV-F12038HB24	Ball	24	21.6~26.4	0.75	4000	119.49	7.81	44.47	236
AV-F12038MB24	Ball	24	21.6~26.4	0.30	3000	107.54	6.66	41.51	236
AV-F12038LB24	Ball	24	21.6~26.4	0.20	2000	79.66	5.26	39.98	236



YELLOW
BLACK
AUX
MAIN
W2
U2
V2
U1
V1
W1
L
N
BLUE
BROWN
3
2
1



190,0
Rp 3/8
12,0
245,0
100,0
160,0
199,0



324,0
231,5
92,5
127,0
Rp 1 1/2
Rp 1 1/2
239,0
140,0
219,5
170,0
204,5
451,0

CM10-3 A-R-A-E-AVBE

Compact, reliable, horizontal, multistage, end-suction centrifugal pump with axial suction port and radial discharge port. The shaft, impellers and chambers are made of stainless steel. The inlet and discharge parts are made of cast iron. The mechanical shaft seal is a special designed, unbalanced O-ring seal. Pipework connection is via internal Whitworth pipe threads, Rp (ISO 7/1). The pump is fitted with a 1-phase, foot-mounted, fan-cooled asynchronous motor.

Liquid:

Pumped liquid:	Water
Liquid temperature range:	-20 .. 90 °C
Liquid temp:	20 °C
Density:	998.2 kg/m³
Kinematic viscosity:	1 mm2/s

Technical:

Speed for pump data:	2900 rpm
Actual calculated flow:	11.6 m³/h
Resulting head of the pump:	30.01 m
Primary shaft:	AVBE
Approvals on nameplate:	CE,WRAS,ACS,TR
Curve tolerance:	ISO9906:2012 3B

Materials:

Pump housing:	Cast iron EN-JL1030 AISI 30 B
Impeller:	Stainless steel DIN W.-Nr. 1.4301 AISI 304
Rubber:	EPDM

Installation:

Maximum ambient temperature:	55 °C
Maximum operating pressure:	10 bar
Max pressure at stated temp:	6 bar / 90 °C 10 bar / 40 °C
Flange standard:	WHITWORTH THREAD RP
Pump inlet:	Rp 1 1/2
Pump outlet:	Rp 1 1/2

Electrical data:

Motor type:	90SB
IE Efficiency class:	IE1
Rated power - P2:	1.9 kW
Mains frequency:	50 Hz
Rated voltage:	1 x 220-240 V
Service factor:	1
Rated current:	11,0-10,0 A
Rated speed:	2755-2770 rpm
Enclosure class (IEC 34-5):	: IP55
Insulation class (IEC 85):	F

Others:

Minimum efficiency index, MEI ≥:	0,7
Net weight:	32.6 kg
Gross weight:	35.1 kg

Sizing result

Type	CM10-3	
Quantity * Motor	1 * 1.9 kW	
Flow	11.6	m³/h (+13%)
H total	30.01	m
Power P1	1.992	kW
Power P2	1.529	kW
Eta pump	62.1	%
Eta motor	76.7	%
Eta pump+motor	47.7	% =Eta pump * Eta motor
Flow total	70794	m³/year
Energy consumption	12108	kWh/Year
Price	On request	
Price + energy costs	On request	/10Years
Life cycle cost	26595	€ /10Years

Load profile

	1	
Flow	100	%
Head	100	%
P1	1.992	kW
Eta total	47.7	%
Time	6840	h/a
Energy consumption	12108	kWh/Year
Quantity	1	

dp pumps

Technical specifications sheet

Part number **290102251050U**

Description **DPV 10/5 B~Oval G 6/4~2,2kW 230/400V~50Hz 2P~IEC 90L~IE3~Fixed Ca Sic EPDM**

Vertical centrifugal pump, suction and discharge connections in-line.

Quotation details

Quotation number
Project
Position

Search criteria

Medium to be pumped	Water
Flow	11.30 m3/h
Pressure	3.5 bar

Hydraulic efficiency

Minimum efficiency index according: Commission Regulation (EU) No 547/2012	MEI ≥ 0.70

Actual duty point

Flow	11.3 m3/h
Pressure	3.5 bar
NPSH	1.5 m
Efficiency	65.2 %
Motor power	1.7 kW
Frequency	50.0Hz

Best efficiency point

Flow	9.5 m3/h
Pressure	4.1 bar
NPSH	1 m
Efficiency	67 %
Motor power	1.63 kW
Frequency	50Hz

Connection base

Connection type	Oval
DIN connection standard	DIN-ISO 228-1
ASME connection standard	
JIS connection standard	
DIN connection size	G 6/4
ASME connection size	
JIS connection size	
DIN connection pressure class	PN16
ASME connection pressure class	
JIS connection pressure class	
Material S/D casing	AISI304
Material flanges	Cast Iron JL1040
Material baseplate	Cast Iron JL1040

Seal data

Shaft diameter	ø 16mm
Seal diameter	ø 16mm
Construction shaft seal	Fixed
Seal code	11
Shaft seal type	MG12-G60
Material mechanical seal	B Q1 E GG
Material shaft seal rotor	Ca
Material shaft seal stator	Sic
Material shaft seal elastomer	EPDM
Material pump elastomer	EPDM
Material seal cover	
Pressure class shaft seal	PN10
Temperature range shaft seal	-20/+100℃

Basic hydraulic data

Maximum working pressure	PN25+100℃
Maximum liquid temperature	140℃+PN16
Minimum liquid temperature	-20℃
Material hydraulic	AISI304

Plug

Air relieve construction	Vent. plug
Material plug	AISI304

For details contact

DP Pumps
PO Box 28
2400AA Alphen a/d Rijn
The Netherlands

NL

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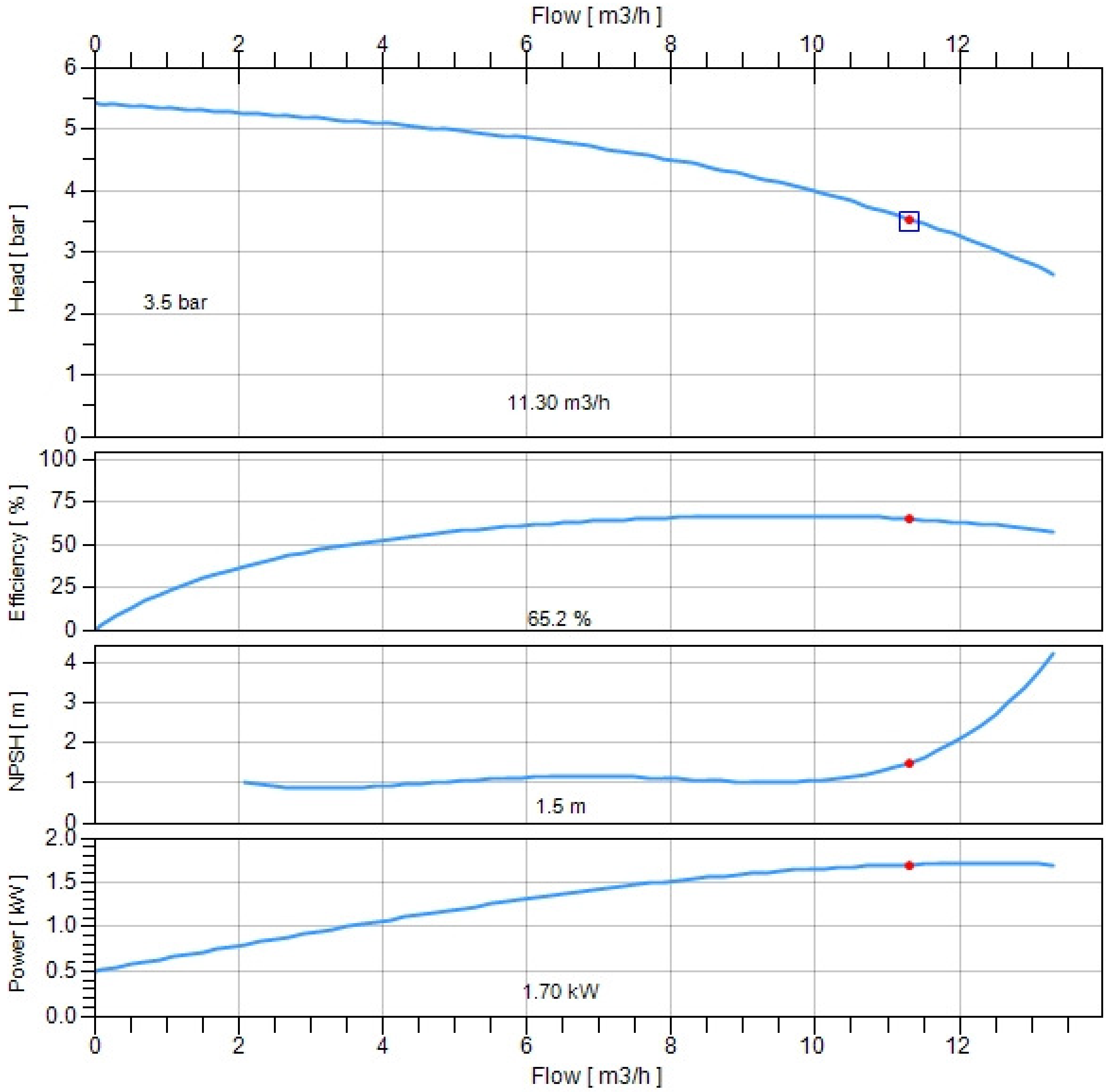
Hydraulic performance sheet

Part number	**290102251050U**
Description	**DPV 10/5 B~Oval G 6/4~2,2kW 230/400V~50Hz 2P~IEC 90L~IE3~Fixed Ca Sic EPDM**

Vertical centrifugal pump, suction and discharge connections in-line.

Search criteria		**Actual duty point**	
Medium to be pumped			
Flow	11.30 m3/h	Flow	11.30 m3/h
Pressure	3.5 bar	Pressure	3.5 bar
		Efficiency	65.2 %
		NPSH	1.5 m
		Power	1.70 kW
		Frequency	50.0Hz



Duty point
- Actual
- Required

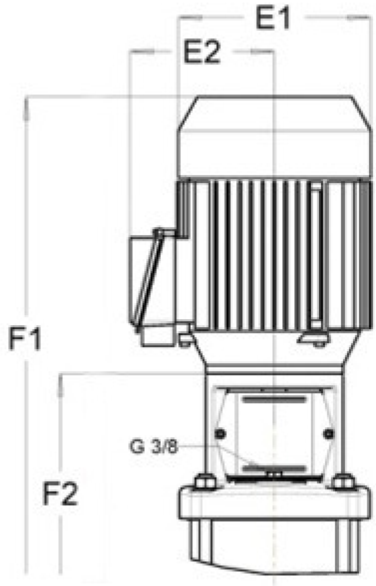
dp pumps

Dimensions sheet

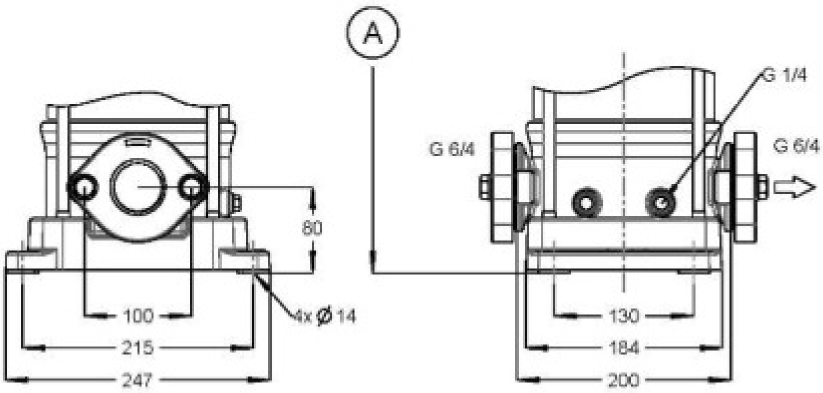
Part number **290102251050U**

Description **DPV 10/5 B~Oval G 6/4~2,2kW 230/400V~50Hz 2P~IEC 90L~IE3~Fixed Ca Sic EPDM**

Vertical centrifugal pump, suction and discharge connections in-line.



Motor width (E1)	185mm
Motor width (E2)	139mm
Total height (F1)	742
Total height (F2)	436mm
Total net weight	45kg



dp pumps

Motor specifications

Part number **3710051022**

Description **Motor DMC 2,2kW 230/400V 2P IE3 90L IP55 Pos. 800**

Electric Data

Rated power output	2,2kW
Maximum power output	3,4kW
Rated voltage	230/400V
Phases	3ph
Frequency	50/60Hz
Voltage range	207-253/360-440V
Motor poles	2P
ATEX class	
Duty class	S1
Insulation class	F (rise-B)
Moment of inertia	0,0019kgm2
Motor standard	IEC
Capacitor	
Motor efficiency	85,9%/86,5%
Motor efficiency class	IE3

50Hz

Tolerance rated voltage	±10%
Rated speed	2900rpm
Starting current factor (Ia/In)	8.8
Rated current (In)	8/4,6A
Maximum current (Imax)	10,7/6,2A
Rated Cos phi	0.8
Sound pressure	55dB(A)(A)
Rated nominal torque	7,3Nm
Rated starting torque	29,2Nm

60Hz

Tolerance rated voltage	-10% / +25%
Rated speed	3480rpm
Starting current factor (Ia/In)	8.6
Rated current (In)	7,1/4,1A
Maximum current (Imax)	10,7/6,2A
Rated Cos phi	0.9
Sound pressure	58dB(A)(A)
Rated nominal torque	6,0Nm
Rated starting torque	22,2Nm

Motor protection

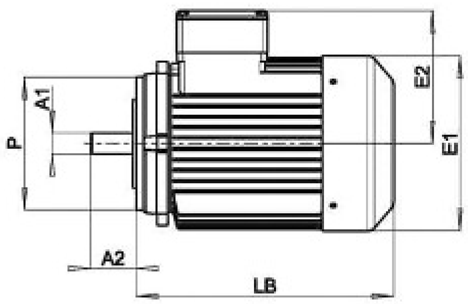
Motor protection class	IP55
Temperature sensor	
Rain cover	
Anti condensation heater	

Mechanical data

Shaft execution	smooth shaft
Maximum starts per hour	30
Cable gland	1xM20x1,5
VFD allowance	VFD allowed max. 400V

Dimensions

Diameter shaft A1	24mm
Length shaft A2	50mm
Diameter motor E1	185mm
Terminal box height E2	139mm
Diameter flange P	140mm
L. motor (without shaft) LB	306mm
Frame size	90L
Motor construction type	IM V18
Motor face	EC 60034-7 Form FT 115



Bearings / lubrication

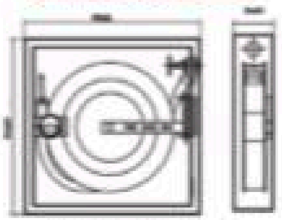
Grease nipple	
Bearing fixation pos	D-end
D-end bearing type	6305-2Z-C3
Bearing grease	Lithium based -20°/+160

Details

Motor label	DMC
Weight	20kg
Lifting lugs	
Motor finish	RAL5002
Rated max. amb. temp.	40℃
Material housing	Aluminium

1½” SYNTHETIC HOSE CABINET

FIRE HOSE CABINET WITH EXTINGUISHER AND ONE DOOR



MODEL SF4000 FOR 1.5" HOSE
MODEL SF5000 FOR 2.5" HOSE

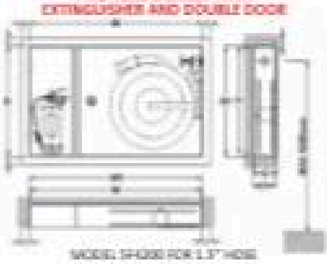
FIRE HOSE CABINET WITH EXTINGUISHER AND ONE DOOR

MODEL SF4400 FOR 1.5" HOSE
MODEL SF5400 FOR 2.5" HOSE

FIRE HOSE CABINET WITH EXTINGUISHER ONE DOOR AND ADDITIONAL VALVE

MODEL SF4600 FOR 1.5" HOSE
MODEL SF5600 FOR 2.5" HOSE

FIRE HOSE CABINET WITH EXTINGUISHER AND DOUBLE DOOR



MODEL SF4200 FOR 1.5" HOSE
MODEL SF5200 FOR 2.5" HOSE

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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