Design A Mechanical Systems for Palestinian Embassy in Amman-Jordan

By

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Project Name

Design A Mechanical Systems for Palestinian Embassy in

Amman-Jordan

Done By

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

Supervisor signature

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Examine committee signature

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Department Head signature

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Dedication

الى من ربياني صغيرا

الى كل من علمني واخذ بيدي وانار لي طريق العلم والمعرفة

الى كل من شجعني في رحلتي نحو التميز والنجاح

الى كل من ساندني ووقف بجانبي

الى كل من قال لي: لا فكان سببا في تحفيزي

الى من ضاقت السطور من ذكرها فوسعها قلبي (*Asmaa Abu Arquob*)

الى من ضحوا بحريتهم من اجل حريتنا

الى من هم اكرم منا جميعا

الى كل من قال:

لا اله الا الله ... محمد رسول الله

Acknowledgement

My thanks go first to my advisor Eng. Kazem Osaily, his guidance and support made this work possible.

I wish to thank Dr. Ishaq seder, Eng. Mohammed Awad. I sincerely believe that this work would not without their inspiration.

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

Abstract

This project deals with the design of mechanical systems for an embassy in Amman city which consists of four stories with a total area of 2864 m^2. So that the embassy serves thousands of Palestinian people living in Jordan.

Mechanical systems include heating, ventilation and air conditioning (HVAC systems), water supply, drainage system and firefighting system.

This project is done as an applied for several engineering courses which has been studies in our Specialization.

This project discus briefly theory needed for the design of mechanical systems. Design output is then displaced on drawing. These drawings will include: piping networks for water distribution, drain and sewage and firefighting system. Also drawing will detail duct systems and different equipment required for the embassy.

يهدف هذا المشروع الى تصميم نظام ميكانيكي متكامل للسفارة الفلسطينية في الاردن, حيث يتواجد الالاف من الفلسطينيين يعيشون ويعملون هناك.

النظام الميكانيكي المراد تصميمه يشمل التدفئة, التكييف, والتهوية, نظام تزويد المياه (الساخنة والباردة), نظام صرف صحي متكامل, نظام تصريف مياه الامطار, اضافة الى ذلك نظام اطفاء الحريق.

نظام التدفئة والتكييف نظام مركب يتكون من مشعات حرارية او ملفات (كويلات) مركبة عليها مراوح لدفع الهواء وتمريره عليها, حيث ان النظام هو نظام مائي كامل يزود الملفات بالمياه الساخنة من بويلر والمياه الباردة تصل من شيلر.

يعتبر هذا المشروع تطبيق لما تم تعلمه ودراسته من متطلبات دائرة الهندسة الميكانيكية وهندسة التكييف والتبريد, ويحقق المشروع النظريات والمبادئ الهندسية المطبقة في تصميم الانظمة والخدمات الميكانيكية للأبنية.

مخرجات المشروع تتحقق في الحسابات المرفقة والمخططات التي تم انجازها حيث ان هذه المخططات تحوي شبكات الانابيب للمياه الساخنة والباردة والصرف الصحي والامطار وشبكات التدفئة والتكييف والدكتات المرافقة بالإضافة الى نظام اطفاء الحريق.

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CHAPTER ONE

INTRODUCTION

CHAPTER 1

1.1 Project Outline:

Chapter One:-

Includes the overview about project, project objectives and benefits.

Chapter Two:-

Includes comfort conditions inside embassy, psychometric characteristics, heat transfer through building and calculation of the overall heat transfer coefficients for all structures of embassy.

Chapter Three:-

Includes overview about HVAC systems, heating system and heating load calculation procedures also the sources of heat loss inside embassy. It contains air conditioning system and how to calculate cooling load from all sources of heat gain inside embassy and duct design and finally selection of equipment.

Chapter Four:-

Includes overview about plumbing systems, water distribution system (cold and hot water) and how potable water shall be distributed inside embassy by using suitable pipes and how the pipes could be designed, also this chapter contains the procedures to calculate the required quantity of potable water for daily usage to know the quantity of tanks that required to store this quantity, designing the storm and rain water drainage system.

Chapter Five:-

Includes overview about firefighting system , calculation and distribution and drawing system on different facilities.

1.2 Scope of Project:

The scope of the project is to deal with the design of mechanical systems, This includes the following main topics:

1) Designing of HVAC system for building.
2) Designing and overview about plumbing systems, water distribution system.
3) Designing and calculation of firefighting system for building.

1.3 Project Objectives:

1) The main objectives of this project is to study criteria for designing mechanical systems.
2) Design domestic water system and design grid of pipes to sewage and drainage systems.
3) Design HVAC system for all floors.
4) Design firefighting system for all floors.

1.4 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) Embassy form the important mechanical design because it needs special care to make inside climate more comfortable and healthier, so this field was chosen to gain more in designing mechanical systems.

1.5 Embassy Description:

The embassy named “Palestinian Embassy in Jordan” is located in Amman city which is planned to service thousands of Palestinian community living in Jordan.
It contains consists of four stories, with a total area of 2864 (m^2). And it contains the following administration departments:-

1) Mechanical and electrical services department.
2) Consular, Cultural ,Passports departments.
3) Economic and management department.
4) Political and military department.

The embassy also has the following departments:-

1) Secretary department.
2) Waiting and reception department.
3) Meeting department.
4) Security department.
5) Secret rooms.
6) Archive department.

In addition to these departments, the embassy contains other service departments such as maintenance, food, laundry, stores, theater, and offices.

1.6 Budget:

Table 1.1 Budget One.

Task	Cost (JD)
Using Internet	10
Printing Papers	120
Reprinting Paper	20
Buying Books	10
Total	160

1.7 First Semester Time Table:

Table 1.2 Time table.

Task \ Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Select Project Name	■	■														
Gather Information		■	■	■	■											
Writing Introduction					■	■	■									
Air Conditioning And Heating System							■	■	■	■	■					
Plumping Systems											■	■	■	■		
Printing Final Copy														■	■	■

1.8 Second Semester Time Table:

Table 1.3 Time table.

Task \ Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Information Gathering	■	■	■													
Duct Design Calculations		■	■	■	■	■	■									
Drawing Planes & Selection Of Equipment's						■	■	■	■	■	■	■				
Firefighting System											■	■	■	■	■	
Printing Final Copy														■	■	■

CHAPTER TWO

HUMAN COMFORT

CHAPTER 2

2.1 Human Comfort

The process of comfort heating and air conditioning is simply a transfer of energy from one substance to another. This energy can be classified as either sensible or latent heat energy.

Sensible Heat is heat energy that, when added to or removed from a substance, results in a measurable change in dry-bulb temperature.

Latent Heat content of a substance are associated with the addition or removal of moisture. Latent heat can also be defined as the “hidden” heat energy that is absorbed or released when the phase of a substance is changed. For example, when water is converted to steam, or when steam is converted to water.

The necessity for comfort air conditioning stems from the fact that the metabolism of the human body normally generates more heat than it needs. This heat is transferred by convection and radiation to the environment surrounding the body. The average adult, seated and working, generates excess heat at the rate of approximately 450 Btu/hr [132 W]. About 60% of this heat is transferred to the surrounding environment by convection and radiation, and 40% is released by perspiration and respiration. As the level of physical activity increases, the body generates more heat in proportion to the energy expended. When engaged in heavy labor, as in a factory for example, the body generates 1.450 Btu/hr [425 W]. At this level of activity, the proportions reverse and about 40% of this heat is transferred by convection and radiation and 60% is released by perspiration and respiration.

In order for the body to feel comfortable, the surrounding environment must be of suitable temperature and humidity to transfer this excess heat. If the temperature of the air surrounding the body is too high, the body feel uncomfortably warm. The body responds by increasing the rate of perspiration in order to increase the heat loss through evaporation of body moisture. Additionally, if the surrounding air is too humid, the air is nearly saturated and it is more difficult to evaporate body moisture. If the temperature of the air surrounding the body is too low, however, the body loses more heat than it can produce. The body responds by constricting the blood vessels of the skin to reduce heat loss.

2.1.1 Factors Affecting Human Comfort

1) Dry Air:

The dry air is a complex mixture of several gases such as nitrogen ,oxygen ,carbon dioxide and other gases such as argon ,carbon monoxide and neon .It does not contain water vapor .the presence of nitrogen in the air represents about 78% by volume while the oxygen occupies about 21% by volume .The other gases represent less than 1%.

2) Moist Air:

The moist air is mechanical mixture of dry air and water vapor. Thus, when moist air is cooled, it loses moisture due to the condensation of the water vapor in the air.

3) Humidity:

The moisture content of the air is referred to as its humidity .This moisture content can be expressed in terms of volume, masses, and moles of pressure.

4)Saturation:

Saturation indicates the maximum amount of water vapor that can exist in one cubic meter of air at a given temperature .It does not depend on the mass and pressure of the air which may simultaneously exist in the same space.

5) Partial Pressure:

Low pressure air-water vapor mixture follows closely the Gibbs-Dalton law of partial pressure. This law states that the total pressure of a mixture of gases is the sum of the partial pressure of each of its constituent gas occupies the entire volume and has the same temperature of the mixture.

6) Dry Bulb Temperature:

Dry bulb temperature is the air temperature that is measured by an accurate thermometer or thermocouple where the measuring instrument is shielded to reduce the effect of direct radiation.

7) Wet Bulb Temperature:

The air temperature measured, using a wetted thermometer bulb, is known as wet bulb temperature .When unsaturated air passes over a wet thermometer bulb, water evaporates from the wetted bulb. Vaporizing latent heat is absorbed by the vaporizing water and thus causes the temperature of the wetted thermometer bulb to fall. The instrument used to measure the wet bulb temperature is called physchrometer.

8) Dew-Point Temperature:

The dew-point temperature is the saturation temperature corresponding to the partial pressure of the water vapor in the surrounding air. When the dew-point temperature is reached, condensation starts as the moist cooled at constant pressure .Further cooling results in more condensation of water vapor. Moreover, at the dew-point temperature or below, the air is said to be saturated because the air is mixed with the maximum possible amount of water vapor.

9) Humidity:

The humidity ratio w, is defined as the mass of water vapor associated with unit mass of dry air .

10) Relative Humidity:

The relative humidityis the ratio of actual partial pressure of the water vapor in the air p_v , partial pressure of the water vapor ($\frac{P_v}{P_s}$.).

2.1.2 ASHRAE Comfort Chart:

Research studies have been conducted to show that, with a specific amount of air movement, thermal comfort can be produced with certain combinations of dry-bulb temperature and relative humidity. When plotted on a psychometric chart, these combinations form a range of conditions for delivering acceptable thermal comfort to 90% of the people in a space. This “comfort zone” and the associated assumptions are defined by ASHRAE Standard 55, Thermal Environmental Conditions for Human Occupancy. Determining the desired condition of the space is the first step in estimating the cooling and heating loads for the space. In this embassy, we will choose

24.5 ºC [76ºF] dry-bulb temperature,40% relative humidity and the air velocity less than 0.23 m/s as the desired indoor condition during the cooling season**.**

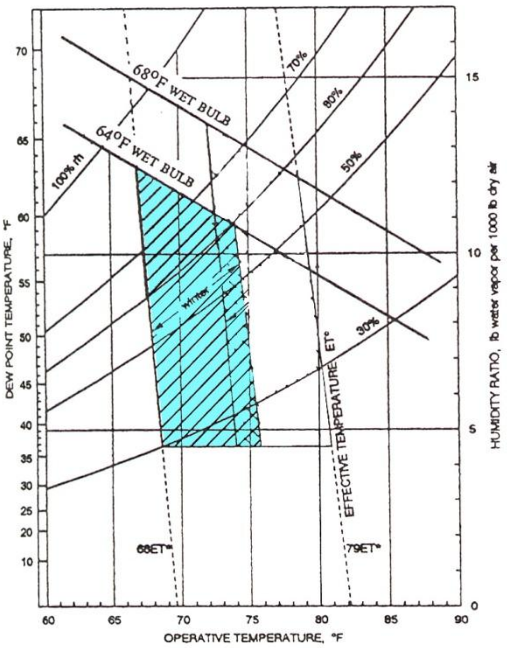


Figure 2.1 comfort zone for operating and temperature and relative humidity

2.1.3 Comfort Condition Inside Embassy:

All calculation (heating and cooling loads) will be made according to specified values for inside conditions of embassy design in Table 2.1 below refer to dry bulb temperature and relative humidity in both summer and winter seasons.

Table 2.1Indoor Design Conditions

Room or Area	**Summer**		**Winter**	
	T_{db} Degrees C (Degrees F)	**RH Percent**	**T_{db} Degrees C (Degrees F)**	**RH Percent**
Bedroom	24 (75)	45 (±5)	22 (72)	30 (±5)
Telecom .Room	20 (68)	50	18 (64)	--

Room or Area	Summer		Winter	
	T_{db} Degrees C (Degrees F)	RH Percent	T_{db} Degrees C (Degrees F)	RH Percent
Clinic	24 (75)	50	21 (70)	45
Mosque	20 (68)	45	18 (64)	30
Passports&Conditions&Identities	22 (72)	50	20 (68)	30
Multipurpose Hall	20 (68)	45	19 (66)	30
Cafeteria	22 (72)	40	20 (68)	40
Intelligence	24 (75)	50	22 (72)	45
Guard	24 (75)	45	22 (72)	45
Consul	24 (75)	45	22 (72)	45
Vice-Consul	24 (75)	45	22 (72)	45
President of the Cultural Dependency	24 (75)	45	22 (72)	45
Assistant Chief Dependency	24 (75)	45	22 (72)	45
Staff Translators	24 (75)	45	20 (68)	45
President of the Economic Dependency	24 (75)	45	22 (72)	45
Aides	24 (75)	45	20 (68)	45
Responsible for the Economic Aspects	24 (75)	45	22 (72)	45
Responsible for the Commercial Aspects	24 (75)	45	22 (72)	45
Responsible for the Agricultural Aspects	24 (75)	45	22 (72)	45
Secretarial & Waiting	24 (75)	45	20 (68)	45
Secret Room	24 (75)	45	22 (72)	45
Library	24 (75)	45	20 (68)	30
President of Political Department	24 (75)	45	22 (72)	45
Exhibition	24 (75)	45	20 (68)	45
Mechanical Equipment Rooms (MERs)	Ventilation Only		10 (50)	--
Generator Room	Ventilation Only		10 (50)	--

Room or Area	Summer		Winter	
	T_{db} Degrees C (Degrees F)	**RH Percent**	**T_{db} Degrees C (Degrees F)**	**RH Percent**
Media Center	24 (75)	45	20 (68)	30
Conference Rooms	24 (75)	45	20 (68)	45
Managing Department	24 (75)	45	22 (72)	45
Kitchen	19 (66)	45	15 (59)	30
Water Closet (WC)	Ventilation Only		19 (66)	30

2.1.4 Outside Design Condition

2.1.4.1 Outside Design Condition For Summer:
$T_{dry\ bulb}$ =32.7 [°C]

Relative humidity = 38 %

T_{wet} = 18.1 [°C]

Max wind speed = 1.2 [m/s]

Design month = July

2.1.4.2 Outside Design Condition For Winter :
$T_{dry\ bulb}$ = 3.2 [°C]

Relative humidity = 67%

T_{wet} = 6.5 [°C]

Max wind speed = 1.8 [m/s]

Design month = January

2.2 Over All Heat Transfer Coefficient “U” :

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

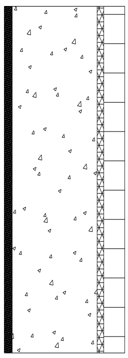
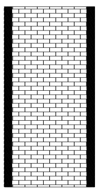
R_i:Inside film resistance of inside wall ,and ceiling ($R_i = 0.12\ m^2.C^0/W$) .

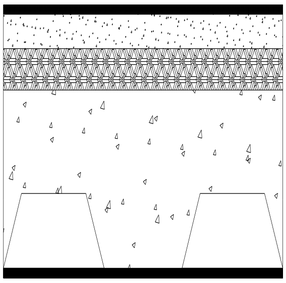
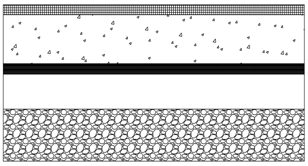
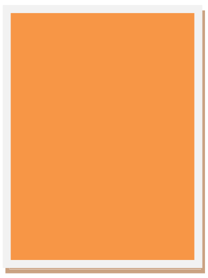
R_o:Outside film resistance of outside wall ,floors ,and ceiling ($R_o = 0.06\ m^2.C^0/W$) .

Δx :Distance of construction material (m).

K :Thermal conductivity of construction material ($W/m\ .C^0$).

Table2.2Overall Heat Transfer Coefficients.

	Construction detail	Construction material	Material thickness [m]	Thermal conduction [W/m.°C]	U [W/m².°C]
Outside walls		1- stone 2-Insulation 3-Concrete 4- plaster	0.05 0.20 0.02 0.03	1.7 1.75 0.04 1.2	1.17
Inside wall		1- plaster 2- Block 3- plaster	0.015 0.07 0.015	1.2 0.95 1.2	2.94

Roof		1- Asphalt 2- Concrete 3-Insulation 4- Concrete 5- Block 6- plaster	0.02 0.04 0.02 0.05 0.15 0.02	0.81 1.75 0.04 1.75 0.95 1.2	0.77
Ground		1-Tiles 2-Concrete 3- Mortar 4- Sand 5- rocks	0.02 0.12 0.02 0.1 0.5	1.1 1.75 1.2 0.7 1.05	1.146
Window		1-glass	-	-	3.2
doors		1-wood	0.04	0.17	3.1

CHAPTER THREE

HVAC SYSTEM

CHAPTER 3

3.1 HVAC Systems Classifications

HVAC systems are classified into two basic categories: all-water systems, and split DX system systems, table (3-1) listed HVAC systems types are used in this project.

All-water systems or Water based systems use a single chiller plant or chiller plus boiler to produce water which is then pumped around a building to, most commonly, fan coil units; a fan blows air over a coil containing the water, which then cools or heats the room air. The heat rejected from the room to the water is then pumped back to the chiller unit where it is rejected by a condenser to external air. The water is then chilled or heated again and pumped back to the room units.

Unitary Packaged Systems – similar in nature to individual systems but serve more rooms or even more than one floor, have an air system consisting of fans, coils, filters, ductwork and outlets.

Table 3.1 HVAC systems classifications

NO	HVAC systems category	HVAC system
1	**All-Water**	**Fan coils , ducted fan coils**
2	**Split DX system. (Individual Systems)**	**Split conditioner units**

3.1.1 Fan-Coil Unit & Fan-Coil with Duct

In all internal spaces between different sections in the embassy, a fan coils and fan coil with duct system were installed to Serve this area.

Fan coils units were selected based on several factors, the most important of them its ability to provide adequate air flow to provide the required cooling in summer and heating required in winter, Fan-coil system units have a finned-tube coil, filter, and fan section. The fan recirculates air continuously from the space through the coil, which contains either hot or chilled water. Some units have electric resistance heaters or steam coils, It is controlled either by a manual on/off switch or by thermostat.

The fan coil with duct units regulate the volume of air and often heat the air with hot water, steam, or electric resistance coils in response to space temperature conditions. The terminal units are equipped with fans (fan-powered) to recirculate room air for energy conservation and temperature control. The fan-powered boxes may be either constant volume discharge or variable volume.

In all internal large spaces between different sections in the embassy, a fan coils with duct system were installed to serve this area. Each duct contains a number of grills that’s covered the total cooling and heating load.

3.1.2 Split Unit

In all internal spaces in basement floor in the embassy, a split units will installed to serve this area. Split units are divided to two part out door unit which contains condenser and compressor, in door unit which contains evaporator, filter, fan to circulate the air inside the space, and water drain.

3.2 Cooling Load Estimations

The selection of ventilating, and air conditioning (AC) system components and equipment should always be based on an accurate determination of the building cooling load.

3.2.1 Heat Gain Through Sunlit Walls And Roofs

$$Q=U.A.(CLTD)_{corrected}. \tag{3.1}$$

Q : cooling load [kW].

U: over all heat transfer coefficient [$W/m^2.°C$].

A : surface area [m^2].

CLTD correct : cooling load temperature deference correction.

$$(CLTD)_{corrected} =(CLTD+LM)k+(25.5-Ti)+(To,m-29.4)f \tag{3.2}$$

CLTD : cooling load temperature deference correction, (from appendix A) Table(1).

LM : latitude correction factor, (from appendix A) Table(2).

k : color adjustment ,k=1 for dark roof and 0.5 for light roof surface.

f: roof fan factor equal 0.75 because there is an attic .

Ti : inside design wall temp .

$T_{o,m}$: out design door main temperature .

Note: CLTD value for roofs ,walls, are taken depending on U values and time of day from CLTD ASHREA table on appendix.

3.2.2 Heat Gain Through Inside Walls and Ground

$$Q= U.A .\Delta t \tag{3.3}$$

Q: loading load gain inside walls.

A: inside walls area.

U: overall heat transfer coefficient.

Δt: temperature deference between inside air conditioning space and beside air temperature space.

3.2.3 Heat Gain Due To Glass Windows

$$Q_{tr}=A\ (SHG)\ (SC)\ (CLF) \tag{3.4}$$

Q_{tr} : Heat gain due to solar transmission through glass windows(Watt)

a) solar heat gain factor (SHG):

This factor represents the amount of solar energy they would be received by floor, furniture and the inside walls of the room and can be extracted;(from appendix A) Table(3).

b) shading coefficient (SC):

It accounts from for different shading effects of the glass wall or window and can be extracted (from appendix A) Table(4). For single and double glass, as well as, for insulation glass with internal shading (venetian blinds, curtains, drapes, roller shades, etc.).the shading coefficient, SC is defined as the ratio of solar heat gain of glass window of the space to the solar heat gain of double strength glass.

c) cooling load factor (CLF):

This represents the effect of the internal walls, floor, and furniture on the instantaneous cooling load, and can be extracted (from appendix A) Table(5). For glass with interior shading. It accounts for the variation of shag factor with time, mass capacity of the structure and the internal shading.

3.2.4 Convection Heat Gain

The convicted cooling load by the glass is calculated by this equation

$Q=U.A.(CLTD)_{corrected}$. (3.5)

3.2.5 Heat Gain Due To Occupants

Q total for occupant = Q sensible + Q latent ;(from appendix A) Table(6). (3.6)

Q latent = heat gain latent * No. of people* CLF ;(CLF = 0.6).

Q sensible = heat gain sensible * No. of people* CLF ;(CLF = 0.6).

3.2.6 Heat Gain Due To Lights

Q_{Lt} = lighting intensity*A*CLF* ballast factor (3.7)

Lighting intensity: 10-30 w/m^2 for apartment so we will take $30W/m^2$.

A : floor area.

CLF = cooling load factor, dimensionless. (from appendix A) Table(7).

Similar to the sensible heat gain from people, a cooling load factor (CLF) can be used to account for the capacity of the space to absorb and store the heat generated by the lights. If the lights are left on 24 hours a day, or if the air conditioning system is shut off or set back at night, the CLF is assumed to be equal to 1.

Ballast factor = 1.2 for fluorescent lights, 1.0 for incandescent lights.

3.2.7 Heat gain Due To infiltration

$$Q_{inf} = \frac{V_f}{V_{outside}} * (h_o - h_i) \quad (3.8)$$

From psychometric chart we get :-

- $V_{outside} = 0.885\ m^3/Kg$
- $h_o = 67\ kJ/kg$
- $h_i = 49\ kJ/kg$
- $V_f \rightarrow 6\ L/\sec\ per\ person.$

3.2.8 Heat Gain Due To Ventilation

$$Q\ ven = m^{\cdot} * C_{pair} * (t_{out} - t_{in})air \quad (3.9)$$

$m^{\cdot}$: total flow rate for fresh air (kg/s) = V_f / v

C_{pa} :Specific heat of air = 1.005 kJ/kg.k.

T_{in}: the inside temperature C^o.

t_{out}: the outside temperature C^o.

V_f : rate of ventilation= no. of people * outdoor air .

outdoor air = (6L/s)/person.

v : specific volume for air @ t max = 32.7 C^o and Φ = 38 % ;v = 0.855 (m^3/kg).

3.3 Heating Load Estimations

The space heating load is the rate at which heat must be added to a space in order to maintain the desired conditions in the space ,generally a dry-bulb temperature.

In general, the estimation of heating loads assumes worst conditions for the space. The winter design outdoor temperature is used for determining the conduction heat loss through exterior surfaces. No credit is given for heat gain from solar radiation through glass or from the sun's rays warming the outside surfaces of the building. Additionally, no credit is given for internal heat gains due to people, lighting, and equipment in the space.

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.

The heating load for a space can be made up of many components, including:

1) Conduction heat loss to the outdoors through the roof, exterior walls, skylights, and windows
2) Conduction heat loss to adjoining spaces through the ceiling, interior partition walls, and floor
3) Heat loss due to cold air infiltrating into the space from outdoors through doors, windows, and small cracks in the building envelope.

When calculating heating loss by conduction through the roof, the exterior walls, and the windows, no credit is given for the effect of the sun shining on the outside surfaces. With this assumption, the amount of heat transferred through the surface is a direct result of the temperature difference between the outdoor and indoor surfaces (T is used instead of CLTD).

The amount of heat loss through a roof, an exterior wall, or a window depends on the area of the surface, the overall heat transfer coefficient of the surface, and the dry-bulb temperature difference from one side of the surface to the other.

The equation used to predict the heat loss by conduction is:

$$Q = U \times A \times \Delta t \tag{3.10}$$

Q = the rate at which heat transfer in watts [W].

U = overall heat-transfer coefficient of the surface [W/m^2. K].

A = Area of the layer which heat flow through, which in our project may be an area of wall, window, or ceiling…,[m^2].

Δt = desired indoor dry-bulb temperature (Ti) minus the design outdoor dry bulb temperature (T_o), [°C].

3.3.1 Heat Loss by Infiltration

Infiltration is the leakage of outside air through cracks and clearances around the windows and doors. The amount of infiltration depends mainly on the tightness of the windows and doors on the outside wind velocity or the pressure difference between the outside and inside the heat load due to infiltration is given by**:**

$$Q_{inf} = \frac{V_{inf}}{V_{outside}} * (h_o - h_i) \tag{3.11}$$

$$V_{inf} = K*L*(0.613(s1 * s2 * v)^{\wedge}2)^{2/3} \tag{3.12}$$

Q_{inf}: the infiltration heat load [W].

V_{inf}:the volumetric flow rate of infiltrated air $[m^3/s]$.

$V_{outside}$:the outside volumetric flow rate $[m^3/Kg\ \ dry\ air]$.

h_o ,h_i: $are\ the\ outside\ and\ inside\ enthapies\ of\ infiltrated\ air,\ respectively$ [KJ/Kg].

k: the coefficient of infiltration air for windows, (from appendix A) Table(9).

l: the crack length [m].

s_1: the factor that depends on the topography of the location of the building, (from appendix A) Table(10).

s_2: another coefficient that depends on the height of the building and terrain of its location, (from appendix A) Table(10).

V_o: the measured wind speed [m/s].

These include dry-bulb temperature (T_{out}) , relative humidity out (Φ_{out}) and average air speed (v) . these values are usually tabulated weather station reports.

3.4 Sample of Heating and Cooling Load

For second floor .

For room #D1 Official Military Room.

3.4.1 Heating Load Calculation

1) ForOutside Wall

$Q_{wall} = U \times A \times \Delta t$ (3.9)

Q_{wall}=1.176*(15.67)*(24-4.2) =365 W.

2) For Inside Wall.

Q_{wall}=2.94*(19.65)*(14.1)=814.6 W.

3) For Roof

Q_{roof}=0.77*(13.85)*(24-4.2)=211 W.

4) For Floor

Q_{floor}=0.77*(13.85)*(14.1) =150 W.

5) For Window

Q_{window}=3.2*(6.08)*(24 – 4.2) =385 W.

6)For Door

Q_{door}=3.1* (2.1) *(14.1) =92 W.

7) For Infiltration Due Windows.

$Q_{inf} = \frac{V_{inf}}{V_{outside}} * (h_o - h_i)$ (3.11)

$V_{inf} = K*L*(0.613(s1 * s2 * v)^2)^{2/3}$ (3.12)

V_{inf}=0.43*[14] * [0.613*(1*0.69*1.8)^2]$^{2/3}$ =5.8 m^3/h.

$Q_{inf} = \frac{0.0016}{0.855} * (49 - 5)$ =82 W.

$Q_{total\ heating\ Load} = \sum Q$ =2100 W = 2.1 KW .

3.4.2 Cooling Load Calculation

1) Heat Gain Through Sunlit Walls and Roof

Q=U.A.(CLTD)corrected (3.1)

$(CLTD)_{corr}$=(CLTD+LM)k+(25.5-Ti)+(To,m-29.4)f (3.2)

Table 3.2 Factors of Heat Gain Through Sunlit Walls and Roof

Walls	CLTD	LM	(CLTD)corrected
East	17	0	16.025
Roof	7	0.5	11

Q_{East}=1.176*(8.56)*16.025=161.3 W.
Q_{Roof}=0.77*(13.85)*11=117 W.

2) Heat Gain Through Inside Walls and Ground
$Q = U \times A \times \Delta t$ (3.3)
Q_{West}=2.94*(9.5)*5.8=162 W.
Q_{North}=1.176*(10.15)*8.7=104 W.
Q_{South}=2.94*(10.15)*5.8=173 W.
Q_{Ground}=0.77*(13.85)*5.8=62 W.

3) Heat Gain Due To Glass Window
Q_{tr}=A (SHG) (SC) (CLF) (3.4)

Table 3.3Factors of Heat Gain Due To Glass Window

Walls	SHG	SC	CLF
East	678	1	0.42
North	126	1	0.7

Q_{tr}=A (SHG) (SC) (CLF)

Q_{East}=3.04(678)(1)(0.42) =866 W.

Q_{East}=3.04(126)(1)(0.7) =268 W.

4) Heat Gain Due To Solar Conviction
Q=U.A.$(CLTD)_{corrected}$. (3.5)
Q=(3.2)(3.04)(16.025)=156W.

5) Heat Generated By People

Q latent = heat gain latent * No. of people* CLF ;(CLF = 0.6). (3.6)

Q latent = 6(70)(0.6)=252W.

Q sensible = heat gain sensible * No. of people* CLF ;(CLF = 0.6).

Q sensible = 6(40)(0.6)=144W.

6) Heat Gain Due To Lights

Q_{Lt} = lighting intensity*A*CLF* ballast factor (3.7)

Q_{Lt} =(20)(13.85)(1)(1)=277W.

7) Heat Gain Due To Ventilation

$Q_{ven} = m^{\cdot} * C_{pair} * (t_{out}-t_{in})air$ (3.9)

$m^{\cdot} = \frac{V_f}{V} = \frac{10*(6\ l/s)}{0.855(1000)} = 0.07$ kg/sec.

Q_{ven}=0.07*1.005*(32.7 – 24)=612 W.

8) Heat Gain Due To Infiltration.

$$Q_{inf} = \frac{V_f}{V_{outside}} * (h_o - h_i) \quad (3.8)$$

Q_{inf} = 6/0.885 *(67-49) = 122W.

$Q_{total\ Cooling\ Load} = \sum Q$ = 3354 W = 3.4 KW .

3.5 Total Cooling And Heating Loads For Embassy.

Table 3.4 Total cooling and heating loads for basement floor .

Number	Name	Cooling load (KW)	Heating load (KW)
A1	Bedroom	5.1	3.2
A2	Telecommunication room	6.8	3.9
A3	Storage	4.1	1.3
A4	Clinic	6.8	4.2
A5	Mosque	11.2	7.3
A6	Storage	4.1	1.3
A7	MERs	2	--
A8	Generator	1.5	--
Total		41.6	21.2

Table 3.5 Total cooling and heating loads for ground floor .

Number	Name	Cooling load (KW)	Heating load (KW)
B1	Passports &Condition	48.2	32.3
B2	Multipurpose Hall	30.5	22.8
B3	Guard	2.4	1.02
B4	Consul	4.6	2.8
B5	Vice-Consul	4.3	2.8
B6	President of Cultural Depart	5.1	3.15
B7	Secretarial &Waiting	4.8	3.8
B8	Assistant Chief Dependency	5.3	3.6
B9	Staff Translators	7.5	4.1
B10	Secret Room	7.6	3.8
B11	President of Economic Depart	5.2	3.8
B12	Aides	2.8	1.83
B13	Responsible for the Economic Aspects	2.55	1.6
B14	Responsible for the Commercial Aspects	2.6	1.65
B15	Responsible for the Agricultural Aspects	2.5	1.53
B16	Intelligence	5.44	3.36
B17	Multipurpose Hall	30.5	22.8
B18	Cafeteria	14.7	9.3
Total		187	126

Table 3.6 Total cooling and heating loads for first floor.

Number	Name	Cooling load (KW)	Heating load (KW)
C1	Media Center	12.7	8.3
C2	Library	34.6	21.7
C3	Accountants	4.3	2.1
C4	Storage	1.4	0.9
C5	Secretarial &Waiting	4.6	3.8
C6	Responsible for the Finances & Budget	5.7	3.15
C7	Responsible for Expenditures	4.5	3.2
C8	Recruits	5.7	3.01
C9	Managing Department	7.9	5.3
C10	Assistant Managing Depart	6.3	4.2
C11	Secret Room	8.6	4.6
C12	General Service Staff	8.4	5.45
C13	Assistance Office	3.4	2.1
C14	President of Political Depart	7.3	5.02

C15	Political Department	17.6	9.4
C16	Exhibition	20.4	13.5
C17	Chamber Communications	10.8	6.3
C18	Kitchen	1.8	0.08
Total		166	102.11

Table 3.7 Total cooling and heating loads for second floor.

Number	Name	Cooling load (KW)	Heating load (KW)
D1	Official Military Reports	3.4	2.1
D2	Printing Office	2.4	1.4
D3	Photography	4.2	3.2
D4	Files &Communication	2.4	1.4
D5	Assistant City	3.3	2.0
D6	President of the Military Depart	5.8	4.3
D7	Assistant Chief Dependency	5.2	4.2
D8	Secret Room	4.6	3.2
D9	Ambassador Room	9.6	6.3
D10	First Secretary	4.9	3.2
D11	Second Secretary	4.2	2.4
D12	Special Meeting Room	6.8	4.2
D13	Deputy Ambassador Room	5.7	3.2
Total		62.5	41.1

3.6 Sample of Calculations For Fan Coil System.

For room # D1 Official Military Room:

Q = 3.4 Kw

$Q = \dot{m} * C.p * \Delta T$

Q : total heat losses [kW].

$\dot{m}$: mass flow rate[kg/s].

C_p: specific heat capacity at constant pressure

C_p water = 4.18 [kj/kg c]

ΔT : water temperature difference = 8 C^0.

So, $\dot{m}$= 0.1 kg/s

$A = \frac{\dot{m}}{\delta * v}$

Where: A: cross – sectional area of pipe

$\dot{m}$: Mass flow rate[kg/s].

δ: Water mass density 1000 [kg/m^3].

$A = \frac{\dot{m}}{\delta * v} = \frac{0.1}{1000*2} = 0.05 * 10^{-3}\ m^2$

d = $\sqrt[2]{\frac{4(\,0.05*10^{-3}\,)m^2}{\pi}}$ = 7.97*10^{-3} m = 0.314 inch, so d selected =0.5[inch]

Where d = pipe cross – sectional diameter (m).

3.7 Total Calculated Data For (FCU) In Embassy.

Table 3.8 Calculated Data for (FCU) for Ground Floor due to Cooling Load.

No	Name	Load KW	Flow kg/s	Diameter [inch]	Diameter Selection. inch	cfm
1	B1	48.2	1.44	1.182	1	4535
2	B2	30.5	0.91	0.946	1	2861
3	B3	2.4	0.07	0.266	0.5	225
4	B4	4.6	0.14	0.372	0.5	432
5	B5	4.3	0.13	0.358	0.5	403
6	B6	5.1	0.15	0.388	0.5	487
7	B7	4.8	0.14	0.377	0.5	451
8	B8	5.3	0.16	0.394	0.5	509
9	B9	7.5	0.22	0.473	0.5	700
10	B10	7.6	0.23	0.483	0.5	710
11	B11	5.2	0.16	0.393	0.5	500
12	B12	2.8	0.08	0.366	0.5	235
13	B13	2.55	0.08	0.086	0.5	230

14	B14	2.6	0.08	0.086	0.5	230
15	B15	2.5	0.07	0.085	0.5	228
16	B16	5.44	0.16	0.393	0.5	509
17	B17	30.5	0.91	0.946	1	2861
18	B18	14.7	0.45	0.420	0.5	1440

Table 3.9 Selection Data for Fan Coils Units and Grills in Ground Floor.

No	Name	Q[kw]	cfm	FCU model	Grill dim
1	B1	48.2	4535	42CED014	18*30
2	B2	30.5	2861	42CED014	18*30
3	B3	2.4	225	42CED003	8*12
4	B4	4.6	432	42CED005	10*12
5	B5	4.3	403	42CED005	10*12
6	B6	5.1	487	42CED005	10*12
7	B7	4.8	451	42CED005	10*20
8	B8	5.3	509	42CED006	12*20
9	B9	7.5	700	42CED008	12*20
10	B10	7.6	710	42CED008	12*20
11	B11	5.2	500	42CED006	12*20
12	B12	2.8	235	42CED003	8*12
13	B13	2.55	230	42CED003	8*12
14	B14	2.6	230	42CED003	8*12
15	B15	2.5	228	42CED003	8*12
16	B16	5.44	509	42CED006	12*20
17	B17	30.5	2861	42CED014	18*30
18	B18	14.7	1440	42CED014	18*30

Table 3.10 Calculated Data for (FCU) for First Floor due to Cooling Load.

No	Name	Load KW	Flow kg/s	Diameter [inch]	Diameter Selection. inch	cfm
1	C1	12.7	0.38	0.788	1	1187
2	C2	34.6	1.03	1.02	1	3263
3	C3	4.3	0.13	0.358	0.5	403
4	C4	1.4	0.04	0.198	0.5	132
5	C5	4.6	0.14	0.370	0.5	432
6	C6	5.7	0.17	0.394	0.5	530
7	C7	4.5	0.14	0.372	0.5	424
8	C8	5.7	0.17	0.394	0.5	530
9	C9	7.9	0.24	0.384	0.5	742
10	C10	6.3	0.19	0.433	0.5	593
11	C11	8.6	0.26	0.512	0.5	805
12	C12	8.4	0.25	0.496	0.5	790
13	C13	3.4	0.11	0.317	0.5	320
14	C14	7.3	0.22	0.394	0.5	687
15	C15	17.6	0.55	0.788	1	1657
16	C16	20.4	0.61	0.788	1	1920
17	C17	10.8	0.32	0.552	1	1017
18	C18	1.8	0.05	0.231	0.5	170

Table 3.11 Selection Data for Fan Coils Units and Grills in First Floor.

No	Name	Q[kw]	cfm	FCU model	Grill dim
1	C1	12.7	1187	42CED014	18*30
2	C2	34.6	3263	42CED014	18*30
3	C3	4.3	403	42CED005	10*12
4	C4	1.4	132	42CED002	6*12
5	C5	4.6	432	42CED005	10*12

6	C6	5.7	530	42CED006	12*20
7	C7	4.5	424	42CED005	10*12
8	C8	5.7	530	42CED006	12*20
9	C9	7.9	742	42CED008	14*20
10	C10	6.3	593	42CED006	14*20
11	C11	8.6	805	42CED009	16*20
12	C12	8.4	790	42CED008	14*20
13	C13	3.4	320	42CED004	12*20
14	C14	7.3	687	42CED007	14*20
15	C15	17.6	1657	42CED014	18*30
16	C16	20.4	1920	42CED014	18*30
17	C17	10.8	1017	42CED014	18*30
18	C18	1.8	170	42CED002	6*12

Table 3.12 Calculated Data for (FCU) for Second Floor due to Cooling Load.

No	**Name**	**Load KW**	**Flow kg/s**	**Diameter [inch]**	**Diameter Selection. inch**	**cfm**
1	D1	3.4	0.10	0.314	0.5	318
2	D2	2.4	0.07	0.262	0.5	254
3	D3	4.2	0.13	0.358	0.5	396
4	D4	2.4	0.07	0.262	0.5	254
5	D5	3.3	0.09	0.297	0.5	264
6	D6	5.8	0.17	0.394	0.5	551
7	D7	5.2	0.15	0.353	0.5	490
8	D8	4.6	0.14	0.370	0.5	424
9	D9	9.6	0.29	0.412	0.5	911
10	D10	4.9	0.15	0.380	0.5	466
11	D11	4.2	0.13	0.358	0.5	394

12	D12	6.8	0.20	0.394	0.5	636
13	D13	5.7	0.17	0.394	0.5	530

Table 3.13 Selection Data for Fan Coils Units and Grills in Second Floor.

No	Name	Q[kw]	cfm	FCU model	Grill dim
1	D1	3.4	318	42CED004	10*16
2	D2	2.4	254	42CED003	8*12
3	D3	4.2	396	42CED004	10*12
4	D4	2.4	254	42CED003	8*12
5	D5	3.3	264	42CED003	8*12
6	D6	5.8	551	42CED006	12*20
7	D7	5.2	490	42CED005	10*12
8	D8	4.6	424	42CED005	10*12
9	D9	9.6	911	42CED010	18*30
10	D10	4.9	466	42CED005	10*12
11	D11	4.2	394	42CED004	10*16
12	D12	6.8	636	42CED007	14*20
13	D13	5.7	530	42CED006	12*20

3.8 Sample of Calculations For Fan Coils With Duct In Basement Floor.

Using of equal pressure drop method for B1 at ground floor with Q_{Total} = 48.2 KW, and $V_{(required\ air\ velocity)}$ = 4 m/s, from relative friction losses chart at $\dot{m}_{(air\ flow\ rate)}$ = 2.14 m^3/s, we will divided main duct into two equal ducts.

For B1 passports & conditions At Ground Floor With Q_{Total} = 48.2 KW.

$$\dot{m} = \frac{\pi}{4} * d^2 * v$$

$$d = \sqrt[2]{\frac{4*0.2}{4*\pi}} = 0.58 \text{ m.}$$

$$\frac{\Delta p}{El} = 2 \text{ Pa/m.}$$

For B1 ducted area the specifications of duct and grills shown below in the Table (3.14).

Table 3.14 B1 at ground floor with duct and grills specifications.

NO	Branch Name	Flow m^3/s	Flow cfm	Grill size inch	Velocity m/s	Duct Size mm
1	A-B	0.31	657	12*20	4	330W * 257H
2	B-C	0.28	593	12*20	3.9	310W * 241H
3	C-D	0.25	529	10*12	3.6	280W * 235H
4	D-E	0.23	487	10*12	2.9	265W * 227 H

Table 3.15 B1 Summary of Ducts and its Fan Coil Types at Ground Floor.

No	Name	Load KW	Flow kg/s	Diameter inch	Diameter Selection. inch	Flow cfm	Fan Coil Type
1	B1	24.2	0.658	1.18	1	2268	42CED014

3.9 Total Calculated Data for Fan Coil with Duct in Embassy.

Table 3.16 B1 at ground floor with duct and grills specifications.

NO	Branch Name	Flow m^3/s	Flow cfm	Grill size inch	Velocity m/s	Duct Size mm
1	A-B	0.31	657	12*20	4	330W * 257H
2	B-C	0.28	593	12*20	3.9	310W * 241H

3	C-D	0.25	529	10*12	3.6	280W * 235H
4	D-E	0.23	487	10*12	2.9	265W * 227 H

Table 3.17 B1 Summary of Ducts and its Fan coil types at ground floor.

No	Name	Load KW	Flow kg/s	Diameter inch	Diameter Selection. inch	Flow cfm	Fan Coil Type
1	B1	24.2	0.72	1.18	1	2268	42CED014

We will divided the load in B2 room into two ducts, and B17 room is the same it.

Table 3.18 B2 &B17 at ground floor with duct and grills specifications.

NO	Branch Name	Flow m^3/s	Flow cfm	Grill size inch	Velocity m/s	Duct Size mm
1	A-B	0.23	487	10*12	4	265W * 227H
2	B-C	0.18	381	10*12	3.8	258W * 205H
3	C-D	0.16	339	10*12	3.6	255W * 188H
4	D-E	0.10	222	8*12	3.2	240W * 165 H

Table 3.19 B2 &B17 Summary of Ducts and its Fan coil types at ground floor.

No	Name	Load KW	Flow kg/s	Diameter inch	Diameter Selection. inch	Flow cfm	Fan Coil Type
1	B2	15.25	0.658	1.18	1	1430	42CED014

Table 3.20 C2 at first floor with duct and grills specifications.

NO	Branch Name	Flow m^3/s	Flow cfm	Grill size inch	Velocity m/s	Duct Size mm
1	A-B	0.25	530	12*20	5	330W * 227H

2	B-C	0.20	424	10*12	4.6	288W * 210H
3	C-D	0.18	381	10*12	4.2	260W * 198H
4	D-E	0.14	297	8*12	3.6	252W * 175 H

Table 3.21 C2 Summary of Ducts and its Fan coil types at first floor.

No	Name	Load KW	Flow kg/s	Diameter inch	Diameter Selection. inch	Flow cfm	Fan Coil Type
1	C2	17.3	0.515	0.51	0.5	1632	42CED014

Table 3.22 C16 at first floor with duct and grills specifications.

NO	Branch Name	Flow m^3/s	Flow cfm	Grill size inch	Velocity m/s	Duct Size mm
1	A-B	0.12	254	8*12	4.2	232W * 150 H
2	B-C	0.11	233	8*12	4.0	219W * 141 H
3	C-D	0.11	233	8*12	3.8	210W * 128 H
4	D-E	0.10	212	8*12	3.6	195W * 119 H

Table 3.23 C16 Summary of Ducts and its Fan coil types at first floor.

No	Name	Load KW	Flow kg/s	Diameter inch	Diameter Selection. inch	Flow cfm	Fan Coil Type
1	C16	10.1	0.263	0.394	0.5	829	42CED014

3.10 Selections Of Other HVAC System Components

1- Split unit :

we will install split units in all spaces in basement floor, that's made by MITSUBISHI ELECTRIC.

Model: PKA-A18HA4

(See Catalog)

2- Boiler:

Boiler capacity = Total heating load * corrections factor

= 269.21*1.2 = 323 KW.

Boiler model: Super Plus 300/3.

(See Catalog)

3- Expansion tank:

Expansion tank volume has been determent according to boiler capacity.

An expansion tank with volume of 1250

(See Catalog)

4- Chiller :

Chiller model: PSC4-145,with hermetic compressor R-410a.

(See Catalog)

5- Pumps :

Standard pumps and trim based on chiller capacities according to American slandered have been selected using pump tables in appendix.

CHAPTER FOURE

Plumbing System

CHAPTER 4

4.1 Introduction

Plumbing design, is the system of pipes drains fittings, valves, valve assemblies, and devices installed in a building for the distribution of water for drinking and washing, and the removal of waterborne wastes, and the skilled trade of working with pipes, tubing and plumbing fixtures in such systems.

Plumbing fixtures are exchangeable devices using water that can be connected to a building's plumbing system, Some examples of fixtures include water closets (also known as toilets), urinals, bidets, showers, bathtubs, utility and kitchen sinks, lavatory.

Water supply system, there are two basic types of water distribution systems for building:

1. up feed distribution system .
2. down feed distribution system.

in this project we will use the down feed distribution system, the supply of water for the embassy is received from the municipal, Usually the water pressure at the supply point of the municipality be between (35-50) psi, this water enters the well of the embassy and then by using pumps which pumping the water to the tanks called gravity tanks which located on the roof ,the water from the gravity tank on the roof surface provides the fixtures that are located in the floors below.

Minimum pressure required in the top floor is usually (15) psi for flush tank and maximum pressure on the lowest floor should not exceed (50) psi otherwise pressure reducing valves are used to reduce the pressure, if you use or pipe diameters change in the internal network, the pressure inside the tube does not change, which is changing the flow rate.

4.2 Calculations Hot and Cold demand

4.2.1 Water Service Sizing

To determine the water service water size in building, a technique called water supply fixture unit (WSFU) is used; WSFU = Water Supply Fixture Unit.

The following Tables will show the water supply fixture unit for the floor plane :

Using Table(1) for estimating demand : (See appendix (B))

a) Table 4.1 WSFU for basement floor

Fixture type	No. of Fixture	WSFU from Table (1) (FU)	Total No. of WSFU for cold water	Total No. of WSFU for hot water	Total No. of WSFU
Lavatory (General)	1	2*3/4	1.5	1.5	2
WC (General) flush tank	1	5	5	__	5
Bathtub(General)	1	4*3/4	3	3	4
Kitchen Sink(General)	3	4*3/4	3	3	12
Total			12.5	7.5	23

*By using interpolation the required flow is : (See appendix (B)) Table(2).

Hot and cold water = 16.1 gpm.

Cold water = 10 gpm.

Hot water = 6.25 gpm.

b) Table 4.2 WSFU for ground floor.

Fixture unit	No. of Fixture	WSFU from Table (1) (FU)	Total No. of WSFU for cold water	Total No. of WSFU for hot water	Total No. of WSFU
Lavatory (General)	12	2*3/4	18	18	24
Urinal(General) flush tank	4	3	12	--	12
WC (General) flush tank	12	5	60	__	60
kitchen sink (General)	2	4*3/4	6	6	8
Total			96	24	104

*By using interpolation the required flow is : (See appendix (B)) Table(2).

Hot and cold water = 45.8 gpm.

Cold water = 42.2 gpm.

Hot water = 16.32gpm.

c) Table 4.3 WSFU for first floor.

Fixture unit	No. of Fixture	WSFU from Table (1) (FU)	Total No. of WSFU for cold water	Total No. of WSFU for hot water	Total No. of WSFU
Lavatory (General)	8	2*3/4	12	12	16
Urinal(General) flush tank	4	3	12	--	12
WC (General) flush tank	8	5	40	—	40
kitchen sink (General)	1	4*3/4	3	3	4
Total			67	15	72

*By using interpolation the required flow is : (See appendix (B)) Table(2).

Hot and cold water = 35.1 gpm.

Cold water = 36.8 gpm.

Hot water = 11 gpm.

d) Table 4.4 WSFU for second floor.

Fixture unit	No. of Fixture	WSFU from Table (1) (FU)	Total No. of WSFU for cold water	Total No. of WSFU for hot water	Total No. of WSFU
Lavatory (General)	7	2*3/4	10.5	10.5	14
Urinal(General) flush tank	2	3	6	--	6
WC (General) flush tank	7	5	35	--	35
kitchen sink (General)	1	4*3/4	3	3	4
Total			54.5	13.5	59

*By using interpolation the required flow is : (See appendix (B)) Table(2).

Hot and cold water = 33 gpm.

Cold water = 31.6 gpm.

Hot water = 10 gpm.

4.2.2 Friction Method

The water velocity in the piping system in building is not preferred to exceed 8fps. Outside building it may exceeds 8 fps. Note : (1m = 3.28 ft).

1) Calculate static head for basement floor.

floor to floor height is 3 m.

Static head = floor to floor height + tank outlet height - sink faucet outlet height
Sink faucet outlet above basement level = 1m = 3.28 ft.
Tank outlet above roof surface(3+3+3+3+2) = 14 m = 45.92 ft.
Static head = 45.92 – 3.28 = 42.64 ft.
So then the static pressure = static head * 0.433 psi/ft = 42.64 * 0.433 = 18.5 psi.

2) Total equivalent length.

To calculate the equivalent length, we will calculate the equivalent length at roof surface to the farthest outlet (Sink faucet) at the basement floor at farthest collector.

a) For cold water system:

Total length from tank outlet to the basement floor through risers = 16 m = 52.5 ft.

Total length from riser to the collector = 10 m = 32.8 ft.

Total length from collector to Sink faucet outlet = 20 m = 65.6 ft.

Total length from tank outlet to the farthest outlet at the basement floor = (16+10+20) =46 m = 151 ft.

Total equivalent length = total length * 1.5 = 46 * 1.5 = 69 m = 226.3 ft.

b) For hot water system :

Total length tank outlet to the basement floor through risers = 16 m = 52.5 ft.

Total length from riser to the collector = 10 m = 32.8ft.

Total length from collector to Sink faucet outlet = 20 m = 65.6 ft.

Total length from tank outlet to the farthest outlet at the basement floor = (16+10+20) =46 m = 151 ft.

Total equivalent length = total length * 1.5 = 46 * 1.5 = 69 m = 226.3 ft.

3) Minimum flow pressure and friction head.

The minimum required flow pressure at the most remote outlet on the basement floor (Sink faucet) is 8 psi.

a- For cold water system:

Friction head = static pressure – minimum flow pressure

Friction head = 18.5 – 8 = 10.5 psi.

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

friction/100ft = 10.5 psi/226.3*100 ft = 3.94 (psi/100ft).

b- For hot water system:

Friction head = static pressure – minimum flow pressure

Friction head = 18.5 – 8 = 10.5 psi.

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

friction/100ft = 10.5 psi/226.3*100 ft = 3.94 (psi/100ft).

4) From Figure (1) for steel pipes (See appendix (B)).

Note: We will use this system in two Raisers, one of them for the cold and hot the other one.

Table 4.5 sizing pipe for cold water.

Distance between floor and branches	Flow rate (gpm)	Pipe size (inch)	Friction (psi/100ft)	Velocity (fps)
From tank to second floor	120.6	2 ½	3.94	8
Branch second floor	31.6	1 ½	2.84	5
From second to first floor	89	2 ½	2.84	5
Branch first floor	36.8	1 ½	4.25	5
From first to ground floor	52.2	2	2.1	4
Branch ground floor	42.2	1 ½	5	5
From ground to basement floor	10	1	3	3.8
Branch basement floor	10	1	3	3.8

Table 4.6 sizing pipe for hot water.

Distance between floor and branches	Flow rate (gpm)	Pipe size (inch)	Friction (psi/100ft)	Velocity (fps)
From tank to second floor	43.6	2	3.94	6
Branch second floor	10	1	2.8	4.25
From second to first floor	33.6	2	0.95	3
Branch first floor	11	1	3	3.8
From first to ground floor	22.6	1 ¼	2.8	4.25
Branch ground floor	16.3	1 ¼	2.5	4

From ground to basement floor	6.25	3/4	3.6	3.8
Branch basement floor	6.25	3/4	3.6	3.8

4.3 Drainage piping sizing

The required pipe sizing are calculated by using a concept of fixture unit instead of using gpm of drainage water, we use drainage fixture units (dfu). This unit takes into account not only the fixtures water use but also its frequency of use, that is the (dfu) has a built–in diversity factor.

This enable us, exactly as for water supply, to add the dfu of varies fixtures to obtain the maximum expected drainage flow. Drainage pipes are then sized for particular number of drainage fixtures units, according to Tables. (See appendix (B)) Table(3) & Table(4).
Built into these tables are the fill factors that are :
- Branches (Horizontal Pipes) to run maximum of (50%) fill.
- Stacks (Vertical Pipes) are designed to run at maximum of (25%-33%) fill.
- Building drain and swear drains may run somewhat higher (Over 50%) fill.

Tables will show the drainage fixture unit (dfu) for the roof plane.

a) Table 4.7 dfu for basement floor.

Fixture unit	No. of Fixture	Drainage Fixture Unit value, dfu Table (4)	dfu value (Horizontal Branch)	Diameter of Pipe, in. Table (3)
WC. Stack(E)	1	6	6	4
Lavatory. Stack(E)	1	1	1	2
Bathtubr. Stack(E)	1	6	6	4
Kitchen Sink. Stack(E)	1	2	2	3

b) Table 4.8 dfu for ground floor.

Fixture unit	No. of Fixture	Drainage Fixture Unit value, dfu Table (4)	dfu value (Horizontal Branch)	Diameter of Pipe, in. Table (3)
WC. Stack(A)	5	6	30	4
WC. Stack(B)	4	6	24	4
WC. Stack(F)	2	6	12	4
Urinal. Stack(A)	2	4	8	4

Urinal. Stack(B)	2	4	8	4
Lavatory. Stack(C)	5	1	5	2
Lavatory. Stack(D)	4	1	4	2
Lavatory. Stack(F)	2	1	2	2
Kitchen Sink. Stack(F)	1	2	2	2

c) Table 4.9 dfu for first floor.

Fixture unit	No. of Fixture	Drainage Fixture Unit value, dfu Table (4)	dfu value (Horizontal Branch)	Diameter of Pipe, in. Table (3)
WC. Stack(A)	4	6	24	4
WC. Stack(B)	4	6	24	4
Urinal. Stack(A)	2	4	8	4
Urinal. Stack(B)	2	4	8	4
Lavatory. Stack(C)	4	1	4	2
Lavatory. Stack(D)	4	1	4	2
Kitchen Sink. Stack(C)	1	2	2	2

d) Table 4.10 dfu for second floor.

Fixture unit	No. of Fixture	Drainage Fixture Unit value, dfu Table (4)	dfu value (Horizontal Branch)	Diameter of Pipe, in. Table (3)
WC. Stack(A)	4	6	24	4
WC. Stack(B)	2	6	12	4
Urinal. Stack(A)	2	4	8	2
Lavatory. Stack(C)	4	1	4	2
Lavatory. Stack(D)	2	1	2	2
Kitchen Sink. Stack(C)	1	2	2	2

Table 4.11 dfu for vertical stack.

Stack	dfu value (Stack)	Diameter of Pipe, in. Table (3)
A	102	4
B	76	4
C	17	4
D	10	4
E	15	4
F	16	4

4.4 Sanitary Drainage System

4.4.1 Manhole Design

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.

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

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

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

Θ 120 cm for manhole depth > 250 cm.

4.4.2 Manholes Calculations

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 = -0.6m

Depth = 0.6

Invert level=Top level-Depth = -0.6- 0.6 = -1.2m

For manhole #. 2 :

The distance between manhole 1 & manhole 2 is 10 m.

Invert level for manhole 2 is:

Y = ((S*Slope) + 0.075)

Where: S is the distance between manhole 1 & manhole 2.

Slope is 1.5%

7.5 cm, is the point in manhole 2 where the pipe will be connected.

So:

Y = ((10 * Slope) + 0.075)

= ((10 * 0.015) + 0.075)

= 0.225

Top level = -0.6m

Invert level of manhole 2 = Invert level of M1 – Y = -1.2 - 0.225 = -1.43 m.

Depth = $T.L_{M2}$ - $I.L_{M2}$ = -0.6 + 1.43 = 0.83 m.

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

Table 4.12 Manholes Calculations.

Manhole #	Top level (m)	Invert level (m)	Depth (m)	Diameter (m)	Cover type
M_1	-0.6	-1.2	0.6	0.60	Medium duty
M_2	-0.6	-1.43	0.83	0.60	Medium duty
M_3	-0.6	-1.65	1.05	0.80	Medium duty

M_4	-0.6	-1.88	1.28	0.80	Medium duty
M_5	-0.6	-2.1	1.5	0.80	Medium duty
$D.M_6$	-0.6	-2.33	1.73	1.00	Medium duty
M_7	-0.85	-2.8	2.05	1.00	Medium duty
$D. M_8$	-0.85	-3.03	2.23	1.00	Medium duty
M_9	-2.7	-5.15	2.45	1.00	Medium duty
M_{10}	-2.7	-4.93	2.23	1.00	Medium duty
M_{11}	-2.7	-4.71	2.01	1.00	Medium duty
M_{12}	-2.7	-4.48	1.78	1.00	Medium duty
M_{13}	-2.7	-4.26	1.56	1.00	Medium duty
M_{14}	-2.7	-4.04	1.34	1.00	Medium duty
M_{15}	-2.7	-3.82	1.12	1.00	Medium duty
M_{16}	-2.7	-3.59	0.89	0.6	Medium duty
$D.M_{17}$	-1.5	-2.84	1.34	1.00	Medium duty

4.4.3 Selection The Diameter And The Slope Of The Drainage Pipe System

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.

1) We will use pipes (Branches) from fixture unit to the floor drainage (F.D.) with diameter (2") for lavatory and shower and with slope(2%).
2) 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%).
3) 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.
4) 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.
5) 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.

6) We will use a stack with diameter (4") in order to drain the waste water to the manholes.

4.4.4 Drainage Piping Fill

1) Branches are designed to run maximum of 50% fill.
2) Stacks are designed to flow between 25 – 30 % maximum.
3) Building drains and sewer drains may be designed over 50% fill.

4.4.5 Drainage Piping Velocity

1) For branches the recommended velocity is 2 ft/s.
2) For building the recommended velocity is 3 ft/s.
3) For greasy the recommended velocity is 4 ft/s.

Velocity of water flow through drainage piping depends on:

1) Pipe diameter.
2) Slope.

For the same diameter large pipe diameter required lower slope
For pipes of diameter $\leq$ 3" the minimum slope is 1/4 in/ ft.

For pipes of diameter $\geq$ 4" the minimum slope is 1/8 in/ ft.

CHAPTER FIVE

FIRE FIGHTING SYSTEM

CHAPTER 5

5.1 The Fire Triangle

There are three (3) components required for combustion to occur:

Fuel – to vaporize and burn

Oxygen – to combine with fuel vapor

Heat – to raise the temperature of the fuel vapor to its ignition temperature

The following is the typical "fire triangle", which illustrates the relationship between these three components:

Figure 5.1 the fire triangle

5.2 Classifications of Fire

Fires are classified into five groups as follows:

Class A: Class A fires involve common combustibles such as wood, paper, cloth, rubber, trash and plastics. They are common in typical commercial and home settings, but can occur anywhere these types of materials are found.

Class B: Class B fires involve flammable liquids' gases, solvents, oil, gasoline, paint, lacquers, tars and other synthetic or oil-based products. Class B fires often spread rapidly and, unless properly secured, can reflash after the flames are extinguished.

Class C: Class C fires involve energized electrical equipment, such as wiring, controls, motors, data processing panels or appliances. They can be caused by a spark, power surge or short circuit and typically occur in locations that are difficult to reach and see.

Class D: Class D fires involve combustible metals such as magnesium and sodium. Combustible metal fires are unique industrial hazards which require special dry powder agents.

Class K: Class K fires involve combustible cooking media such as oils and grease commonly found in commercial kitchens. The new cooking media formulations used form commercial food preparation require a special wet chemical extinguishing agent that is especially suited for extinguishing and suppressing these extremely hot fires that have the ability to reflash.

A	Common Combustibles	Wood, Paper, Cloth, Etc.
B	Flammable Liquids & Gases	Gasoline, Propane other Solvents
C	Live Electrical Equipment	Computers, Fax Machines, Etc.
D	Combustible Metals	Magnesium, Lithium, Titanium
K	Cooking Media	Oils, Lards, Fats

Figure 5.2 types of fires as classified

5.3 Fire Signatures

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

5.4 Types of Firefighting Systems

Fire systems are classified as follows:

5.4.1 Portable 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 Firefighting Extinguishers**

1) Water extinguishers.

2) Water spray water extinguishers.
3) Antifreeze solution extinguishers.
4) Foam fire extinguishers, hand and wheeled.
5) Carbon dioxide extinguishers.
6) Clean agent extinguishers.
7) Dry chemical extinguishers, hand and wheeled.
8) Wet chemical extinguishers.
9) Liquid gas-type extinguishers.
10) Combustible metal extinguishers, hand and wheeled.
11) Residential kitchen cooking fire extinguishers.

- **Types of Occupancies for Protection by Fire Extinguishers.**

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

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

3) Extra (high) hazard occupancy:
   Defined as a room, space, or enclosure where the combustibility of contents of the storage, handling, or manufacturing of class A combustible material in which the quantity of class A material is high, or where large amount of class B flammables (more than 5 gallons) are present, and where rapidly developing fires with high rates of heat release are expected.
   Extra (high) hazard occupancies could consist of wood working, vehicle repair, air craft and boat servicing, cooking areas, individual product displays and storage and manufacturing processes such as painting, dipping, coating, and flammable liquid handling.

4) Mixed occupancies:
   Building featuring more than one occupancy may be protected on a room or area basis, with extinguishers appropriately placed for the occupancy. An example is a school, which would be expected to be protected with extinguishers rated for class hazards and light hazard occupancy, but also may contain a laboratory with a significant quantity of flammable liquid hazard, which would be protected by extinguishers rated for class B hazards and ordinary hazard occupancy.

5) Specialized occupancies:
   Aircraft hangar.

5.4.2 Installed Firefighting Systems

Automatic fire fighting system are designed and installed in buildings to protect them from fire, these systems are operating as automatic without any human influence when the fire be started.

every installed system has a general components such as pipes, smoke and fire detectors, nozzles and sprinklers, alarm, control panel, and firefighting materials, these systems are divided into two main parts mechanical and electrical parts, the mechanical parts are explained above and electrical component as software installed on CPU and memory in control panel to control of subsystem, the control panel supplied by AC current and DC current from batteries if the current from network is cutoff .

- **Types of Installed Firefighting Systems**

1) Water firefighting system.

- Sprinklers.
- Spray.
- Foam.

2) Carbon dioxide system.
3) Dry chemical system.
4) Halon system.
5) FM 200 system.

5.5 FM 200 Firefighting Systems

FM-200 (Heptafluoropropane, CF3CHFCF3) is a colorless, non-toxic gas, and a clean and effective fire suppression agent. It is normally shipped and stored as a liquefied compressed gas, and hence is typically handled under saturated conditions, the liquid and vapor phases coexist in equilibrium. An understanding of the physical properties of FM-200 and the safe and proper techniques for handling liquefied compressed gases allows the agent to be safely transferred from shipping cylinders to the desired end-use container**.**

5.5.1 Physical and Chemical Properties of FM 200

Some of the more important physical and chemical properties of FM-200

Table 5.1 physical properties of FM200

Physical Properties	Measurement
Molecular weight	170.03
Boiling point at 1 atm	–16.34 °C
Freezing point	–131 °C
Critical temperature	101.75 °C
Critical pressure	2.91 MPa
Critical volume	1.61 L/Kg
Critical density	594.25Kg/L
Critical compressibility	0.225
Acentric factor	0.356
Specific heat, saturated liquid	1.184 (Cp) at 25°C, KJ/Kg per °C
Specific heat, saturated vapor	0.859 (Cp) at 25°C, KJ/Kg per °C
Specific heat, superheated vapor	0.808 (Cp) at 25°C, KJ/Kg per °C
Thermal conductivity, liquid	0.069 W/Mk at 25°C
Thermal conductivity, vapor	0.0126 W/Mk at 25°C
Viscosity, liquid	0.184Centipoise at 25°C
Viscosity, vapor	0.0127Centipoise at 25°C
Surface tension	7.00 MN/M at 25°C

Table 5.2 chemical properties of fm200

Chemical Properties	Measurement
Chemical Name	1,1,1,2,3,3,3-Heptafluoropropane
Molecular Formula	CF3CHFCF3
Molecular weight	170.03
CAS Registry Number	431-89-0
ASHRAE Designation	HFC-227ea

5.5.2 Advantages and Disadvantages of FM 200

- **Advantages of FM200**
  - Fast and effective.
  - No significant reduction in oxygen levels.
  - Clean gaseous agent leaving no residue.
  - Zero ozone depleting potential.
  - Low global warming potential related of Halon.
  - Short atmospheric life span.
  - Electronically non-conductive.
  - Safe for use in fully occupied areas.
  - Minimal storage requirement.
  - Versatile range of containers, nozzle and ancillaries.
  - Extensively tested, recognized and approved worldwide.
  - Effective on site installation.

- **Disadvantages of FM 200**
  - Forms minimal decomposition products.
  - Higher agent cost.

5.6 Sequence of Operations of FM 200 Systems.

FM 200 system is gas suppression system extinguished in the space as gas vapor at high pressure (4-6) bar to cover the protected area in the following sequence of operation:

1) Once first detector in the space sending smoke directly send signal to control panel.

2) Control panel sending the following signal:

- Actuating 1st stage alarm.
- Shutdown A/C or ventilation system.
- Closing automatic roll up shutter.

3) On control panel receiving signal from 2nd detector, sending the following signal.

- Actuating 2nd stage alarm system.
- To fire alarm system in the building.
- Actuating FM200 solenoid valve directly controlling the FM 200 gas flow.
- After (30-60) sec, the solenoid valve start relapsing the gas from cylinder.
- After (20-40) sec, the solenoid valve start relapsing the gas.

4) Anyone in the building can release manually the gas in case there is fire and the system not responded automatically.

5.7 Clean Agent Estimation.

The clean agent (FM-200) Heptafluoropropane is widely used as a substitute for Halon. Halon 1301 is an effective fire suppressant and has been widely used in total flooding gas protection system**,** but the physical and chemical properties of FM-200 are not the same as Halon 1301, FM200 has better properties than Halon 1301.

The steps needed to design the system including the limitations imposed on the requirements of standards (NFPA2001).

To design FM-200 system, we must follow these steps:

1) Perform a hazard analysis and survey of protected area.
2) Determine the design concentration required for the hazard.
3) Calculate the volume of the protected area.
4) Calculate FM-200 agent quantity to provide required design concentration at minimum expected ambient temperature in protected area.

First of all, is must select the type of hazard which the system will operate with it, and the hazard is three types as:

- **Class A Fires**: Fire in ordinary combustible materials, such as wood, cloth, paper, rubber, and many plastics.
- **Class B Fires**: Fire in flammable liquids, oils, greases, tars, oil-based paints, lacquers, and flammable gases.
- **Class C Fires**: Fire that involves energized electrical equipment where the electrical resistivity of the extinguishing media is of importance.

The second step, is determine the design concentration and this value depend on type of hazard, from (NFPA2001) chart the minimum design concentration of three class as following:

- **Class A Fires**: minimum design concentration is 1.2%.
- **Class B Fires**: minimum design concentration is 1.3%.
- **Class C Fires**: minimum design concentration is 1.2%.

Third step, is calculating the volume of spaces that need to install FM200 in it with following equation

V= L*W*H (5.1)

Where is:

V: volume of space [m^3].

L: length of space [m].

W: Width of space [m].

H: High of space [m].

Finally, the last step to calculate the weight of FM200 we need to protect this area by this equation:

$$W=\frac{V}{S}*\left(\frac{C}{100-C}\right) \quad (5.2)$$

Where is:

W: Weight of FM200 [kg].

V: Net Volume of the Hazard [m^3].

S: Specific Volume of superheated agent vapor at 1 atmosphere and the design temperature[m^3/Kg].

C: FM 200 Design Concentrations.

The specific volume of superheated FM-200 vapor, S, may be approximated using the following equation:

S =0.12693 + 0.0005131 T (5.3)

Where:

T = temperature in °C

Nozzles in the system must be installed in a vertical position with the nozzle facing down, nozzles are available in both 180° and 360° discharge patterns. The 180° (sidewall) nozzle is designed for installation along the walls of the hazard, with the discharge directed away from the wall on which it is installed. The 360° nozzle is designed to be installed in the center of the area being protected.

180 ° nozzles must be located 0.3 ± 0.05m from a wall, with the orifices directed away from the wall. The nozzle shall be located as close to the centre of the wall as possible, but at least 1/3 of the way along the wall.

180 ° nozzles have a maximum coverage area defined as any rectangle that can be inscribed in a semicircle of distance 14.73m (48.3 ft), as seen in table 5.3

180 °nozzles may be used in a back-to-back configuration. The nozzles should be placed 0.3 m to 0.6 m (1 to 2 ft) apart.

360° Nozzles must be located as close to the centre of the enclosure apossible.360° Nozzles have a maximum area defined as any rectangle that can be inscribed in a circle of radius 9.06 m (29.7 ft) , as seen in table 5.3

Nozzles must be installed so that the orifices are located 0.15 ± 0.05 m (6 ± 2 inches) below the ceiling.

Table 5.3 maximum nozzle straight line distances.

Nozzle	Distances (m)	Distances (ft)
180°	14.73	48.33
360°	9.06	29.73

When designing pipe network systems, the following design parameters should be considered to avoid system reject as 70.6 psi (4.87 bar) minimum nozzle pressure, 80 % maximum agent in pipe, and between 6 - 10 seconds discharge time.

So the pipes diameter are determined depending on flow rate of FM200, and the flow rate of gas can be calculated by division the weight of FM200 on 10 sec, 10sec is the maximum time for discharge gas into spaces, the following table from (NFPA2001) chart explain the relationship between flow rate and pipes diameter.

Table 5.4 relation between pipe diameter and flow rate.

Pipe Size(in)	Minimum Flow Rate (kg/sec)	Maximum Flow Rate (kg/sec)
3/8	(0.27)	(0.91)
1/2	(0.45)	(1.36)
3/4	(0.91)	(2.50)
1	(1.59)	(3.86)
1 1/4	(2.72)	(5.67)
1 1/2	(4.08)	(9.07)

2	(6.35)	(13.61)
2 1/2	(9.07)	(24.95)
3	(13.61)	(40.82)
4	(24.95)	(56.70)
5	(40.82)	(90.72)
6	(54.43)	(136.10)

5.8 Sample of Weight for FM200.

For second floor.

For room #D1 Official Military Room.

1) V= L*W*H (5.1)

V= 13.85*3 = 41.55 m^3

2) $W= \frac{V}{S} * (\frac{C}{100-C})$ (5.2)

For maximum weight at T=27°C, S= 0.1420 [m^3/Kg].

W= (41.55/0.1377)*(8.4/100-8.4) = 27.7 Kg.

For minimum weight at T=21°C, S= 0.1377 [m^3/Kg].

W= (41.55/0.1420)*(8.4/100-8.4) = 26.8 Kg.

3) Flow rate of FM200.

Q = 27.7/10 = 2.77 [kg/sec]

The diameter pipe from table(5.4) is 3/4 in .

The number of nozzle is one from 360° type.

5.9 Total Weight of FM200 for Embassy.

Table 5.5 total weight of FM200 for basement floor (ZONE 1).

Number	Area(m^2)	FM Weight(Kg)	Number of Nozzle 180°or 360°	Pipe Diameter(in)
A1	30.86	50	1-180°	1 1/4
A2	21.91	36	1-360°	1
A3	21.83	36	1-360°	1

A4	33.38	54	1-360°	1 1/4
A5	40.46	65	1-360°	1 1/4
A6	22.17	36	1-360°	1
A7	13.88	28	1-180°	3/4
A8	18.63	31	1-180°	1
Total		336		

The diameter of outlet pipe of cylinder is 3(in), from (NFPA2001) chart.

Table 5.6 total weight of FM200 for ground floor (ZONE 2).

Number	Area(m^2)	FM Weight(Kg)	Number of Nozzle 180°or 360°	Pipe Diameter(in)
B1	124.13	202	1-180°	2
B2	102.30	166	2-360°	1 1/2
B16	10.02	17	1-180°	1/2
B17	102.30	166	2-360°	3/4
B18	27.07	44	1-360°	1
Total		595		

The diameter of outlet pipe of cylinder is 4(in), from (NFPA2001) chart.

Table 5.7 total weight of FM200 for ground floor (ZONE 3).

Number	Area(m^2)	FM Weight(Kg)	Number of Nozzle 180°or 360°	Pipe Diameter(in)
B3	16.35	27	1-360°	3/4
B4	25.79	43	1-360°	1
B5	17.64	28	1-360°	3/4
B6	21.74	36	1-360°	1
B7	24.24	38	1-360°	1
B8	20.46	35	1-360°	1
B9	32.63	54	1-360°	1 1/4
B10	26.29	44	1-360°	1
B11	17.9	28	1-360°	1/2
B12	46.92	77	1-180°	1 1/4
B13	17.06	28	1-180°	1/2
B14	6.37	11	1-180°	3/8
B15	10.27	16	1-180°	1/2
Total		357		

The diameter of outlet pipe of cylinder is 3(in), from (NFPA2001) chart.

Table 5.8 total weight of FM200 for first floor (ZONE 4).

Number	Area(m^2)	FM Weight(Kg)	Number of Nozzle 180°or 360°	Pipe Diameter(in)
C1	7.80	13	1-360°	1/2
C2	12.8	22	1-360°	3/4
C14	27.09	44	1-360°	1
C15	32.64	54	1-360°	1 1/4
C16	26.36	43	1-360°	1
Total		176		

The diameter of outlet pipe of cylinder is 2(in), from (NFPA2001) chart.

Table 5.9 total weight of FM200 for first floor (ZONE 5).

Number	Area(m^2)	FM Weight(Kg)	Number of Nozzle 180°or 360°	Pipe Diameter(in)
C3	12	21	1-360°	3/4
C4	20.04	35	1-180°	1
C5	19.15	33	1-360°	1
C6	16.98	30	1-360°	1
C7	15.71	26	1-360°	3/4
C8	4.22	7	1-360°	3/8
C9	11.38	20	1-360°	3/4
C10	17.1	31	1-360°	1
C11	16.07	30	1-360°	1
C12	21.93	36	1-360°	1
C13	31.99	53	1-360°	1 1/4
C17	22.44	37	1-360°	1
C18	19.63	35	1-180°	1
Total		394		

The diameter of outlet pipe of cylinder is 3(in), from (NFPA2001) chart.

Table 5.10 total weight of FM200 for second floor (ZONE 6).

Number	Area(m^2)	FM Weight(Kg)	Number of Nozzle 180°or 360°	Pipe Diameter(in)
D1	13.85	28	1-360°	3/4
D2	7.1	13	1-360°	1/2
D3	11.29	20	1-360°	3/4
D4	7.06	13	1-360°	1/2
D5	13.71	23	1-360°	3/4
D12	30.88	52	1-360°	1 1/4

D13	26.65	44	1-360°	1
Total		193		

The diameter of outlet pipe of cylinder is 2 1/2(in), from (NFPA2001) chart.

Table 5.11 total weight of FM200 for second floor (ZONE 7).

Number	Area(m^2)	FM Weight(Kg)	Number of Nozzle 180°or 360°	Pipe Diameter(in)
D6	21.51	36	1-360°	1
D7	23.19	38	1-360°	1
D8	26.63	40	1-360°	1 1/4
D9	48.08	78	1-360°	1 1/4
D10	13.81	23	1-360°	3/4
D11	16.71	31	1-360°	1
Total		246		

The diameter of outlet pipe of cylinder is 2 1/2(in), from (NFPA2001) chart.

5.10 Selections of other FM200 System Components.

1) Nozzles.

Type of nozzles are installing in parts of embassy. that's made by FIKE Company.

Model: (180°-80-060/80-066), (360°-80-052/80-058).

(See Catalog)

2) Heat Detector.

Heat detectors made by EDWARDS SIGNALING Company, and will installing in every spaces protecting by firefighting system.

Model: 281B-PL.

(See Catalog)

3) **Smoke Detector.**

Smoke detectors made by Imagination at Work Company, and will installing in every spaces protecting by firefighting system.

Model: 541NCSRXT.

(See Catalog)

4) Control Panel.

Every zone need control panel to process any signal coming from any sensor.

Model: HCP-1008E.

(See Catalog)

5) Cylinder of FM200 Agent.

Cylinders that's used in every zone made by FIKE Company .

Model: 4BW500.

(See Catalog)

References:

[1] Ronald L.Howell, Principles of Heating Ventilating and Air Conditioning 6th edition, ASHRAE, USA, 2009.

[2] Mohammad A. Hammed, Heating and Air conditioning3rd edition , Jordan, 1996.

[3] Brain L.Olsen,Plumbing System 2nd edition,Missouri Group, USA, 1982.

[4] Dennis Kubicki, FIRE PROTECTION DESIGN CRITERIA 3rd edition, Washington, D.C, 1982.

[5] http://www.nfpa.org/codes-and-standards/document-information- .

APPENDIX (A)

Table(1)

LE 9–4 Cooling load temperature differences (CLTD) for various construction groups of sunlit walls, °C.

North Latitude Wall Facing	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																											
	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
E	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
.	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
Ξ	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
	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
V	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
r	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
N	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																											
I	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
E	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
(	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
E	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
;	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
N	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
V	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
W	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																											
(	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
E	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
3	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
E	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
;	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
W	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
[illegible]	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
NW	14	13	12	11	10	9	8	7	6	6	5	5	6	6	6	7	9	10	12	14	15	15	15	15	22	5	15	10
	Group D Walls																											
N	8	7	7	6	5	4	3	3	3	3	4	4	5	6	6	7	8	9	10	11	11	10	10	9	21	3	11	8
NE	9	8	7	6	5	5	4	4	6	8	10	11	12	13	13	13	14	14	14	13	13	12	11	10	19	4	14	10
E	11	10	8	7	6	5	5	5	7	10	13	15	17	18	18	18	18	18	17	17	16	15	13	12	16	5	18	13
SE	11	10	9	7	6	5	5	5	5	7	10	12	14	16	17	18	18	18	17	17	16	15	14	12	17	5	18	13
S	11	10	8	7	6	5	4	4	3	3	4	5	7	9	11	13	15	16	16	16	15	14	13	12	19	3	16	13
SW	15	14	12	10	9	8	6	5	5	4	4	5	5	7	9	12	15	18	20	21	21	20	19	17	21	4	21	17
W	17	15	13	12	10	9	7	6	5	5	5	5	6	6	8	10	13	17	20	22	23	22	21	19	21	5	23	18
NW	14	12	11	9	8	7	6	5	4	4	4	4	5	6	7	8	10	12	15	17	18	17	16	15	22	4	18	14

Table(2)

TABLE 9-2 Latitude-Month correction factor LM, as applied to walls and horizontal roofs, north latitudes.

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

Table(3)

TABLE 9-7 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(4)

TABLE 9-8 Shading coefficient (SC) for glass windows without interior shading.[1]

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

Table(5)

TABLE 9–10 Cooling load factors (CLF) for glass windows without interior shading, north latitudes.

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

Table(6)

TABLE 9-13 Heat gain rate from miscellaneous appliances, W.[a]

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

Table(7)

TABLE 9-14 Cooling load factor $(CLF)_u$, for lights.

Number of hours after lights are turned On	Fixture X[c] hours of operation 10	Fixture X[c] hours of operation 16	Fixture Y[c] hours of operation 10	Fixture Y[c] hours of operation 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(8)

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

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

Table(9)

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

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

Table(10)

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

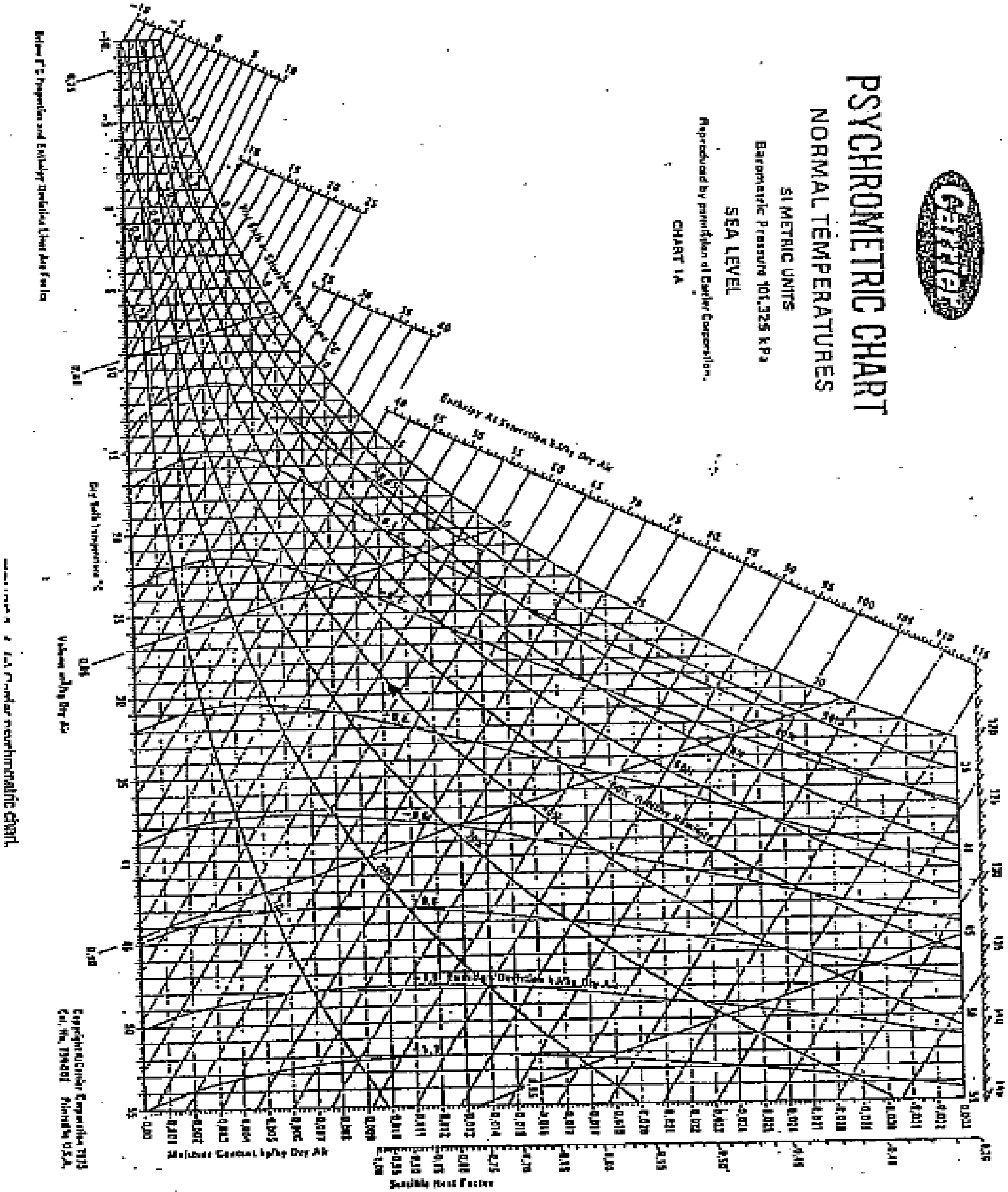
№	Topography of Location	Value of S_1
1	Protected locations by hills or buildings (wind speed = 0.5 m/s)	0.9
2	Unprotected locations such as sea shores, hill tops, etc.	1.1
3	Locations other than that listed in item (1) or (2) of this table.	1.0

Table(11)

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

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

Figure (1)


PSYCHROMETRIC CHART
NORMAL TEMPERATURES
SI METRIC UNITS
Barometric Pressure 101.325 kPa
SEA LEVEL
Reproduced by permission of Carrier Corporation.
CHART 1A
Enthalpy At Saturation kJ/kg Dry Air
Dry Bulb Temperature °C
Moisture Content kg/kg Dry Air
Sensible Heat Factor

APPENDIX (B)

Table(1)

Table 9.3 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[f]	Private	Automatic	1	½
Drinking fountain	Offices, etc.	Faucet ⅜ in.	0.25	½
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[e]
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(2)

Table 9.4 Table for Estimating Demand

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

Table(3)

Table 10.4 Horizontal Fixture Branches and Stacks

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

Table(4)

Type of Fixture or Group of Fixtures	Drainage Fixture Unit Values
Automatic clothes washer (2" standpipe)	3
Bathroom group consisting of a water closet, lavatory and bathtub or shower stall:	
Flushometer valve closet	8
Tank-type closet	6
Bathtub (with or without overhead shower) 1 1/2" trap	2
Bidet 1 1/2" trap	3
Clinic sink	6
Combination sink-and-tray with food waste grinder 1 1/2" trap	4
Combination sink-and-tray with one 1 1/2" trap	2
Combination sink-and-tray with separate 1 1/2" traps	3
Dental unit or cuspidor	1
Dental lavatory	1
Drinking fountain	1/2
Dishwasher, domestic	2
Floor drains with 2" waste	3
Kitchen sink, domestic, with one 1 1/2" trap	2
Kitchen sink, domestic, with food waste grinder	2
Lavatory with 1 1/4" waste	1
Laundry tray (1 or 2 compartments)	2
Shower stall, domestic 2" trap	2
Showers (group) per head	2
Sinks:	
Surgeon's	3
Flushing rim (with valve)	6
Service (trap standard)	3
Service (P trap)	2
Pot, scullery, etc.	4
Urinal, pedestal, siphon jet blowout	6
Urinal, stall lip	4
Urinal stall, washout	4
Urinal trough (each 6-foot section)	2
Wash sink (circular or multiple) each set of faucets	2
Water closet, tank-operated	4
Water closet, valve-operated	6
Fixtures not listed above:	
Trap Size 1 1/4" or less	1
Trap Size 1 1/2"	2
Trap Size 2"	3
Trap Size 2 1/2"	4
Trap Size 3"	5
Trap Size 4"	6

Figure (1)

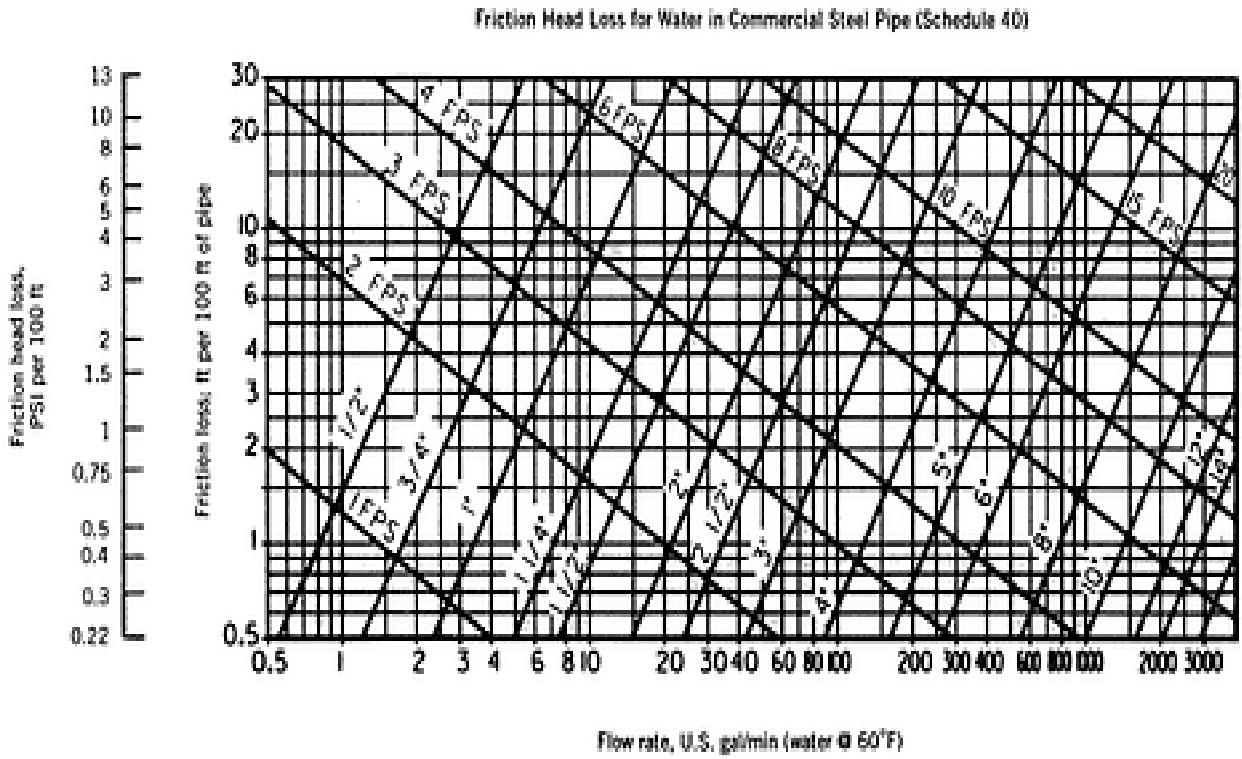


Figure 9.5 Chart of friction head loss in Schedule 40 black iron or steel pipe, for water at 60°F, in feet of water and psi per 100 ft of equivalent pipe length. Pipe sizes are nominal. (Reprinted by permission of the American Society of Heating, Refrigerating and Air-Conditioning Engineers, Atlanta, Georgia, from the 1993 *ASHRAE Handbook—Fundamentals*.)

Catalogues, Charts and Tables