Palestine Polytechnic University

College of Engineering

Mechanical Engineering

Department of Refrigeration and Air-Conditioning

Graduation Project

Design and Documentation The Mechanical System of Two Hundred Fifty Bed at Halhoul Hospital

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Palestine Polytechnic University

College of Engineering

Mechanical Engineering Department

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Graduation Project Evaluation

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 fulfillments of the requirements of (B.SC) degree.

Supervisor Signature

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Committee signature

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Department Headmaster Signature

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Dedication

To The Souls of Our Ancestors

Who Left With Rivers Of Benevolence

To Our Parents Those Who Were Mentors, Teachers and Friends

Who Were Guidance with Their Endless Giving

To Our Teachers

Who Were Candles, Lighting Our Path to Excellence

To Our Beloved University

Where Our Hearts Will Remain

To All Those

We Promis

The Promise of the Blood of Martyrs

The Promise of Hungry Prisoners

That We Shall Forever Be Loyal Servants

To Our Glorious Palestine

Acknowledgement

Our thanks go first to Allah

And then our parents

And our project supervisor

Dr. Ishaq sider

His guidance and support made this work possible

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

This project aims to design a mechanical service for hospital in Halhoul city which includes 250 beds. So that the hospital services thousands of Palestinian people living in Halhoul.

The project is going to integrate service to the hospital in regard to the air conditioning , fire fighting system and plumbing systems. For the air conditioning, the Variable Refrigeration Volume system (VRV) is to be used , which is the most environmental friendly because of its efficiency in elimination both sound and environmental pollution , which reduce the consumption of the electrical energy. regarding the fire fighting system , the pump system that provides the water with the required pressure. Finally , in the plumbing system the water with the required pressure to each fixture unit inside the hospital and gets rid of waste water in a safe and healthy .

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Chapter 1

Introduction

1.1 General Overview

The Government hospitals in Palestine had an essential and vital rule, in promoting the general health of the Palestinians people, like Halhoul hospital. Halhoul hospital have different sections, including internal medicines, Pediatrics, Orthopedic, Surgery, Gynecology, Lab investigation, X-ray and Ultra sound in addition to outpatient clinics.

The different mechanical installation systems including central heating system, air conditioning system, water supply system, drainage supply system, and medical gasses system are not less important for the patients than the medical service itself so, such installations must be in the best manner in addition to the continuous maintenance needed to guarantee best performance.

Halhoul hospital as one of these governmental hospitals study, hoping through survey and evaluation of the mechanical systems to race problems and provide solutions for them, to full fill one of the polytechnic university aims to help the society.

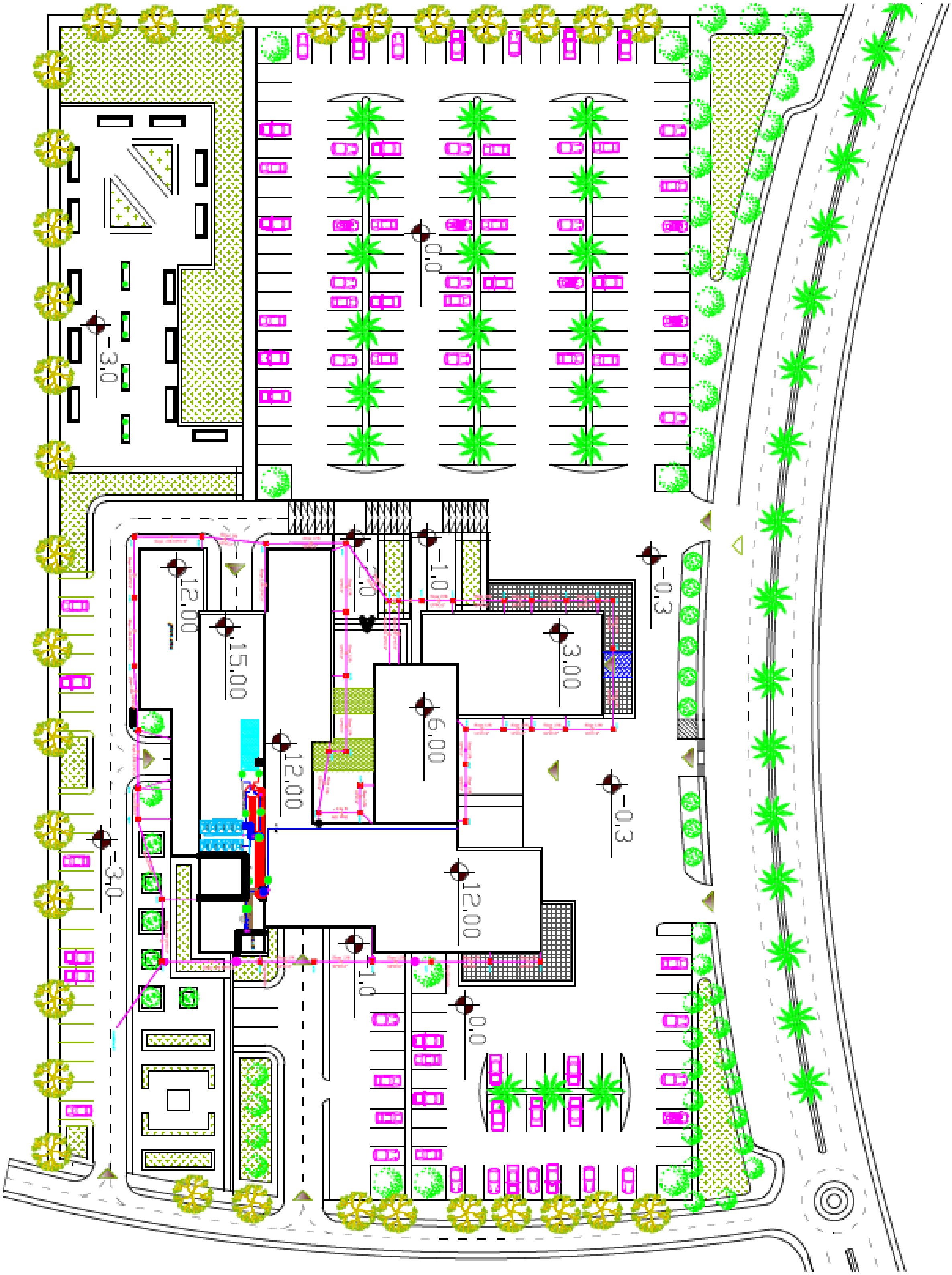


Figure 1.1: Horizontal plan for the hospitals

1.2 Project benefits:

1. The main benefit is to fulfill the graduation requirements of Palestine Polytechnic University, and be familiar with all mechanical design of system installed in building to be ready in working in this field after graduation .
2. To be familiar with the different mechanical drawings.

1.3 Project objectives:

The following main points summarize the objectives of this project:

1. To calculate and design a Variable Refrigeration Volume (VRV) air conditioning system.
2. To calculate and design the plumbing system including water supply and waste water systems for the hospital.
3. To calculate and design suitable fire fighting system that covers the requirements of the building.
4. To prepare the required drawings for the relevant systems on AutoCAD program in details.
5. To select the required equipment of the systems.
6. To prepare suitable bill of quantities table (BOQ) for the relevant systems

1.4 Description of Project Idea

The hospital named "Halhoul Hospital" is located in Halhoul in Hebron, which is planned to service thousands of people in Halhoul, it contains four floor, each floor area almost $(3000)m^2$.

The hospital also has the following medical departments:

- Delivery department.
- Surgery department.
- Emergency department.
- Labs of medical test.
- Radiology department.

1.5 Time table

Table 1.1: Time table for first semester.

Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Project selection and proposal	■	■	■												
Information gathering	■	■	■	■	■										
Search for previous projects	■	■	■	■	■	■									
Load calculation				■	■	■	■								
Fire fighting system								■	■	■					
Medical gases system											■	■			
project documentation						■	■	■	■	■	■	■	■		
Project printing														■	■

Table 1.2: Time table for second semester.

Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Plumping system	■	■	■												
Drainage system				■	■										
HVAC system						■	■	■	■						
Drawing				■	■	■	■	■	■	■	■	■	■		
Project printing														■	■

1.6 Project layout

- Chapter one:

  Introduction: Include an overview about the project, and the importance of the mechanical systems.

- Chapter two:

  Loads calculation: Include an overview about the Thermal loads of the building account in the summer and winter.

- Chapter three:

  Heating, ventilation and air conditioning (HVAC)

- Chapter Four:

  Plumbing system: Include an overview about the water supply, drainage system, plumbing materials, water distribution in buildings, water service sizing.

- Chapter five:

  Fire fighting system.

- Chapter six:

  Medical gases.

- Chapter seven :

  Refrigerators.

- Appendix.

Chapter 2

Loads Calculation

A heating system is combination of equipment that is used to raise the temperature in any location. This can be accomplished several ways, using energy sources such as: solar, oil, wood, electricity and gas. Many systems are used for this purpose, such as heating by hot water or heating by warm air, sometime small heaters are used for this purpose, there are many criteria's that will be taken to select the suitable system such as cost, efficiency, flexibility and type of building.

2.1 The composition of heat gains

Heat gains are either sensible, tending to cause a rise in air temperature, or latent, causing an increase in moisture content. In comfort air conditioning sensible gains originate from the following sources:

1. Solar radiation through windows.
2. Transmission through the building envelope and by the natural infiltration of warmer air from outside.
3. persons.
4. Electric lighting.
5. Business machines and the like.

2.2 Air conditioning system

HVAC stands stands for heating, ventilating, air-conditioning. it's a process that simultaneously conditions air, distributes it combined with the outdoor air to the conditioned space and controls and maintains the required space temperature, humidity, air movement, air cleanliness, sound level, and pressure differential within predetermined limits for the health and comfort of the occupants, for product processing or both.

2.2.1 The Cooling load

To determine the size of the necessary refrigeration plant the cooling load should be calculated at about 15.00 h sun-time for the entire building.

2.2.2 Cooling load sources

The cooling loads for a given space consist of the following heat gains:

1. Heat gains that transmitted through building structures such as walls, floors and roof that are adjacent to unconditioned spaces .The heat transmitted is caused by temperature difference that exists on both sides of structures
2. Heat gain due to solar effect which include:
   - Solar radiation transmitted through the glass and absorbed by inside surfaces and furniture.
   - Solar radiation absorbed by walls, glass windows, glass doors and roofs that are exposed to solar radiation.
3. Sensible and latent heat gains brought into the space as a result of infiltration of air through windows and doors
4. Sensible heat produced in space by lights, appliances, motors and other miscellaneous heat gains.
5. Latent heat produced from cooking, hot baths, or any other moisture producing equipment.
6. Sensible and latent heat produced by occupants.

2.3 Overall Heat Transfer Coefficient

The overall heat transfer coefficient represents the total resistance experienced as heat is transferred between fluids or between a fluid and a solid. The overall heat transfer coefficient U can be determined from Eq. 2.1 below:

$$U = \frac{1}{\frac{1}{h_i} + \Sigma\frac{\Delta x_i}{k_i} + \frac{1}{h_o}} \tag{2.1}$$

Where:
U : Is the overall heat transfer coefficient .
h_i : Is the inside film heat transfer coefficients.
h_o : Is the outside film heat transfer coefficients .
Δx_i: Is the thickness of wall layers.
k_i: Is the thermal conductivity .

The following tables contains all the inside and outside design conditions needed for the next calculations.

- Outdoors design conditions Table 2.1.

Table 2.1: Outdoors design conditions .

Season	T_{out} ^oC	ϕ_{out} %	h_{out} kJ/kg
Summer	30	55.00	67.00

- Indoors design conditions Table 2.2.

Table 2.2: Indoors design conditions

Season	T_{in} ^oC	ϕ_{in} %	h_{in} kJ/kg
Summer	24	50.00	48.00

- The overall heat transfer coefficient for outside walls Table 2.3. And the section for outside walls Fig 2.1.

Table 2.3: The overall heat transfer coefficient for outside walls

Construction material	Material thickness $[m]$	Thermal conduction $[W/m.^oC]$	U $W/m^{2o}C$
1-stone	0.05	1.70	
2-Concrete	0.10	1.75	
3-Insulation	0.03	0.03	
4-Block	0.10	0.95	
5-Plaster	0.02	1.2	
Total			0.804

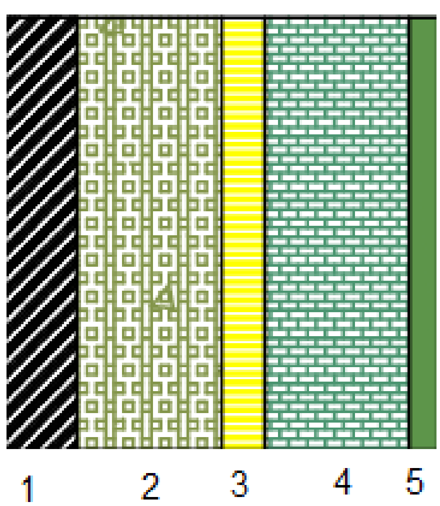


Figure 2.1: The section for outside walls

- The overall heat transfer coefficient for inside walls Table 2.4. And the section for inside walls Fig 2.2.

Table 2.4: The overall heat transfer coefficient for inside walls

Construction material	Material thickness $[m]$	Thermal conduction $[W/m.^oC]$	U $W/m^{2o}C$
1-Plaster	0.02	1.2	
2-Block	0.10	0.95	
3-Plaster	0.02	1.2	
Total			2.45

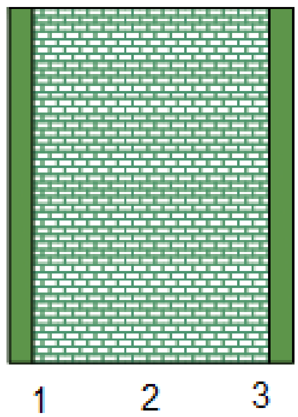


Figure 2.2: The section for inside walls

- The overall heat transfer coefficient for roof Table 2.5. And the section for the roof Fig 2.3.

Table 2.5: The overall heat transfer coefficient for roof

Construction material	Material thickness $[m]$	Thermal conduction $[W/m.^oC]$	U $W/m^{2o}C$
1-Tiles	0.005	0.99	
2-Mortar	0.03	1.40	
3-Sand	0.10	0.30	
4-Bitumen	0.01	0.18	
5-Concrete	0.08	1.75	
6-Block	0.14	0.95	
7-Plaster	0.02	1.20	
With brick			1.016
Without brick			1.194

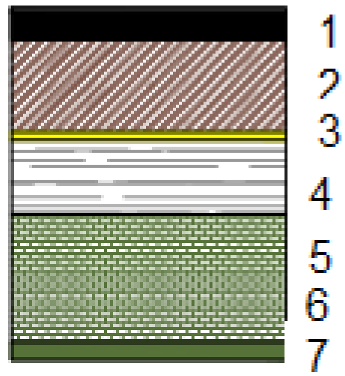


Figure 2.3: The section for roof

- The overall heat transfer coefficient for ground Table 2.6. And the section for the ground Fig 2.4.

Table 2.6: The overall heat transfer coefficient for ground

Construction material	Material thickness $[m]$	Thermal conduction $[W/m.^oC]$	U $W/m^{2o}C$
1-Tiles	0.005	0.99	
2-Mortar	0.03	1.40	
3-Sand	0.10	0.30	
4-Bitumen	0.01	0.18	
5-Concrete	0.08	1.75	
Total			1.038

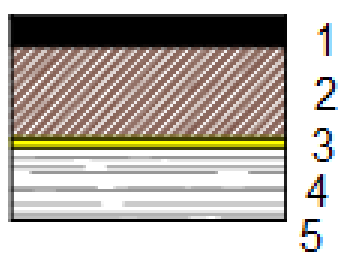


Figure 2.4: The section for ground

2.4 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.

2.4.1 Total cooling load calculations for the sample room:

Table 2.7: Area for sample room

Room	Inside wall m^2	Outside Wall m^2	Ceiling Area m^2	Ground Area m^2	windows area m^2	Doors Area m^2
15	44.76	27.20	54.70	54.70	4.45	3.6

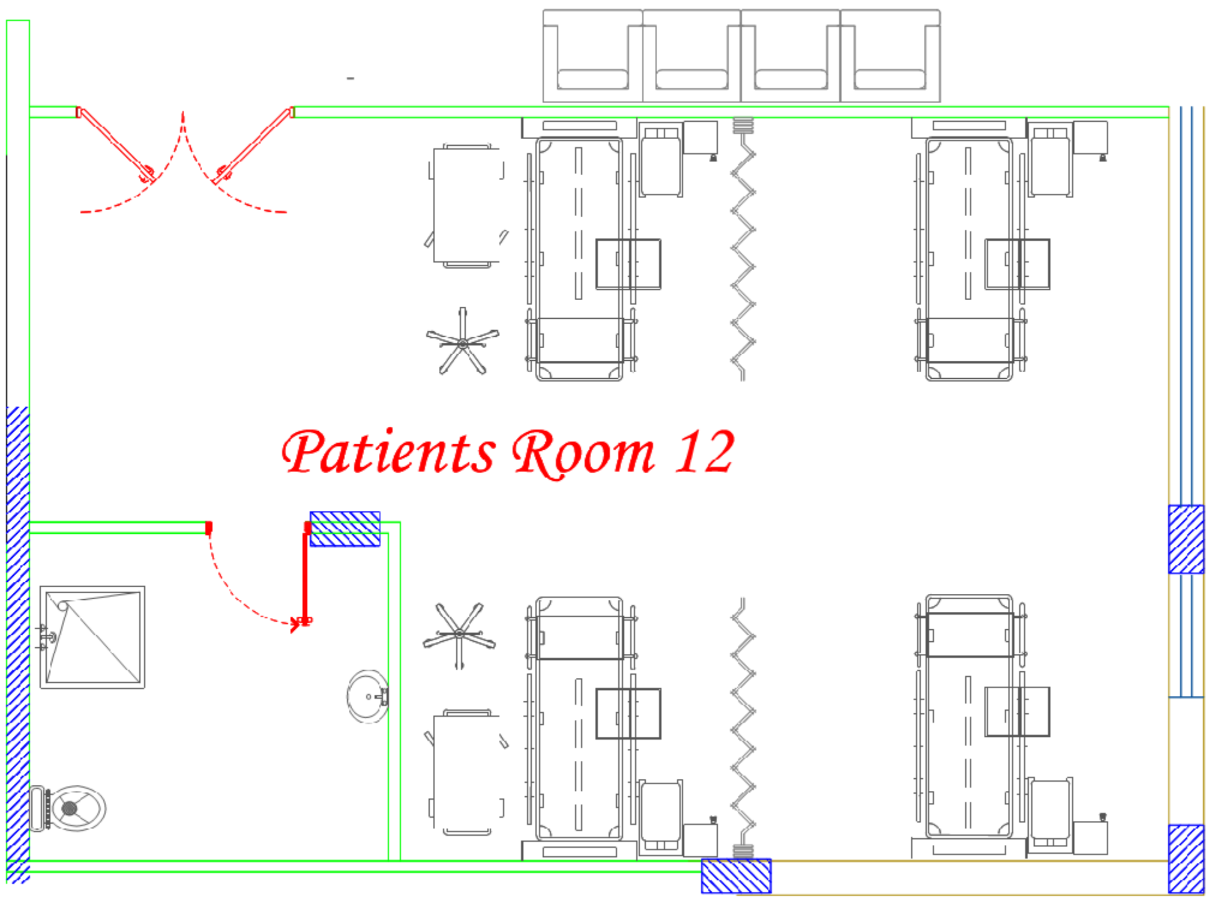


Figure 2.5: Sample room

Heat gain through walls and ceiling:

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

$$\dot{Q} = U * A * \Delta T \tag{2.2}$$

Where:

Q: Is the heat gain through walls and ceiling. [W]
U: Is the overall heat transfer coefficient. $[W/(m^2 * {}^oC)]$
A: Is the area of the walls and ceiling.$[m^2]$
ΔT : Is the difference between the inlet and outlet temperature. [°C]
But the value of ΔT also called the cooling load temperature deference (CLTD), the value of CLTD is need to be corrected so the actual value is found for different cases and hence it will be called the corrected CLTD.

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

$$\dot{Q} = UA(CLTD)_{corr} \tag{2.3}$$

CLTD: is called cooling load temperature difference for sunlit roofs and walls (Appendix B) Table (2)

$$(CLTD)_{corr} = (CLTD + LM) * K + (25.5 - T_i) + (T_{o,m} - 29.4) * f \tag{2.4}$$

$(CLTD)_(corr)$ for windows:
LM:Latitude correction factor for horizontal and vertical surfaces (Appendix B)Table (B-1)
K: colors adjustment factor such that:
k=1.0 for dark coloured walls.
k= 0.83 for permanent medium colour walls.
k=0.65 for Permanent Light coloured walls.
$(25.5-T_i)$: a correction factor for indoor design temperature where T_i is the room design temperature °C.
$(T_{o,m} - 29.4)$: a correction factor for outdoor mean temperature $(T_{o,m})$

$$T_{o,m} = \frac{T_{max} + T_{min}}{2} \tag{2.5}$$

Where:
T_{max}: maximum average daily temperature, °C.
T_{min}: minimum average daily temperature, °C.
T_{max} = 36.1 °C ; from Palestinian Code.
T_{min} = 13.7 °C ; from Palestinian Code.
Then: $T_{o,m}$ = 24.9 °C.
f: attic or roof fan factor such that:
f=1.0 if there is no attic or roof fan
f = 0.75 if there is an attic or roof fan
from eg.2.4 then :
$(CLTD)_{corr} = (8 - 0.5) * 0.65 + (25.5 - 24) + (24.9 - 29.4) * 1$
$(CLTD)_{corr} = 6.90^oC$
In the following table(2.8) is the corrected CLTD for walls and roof and it is tabulated as follows:

Table 2.8: CLTD for walls and roof

Wall	CLTD	LM	$CLTD_{corr}$
N	8.00	-0.50	6.90
NE	10.00	-0.50	8.20
E	13.00	-0.50	10.20
SE	12.00	-1.60	8.80
S	9.00	-3.30	5.80
SW	11.00	-1.60	8.20
W	15.00	-0.50	11.50
NW	12.00	-0.50	9.50
Roof	14.00	0.00	11.20

2.4.2 Sample Calculation

Using patient room 12 at third floor as a sample calculation:

- Heat gain through ceiling $\dot{Q}_{Ceiling}$:

  $\dot{Q}_{Ceiling} = (U_1 * A_1 + U_2 * A_2)\Delta T$

  Where:

  $U_1 : UCeilingWithbrick.$

  $U_2 : UCeilingWithoutbrick.$

  $A_1 = 4/5 * ACeiling$

  $A_2 = 1/5 * ACeiling$

  $\dot{Q}_{Ceiling} = (1.016 * \frac{4}{5} * 54.7 + 1.194 * \frac{1}{5} * 54.7) * 6$

  $\dot{Q}_{Ceiling} = 345[W] = 0.345[kW]$

- Heat gain through walls $\dot{Q}_{Walls}$:

  $A_N = (9.8 * 3) - (1.8 * 2) = 25.80m^2$

  $A_E = (6.8 * 3) - (4.5 * 1) = 15.90$

  $A_S = (4 * 3) - (0) = 12.00m^2$

  $A_W = (3.6 * 3) - (0) = 10.80m^2$

  $\dot{Q}_N = 2.45 * 25.80 * 6.90 = 0.189kW$

  $\dot{Q}_E = 0.804 * 15.90 * 10.2 = 0.131kW$

  $\dot{Q}_S = 0.804 * 12 * 5.80 = 0.056kW$

  $\dot{Q}_W = 2.45 * 10.80 * 6.90 = 0.079kW$

  $\dot{Q}_{Walls} = 0.189 + 0.131 + 0.056 + 0.079 = 0.455kW$

- Heat gain through glass $\dot{Q}_{Glas}$:

$$\dot{Q}_{Glas} = \dot{Q}_{tr} + \dot{Q}_{conv} \tag{2.6}$$

Where:
$\dot{Q}_{tr}$: transmission heat gain.
$\dot{Q}_{conv}$: convection heat gain.

$$\dot{Q}_{tr} = A * (SHG) * (SC) * (CLF) \tag{2.7}$$

Where:
A :glass area,m^2
SHG: solar heat gain factor.
SC: shading coefficient.
CLF: cooling load factor.
$A_E = 6.4 * 1 = 6.4m^2$
SHG in W/m^2 $\Rightarrow$from (Appendix B)Table (B-7)
E = 678
SC = 0.2$\Rightarrow$ from (Appendix B)Table (B-9)
CLF at 14:00 o'clock$\Rightarrow$ from (Appendix B)Table (B-11)
$\dot{Q}_{tr.E} = 6.4 * 678 * 0.2 * 0.22 = 0.191kW$
$\dot{Q}_{tr} = 0.191kW$
$\dot{Q}_{conv.} = UA(CLTD)_{corr}$
CLTD = 7 °C at 14:00 o'clock $\Rightarrow$ from (Appendix B)Table (B-12)
k = 1 for glass
f = 1 for glass
$\dot{Q}_{conv.E} = 3.5 * 6.4 * 7 = 0.156kW$
$\dot{Q}_{conv.} = 0.156kW$
$\dot{Q}_{Glass} = 0.191 + 0.156 = 0.347kW$

- Heat gain through light $\dot{Q}_{Lt.}$:

$$\dot{Q}_{Lt.} = light\ intensity * A * (CLF)_{Lt.} * diversity\ factor \tag{2.8}$$

light intensity = 10-30 W/m^2 for apartment, so we will take 30W/m^2.
A: floor area = 54.7m^2.

$(CLF)_{Lt.} = 0.84 \Rightarrow$ from (Appendix B)Table (B-14)

Diversity factor = 0.95 $\Rightarrow$ from (Appendix B)Table (B-15) .

$\dot{Q}_{Lt.} = 30 * 54.7 * 0.84 * 0.95 = 1.310kW$.

- Heat gain through infiltration $\dot{Q}_f$:

  $\nu_{out} = 9.2m/s \Rightarrow$ from Palestinian Code.

  $\vartheta = 0.88m^3/kg \Rightarrow$ from psychrometric chart.

  $h_o = 68.13kJ/kg \Rightarrow$from psychrometric chart.

  $h_i = 38.5kJ/kg \Rightarrow$from psychrometric chart.

  Calculate the infiltration air rate and compute the resulting heating load due to infiltration by using this equation:

$$\dot{Q}_f = \frac{\frac{\dot{V}_f}{V_o} * (h_{in} - h_o)}{3600} \tag{2.9}$$

$$\dot{V}_f = (k * L * 0.613(S_1 * S_2 * \nu_o)^2)^{2/3} \tag{2.10}$$

Where:

$\dot{Q}_f$: rate of heat transfer due to infiltration, $[kW]$

$\dot{V}_f$: volumetric flow rate of infiltrated air,$[m^3/h]$

V_o: specific volume of outside air, $[m^3/kg]$

h_{in}: enthalpy at inside conditions, kJ/kg

h_o: enthalpy at outside conditions,kJ/kg

k: infiltration coefficient

L: crack length,m.

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

S_2: coefficient that depends on the height of the building and the terrain of its location.

V_o: outside air velocity, $[m/s]$.

$\dot{V}_f = 0.7 * 12.3 * (0.613(1 * 0.79 * 9.2)^2)^{2/3} = 87.5m^3/h$

$\dot{Q}_f = [(87.5/0.88) * (67 - 48)]/3600 = 0.5kW$

- Heat gain through occupants $\dot{Q}_{oc.}$:

$$\dot{Q}_{oc.} = \dot{Q}_{sensible} + \dot{Q}_{latent} \tag{2.11}$$

$$\dot{Q}_{sensible} = heat\ gain\ sensible * No.of\ people * (CLF)_{oc.} * Diversity\ Factor \tag{2.12}$$

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

heat gain sensible = $70W \Rightarrow$ from (Appendix B)Table (B-17)

No. of people = 16

$(CLF)_{oc.} = 0.79 \Rightarrow$ from (Appendix B)Table (B-16)

Diversity Factor = $0.6 \Rightarrow$ from (Appendix B)Table (B-15)

$\dot{Q}_{sensible} = 70 * 16 * 0.79 * 0.6 = 0.531kW$

$$\dot{Q}_{latent} = heat\ gain\ latent * No.of\ people * Diversity\ Factor \tag{2.13}$$

heat gain latent = 44

$\dot{Q}_{latent} = 44 * 16 * 0.60 = 0.423kW$

$\dot{Q}_{oc.} = 0.531 + 0.423 = 0.954kW$

- Heat gain Due to ventilation $\dot{Q}_{vent.}$:

$$\dot{Q}_{vent} = \dot{m} * C_P * (T_{out} - T_{in}) \tag{2.14}$$

Where: $\dot{m} = \frac{V*N}{3600} * \rho$

V: The volume of the room $[m^3]$.

N: The number of air change per hour.

ρ The density of air $[kg/m^3]$.

C_p of air is 1 [kJ/kg].

ρ for air is 1.25 $[kg/m^3]$.

$\dot{Q}_{vent.} = ((164.1 * 2)/3600) * 1 * 1.25 * 6$

$\dot{Q}_{vent.} = 6.57KW$.

- Heat gain Due to inner door $\dot{Q}_{door}$:

$\dot{Q}_{door} = U * A * \Delta T$.

$\dot{Q}_{door} = 2.8 * 3.6 * 6 = 0.061kW$.

The total heat loss from sample room is:

$\dot{Q}_T = 11.172kW$.

2.5 Heating Load

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

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

- Heat loss through all exposed walls, ceiling, floor, windows, doors, and walls between a heated space and an unheated space (partition walls).
- 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.
- Domestic hot water load.
- Miscellaneous loads such as emergency heating loads and safety factor heating load.

2.5.1 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 space.

   $\Delta T_{un} = 0.5 * (T_{in} - T_{out})$
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 $\dot{Q} = UA(T_{in} - T_{out})$. Where:

   $\dot{Q}$: rate of heat transfer, [W]
7. Compute heat loss from bellow-grade walls and floor.
8. Calculate the infiltration air rate and compute the resulting heating load due to infiltration by using equation(2.9).
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.

The following tables contains all the inside and outside design conditions needed for the next calculations.

Table 2.9: Outdoors design condition .

Season	T_{out}	ϕ_{out}	h_{out}
	^oC	$\%$	kJ/kg
Winter	5	65.00	14.00

Table 2.10: Indoors design condition

Season	T_{in}	ϕ_{in}	h_{in}
	^oC	$\%$	kJ/kg
Winter	24	50.00	48.00

2.5.2 Sample Calculation

Using patient room 12 as a sample calculation:

- Heat loss through ceiling $\dot{Q}_{Ceiling}$

  $\dot{Q}_{Ceiling} = (1.016 * \frac{4}{5} * 54.7 + 1.194 * \frac{1}{5} * 54.7) * 19$

  $\dot{Q}_{Ceiling} = 1092[W] = 1.09[kW]$

- Heat loss through walls $\dot{Q}_{Walls}$:

  $\dot{Q}_{Walls} = U_W all * A_W all * \Delta T$

  $\dot{Q}_{Walls} = 0.804 * 37.80 * 19$

  $\dot{Q}_{Walls} = 2036[W] = 1.936[kW]$

- Heat loss through unconditioned walls $\dot{Q}_{un.walls}$:

  $\dot{Q}_{un.walls} = U_{un.walls} * A_{un.walls} * \Delta T$

  $\dot{Q}_{un.wall} = 2.45 * 18.6 * 10[W] = 0.356[kW]$

- Heat loss through infiltration $\dot{Q}_f$:

  k = 0.70 ;from (Appendix B)Table (B-18)

  $S_1 = 1$; from (Appendix B)Table (B-19)

  $S_2 = 0.79$; from Table (Appendix B)Table (B-20)

  $\nu_o = 12.8m/s$; from Palestinian Code

  $v_o = 0.79m^3/kg$; from psychrometric chart

  $h_o = 13.03kJ/kg$; from psychrometric chart

  $h_i = 32.9kJ/kg$; from psychrometric chart

  $L = 12.3[m]$

$\dot{V}_f = (0.70 * 26.8(0.613(1 * 0.79 * 12.8)^2)^{2/3} = 343m^3/h$

$\dot{Q}_f = [(343/0.79) * (32.9 - 13.03)]/3600 = 2.32kW$

- Heat loss through windows $\dot{Q}_{Window}$:

  $\dot{Q}_{Window} = U_{Window} * A_{Window} * \Delta T$

  $\dot{Q}_{Window} = 3.5 * 6.4 * 16$

  $\dot{Q}_{Window} = 358W = 0.358kW$

- Heat loss through doors $\dot{Q}_{door}$

  $\dot{Q}_{doors} = U_{doors} * A_{doors} * \Delta T$

  $\dot{Q}_{doors} = 2.8 * 3.6 * 10 = 301W$

  $\dot{Q}_{doors} = 0.301kW$

- Take Safety Factor 15%

  The total heat loss from sample room is:

  $\dot{Q}_T = 7.3kW$

2.6 Total cooling and heating loads for hospital.

- O.P :Operating Room.
- P.R :Patients Room.
- R.R :Recovery Room.
- D.R :Doctors Room.
- XR.R:X Rays Room.
- W.R:Waiting Room.
- K.R:Kitchen Room.

Table 2.11: Total cooling and heating loads for basement floor

No	Room	Cooling load *kW*	Heating load *kW*
1	D.R 1	12.1	9.6
2	D.R 2	11.7	8.5
3	D.R 3	12.3	9.1
4	D.R 4	10.9	7.9
5	K.R 1	10.3	9.8
6	K.R 2	10.9	9.9
7	W.R	11.5	9.1
	Total	68.7	53.5

Table 2.12: Total cooling and heating loads for ground floor

No	Room	Cooling load *kW*	Heating load *kW*
1	D.R 1	11.3	6.5
2	D.R 2	11.9	6.8
3	D.R 3	10.9	9.1
4	D.R 4	12.9	10.5
5	D.R 5	12.1	9.3
6	D.R 6	1.9	9.4
7	D.R 7	11.9	8.4
8	D.R 8	11.8	8.2
9	D.R 9	11.3	8.3
10	D.R 10	1.1	7.1
11	D.R 11	9.2	7.4
12	D.R 12	12.7	10.6
13	D.R 13	11.5	8.6
14	D.R 14	1.9	9.1
15	D.R 15	12.6	9.3
16	D.R 16	1.4	7.5
17	D.R 17	9.9	7.7
18	D.R 18	9.6	6.3
19	D.R 19	13.3	11.0
20	D.R 20	11.2	8.7
21	D.R 21	12.7	10.2
22	D.R 22	11.5	8.9
23	XR.R 1	3.2	2.1
24	XR.R 2	2.3	1.5
25	XR.R 3	2.5	1.6
26	XR.R 4	2.2	1.4
27	W.R 1	16.5	11.2
28	W.R 2	14.9	10.1
29	K.R	12.8	10.2
30	P.R 1	11.3	9.3
31	P.R 2	9.8	7.6
32	P.R 3	11.2	10.1
	Total	339.3	245.7

Table 2.13: Total cooling and heating loads for first floor

No	Room	Cooling load kW	Heating load kW
1	P.R 1	12.8	7.3
2	P.R 2	11.1	7.8
3	P.R 3	9.9	7.2
4	P.R 4	10.9	7.1
5	P.R 5	10.3	6.6
6	P.R 6	10.4	6.8
7	P.R 7	10.2	6.5
8	P.R 8	11.1	7.3
9	P.R 9	10.6	7.0
10	P.R 10	10.5	7.1
11	P.R 11	11.9	7.7
12	P.R 12	11.3	7.6
13	P.R 13	11.9	8.0
14	P.R 14	10.8	6.9
15	P.R15	10.9	7.2
16	R.R 1	7.3	4.4
17	R.R 2	7.9	5.1
18	R.R 3	6.1	3.9
19	R.R 4	6.1	3.9
20	R.R 5	6.8	4.9
21	R.R 6	11.5	7.6
22	D.R 1	10.7	7.1
23	D.R 2	10.2	6.5
24	D.R 3	7.9	4.5
25	D.R 4	6.2	3.9
26	D.R 5	5.8	3.6
27	D.R 6	3.1	1.9
28	D.R 7	1.9	1.2
29	D.R 8	2.2	1.3
30	D.R 9	11.6	8.2
31	O.R 1	12.8	7.3
32	O.R 2	12.3	7.1
33	O.R 3	14.6	10.1
34	O.R 4	11.1	6.9
35	O.R 5	13.1	8.2
36	W.R	12.2	9.9
37	XR.R 1	10.9	6.5
38	XR.R 2	11.2	7.3
39	XR.R 3	9.7	6.4
40	XR.R 4	11.5	11.8
	Total	383.8	215.6

Table 2.14: Total cooling and heating loads for second floor

No	Room	Cooling load *kW*	Heating load *kW*
1	P.R 1	15.3	12.9
2	P.R 2	11.1	8.1
3	P.R 3	12.2	11.2
4	P.R 4	1.2	11.2
5	P.R 5	11.9	10.9
6	P.R 6	11.8	9.1
7	P.R 7	12.2	9.7
8	P.R 8	10.3	7.1
9	P.R 9	10.5	7.5
10	P.R 10	10.3	7.6
11	P.R 11	11.9	6.5
12	P.R 12	10.2	7.2
13	R.R 1	6.2	4.2
14	R.R 2	7.5	4.3
15	R.R 3	5.7	4.1
16	R.R 4	6.4	3.8
17	D.R 1	8.2	4.2
18	D.R 2	8.4	3.8
19	D.R 3	6.1	3.9
20	D.R 4	11.3	8.9
21	D.R 5	6.6	4.2
22	O.R 1	14.2	9.9
23	O.R 2	12.2	8.7
24	W.R 1	10.3	9.1
25	W.R 2	10.9	9.5
26	XR.R 1	12.1	10.3
27	XR.R 2	11.3	9.3
28	K.R	6.8	3.5
	Total	266.3	175.6

Table 2.15: Total cooling and heating loads for third floor

No	Room	Cooling load *kW*	Heating load *kW*
1	P.R 1	11.3	8.3
2	P.R 2	12.6	12.1
3	P.R 3	12.3	9.6
4	P.R 4	17.1	14.2
5	P.R 5	11.9	10.3
6	P.R 6	11.1	7.9
7	P.R 7	9.8	6.9
8	P.R 8	11.2	9.2
9	P.R 9	11.3	8.9
10	P.R 10	12.2	9.4
11	P.R 11	15.3	13.9
12	P.R 12	11.2	7.3
13	P.R 13	10.4	7.9
14	P.R 14	10.3	9.5
15	P.R 15	11.4	9.2
16	R.R 1	6.5	4.6
17	D.R 1	2.2	1.3
18	D.R 2	1.5	1.1
19	D.R 3	8.3	4.1
20	D.R 4	5.6	3.6
21	D.R 5	5.1	3.4
22	O.R 1	15.2	11.3
23	W.R 1	9.9	6.5
24	W.R 2	12.3	9.1
	Total	245.8	155.9

Table 2.16: Total cooling and heating loads for forth floor

No	Room	Cooling load *kW*	Heating load *kW*
1	P.R 1	11.3	8.3
2	P.R 2	12.6	12.1
3	P.R 3	12.3	9.6
4	P.R 4	9.8	7.9
5	D.R	10.8	8.9
6	N.R	16.6	12
	Total	72.8	58.9

Chapter 3

Heating, Ventilation and Air Conditioning (HVAC)

3.1 Variable Refrigerant Flow (VRF) Systems

3.1.1 Overview

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

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

3.1.2 Variable Refrigerant Flow (VRF) Systems

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

Currently widely applied in large buildings . The VRF technology/system was developed and designed by Daikin Industries, Japan who named and protected the term variable refrigerant volume (VRV) system so other manufacturers use the term VRF "variable refrigerant flow". In essence both are same. With a higher efficiency and increased controllability, the

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

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

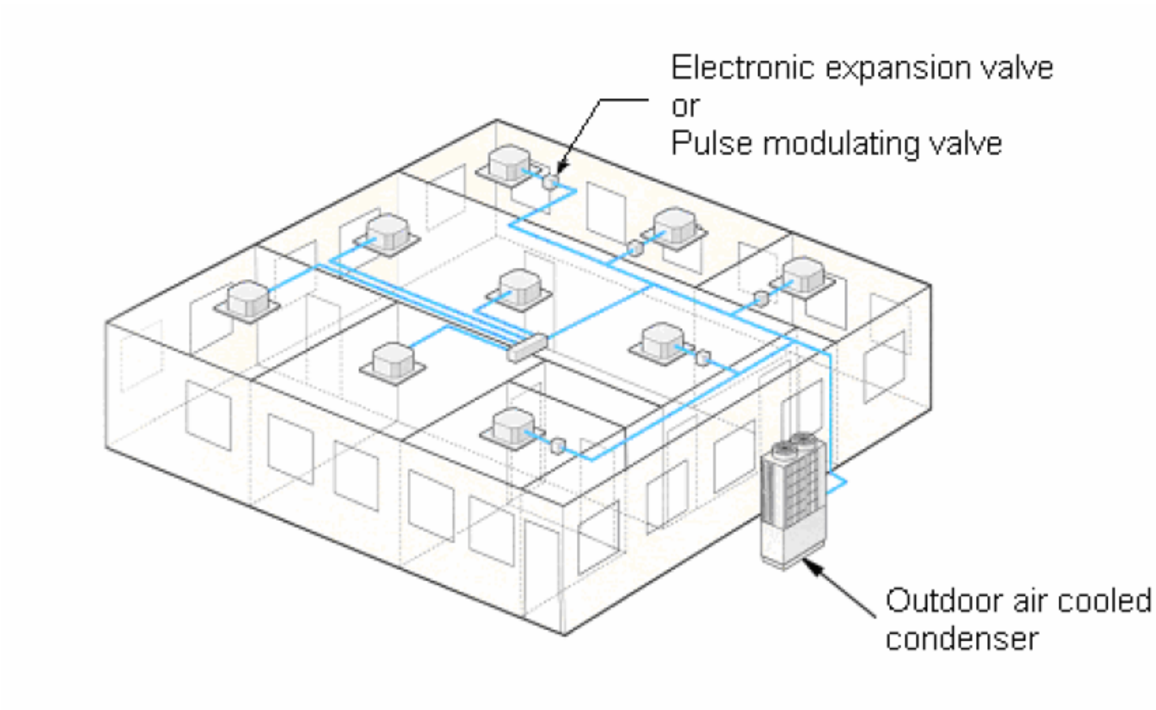


Figure 3.1: VRF system with multiple indoor evaporator units

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 Btuh. A schematic VRF arrangement is indicated below:

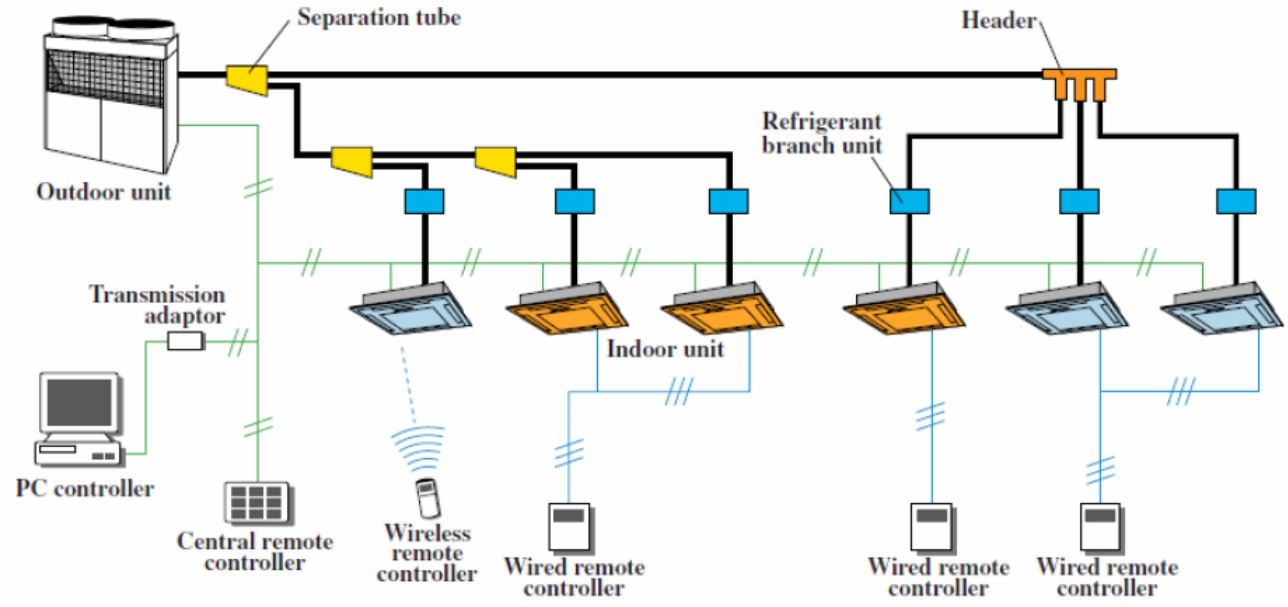


Figure 3.2: A schematic VRF arrangement

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.

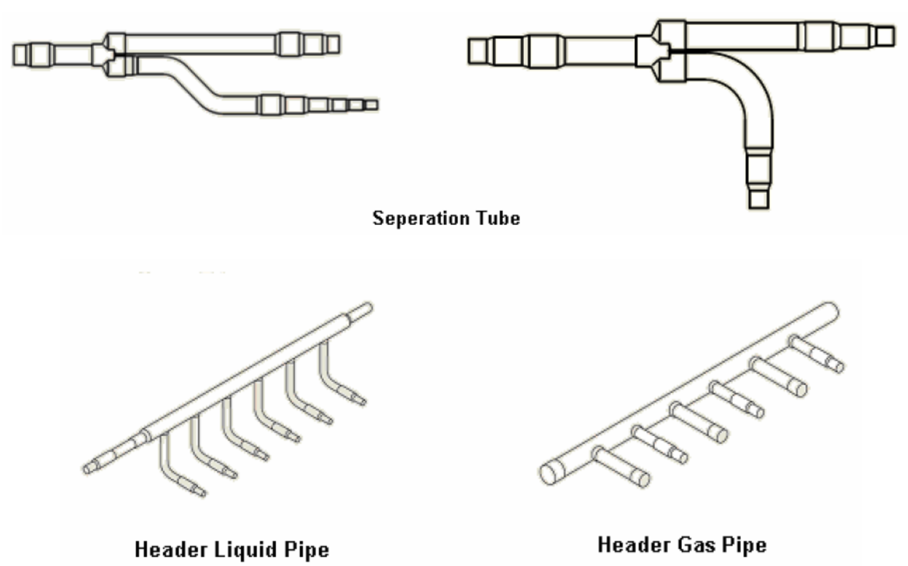


Figure 3.3: A schematic VRF arrangement

3.1.3 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.

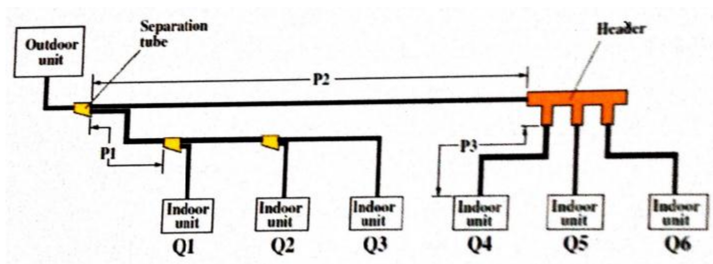


Figure 3.4: Indoor and out door capacity

- 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)

3.1.4 Building Load Profile

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

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 $\pm 1^{o}F(\pm 0.6^{o}C)$, 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).

3.1.5 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 exists in Hebron. Outdoor and indoor units are selected according to the thermal load of the building.

Outdoor unit

We are chosen three compact packages outdoor units tow packages individual for three units and the third individual for tow units, with capacity 48 HP,46 HP and 20 HP .

Figure 3.5: Out door units

Table 3.1: Outdoor unit details for basement and ground floors.

Unit	Cooling Load (HP)	Cooling load (kW)	Outdoor Unit Name
Unit 1-1	16		RVXVHT160GE
Unit 1-2	16	137.4	RVXVHT160GE
Unit 1-3	16		RVXVHT160GE
Unit 2-1	14		RVXVHT140GE
Unit 2-2	16	128.5	RVXVHT160GE
Unit 2-3	16		RVXVHT160GE
Unit 3-1	10	56	RVXVHT100GE
Unit 3-2	10		RVXVHT100GE

Indoor unit

In this project there are two types of indoor units selected, which are split and cassette units. The figure below shows the two types of selected units:

Figure 3.6: Split unit

Figure 3.7: Cassette unit

The selected indoor units for the basement and ground floor are listed in the tables below:

Table 3.2: Outdoor unit details

Indoor Unit Type	Cooling load (kW)	Indoor Unit Name	Quantity
Cassette(4 way)	11.2	AVXC4H112E	15
Cassette(4 way)	12.8	AVXC4H128E	2
Cassette(4 way)	14	AVXC4H140E	8
Split(Neoforte)	5.6	AVXWNH056EE	17
Split(Neoforte)	7.1	AVXWNH071EE	10

3.2 Mechanical ventilation

3.2.1 Overview of ventilation

Ventilation is the process of supplying and removing air by natural or mechanical means to and from a building. The design of a buildings ventilation system should meet the minimum requirements of the building (Ventilating Systems) regulations. There are two ways for Ventilation:

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

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

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

1. Air changes per hour. 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.

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

3. Airflow rate per unit floor area. 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 & by first method air changes per hour.

3.2.2 Objectives of ventilation

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

Designing of mechanical ventilation

Steps of designing mechanical ventilation:

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

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

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

4. converts the value to cubic feet per minute (CFM).

Sample calculation

Using bathroom the volume is 18.15 m^3

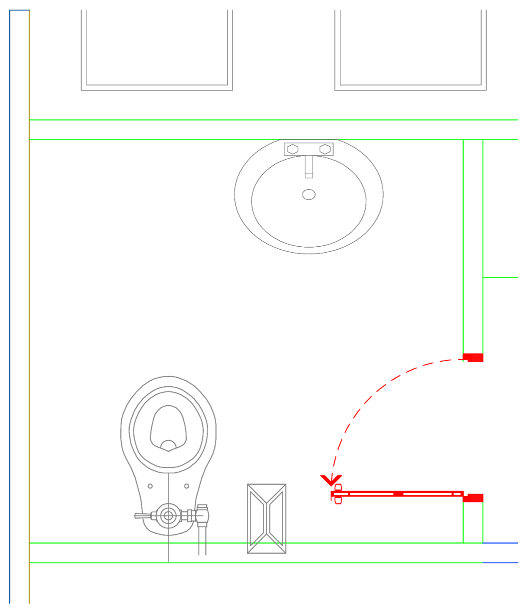


Figure 3.8: Sample bathroom

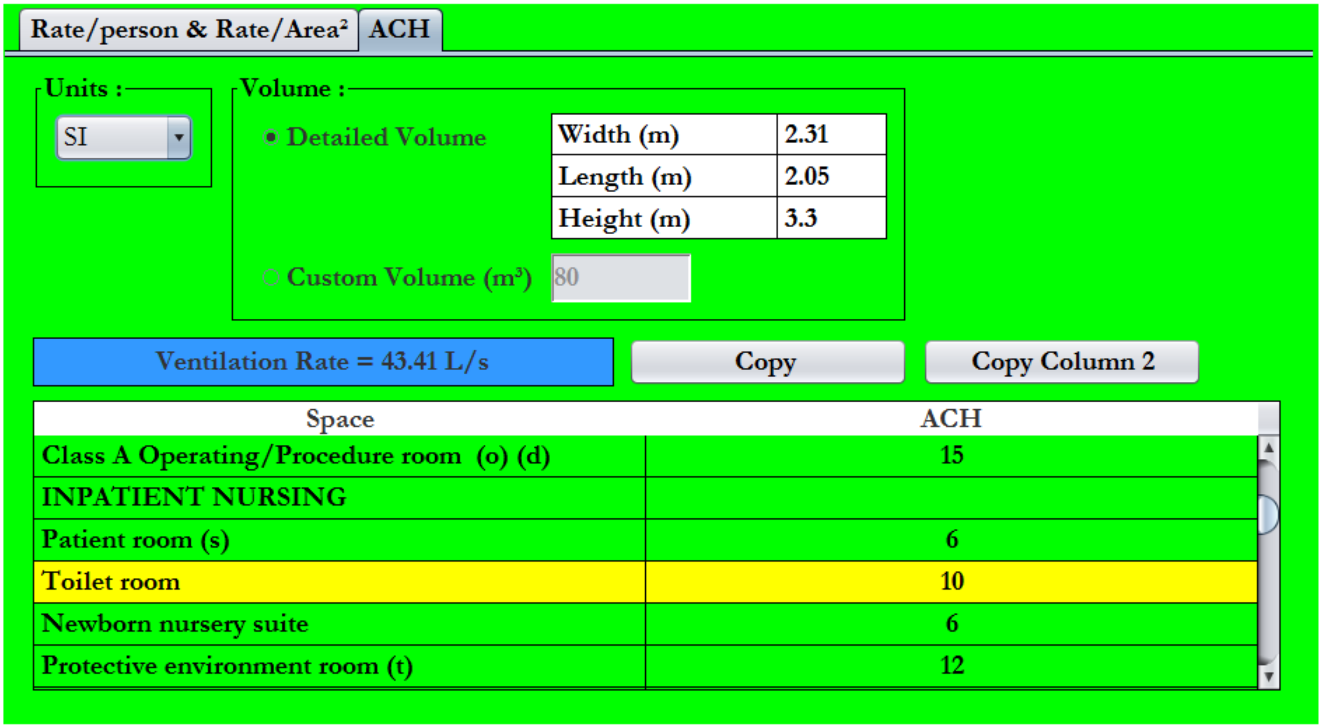


Figure 3.9: Sample calculation of ventilation

Table 3.3: : Ventilation rate

Room	Volume (m^3)	Ventilating Rate (L/s)	Ventilating Rate (CFM)
Kitchen	240	88	186.5
Bathrooms*	525	1458	3089.3

Chapter 4

Plumbing System

4.1 Introduction

In order to maintain daily operations and patient care services, health care facilities need to develop an Emergency Water Supply Plan (EWSP) to prepare for, respond to, and recover from a total or partial interruption of the facilities' normal water supply. Water supply interruption can be caused by several types of events such as natural disaster, a failure of the community water system, construction damage or even an act of terrorism. Because water supplies can and do fail, it is imperative to understand and address how patient safety, quality of care, and the operations of your facility will be impacted. Below are a few examples of critical water usage in a health care facility that could be impacted by a water outage. Water may not be available for:

- Hand washing and hygiene.
- Drinking at faucets and fountains.
- Food preparation.
- Flushing toilets and bathing patients.
- Laundry and other services provided by central services (e.g., cleaning and sterilization of surgical instruments).
- Reprocessing of medical equipment (e.g., endoscopes, surgical instruments, and accessories) after use on a patient.
- Patient care (e.g., hemodialysis, hemofiltration, extracorporeal membrane oxygenation, hydrotherapy).
- Radiology.
- Fire suppression sprinkler systems.
- Water-cooled medical gas and suction compressors (a safety issue for patients on ventilation).

- Heating, ventilation, and air conditioning (HVAC).
- Decontamination/hazmat response.

A health care facility must be able to respond to and recover from a water supply interruption. A robust EWSP can provide a road map for response and recovery by providing the guidance to assess water usage, response capabilities, and water alternatives.

The Emergency Water Supply Planning Guide for Hospitals and Health Care Facilities provides a four step process for the development of an EWSP:

1. Assemble the appropriate EWSP Team and the necessary background documents for your facility;
2. Understand your water usage by performing a water use audit;
3. Analyze your emergency water supply alternatives; and
4. Develop and exercise your EWSP

The EWSP will vary from facility to facility based on site-specific conditions, but will likely include a variety of emergency water supply alternatives evaluated in step #3 above. How the EWSP is developed for a health care facility will depend on the size of the facility. For a small facility, one individual may perform multiple functions, and the process may be relatively simple with a single individual preparing an EWSP of only a few pages. However, for a large regional hospital, multiple parties will need to work together to develop an EWSP. In this case the process and the plan would be more complex. However, regardless of size, a health care facility must have a robust EWSP to be prepared to ensure patient safety and quality of care while responding to and recovering from a water emergency.

4.2 Water Supply system

4.2.1 Calculations of hot and cold water supply systems

To determine the pipe size for cold and hot water supply system the water supply fixture unit (WSFU) for each fixture unit must be determined and total fixture unit on each piping run out be calculated, the minimum floor pressure required at the critical fixture unit must be determined.

Example: calculation of water supply unit (WSFU) in the Bathroom shown fig4.1. There was three fixtures (shower, lavatory, and water closet with flush valve) each have (WSFU) as following Table 4.1 WSFU of cold and hot water for the bath room.

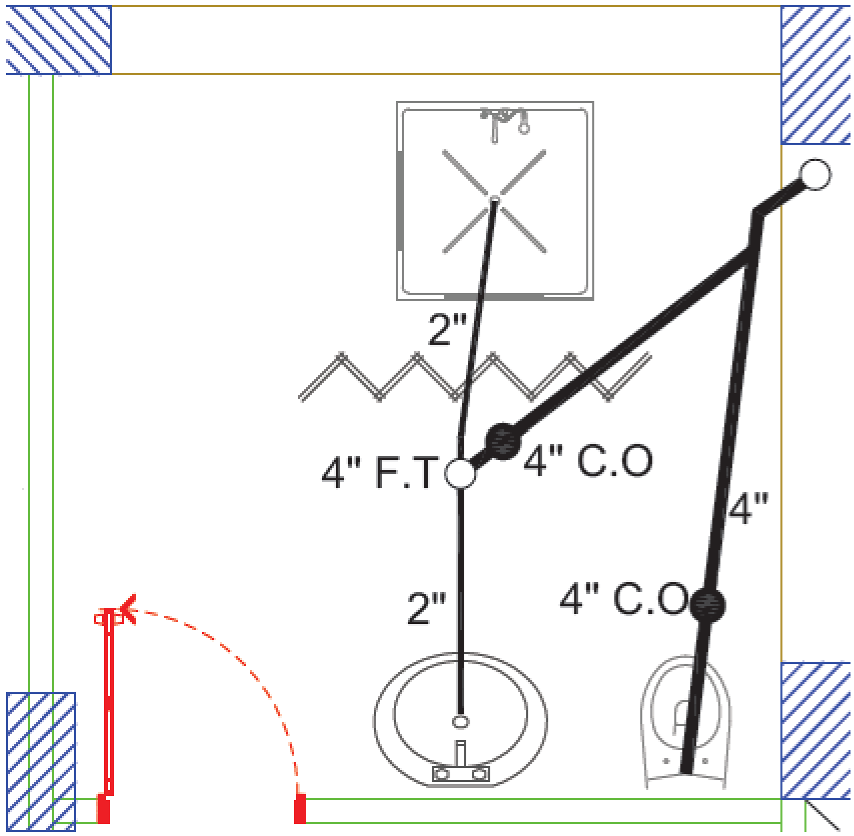


Figure 4.1: Sample path room

Table 4.1: WSFU of cold and hot water for the bath room.

Fixture Unit	No. of Units	Load from table public	Total of WSFU for cold water	Total of WSFU for hot water	Total of WSFU For hot and cold water
Water closet	1	3	3	-	3
Lavatory	1	3/4*1	0.75	0.75	1
Bath tub	1	3/4*2	1.5	1.5	2
			Σ =5.25 WSFU	Σ =2.25 WSFU	Σ =6 WSFU

The following Table 4.2 shown WSFU of cold and hot water for basement floor.

Table 4.2: WSFU of cold and hot water for the basement floor.

Fixture Unit	No. of Units	Load from table public	Total of WSFU for cold water	Total of WSFU for hot water	Total of WSFU For hot and cold water
Water closet	4	3	12	-	12
Lavatory	7	3/4*1	5.25	5.25	7
Sink	10	3/4*2	15	15	20
Bath tub	3	3/4*2	4.5	4.5	6
			Σ =36.75 WSFU	Σ =24.75 WSFU	Σ =45 WSFU

The following Table 4.3 WSFU of cold and hot water for ground floor.

Table 4.3: WSFU of cold and hot water for the ground floor.

Fixture Unit	No. of Units	Load from table public	Total of WSFU for cold water	Total of WSFU for hot water	Total of WSFU For hot and cold water
Water closet	40	3	120	-	120
Lavatory	46	3/4*1	34.5	34.5	46
Sink	5	3/4*2	7.5	7.5	10
Bath tub	5	3/4*2	7.5	7.5	10
			Σ =169.5 WSFU	Σ =49.5 WSFU	Σ =186 WSFU

The following Table 4.4 WSFU of cold and hot water for first floor.

Table 4.4: WSFU of cold and hot water for the first floor.

Fixture Unit	No. of Units	Load from table public	Total of WSFU for cold water	Total of WSFU for hot water	Total of WSFU For hot and cold water
Water closet	19	3	57	-	57
Lavatory	21	3/4*1	15.75	15.57	21
Bath tub	17	3/4*2	25.5	25.5	34
			Σ =98.25 WSFU	Σ =41.25 WSFU	Σ =112 WSFU

The following Table 4.5 WSFU of cold and hot water for second floor.

Table 4.5: WSFU of cold and hot water for the second floor.

Fixture Unit	No. of Units	Load from table public	Total of WSFU for cold water	Total of WSFU for hot water	Total of WSFU For hot and cold water
Water closet	16	3	48	-	48
Lavatory	18	3/4*1	13.5	13.5	18
Bath tub	12	3/4*2	18	18	24
			Σ =79.5 WSFU	Σ =31.5 WSFU	Σ =90 WSFU

The following Table 4.6 WSFU of cold and hot water for third floor.

Table 4.6: WSFU of cold and hot water for the third floor.

Fixture Unit	No. of Units	Load from table public	Total of WSFU for cold water	Total of WSFU for hot water	Total of WSFU For hot and cold water
Water closet	21	3	63	-	63
Lavatory	22	3/4*2	16.5	16.5	22
Bath tub	14	3/4*2	21	21	28
			Σ =100.5 WSFU	Σ =37.5 WSFU	Σ =113 WSFU

The following Table 4.7 WSFU of cold and hot water for fourth floor.

Table 4.7: WSFU of cold and hot water for the fourth floor.

Fixture Unit	No. of Units	Load from table public	Total of WSFU for cold water	Total of WSFU for hot water	Total of WSFU For hot and cold water
Water closet	2	3	6	-	6
Lavatory	6	3/4*1	4.5	4.5	6
Bath tub	6	3/4*2	9	9	12
			Σ =19.5 WSFU	Σ =13.5 WSFU	Σ =24 WSFU

4.2.2 Flow rate calculations

By using table (B-21 / Appendix B) for supply system predominantly for flush tank for ground floor the estimating demand in gpm for cold water = 106.5 WSFU. So, by using interpolation = 8.75 gpm. Now we calculate the (gpm) for each floor so, (gpm) for each floor as in the following tables 4.8:

Table 4.8: The WSFU and gpm for all floors.

No. of Floor	Total No. of WSFU for cold water	Total No. of WSFU for hot water	Total No. of WSFU for hot& cold water	Total No. of gpm for cold water	Total No. of gpm for hot water	Total No. of gpm for hot & cold water
Basement	36.75	24.75	45	23.75	16.85	27
Ground	169.5	49.5	186	58.9	28.8	62.2
First	98.25	41.25	112	43.65	25.5	47
Second	79.5	31.5	90	38.85	20.75	41.5
Third	100.5	37.5	113	44.125	23.75	47.25
Fourth	19.5	13.5	24	13.7	10.1	15.8

4.2.3 Pipe size calculations

The maximum instantaneous water demand on:

1. The amount of total WSFU for cold water = 504 WSFU.

2. The amount of total WSFU for hot water = 198 WSFU.

The total WSFU for cold and hot water = 702 WSFU.

So, the total demand for cold and hot water = 161.36 gpm.

The available mains pressure at the level outlet is:

Main pressure = static head pressure + friction head pressure + main flow pressure

Static head = [height of floors + height of water tank + height of stairs well – height of fixture unit]

Height of floors = 3 m

Height of stairs well = 3m

Height of water tank as selected = 2m

Height of sink = 1.05m

So we find Conversion meter to ft

1ft = 12 in * 2.54 cm = 30.48 cm

So, the static head = 3 + 2 + 3 – 1.05 = 6.95 m = 22.796 ft

Static pressure = 22.796 * 0.433 = 9.87 psi

Total equivalent length (TEL): the distance from water tanks to the collector in ground floor + distance from collector to fixture unit

TEL = longest run * 1.5

TEL= 39 * 1.5 = 58.5 ft

Main flow pressure of the critical fixture = 8 psi

Friction head = static pressure – main flow pressure = 9.87 – 8 = 1.87 psi

Uniform friction loss = friction head / TEL = 1.87 / 58.5 =1.87 / (0.585 *100)

Uniform friction loss = 3.19 psi/100ft

Selection of water pipes diameters:

By using chart of friction head loss (figure B-22 / Appendix B) for galvanized steel pipes we select diameters of pipes refer to calculated values of the main pipe that supply cold water from tanks to distribution points on the roof .The diameter is 2.5" refer to calculated values for flow rate (125.72 gpm) , and friction head loss(3.19 psi/100ft) for riser. We have 2 risers in two regions.

The following table 4.9 shows the diameters of hot and cold water pipes for all floors.

we select two-pump standby WB200/185D from NINGBO YINZHOU H.T. INDUSTRY COMPANY.

Table 4.9: Diameter of pipe sizing of water supply in inch for each floor.

No. of floor	No. of collector	Total load of cold water (gpm)	Total load of hot water (gpm)	Friction of head loss	Diameter of cold water pipe	Diameter of hot water pipe
Basement	1	9.65	5.65	2.72	1"	3/4"
	2	8.6	7.25	2.19	1"	3/4"
	3	8.6	7.25	2.19	1"	3/4"
Ground	1	17.3	6.125	2.14	$1\frac{1}{4}$"	3/4"
	2	11	5	3.62	1"	3/4"
	3	6.1	1.5	4.2	3/4"	3/4"
	4	6.12	5	4	3/4"	3/4"
	5	22.62	6.68	3.52	$1\frac{1}{4}$"	1"
	6	8.6	5	2.3	1"	3/4"
	7	11.09	4	3.62	1"	3/4"
	8	13.7	6.57	2.62	$1\frac{1}{4}$"	1"
	9	12.65	3	4.69	1"	3/4"
	10	12.65	3	4.69	1"	3/4"
First	1	11	5	3.62	1"	3/4"
	2	11	5	3.62	1"	3/4"
	3	8.25	4.6	2.13	1"	3/4"
	4	6.1	4	4.2	3/4"	3/4"
	5	11	5	2.55	1"	3/4"
	6	5	3.5	2.8	3/4"	3/4"
	7	8.75	5	2.37	1"	3/4"
	8	12.65	8.56	4.69	1"	3/4"
Second	1	6.4	4	4.2	3/4"	3/4"
	2	11	5	2.55	1"	3/4"
	3	11	5	3.62	1"	3/4"
	4	8.25	4.6	2.13	1"	3/4"
	5	5	3.5	2.8	3/4"	3/4"
	6	8.25	5	2.13	1"	3/4"
	7	8.75	5	2.37	1"	3/4"
Third	1	11	5	3.62	1"	3/4"
	2	13.65	5	5.4	1"	3/4"
	3	11	5	3.62	1"	3/4"
	4	11	5	3.62	1"	3/4"
	5	5	3	2.8	3/4"	3/4"
	6	6	2.7	3.92	3/4"	3/4"
	7	8.75	5	2.37	1"	3/4"
	8	8.25	5	2.13	1"	3/4"
Fourth	1	5	5	2.8	3/4"	3/4"
	2	5.56	5.56	3.41	3/4"	3/4"
	3	6.125	5	4.07	3/4"	3/4"

4.3 Sanitary 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

4.3.1 Drainage system components

The main components of drainage system are:

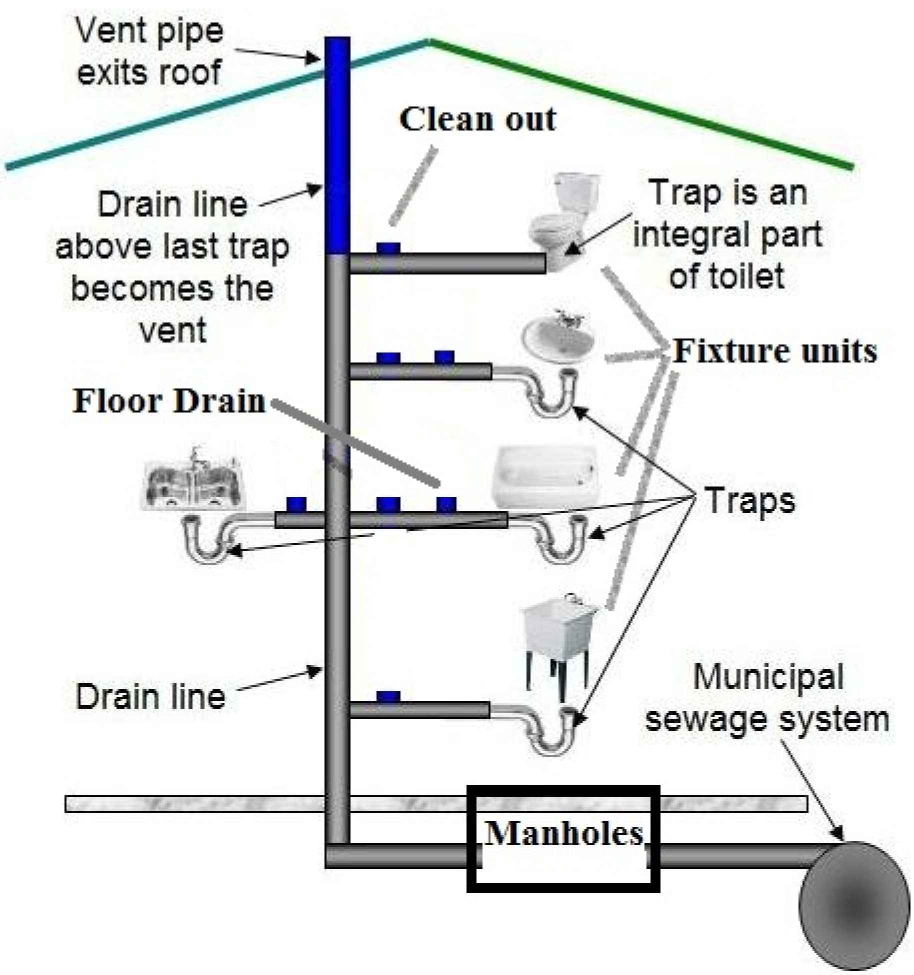


Figure 4.2: Drainage system components

A: Fixture units

B: Trap

C: Clean out

D: Drainage pipe

E: Stack and vent pipes

F: Manholes

G: Septic tank or municipal sewage system

H: Accessories

4.3.2 Sanitary drainage

procedure and pipe sizing

Pipe size is calculated by using a concept of fixture units (DFU) instead of using gpm of drainage water. This unit takes into account not only the fixtures water use but also its frequency of use, which is the DFU has a built–in diversity factor. This enables us, exactly as for water supply to add DFU of various fixtures to obtain the maximum expected drainage flow. Drainage pipes sized for a particular number of drainage fixture units, according to Tables (B-21, B-22, B-23)/ Appendix B. 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.

Design procedure:

1: Calculation of the number of DFU for each branch .

2: Calculation of the number of DFU for each stack.

3: Choosing the branch pipe diameter.

4: Choosing the stack pipe diameter .

5: Comparing the stack pipe diameter with branch diameter.

6: Choosing the building drain pipe diameter .

To achieve the recommended velocities which are 3 fps in building drain, it will be chosen the slope and flow velocity in building drain.

The following figure 4.3 and shows sample of stacks:

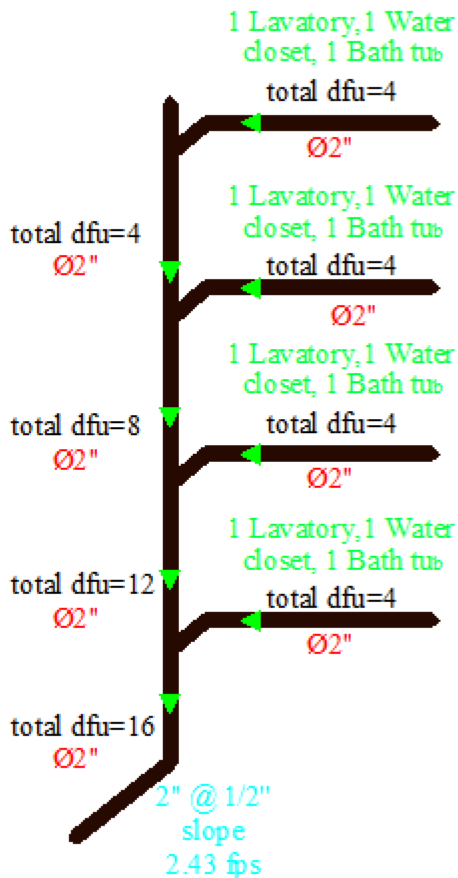


Figure 4.3: Sample of stacks

The following Table 4.10 will show the drainage fixture unit (dfu).

Table 4.10: The drainage fixture unit (dfu).

Stake	dfu value	Diameter of pipe [inch]
A	55	4
B	26	4
C	75	4
D	11	4
E	26	4
F	32	4
G	26	4
H	40	4
I	40	4
J	40	4
K	27	4
L	47	4
M	89	4
N	41	4
O	47	4
P	26	4
Q	46	4
R	42	4
S	42	4
T	29	4
U	39	4
V	9	4
W	7	4
X	7	4
Y	9	4
Z	9	4
A1	12	4
A2	28	4
A3	22	4
A4	42	4
A5	53	4
A6	42	4
A7	41	4

4.3.3 Manhole design

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

We design the manhole around the building so as that the sewage comes from the stacks flows in, then the sewage flows from one manhole to another so as reaching the septic tank . 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 then we calculate the height of the other manhole depending on the spacing between manholes and the slope of drainage pipes between manhole to be1.5%.

As a result of these calculations we estimate the invert level of the manhole that is the depth of the pipe entering the manhole and we choose the diameter of the manhole depending on the depth of the manhole as below.

ϕ 60 cm for manhole depth (50-100) cm.

ϕ 80 cm for manhole depth (100-150) cm.

ϕ 100 cm for manhole depth (150-250) cm.

ϕ 120 cm for manhole depth(250-∞) cm.

Manholes Calculations

The depth of the first manhole is 60 cm, the calculation of the second manhole done according to the first manhole and so on. Using the following steps we does the calculations: Depth: $(Depth_{Manholes(x)} = (Depth_{Manholes(x-1)} + (Slope * Distance) + 5 + LevelDifference)[cm]$

Top level: Manholes face level on the ground

Outlet level = Top level-Depth MAN [m]

Invert level = Outlet Level of MAN + 5 [m]

The figure 4.4 below shows the details of the manholes:

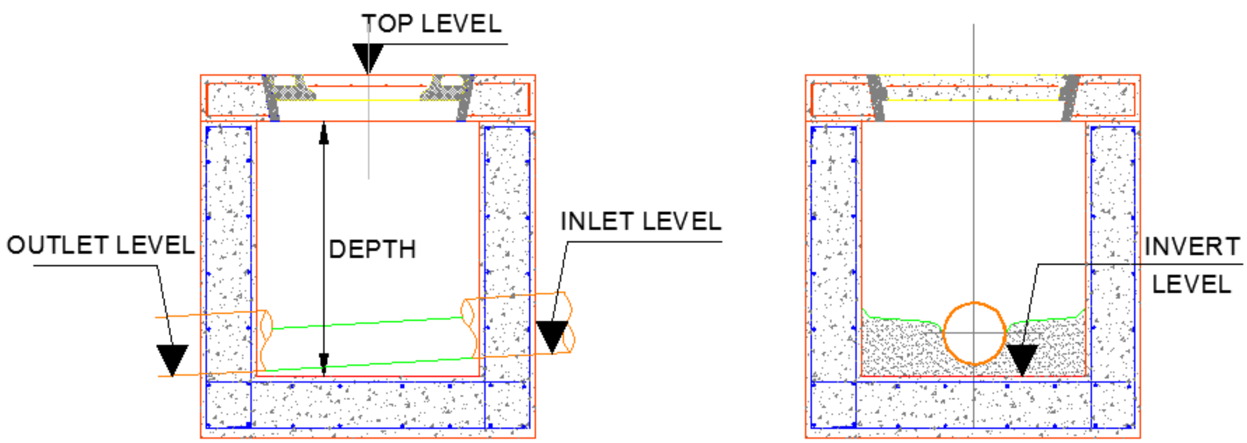


Figure 4.4: The details of the manholes.

We assume the depth of the first manhole to be (60 cm) and we calculate the second manhole according to it and so on.

For Manhole.1:

Top level = 0.0 m

Depth = 0.6

Outlet level=Top level-Depth = 0.0- 0.6 = -0.6 m

For MAN.2:

The distance between MAN.1 & MAN.2 is 8 m. Depth of MAN.2 is: Depth = 60+(.015*800)+5+0= 77 cm Outlet level MAN.2 =Top level-Depth MAN.2= 0.0- 0.77 = -0.77m Slope is 1.5Invert level of MAN.2 = Outlet Level of MAN.2 + 5 cm= -0.72 m

The following table 4.11 shows calculations and dimensions of all manholes that used in our project.

Drop Manholes

When a sewer connects with another sewer, where the difference in level between invert level of branch sewer and water line in the main sewer at maximum discharge is greater than 0.6 m, a manhole may be built either with vertical or nearly vertical drop pipe from higher sewer to the lower one (Figure 4.5). The drop manhole is also required in the same sewer line in sloping ground, when drop more than 0.6 m is required to control the gradient and to satisfy the maximum velocity i.e., non-scouring velocity.

The drop pipe may be outside the shaft and encased in concrete or supported on brackets inside the shaft. If the drop pipe is outside the shaft, a continuation of the sewer should be built through the shaft wall to form a rodding and inspection eye, provided with half blank flange (Figure 4.5). When the drop pipe is inside the shaft, it should be of cast iron and provided with adequate arrangements for rodding and with water cushion of 150 mm depth at the end. The diameter of the drop pipe should be at least equal to incoming pipe.

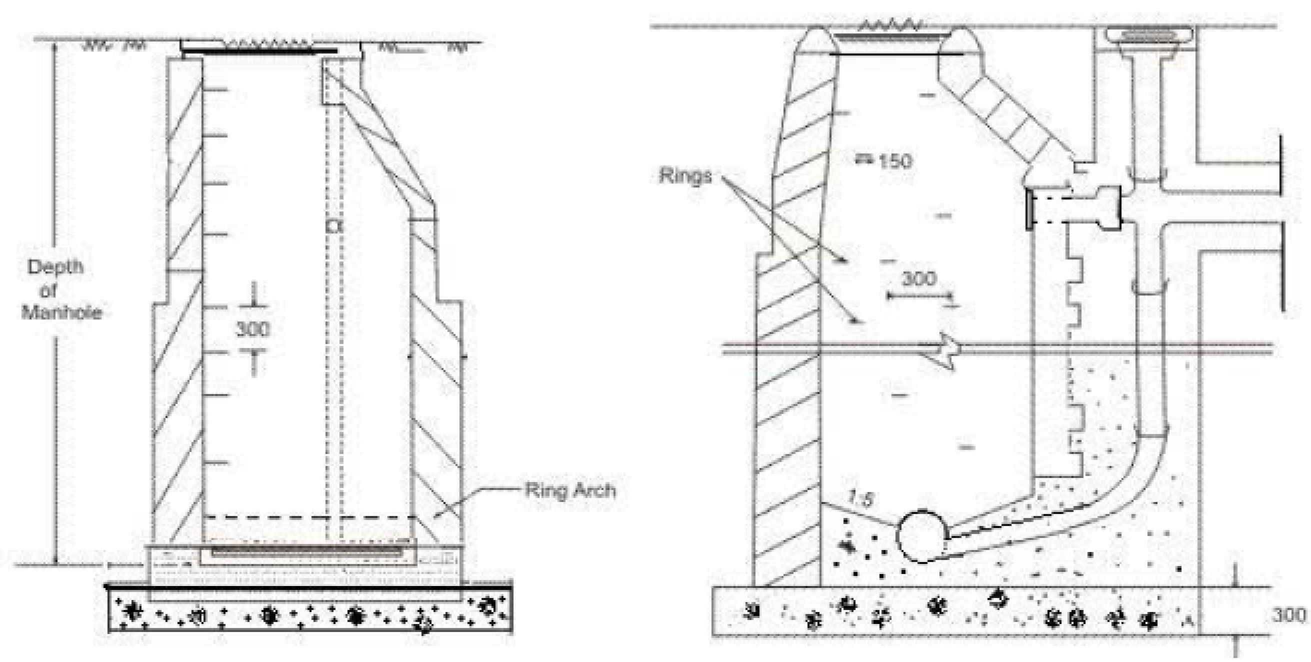


Figure 4.5: The details of the manholes.

Table 4.11: Manholes Calculations.

MAN.NO	Top Level [m]	Invert Level [m]	Outlet Level [m]	Depth [cm]	Diameter [cm]	Cover
MH_1	0.0	-0.55	-0.60	60	60	Medium duty
MH_2	0.0	-0.72	-0.77	70	60	Medium duty
MH_3	0.0	-0.85	-0.90	90	60	Medium duty
MH_4	0.0	-0.98	-1.03	103	80	Medium duty
MH_5	0.0	-1.08	-1.13	113	80	Medium duty
MH_6	0.0	-1.20	-1.25	125	80	Medium duty
MH_7	-0.3	-1.35	-1.40	110	80	Medium duty
MH_8	-0.3	-1.55	-1.60	130	80	Medium duty
MH_9	-0.3	-1.72	-1.77	147	80	Medium duty
MH_{10}	-0.3	-1.80	-1.85	155	100	Medium duty
MH_{11}	-0.3	-1.91	-1.96	166	100	Medium duty
MH_{12}	-0.3	-2.03	-2.08	178	100	Medium duty
MH_{13}	-0.3	-2.13	-2.18	188	100	Medium duty
MH_{14}	-1.0	-2.28	-2.33	133	80	Medium duty
MH_{15}	-1.0	-2.39	-2.44	144	80	Medium duty
MH_{16}	-1.5	-2.50	-2.55	105	80	Medium duty
MH_{17}	-1.5	-2.56	-2.61	111	80	Medium duty
MH_{18}	-1.7	-2.25	-2.30	60	60	Medium duty
MH_{19}	-1.7	-2.35	-2.40	70	60	Medium duty
MH_{20}	-1.7	-2.48	-2.53	83	60	Medium duty
MH_{21}	-1.7	-2.66	-2.71	101	80	Medium duty
MH_{22}	-1.7	-2.74	-2.79	109	80	Medium duty
MH_{23}	-1.7	-2.95	-3.00	130	80	Medium duty
MH_{24}	-2.0	-2.84	-2.89	119	80	Medium duty
MH_{25}	-2.0	-3.04	-3.09	139	80	Medium duty
MH_{26}	-3.0	-3.57	-3.62	62	60	Medium duty
MH_{27}	-3.0	-3.76	-3.81	81	60	Medium duty
MH_{28}	-3.0	-3.95	-4.00	100	80	Medium duty
MH_{29}	-3.0	-4.13	-4.18	118	80	Medium duty
MH_{30}	-3.0	-4.33	-4.38	138	80	Medium duty
MH_{31}	-3.0	-4.52	-4.57	175	100	Medium duty
MH_{32}	-3.0	-4.70	-4.75	157	100	Medium duty
MH_{33}	-3.0	-4.81	-4.86	186	100	Medium duty
MH_{34}	-3.0	-5.04	-5.09	209	100	Medium duty
MH_{35}	0.0	-0.55	-0.60	60	60	Medium duty
MH_{36}	0.0	-0.75	-0.80	80	60	Medium duty
MH_{37}	0.0	-0.93	-0.98	98	60	Medium duty
MH_{38}	-1.0	-1.55	-1.6	60	60	Heavy duty
MH_{39}	-1.0	-1.72	-1.77	77	60	Heavy duty
MH_{40}	-1.0	-1.89	-1.94	94	60	Medium duty
MH_{41}	-3.0	-5.23	-5.28	228	100	Medium duty

4.3.4 Storm drainage

Here we will talk about the choice of diameter and slope of the drainage pipe system and we will take the following Bathroom as an example of how we will choose the diameter and the slope of the drainage pipe system.

- We will use pipes (Branches) from fixture unit to the floor drainage (F.D.) with diameter (2") for lavatory and shower and with slope(1%).
- We will use pipes (Building Drains) from fixture unit to the manhole with diameter (4") for water closet with flush valve and with slope (1% - 2%).
- We will use pipes (Sewage Pipes) between manholes with diameter (6") and with slope (1.5%), and the waste water will transfer between manholes until it reach the main Manhole.
- We will use floor trap (F.T.) at the end of the branches as a collection box for this pipes and in order to provide a water seal to prevent odors, sewage gases and vermin's from entering building.
- We will use clean out (C.O) at the end of the branches in order to clean the pipes from any things that can blockage and close the pipes.
- We will use a stack with diameter (4") in order to drain the waste water to the manholes.

The design procedure

1. Draw an isometric of the entire system to show all the fixtures.
2. Assign drainage unit to each fixture, if a fixture not listed specifically base DFU requirement on its trap size. Drainage requirements not due to fixtures, such as non-recalculated of cooling water or process water, use conversion of 1gpm=2DFU.
3. Find the total of DFU in each drainage pipe and mark them on the drawing.
4. Determined the required size of horizontal fixture branches and stacks.
5. Determined the size and slop of the building drain and its branches and the building sewer.
6. Determined that the size and slop that found in step5 meet the requirement of the code .

Chapter 5

Fire fighting system

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

5.1 Types of fire fighting system

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

5.1.1 Fire extinguishers

Portable fire extinguishers can contain a wide variety of extinguishing agents; the portable 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.

Types of portable fire fighting extinguishers:

The principle fire extinguisher types currently available include Fig.

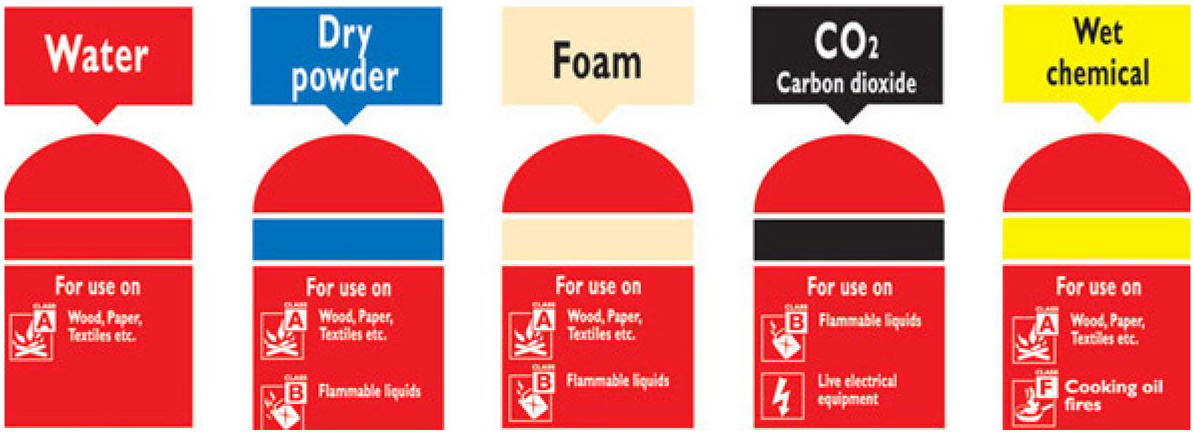


Figure 5.1: Fire extinguishers

1. Foam: fire extinguishers extinguish the fire by taking away the heat element of the fire triangle. Foam agents also separate the oxygen element from the other elements. Water extinguishers are for Class A fires only - they should not be used on Class B or C fires. The discharge stream could spread the flammable liquid in a Class B fire or could create a shock hazard on a class C fire. Foam extinguishers can be used on Class A and B fires only. They are not for use on Class C fires due to the shock hazard.
2. Carbon Dioxide: Carbon dioxide fire extinguishers extinguish the fire by taking away the oxygen element of the fire triangle and also by removing the heatwith a very cold discharge. Carbon dioxide can be used on Class B and C fires. They are usually ineffective on Class A fires.
3. Clean agent extinguishers: Halogenated or Clean Agent extinguishers include the halon agents as well as the newer and less ozone depleting halocarbon agents. They extinguish the fire by interrupting the chemical reaction of the fire triangle.
4. Dry chemical extinguishers, hand and wheeled: fire extinguishers extinguish the fire primarily by interrupting the chemical reaction of the fire triangle.
5. Wet chemical extinguishers: Wet Chemical is a new agent that extinguishes the fire by removing the heat of the fire triangle and prevents reigniting by creating a barrier between the oxygen and fuel elements and use in kitchen.
6. Dry Powder: extinguishers are similar to dry chemical except that they extinguish the fire by separating the fuel from the oxygen element or by removing the heat element of the fire triangle.

5.1.2 Fire hose reel

Fire hose reel systems consist of pumps, pipes, water supply and hose reels located strategically in a building, ensuring proper coverage of water to combat a fire fig.5.2. The system is manually operated and activated by opening a valve enabling the water to flow into the hose that is typically 30 meters away. The usual working pressure of a fire house can vary between 8 and 20 (116 and 290 psi). Fire hose reels are provided for use by occupants as a first attack fire fighting measure but may, in some instances, also be used by fire fighters. When stowing a fire hose reel, it is important to first attach the nozzle end to the hose reel valve, then close the hose reel valve, then open the nozzle to relieve any pressure in the wound hose, then close the nozzle.

Figure 5.2: Fire hose reel

5.1.3 Fire hydrate system

Fire hydrant systems fig.5.3. are installed in buildings to help fire fighters quickly attack the fire. Essentially, a hydrant system is a water reticulation system used to transport water in order to limit the amount of hose that fire fighters have to lay; thus speeding up the fire fighting process. Fire hydrants are for the sole use of trained fire fighters (which includes factory fire fighting teams). Because of the high pressures available serious injury can occur if untrained persons attempt to operate the equipment connected to such installations. Fire hydrant systems sometimes include ancillary parts essential to their effective operation such as pumps, tanks and fire service booster connections. These systems must be maintained and regularly tested if they are to be effective when needed.

Figure 5.3: Fire hydrate system

5.1.4 Automatic sprinkler system

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

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

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

5.2 Calculating the A-Rated extinguishers required

According to BS5306:8-2000 you should have no less than 26A (provided by 2 extinguishers) of fire protection per floor, where the floor area exceeds $100m^2$. The A-Rating required for a single floor in a property can be calculated using the following formula Eq.(5.1):

$$A - RatingRequired = FloorArea * 0.065 \tag{5.1}$$

The number of extinguishers required to cover this A-Rating can then be calculated as below Eq.(5.2):

$$Extinguishersperfloor = \frac{A - RatingRequired}{extinguisherA - Rating} \tag{5.2}$$

The A-Rating of a fire extinguisher is printed onto the extinguisher body, as marked in Figure This will vary dependent on the size, make and type of extinguisher used see appendix B.

- A-Rating Required calculation:

  A-Rating Required for ground floor = 2858 * 0.065 = 185.77m^2

  A-Rating Required for first floor = 2396 * 0.065 = 155.70 m^2

  A-Rating Required for second floor = 2074 * 0.065 = 134.80 m^2

  A-Rating Required for third floor = 2074 * 0.065 = 134.80 m^2

  A-Rating Required for fourth floor = 568 * 0.065 = 36.80 m^2

- Extinguishers per floor calculation:

  Extinguisher for ground floor = 185.77/26 = 7

  Extinguisher for first floor = 155.70/26 = 6

  Extinguisher for second and third floor = 134.80 /26 = 5

  Extinguisher for fourth floor = 36.8/26 = 2

- Fire hose calculation and pump selection.

  The pipe is manufacturing from steel. We select pipe with diameter D=4 inch riser and branch is D=4 inch its loss coefficient $k = 0.045 * 10^3 m^3$ For riser 17.5 m

  $Area(A) = \frac{\pi D^2}{4} = \frac{\pi * 0.11^2}{4}$ =0.009485m^2 Flow rate($Q_{efectiv}$) = $100gpm$

  which equal 0.00639 m^3

  The velocity in the pipe defined in the equation:

  $V = \frac{Q}{A} = 0.00639/0.009485 = 0.673m/s$

  Reynolds number (Re):

  $Re = \frac{\rho * V * D}{\mu}$

$Re = 1000 * 0.673 * 0.11/0.001 = 74030$

from mody chart Fig.5.4 the friction factor (f)=0.03

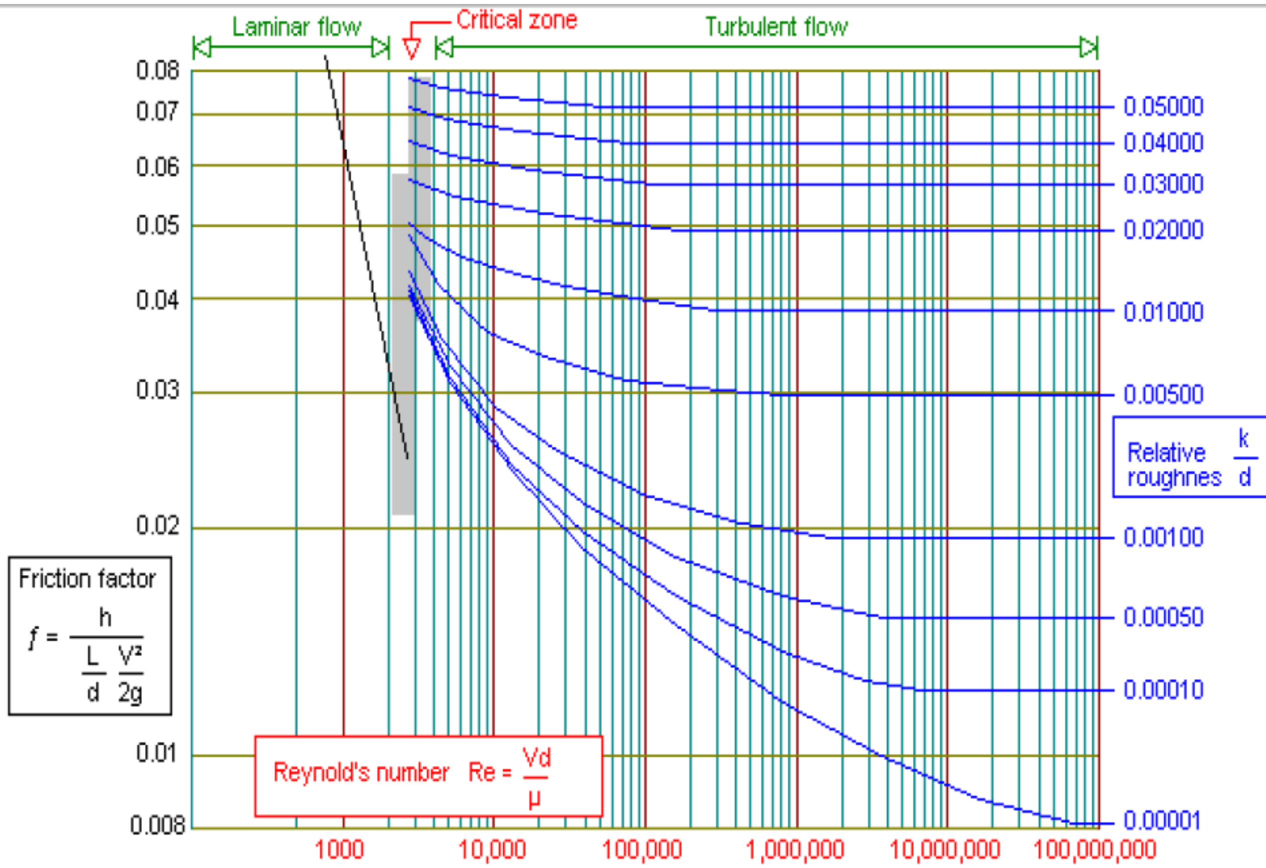


Figure 5.4: Moody chart

- Head loss: $h_{fr} = \frac{flV^2}{2g*0.1524} = 0.113m$

  The same calculation on branch we find $h_{fp} = 0.102$

  Major h_f=0.113 +0.102= 0.215 m.

  Miner losses h_f (fitting), Equivalent length (in meters) of straight pipe for fittings like bends, returns tees and valves. From Table of equivalent length Table B-25 see appendix B

  We use 4 regular 90 deg tow sex inch and one four inch and one 1.5.

  H_f = 2*2.7+1.8+0.7 =7.9 m losses

  Total head losses = head major + head miner =0.215+7.9=8.115 m.

  Factor of safety = 8.115*1.15= 9.33

  Turn it into pressure

  P= 9.81*1000*9.33=91549.37 Pascal .

P loss =0.915 bar

Total pressure = pressure require + pressure loss Total pressure = 4.5+0.915=5.5 bar

5.3 Selections of other fire fighting system components

1. Fire hose :

   We need a hose length of 30 meter.

   Selection : kiddeModel 31A.

2. Pumps:

   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 discharge header (to fire fighting network).

   Pumping should be included:

   (a) Electrical fire fighting pump. Xylem Model 2.5X2.5X7F.

   (b) Diesel Fire fighting Pump,(Stand-by pump).Xylem Model 3X2X11F-S . Diesel pump works if:

      i. The electrical pump is out of service, or if there is a lack of electricity.

      ii. The electrical pump is working but can't satisfy system water requirements.

   (c) Jockey Pump: work to make up the system pressure in case of leakage or during the first seconds of fire.Peerless Model J - J65F.

3. Fire Extinguishers:

   Wet Chemical Extinguishers.

   HCFC Extinguishers.

   Carbone dioxide.

Chapter 6

Medical gases

6.1 introduction

Health care is in a constant state of change, which forces the plumbing engineer to keep up with new technology to provide innovative approaches to the design of medical-gas systems. In designing medical-gas and vacuum systems, the goal is to provide a safe and sufficient flow at required pressures to the medical-gas outlet or inlet terminals served. System design and layout should allow convenient access by the medical staff to outlet/inlet terminals, valves, and equipment during patient care or emergencies. This section focuses on design parameters and current standards required for the design of nonflammable medical-gas and vacuum systems used in therapeutic and anesthetic care. The plumbing engineer must determine the needs of the health-care staff. Try to work closely with the medical staff to seek answers to the following fundamental design questions at the start of a project:

- How many outlet/inlets are requested by staff?
- How many outlet/inlets are required?
- Based on current conditions, how often is the outlet/inlet used?
- Based on current conditions, what is the average duration of use for each outlet/inlet?
- What is the proper usage (diversity) factor to be used?

  Schematic diagram for the medical gases network Fig.6.1 .

6.2 Medical gas flow rates

Each station must provide a minimum flow rate forthe proper functioning of connected equipment under design and emergency conditions. The flow rates and diversity factors vary for individual stations in each system depending on the total number of outlets and the type of care provided. The flow rate from the total number of outlets, without regard for any diversity, is called the “total connected load.” If the total connected load were used for sizing purposes, the result would be a vastly oversized system, since not all

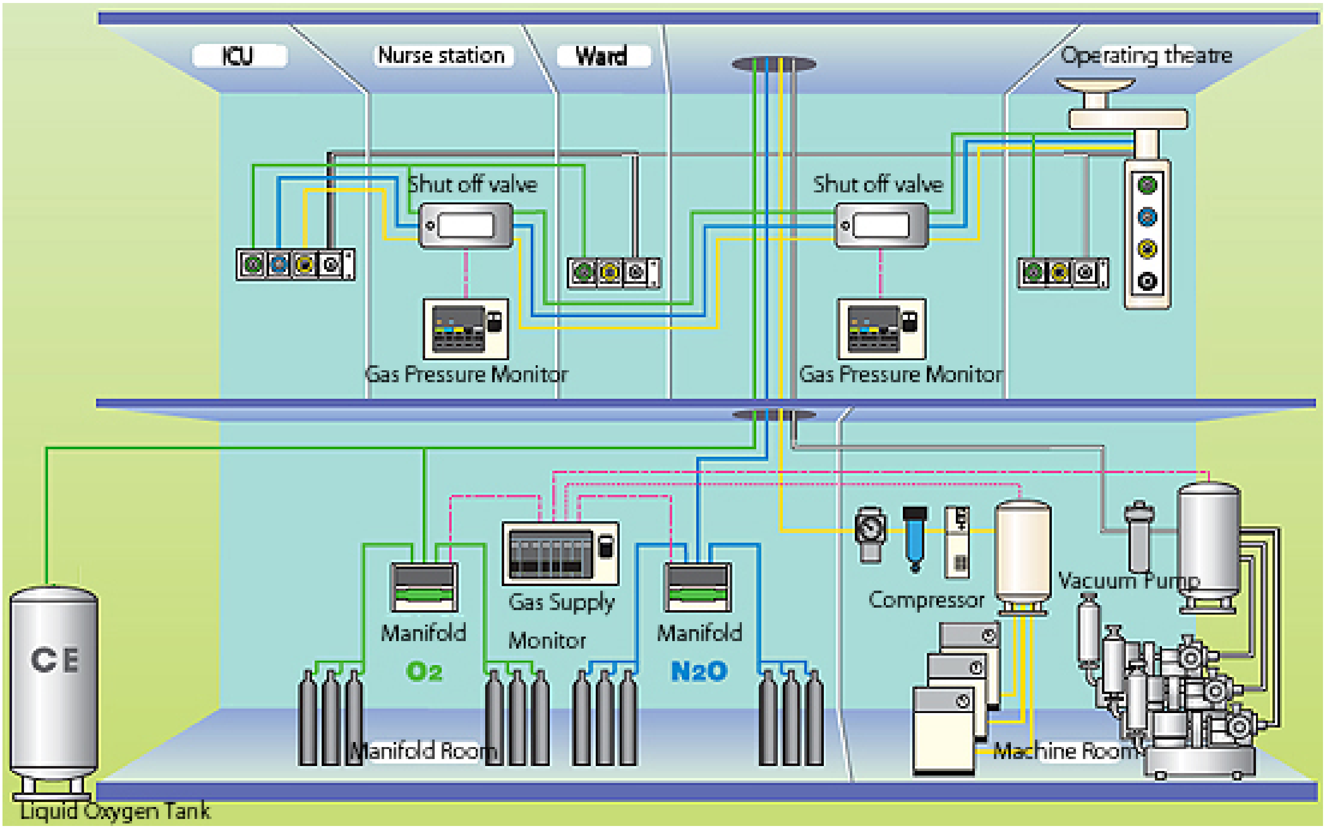


Figure 6.1: Schematic diagram for the medical gases network

of the stations in the facility will be used at the same time. A diversity, or simultaneous-use factor, is used to allow for the fact that not all of the stations will be used at once. It is used to reduce the system flow rate in conjunction with the total connected load for sizing mains and branch piping to all parts of the distribution system. This factor varies for different areas throughout any facility. The estimated flow rate and diversity factors for various systems, area stations. Total demand for medical-gas systems varies as a function of time of day, month, patient-care requirements, and facility type. The number of stations needed for patient care is subjective and cannot be qualified based on physical measurements. Knowing the types of patient care and/or authority requirements will allow placement of stations in usage groups. These groups can establish demand and simultaneous-use factors (diversities), which are used in the calculation for sizing a particular system. All medicalgas piping systems must be clearly identified using an approved color-coding system similar to that shown in Table 6.1 .

Table 6.1: Color Coding for Piped Medical Gases

Gas intended for medical use	United States Color
Oxygen	Green
Carbon dioxide	Gray
Nitrous oxide	Blue
Cyclopropane	Orange
Helium	Brown
Nitrogen	Black Silver on black
Air	Yellow
Vacuum	White
Gas mixtures (other than mixtures of oxygen and nitrogen)	Color marking of mixtures shall be a combination of color corresponding to each component gas.
Gas mixtures of oxygen and nitrogen 19.5 to 23.5% oxygen All other oxygen concentrations	Yellowa Black and green

6.3 Medical gas system design checklist

As any hospital facility must be specially designed to meet the applicable local code requirements and the health-care needs of the community it serves, the medical-gas and vacuum piping systems must also be designed to meet the specific requirements of each hospital. Following are the essential steps to a well-designed and functional medical-gas piped system, which are recommended to the plumbing engineer:

1. Analyze each specific area of the health-care facility to determine the following items:
   - Which piped medical-gas systems are required?
   - How many of each different type of medical-gas outlet/inlet terminal are required?
   - Where should the outlet/inlet terminals be located for maximum efficiency and convenience?
   - Which type and style of outlet/inlet terminal best meet the needs of the medical staff?
2. Anticipate any building expansion and plan in which direction the expansion will take place (vertically or horizontally). Determine how the medical-gas system should be sized and valved in order to accommodate the future expansion.
3. Determine locations for the various medical-gas supply sources.
   - Bulk oxygen (O_2).
   - High-pressure cylinder manifolds ($O_2, N_2O\ or\ N_2$).
   - Vacuum pumps (VAC).

- Medical-air compressors (MA).

4. Prepare the schematic piping layout locating the following:
    - Zone valves.
    - Isolation valves.
    - Master alarms.
    - Area alarms.

6.4 Type of medical gases:

1. Oxygen

   Oxygen is one of the most extensively used at atmospheric temperatures and pressures exists and its a colorless, odorless, non-flammable and tasteless gas. Primarily used by patients with respiratory or airway obstruction and to relieve. symptoms and signs associated with respiratory distress, therapy, anesthesia, used for face mask and ventilator. Oxygen should be avoided as a power source because of fire risk and 90 cost, and should not be used where medical air is available, Oxygen supplied to hospitals by multiple standard cylinders. Pressures are usually around 55 psi.

   ### Oxygen is generally supplied from:

    - A liquid source such as a large vacuum-insulated evaporator (VIE).
    - Liquid cylinders or compressed gas cylinders.
    - A combination of these to provide the necessary stand-by/back-up capacity.
    - Oxygen can also be supplied from an oxygen concentrator (pressure-swing adsorbed). Such systems are usually installed where liquid or cylinders are expensive, unavailable or impracticable.

2. Nitrous Oxide (NO_2): Nitrous Oxides a medical gas that used for anesthetic and analgesic purposes, being mixed with air, oxygen, and nebulizer agents. It delivered to the hospitals in standard tanks. System pressures around 50 psi.

3. Medical air MA4 Medical Air is primarily used for respiratory therapy. it supplied by a special air compressor to patient care areas using clean outside air. Pressure are maintained around 55 psi.

4. Medical Vacuum

   Medical Vacuum Primarily used for patient treatment in surgery, recovery, and ICU to remove fluids and aid in drainage, but it doesn't used in Infectious Diseases Unit (IDU). Medical vacuum systems operate low flow rates at the terminal units (40 L/min), it usually supplied to hospitals by vacuum pump systems. Continuous vacuum is maintained around 22 inches of mercury.

5. Anesthetic Anesthetic gas scavenging system:

   Anaesthetic Gas Scavenging System (AGSS) used for example in anesthetic and operating room. Used to capture and carry away gasesvented from the patient breathingcircuit during the normal operation ofgas anesthesia or analgesiaequipment. AGSS incorporate a mechanical pump to assist with the disposal of the waste gas.

Chapter 7

Refrigerators

7.1 Cooling Load Calculation for Refrigeration

Using this law to find Cooling Load Calculation:

$$Q = UA\Delta T \tag{7.1}$$

Q : Cooling Load in [kW] .
U : Overall heat transfer coefficient in $[W/m^2.^oC]$.

$$U = \frac{1}{\frac{1}{h_i} + \Sigma \frac{\Delta x_i}{k_i} + \frac{1}{h_o}} \tag{7.2}$$

h_{in} : is the Inside Convection Coefficient 9.37 $W/m^2.^oC$.
h_{out}: is the Outside Convection Coefficient 22.7 $W/m^2.^oC$.
K: is the thermal conductivity for material in $[W/m^oC]$.
ΔX: is the Thickness of the material in [m] .
A: Surface area in $[m^2]$.
A=Length * Width.
ΔT: The difference in temperature $[^oC]$.
Temperature surrounding T_{sur}:
$T_{sur} = 30^oC$
Room Temperature T_{Room} :
$T_{Room} = T_{in} + 2/3(T_{sur} + T_{in})$
T_{in}: is the storage temperature of product = 5 ^oC .
T_{Room} = 5 + 2/3 (30 +5)
T_{Room} = 28.3 ^oC.

7.1.1 The Overall Heat Transfer Coefficient

1. External Walls:

   The following figure 7.1 shows external wall details.The variable of heat transfer coefficient Table 7.1.

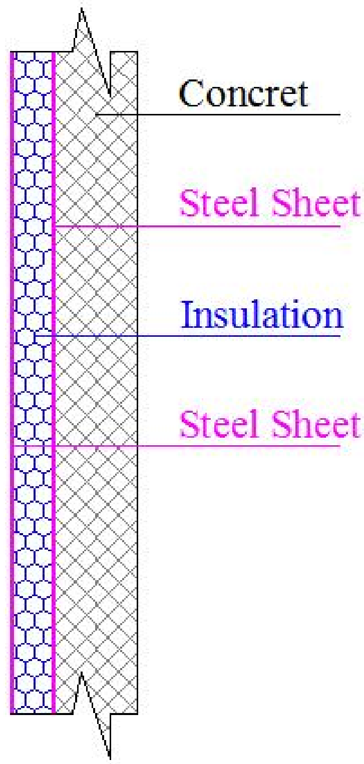


Figure 7.1: External wall details

Table 7.1: Variable of heat transfer coefficient for external wall.

Material	K ($W/m.^oC$)	Thickness (m)
Concrete	1.750	0.300
Steel Sheet	16.00	0.002
Insulation	0.050	0.070
Steel Sheet	16.00	0.002

Thickness of the wall = 0.37 m .

$$U = \frac{1}{\frac{1}{9.37}+\frac{0.3}{1.75}+\frac{0.002}{16}+\frac{0.07}{0.05}+\frac{0.002}{16}+\frac{1}{22.7}}$$

U= 0.58 $W/m^2.^oC$.

$\Delta T = T_{sur} - T_{in}$

ΔT= 30 – 5 = 25^oC .

$A - ExternalWall$= 3.74 * 3.05 = 11.4 m^2 .

$\dot{Q}_{ExternalWall_1}$ = 0.58 * 25 * 11.4

$dotQ_{ExternalWall_1}$= 165 W = 0.165 kW.

2. Internal Wall_1:

   The following figure 7.2 shows internal wall details.The variable of heat transfer coefficient Table 7.2.

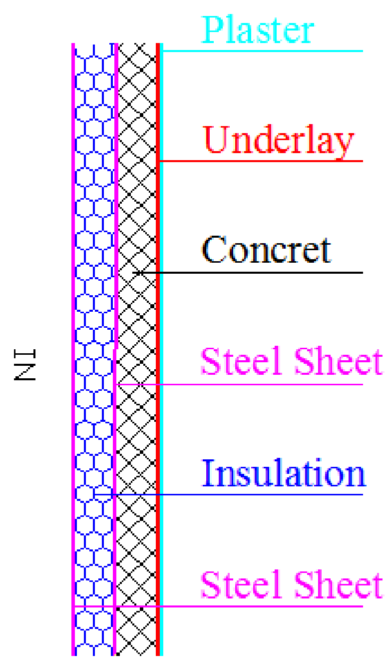


Figure 7.2: internal wall details

Table 7.2: Variable of heat transfer coefficient for internal wall.

Material	K ($W/m.^oC$)	Thickness (m)
Plaster	1.200	0.002
Underlay	0.980	0.008
Concert	1.750	0.200
Steel Sheet	16.00	0.002
Insulation	0.050	0.070
Steel Sheet	16.00	0.002

Thickness of the wall = 0.284 m .

$$U = \frac{1}{\frac{1}{9.37}+\frac{0.002}{1.2}+\frac{0.008}{0.98}+\frac{0.2}{1.75}+\frac{0.002}{16}+\frac{0.07}{0.05}+\frac{0.002}{16}+\frac{1}{9.37}}$$

U= 0.575 $W/m^2.^oC$.

$\Delta T = T_{Room} - T_{in}$

ΔT= 28.3 – 5 = 23.3^oC .

$A - internalWall$= 4.44 *3.05 = 13.54 m^2 .

$Q_{InternalWall-1}$ = 0.575 * 23.3 * 13.54

$Q_{InternalWall-1}$= 181 W = 0.181 kW.

3. Internal Wall_2:

   The following figure 7.3 shows internal wall details.The variable of heat transfer coefficient Table 7.3.

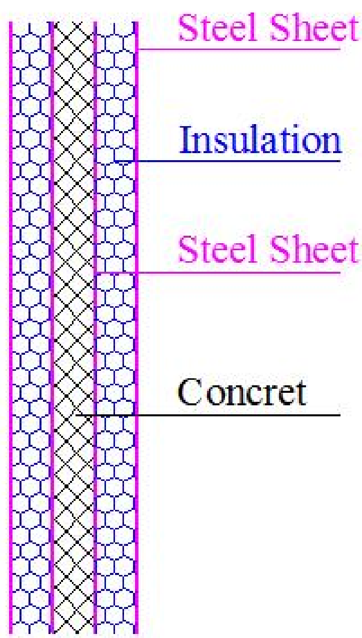


Figure 7.3: internal wall-2 details

Table 7.3: Variable of heat transfer coefficient for internal Wall_2.

Material	K $(W/m.^oC)$	Thickness (m)
Steel Sheet	16.0	0.002
Insulation	0.05	0.070
Steel Sheet	16.0	0.002
Concrete	1.75	0.100
Steel Sheet	16.0	0.002
Insulation	0.05	0.070
Steel Sheet	16.0	0.002

Thickness of the wall = 0.284 m .

$$U = \frac{1}{\frac{1}{9.37}+\frac{0.002}{16}+\frac{0.007}{0.05}+\frac{0.002}{16}+\frac{0.1}{1.75}+\frac{0.002}{16}+\frac{0.07}{0.05}+\frac{0.002}{16}+\frac{1}{9.37}}$$

U= 0.325 $W/m^2.^oC$.

$\Delta T = T_{Room} - T_{in}$

ΔT= 5–18 = 23^oC .

$A - internalWall_2$= 4.44 *3.05 = 13.54 m^2 .

$Q_{InternalWall_2}$ = 0.325 * 23 * 13.54

$Q_{InternalWall_2}$= 101 W = 0.101 kW.

4. Internal Wall_3 :

   The same propriety of Internal Wall-2 but the aria is difference

   A = A $_{InternalWall_3}$ - A Door = (3.74 * 3.05) - 4 = 7.4 m2 .

   Q $_{InternalWall_3}$ = 0.575 * 23.3 * 7.4 = 99 W = 0.099 kW .

5. Ground:

   The following figure 7.4 shows Ground details.The variable of heat transfer coefficient Table 7.4.

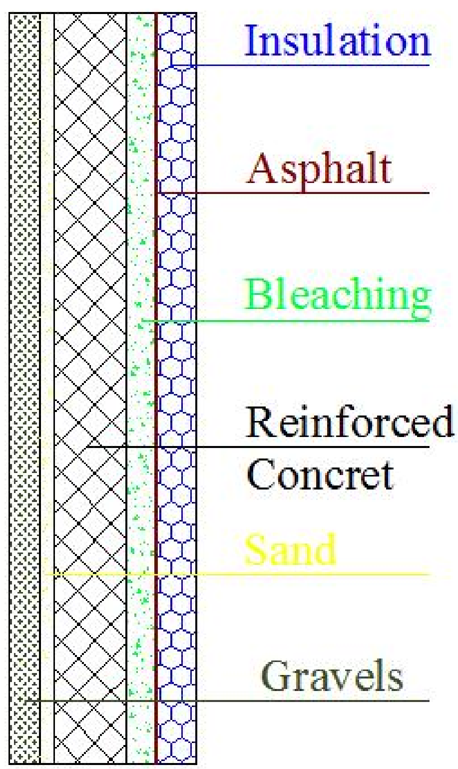


Figure 7.4: Ground details

Table 7.4: Variable of heat transfer coefficient for Ground.

Material	K ($W/m.^oC$)	Thickness (m)
Insulation	0.05	0.100
Asphalt	0.30	0.002
Bleaching	0.98	0.050
Reinforced Concrete	0.88	0.200
Sand	0.68	0.020
Gravels	0.58	0.050

Thickness of the ground = 0.284 m .

$$U = \frac{1}{\frac{1}{9.37}+\frac{0.1}{0.05}+\frac{0.002}{0.3}+\frac{0.05}{0.98}+\frac{0.2}{0.88}+\frac{0.02}{0.68}+\frac{0.05}{0.58}}$$

U= 0.399 $W/m^2.^oC$.

$\Delta T = T_{Ground}$

ΔT= 5 ^oC .

$A - Ground$= 4.44 *3.74 = 16.6 m^2 .

Q_{Ground} = 0.399 * 5 * 16.6

Q_{Ground}= 33 W = 0.033 kW.

6. Ceiling:

   The following figure 7.5 shows Ceiling details.The variable of heat transfer coefficient Table 7.5.

Table 7.5: Variable of heat transfer coefficient for Ceiling.

Material	K ($W/m.^oC$)	Thickness (m)
Tiles	1.10	0.005
Concrete	1.75	0.050
Insulation	0.05	0.096
Concrete	1.75	0.15
Steel Sheet	16.0	0.002

Thickness of the Ceiling = 0.362 m .

$$U = \frac{1}{\frac{1}{9.37}+\frac{0.005}{1.1}+\frac{0.05}{1.75}+\frac{0.096}{0.05}+\frac{0.15}{1.75}+\frac{0.002}{16}+\frac{1}{9.37}}$$

U=0.444 $W/m^2.^oC$.

ΔT =28.3-5

ΔT=23.3 ^oC .

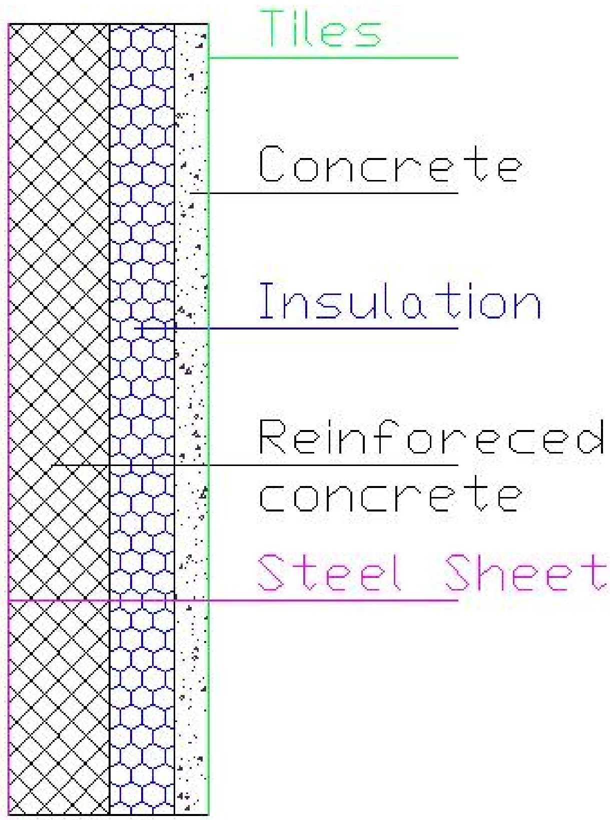


Figure 7.5: Ceiling details

$A_{Ceiling}$= 4.44 *3.74 = 16.6 m^2 .

$Q_{Ceiling}$ = 0.444 *23.3 * 16.6

$Q_{Ceiling}$= 172 W = 0.172 kW.

7. Door:

The following figure 7.6 shows Door details.The variable of heat transfer coefficient Table 7.6.

Table 7.6: Variable of heat transfer coefficient for Door.

Material	K ($W/m.^oC$)	Thickness (m)
Steel Sheet	16.0	0.002
Insulation	0.05	0.056
Wood	0.16	0.040
Steel Sheet	16.0	0.002

Thickness of the Door = 0.1 m .

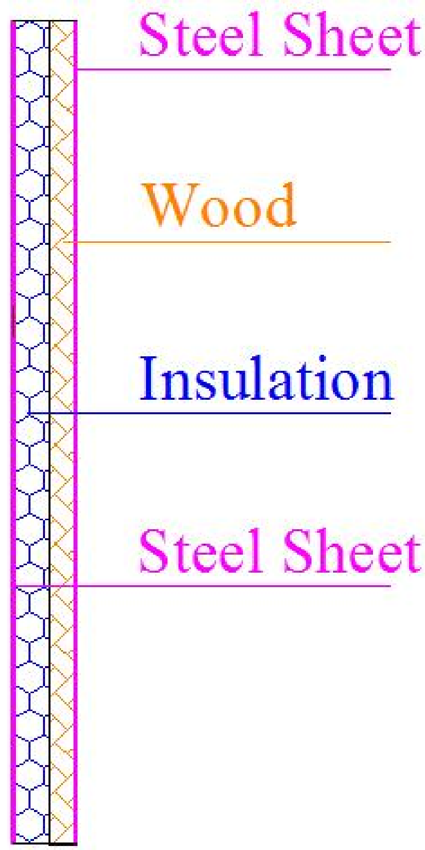


Figure 7.6: Ceiling details

$$U = \frac{1}{\frac{1}{9.37}+\frac{0.002}{16}+\frac{0.056}{0.05}+\frac{0.04}{0.16}+\frac{0.002}{16}+\frac{1}{9.37}}$$

U=0.631$W/m^2.^oC$.

ΔT =28.3-5

ΔT=23.3 ^oC .

$A - Door$= 2*2 = 4 m^2 .

Q_{Door} = 0.631 *23.3 *4

Q_{Door}= 59W = 0.059 kW.

7.1.2 Cooling Load Calculation For Rooms

Using this law to calculate cooling load for rooms:

$$\dot{Q}_{Total} = \dot{Q}_{Envelope} + \dot{Q}_{Product} + \dot{Q}_{Air} + \dot{Q}_{Service} + \dot{Q}_{Respiration} \quad (7.3)$$

For Refrigerator:

- $\dot{Q}$ Envelope Calculation:

  $\dot{Q}$: heat gain from walls, doors, windows, floor and ceiling.

  $\dot{Q} = \dot{Q}_1 + \dot{Q}_{Solar}$.

$$\dot{Q} = \dot{Q}_{Wall} + \dot{Q}_{Door} + \dot{Q}_{Floor} + \dot{Q}_{Ceiling} \tag{7.4}$$

  $\dot{Q}_{Wall} = \dot{Q}_{Externalwall_1} + \dot{Q}_{InternalWall_1} + \dot{Q}_{InternalWall_2} + \dot{Q}_{InternalWall_3}$

  = 0.165+0.181 + 0.101 +0.099 = 0.546.

  $\dot{Q}_1$ = 0.546 + 0.033 + 0.172+ .059 = 0.81 kW.

  $\dot{Q}_{Solar} = 0$

  $\dot{Q}_{Envelope}$ = 0 + 0.81 = 0.81 kW .

- $\dot{Q}$ Product Calculation:

$$\dot{Q}_{Product} = \dot{Q}_2^{*} + \dot{Q}_2^{**} + \dot{Q}_{Packaging} \tag{7.5}$$

  $\dot{Q}_2^{*} = \dot{m}cp\Delta T$.

  When:

  $\dot{m}$ = (m$_{Product}$ / Time Cooling)

  Time Cooling: Working Time Per a Day .

  $\Delta T = \Delta T_{sur} = 30^oC$.

  $\dot{Q}_2^{*}$ = 1.65 kW . $\dot{Q}_2^{**}$ = 0 Used to freeze

$$\dot{Q}_{Packaging} = (m_{Material}/TimeCooling) * cp * \Delta T \tag{7.6}$$

  Where: m $_{Material}$ = m * N .

  m : is the mass of one pallet = 15 kg .

  N: is the number of pallets in the room = 20.

  m $_{Material}$ = 15 * 20 = 300 kg .

  cp : is the Specific Heat for Pallet = 0.67 kJ/kg.K .

  $\Delta T = \Delta T_{sur} = 30^oC$.

  $\dot{Q}_{Packaging}$ = (300 / (4 * 16 * 3600)) * 0.67 * 30 = 0.105 kW .

  $\dot{Q}_{Product}$ = 1.65 + 0 + 0.105 = 1.755kW.

Table 7.7: product used.

Product	cp	m	$\dot{m}$	$\dot{Q}_2^*$
Apple	3.64	40	0.000694	0.075833
Avocados	3.01	40	0.000694	0.062708
Bananas	3.35	40	0.000694	0.069792
Bass	3.43	30	0.000521	0.053594
Black Barry	3.64	20	0.000347	0.037917
Butter	2.72	30	0.000521	0.0425
Cabbage	3.94	50	0.000868	0.102604
Carrots	3.81	20	0.000347	0.039688
cheese	3.27	40	0.000694	0.068125
Chicken	2.72	80	0.001389	0.113333
cucumber	4.1	100	0.001736	0.213542
eggs	3.18	30	0.000521	0.049688
Eggplant	3.98	50	0.000868	0.103646
Grapes	3.6	50	0.000868	0.09375
Lemons	3.81	60	0.001042	0.119063
Milk	3.81	40	0.000694	0.079375
Tomatoes	3.98	120	0.002083	0.24875
Watermelon	3.94	100	0.001736	0.205208
Σ				1.653281

- $\dot{Q}_{Air}$ Calculation:

$$\dot{Q}_{Air} = \dot{Q}_{Infiltration} + \dot{Q}_{Ventilation} \tag{7.7}$$

$\dot{Q}_{Infiltration}$ = 0 kW.

Prove it :

$\dot{Q}_{Infiltration}$ = (1250 / 3600) * $\dot{v}$ * (T$_{Room}$ − T$_{in}$) $\dot{v}$ = K * L * 0.613 * (S1 * S2 * v_o)2 (3 / 2)

L : Perimeter of the door .

L = 2 * 3 + 2 * 3 = 12 m .

K : The infiltration air coefficient = 0.25 .

S1 : Factor that depend on the topography of the location of the building = 0.9 .

S2: Coefficient that depend on the height of the building and the term of its location = 0.74 .

v_o : The wind velocity = 0.5 mL / sec .

v_o = 0.25 * 12 * 10-3 * 0.613 * (0.9 * 0.74 * 0.5)2 (3 /2)

= 5.3 * 10^{-5} mL / sec .

$\dot{Q}_{Infiltration} = (1250/3600) * 5.3 * 10^{-5} * (25.1–0) = 0.0004 \approx 0$ kW .

- $\dot{Q}_{Ventilation}$ Calculation:

$$\dot{Q}_{Ventilation} = \dot{Q}_{Product} + \dot{Q}_{People} \tag{7.8}$$

$\dot{Q}_{Product} = m_o * (h_{out} – h_{in})$
From Psychometric Chart:
$h_{out} = 72J/kg.^oC@Tout = 30^oC\&R.H = 56\%.$
$h_{in} = 17J/kg.^oC@Tin = 5^oC\&R.H = 85\%$.
$m_o = \rho_{Air} * v_o$
ρ_{Air}: it is the density of the air = 1.2 kg/m^2.
V_o = v * a.
V : Volume of the room in[m^3] .
V = 4.44 * 3.74 * 3.05 = 50.6 m^3.
a : number of air change each second , it depend for the volume of the room .
from interpolation a = 21.3 L/s . [Table 10-7]
$\dot{m}$ = 1.2 * 50.6 * (21.3 /1000) = 1.293 m^3/s .
$\dot{Q}_{Product}$ = 1.293 * (72 – 17) = 71.13 W = 0.071 kW .
$\dot{Q}_{People} = \dot{m} * (h_{out} – h_{in}) * (houroccupied/24) * a$
When:
a : The number of people inside the room = 2 .
$\dot{m} = \rho_{Air} * \dot{V}$
$\dot{V} = 20m^3/h.$
$\dot{m} = 1.2 * (20/3600) = 6.66 * 10^3 kg/s.$
hour occupied: is the time needed to work in the room = 2 hours
$\dot{Q}_{People}$= 6.66 * 10-3 * 55* (2/24) * 2 = 0.061 W = 6.1 * 10-5 kW .
$\dot{Q}_{Ventilation}$ = 0.071+ 6.1 * 10-5 = 0.0711 kW .
$\dot{Q}_{Air}$ = 0 + 0.0711 = 0.0711 kW .

- $\dot{Q}_{Service}$ Calculation:

$\dot{Q}_{Service} = \dot{Q}_{People} + \dot{Q}_{Light}.$
$\dot{Q}_{People} = n * \dot{Q}_{Person} * (Workinghours/24)$
$\dot{Q}_{Person}$ = 0.275.
$\dot{Q}_{People}$ = 2 * 0.275 * (2 / 24) = 0.046 kW .
$\dot{Q}_{Light}$ = P$_{Light} * CLF * N$

$\dot{Q}_{Light}$= 24 W. CLF: Cooling Load Factor of Lighting = 0.88 .

N: Number of Lights

N = 2

$\dot{Q}_{Light}$ = 24 * 0.88 * 2 = 42.24 W = 0.0422 kW

$\dot{Q}_{Service}$ = + 0.046 + 0.0422 = 0.088 KW .

- $\dot{Q}_{Respiration}$ Calculation:

$\dot{Q}_{Respiration} = m * q_{Rips}$

$\dot{Q}_{Respiration}$: is the rate of respiration .

m : is the mass of the product in the room in [kg] .

q_{Rips} Rate of heat given off Breathing product .

q_{Rips} = 0.029 . [Table 10-12] .

$\dot{Q}_{Respiration}$ = 0.029 * 1000 = 29 W = 0.029 kW .

Consequently:

$\dot{Q}_{Total}$ = 0.81 + 1.755+ 0.0711 +0.088+ 0.029 = 2.75 kW .

$\dot{Q}_{Total}$ =2.75*F.S = 2.75*1.5 = 4.125 Kw

The following figure 7.8 for the cycle in PH diagram and the values of points in cycle figure 7.7 from Cool pack

Point	T	P	v	h	s
	[°C]	[bar]	[m^3/kg]	[kJ/kg]	[kJ/(kg K)]
1	4.999	3.496	0.058019	400.073	1.7194
2	37.960	8.868	0.023373	419.252	1.7194
3	37.960	8.868	0.023373	419.252	1.7194
4	35.000	8.868	N/A	248.748	N/A
5	N/A	3.496	N/A	248.748	N/A
6	5.000	3.496	0.058015	400.073	1.7194
15	N/A	8.868	N/A	248.748	N/A

Figure 7.7: The values of points in cycle.

$q_e = h_1 – h_5$
= 400.073– 248.748 = 151.325 kJ/kg .
$q_c = h_2 – h_4$
= 419.252 – 248.748 = 170.504 kJ/kg .
$W_c = h_2 – h_1$
= 419.252 – 400.073 = 19.179 W
$\dot{Q}_e = \dot{m}Rq_e$
$\dot{m}R = Q_e/q_e = 4.125/151.315 = 0.02726kg/s.$

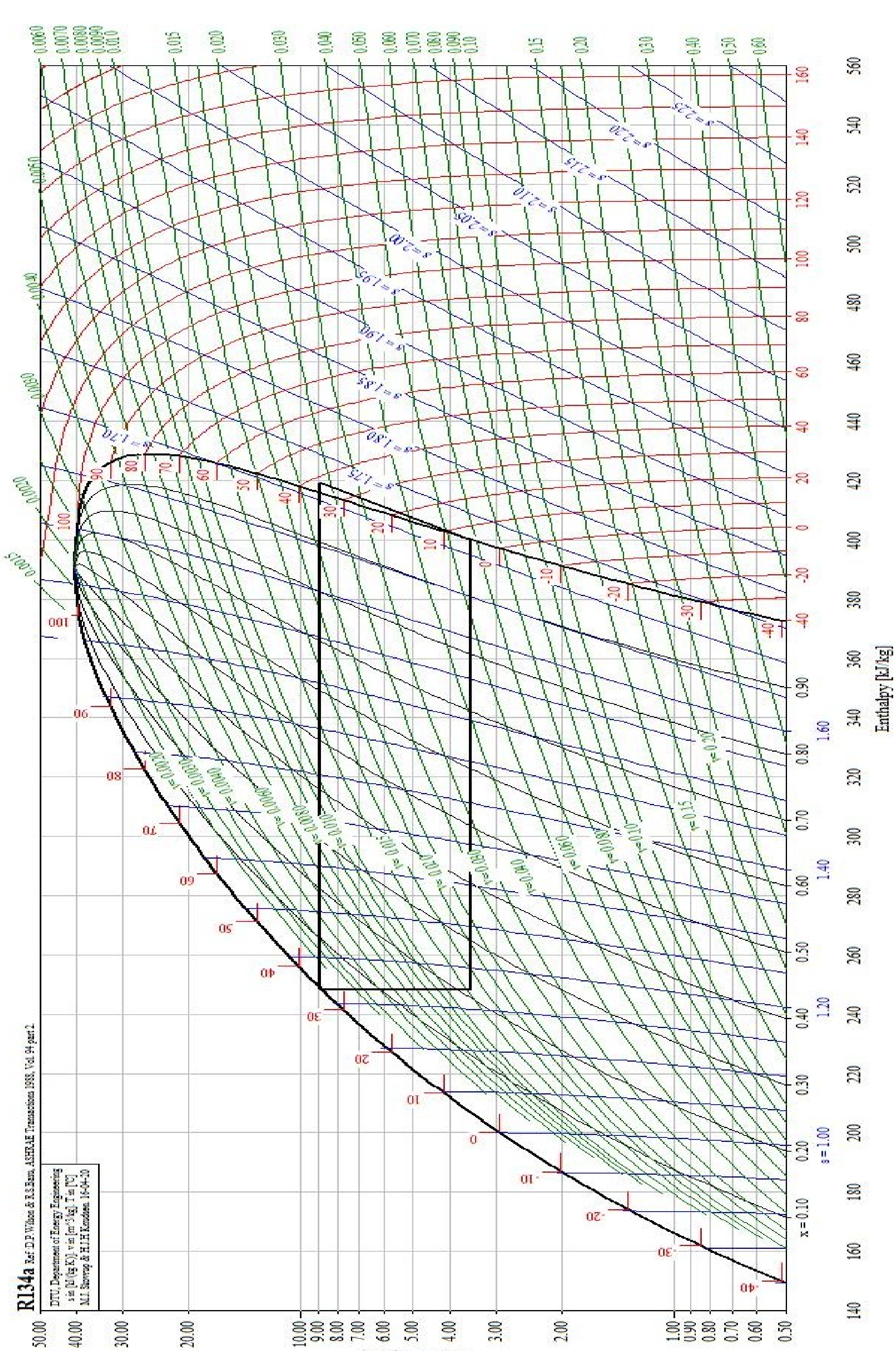


Figure 7.8: The cycle in the PH diagram

$\dot{Q}_c = \dot{m}Rq_c$
=0.02726 *170.504=4.648 kW .
P= $\dot{m}W_c$
=0.02726 *19.179
= 0.5228 kW = 0.701086348 hp hp : horsepower [electric] .
Coefficient of performance (cop) = q_e / W = 151.315/19.179 = 7.889

7.1.3 Compressor selection

By Using BITZER-Software : compressor data sheet figure 7.9 & 7.10 below.

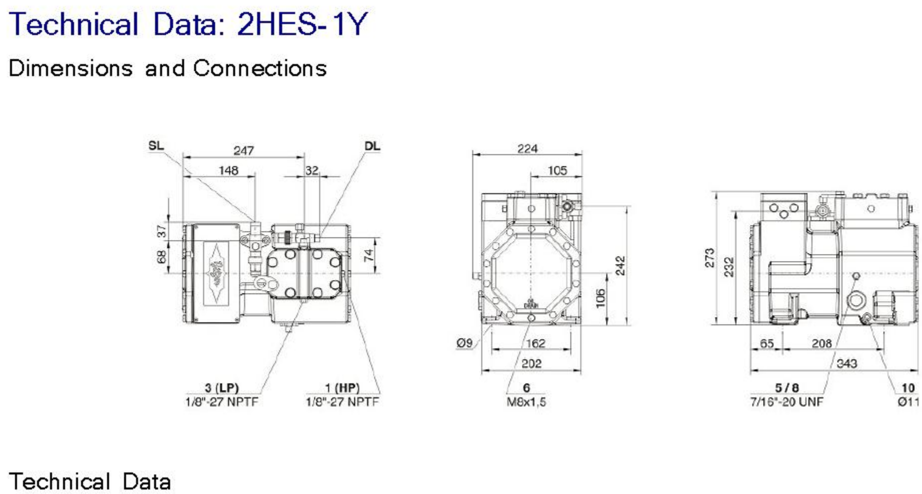
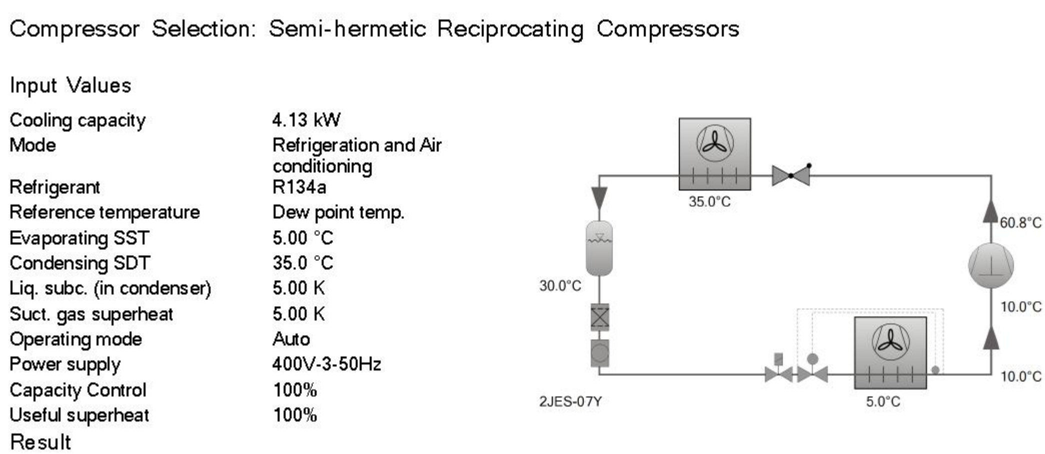


Figure 7.9: The cycle in the PH diagram


Compressor Selection: Semi-hermetic Reciprocating Compressors

Input Values

Cooling capacity	4.13 kW
Mode	Refrigeration and Air conditioning
Refrigerant	R134a
Reference temperature	Dew point temp.
Evaporating SST	5.00 °C
Condensing SDT	35.0 °C
Liq. subc. (in condenser)	5.00 K
Suct. gas superheat	5.00 K
Operating mode	Auto
Power supply	400V-3-50Hz
Capacity Control	100%
Useful superheat	100%

Result

Figure 7.10: The cycle in the PH diagram

For more about data sheet go to appendix B

7.1.4 Condensers selection

By Using BITZER-Software

Condenser data sheet figure 7.11 & 7.12 & 7.12 below.

Compressor Selection: Condensing Units

Input Values

Cooling capacity	4.13 kW
Series	Standard
Refrigerant	R134a
Reference temperature	Dew point temp.
Evaporating SST	5.00 °C
Ambient temp.	32.0 °C
Suction gas temperature	20.00 °C
Useful superheat	100%
Operating mode	Auto
Power supply	400V-3-50Hz
Capacity Control	100%

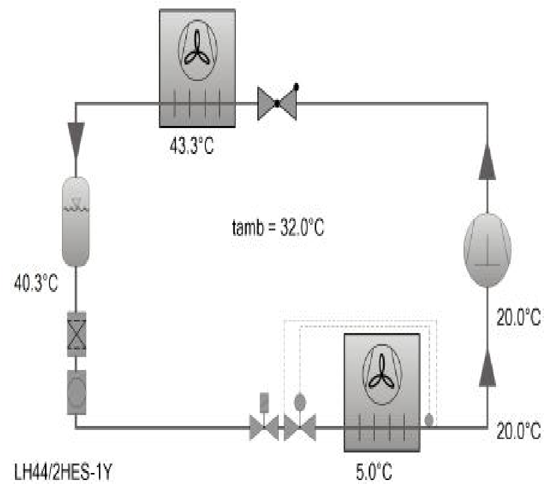


Figure 7.11: Condensing units.

Technical Data: LH44/2GES-2Y

Dimensions and Connections

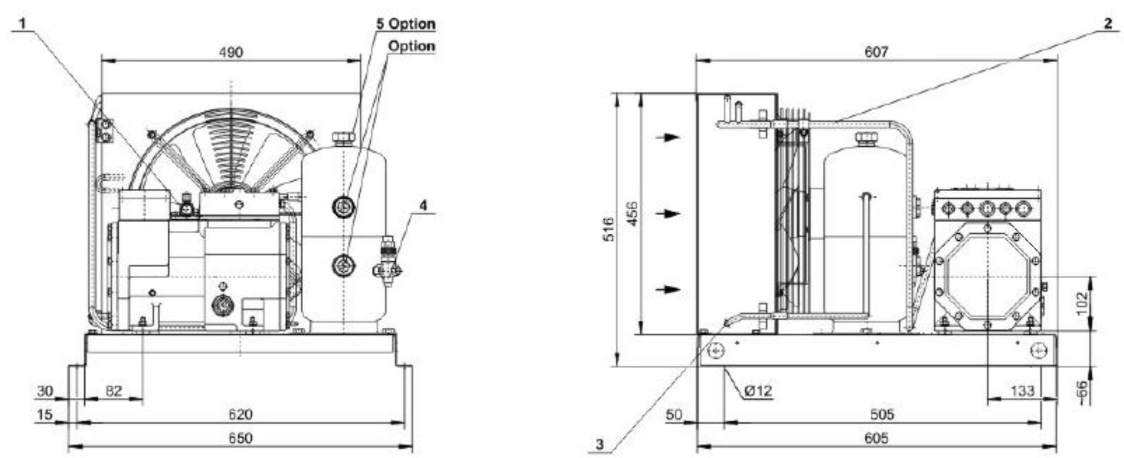


Figure 7.12: Technical data.

Technical Data

Technical Data	
Weight	81 kg
Total width	650 mm
Total depth	607 mm
Total height	516 mm
Connection suction line	16 mm - 5/8"
Connection liquid line	10 mm - 3/8"
	1
Voltage (more on request)	230V-1-50Hz (Standard)
Current / Power consumption of each fan	0,56 A / 125 W
Air flow condenser 50Hz	1840 m³/h
Voltage (more on request)	230V-1-60Hz (Standard)
Current / Power consumption of each fan	0,78 A / 175 W
Air flow condenser 60Hz	2070 m³/h
Coil Volume	2,5 dm3
Receiver type (Standard)	FS056
Max. refrigerant charge 90% at 20°C	
R22	6,1 kg
R134a	6,2 kg
R407C	5,8 kg
R404A/R507A	5,4 kg
Receiver type (Option)	FS076
R22	8,5 kg
R134a	8,6 kg
R407C	8,1 kg
R404A/R507A	7,5 kg
Extent of delivery (Standard)	
Discharge line	Standard
Protective charge	Standard
Available Options	
Oil separator	Option
Check valve	Option
High & low pressure switch	Option
Dressed unit	Option
Weather protective housing	Option
Fans: elect. Speed control	Option
Sound measurement	
Sound power level (-10°C / 45°C)	73,5 dB(A) @ 50Hz
Sound pressure level @ 1m (-10°C / 45°C)	65,5 dB(A) @ 50Hz
Data of compressors: see compressor program	

Figure 7.13: Technical data.

7.2 Cooling Load Calculation for freezer

Using this law to find Cooling Load Calculation:

$Q = UA\Delta T$ eg 6.1.

Q : Cooling Load in [kW] .

U : Overall heat transfer coefficient in $[W/m^2.^oC]$.

$U = \frac{1}{\frac{1}{h_i} + \Sigma\frac{\Delta x_i}{k_i} + \frac{1}{h_o}}$

h_{in} : is the Inside Convection Coefficient 9.37 $W/m^2.^oC$.

h_{out}: is the Outside Convection Coefficient 22.7 $W/m^2.^oC$.

K: is the thermal conductivity for material in $[W/m^oC]$.

ΔX: is the Thickness of the material in [m] .

A: Surface area in $[m^2]$.

A=Length * Width.

ΔT: The difference in temperature $[^oC]$.

1. External Wall:

   $\Delta T = T_{sur} - T_{in}$

   ΔT= 30–18=48

   $A_{ExternalWall_1} = 3.74 * 3.05 = 11.4m^2$.

$\dot{Q}_{ExternalWall_1}$ = 0.58 * 48 * 11.4 = 0.317 kW.

2. Internal Wall$_1$:

   $\Delta T = T_{Room} - T_{in}$

   = 28– -18 = 46 °C .

   A = $A_{InternalWall}$–A_{Door}

   = (4.44 * 3.05)

   = 13.54m^2.

   A =$A_{InternalWall} - A_{Door}$

   = (3.74 * 3.05) - 4

   = 7.4m^2 .

   $\dot{Q}_{InternalWall_1}$ = 0.575 * 46 * 20.94 = 0.584 kW .

3. Internal Wall$_2$:

   $\Delta T = T_{Room} - T_{in}$

   = 5– -18 = 23 °C .

   A = $A_{InternalWall_2}$

   = (4.44 * 3.05)

   = 13.54m^2.

   $\dot{Q}_{InternalWall_2}$ = 0.325 * 23 * 13.54 = 101W = 0.101 kW.

4. Ground :

   $\Delta T = T_{Ground} - T_{in}$

   = 5– -18 = 23 °C .

   A = A_{Ground}

   = (4.44 * 3.74)

   = 16.6m^2.

   $\dot{Q}_{Ground}$ = 0.399 * 23 * 16.6 = 0.153 kW .

5. Ceiling :

   $\Delta T = 28 - T_{in}$

   = 28- -18 = 46 °C .

   A = $A_{Ceiling}$

   = (4.44 * 3.74)

   = 16.6m^2.

   $\dot{Q}_{Ceiling}$ = 0.444 * 46 * 16.6 = 0.339 kW .

6. Door :

   $\Delta T = T_{Room} - T_{in}$

   = 28- -18 = 46 °C .

   A = A_{Door}

   = (2*2)

   = $4m^2$.

   $\dot{Q}_{Door}$ =0.631 * 46 * 4 = 0.116 kW .

Use this law to calculate cooling load for rooms:

$\dot{Q}_{Total} = \dot{Q}_{Envelope} + \dot{Q}_{Product} + \dot{Q}_{Air} + \dot{Q}_{Service} + \dot{Q}_{Respiration}$

For Refrigerator:

- $\dot{Q}_{Envelope}$ Calculation:

  $\dot{Q}_{Envelope}$: heat gain from walls, doors, windows, floor and ceiling.

  $\dot{Q}_{Envelope} = \dot{Q}_1 + \dot{Q}_{Solar}$.

  $\dot{Q} = \dot{Q}_{Wall} + \dot{Q}_{Door} + \dot{Q}_{Floor} + \dot{Q}_{Ceiling}$

  $\dot{Q}_{Solar} = 0$

  $\dot{Q}_{Envelope}$ = 0.685+0.47+0.339+0.116+0 = 1.61 kW .

- $\dot{Q}$ Product Calculation:

  $\dot{Q}_{Product} = \dot{Q}_2^{*} + \dot{Q}_2^{**} + \dot{Q}_{Packaging}$

  $\dot{Q}_2^{*} = \dot{m} cp \Delta T$.

  When:

  $\dot{m}$ = (m$_{Product}$ / Time Cooling)

  Time Cooling: Working Time Per a Day .

  $\Delta T = \Delta T_{sur} = 30^oC$.

  $\dot{Q}_2^{*}$ = 0.855 kW .

  $\dot{Q}_2^{**}$ =(m/time)*$\Delta h + (m/time) * cp * \Delta T$

  = (1000/11*3600)*47+ (1000/16*3600)*1.6*(0- -18)

  =1.18 kW +0.5 kW = 1.68 kW

  $\dot{Q}_{Packaging} = (m_{Material}/TimeCooling) * cp * \Delta T$

  Where: m $_{Material}$ = m * N .

  m : is the mass of one pallet = 15 kg .

  N: is the number of pallets in the room = 20.

  m $_{Material}$ = 15 * 20 = 300 kg .

  cp : is the Specific Heat for Pallet = 0.67 kJ/kg.K .

$\Delta T = \Delta T_{sur} = 30^oC.$

$\dot{Q}_{Packaging}$ = (300 / (4 * 16 * 3600)) * 0.67 * 30 = 0.105 kW .

$\dot{Q}_{Product}$ = 0.885+1.68+0.105 = 2.535 kW.

Table 7.8: product used.

Product	cp	m	$\dot{m}$	$\dot{Q}_2^*$
Beef	1.59	120	0.002083	0.099375
Chicken	1.63	120	0.002083	0.101875
Clams	1.51	40	0.000694	0.031458
Codfish	1.63	70	0.001215	0.059427
Halibut	1.67	80	0.001389	0.069583
Ice cream	1.67	30	0.000521	0.026094
lamp	1.55	50	0.000868	0.040365
Oysters	1.72	60	0.001042	0.05375
Reindeer	1.55	40	0.000694	0.032292
salmon	1.55	80	0.001389	0.064583
Sausage	1.34	100	0.001736	0.069792
sword fish	1.67	80	0.001389	0.069583
tripe	1.72	50	0.000868	0.044792
veal	1.59	50	0.000868	0.041406
white fish	1.63	60	0.001042	0.050938
Σ				1.653281

- $\dot{Q}_{Air}$ Calculation:

  $\dot{Q}_{Air} = \dot{Q}_{Infiltration} + \dot{Q}_{Ventilation}$

  $\dot{Q}_{Infiltration}$ = 0 kW.

  $\dot{Q}_{Ventilation} = \dot{Q}_{Product} + \dot{Q}_{People}$

  $\dot{Q}_{Product} = \dot{m} * (h_{out} – h_{in})$

  $\dot{Q}_{Product}$ = 1.293 * (72 – 10) = 80.16 W = 0.08 kW .

  $\dot{Q}_{People} = \dot{m} * (h_{out} – h_{in}) * (houroccupied/24) * a$

  $\dot{Q}_{People}$ = 6.66 * 10-3 * 55* (2/24) * 2

  $\dot{Q}_{People}$ = 0.061 W = 6.1 * 10-5 kW.

  $\dot{Q}_{Ventilation}$ = 0.08+ 6.1 * 10-5 = 0.08 kW.

  $\dot{Q}_{Air}$ = 0 + 0.08 = 0.08 kW.

- $\dot{Q}_{Service}$ Calculation:

  $\dot{Q}_{Service} = \dot{Q}_{People} + \dot{Q}_{Light}$.

  $\dot{Q}_{People} = n * \dot{Q}_{Person} * (Workinghours/24)$

  $\dot{Q}_{Person}$ = 0.275. [Table 10-14] .

$\dot{Q}_{People}$ = 2 * 0.275 * (2 / 24) = 0.046 kW .

$\dot{Q}_{Light}$ = P$_{Light}$ * CLF * N

$\dot{Q}_{Light}$= 24 W.

CLF: Cooling Load Factor of Lighting = 0.88 .

N: Number of Lights

N = 2

$\dot{Q}_{Light}$ = 24 * 0.88 * 2 = 42.24 W = 0.0422 kW

$\dot{Q}_{Service}$ = + 0.046 + 0.0422 = 0.088 KW .

- $\dot{Q}_{Respiration}$ Calculation:

  $\dot{Q}_{Respiration} = m * q_{Rips}$

  $\dot{Q}_{Respiration}$: is the rate of respiration .

  m : is the mass of the product in the room in [kg] .

  q_{Rips} Rate of heat given off Breathing product .

  q_{Rips} = 0.029 . [Table 10-12] .

  $\dot{Q}_{Respiration}$ = 0.029 * 1000 = 29 W = 0.029 kW .

  Consequently:

  $\dot{Q}_{Total}$ = 1.61 + 2.535+ 0.08 +0.088+ 0.029 = 4.35 kW .

  $\dot{Q}_{Total}$ =4.35 * F.S = 4.35 * 1.5 = 6.5 kW.

The following figure 7.15 for the cycle in PH diagram and the values of points in cycle figure 7.14 from Cool pack

Point	T	P	v	h	s
	[°C]	[bar]	[m^3/kg]	[kJ/kg]	[kJ/(kg K)]
1	-17.916	3.260	0.060907	357.822	1.6236
2	40.469	16.065	0.012189	389.924	1.6236
3	40.469	16.065	0.012189	389.924	1.6236
4	34.676	16.065	N/A	254.208	N/A
5	N/A	3.260	N/A	254.208	N/A
6	-17.916	3.260	0.060907	357.822	1.6236
15	N/A	16.065	N/A	254.208	N/A

Figure 7.14: The values of points in cycle.

$q_e = h_1 – h_5$
= 357.822 – 254.208 = 103.14 kJ/kg .
$q_c = h_2 – h_4$

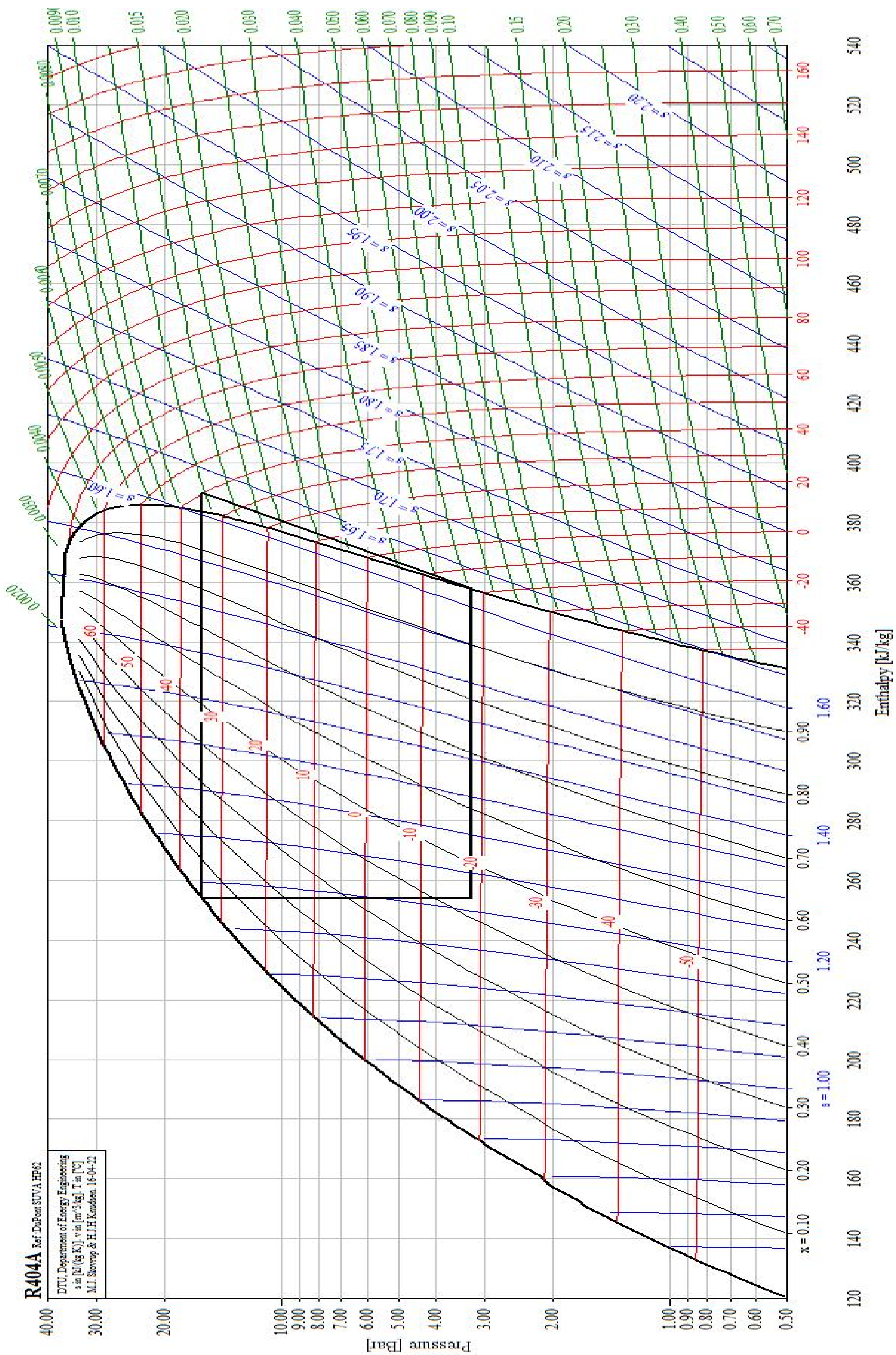


Figure 7.15: The cycle in the PH diagram

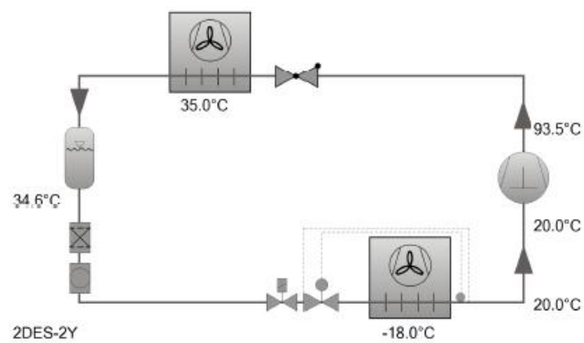
$q_c = 389.924 - 254.208 = 135.716$ kJ/kg .
$W_c = h_2 - h_1$
$W_c = 389.924 - 357.822 = 32.102$ kJ/kg .
$\dot{Q}_e = \dot{m}Rq_e$
$\dot{m}R = Q_e/q_e = 6.5/103.14 = 0.063 kg/s.$
$\dot{Q}_c = \dot{m}Rq_c$
$\dot{Q}_c$ =0.063 * 135.716=8.55 kW .
P= $\dot{m}W_c$
=0.063 * 32.102
= 2.02 kW = 2.7 hP hP : horsepower [electric] .
Coefficient of performance (cop) = q_e / W = 103.14/32.102 = 3.212

7.2.1 Compressor selection

By Using BITZER-Software : compressor data sheet figure 7.16 below.

Input Values

Cooling capacity	6.50 kW
Mode	Refrigeration and Air conditioning
Refrigerant	R404A
Reference temperature	Dew point temp.
Evaporating SST	-18.00 °C
Condensing SDT	35.0 °C
Liq. subc. (in condenser)	0 K
Suction gas temperature	20.00 °C
Operating mode	Auto
Power supply	400V-3-50Hz
Capacity Control	100%
Useful superheat	100%



Result

Compressor	2DES-2Y-40S	2CES-3Y-40S
Capacity steps	100%	100%
Cooling capacity	5.89 kW	7.30 kW
Cooling capacity *	5.89 kW	7.30 kW
Evaporator capacity	5.89 kW	7.30 kW
Power input	2.46 kW	3.01 kW
Current (400V)	4.52 A	5.73 A
Voltage range	380-420V	380-420V
Condenser Capacity	8.35 kW	10.32 kW
COP/EER	2.40	2.42
COP/EER *	2.40	2.42
Mass flow	153.0 kg/h	189.6 kg/h
Operating mode	Standard	Standard
Discharge gas temp. w/o cooling	93.5 °C	92.9 °C

Figure 7.16: The compressor data sheet

For more about data sheet go to appendix B

7.2.2 Condensers selection

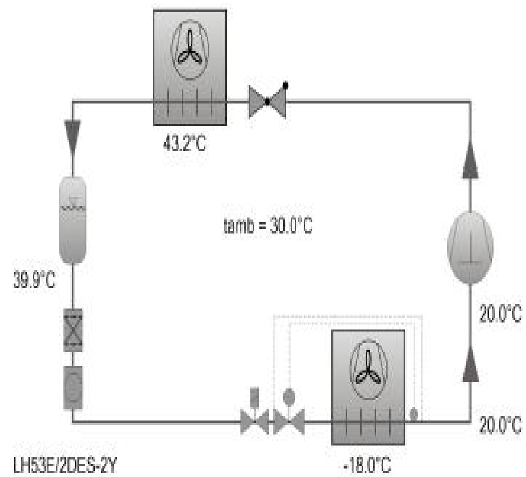
By Using BITZER-Software

Condenser data sheet figure 7.17 below.

Compressor Selection: Condensing Units

Input Values

Cooling capacity	6.50 kW
Series	Standard
Refrigerant	R404A
Reference temperature	Dew point temp.
Evaporating SST	-18.00 °C
Ambient temp.	30.0 °C
Suction gas temperature	20.00 °C
Useful superheat	100%
Operating mode	Auto
Power supply	400V-3-50Hz
Capacity Control	100%



Result

Unit type	LH53E/2DES- 2Y-40S	LH64E/2DES- 3Y-40S	LH64E/2CES- 3Y-40S	LH84E/2CES- 4Y-40S
Capacity steps	100%	100%	100%	100%
Cooling capacity	5.22 kW	5.62 kW	6.72 kW	7.11 kW
Evaporator capacity	5.22 kW	5.62 kW	6.72 kW	7.11 kW
Power input *	2.79 kW	2.88 kW	3.56 kW	3.43 kW
Current (400V)	4.74 A	5.09 A	5.98 A	5.95 A
Voltage range	380-420V	380-420V	380-420V	380-420V
Mass flow	144.5 kg/h	148.6 kg/h	182.3 kg/h	185.9 kg/h
Condensing SDT	43.2 °C	39.5 °C	41.6 °C	38.5 °C
Liquid subcooling	3.00 K	3.00 K	3.00 K	3.00 K
Operating mode	Standard	Standard	Standard	Standard

Figure 7.17: Condenser data sheet.

References

1. Ronald L.Howell, Principles of Heating Ventilating and Air Conditioning 6th edition, ASHRAE, USA, 2009.
2. Health Technical Memorandum,Medical gas pipeline systems The Design, installation, validation and verification, USA,2002.
3. M. A. A. M. Ashamed, Heating and Air Conditioning for Residential Buildings, National Library Department, Jordan, 2007.
4. J. F. Krieger, Handbook of Heating, Ventilation, and Air Conditioning, Boca Raton, CRC.Press LLC, Florida, 2001.
5. Mohammad A. Hammed, Heating and Air conditioning 3rd edition, Jordan, 1996.
6. Brain L.Olsen,Plumbing System 2nd edition,Missouri Group, USA, 1982.
7. Dennis Kubicki,FIRE PROTECTION DESIGN CRITERIA 3rd edition, Washington, D.C,1982.
8. $https://rcwapp.xyleminc.com/fp_{s}elect.asp$.
9. https://engineeringtoolbox.com .
10. $http://www.healthyheating.com/Definitions/Operative-temperature.htm.WHx-C1MrLIU.$
11. https://www.aspe.org/sites/default/files/webfm/ArchivedIssues/2006/20060102/ContinuingEdMed

Appendix (A)

Bill of Quantities

Table 7.9: Bill of quantities.

Item No.	Description	Unit	Qty.	Unit Rate
1.0	Mechanical works In the list of recommended makes, out of two or three makes mentioned in the list, only 1st. Make shall be preferred for use, unless otherwise specified in BOQ. However if non-availability or any other technical reason, the alternative make is allowed. This section shall be read in conjunction with general and particular mechanical technical specifications, mechanical drawings, addendums and invitation to bid conditions except where otherwise indicated. The unit price for all items in this section shall include supplying, installing, testing, and commissioning of mechanical works and materials, unless otherwise specifically mentioned or instructed by engineer. All civil and finishing works related to the concerned items shall be included in the unit price. Preparing of coordinated shop drawing and submitting to the approval of the supervision engineer, coordination with other activities, material storage, removing away from site the remnant of mechanical works and handling over the mechanical works to local mechanical auth. Flexible PVC suitable size conduits and adaptors to be used for connecting motors to power supply. Electrical cables up to mechanical equipment, to be supplied, installed connecting to mains side, testing and to be commissioned by electrical contractor, just cables termination to mechanical equipment to be carried on by mechanical contractor.			
1.1	Waste and drainage system			

Continued on next page

Table 7.9 – *Continued from previous page*

Item No.	Description	Unit	Qty.	Unit Rate
1.1.1	Vertical and horizontal UPVC pipe Supply, install UPVC pipes and fittings similar to (Royal) or E.A. 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.	Dia 2”	ML	180	
B.	Dia 4”	ML	250	
1.1.2	Floor trap and clean out Supply, installation, and commissioning of floor trap melding threaded (15*15) cm chrome plated cover UPVC red siphon (including junction box). And connected it with vertical pipes the price including rings fittings and whatever needed to complete the job as located on drawing specifications and approval of supervision engineer.			
A.	Floor trap size 4” diameter	No.	28	
B.	Floor drain size 4/2” diameter	No.	21	
C.	Clean outs 4” but with closed type cover, size (11*11) cm.	No.	40	
D.	Clean outs 6” but with closed type cover.	No.	2	
1.1.3	Supply, installation, and commissioning all pipes and fittings to and overflow storage tank in basement the price includes manhole inside boiler room and whatever needed to complete the job as located on drawing specifications and approval of supervision engineer.	Job	1	
1.1.4	Supply install and test UPC (UPA) or E.A. external drainage All rain pipes and fittings including connection excavation covering with layer 20 cm sand around the pipe and back filling as shown in drawings and specifications approval of supervisor engineer.			
A.	Size 6 inch diameter	ML	40	

Continued on next page

Table 7.9 – *Continued from previous page*

Item No.	Description	Unit	Qty.	Unit Rate
1.1.5	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.	2	
1.1.6	Supply and install concrete manholes of 15 cm thick walls and base with Medium duty concrete and frames of 8 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.	12	
B.	Size 80 cm (inside diameter)	No.	18	
C.	Size 100 cm (inside diameter)	No.	9	
1.1.7	Supply, install and test drain water and rain concrete channel with low carbon steel frame and mesh cover as shown in drawing and in accordance to specifications and approval engineers.			
A.	Width = 25 cm, h = 30 cm	No.	2	
B.	Ditto but with stainless steel frame and mesh cover.	No.	3	
1.1.8	HVAC Drain Piping Supply, install and test UPVC heavy class drain piping for SPLIT UNITS and Cassette type units for the following diameters of the pipes. The pipes shall be insulated with 6mm thick nitrile rubber and in accordance to specifications and approval engineers.			
A.	25 mm Rm	m	40	
B.	32 mm Rm	m	40	
1.2	Domestic hot and cold water system			

Continued on next page

Table 7.9 – *Continued from previous page*

Item No.	Description	Unit	Qty.	Unit Rate
1.2.1	Main water supply Supply and install galvanized steel main water pipes 2" with asphalt protection (factory covered) which will take from the main line of the city 2", with all necessary fitting e.g. elbow tee union stop valves non return valve and whatever needed to complete the job and all are of approved quality pipes are to be piped and laid underground through 4" PVC pipe from main supply to water storage tank, price shall include piping with all fitting, water meter, steel box excavation insulation with sand back filling disposal of remained excavated soil and charges for connection with main water supply all are according to PWA and approval of supervisor engineer.	L.S	1	
1.2.2	Supply and install galvanized pipes medium class for domestic cold water, hot water and hot water return, the work includes all fittings, valves, required flow direction signs, TOLGO type hangers, all required fittings, the prices includes vidoflex 13 mm for hot water pipes and hot water return.			
A.	Dia 3/4"	ML	110	
B.	Dia 1"	ML	60	
C.	Dia 11/4"	ML	40	
D.	Dia 11/2"	ML	20	
E.	Dia 2"	ML	35	

Continued on next page

Table 7.9 – *Continued from previous page*

Item No.	Description	Unit	Qty.	Unit Rate
1.2.3	Supply and install hot and water collectors type GIACOMINI or E.A. price include all the supplying and installing 16 mm PEX plastic pipes with its 22 mm plastic conduits to be connected from the copper collectors openings up to location of sanitary fixtures outlets according to plans and engineers instructions, with all required hangers (type GIACOMINI) and support, air vent, shut-off valves on the collectors outlets, shut- off valve each collector must have main valve at the entrance of the collector the price include metallic painted steel cabinet of approved quality, including cover with double doors for domestic water collectors. Job as located on drawing specification and approval of supervisor engineer.			
A.	Dia 3/4"	EYE	26	
2.0	HVAC System : Supply of new factory supplied air cooled Variable Refrigerant Flow System. Supply of variable Refrigerant Flow modular type air conditioning system complete with indoor & outdoor units with individual corded controller as per the following capaicties of the IDU and ODU.			
2.1	Outdoor Units Modular type outdoor units equipped with highly efficient scroll compressors with all inverter type compressor(s) only, special acryl precoated heat exchanger, low noise condenser fan, pre coated fin type heat exchangers. The outdoor and indoor units shall be integrated with special super wiring system with a central monitoring remote controller into one common wiring. All refnet piping system shall be imported. Refrigerant should be R410A. All structural frame work platforms required shall be of HVAC vendor as per site conditions.			
A.	48 HP	No.	1	

Continued on next page

Table 7.9 – *Continued from previous page*

Item No.	Description	Unit	Qty.	Unit Rate
B.	46 HP	No.	1	
C.	20 HP	No.	1	
2.2	Indoor Units for above mentioned outdoor unit			
2.2.1	Ceiling mounted four way air discharge cassette indoor units with compact cooling coil, electronic expansion valve and multi speed fan motor, The blower shall be dynamically balanced and designed for silent operation, the filters shall be Plasma and synthetic washable media type arranged for convenient cleaning and replacement, built in drain pump, the drain pan shall be fabricated out of heavy sheet steel insulated with 6mm expanded polyethylene sheet.			
A.	11.2 kW	No.	15	
B.	12.8 kW	No.	2	
C.	14 kW	No.	8	
2.2.2	High wall mounted units with plasma and synthetic washable filter.			
A.	5.6 kW	No.	17	
B.	7.1 17kW	No.	10	
2.3	Wired Remote controls for all the Hi-wall and Cassette type units which shall be sleek and self diagnostic type.	No.		
2.4	Simple Central Controller Unit capable of controlling all the Indoor and outdoor units	No.		
2.5	Refrigerant Piping Supply and installation of Refrigerant Copper piping insulated with Nitrile Rubber Tubular Insulation with covered with polyshield			
A.	54.1 mm with 19 mm thick insulation	M	120	
B.	41.3 mm with 19 mm thick insulation	M	120	
C.	34.9 mm with 19 mm thick insulation	M	70	
D.	28.6 mm with 19 mm thick insulation	M	70	
E.	25.4 mm with 19 mm thick insulation	M	65	
F.	22.2 mm with 13 mm thick insulation	M	65	
G.	19.1 mm with 13 mm thick insulation	M	35	
H.	15.9 mm with 10 mm thick insulation	M	45	
I.	12.7 mm with 10 mm thick insulation	M	160	

Continued on next page

Table 7.9 – *Continued from previous page*

Item No.	Description	Unit	Qty.	Unit Rate
J.	9.5 mm with 8 mm thick insulation	M	60	
K.	6.4 mm with 8 mm thick insulation	M	155	
2.6	Electrical Cabling Armoured copper cables from the isolator to the units at terrace. (Power Cable) (the size of the cabel to selected by the vendor as per the manufacturer standard and to be approved by the consulanat.	L.S		
2.7	Notes			
A.	All civil works pertaining to Air-conditioning like breaking, making, painting of walls, glass etc. as required as per site conditions.			
B.	Supply and installation all of the items mentioned in the previous must be in accordance to specifications and approval engineers.			
C.	Catalogues of all equipments shall be enclosed with Compressor rating charts.			
D.	Incoming Power supply near indoor unit will be provided by other agencies.			
E.	Taxes to be included in the price of equipments /accessories...			
3.2	fire extinguisher cylinder: Supply and install the CO_2 " 3kg" , HCFC "3kg",and Wet chemical "3kg".			
A.	CO_2 fire extinguisher cylinder	No	10	
B.	HCFC fire extinguisher cylinder	No	35	
C.	Wet fire extinguisher cylinder	No	3	

Appendix (B)

TABLE B - 1 : 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 B-2 Cooling load temperature differences (CLTD) for sunlit roofs, °C.

No.	Roof Description of Construction	U_{ov}, W/m²·°C	Solar Time, *h*																							
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
	Without Suspended Ceiling																									
1	Steel sheet with 25.4 mm (or 50.8 mm) insulation	1.209 (0.704)	0	−1	−2	−2	−3	−2	3	11	19	27	34	40	43	44	43	39	33	25	17	10	7	5	3	1
2	25 mm wood with 25.4 mm insulation	0.963	3	2	0	−1	−2	−2	−1	2	8	15	22	29	35	39	41	41	39	35	29	21	15	11	8	5
3	101.6 mm L.W. concrete	1.209	5	3	1	0	−1	−2	−2	1	5	11	18	25	31	36	39	40	40	37	32	25	19	14	10	7
4	50.8 mm H.W. concrete 25.4 mm (or 50.8 mm) insulation	1.170 (0.693)	7	5	3	2	0	−1	0	2	χ6	11	17	23	28	33	36	37	37	34	30	25	20	16	12	10
5	25.4 mm wood with 50.8 insulation	0.619	2	0	−2	−3	−4	−4	−4	−2	3	9	15	22	27	32	35	36	35	32	27	20	14	10	6	3
6	152.4 mm L.W. concrete	0.897	12	10	7	5	3	2	1	0	2	4	8	13	18	24	29	33	35	36	35	32	28	24	19	16
7	63.5 mm wood with 25.4 mm insulation	0.738	16	13	11	9	7	6	4	3	4	5	8	11	15	19	23	27	29	31	31	30	27	25	22	19
8	203.4 mm L.W. concrete	0.715	20	17	14	12	10	8	6	5	4	4	5	7	11	14	18	22	25	28	30	30	29	27	25	22
9	101.6 mm H.W. concrete with 25.4 mm (or 50.8 mm) insulation	1.136 (0.681)	14	12	10	8	7	5	4	4	6	8	11	15	18	22	25	28	29	30	29	27	24	21	19	16
10	63.5 mm wood with insulation	0.528	18	15	13	11	9	8	6	5	5	5	7	10	13	17	21	24	27	28	29	29	27	25	23	20
11	Roof terrace system	0.602	19	17	15	14	12	11	9	8	7	8	8	10	12	15	18	20	22	24	25	26	25	24	22	21
12	152.4 mm H.W. concrete with 25.4 mm (or 50.8 mm) insulation	0.664	18	16	14	12	11	10	9	8	8	9	10	12	15	17	20	22	24	25	25	25	24	22	20	19
13	101.6 mm wood with 25.4 mm (or 50.8 mm) insulation	0.602 (0.443)	21	20	18	17	15	14	13	11	10	9	9	9	10	12	14	16	18	20	22	23	24	24	23	22

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

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

TABLE B-4 Cooling load temperature differences (CLTD) for various construction groups of sunlit walls, °C.

North Latitude Wall Facing	Solar Time h: 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Hour of Max. CLTD	Min. CLTD	Max. CLTD	Difference CLTD
Group A Walls																												
N	8	8	8	7	7	7	7	6	6	6	6	6	6	6	6	6	6	6	7	7	7	7	8	8	2	6	8	2
NE	11	11	10	10	10	9	9	9	8	8	8	9	9	9	9	10	10	10	11	11	11	11	11	11	22	8	11	3
E	14	13	13	13	12	12	11	11	10	10	10	11	11	12	12	13	13	13	14	14	14	14	14	14	22	10	14	4
SE	13	13	13	12	12	11	11	10	10	10	10	10	10	11	11	12	12	13	13	13	13	13	13	13	22	10	13	3
S	11	11	11	11	10	10	9	9	9	8	8	8	8	8	8	8	9	9	10	10	11	11	11	11	23	8	11	3
SW	14	14	14	14	13	13	12	12	11	11	10	10	10	9	9	10	10	10	11	12	13	13	14	14	24	9	14	5
W	15	15	15	14	14	14	13	13	12	12	11	11	10	10	10	10	10	11	11	12	13	14	14	15	1	10	15	5
NW	12	12	11	11	11	11	10	10	10	9	9	8	8	8	8	8	8	8	9	9	10	11	11	11	1	8	12	4
Group B Walls																												
N	8	8	8	7	7	6	6	6	5	5	5	5	5	5	5	6	6	7	7	8	8	8	8	8	24	5	8	3
NE	11	10	10	9	9	8	7	7	7	7	8	8	9	9	10	10	11	11	11	12	12	12	11	11	21	7	12	5
E	13	13	12	11	10	10	9	8	8	9	9	10	12	13	13	14	14	15	15	15	15	15	14	14	20	8	15	7
SE	13	12	12	11	10	10	9	8	8	8	8	9	10	11	12	13	14	14	14	14	14	14	14	14	21	8	14	6
S	12	11	11	10	9	9	8	7	7	6	6	6	6	7	8	9	10	11	11	12	12	12	12	12	23	6	12	6
SW	15	15	14	13	13	12	11	10	9	9	8	8	7	7	8	9	10	11	13	14	15	15	16	16	24	7	16	9
W	16	16	15	14	14	13	12	11	10	9	9	8	8	8	8	8	9	11	12	14	15	16	16	17	24	8	17	9
NW	13	12	12	11	11	10	9	9	8	7	7	7	6	6	7	7	8	8	9	11	12	13	13	13	24	6	13	7
Group C Walls																												
N	9	8	7	7	6	5	5	4	4	4	4	4	5	5	6	6	7	8	9	9	9	10	9	9	22	4	10	6
NE	10	10	9	8	7	6	6	6	6	7	8	10	10	11	12	12	12	13	13	13	13	12	12	11	20	6	13	7
E	13	12	11	10	9	8	7	7	8	9	11	13	14	15	16	16	17	17	16	16	16	15	14	13	18	7	17	10
SE	13	12	11	10	9	8	7	6	7	7	9	10	12	14	15	16	16	16	16	16	16	15	14	13	19	6	16	10
S	12	11	10	9	8	7	6	6	5	5	5	5	6	8	9	11	12	13	14	14	14	14	13	12	20	5	14	9
SW	16	15	14	12	11	10	9	8	7	7	6	6	6	7	8	10	12	14	16	18	18	18	13	17	22	6	18	12
W	17	16	15	14	12	11	10	9	8	7	7	7	7	7	8	9	11	13	16	18	19	20	19	18	22	7	20	13

TABLE B-5: Description of wall construction groups.

Group No.	Description Of Construction	$U_{ov.}$ W/m²·°C
	101.6 mm Face Brick + (Brick)	
C	Air space + 101.6 mm face brick	2.033
D	101.6 mm common brick	2.356
C	25.4 mm insulation or air space + 101.6 mm common brick	0.987-1.709
B	50.6 mm insulation + 101.6 mm common brick	0.630
B	203.2 mm common brick	1.714
A	Insulation or air space + 203.2 mm common brick	0.874-1.379
	101.6 mm Face Brick + (H.W. Concrete)	
C	Air space + 50.8 mm concrete	1.987
B	50.8 mm insulation + 101.6 mm concrete	0.658
A	Air space or insulation + 203.2 mm or more concrete	0.625-0.636
	101.6 mm Face Brick + (L.W. or H.W Concrete Block)	
E	101.6 mm block	1.811
D	Air space or insulation + 101.60 mm block	0.868-1.397
D	203.2 mm block	1.555
C	Air space or 25.4 mm insulation + 152.4 mm or 203.2 mm block	1.255-1.561
B	50.8 insulation + 203.2 mm block	0.545-0.607
	101.6 mm Face Brick + (Clay Tile)	
D	101.6 mm tile	2.163
D	Air space + 101.6 mm tile	1.595
C	Insulation + 101.6 mm tile	0.959
C	203.2 mm tile	1.561
B	Air space or 25.4 mm insulation + 203.2 mm tile	0.806-1.255
A	50.8 mm insulation + 203.2 mm tile	0.551
	L.W. Concrete Wall + (Finish)	
E	101.5 mm concrete	3.321
D	101.6 mm concrete + 25.4 mm or 50.8 mm insulation	1.136 - 0.675
C	50.8 mm insulation+101.6 mm concrete	0.675
C	203.2 mm concrete	2.782
B	203.2 mm concrete + 25.4 mm or 50.8 mm insulation	1.061 - 0.653
A	203.2 mm concrete + 50.8 mm insulation	0.653
B	304.8 mm concrete	2.390
A	304.8 mm concrete + insulation	0.642
	L.W. and H.W. Concrete Block + (Finish)	
F	101.6 mm block + air space/insulation	0.914-1.493
E	50.8 mm insulation + 101.6 mm block	0.596-0.647
E	203.2 mm block	1.669-2.282
D	203.2 mm block + air space/insulation	0.846-0.982
	Clay Tile + (Finish)	
F	101.6 mm tile	2.379
F	101.6 mm tile +air space	1.720
F	101.6 mm tile + 25.4 mm insulation	0.993
D	80.8 mm insulation + 10.4 mm tile	0.825
C	203.3 mm tile + air space/25.4 mm insulation	0.857-1.312
B	50.8 mm insulation + 203.2 mm tile	0.562

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

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

TABLE B-7: 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 B-8 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 B-9: Shading coefficient (SC) for glass windows with interior shading.

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

Note: Shading coefficient SC, for other shading types and shading devices that are not included in Table 9–9 are as follows:

Dark venetian blinds	0.72
Canva awning	0.25
Roof overhang	0.25
Outside shading screen	0.30
Wood sash	0.85

TABLE B- 10 :

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 B-12:

Cooling load temperature differences (CLTD) for convection heat gain for glass windows.

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

TABLE B-16:

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

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

TABLE B-14: Cooling load factor (CLF)$_{LI}$, for lights.[3]

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

TABLE B-15: Diversity factor for selected applications.[4]

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

TABLE B-17: 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 B-18: 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 B-19: Values of the factor S_1 of Eq.(2.10)

№	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 B-20:. Values of the factor S_2 of Eq.(2.10)

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

TABLE B-21: Conversion of Fixture Units to Equivalent GPM

Demand (Load) Fixture Units	Demand (Load), gpm system with Flush Tanks	Demand (Load), gpm system with Flush Valves
1	0	-
2	1	-
3	3	-
4	4	-
5	6	-
10	8	27
20	14	35
30	20	41
40	25	47
50	29	52
60	32	55
70	35	59
80	38	62
90	41	65
100	44	68
140	53	78
180	61	87
200	65	92
250	75	101
300	85	110
400	105	126
500	125	142
750	170	178
1000	208	208
1250	240	240
1500	267	267
1750	294	294
2000	321	321
2500	375	375
3000	432	432
4000	525	525
5000	593	593
10000	769	769

TABLE B-22: 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	½
Bathtub	General	Faucet	4	½
Clothes washer	Private	Faucet	2	½
Clothes washer	General	Faucet	4	½
Combination fixture	Private	Faucet	3	½
Dishwasher[e]	Private	Automatic	1	½
Drinking fountain	Offices, etc.	Faucet ⅜ in.	0.25	⅜
Kitchen sink	Private	Faucet	2	½
Kitchen sink	General	Faucet	4	½
Laundry trays (1–3)	Private	Faucet	3	½
Lavatory	Private	Faucet	1	⅜
Lavatory	General	Faucet	2	½
Separate shower	Private	Mixing valve	2	½
Service sink	General	Faucet	3	½
Shower head	Private	Mixing valve	2	½
Shower head	General	Mixing valve	4	½
Urinal	General	Flushometer	5	¾[d]
Urinal	General	Flush tank	3	½
Water closet	Private	Flushometer	6	1
Water closet	Private	Flushometer/tank	3	½
Water closet	Private	Flush tank	3	½
Water closet	General	Flushometer	10	1
Water closet	General	Flushometer/tank	5	½
Water closet	General	Flush tank	5	½

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

TABLE B-23 : Required Minimum Flow Rates and Pressures during Flow for Fixtures

Fixture	Pressure, psi*	Flow, gpm
Basin faucet	8	3
Basin faucet, self-closing	12	2.5
Sink faucet, ⅜-in	10	4.5
Sink faucet, ½-in	5	4.5
Dishwasher	15–25	†
Bathtub faucet	5	6
Laundry tub cock, ¼-in	5	5
Shower	12	3–10
Water closet ball cock	15	3
Water closet flush valve	15–20	15–40
Urinal flush valve	15–20	15
Garden hose, 50 ft, and sill cock	30	5

*Residual pressure in pipe at entrance to fixture. 20 psi minimum required at water conserving type fixture. Verify minimum pressure reqirements with fixture manufacturer.

†As specified by fixture manufacturer.

Table B_25: Equivalent Length.

Equivalent Length of Straight Pipe for Valves and Fittings (meter)														
Flanged Fittings		Pipe Size												
		1/2	3/4	1	1 1/4	1 1/2	2	2 1/2	3	4	5	6	8	10
Elbows	Regular 90 deg	0.3	0.4	0.5	0.6	0.7	0.9	1.1	1.3	1.8	2.2	2.7	3.7	4.3
	Long radius 90 deg	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.3	1.5	1.7	2.1	2.4
	Regular 45 deg	0.1	0.2	0.2	0.3	0.4	0.5	0.6	0.8	1.1	1.4	1.7	2.3	2.7
Tees	Line flow	0.2	0.3	0.3	0.4	0.5	0.5	0.6	0.7	0.9	1.0	1.2	1.4	1.6
	Branch flow	0.6	0.8	1.0	1.3	1.6	2.0	2.3	2.9	3.7	4.6	5.5	7.3	9.2
Return Bends	Regular 180 deg	0.3	0.4	0.5	0.6	0.7	0.9	1.1	1.3	1.8	2.2	2.7	3.7	4.3
	Long radius 180 deg	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.3	1.5	1.7	2.1	2.4
Valves	Globe	11.6	12.2	13.7	16.5	18.0	21.4	23.5	28.7	36.6	45.8	58.0	79.3	94.6
	Gate	0.0	0.0	0.0	0.0	0.3	0.8	0.8	0.9	0.9	0.9	1.0	1.0	1.0
	Angle	4.6	4.6	5.2	5.5	5.5	6.4	6.7	8.5	11.6	15.3	19.2	27.5	36.6

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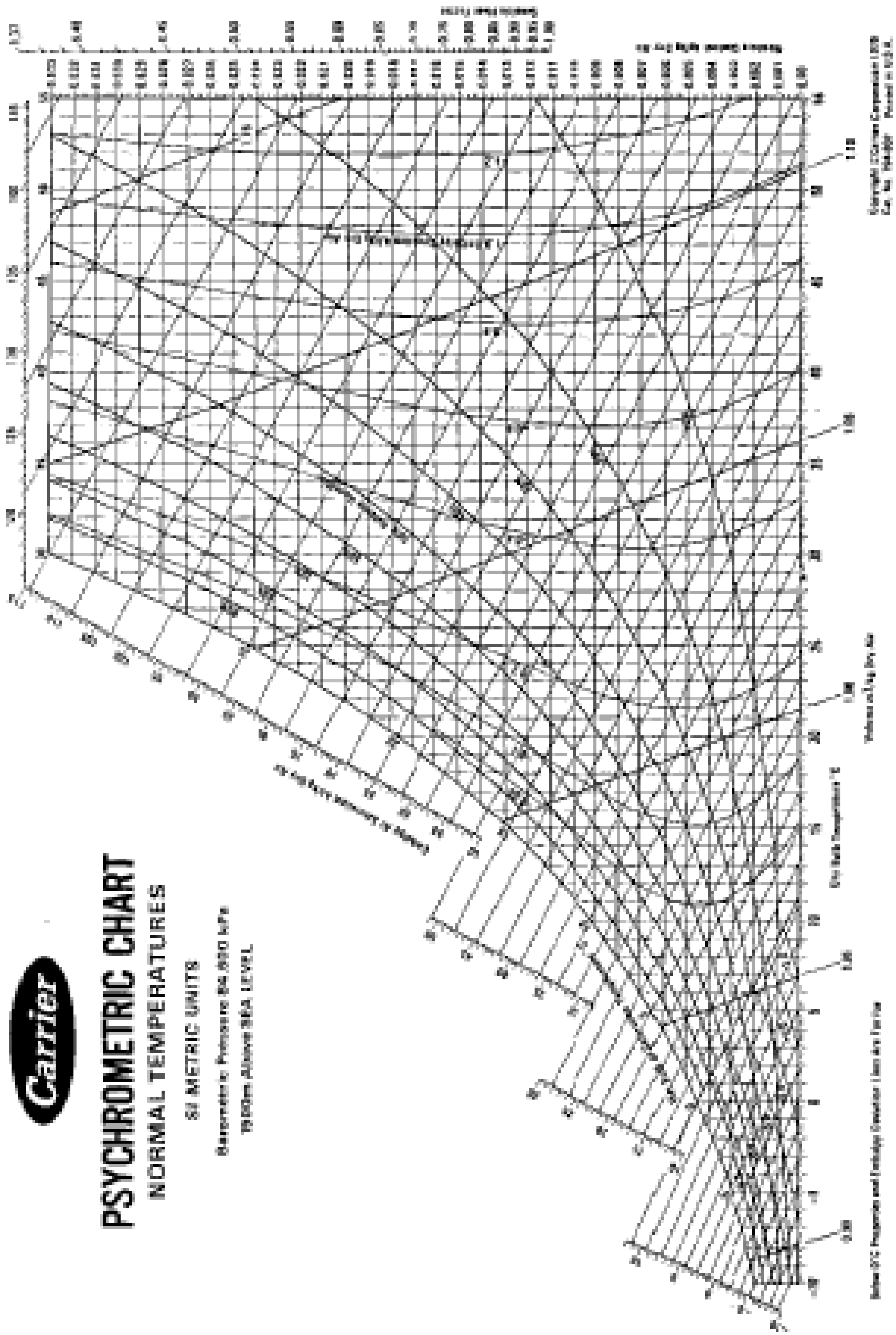
Table of A rating 1

Type	Size	A-Rating
Water	3ltr	13A
Water	6ltr	13-21A
Water	9ltr	13A
AFF Foam	3ltr	13A
AFF Foam	6ltr	21A
ABC Powder	2kg	13A
ABC Powder	4kg	21A
ABC Powder	6kg	34A
Wet Chemical	6ltr	13A

Typical examples of A-Ratings

.


Carrier
PSYCHROMETRIC CHART
NORMAL TEMPERATURES
SI METRIC UNITS

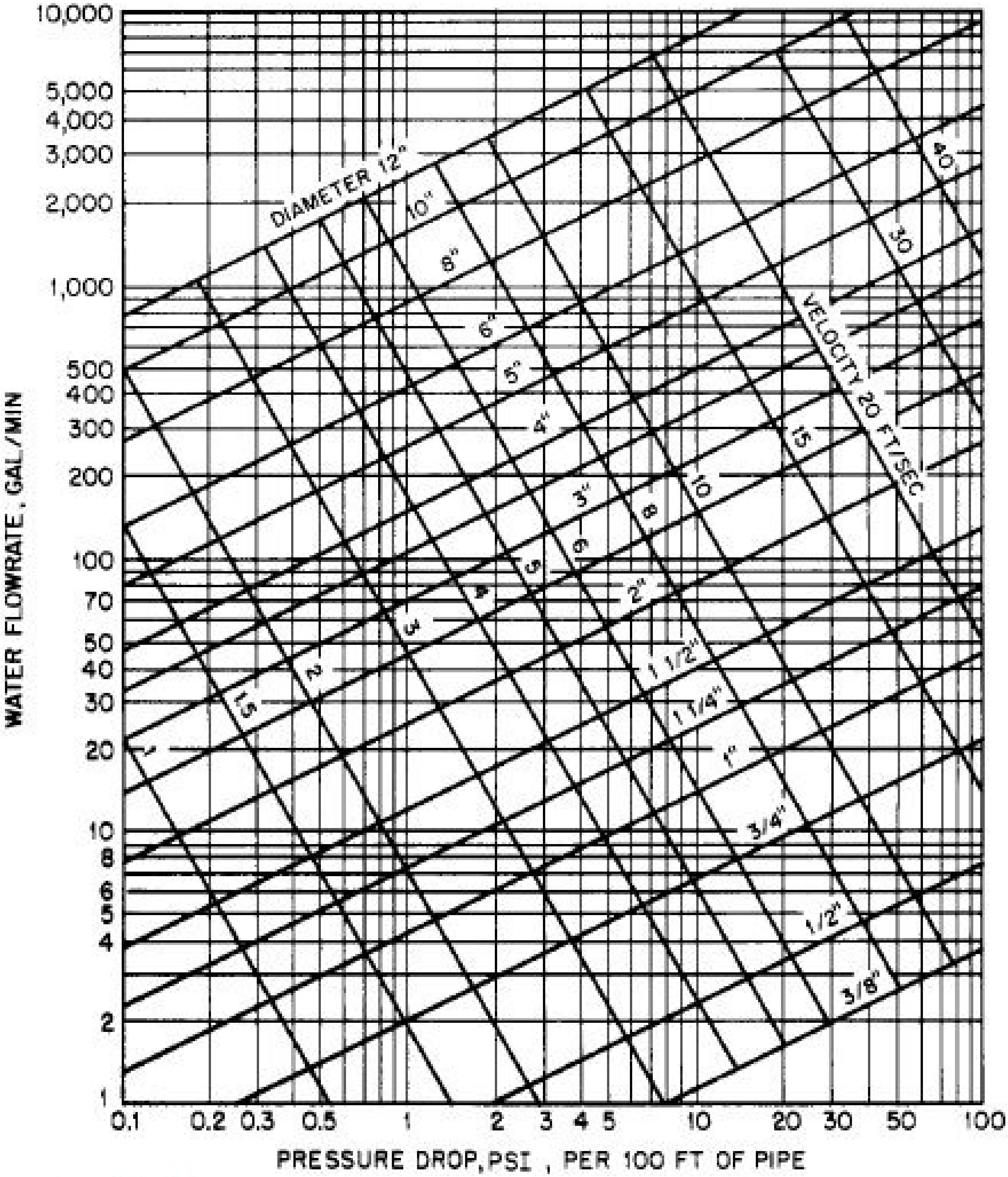


FIGURE B-24 Chart for determination of flow in pipes such as galvanized steel and wrought iron that will be fairly rough after 15 to 20 years of use.

درجات حرارة المنطقة الرابعة(س°)

الشهر	1	2	3	4	5	6	7	8	9	10	11	12
المتوسط الشهري	8.3	8.2	9.5	17.4	19.9	21.7	23.6	24	22.3	20.1	16	10.8
المتوسط الشهري للدرجة القصوى	11.2	11.8	13.6	20.8	25.3	27.5	29.3	30	27.4	21.2	19.3	13.7
المتوسط الشهري للدرجة الدنيا	5.3	4.7	5.4	13.9	14.5	15.8	17.9	18	17	15.9	12.6	7.9
المدى	5.9	7.2	8.3	6.9	10.8	11.7	11.4	12	10.4	8.3	6.7	5.8
الدرجة القصوى	14.3	19.7	19.7	34.1	33.2	33.2	35.8	36.1	36.1	32.9	28.6	25.3
الدرجة الدنيا	-2	1.2	-1.3	4.4	7	10.9	13.8	13.7	14.7	14	11.9	6.6

درجة الحرارة التصمية للمنطقة الرابعة.
صيفاً: 30 س°
شتاءً: 4.7 س°

قيم الرطوبة النسبية التصميمية (بالمائة)

	صيفاً		شتاءً	
	ادنى	اقصى	ادنى	اقصى
المنطقة الاولى	44	49	65.7	69.3
المنطقة الثانية	44	49	65.7	69.3
المنطقة الثالثة	55.5	61.9	68	69.7
المنطقة الرابعة	49.7	53.7	68	71.7
المنطقة الخامسة	61.5	65.2	65.9	73.7
المنطقة السادسة - غزة	75	77	62	69
المنطقة السابعة- غزة	55.5	61.9	68	69.7

TABLE (P-3) BUILDING DRAINS AND SEWERS

DIAMETER OF PIPE (inches)	MAXIMUM NUMBER OF DRAINAGE FIXTURE UNITS CONNECTED TO ANY PORTION OF THE BUILDING DRAIN OR THE BUILDING SEWER, INCLUDING BRANCHES OF THE BUILDING DRAIN[a]			
	Slope per foot			
	$^1/_{16}$ inch	$^1/_8$ inch	$^1/_4$ inch	$^1/_2$ inch
$1^1/_4$	—	—	1	1
$1^1/_2$	—	—	3	3
2	—	—	21	26
$2^1/_2$	—	—	24	31
3	—	36	42	50
4	—	180	216	250
5	—	390	480	575
6	—	700	840	1,000
8	1,400	1,600	1,920	2,300
10	2,500	2,900	3,500	4,200
12	3,900	4,600	5,600	6,700
15	7,000	8,300	10,000	12,000

For SI: 1 inch = 25.4 mm, 1 inch per foot = 83.3 mm/m.
a. The minimum size of any building drain serving a water closet shall be 3 inches.

HORIZONTAL FIXTURE BRANCHES AND STACKS[a]

DIAMETER OF PIPE (inches)	MAXIMUM NUMBER OF DRAINAGE FIXTURE UNITS (dfu)			
	Total for horizontal branch	Stacks[b]		
		Total discharge into one branch interval	Total for stack of three branch Intervals or less	Total for stack greater than three branch intervals
$1^1/_2$	3	2	4	8
2	6	6	10	24
$2^1/_2$	12	9	20	42
3	20	20	48	72
4	160	90	240	500
5	360	200	540	1,100
6	620	350	960	1,900
8	1,400	600	2,200	3,600
10	2,500	1,000	3,800	5,600
12	3,900	1,500	6,000	8,400

CO_2 EXTINGUISHERS

APPROVED MODELS

MODEL	CAPACITY	FIRE RATING
CD2S	2 kg	34 B
CD2SZ	2 kg	55 B
CD2Gi	2 kg	21 B
CD5Gi	5 kg	55 B

STANDARD MODELS

MODEL	CAPACITY	TYPE	DESCRIPTION
CD 2-6	2 kg	Portable	Stored Pressure
CD 5-L	5 Lbs	Portable	Stored Pressure
CD 10-L	10 Lbs	Portable	Stored Pressure
CD 5-6	5 kg	Portable	Stored Pressure
CD 6-6	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

Page 6 | Extinguishers

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Applications

WB & 2WB Series of stainless steel pumps are designed for general purpose WB with single impeller and 2WB with twin impellers. They are suitable for domestic, commercial and industrial service. The applications include:

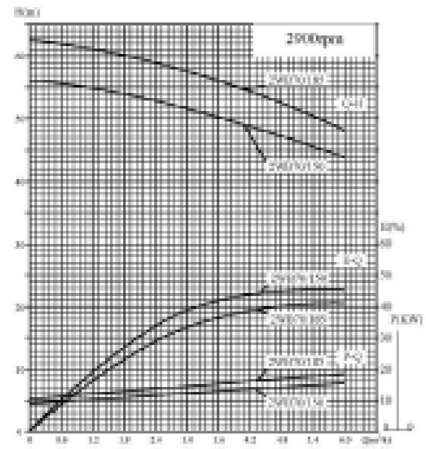
- water transfer;
- water supply;
- water circulation;
- pressure systems;
- irrigation.

FEATURES

- Back-pull-out design;
- All wet components in 304 stainless steel;
- Hard face mechanical seal as standard;
- Impeller type: Closed;

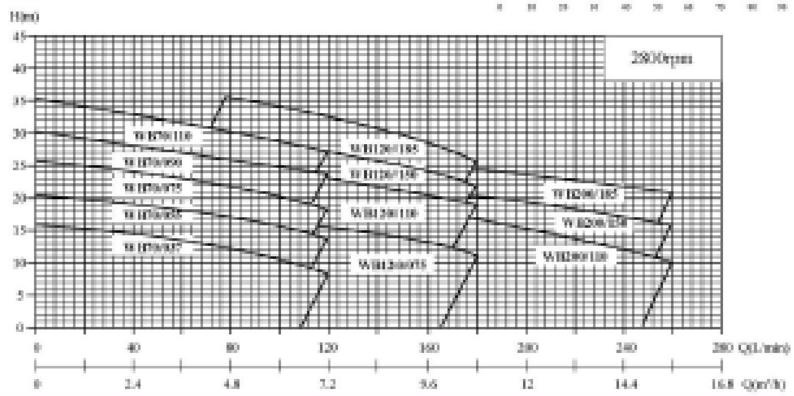
Technical Data

- Liquid: clean water or non-aggressive liquids compatible with AISI 304 stainless steel;
- Max. working pressure: 8 bar for WB, 10 bar for 2WB
- Flows up to 16 m³/h;
- Heads up to 62m;
- Liquid temperature: -15℃ to +80℃;
- IP55 TEFC motor standard;
- F class insulation;
- Continuously rated;
- Suction Size: 1-1/4 & 1-1/2 inch;
- Discharge Size: 1";
- Motor Power: 0.37-1.85 KW



Range Chart

Refer to individual curvse for final selection.

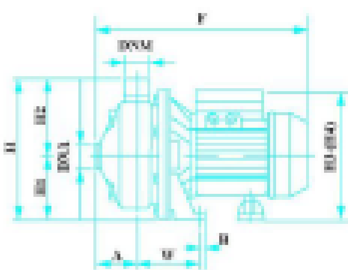


Performance Data

Water test temperature: 20℃. Performance limits: ISO2548. Specifications for standard class C Pump.

3 phase / 1 phase	Power			Capacity												
			L/min	20	40	60	80	100	120	140	160	180	200	220	240	260
			m³/h	1.2	2.4	3.6	4.8	6.0	7.2	8.4	9.6	10.8	12	13.2	14.4	15.6
	Kw	Hp	Head (m)													
WB70/037	0.37	0.5		15.5	14.5	13.5	12.5	11.5	10	13.5	12.2	11	15	13	11.5	9
WB70/055	0.55	0.75		19	18	17	16	15	13.5	21	19.5	18	19.5	18	16.5	15
WB70/075	0.75	1.0		25	23.5	22.5	21.5	20	18.5	25	23.5	21	24	23	22	21
WB70/090	0.90	1.2		29	28	27	25.5	24	22.5	29.5	28	25				
WB70/110	1.10	1.5		33	32	31	29.5	28.5	26.5	18	17	16				
WB120/075	0.75	1.0			18.3	17.5	16.7	15.8	14.8	22.3	21.5	20.5				
WB120/110	1.10	1.5			26	25	24	23	22	26.5	25.5	24.5				
WB120/150	1.50	32.0			31	30	29	28	26.5							
WB120/185	1.85	2.5			36.5	35.5	34	33	31.5							
WB200/110	1.10	1.5				21	20.5	20	19							
WB200/150	1.50	2.0				25	24.5	24	23							
WB200/185	1.85	2.5				28.5	28	27.5	27							
2WB70/150	1.50	2.0		54	52	50	47	43								
2WB70/185	1.85	2.5		61	58	56	52	48								

Dimensions



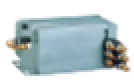
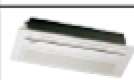
Model 3 Phase / 1 Phase	Dimensions (mm)																Weight kg
	A	C	F	H	H1	H2	*H3	*H4	M	N	N1	S	W	B	DNA	DNM	
WB70/037	52	213	315	232	108	124	241	213	39	120	158	9	92	13	G1"1/4	G1"	8.1
WB70/055	52	213	315	232	108	124	241	213	39	120	158	9	92	13	G1"1/4	G1"	8.8
WB70/075	52	213	315	232	108	124	241	213	39	120	158	9	92	13	G1"1/4	G1"	10
WB70/090	52	213	315	232	108	124	241	213	39	120	158	9	92	13	G1"1/4	G1"	11
WB70/110	52	235	386	252	120	132	234	234	39	140	180	9	94	13	G1"1/4	G1"	14.6
WB120/075	52	213	315	232	108	124	240	213	39	120	158	9	92	13	G1"1/4	G1"	10
WB120/110	52	213	370	232	108	124	224	224	39	120	158	9	92	13	G1"1/4	G1"	11.6
WB120/150	52	235	386	252	120	132	234	234	39	120	180	9	94	13	G1"1/4	G1"	15.8
WB120/185	52	235	386	252	120	132	234	234	39	120	180	9	94	13	G1"1/4	G1"	17
WB200/110	52	213	370	232	108	124	224	224	39	120	158	9	92	13	G1"1/4	G1"	11.6
WB200/150	52	213	370	232	108	124	224	224	39	120	158	9	92	13	G1"1/4	G1"	15
WB200/185	52	213	370	232	108	124	224	224	39	120	158	9	92	13	G1"1/4	G1"	16
2WB70/150	87	235	416	252	120	132	234	234	39	140	180	9	94	13	G1"1/4	G1"	17.8
2WB70/185	87	235	416	252	120	132	234	234	39	140	180	9	94	13	G1"1/4	G1"	19.6

H3 for motors on single phase

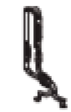
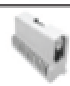
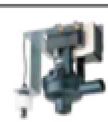
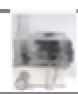
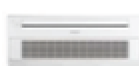
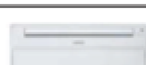
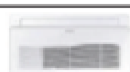
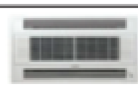
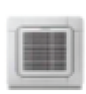
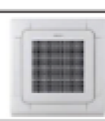
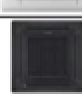
H4 for motors on three phase

The specifications may change without notice.

2-2-3 Accessory

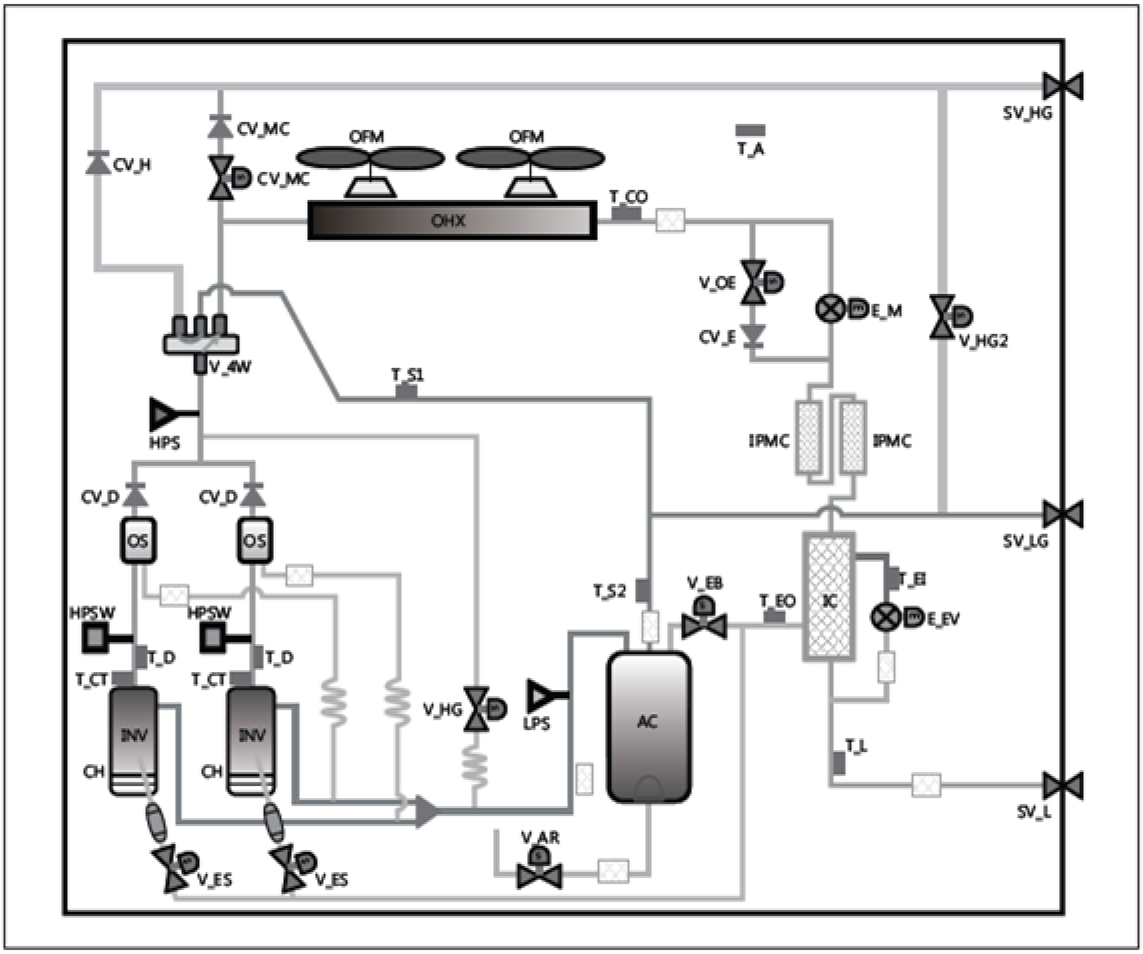
Classification		Model	Relevant Product Group	Description	Option class
Refnet Joint		MXJ-YA1509A MXJ-YA2212A MXJ-YA2512A MXJ-YA2815A MXJ-YA3119A MXJ-YA3819A	Outdoor Unit	Including Liquid pipe, Gas pipe, Insulating materials	Requisite
Refnet header		MXJ-HA2512A MXJ-HA3115A MXJ-HA3819A	Outdoor Unit	Including Liquid pipe, Gas pipe, Insulating materials	Option
Outdoor unit connection pipe		MXJ-T3819A	Outdoor unit	Liquid pipe, Gas pipe	Option
Distributor kit		MXD-A13K116	Wall-mounted, Ceiling	Below 4.0kW(1 room)+5.2kW~9.0kW(1 room)	Option
		MXD-A13K200		Below 4.0kW(2 rooms)	
		MXD-A16K200		5.2kW~9.0kW(2 rooms)	
		MXD-A22K200		5.2kW~7.2kW(2 rooms)	
		MXD-A13K216		Below 4.0kW(2 rooms) + 5.2kW~9.0kW(1 room)	
		MXD-A13K300		Below 4.0kW(3 rooms)	
		MXD-A16K213		Below 4.0kW(1 room)+5.2kW~9.0kW(2 rooms)	
		MXD-A16K300		5.2kW ~ 9.0kW(3 rooms)	
Drain Pump		MDP-E075SEE	Duct type (Slim)	750mm drain up	Option
		MDP-075SA	Duct type (Low pressure)		
		MDP-075SB	Duct type (High pressure)		
		MDP-H075SA	Duct type (Built-in)		
Front Panel		MGKH181M1	1 way cassette	Cooling / Cooling & Heating	Requisite
		MGGH1031M1	2 way cassette		
		MGCH0951M3	4 way cassette		

Accessory

Product	Image	Model	Remark
PDM KIT		MXD-A38K2A	8~12HP
		MXD-A12K2A	14~16HP
		MXD-A58K2A	18~26HP
S-Plasma Ion KIT		MSD-CAN1	4Way Cassette S 4Way Cassette S(600x600)
		MSD-EAN1	ERV-Plus
Motion detect Sensor		MCR-SMA	4Way Cassette S (600x600)
ERV CO2 Sensor		MOS-C1	ERV, ERV PLUS
Drain Pump		MDP-N047SNC0D	OAP Duct (14.0 kW)
		MDP-N047SNC1D	HSP Duct (22.0 / 28.0 kW) OAP Duct (22.4 / 28.0 kW)
		MDP-M075SGU1D	MSP Duct (9.0 / 11.2 kW)
		MDP-M075SGU2D	MSP Duct (12.8 / 14.0 kW) HSP Duct (11.2 / 12.8 / 14.0 kW)
		MDP-M075SGU3D	MSP Duct (5.6 / 7.1 kW)
		MDP-E075SEE3D	Slim Duct (2.0~14.0 kW)
		MDP-G075SP	Duct S (External, All Capacities)
		MDP-G075SQ	Duct S (Internal, 3.5 kW~14 kW)
Panel		PC1NUSMAN	Slim 1Way Cassette
		PC1NUPMAN	Slim 1Way Cassette (Z-sliding)
		PC1MWSKAN	1Way Cassette (1.7 kW, 2.2 kW)
		PC2NUSMEN	2Way cassette
		PC4SUSMAN	4Way Cassette S(600x600) (Waffle)
		PC4SUSMEN	4Way Cassette S(600x600) (Classic)
		PC4NUSKAN	4 Way cassette S (Waffle)
		PC4NUSKEN	4 Way cassette S (Classic)
		PC4NBSKAN	4 Way cassette S (Waffle, Black)

System Model			Outdoor Unit Selection									
Capacity	System Model Code	Number of Modules	8HP AM080JXVHGH/EU	10HP AM100JXVHGH/EU	12HP AM120JXVHGH/EU	14HP AM140JXVHGH/EU	16HP AM160JXVHGH/EU	18HP AM180JXVHGH/EU	20HP AM200JXVHGH/EU	22HP AM220JXVHGH/EU	24HP AM240HXVAGH/EU	26HP AM260HXVAGH/EU
8HP	-	1	1									
10HP	-	1		1								
12HP	-	1			1							
14HP	-	1				1						
16HP	-	1					1					
18HP	-	1						1				
20HP	-	1							1			
22HP	-	1								1		
24HP	-	1									1	
26HP	-	1										1
24HP*	AM240JXVHGH1EU*	2			2							
26HP*	AM260JXVHGH1EU*	2			1	1						
28HP	AM280JXVHGH1EU	2			1		1					
30HP	AM300JXVHGH1EU	2			1			1				
32HP	AM320JXVHGH1EU	2			1				1			
34HP	AM340JXVHGH1EU	2			1					1		
36HP	AM360JXVHGH1EU	2				1				1		
38HP	AM380JXVHGH1EU	2					1			1		
40HP	AM400JXVHGH1EU	2				1						1
40HP*	AM400JXVHGH1EU*	2							2			
42HP	AM420JXVHGH1EU	2							1	1		
44HP	AM440JXVHGH1EU	2								2		
46HP	AM460JXVHGH1EU	3			2					1		
48HP	AM480JXVHGH1EU	3			1	1				1		
50HP	AM500JXVHGH1EU	3			1		1			1		
52HP	AM520JXVHGH1EU	3			1			1		1		
54HP	AM540JXVHGH1EU	3			1				1	1		
56HP	AM560JXVHGH1EU	3			1					2		
58HP	AM580JXVHGH1EU	3				1				2		
60HP	AM600JXVHGH1EU	3					1			2		
62HP	AM620JXVHGH1EU	3							2	1		
64HP	AM640JXVHGH1EU	3							1	2		
66HP	AM660JXVHGH1EU	3								3		
68HP	AM680JXVHGH1EU	4			2					2		
70HP	AM700JXVHGH1EU	4			1	1				2		
72HP	AM720JXVHGH1EU	4			1		1			2		
74HP	AM740JXVHGH1EU	4			1			1		2		
76HP	AM760JXVHGH1EU	4			1				1	2		
78HP	AM780JXVHGH1EU	4			1					3		
80HP	AM800JXVHGH1EU	4				1				3		

8 Cycle diagram



Classification	Description
INV	Inverter Compressor
OFM	Outdoor Fan Motor
OHX	Outdoor Heat Exchanger
AC	Accumulator
OS	Oil Separator
IC	Intercooler
IPMC	IPM Cooler
CH	Crank Case Heater
HPS	High Pressure Sensor
LPS	Low Pressure Sensor
HPSW	High Pressure Switch
E_M	Main EEV
E_EV	EVI EEV
V_MC	Main Cooling Valve
V_ES	EVI Solenoid Valve
V_EB	EVI Bypass Valve
V_HG1	Hot Gas Bypass Valve 1
V_HG2	Hot Gas Bypass Valve 2

Classification	Description
V_4W	4Way Valve
V_AR	Accumulator Oil Return Valve
V_OE	Outdoor EEV Valve
CV_E	EEV Bypass Check Valve
CV_D	Discharge Check Valve
CV_H	HR Check valve
CV_MC	Main Cooling Check Valve
T_D	Discharge Temp. Sensor
T_S1	Suction Temp. Sensor 1
T_S2	Suction Temp. Sensor 2
T_CO	Cond Out Temp. Sensor
T_EI	EVI In Temp. Sensor
T_EO	EVI Out Temp. Sensor
T_L	Liquid Tube Temp. Sensor
T_CT	Comp. Top Temp. Sensor
T_A	Ambient Temp. Sensor
SV_HG	Low Gas Pipe Service Valve
SV_LG	Ambient Temp. Sensor
SV_L	Liquid Pipe Service Valve

Indoor Unit (cont.)

■ 4 way cassette type

Model				AVXC4H056E*	AVXC4H071E*	AVXC4H112E*	AVXC4H128E*	AVXC4H140E*
Power supply			ø, V, Hz	1, 220~240, 50				
Remark				Heat pump				
Performance	Capacity	Cooling*1)	Btu/h	19,100	24,300	38,000	44,000	48,000
			kW	5.6	7.1	11.2	12.8	14.0
		Heating*2)	Btu/h	21,500	27,300	43,000	47,000	54,000
			kW	6.3	8.0	12.5	13.8	16.0
	Sound Level*3)		dB	38/35	40/37	44/41	46/43	47/44
Power	Fan motors	Model	-	OSME-186SAC(S032)	OSME-186SAC(S032)	OSME-856SAC(S816)	OSME-856SAC(S816)	OSME-856SAC(S816)
		Type	-	Turbo fan	Turbo fan	Cross fan	Cross fan	Cross fan
		Output	W	26	26	58	72	85
		Air flow rate(Cool/Heat)	m³/min	16.0/18.1	16.0/18.1	26.1/28.4	28.3/30.9	28.9/32.3
	Running current	-	A	0.5	0.5	0.71	0.73	0.78
	Power Input	-	W	110	110	160	164	172
Refrigerant Control				EEV(Electronic Expansion Valve)				
Piping connections		Liquid(Flare)	mm	6.35	9.52	9.52	9.52	9.52
		Gas(Flare)	mm	12.7	15.88	15.88	15.88	15.88
		Drain	mm	VP 25, external diameter 32, internal diameter 25				
Set Size	Net weight		kg	26	26	29.5	29.5	29.5
	Shipping weight		kg	31	31	35.5	35.5	35.5
	Net dimension (WxHxD)		mm	840x230x840	840x230x840	840x298x840	840x298x840	840x298x840
	Shipping dimension(WxHxD)		mm	939x324x923	939x324x923	939x382x923	939x382x923	939x382x923
Panel Size	Net weight		kg	4.9	4.9	4.9	4.9	4.9
	Shipping weight		kg	10	10	10	10	10
	Net dimension (WxHxD)		mm	950x42x950	950x42x950	950x42x950	950x42x950	950x42x950
	Shipping dimension (WxHxD)		mm	1,067x134x1,067	1,067x134x1,067	1,067x134x1,067	1,067x134x1,067	1,067x134x1,067
Function / Option	Auto restart		Yes/No	Yes	Yes	Yes	Yes	Yes
	Auto change over		Yes/No	No	No	No	No	No
	Centralized controller (On/Off)		Yes/No	Yes(Option)	Yes(Option)	Yes(Option)	Yes(Option)	Yes(Option)
	Group/Individual control for R/C		Yes/No	Yes(Option)	Yes(Option)	Yes(Option)	Yes(Option)	Yes(Option)
	Troubleshooting by L.E.D		Yes/No	Yes	Yes	Yes	Yes	Yes
	Auto swing (Up/Down)		Yes/No	Yes	Yes	Yes	Yes	Yes
	Max. installation ceiling height		mm	255	255	315	315	315
	Drain pump		Yes/No	Yes	Yes	Yes	Yes	Yes

Indoor Unit (cont.)

■ 4 way cassette type

Model				AVXC4H056E*	AVXC4H071E*	AVXC4H112E*	AVXC4H128E*	AVXC4H140E*
Power supply			ø, V, Hz	1, 220-240, 50				
Remark				Heat pump				
Performance	Capacity	Cooling*1	Btu/h	19,100	24,300	38,000	44,000	48,000
			kW	5.6	7.1	11.2	12.8	14.0
		Heating*2	Btu/h	21,500	27,300	43,000	47,000	54,000
			kW	6.3	8.0	12.5	13.8	16.0
	Sound Level*3		dB	38/35	40/37	44/41	46/43	47/44
Power	Fan motors	Model	-	OSME-186SAC(S032)	OSME-186SAC(S032)	OSME-856SAC(S816)	OSME-856SAC(S816)	OSME-856SAC(S816)
		Type	-	Turbo fan	Turbo fan	Cross fan	Cross fan	Cross fan
		Output	W	26	26	58	72	85
		Air flow rate(Cool/Heat)	m³/min	16.0/18.1	16.0/18.1	26.1/28.4	28.3/30.9	28.9/32.3
	Running current	-	A	0.5	0.5	0.71	0.73	0.78
	Power input	-	W	110	110	160	164	172
Refrigerant Control				EEV(Electronic Expansion Valve)				
Piping connections		Liquid(Flare)	mm	6.35	9.52	9.52	9.52	9.52
		Gas(Flare)	mm	12.7	15.88	15.88	15.88	15.88
		Drain	mm	VP 25, external diameter 32, internal diameter 25				
Set Size	Net weight		kg	26	26	29.5	29.5	29.5
	Shipping weight		kg	31	31	35.5	35.5	35.5
	Net dimension (WxHxD)		mm	840x230x840	840x230x840	840x288x840	840x288x840	840x288x840
	Shipping dimension(WxHxD)		mm	939x324x923	939x324x923	939x382x923	939x382x923	939x382x923
Panel Size	Net weight		kg	4.9	4.9	4.9	4.9	4.9
	Shipping weight		kg	10	10	10	10	10
	Net dimension (WxHxD)		mm	950x42x950	950x42x950	950x42x950	950x42x950	950x42x950
	Shipping dimension (WxHxD)		mm	1,067x134x1,067	1,067x134x1,067	1,067x134x1,067	1,067x134x1,067	1,067x134x1,067
Function / Option	Auto restart		Yes/No	Yes	Yes	Yes	Yes	Yes
	Auto change over		Yes/No	No	No	No	No	No
	Centralized controller (On/Off)		Yes/No	Yes(Option)	Yes(Option)	Yes(Option)	Yes(Option)	Yes(Option)
	Group/Individual control for R/C		Yes/No	Yes(Option)	Yes(Option)	Yes(Option)	Yes(Option)	Yes(Option)
	Troubleshooting by L.E.D		Yes/No	Yes	Yes	Yes	Yes	Yes
	Auto swing (Up/Down)		Yes/No	Yes	Yes	Yes	Yes	Yes
	Max. installation ceiling height		mm	255	255	315	315	315
	Drain pump		Yes/No	Yes	Yes	Yes	Yes	Yes

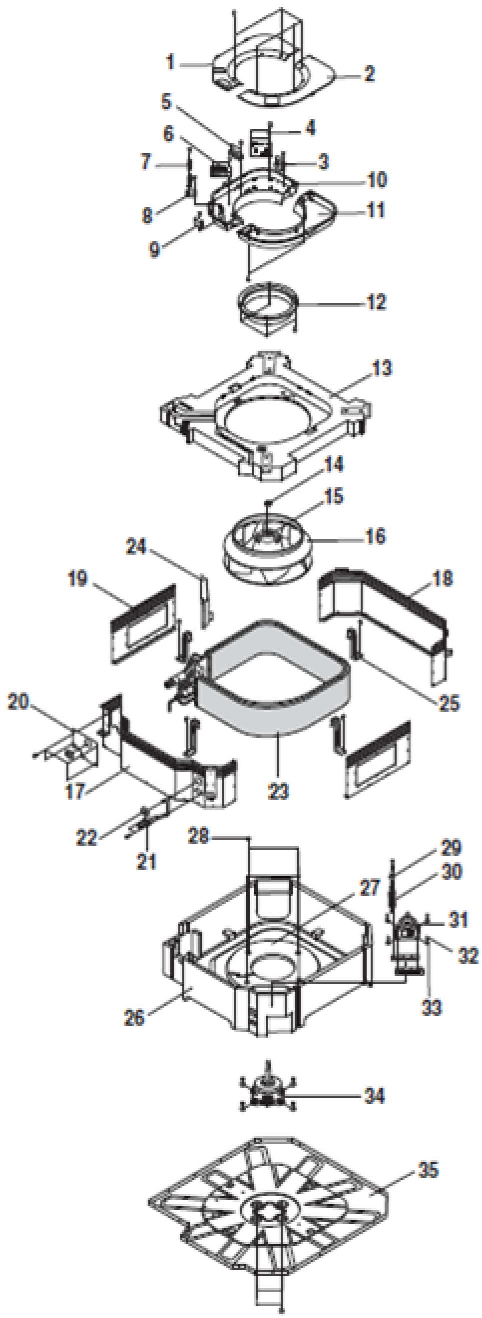
Indoor Unit (cont.)

■ 4 way cassette type

Model				AVXC4H056E*	AVXC4H071E*	AVXC4H112E*	AVXC4H128E*	AVXC4H140E*
Power supply			ø, V, Hz	1, 220~240, 50				
Remark				Heat pump				
Performance	Capacity	Cooling*1)	Btu/h	19,100	24,300	38,000	44,000	48,000
			kW	5.6	7.1	11.2	12.8	14.0
		Heating*2)	Btu/h	21,500	27,300	43,000	47,000	54,000
			kW	6.3	8.0	12.5	13.8	16.0
	Sound Level*3)		dB	38/35	40/37	44/41	46/43	47/44
Power	Fan motors	Model	-	OSME-196SAC(S032)	OSME-196SAC(S032)	OSME-856SAC(S816)	OSME-856SAC(S816)	OSME-856SAC(S816)
		Type	-	Turbo fan	Turbo fan	Cross fan	Cross fan	Cross fan
		Output	W	26	26	58	72	85
		Air flow rate(Cool/Heat)	m³/min	16.0/18.1	16.0/18.1	26.1/28.4	28.3/30.9	28.9/32.3
	Running current	-	A	0.5	0.5	0.71	0.73	0.78
	Power input	-	W	110	110	160	164	172
Refrigerant Control				EEV(Electronic Expansion Valve)				
Piping connections		Liquid(Flare)	mm	6.35	9.52	9.52	9.52	9.52
		Gas(Flare)	mm	12.7	15.88	15.88	15.88	15.88
		Drain	mm	VP 25, external diameter 32, internal diameter 25				
Set Size	Net weight		kg	26	26	29.5	29.5	29.5
	Shipping weight		kg	31	31	35.5	35.5	35.5
	Net dimension (WxHxD)		mm	840x230x840	840x230x840	840x298x840	840x298x840	840x298x840
	Shipping dimension(WxHxD)		mm	939x324x923	939x324x923	939x382x923	939x382x923	939x382x923
Panel Size	Net weight		kg	4.9	4.9	4.9	4.9	4.9
	Shipping weight		kg	10	10	10	10	10
	Net dimension (WxHxD)		mm	950x42x950	950x42x950	950x42x950	950x42x950	950x42x950
	Shipping dimension (WxHxD)		mm	1,067x134x1,067	1,067x134x1,067	1,067x134x1,067	1,067x134x1,067	1,067x134x1,067
Function / Option	Auto restart		Yes/No	Yes	Yes	Yes	Yes	Yes
	Auto change over		Yes/No	No	No	No	No	No
	Centralized controller (On/Off)		Yes/No	Yes(Option)	Yes(Option)	Yes(Option)	Yes(Option)	Yes(Option)
	Group/Individual control for R/C		Yes/No	Yes(Option)	Yes(Option)	Yes(Option)	Yes(Option)	Yes(Option)
	Troubleshooting by L.E.D		Yes/No	Yes	Yes	Yes	Yes	Yes
	Auto swing (Up/Down)		Yes/No	Yes	Yes	Yes	Yes	Yes
	Max. installation ceiling height		mm	255	255	315	315	315
	Drain pump		Yes/No	Yes	Yes	Yes	Yes	Yes

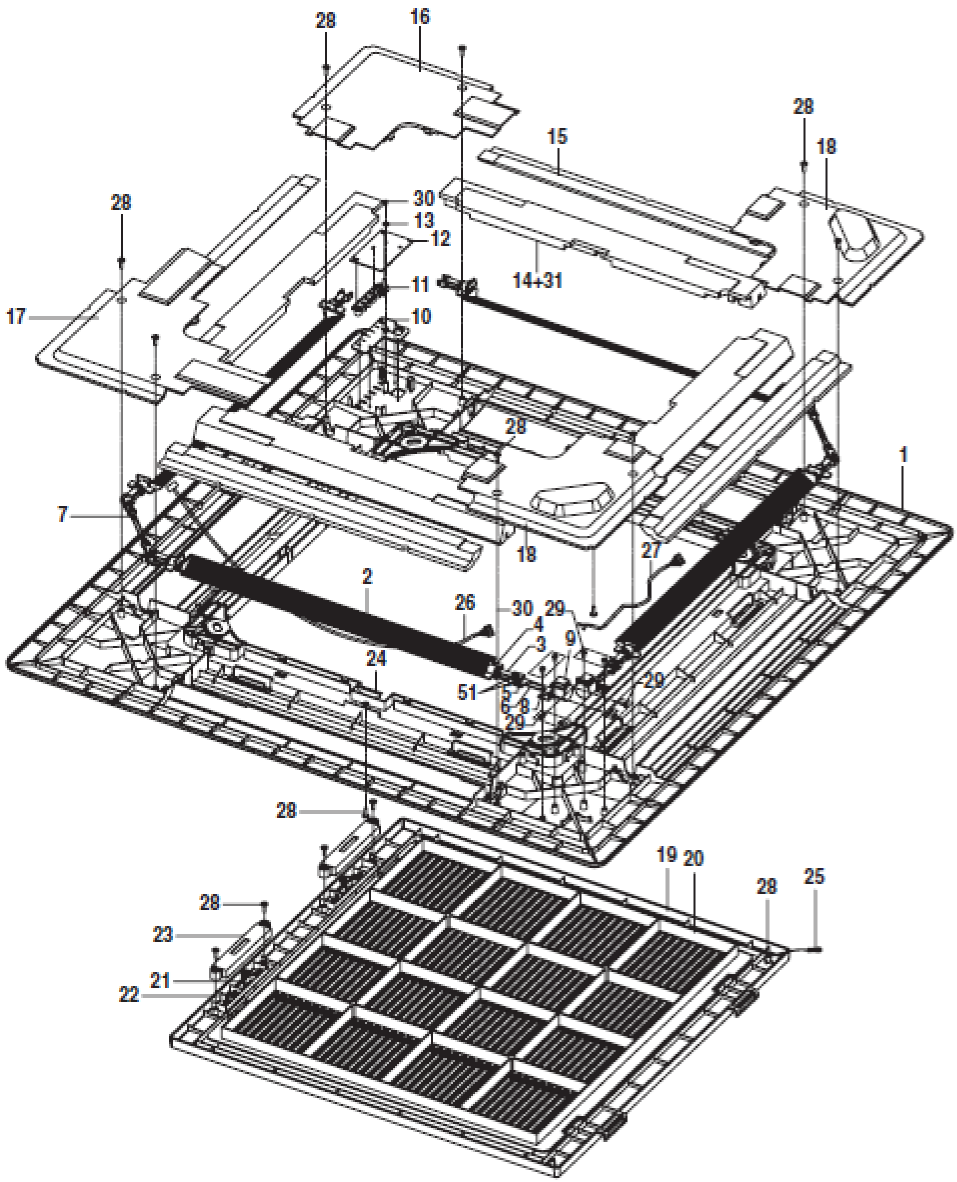
4 way cassette type (cont.)

■ **Body(11.2kW~14.0kW)**



4 way cassette type (cont.)

■ Panel



■ **Parts List**

No.	Code No.	Description	Specification	Q'TY	SA/SNA
				AGCH095IKE	
1	DB64-01143B	PANEL FRONT	HIPS	1	SNA
2	DB66-00757C	BLADE-H	SAN/GF20	4	SA
3	DB61-01871A	CONNECTOR BLADE	POM	8	SNA
4	DB61-01870A	HOLDER BLADE	ABS	8	SNA
5	DB66-00756A	JOINT UNIVERSAL	POM	6	SNA
6	DB66-00759A	LINK MOTOR	POM	2	SNA
7	DB66-00758A	LINK BLADE	POM	2	SNA
8	DB61-01872A	BRACKET MOTOR	SGCC-M	2	SNA
9	DB31-10129C	MOTOR STEP	GSP-24RW-045	2	SA
10	DB64-01141A	INLAY PCB	PC	1	SA
11	DB64-01142A	BUTTON PCB	ABS	1	SNA
12	DB93-02803A	ASS'Y PCB DISPLAY	ASS'Y	1	SA
13	-	WASHER	-	1	SNA
14	DB69-00947A	CUSHION IN	EPS	4	SNA
15	DB69-00948A	CUSHION OUT	EPS	4	SNA
16	DB63-01014B	COVER A	HIPS	1	SNA
17	DB63-01015B	COVER B	HIPS	1	SNA
18	DB63-01016B	COVER C	HIPS	2	SNA
19	DB64-01144B	GRILLE AIR INLET	HIPS	1	SNA
20	DB74-00002A	FILTER AIR	PP	1	SA
21	DB64-01145A	KNOB SLIDE	HIPS	2	SNA
22	DB67-00030A	SPRING KNOB	STS304	2	SNA
23	DB63-01036A	COVER KNOB	HIPS	2	SNA
24	DB70-00302A	PLATE HANGER	STS304	2	SNA
25	DB65-00023A	CLIP WIRE ASS'Y	ASS'Y	1	SNA
26	DB39-00082D	CONNECT WIRE M-D	ASS'Y	1	SA
27	DB39-00542C	CONNECT WIRE MOTOR	ASS'Y	1	SA
28	6002-001079	SCREW TAPPING	TH, +, 2S, M4, L10	17	SNA
29	6002-000536	SCREW TAPPING	PH, +, 2S, M4, L8	8	SNA
30	6002-000534	SCREW TAPPING	PH, +, 2S, M3, L8	1	SNA
31	DB72-00298A	SEAL CUSHION	FLOCKED	4	SNA