Palestine Polytechnic University

College of Engineering & Technology

Mechanical Engineering Department

Graduation Project

Design of Mechanical Systems for a Hospital in Birzeit City

Project Team

Mahmoud Qabaja   Abdulla Salih   Ahmad Abo omeir

Project Supervisor

Eng.Kazem Osaily

Hebron-Palestine

June, 2010

Palestine Polytechnic University

Hebron-Palestine

College of Engineering & Technology

Mechanical Engineering Department

Project Name

Design of Mechanical System for Hospital in Birzeit City

Project Team

Mahmoud Kabaja Abdulla Salih Ahmad Abo omeir

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

Supervisor signature

………………………………

Examine committee signature

………………… ……………… ……………..

Department Head signature

…………………………..

Dedication

We gift graduation project

Firstly to our parents that supporting

Us till we reach to this stage

To our confreres in this university

To who appreciates the importance of science

To whom exist inside occupation prisons

To every person who makes every effort

To liberate our home

For all, we gift this done

Acknowledgement

Our thanks go first to our advisor eng.Kazem Osaily, his guidance and support made this work possible.

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

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

Abstract

This project deals with the design of mechanical systems for a hospital in Bier zait city which consists of eight stories with a total area of 9000 [m^2].

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

This project discuses briefly theory needed for the design of mechanical systems. Design output is then displaced on drawing . These drawing will include : piping networks for water distribution , drain and sewage and medical gas system . also drawing will detail duct systems and different equipment required for the hospital.

Table of Contents

List of Tables

List of Figure

CHAPTER ONE

INTRODUCTION

1.1 Project Outline:

Chapter One:

Includes the overview about project , project objectives and benefits.

Chapter Two:

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

Chapter Three:

Includes an overview about HVAC systems , heating system and heating load calculation procedures also the source of heat loss inside hospital. It contains air conditioning system and how to calculate cooling load from all sources of heat gain inside hospital 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 hospital 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, also components of drainage system design and about storm rain water drainage.

Chapter Five:

Includes overview about medical gases 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 medical 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.

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 graduating.

2-Hospitals form the difficult mechanical design because it needs special care to make inside climate more comfortable and healthier , so this field was chosen to be expert mechanical systems.

1.5 hospital description:

The hospital consists of eight stories, each story has an area of 4500 [m^2] and the total area of hospital with surrounding area is about 9000[m^2] . And it contains the following administration departments:-

1- Medical administration.
2- Managerial administration.
3- Financial department and accountancy.

The hospital also has the following medical departments:-

1- Delivery department.
2- Surgery department.
3- Emergency department.
4- Radiology department.
5- Labs of medical test.
6- Pharmacy.

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

1.6 First semester Budget :

Table [1-1] : Budget one

TASK	COST (NIS)
USING INTERNET	100
PRINTING PAPERS	50
REPRINTING PAPER	100
BUYING BOOKS	50
TOTAL	300

1.7 Second semester Budget :

Table [2-1] : Budget two

TASK	COST (NIS)
USING INTERNET	200
PRINTING PAPERS	1400
REPRINTING PAPER	100
BUYING BOOKS	50
TOTAL	1750

1.8 first semester time table :

Table [3-1] : Time table

Week / Task	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Select project name	■	■														
Gather information			■	■												
Writing introduction					■	■	■									
HVAC System								■	■	■	■	■	■			
Printing final copy														■	■	

1.9 Second semester time table :

Table [4-1] : Time table

Week Task	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
HVAC																
MIDICAL GASES																
PLUMPING SYSTEMS																
Billy of Qualities																
Printing final copy																

CHAPTER TWO

HUMAN COMFORT

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 dray 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 looses 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 humidity ϕ , is the ratio of actual partial pressure of the water vapor in the air p_v , partial pressure of the water vapor.

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 80% 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 hospital, we will choose

78ºF [25.6ºC] dry-bulb temperature and 50% relative humidity as the desired indoor condition during the cooling season.

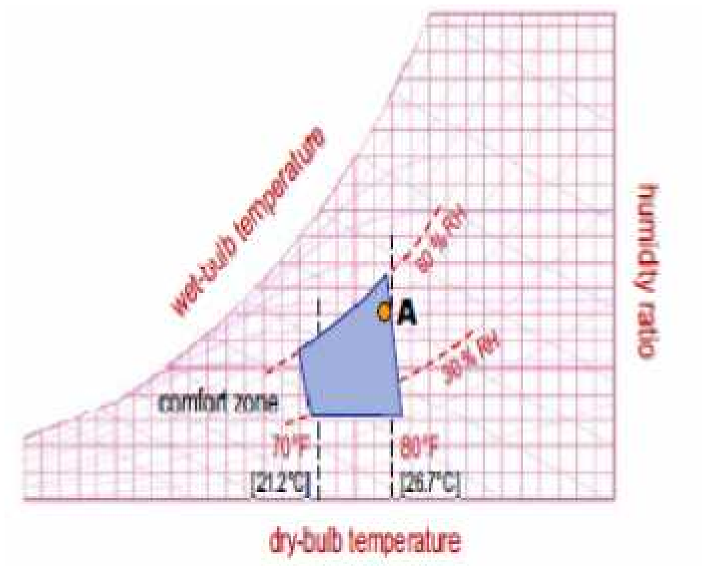


Figure 2-1 comfort zone for operating and temperature and relative humidity

2.1.3 Comfort Condition Inside Hospital

All calculation (heating and cooling loads) will be made according to specified values for inside conditions of hospital design in table (2-1) below refer to dry bulb temperature and relative humidity in both summer and winter seasons.

Table 2-1 Indoor Design Conditions

Room or Area	Summer		Winter	
	Db Degrees C (Degrees F)	RH Percent	Db Degrees C (Degrees F)	RH Percent
Animal Research (Animal Rooms)	18 (65)	60 (±5)	29 (85)	30 (±5)
Auditoriums	24 (76)	60	22 (72)	--

Room or Area	Summer		Winter	
	Db Degrees C (Degrees F)	**RH Percent**	**Db Degrees C (Degrees F)**	**RH Percent**
AIDS Patient Areas	24 (76)	50	25 (78)	30
Autopsy Suites	24 (76)	60	24 (76)	30
Bathrooms & Toilet Rooms	25 (78)	--	22 (72)	--
Blood Banks	22 (72)	50	22 (72)	30
BMT (Bone Marrow Transplant) Patient Areas	24 (76)	50	25 (78)	30
Computer Rooms	21 (70)	40 (±5)	21 (70)	40 (±5)
CT Scanner	24 (76)	50	25 (78)	30
Dialysis Rooms	25 (78)	50	22 (72)	30
Dining Rooms	25 (78)	50	22 (72)	30
Dry Labs	25 (78)	50	22 (72)	30
Electrical Equipment Rooms	Ventilation Only		10 (50)	--
Elevator Machine Rooms, Electric Drive	36 (94)	--	10 (50)	--
Elevator Machine Rooms, Hydraulic	36 (94)	--	10 (50)	--
Emergency Generator	42 (110)	--	4 (40)	--
Examination Rooms	24 (76)	50	25 (78)	30
Gymnasiums	Ventilation Only		21 (70)	--
ICUs (Coronary, Medical, Surgical)	23–29 (75–85)	30–60	23–29 (75–85)	30-60
Isolation Suites	24 (76)	50	25 (78)	30
Kitchens	27 (82)	60	21 (70)	--
Laboratories	24 (76)	50	22 (72)	30
Laundries	28 (84)	60	19 (68)	-
Linear Accelerators	24 (76)	50	25 (78)	30
Locker Rooms	25 (78)	50	22 (72)	30

Room or Area	Summer		Winter	
	Db Degrees C (Degrees F)	**RH Percent**	**Db Degrees C (Degrees F)**	**RH Percent**
Lounges	25 (78)	50	22 (72)	30
Mechanical Equipment Rooms (MERs)	Ventilation Only		10 (50)	--
Medical Media:				
Minor O.R.s (Trauma Rooms)	24 (76)	50	25 (78)	30
Motor Vehicle Maintenance/Storage	Ventilation Only		21 (70)	--
MRI Units	24 (76)	50	25 (78)	30
Offices, Conference Rooms	25 (78)	50	22 (72)	30
Operating Rooms (O.R.s)	17–27 (62-80)	45-55	17-27 (62-80)	45-55
Operating Rooms (O.R.s) - Animal	22 (73)	50	22 (73)	50
Patient Rooms	24 (76)	50	25 (78)	30
Pharmacy	22 (72)	50	22 (72)	30
Radiation Therapy	24 (76)	50	25 (78)	30
Recovery Units	23 (75)	50	23 (75)	30
Smoking Area	25 (78)	50	22 (72)	30
SPECIAL PROCEDURE ROOMS*				
Bronchoscope	24 (76)	50	25 (78)	30
Cardiac Catheterization	17–27 (62-80)	45-55	17-27 (62-80)	45-55
Colonoscopy/EGD	24 (76)	50	25 (78)	30
Cystoscopy	22 (72)	50	25 (78)	50
Endoscopy	24 (76)	50	25 (78)	30
Fluoroscopy	24 (76)	50	25 (78)	30
GI (Gastrointestinal)	24 (76)	50	25 (78)	30
Proctoscopy	24 (76)	50	25 (78)	30

Room or Area	Summer		Winter	
	Db Degrees C (Degrees F)	**RH Percent**	**Db Degrees C (Degrees F)**	**RH Percent**
Sigmoidoscopy	24 (76)	50	25 (78)	30
Spinal Cord Injury Units (SCIUs)	22 (72)	50	27 (82)	30
Supply Processing Distribution (SPD)	24 (76)	50	22 (72)	30
Ethylene Oxide (ETO) MERs	Ventilation only			
Steam Sterilizer MERs	Ventilation only			
Telephone Equipment Rooms	19(65)-23(75)	40-60	19(65)-23(75)	40-60
Therapeutic Pools	26(80)-29(85)	--	29 (85)	--
Transformer Rooms	39 (104)	(Maximum)		
Treatment Rooms	24 (76)	50	25 (78)	30
Warehouses	Ventilation Only		15 (60)	--

2.1.4 Outside Design Condition:

2.3.4.1 Outside Design Condition For Summer:

$T_{\text{dry bulb average}}$ =38 [°C]

Relative humidity = 57 %

T_{wet} = 22 [°C]

Max wind speed = 1.4 [m/s]

Design month = July

2.3.4.2 Outside Design Condition For Winter :

$T_{\text{dry bulb average}}$ =13 [°C]

Relative humidity = 72%

T_{wet} = 2 [°C]

Max wind speed = 1.4 [m/s]

Design month = January

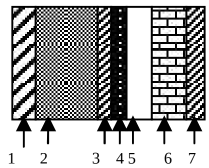
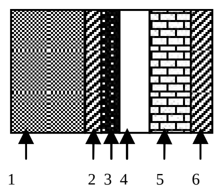
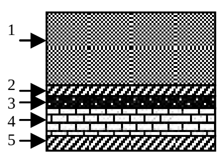
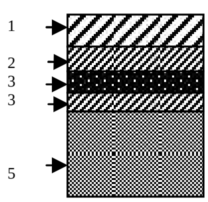
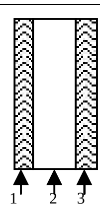
2.2 Over All Heat Transfer Coefficient “U” :

$$U = 1/Rth = \frac{1}{1/hi + \frac{\text{¢}1}{K1} + \frac{\text{¢}2}{K2} + \frac{\text{¢}3}{K3} + ... + 1/ho}$$

Table [2-2]: Overall Heat Transfer Coefficient For Doors And Windows.

Rooms	Windows type	Windows dimension [cm]	Windows Thickness [cm]	Doors type	Doors Dimension [cm]	Door thickness [cm]
Basic rooms	Aluminums profile with double glass	120×105	Glass[4] Air [9] Glass [4]	Double wood	214×90	4
Small rooms	Aluminums profile with single glass	105×60	Glass[4]	Double wood	214×150	4
Patient rooms	Aluminums profile with double glass	105×60	Glass[4] Air [9] Glass [4]	Double wood	214×150	4
Operating Rooms	-	-	-	Double wood	214×180	4
Bath rooms	Aluminums profile with single glass	76×30	Glass [4]	Single wood	214×70	4

Table [2-3] Overall Heat Transfer Coefficients

	Construction detail	Construction material	Material thickness [m]	Thermal conduction [W/m.k]	U [W/m^2.K]
Outside walls		1-Hard stone 2-Concrete 3-Cement plaster 4-Asphalt 5-Air gap 6-Cement brick 7-Cement plaster	0.05 0.14 0.02 0.02 0.06 0.1 0.02	2.2 1.75 1.1 0.8 0.027 1.2 0.8	0.38
Inside walls		1-Concrete 2- Cement plaster 3- Asphalt 4- Air gap 5- Cement brick 6- Cement plaster	0.14 0.02 0.02 0.06 10 0.02	1.75 1.1 0.8 0.027 1.2 0.8	0.37
Roof		1- Concrete 2- Cement plaster 3- Asphalt 4- Cement brick	0.20 0.02 0.02 0.15	1.75 1.1 0.8 0.8	1.8
ground		1-stone 2- Cement plaster 3- Asphalt 4- Cement brick 5- Concrete	0.05 0.02 0.02 0.02 0.20	1.2 1.1 0.8 0.8 1.1	2
Windows		1-glass 2-air gap 3-glass	0.04 0.06 0.04	0.042 0.027 0.042	0.23

doors		1-wood	0.04	0.17	2.4

CHAPTER THREE

HVAC SYSTEM

3.1 HVAC SYSTEMS:

HVAC systems are classified into three basic categories: all-air systems, all-water systems, and air and water systems . Table 3-1 lists HVAC system types are used in this project.

All-air systems meet the entire sensible and latent cooling capacity through cold air supplied to the conditioned space. No supplemental heat removal is required at the zone. Heating may be accomplished at the central air handler or at the zone.

Air and water systems condition spaces by distributing air and water supplies to terminal units installed in the spaces. The air and water are cooled or heated by equipment in a central mechanical room. These systems typically involve air-and-water induction units and fan-coil units.

Table [3-1] HVAC systems classification

HVAC system category	HVAC system
All-air	VAV, Single Duct with Fan-Powered Boxes
Air and water	Fan coil
Unitary DX	Minicentral system air conditioners

3.1.1 ALL-AIR SYSTEMS

In an all-air system a chiller supplies chilled water to one or more air-handling units. The air-handling units consist of mixing plenums where outdoor air and return air are mixed, filters (medium or high efficiency), cooling and/or heating coils, and fans, all contained in an insulated sheet metal housing. Air is distributed from the air handlers through ductwork (often medium-pressure) to terminal units and then to the space through a low-pressure distribution system. The terminal units regulate heating of the air with hot water, steam, or electric resistance coils in response to space temperature conditions. Air is returned from the space to the unit for recirculation or exhaust using return or exhaust fans.

3.1.1.1 VAV, Single Duct with Fan-Powered Boxes :

The VAV terminal 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.

Advantages:

• Plant equipment is centralized for ease of maintenance.
• Central equipment can take advantage of load diversity for optimal sizing.
• Can use air-side economizers effectively.
• Variable-speed drives for fan volume control are cost-effective.
• Provides a great deal of flexibility for multiple zones.
• Provides good dehumidification control.
• Good control of ventilation air quantities.
• Opportunity for high levels of filtration.
• Can use room air as first stage of reheat.

Disadvantages:

• First costs can be higher than for unitary equipment.
• Special attention to acoustics is required.

3.1.2 AIR AND WATER SYSTEMS

3.1.2.1 Fan-Coil Units:

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. The filter is usually a cleanable or replaceable low-efficiency (less than 25%) filter that protects the coil from clogging with dirt and lint. (Although it is not recommended, units can be connected to dampered openings in the outside wall to provide some outdoor air for ventilation.) Fan coils are typically installed in a floor-mounted configuration, but horizontal (overhead) models are also available. Fan coils can be ducted to discharge through several outlets, but fan static pressure capacity is usually very limited. Ventilation is usually provided by ducting tempered out side air to the return side of the unit or directly to the space.

The fan-coil piping system can be either a two pipe or four-pipe configuration. In a four-pipe system, both heating and cooling are available simultaneously, whereas a two-pipe system permits only heating or cooling depending upon the season.

Advantages:

• System can economically provide many temperature control zones.
• The system conserves space and is useful where ceiling heights are restricted.
• Suitable for low-water-temperature heating, such as with heat recovery.

Disadvantages:

• Some fans and motors are very inefficient.
• Dehumidification can be a problem where high latent loads are present.
• Fan coils are maintenance intensive and require regular filter replacement and fan and motor lubrication; condensate drain pans are subject to clogging and overflow and can present infection control problems if located in patient or clinical areas.
• Fans can be noisy.
• A two-pipe system can loose temperature control capability in some seasons.
• Fan coil systems can have high first cost.

3.2 COOLING LOAD ESTIMATIONS :

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

The Cooling Load Temperature Difference/Solar Cooling Load/ Cooling Load Factor (CLTD/SCL/CLF) load estimation method, it’s a simplified hand calculation procedure developed long ago by ASHRAE. Because of its simplicity, it is the most common method used for basic instruction on estimating cooling loads.

The space cooling load is the rate at which heat must be removed from a space in order to maintain the desired conditions in the space, generally a dry-bulb temperature and relative humidity. The cooling load for a space can be made up of many components, including :

1. Solar radiation heat gain through skylights and windows.
2. Conduction heat gain from adjoining spaces through the ceiling, interior Partition walls, and floor.

3. Internal heat gains due to people, lights, appliances, and equipment in the space.

4. Heat gain due to hot, humid air infiltrating into the space from outdoors through doors, windows, and small cracks in the building envelope.

5. Heat gain due to outdoor air deliberately brought into the building for ventilation purposes.

These load components contribute sensible and/or latent heat to the space. Conduction through the roof, exterior walls, windows, skylights, ceiling, interior walls, and floor, as well as the solar radiation through the windows and skylights, all contribute only sensible heat to the space.

The people inside the space contribute both sensible and latent heat. Lighting contributes only sensible heat to the space, while equipment in the space may contribute only sensible heat (as is the case for a computer) or both sensible and latent heat (as is the case for a coffee maker). Infiltration generally contributes both sensible and latent heat to the space.

The cooling coil has to handle the additional components of ventilation and system heat gains. Ventilation contributes both sensible and latent heat to the coil load. Other heat gains that occur in the HVAC system (from the fan, for example) generally contribute only sensible heat.

Note : One of the more difficult aspects of estimating the maximum cooling load for a space is determining the time at which this maximum load will occur. This is because the individual components that make up the space cooling load often peak at different times of the day, or even different months of the year.

3.2.1 Heat Gain Through Sunlit Walls And Roofs:

Direct and diffused solar radiation that is absorbed by walls and roofs result in raising the temp of these surface. Amount of radiation absorb by walls and roofs depends up on time of day, building orientation, type of walls construction and presence of shading.

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

$$Q=U*A*(CLTD)_{corrected} \qquad [3\text{-}1]$$

Where :

Q : cooling load [kW].

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

A : surface area [m^2].

CLTD correct : cooling load temp deference correction.

$$(CLTD)_{corr}=(CLTD+LM)k+(25.5-Ti)+(To,m-29.4)f \qquad [3\text{-}2]$$

CLTD : cooling load temp deference correction.

LM : latitude correction factor .

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 temp .

$T_{o,m} = (T_{max\ in\ july} + T_{min\ in\ July})/2 =$

$= (38+17) /2 = 27.5$ [°C]

Note:

1. All inside design temp are chosen from table [2-1] .
2. K value and f value is 0.5,0.75 respectively and his values are taken from heating and air conditioning books .
3. All area above are pure out side walls (A_{walls}-$A_{windows}$) if wall have a windows.
4. 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 Though Inside Walls and Ground :

Q=U*A*ΔT **[3-3]**

$$Q=U*A*\Delta T \quad [3\text{-}3]$$

Where:

Q: loading load gain inside walls.

A: inside walls area.

U: overall heat transfer coefficient.

ΔT: temp deference between inside air conditioning space and beside air temp space

$\Delta T=2/3*(To-Ti)$.

3.2.3 Heat Gain Due To Glass Windows :

3.2.3.A Heat Transmitted Through Glass :

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

(1) Transmitted component:

it represents the largest component, which is transmitted directly into the interior of the building or the space . this component represents about 42 to 87% of incident, depending on the glass transmissibility value.

(2) Absorbed component:

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

(3) Reflected component:

This component is reflected by glass to the outside of the building . about 8% of the solar energy is reflected back by the glass .

If a certain building has a large area of exposed clear glass then solar radiation is considered a large part of the cooling load. The total cooling load due to exposed glass area is the sum of transmission load due to inside-outside glass surface temperature difference (heat conduction) and heat gain due to solar energy (heat radiation and convection). The amount of solar radiation that can be transmitted through glass depends upon the following factors:

(1) Type of glass (single, double or insulating glass) and availability of inside shading. (such as venetian blinds, construction overhangs, wing walls, etc.)

(2) Hour of the day , day of the month , and month of the year.

(3) Orientation of glass area. (north, northeast, east orientation, etc.)

(4) Solar radiation intensity and solar incident angle.

(5) Latitude angle of the location.

3.2.3.B Transmission Heat Gain :

Heat gain due to solar transmission through glass windows and glass doors is estimated by using tables [A-5] where the following factors are selected:

(a) solar heat gain factor (SHG):

This factor represents the amount of solar energy the would be received by floor, furniture and the inside walls of the room and can be extracted from table [A-5].

(b) Shading coefficient (SC):

It accounts from for different shading effects of the glass wall or window and can be extracted from table [A-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 table [A-4]]for glass with interior shading. It accounts for the variation of SHG factor with time, mass capacity of the structure and the internal shading.

The transmitted cooling load is calculated as follows:

Qtr=A (SHG) (SC) (CLF) **[3-4]**

3.2.3.C Convection Heat Gain :

The convicted cooling load by the glass is calculated from the equation:

Qconv=UA (CLTD) corr. **[3-5]**

Where (CLTD) corr. is calculated by using Eq.(3-1).

3.2.4 Heat Generated By People:

people generate more heat than is needed to maintain body temperature. This surplus heat is dissipated to the surrounding air in the form of sensible and latent heat. The amount of heat released by the body varies with age, physical size, gender, type of clothing, and level of
physical activity.

QS=number of people × sensible heat gain/person × CLF **[3-6]**

QL = number of people × latent heat gain/person **[3-7]**

Where:

QS = sensible heat gain from people, Btu/hr [W]

QL = latent heat gain from people, Btu/hr [W]

CLF = cooling load factor, dimensionless

Similar to the use of the CLTD for conduction heat gain and SCL for solar heat gain, the cooling load factor (CLF) is used to account for the capacity of the space to absorb and store heat. Some of the sensible heat generated by people is absorbed and stored by the walls, floor, ceiling, and furnishings of the space, and released at a later time. Similar to heat transfer by conduction through an external wall, the space can therefore experience a time lag between the time that the sensible heat is originally generated and the time that it actually contributes to the space cooling load. For heat gain from people, the value of CLF depends on :

1) The construction of the interior partition walls in the space,
2) The type of floor covering,
3) The total number of hours that the space is occupied, and.
4) The number of hours since the people entered the space.

3.2.4 Heat Gain From Lighting :

Heat generated by lights in the space is a significant contribution to the cooling Load.

Q = watts × ballast factor × CLF **[3-8]**

Where:

Q = sensible heat gain from lighting, Btu/hr [W]

Watts = total energy input to lights, [W]

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

CLF = cooling load factor, dimensionless

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 1.0.

3.2.5 Heat Generated By Equipment:

There are many types of appliances and equipment in restaurants, schools, office buildings, hospitals, and other types of buildings. This equipment may generate a significant amount of heat and should be accounted for when estimating the space cooling load.

3.2.6 Infiltration:

In a typical building, air leaks into or out of a space through doors, windows, and small cracks in the building envelope. Air leaking into a space is called infiltration. During the cooling season, when air leaks into a conditioned space from outdoors, it can contribute to both the sensible and latent heat gain in the space because the outdoor air is typically warmer and more humid than the indoor air.

Before estimating the heat gain from infiltration, we must first estimate the amount of air that is leaking into the space. There are two methods commonly used to estimate infiltration airflow.

1. The air change method is the easiest, but may be the least accurate of these methods. It involves estimating the number of air changes per hour that can be expected in spaces of a certain construction quality. Using this method, the quantity of infiltration air is estimated using the equation:

Infiltration airflow = (volume of space × air change rate) ÷ 60 **[3-9]**

Infiltration airflow = (volume of space × air change rate) ÷ 3600.

Where:

Infiltration airflow = quantity of air infiltrating into the space, [m^3/s].

Volume of space = length × width × height of space, [m^3].

Air change rate = air changes per hour.

60 = conversion from hours to minutes.

3,600 = conversion from hours to seconds.

2. The crack method is a little more complex and is based upon the average quantity of air known to enter through cracks around windows and doors when the wind velocity is constant.

$$Q_{S,f}=\rho*V_f*Cp*(T_i-T_o) \quad \textbf{[3-10]}$$

Where :

Qs,f : sensible heat load due to infiltration is given by the following equation .

Vf : the volumetric flow rate of infiltration air and his value from equation [3-4].

Cp : specific heat at constant pressure and equal 1000 [J/kg.K] .

ρ : is the density of infiltration air and equal 1.25 [kg/m^3].

Ti : inside design temperature .

To : out side design temperature.

$$Q_{L,f}= \rho_0*V_f *(\mathcal{W}_i- \mathcal{W}_o)*h_{fg} \quad \textbf{[3-11]}$$

Where :

$Q_{l,f}$: latent heat load.

$\mathcal{W}_i$: inside air humidity ratio.

$\mathcal{W}_o$: out side air humidity ratio .

h_{fg}: the enthalpy of evaporation of water vapor .

$$Q_{l,f}=Q_{t,f}-Q_{s,} \quad \textbf{[3-12]}$$

Where:

$$Q_{t,f} = \rho_0 * V_f * (h_i - h_o) \quad [3\text{-}13]$$

Where**:**

hi, ho are insides and outsides enthalpies of infiltration air and form psychometric chart 45,90[kJ/kg] .

3.2.7 Ventilation:

Outdoor air is often used to dilute or remove contaminants from the indoor air. The intentional introduction of outdoor air into a space, through the use of the building's HVAC system, is called ventilation. This outdoor air must often be cooled and dehumidified before it can be delivered to the space, creating an additional load on the air-conditioning equipment. You should never depend on infiltration to satisfy the ventilation requirement of a space. On days when the outdoor air is not moving (due to wind), the amount of infiltration can drop to zero. Instead, it is common to introduce outdoor air through the HVAC system, not only to meet the ventilation needs, but also to maintain a positive pressure (relative to the outdoors) within the building. This positive pressure reduces, or may even eliminate, the infiltration of unconditioned air from outdoors. To pressurize the building, the amount of outdoor air brought in for ventilation must be greater than the amount of air exhausted through central and local exhaust fans.

Note: we will use same equations and method in section 5.1.6

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.

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.

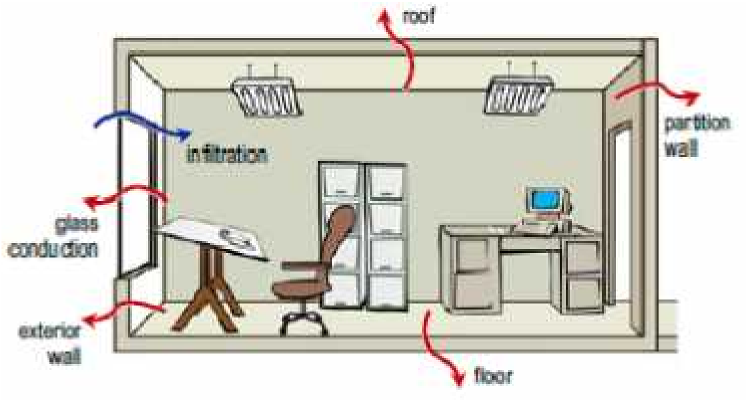


Figure [3-1] Heating load component

In a matter similar to section 5.1, we will focus on the most common conduction heat losses from a space: through the roof, the exterior walls, and the windows.

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:

$$\mathbf{Q = U \times A \times \Delta T} \qquad \textbf{[3-14]}$$

Where:

Q = heat loss by conduction, Btu/hr [W].

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

A = area of the surface, [m^2].

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

3.3.1 Infiltration and Ventilation:

Similar to the cooling season, during the heating season, air may leak in from outdoors through doors, windows, and small cracks in the building envelope. It contributes to the sensible heat loss of the space because the outdoor air is typically colder than the indoor air. Additionally, the outdoor air during the heating season is generally drier than the indoor air. If the building requires humidification, infiltration of cold, dry outdoor air adds to the humidification load. This clinic, however, will only focus on the sensible heat loss due to infiltration and its effect on sizing the sensible heating equipment in the HVAC system.

$$\mathbf{Q_{s,f}=\rho * V_f * Cp * (T_i - T_o)} \qquad \textbf{[3-15]}$$

Where :

Qs,f : sensible heat load due to infiltration is given by the following equation

Vf : the volumetric flow rate of infiltration air and his value from equation [3-4]

Cp : specific heat at constant pressure and equal 1000 [J/kg.K]

ρ : is the density of infiltration air and equal 1.25 [kg/m^3]

Ti : inside design temperature

To : out side design temperature

$Q_{L,f}= \rho*V_f*(\mathcal{W}_i- \mathcal{W}_o)*h_{fg}$ **[3-16]**

Where :

$Q_{l,f}$: latent heat load

$\mathcal{W}_i$: inside air humidity ratio

$\mathcal{W}_o$: out side air humidity ratio

h_{fg}: the enthalpy of evaporation of water vapor

$Q_{l,f} =Q_{t,f}-Q_{s,}$

Where :

$Qt,f = \rho*V_f*(hi-ho)$ **[3-17]**

Where **:**

hi , ho are insides and outsides enthalpies of infiltration air and form psychometric chart 44,32 [kJ/kg].

3.4 Sample Of Heating and Cooling Load :

- Cooling load calculation :

1-Load Gain Through Sun Light Walls and Roofs and from eq [3-1] :

Q= U*A*(CLTD)correction

-Calculation of Cooling Temp Deference Correction and from eq [3-2] :

(CLTD)correction =(CLTD+LM)K+(25.5-Ti)+(To,m-29.4)f

Table [3-2]

Walls	CLTD	LM	CLTD correction
E	17	0	6.57
S	11	0	4.82

QE =0.38*9*(6.57) = 22.4 [W]
QS=0.38*27*4.82= 51.7 [W]

2-Load gain Through inside Walls & Ground and from eqn [3-3] :

Q=U*A*ΔT

QN = 0.37*9*0 =0 [W]

Q_w = 0.37*27*3 = 8.25 [W]
Q_{GRONG}= 2*27*3 = 162 [W]

3-Load Gain Due To Glass Windows :

A-Heat Transmitted Through Glass and from eqn [3-4] :

QTR = A*(SHG)*(SC)*(CLF)

Table [3-3]

Walls	SHG	SC	CLF
E	678	1	0.22

QTR =0.63*678*1*0.22 = 21.61 [W]

B-Heat Gain Due To Solar Convection and from eq [3-5] :

Qconv =U*A*(CLTD)correction
= 0.23*0.63*6.57 =1.24 [W]

4- Heat Generated by People and from eqn [3-6] , [3-7] :

Qs= #of people*sensible heat gain/person*CLF
= 6*65*0.13 = 67 [W]
QL = # of person *latent haet gain*Person *CLF
= 6*30*0.13 = 23.4 [W]

5-Heat Gain From Lighting and from eq [3-8] :

Q=Power*ballast factor*CLM
=6*200*1.2*0.92=2600 [W}

6-Heat Gain Due To filtration and Ventilation and from eq [3-9] ,[3-10],[3-11] :

Q V = ρ*Vf*(hi-ho)

VF=(Volume of space*air change rate)/60

Vf=(72.15*2*)/60 = 0.04 [m3/s]

Qv= 1.25* 0.07*(45) =3.29 [KW]

Qf = 1.2*0.04*(45)=2.29 [kW]

Qtotal =∑ Q = 12.6 [KW]

-Heating Load Calculation :

1-Heat Gain From Outside Walls, Inside Walls ,Roofs, Ground and from eq [3-15] :

Q =U*A* ΔT

Q_E,w = 0.38 *9*20 = 86.41 [W]

Qs,w = 0.38*27*0 = 0 [W]

Q_N,w = 0.37*27*20 =199.8 [W]

Q_W,w =0.37*10.29*3 = 11.42 [W]

2-Heat gain Due Ventilation and Filtration and from eq [3-16] ,[3-17] :

Q V = ρ*Vf*(hi-ho)

VF=(Volume of space*air change rate)/60

Vf=(72.15*2*)/60 = 0.04 [m3/s]

Qv= 1.25* 0.07*(16) =1.4 [KW]

Qf = 1.2*0.04*(16)=0.678 [kW]

Qtotal =∑ Q = 3.42 [KW]

3.5 Sample Of Supply , Fresh and Return air calculation :-

1- Supply air calculation

Q total = ρ*V*(hi-hs) **[3-18]**

Where :

P : air density and equal 1.25 [kg/m3]

V: Volumetric flow rate of supply air [m3/s]

hi : enthalpy of the inside air.

hs : enthalpy of the supply air at supply temperature [12 C]

12.6 = 1.25*V*(45-23)

V= 0.458 [m3/s]

2-Fresh air calculation :

Fresh air =#of person*V/person **[3-19]**

= 4*0.007 =0.028 [m3/s]

3-Return air calculation :

Return air = Supply air-Fresh Air **[3-20]**

=0.458-0.028 = 0.43 [m3/s]

3.6 DUCT DESIGN :

3.6.1 INTRODUCTION TO DUCT SYSTEM AND DUCT DESIGN :

Ducts are used in heating, ventilation, and air conditioning (HVAC) to deliver and remove air. a duct system is often called ductwork. Planning ('laying out'), sizing, optimizing, detailing, and finding the pressure losses through a duct system is called duct design.The objective of duct design is to size the duct so as to minimize the pressure drop through the duct, while keeping the size (and cost) of the ductwork to a minimum. Proper duct design requires a knowledge of the factors that effect pressure drop and velocity in the duct.

3.6.2 GENERAL SYSTEM DESIGN CLASSIFICATION :

Supply and return duct systems are classified with respect to the velocity and pressure air with in the duct.

3.6.2.1 VELOCITY :

There are two types of air transmission systems used for air conditioning application. They are called conventional or low velocity and high velocity systems .The dividing line between these systems is rather nebulous but the following initial supply air velocity are offered as a guide.

Commercial comfort air conditioning :

1. Low velocity…….up to 2500 fpm (12.7m/s). Normally between 1200 and 2200 fpm (6 to 5.2 m/s).
2. High velocity ………above 2500 fpm (12.7 L/S).

Factory comfort air conditioning :

1. Low velocity …….up to 2500 fpm. Normally between 1200 and 2200 fpm.
2. High velocity……..2500 to 5000 fpm.

3.6.2.2 PRESSURE :

Air distribution systems are divided into three pressure categories : low, medium and high. These divisions have the same pressure ranges as indicated;

Low pressure …….up to 3.75 in.wg

Medium pressure…3.75 to 6.75 in. wg

High pressure…….6.75 to 12.25 in.wg

These pressure ranges are total pressures including the losses through the air handling apparatus, ductwork and the air terminal in the space.

3.6.2.3 NOISE LEVEL :

Most straight ductwork naturally attenuates noise. Acoustic lining increases noise attenuation. Fittings such as elbows, dampers, branch take offs, grilles, registers, diffusers, air-handling light fixtures, and variable inlet vanes either create or attenuate noise, depending on their geometry and air velocity. Higher air velocity in fittings creates higher noise levels. Duct velocities of 5.5 m/s (800 fpm) or less generate no audible noise. The following recommendations concerning duct-generated noise are presented in the Table below :

Table [3-3] Maximum recommended duct air flow validities needed to achieve

specified acoustic design :

Main Duct Location	Design RC(N)	Maximum Airflow Velocity, m/s Rectangular Duct	Circular Duct
In shaft or above drywall ceiling	45	17.8	25.4
	35	12.7	17.8
	25	8.6	12.7
Above suspended acoustic ceiling	45	12.7	22.9
	35	8.9	15.2
	25	6.1	10.2
Duct located within occupied space	45	10.2	19.8
	35	7.4	13.2
	25	4.8	8.6

3.6.3 DUCT SHAPE CONSIDERATIONS :

Ducts are usually fabricated in rectangular or round shapes. Recently, flat oval duct, which is usually a round spiral duct that has been stretched to an oval shape, has been utilized more frequently.

3.6.3.1 Round Ducts :

Round ducts have a smaller pressure drop per unit area of all duct types and are generally the most cost effective. Round ducts with spiral construction are available in extended lengths. A system with long sections has fewer joints with lower pressure losses and less leakage than a system constructed of many shorter sections. Round fittings are commercially available and provide a convenient connection to flexible duct; they are easier to insulate and to seal. Slip joints are the most economical to install. Disadvantages of round ducts include: they require more clear height for installation; larger sizes may cause shipping and handling difficulties.

In addition to their economic advantages, round ducts have an extremely important acoustical advantage. Therefore, sound has ample time to attenuate naturally. In practice, fixing a noise problem in rectangular ductwork is more difficult than in round ductwork.

3.6.3.2 Rectangular ducts :

Rectangular ducts are easily shipped when broken down or nested. They provide flat surfaces for tap-ins and hangers and they are conveniently fabricated. Disadvantages to using rectangular ducts (in contrast to other shapes) are: they create higher pressure drop; they use more pounds of metal for the same air-flow rate as round duct; joint length is limited to the sheet widths stocked by the contractor; and joints are more difficult to seal. Also, rectangular transverse joints are more costly to install than round ones.

3.6.4 TYPES OF INSULATION

The most common insulation material for ducts is fiberglass. It is available in either a flexible or rigid form and comes in a variety of densities and thicknesses. The flexible blanket-type insulation is sold in rolls and is easy to apply to either round or rectangular ducts. Flexible insulation easily conforms to irregular surfaces. Rigid insulation comes in pre-formed boards bonded with a thermosetting resin, and works best on rectangular ducts (in some areas, ducts are constructed of a rigid insulation material, minimizing the need for additional insulation) . All duct insulation should have a foil or vinyl facing on the exterior side to prevent moisture from being absorbed into the fiberglass. Kraft paper-faced insulation should never be used on ducts because of its flammability and relatively poor moisture resistance. If any existing insulation has become wet, it should be replaced.

3.7 DUCT SIZING METHODS :

The design of the ductworks in ventilation systems are often done by using the

Velocity Method
Constant Pressure Loss Method (or Equal Friction Method)
Static Pressure Recovery Method

NOTE : we will use in our duct calculation constant pressure loss method

3.7.1 Equal Friction Method

1. Compute the air volume in every room and branch

Use the actual heat, cooling or air quality requirements for the rooms and calculate the required air volume - *q*.

2. Compute the total volume in the system

Make a simplified diagram of the system like the one above.

Use to summarize and accumulate the total volume - q_{total} - in the system.

3. Determine the maximum acceptable airflow velocity in the main ducts

Select the maximum velocity in the main duct on basis of the application environment. To avoid disturbing noise levels - keep maximum velocities within experienced limits:

comfort systems - air velocity 4 to 7 m/s (13 to 23 ft/s)
industrial systems - air velocity 8 to 12 m/s (26 to 40 ft/s)
high speed systems - air velocity 10 to 18 m/s (33 to 60 ft/s)

Use the maximum velocity limits when selecting the size of the main duct.

4. Determine the static pressure drop in main duct

Use a pressure drop table or similar to determine the static pressure drop in the main duct.

5. Determine the duct sizes throughout the system

Use the static pressure drop determined in as a constant to determine the ducts sizes throughout the system. Use the air volumes calculated in for the calculation. Select the duct sizes with the pressure drop for the actual ducts as close to the main duct pressure drop as possible.

6. Determine the total resistance in the system

Use the static pressure from to calculate the pressure drop through the longest part of the duct system. Use the equivalent length which is :

the actual length + additional lengths for bends, T's, inlets and outlets

3.7.2 Sample Of Duct Sizing using Equal Friction Method :

***Reference to CAD DWG [M02]**

A-calculated total volumetric flow rate using equation [3-18] in main Duct [A-B]

VA-B=2366 [L/s] .

B-maximum acceptable air flow velocity [average 4-7[m/s] is 5.5 m/s] in the main duct .

C-from friction chart for round method [reference to A-9 Appendix] at 5.5 [m/s] and 2366 [L/s] then :

Table [3-4]: Main duct sizing

DUCT	VELOCITY [m/s]	AIR FLOW [L/s]	DROP PRESSURE [Pa/m]	DUCT DIAMETER [mm]
A-B	5.5	2366	0.35	~715

D- then from [A-10] We will find rectangular duct dimension [Reference To A-10] .

E- We take drop pressure constant for branch duct, and depending in the volumetric flow rate find branch sizing.

f- to find static pressure and it will depended for longest part of the duct systems .

EL =90.35

Then static pressure = 0.35*90.35 = 31.6 [pa]

Table [3-5] duct sizing

DUCT	VELOCITY [m/s]	AIR FLOW [L/s]	DROP PRESSURE [Pa/m]	DUCT DIAMETER [mm]	REC DUCT [mm]
A-B	5.5	2366	0.35	~715	650X650
C-D	-	1616	0.35	630	550X550
E-F	-	1148	0.35	550	550X450

CHAPTER FOUR

PLUMPING SYSTEM

4.1 PLUMPING SYSTEMS :-

Plumbing :- is the art of installing in buildings the pipes , fixtures and other apparatus for bringing in the water supply and removing liquid and water-carried wastes.

Plumbing fixture : are receptacles intended to receive and discharge water , liquid or water-carried wastes into a drainage system with which they are connected .

Minimum plumbing facilities:-

All code state the minimum plumbing facilities that are required in each building types.

hydraulics : hydraulics is the study of the physical principles that govern the behavior of liquid at rest and motion there are two separate and distinct types of liquid flows with which we are concerned :

-flow in closed pressurized system : a system that is now here open to the atmosphere and operates above atmospheric pressure .this is the type of flow that occurs in domestic water systems:-

-cold water system.

-hot water system.

-flow occurs in all drainage systems (gravity flow)

- sanitary drainage system

- storm drainage system

This type of flow (gravity flow) is caused simply by the slope of pipe containing the liquid .These systems are open to the atmospheric the pipes containing the liquid in gravity flow almost always run only partially full (as compared to completely full in pressurized systems)

Static pressure :-

Static pressure is caused by the weight of water above any point the system .

$P = F/A = W/A$ **[4-1]**

W = weight , A: area

4.1.1 Plumbing materials :-

The knowledge of plumbing materials is necessary for the proper design of efficient safe, reliable and economical plumping systems .

All materials used in plumbing systems should meet the requirements of at least one of the standards related to this topic.

Piping materials and standard fittings :

1- Ferrous metal pipe . (iron steel)

2- Nonferrous metallic pipe . (copper)(brass)

3- Plastic pipe : abs (acrylonitrile butadiene system)

PE (poly ethylene)

PVC (polyvinyl chloride)

CPVC (chlorinated polyvinyl chloride)

4- Nonmetallic pipe other than plastic .

Vitrified clay (term cotta)

Asbestos cement

Concrete pipe

5- Joints between dissimilar.

Thermal expansion :-

For hot water and stream piping ,the problem of thermal .expansion is important ,especially in high rise building or in structures with long horizontal runs .due to the temperature difference, the length of pipe expands depends on the pipe type ,expansion joints and loops are installed every soft depending on pipe size lusts the expansion coefficients and typical expansions for common piping materials.

4.2 Water supply ,distribution :-

There are two basic types of water distribution systems for building

1- Up feed distribution system

2- Down feed distribution system

-Up feed distribution system :-

There are two methods commonly used for up feed distribution system .

1- The supply of water for the building is received from a public street main (usually 35 psi for residential structures ,and about 50 psi for other buildings)

2- Private water supply enters into a pneumatic tank (pressurized tank)and is pressurized from approximately 35 to 60 psi

In both systems the height of the building is directly proportional to the pressure water.

-Down feed distribution system:-

The water from the gravity tank on the roof serves the floors below by down feed distribution (gravity) system.

Minimum press required on the top floor is usually is 15 psi (for flues value) , and max press on the lowest floor should not exceed 50 psi ,otherwise pressure – reading values are used to reduce the pressure .

Zoning multistory building :-

In a multistory building if is logical and economical to limit the height of the water zone to 15 stories each .for example ,a 45 –story building can be divided into three zones.

Flow pressure :- the pressure available at the fixtures when the outlet is wide open it must be equal or exceed the minimum fixture pressure see B-3 .

in adequate pressure :- the pressure is the said to be inadequate when the city main pressure is insufficient to provide the required minimum flow pressure .In this case a pressurized (pneumatic)tank or an over roof tank (gravity tank) is to used .

for the flow condition

main press= static head + friction head + flow press

4.2.1 water service sizing :

wsfu :- water supply fixture unit it is used to calculate the probable

maximum water demand (max . requirement of water for building)

this wsfu technique is used and becomes more accurate as the number of fixture increase because the system is based on diversity between fixture in use .

wsfu technique should never be applied to installations with only a few fixture , because in such installations ,the additional use of a single fixture can drastically change the total usage pattern .

in this case ,I.e. for small installation such as residences and small stores use the unite of bathroom groups and converted to gpm ,plus individual fixture flow rates (in gpm) .

4.2.2 water pipe sizing :-

1- By friction head loss

2- By velocity limitation

-Water pipe sizing by friction head loss :-

The procedure is as follows:-

-Step 1 :- draw a rise (plumbing section).on this riser show:-

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

-Step 2:- show the wsfu for each fixture and fixture unit total on each piping run out .use separate fixture units for hot and cold water where applicable

-Step 3:- total the fixture units in each branch of the system .show both cold and hot water fixture units .(it is understood that hot water pipe sizing will require a separate diagram and calculation)

Add the continuous water loads

-Step 4:-show source pressure (minimum) and the minimum flow pressure required of the most remote out lets

-Step 5:-determine the pressure available for friction head loss from the service point to the final out let.

-Step 6:-determine the required pipe size in each section using the friction head loss data calculated in step 5 and the friction head charts .section is normally based on uniform friction head loss per foot throughout and a maximum water velocity – usually 8 fps , except that branches feeding quick dosing devices such as flush values should be limited about 4 fps to avoid water hammer .

4.2.3 Water pipe sizing by velocity limitation :-

As we said the water velocity in the piping system in building is not preferred to exceed 8fps .Outside building it may exceeds 8 fps.

Velocity of water for sudden open (flush values ….etc) <4 fps for building where available water pressure is more than adequate to supply all the fixture ,there exists a simplified pipe sizing method based on water velocity considerations .

This method is normally applicable to all private residences ,multiple residences and commercial and industrial building up to three stories in height .

To determine the method applicability , a rapid pressure calculation is made .if this calculation shows that pressure is adequate ,use the following procedure :-

Step 1:-prepare a building riser diagram show all fixture loads in wsfu and gpm in each pipe section include all continuous loads in gpm figures.

Step 2:-identify all branch piping that feeds quick-closing devices such as flush values ,solenoid values(as in clothes washers)and self –closing faucets .the velocity in these branch pipes must be limited to 4 fps to avoid water hammer.

Step 3:- size all individual fixture branches according to the code minimum requirements .

Step 4:- size all other parts of the piping system in accordance with water velocity limitation for the type of piping selected.

4.3 Domestic hot water :

Almost all plumbing fixture except flush – type unit (closet bowls and urinals)require hot water as well as cold.

The usual point of use temperatures are:-

Lavatories ,showers and tubs :- 105 – 120 F° (35-40 C°)

Residential dishwashing and laundry :- 120-140 F° (50-60 C°)

Commercial and institutional kitchens 140 F° (60 C°)

Commercial and institutional laundries 180 F° (80 C°)
Sanitizing use

Note that these are fixture water temperatures. depending on the design and length of the supply piping from the hot water heater ,the water heater out let temperature will be 5 to 20 F° higher than the fixture temp. to compensate for temp .loss in the supply piping .

Note:-

Water heating system is designed to provide hot

Water at the min .required temp. because

- Lower the heat loss in piping
- Slower scale formation in piping
- Avoidance of scalding temp

4.3.1 Type of hot water heaters

1- Instantaneous water heater

   a. Atmore

   b. Gas boiler

2- Tank type water heater

Instantaneous water heater:-

When hot water faucet opens or other fixture demands hot water. they are referred to as tank less heaters because they do not use any sort of storage tank. Should be large enough to provide maximum hot water demand immediately at required temperature .

Tank type water heaters : are the most common used units. their advantages are that they makes or provide a large quantity of heated water available up on demand .

Circulating system are usually provided when the piping run is about 100 ft long

1- Thermosiphion circulation system (the taller the building ,the better the thermosiphio)

2- Forced circulation system (low and long building)

4.3.2 Sizing of hot water heaters :

To determine the required size of a hot water heater for a specific facility is not a simple task. The calculation involves knowledge of:-

- Daily consumption of hot water (GPD).
- Peak load.
- The duration of this peak load.

With these data ,a balance must be made between heating capacity and storage . the larger the burner, the smaller the required storage ,and vice versa.

- For building with long periods of uniform demand (hotels and laundries) a long capacity bummer (rapid recovery) with small storage is indicated, because peaks are small.
- For building with large but in frequent peak loads, such as dormitories and gyms , a small bummer (low recovery node) and a large storage tank are chosen , with this arrangement, the hot water in the tank can supply the large peak load , and the small bummer then has a long period in which to heat the (cool) water in the tank.
- For residences ,apartments :use the following:
  50 l/person/day for the first two persons in a family.
  30 l/person/day for other persons of the family.

4.4 Plumping Calculation :

- Total domestic of water :

1- Total Water consumption = # of bed *GPD

= 82*267.5 = 21935 [GPD] , the storage we will be for 2 day then

= 83 [m3] For one days

= 21935*2day = 43870 Gallon = 166075 [L] = 166 [m^3]

-Volume of Storage Tank = 166 [m^3]

-We need 8 Elevation Tank Each have 10 [m^3]

2- Elevation Tank Height calculation :

-We need to Calculate the pressure required to further Fixture unit.

Total pressure = Friction head + Flow pressure

= 5 psi +15 psi = 20psi <50 psi

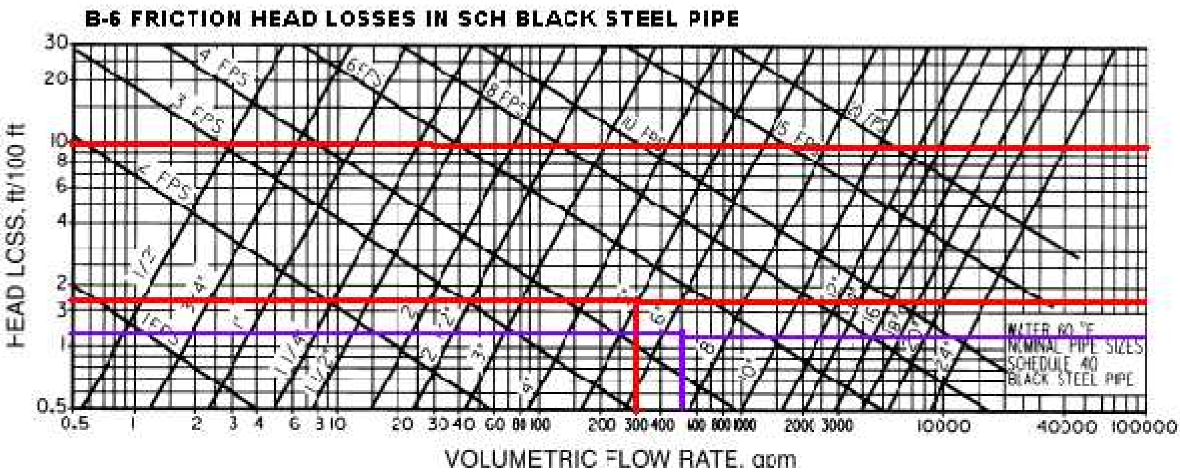
Then 20 psi *2.3 psi/ft =46 Ft above the roofs

3-sample of Estimation demand For Hot and cold Water :

Type Of department	fixture	use	Type of supply control	Fixture unit	Cold water = f.u*(3/4)	Hot water = f.u*(3/4)
senior staff showers and toilets	19 lavatory	Private	Faucet	19×١=19	14.25	14.25
	10 water closets	private	Flushometer	١٠×٣=٣٥	٢٢.٥	
	4showers	private	Mixing valve	4×٢=٨	٦	٦
			Total WSFU		٤2.75	20.25
			Dmand gpm		٤٨.1	٣٥.15

4-Sample pipe sizing :

Maximum velocities acceptable in main pipe is 5 [ft/s] and maximum friction losses 10 psi/100ft



5- Sample of sizing :

Total Pump head = Elevation + friction losses

Elevation : distance between pump outlet and longest point and include fitting

Friction head : friction in longest part including fitting

Elevation = 4.5X8+15 = 50 m =167 feet

Friction head = (3.5*167)/100 = 5.8 psi

1psi = 2.31 feet Then 5.8 psi equal 13.5feet

Total pump head = 167+13.5 = 180 feet = 54 m

4.5 **DRANAGE PIPING STRING :**

Pipe size are calculate by using a concept of fixture units. Instead of using gpm of drainage water , we use drainage fixture units DFU.This unit takes into account not only the fixture's water use but also its frequency of use , that is the DFU has a built-in diversity factor.

This enables us , exactly as for water supply , to add the DFU of various fixtures to obtain the maximum expected drainage flow. Drainage pipes are then sized for a particular number of drainage fixture units, according to tables.

Built into these table are the fill factors that are:

- 50% fill in horizontal branches.
- (25-33)%fill in stacks.
- Some-water more than 50%fill in building drains.

4.5.1 The design procedure following:

STEP1:Draw an isometric of the entire system showing all fixtures.

STEP2:Assign drainage unit to each fixture, if a fixture is not listed specifically , base the DFU requirement on its trap size .

Drainage requirements not due to fixtures ,such as non recalculated of cooling water or process water, use the conversion of 1gpm=2dfu. (e.g.2gpm of process water at any drain should be counted as 4dfu, and so forth).(continuous drain loud; 1gpm=2dfu).

STEP3: Total the drainage fixture units in each drainage pipe and mark them on the drawing.

STEP4: Determine the required size of horizontal fixture branches and stacks .

STEP5:Determine the size and slop of the building drain and its branches , and the building sewer ..

STEP6:Determine that the size and slops found in step5 meet the requirements of the code .

4.5.2 daring accessories:-

In addition to fixture drains ,traps and piping ,there are a number of device ,connection and accessories to drainage systems with which you should be familiar.

a- Cleanouts :- no matter how well designed , drainage system will eventually be blocked ,.blockage occurs most frequently at points where drainage pipes change direction and size and size, and at fittings therefore cleanout fittings should be provided :-

- At the base of every soil and waste stack.
- At all changes of direction large than 45°.
- At the point where the building drain exits the building .
- Along all horizontal runs at a frequency of not more than 75 ft apart for drainage pipe 4 in diameter or less and not more than 100 ft apart for large pipe .
- Wherever the designer feels that there is a possibility of soil buildup and blockage .

All cleanouts must be accessible enough space around the cleanout to manipulate the cleaning equipment .

b- Interceptors (separators) :-

When waste water from fixture contain materials that can cause blockages or harm the building drainage system ,public sewer or treatment plant ,interceptors are used to separate harmful materials (sand, grease ,oil ,hair ,gravel and flammable liquids)from waste water which could cause blockage of drainage piping .

- For commercial kitchens grease separator is used .

c- Traps :-

The principle function of a trap is the into provide a water seal between the drainage piping that connects to the outside sewer and the fixture .this water seal prevents entry into the building of odors , sewer gas and vermin from the sewer ,via the fixture .

- Every plumbing fixture must be trapped ,except for a few very special cases such as fixture with indirect (air – gap) waste connection and certain fixture that discharge through interceptors .
- The design of the trap ,its location and the drainage piping connected to it are each important in its proper functioning.
- The only fixture that is self –trapped is the water closet.

- All traps operate on the principle of siphon age a water is added to the inlet end , an equal amount (quantity) of water leaves the outlet end ,provided the pressure at both ends are approximately equal.
- The maximum allowable pressure difference between inlet and outlet of the trap is ± 1“ of water .
- The depth of the trap is in the range of 2“-4“. 1“ of water equal to :-

  1 ft =12“ =0.433 psi

  1“=x=?

  X=0.433 *1/12=0,036 psi.

- Assuming the min-depth for trap to be 2“(since this is the easiest trap to blow out or siphon out),let us calculate the pressure required to below out or siphon out the trap :

  To destroy the trap seal we need to lift either side of water seal by 2“.

  That means ,the critical pressure which will support 2“ of water in the trap is 2“of water is equal to   2*.443 /12= 0.072 psi.

  That is less than one –tenth of psi .these figures hold regardless of the trap size .only the depth of the trap controls the pressure necessary to destroy the trap seal .this should make very obvious need for effective venting to equalize pressure on both sides of the trap seal.

4.5.3 venting ,principle of venting:-

- Every vent extends through the roof into outside air .
- Vent stack :- separate stack for venting .stack vent :- vent extension of a soil or waste stack.
- The sack always extends into fresh air so that it can supply or exhaust air as required by flow waste in the drain piping.

Functions of venting :-

1- It provides an air vent at fixture trap .this ensures atmospheric pressure on the outlet side of the fixture trap (equalize the pressure at both sides of the trap) so prevents the trap seal from being blown out or sucked out due to pressure difference generated by drainage flow.

2- It provides a safe path to exhaust sewer gases and foul odors .building vent piping acts as a sewer vent in the absence of a building trap and a street level fresh air vent .

3- It fills the drainage piping with fresh air , thus reading odors , corrosion and the formation of slime piping.

4- It aids in the smooth flow of drainage that occurs when air moves freely in a drain pipe.

-Recommended procedures in placing and sizing vents:-

- Every drainage stack must extend through the roof to fresh air .
- Every soil or waste stack more than one story high must have a parallel vent stack.
- The lower end connection of the vent stack to the drain stack must be below the lowest horizontal branch drain connection .
- the vent stack may extend through the roof parallel to the soil stack extension (stack vent) in practice it is almost always connected to the stack vent just below the roof ,at least 6“ above the flood level of the highest fixture connected to the waste stack .
- because outside vent terminals carry noxious odors and gases, they may not be closer than 10 ft .horizontally from any door, window or air intake unless they are at least 2 ft above the top of the opening .these terminals should terminate 12“ above a pitched roof and at least 7 ft above a flat roof that can be use for other purposes.
- In climates where freezing of the moist warm air exiting a vent terminal is possible ,the exposed portion must be kept as short possible .also ,because freezing tends to block small pipes ,such vents should not be smaller than 3“.in practice,4“ is the size commonly used .

(g) all horizontal vent piping must slope to the drainage system .low points not are not permitted ,as moisture will condense there to water ,and vent pipe will be partially or fully blocked.

4.6 types of vents :

- Individual vent :- simplest ,most direct ,most effective (and most expensive) way of venting a fixture trap is to provide an individual vent for every trap this vent arrangement is also called continuous venting and back venting .
- Branch vent:- is a vent connecting one or more individual vents to avent stack\or a stack vent.
- Common vent : is a single vent that connects to a common a drain for back - to – back fixture.
- Circuit and loop vents:-

Circuit vent connects to a vent stack.

Loop vent connects to a stack vent.

- Wet vents :- is a vent that vent a fixture serves as a waste line for other fixture ,except water closets and kitchen sinks.
- Stack venting : is used in single family homes and on the top floor of multistory buildings .

4.6.1 Drainage and vent piping design :

Rules Because the primary purpose of vent piping is equalization of pressures ,length is very important .thus vent piping is sized according to the size of the drain pipe that it vents (number of DFU) and its own length.

governing vent piping:-

- The diameter of a vent pipe may not be less than 1.25’’ or half the size of the drain pipe that it vents , whichever is larger .
- A relief vent may not be less than half the size of the drain pipe to which it is connected .

- When fixtures other than water closets , discharge downstream from a water closet into a fixture branch , each such fixture shall be individually vented . this procedure is called re venting .

4.7 Septic tank:

Where there is no sanitary sewer systems available it is necessary to private sewage treatment facilities that will handle all the effluent from a building's fixtures including black and water.

When there is adequate area around the house and the soil is absorbent (sandy soil) the problem is easily solved but with clay-type soil the problem is more difficult.

In densely populated areas with houses on 40*100 ft lots the situation is very difficult.

The sewage fluids enters the septic tank solids sink to the bottom of the tank .Bacterial action breaks up the solids and aids in purifying the fluids . A very small amount of sludge slowly builds up at the bottom of the top surface of a scum forms at the top surface of the contents.

The outflow pipe that carries the liquid effluent into the surrounding earth is located and protected in away that prevents its being clogged.

The septic tank needs to be pumped out at intervals because of sludge accumulation every (5-10) years.

- Septic Tank Selection :

From table B-11 Septic Tank Capacity is 3500 [GALLON]

CHAPTER FIVE

MEDICAL GASES

5.1 INTRODUCTION :

Health care is in a constant state of change, which forces the plumbing engineer to keep up with new technology to provide innovative approaches to the design of medical-gas systems. In designing medical-gas and vacuum systems, the goal is to provide a safe and sufficient flow at required pressures to the medical-gas outlet or inlet terminals served. System design and layout should allow convenient access by the medical staff to outlet/inlet terminals, valves, and equipment during patient care Or emergencies.

This chapter focuses on design parameters and current standards required for the design of nonflammable medical-gas and vacuum systems used in therapeutic and anesthetic care. The plumbing engineer must determine the needs of the health-care staff .

As any hospital facility must be specially designed to meet the applicable local code requirements and the health-care needs of the community it serves, the medical-gas and vacuum piping systems must also be designed to meet the specific requirements of each hospital.

Following are the essential steps to a well-designed and functional medical-gas piped system, which are recommended to the plumbing engineer :

1. Analyze each specific area of the health-care facility to determine the following items.

A. piped medical-gas systems are required .

B. Number of each different type of medical-gas outlet/inlet terminal are required.

C. The outlet/inlet terminals be located for maximum efficiency and convenience.

2.Anticipate any building expansion and plan in which direction the expansion will take place (vertically or horizontally). Determine how the medical-gas system should be sized and valued in order to accommodate the future expansion.

3. Determine locations for the various medical-gas supply sources

4. Prepare the schematic piping layout locating the following :

A. Zone valves

B. Isolation valves.

C. Master alarms

5. Calculate the anticipated peak demands for each medical-gas system. Appropriately size each particular section so as to avoid exceeding the maximum pressure drops allowed.

5.2 MEDICAL GASES FLOW RATE

Each station must provide a minimum flow rate for the proper functioning of connected equipment under design and emergency conditions. The flow rates and diversity factors vary for individual stations in each system depending on the total number of outlets and the type of care provided.

The flow rate from the total number of out lets, without regard for any diversity, is called the total connected load. If the total connected load were used for sizing purposes, the result would be a vastly oversized system, since not all of the stations in the facility will be used at the same time. A diversity, or simultaneous-use factor, is used to allow for the fact that not all of the stations will be used at once. It is used to reduce the system flow rate in conjunction with the total connected load for sizing mains and branch piping to all parts of the distribution system. This factor varies for different areas throughout any facility.

A schematic diagram of a typical MGPS is shown in the "Operational management" volume of this HTM. This diagram shows the pipeline distribution system from the gas source to the point of use that is the terminal units.

There are three aspects of gas flow to consider when designing the pipeline distribution system :

a. the flow which may be required at each terminal unit

b. the flow required in each branch of the distribution system (see the schematic, which shows a system with several main branches)

c. the total flow, i.e. the sum of the flows in each branch

The total flow for the system is the sum of the diversified flows to each department

all flows are in normal liters per minute (l/min) unless otherwise stated

5.3 PROVISION OF TERMINAL UNIT :

A typical schedule of provision of terminal units is given in Table 1 Medical treatment policy is evolutionary, and therefore the project team should review the requirements for individual schemes.

Where an anaesthetic equipment testing area is provided, it will be necessary to provide medical gases for the testing and calibration of anaesthetic equipment. A full range of medical gas terminal units will be required, but wherever possible, medical air should be used for testing purposes. If medical air is provided instead of the medical gas, the terminal units must be clearly labeled to prevent confusion: "TEST PANEL – GAS TERMINAL UNITS CONNECTED TO 4-BAR MEDICAL AIR ONLY .

Mounting heights for terminal units should be between 900 mm and 1400 mm above finished floor level (FFL) when installed on walls or similar vertical surfaces.

Terminal units should be mounted in positions which give the shortest practicable routes for flexible connecting assemblies, between the terminal unit and apparatus. Terminal units may be surface or flush mounted. They may also be incorporated with electrical services, nurse call systems and TV and radio audio services, in proprietary fittings such as bedhead trunking, wall panel systems and theatre pendant fittings.

When planning the installation of theatre pendant fittings, the location of the operating luminaire and other ceiling-mounted devices should be taken into consideration. When the operating room is provided with an ultra-clean ventilation (UCV) system, it may be more practicable (and cost-effective) to have the services (both medical gas and electrical) incorporated as part of the UCV system partial walls.

Terminal units which are wall mounted should be located as follows:

a. distance between centres of adjacent horizontal terminal units.
(i) 35 ± 2.5 mm for three or more terminal units) .
(ii) 150 ± 2.5 mm for two terminal units only).

This should be sufficient for double flow meters to be used, for example between an (oxygen terminal unit and a vacuum terminal unit serving two bed spaces.

b. the distance between the centre of the terminal unit and a potential obstruction on either side (for example when installed in a corner should be a minimum of 200 mm on either side).

[Table5-1]: provision of terminal units

Department	**O2**	**N2O**	**N2O/O2**	**MA4**	**SA7**	**VAC**	**AGSS**
Accident and emergency department							
Resuscitation room per trolley space	1	1	_	1	_	1	1
Major treatment/plaster room per trolley space	1	1	1p	1	1p	1	1
Post-anesthesia recovery per trolley space	1	_	_	1p	_	1	_
Treatment room/cubicle	1	_	_	_	_	1	_
Operating department							
Anesthesia room	1	1	_	1	_	1	1
Operating theatre Anesthetist	1	1	_	1	1p	2	1
Surgeon	1	1	_	1	1p	2	1

Post-anesthesia recovery per bed space	1	_	_	1	_	1	_
Equipment service room per work space	1	1	_	1	1p	1	1
Maternity department							
Delivery suite Normal delivery room Mother	1	_	1	_	_	1	_
Baby	1	_	_	1	_	1	_
Abnormal delivery room Mother	1	1	1	1	_	2	1
Baby	1	_	_	1	_	1	_
Operating suite Anesthesia room	1	1	_	1	_	1	1
Operating theatre Anesthetist	1	1	_	_	_	1	_
In-patient accommodation							
Single bedroom	1	_	_	_	_	1	_
Multi bedroom	1	_	_	_	_	1	_
p = project team option							

5.4TYPE OF MEDICAL GASES

5.4.1 Oxygen

Oxygen may be used for patients requiring supplemental oxygen via a mask. Usually accomplished by a large storage system of liquid oxygen at the hospital which is evaporated into a concentrated oxygen supply, pressures are usually around 55 psi. In small medical centers with a low patient capacity, oxygen is usually supplied by multiple standard cylinders.

To calculate the amount of oxygen gas in the hospital there is a table (5-2) where each equation into the hospital n number of beds Q the flow oxygen , Private and through which knowledge of the amount of gas flow L/M space you need to know and which is the diameter of the pipe through the existing tables in APPENDEX .

Table [5-2] flow of oxygen :

Department	Design flow for each terminal unit (l/min)	n	Diversified flow Q (l/min)		
In-patient accommodation (ward unit):					
Single 4-bed rooms and treatment room	10	0	Qw=10+[(n-1)6/4]	=	0
Ward block/department	10	0	Qd=Qw[1+(nW-1)/2]	=	0
Accident & emergency:					
Resuscitation,per trolley space	100	0	Q=100+[(n-1)6/4]	=	0
Major treatment/plaster room per trolly space	10	0	Q=10+[(n-1)6/4]	=	0
Post-anaesthesia recovery,per trolly space	10	0	Q=10+[(n-1)6/8]	=	0
Treatment room/cubical room	10	0	Q=10+[(n-1)6/10]	=	0
Operating:					
Anaethetic rooms	100	0	Q=no addition made		
Operating rooms	100	0	Q=100+(n1-1)10	=	0
Post anaesthetisia recovery	10	0	Q=10+(n-1)*6	=	0
Maternity:					
LDRP rooms:					
Mother	10	0	Q=10+[(n-1)6/4]	=	0
Baby	10	0	Q=10+[(n-1)3/4]	=	0
Operating suites:		0			
Anaethetist	100	0	Q=100+(nS-1)6	=	0
Paediatrician	10	0	Q=10+(n-1)3	=	0
Post anaesthetisia recovery	10	0	Q=10+[(n-1)3/4]	=	0
In-patient accommodation:					
Single/multi-bed wards	10	0	Q=10+(n-1)3	=	0
Nursery per cot space	10	0	Q=10+[(n-1)3/2]	=	0
Special care baby unit	10	0	Q=10+(n-1)3	=	0
Radiological:					
All anaesthetic and procedures rooms	100	0	Q=10+[(n-1)6/3]	=	0
Critical care areas	10	0	Q=10+[(n-1)6]3/4	=	0
Coronary care unit (CCU)	10	0	Q=10+[(n-1)6]3/4	=	0
High-dependency unit (HDU)	10	0	Q=10+[(n-1)6]3/4	=	0
Renal	10	0	Q=10+[(n-1)6/4]	=	0
CPAP ventilation	75	0	Q=75n*75%	=	0
Adult mental illness accommodation:					
Electro-convulsive therapy (ECT) room	10	0	Q=10+[(n-1)6/4]	=	0
post anaesthetisia,per bed space	10	0	Q=10+[(n-1)6/4]	=	0
Oral surgery/orthodontic:					
Consulting rooms,type 1	10	0	Q=10+[(n-1)6/2]	=	0
consulting rooms,type 2&3	10	0	Q=10+[(n-1)6/3]	=	0
Recovery room ,per bed space	10	3	Q=10+[(n-1)6/6]	=	12
Out-patient:					
Treatment rooms	10	0	Q=10+[(n-1)6/4]	=	0
Equipment service rooms,sterile services etc	100		residual capacity will be adequate without an aditional allowance		

5.4.2 NITROUS OXIDE :

Nitrous Oxide is supplied to various surgical suites for its anesthetic functions during pre-operative procedures. Delivered to the hospital in standard tanks and supplied through the Medical Gas system. System pressures around 50 psi.

Nitrous Oxide gas calculations are the same as the previous gas calculations but there is a difference in flow rate equations and it is in table (5-3).

Table [5-3] flow of Nitrous Oxide :

Department	Design flow for each terminal unit (l/min)	n	Diversified flow Q (l/min)		
Accident & emergency:resuscition room , per trolley space	10	0	Qw=10+[(n-1)6/4]	=	0
Operating	15	0	Qw=15+(nT-1)6	=	0
Maternity:Operating suites	15	0	Qw=15+(nS-1)6	=	0
Radiological:All anaesthetic and procedures rooms	15	0	Qw=10+[(n-1)6/4]	=	0
Critical care areas	15	0	Qw=10+[(n-1)6/4]	=	0
Oral surgery/orthodontic:Consulting rooms,type 1	10	0	Qw=10+[(n-1)6/4]	=	0
Other departments	10	0	No additional flow included	=	0
Equipment service room	15	0	No additional flow included	=	0

5.4.3 MEDICAL AIR

Medical Air is supplied by a special air compressor to patient care areas using clean outside air. Pressures are maintained around 55 psi.

Medical Air gas calculations are the same as the previous gas calculations but there is a difference in flow rate equations and it is in table (5-4).

.

Table[5-4]FLOW OF Medical Air :

Department	Design flow for each terminal unit (l/min)	n	Diversified flow Q (l/min)		
In-patient accommodation (ward unit):					
Single 4-bed rooms and treatment room	20	0	Qw=20+[(n-1)10/4]	=	0
Ward block/department	20	0	Qd=Qw[1+(nW-1)/2]	=	0
Accident & emergency:					
Resuscitation per trolley space	40	0	Q=40+[(n-1)20/4]	=	0
Major treatment/plaster room per trolly space	40	0	Q=40+[(n-1)20/4]	=	0
Post-anaesthesia recovery,per trolly space	40	0	Q=40+[(n-1)40/4]	=	0
Operating:					
Anaethetic rooms	40	0	Q=no addition made		
Operating rooms	40	0	Q=40+[(nT-1)40/4]	=	0
Post anaesthetis a recovery	40	0	Q=40+[(n-1)10/4]	=	0
Maternity:					
LDRP rooms	40	0	Q=40+[(n-1)40/4]	=	0
Baby	40	0	Q=40+[(n-1)40/4]	=	0
Operating suites:					
Anaethetist	40	0	Q=40+[(nS-1)10/4]	=	0
Post-anaethetis a recovery	40	0	Q=40+[(n-1)40/4]	=	0
Neonatal unit (SCBU)	40	0	Q=40n	=	0
Radiological:					
All anaesthetic and procedures rooms	40	0	Q=40+[(n-1)40/4]	=	0
Critical care areas	80	0	Q=80+[(n-1)80/2]	=	0
High-dependency unit (HDU)	80	0	Q=80+[(n-1)80/2]	=	0
Renal	20	0	Q=20+[(n-1)10/4]	=	0
Oral surgery/orthodontic:					
Major dental surgery rooms	40	0	Q=40+[(n-1)40/2]	=	0
Other departement:	40	0	No additional flow included	=	0
Equipment service rooms	40	0	No additional flow included	=	0

5.4.4 MEDICAL VACUUM :

Medical Vacuum in a hospital supports vacuum equipment and evacuation procedures, usually supplied by various vacuum pump systems exhausting to the atmosphere. Continuous vacuum is maintained around 22 inches of mercury. Executive.

Medical Vacuum gas calculations are the same as the previous gas calculations but there is a difference in flow rate equations and it is in table (5-5).

Table [5-5] flow of Medical Vacuum :

Department	Design flow for each terminal unit (l/min)	n	Diversified flow Q (l/min)		
In-patient accommodation:					
Ward unit	40	0	Qw=40	=	0
Multiple ward units	40	0	Qd=40−[(n-1)40/4]	=	0
Accident & emergency:					
Resuscitation,per trolley space	40	0	Q=40−[(n-1)40/4]	=	0
Major treatment/plaster room per trolly space	40	0	Q=40−[(n-1)40/4]		0
Post-anaesthesia recovery,per trolly space	40	0	Q=40−[(n-1)40/4]	=	0
Treatment room/cubical room	40	0	Q=40−[(n-1)40/8]	=	0
Operating:					
Anaethetic rooms	40	0	No addition flow included		0
Operating rooms					
Anaesthetist	40	0	Q=40	=	0
Surgeon	40	0	Q=40	=	0
Operating suites:	40	0	Qs=80−[(nS-1)80/2]	=	0
Post anaesthetisia recovery	40	0	Q=40−[(n-1)40/4]	=	0
Maternity:					
LDRP rooms:					
Mother	40	0	Q=40−[(n-1)40]/4	=	0
Baby	40	0	No addition flow included		0
Operating suites:					
Anaesthetist	40	0	Q=40		0
Obstetrician	40	0	Q=40	=	0
Operating suites	80	0	Qs=80−[(nS-1)80/2]	=	0
Post anaesthetisia recovery	40	0	Q=40−[(n-1)40/4]	=	0
In-patient accommodation:					
Ward unit comprising single,multi-bed & treatment room	40	0	Q=40		0
Multi-ward unit	40	0	Qs=40−[(n-1)40/2]	=	0
Nursery,per cot space	40	0	No addition flow included	=	0
Special care baby unit SCBU	40	0	Q=40−[(n-1)40/4]	=	0
Radiological/diagnostic departments:					
All anaesthetic and procadures rooms	40	0	Q=40−[(n-1)40/8]		0
Critical care areas	40	0	Q=40−[(n-1)40/4]	=	0
High dependency unit (HDU)	40	0	Q=40−[(n-1)40/4]		0
Renal	40	0	Qd=40−[(n-1)40/4]	=	0
Adult mental illness accommodation:					
Electro convulsive therapy (ECT) room	40	0	Q=40−[(n-1)40/4]	=	0
post anaesthelisia,per bed space	40	0	Q=40−[(n-1)40/8]	=	0
Oral surgery/orthodontic:					
Consulting rooms,type 1	40	0	Dental vacuum only		
consulting rooms,type 2&3	40	0	Dental vacuum only		
Recovery room ,per bed space	40	0	Q=40−[(n-1)40/8]	=	0
Out-patient:					
Treatment rooms	40	0	Q=40−[(n-1)40/8]	=	0
Equipment service rooms,sterile services,etc	40		residual capacity will be adequate without an aditional allowance	=	

7.4.5 ANAESTHETIC GAS SCAVENGING SYSTEMS:

Anaesthetic gas scavenging systems (AGSS) transport exhaled and waste anaesthetic gases from the exhaust valve of an anaesthetic ventilator or anaesthetic breathing system into the atmosphere at a safe location away from the operating theatre , 'Active' AGSS incorporate a mechanical pump to assist with the disposal of the waste gase.

(AGSS) gas calculations are the same as the previous gas calculations but there is a difference in flow rate equations and it is in table (5-6).

Table (5-6) flow of (AGSS)

Department	Design flow for each terminal unit(v) (l/min)	n	Diversified flow Q (l/min)		
Accident & emergency:resuscition room , per trolley space	130	0	Q=V+[(n-1)V/4]	=	0
Operating	130	0	Qw=V+(nT-1)V	=	0
Maternity:Operating suites	130	0	Qw=V+(nS-1)V	=	0
Radiological:All anaesthetic and procedures rooms	130	0	Qw=V+[(n-1)V/4]	=	0
Oral surgery/orthodontic:Consulting rooms,type 1	130	0	Qw=V+[(n-1)V/4]	=	0
Other departments	130	0	Qw=V+[(n-1)V/3]	=	0

5.5 CALCULATION OF MEDICAL GASES

5.5.1 Flow of gases

5.5.1.1 Eighth floor

5.5.1.1.1 Oxygen

1. Operating rooms

Q=100+(n-1)10 From table [5-2]

Q : The flow of oxygen gases (L/m)

n : Number of beds

Q=100+(1-1)10

Q=100 L/m

There are three operating rooms on the eighth floor

2.Recovery rooms

Q=10+(n-1)6 From table (5-2)

Q=10+(2-1)6

Q=16 L/m

There are five recovery rooms on the eighth floor.

3. ICU rooms

Q=10+[(n-1)6]3/4 From table [5-2]

Q=10+[(1-1)6]3/4

Q=10 L/m

There are five ICU rooms on the eighth floor

5.5.1.1.2 NITROUS OXIDE

1. Operating rooms

Q=15+(n-1)6 From table (5-3)

Q :The flow of Nitrous Oxide gases (L/M)

n :Number of beds

Q=15+(1-1)6

Q= 15 L/m

5.5.1.1.3 Medical Air

1. Operating rooms

Q=40+[(n-1)40/4] From table (5-4)

Q :The flow of Medical Air gases (L/M)

n :Number of beds

Q=40+[(1-1)40/4]

Q=40 L/m

2.Recovery rooms

Q=40+[(n-1)10/4]

Q=40+[(2-1)10/4] = 42.5 L/m

3.ICU rooms

Q=80+[(n-1)80/2]

Q=80+[(1-1)80/2]

Q=80 L/m

7.5.1.1.4 Medical Vacuum

1. Operating rooms

We need flow of Medical Vacuum gases in operating room Always 80 L/m From Table [7-5].

2.Recovery rooms

Q= 40+[(n-1)40/4]

Q=40+[(2-1)40/4]

Q=50 L/m

3.ICU rooms

Q=40+[(n-1)40/4]

Q=40+[(1-1)40/4]

Q=40 L/m

5.5.1.1.5 Anaesthetic gas scavenging systems (AGSS)

1. Operating rooms

Q=130+[(n-1)130/4] From Table (5-6)

Q :The flow of (AGSS) gases (L/m)

n :Number of beds

Q=130+[(1-1)130/4] = 130 [L/m]

Table (5-7)

The flow of medical gas in the all of the floors of the hospital :

	Oxygen	Nitrous Oxide	Medical Air	Medical Vacuum	(AGSS)

Eighth floor	314 L/m	65 L/m	385 L/m	440 L/m	360 L/m
Seventh Floor	162 L/m	15 L/m	40 L/m	440 L/m	130 L/m
Sixth floor	179 L/m	42 L/m	295 L/m	680 L/m	520 L/m
Fourth Floor	37 L/m	-	-	85 L/m	-
Third Floor	47 L/m	25 L/m	140 L/m	155 L/m	360 L/m

5.5.2MECHANICAL EQUPMENT :

5.5.2.1 cylinder Oxygen :

The amount of oxygen gas m^3/h = F×60 min/1000 lit from Medical gas **pipeline systems book.**

F : The amount of oxygen gas flowing in all hospital L/m

The amount of oxygen gas m^3/h=739×60/1000

=44.34 m^3/h

- **Number of cylinder Oxygen gases**= The amount of oxygen gas m^3/h/ Capacities of oxygen gas cylinders m^3

-Capacities of oxygen gas cylinders=6540 liters from Medical gas pipeline systems book and table in APPENDEX.

Number of cylinder Oxygen gases= 44.34 /6.54

= 6.7 ≈7 cylinders

* Are seven cylinders in the case of operating permanent and seven other cylinders in the case of stand by.

5.5.2.2 CYLINDER NITROUS OXIDE :

The amount of Nitrous Oxide gas m^3/h = F×60 min/1000 lit from Medical gas pipeline systems book.

F : The amount of Nitrous Oxide gas flowing in all hospital L/m

The amount of Nitrous Oxide gas m^3/h=147×60/1000 =8.82 m^3/h.
-Number of cylinder Nitrous Oxide gases= The amount of Nitrous Oxide gas m^3/h/ Capacities of Nitrous Oxide gas cylinders m^3.

-Capacities of Nitrous Oxide gas cylinders=4740 liters from Medical gas pipeline systems book and table in APPENDEX.

Number of cylinder Oxygen gases= 8.82/4.74

= 1.86 ≈ 2 cylinders

Are two cylinders in the case of operating permanent and two other cylinders in the case of stand by

5.5.2.3 compressor of Medical Air

The amount of Medical Air gas m^3/h = F×60 min/1000 lit from Medical gas pipeline systems book

F : The amount of Medical Air gas flowing in all hospital L/m

The amount of Medical Air gas m^3/h =860×60/100

= 51.6 m^3/h.

We need a compressor can compress 55 m^3/h of the Medical Air gases.

5.5.2.4 PUMP OF MEDICAL VACCUM :

The amount of Medical Vacuum gas m^3/h = F×60 min/1000 lit from Medical gas pipeline systems book.

F : The amount of Medical Vacuum gas flowing in all hospital L/m

The amount of Medical Vacuum gas m^3/h=1800×60/1000

=108 m^3/h.

We need to be able suction pump 115 m^3/h of the gas to the outside air

5.5.2.5 PUMP(AGSS)

The amount of (AGSS)gas m^3/h = F×60 min/1000 lit from Medical gas pipeline systems book.

F : The amount of (AGSS)gas flowing in all hospital L/m

The amount of (AGSS)gas m^3/h = 1370×60/1000

$=82.5\ m^3/h.$

We need to be able suction pump 85 m^3/h of the gas to the outside air.

- Conclusion :

In this project we are design mechanical systems for a hospital this include

- recognizing different HVAC systems ,duct calculations ,cooling and heating calculations ,and were used software programs instead of charts

- knowing plumping systems , calculations of different pipes diameters and manholes calculations .

- recognizing medical gas systems ,the mechanical parts needed by the system ,calculations of pipes diameter, and where every gas can be founded

REFERACE:

1-The American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE), *international* technical society for all individuals and organizations interested in heating, ventilation, air-conditioning, and refrigeration ,American

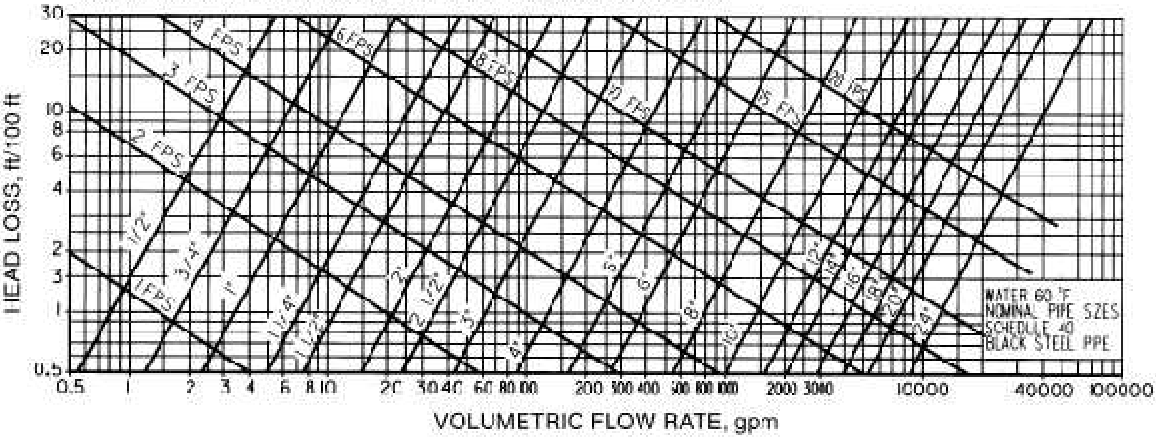
2- Sheet Metal and Air Conditioning Contractors' National Association (SMACNA) international association of union contractors, has 1,944 members in 98 chapters throughout the United States, Canada, Australia and Brazil

3-Arnell.N.1996,Plumping system,1 st ed,John Wiley & sons ,New York

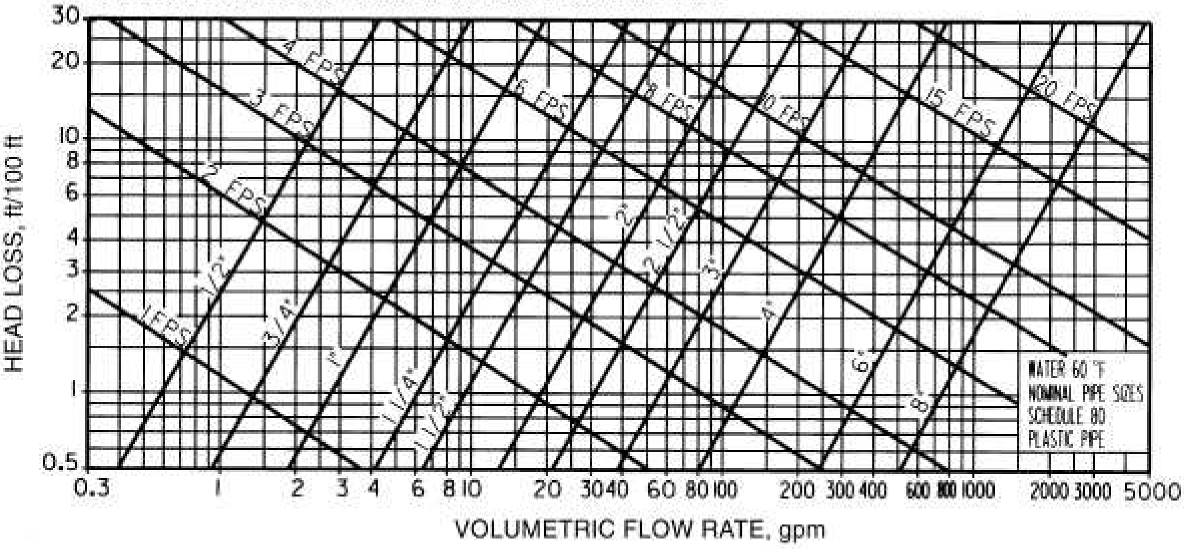
4- Executive Agency of the Department of Healt,1997h ,NHS, Medical gas pipeline systems ,London

5- The American Society of Plumping Engineers (ASPE),2001.Volume 3 special Plumping systems , American

B-6 FRICTION HEAD LOSSES IN SCH BLACK STEEL PIPE



B-7 FRICTION HEAD LOSSES IN SCH PLASTICE PIPE



APPENDEX B

B-1 Estimation 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	101
300	85	300	110
400	105	400	125
500	125	500	142
750	170	750	175
1000	210	1000	215
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

B-2 Total Estimation Hot Water Demand

Building Type	Hot Water[a] per Person, gal/day	Maximum Hourly Demand, Portion of Daily Use, gal	Duration of Peak Load, hr	Storage Capacity, Portion of Daily Use, gal	Heating Capacity Portion of Daily Use, gph
Residences, apartments, hotels[b]	20–40	1/7	4	1/5	1/7
Office buildings	2–3	1/5	2	1/5	1/6
Factory buildings	5	1/3	1	2/5	1/8

B-3 Minimum Pressure Required By Typical Plumping Fixture

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

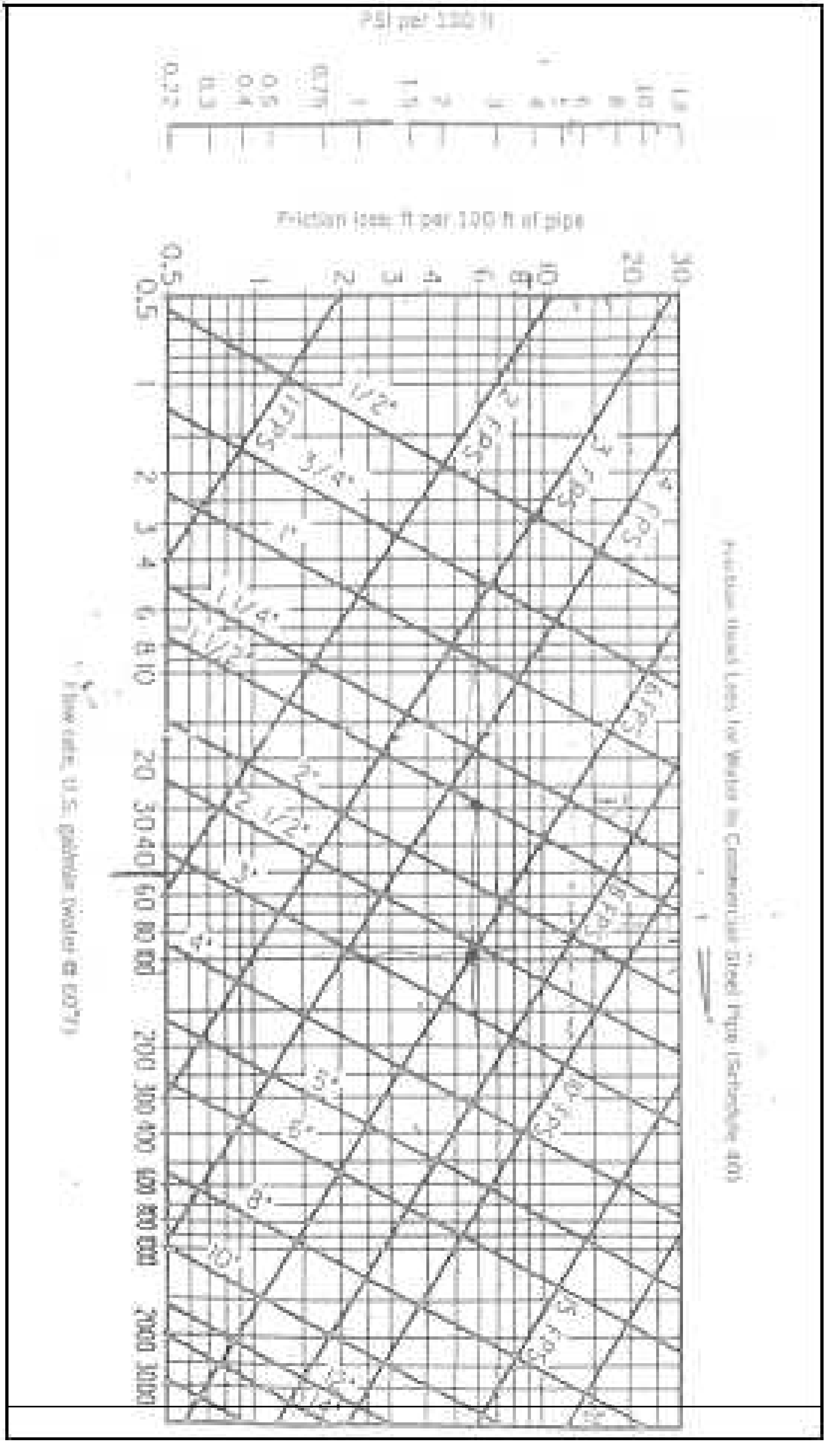
B-4 Recomenden Flow Rate For Typical Plumping

Fixture Type	Flow, gpm
Lavatory	3
Sink	4.5
Bathtub	6
Laundry tray	5
Shower	3–10
Water closets	
tank type	3
flush valve[a]	15–40
Urinal flush valve	15
Garden hose	
⅝-in. sill cock	3⅓
¾-in. sill cock	5
Drinking fountain	¾

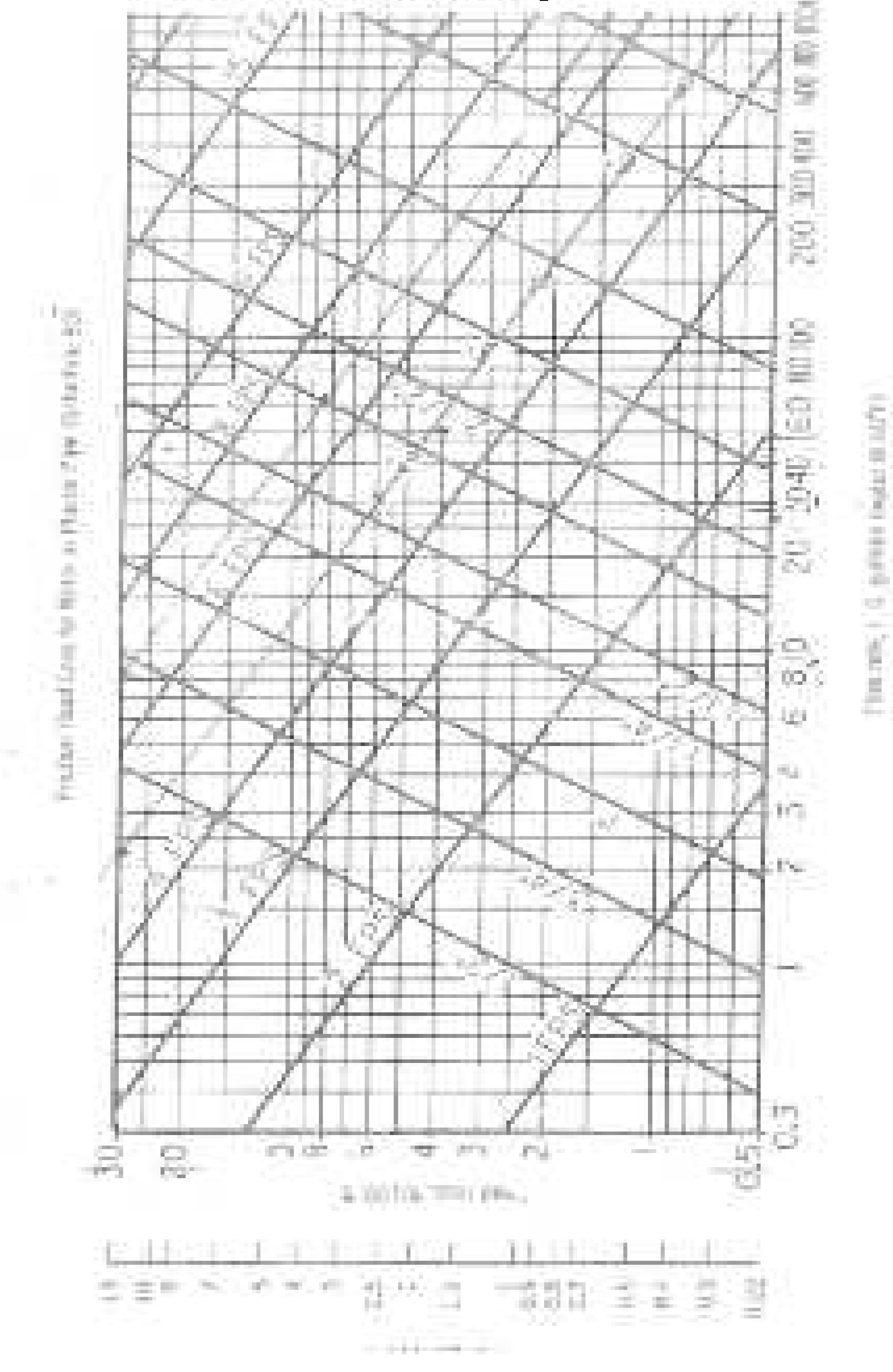
B-5 Water Supply Fixture Unite

Fixture[a]	Use	Type of Supply Control	Fixture Units[b]	Min. Size of Fixture Branch,[c] in.
Bathroom group[d]	Private	Flushometer	[illegible]	—
Bathroom group[d]	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
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

B-6 Frictio Head Losses in SCH 40 Black Steel IRon



B-7 Friction Head Losses in Sch Plastic Pipe



APPENDX A

A-1 cooling load factor due to equpment

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

A-2 Cooling Load Factor Due To Lighting

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

A-3 Cooling Load Tempresure Defferance For Convection Heat For Glass Windows

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

A-4 Cooling Load Factor For Glass Windows With Interor SHading

Fenestration Facing	Solar Time, h																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
N	0.08	0.07	0.06	0.06	0.07	0.73	0.66	0.65	0.73	0.80	0.86	0.89	0.89	0.86	0.82	0.75	0.78
NNE	0.03	0.03	0.02	0.02	0.03	0.64	0.77	0.62	0.42	0.37	0.37	0.37	0.36	0.35	0.32	0.28	0.23
NE	0.03	0.02	0.02	0.02	0.02	0.56	0.76	0.74	0.58	0.37	0.29	0.27	0.26	0.24	0.22	0.20	0.16
ENE	0.03	0.02	0.02	0.02	0.02	0.52	0.76	0.80	0.71	0.52	0.31	0.26	0.24	0.22	0.20	0.18	0.15
E	0.03	0.02	0.02	0.02	0.02	0.47	0.72	0.80	0.76	0.62	0.41	0.27	0.24	0.22	0.20	0.17	0.14
ESE	0.03	0.03	0.02	0.02	0.02	0.41	0.67	0.79	0.80	0.72	0.54	0.34	0.27	0.24	0.21	0.19	0.15
SE	0.03	0.03	0.02	0.02	0.02	0.30	0.57	0.74	0.81	0.79	0.68	0.49	0.33	0.28	0.25	0.22	0.18
SSE	0.04	0.03	0.03	0.03	0.02	0.12	0.31	0.54	0.72	0.81	0.81	0.71	0.54	0.38	0.32	0.27	0.22
S	0.04	0.04	0.03	0.03	0.03	0.09	0.16	0.23	0.38	0.58	0.75	0.83	0.80	0.68	0.50	0.35	0.27
SSW	0.05	0.04	0.04	0.03	0.03	0.09	0.14	0.18	0.22	0.27	0.43	0.63	0.78	0.84	0.80	0.66	0.46
SW	0.05	0.05	0.04	0.04	0.03	0.07	0.11	0.14	0.16	0.19	0.22	0.38	0.59	0.75	0.83	0.81	0.69
WSW	0.05	0.05	0.04	0.04	0.03	0.07	0.10	0.12	0.14	0.16	0.17	0.23	0.44	0.64	0.78	0.84	0.78
W	0.05	0.05	0.04	0.04	0.03	0.06	0.09	0.11	0.13	0.15	0.16	0.17	0.31	0.53	0.72	0.82	0.81
WNW	0.05	0.05	0.04	0.03	0.03	0.07	0.10	0.12	0.14	0.16	0.17	0.18	0.22	0.43	0.65	0.80	0.84
NW	0.05	0.04	0.04	0.03	0.03	0.07	0.11	0.14	0.17	0.19	0.20	0.21	0.22	0.30	0.52	0.73	0.82
NNW	0.05	0.05	0.04	0.03	0.03	0.11	0.17	0.22	0.26	0.30	0.32	0.33	0.34	0.34	0.39	0.61	0.82
HORIZ.	0.06	0.05	0.04	0.04	0.03	0.12	0.27	0.44	0.59	0.72	0.81	0.85	0.85	0.81	0.71	0.58	0.42

A-5 Solar Heat Gain Factor For Sun Light Glass

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

A-6 Approximate CLTD Value For Light,Medum,Heavy Weigh Construction Walls

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

A-7 Lattude Month Correction Factor LM,as Applied To Walls and Roofs

Lat.	Month	N	NNW	NW	WNW	W	WSW	SW	SSW	S	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

A-8 Cooling Load Tempresure Defferance CLTD For Sun Light Roofs

No.	Roof Description of Construction	U_w W/m² °C	Solar Time, h																							
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
	Without Suspended Ceiling																									
1	Steel sheet with 25.4 mm (or 50.8 mm) insulation	1.209 (0.704)	0	−1	−2	−2	−3	−2	3	11	19	27	34	40	43	44	43	39	33	25	17	10	7	5	3	1
2	25 mm wood with 25.4 mm insulation	0.961	3	2	0	−1	−2	−2	−1	2	8	15	22	29	35	39	41	41	39	35	29	21	15	11	8	5
3	101.6 mm L.W. concrete	1.209	5	3	1	0	−1	−2	−2	1	5	11	18	25	31	36	39	40	40	37	32	25	19	14	10	7
4	50.8 mm H.W. concrete 25.4 mm (or 50.8 mm) insulation	1.170 (0.693)	7	5	3	2	0	−1	0	2	6	11	17	23	28	33	36	37	37	34	30	25	20	16	12	10
5	25.4 mm wood with 50.8 insulation	0.619	2	0	−2	−3	−4	−4	−4	−2	3	9	15	22	27	32	35	36	35	32	27	20	14	10	6	3
6	152.4 mm L.W. concrete	0.897	12	10	7	5	3	2	1	0	2	4	8	13	18	24	29	33	35	36	35	32	28	24	19	16
7	63.5 mm wood with 25.4 mm insulation	0.738	16	13	11	9	7	6	4	3	4	5	8	11	15	19	23	27	29	31	31	30	27	25	22	19
8	203.4 mm L.W. concrete	0.715	20	17	14	12	10	8	6	5	4	4	5	7	11	14	18	22	25	28	30	30	29	27	25	22
9	101.6 mm H.W. concrete with 25.4 mm (or 50.8 mm) insulation	1.136 (0.681)	14	12	10	8	7	5	4	4	6	8	11	15	18	22	25	28	29	30	29	27	24	21	19	16
10	63.5 mm wood with insulation	0.528	18	15	13	11	9	8	6	5	5	5	7	10	13	17	21	24	27	28	29	29	27	25	23	20
11	Roof terrace	0.602	19	17	15	14	12	11	9	8	7	8	8	10	12	15	18	20	22	24	25	26	25	24	22	21

A-9 Friction CHart For Round Duct

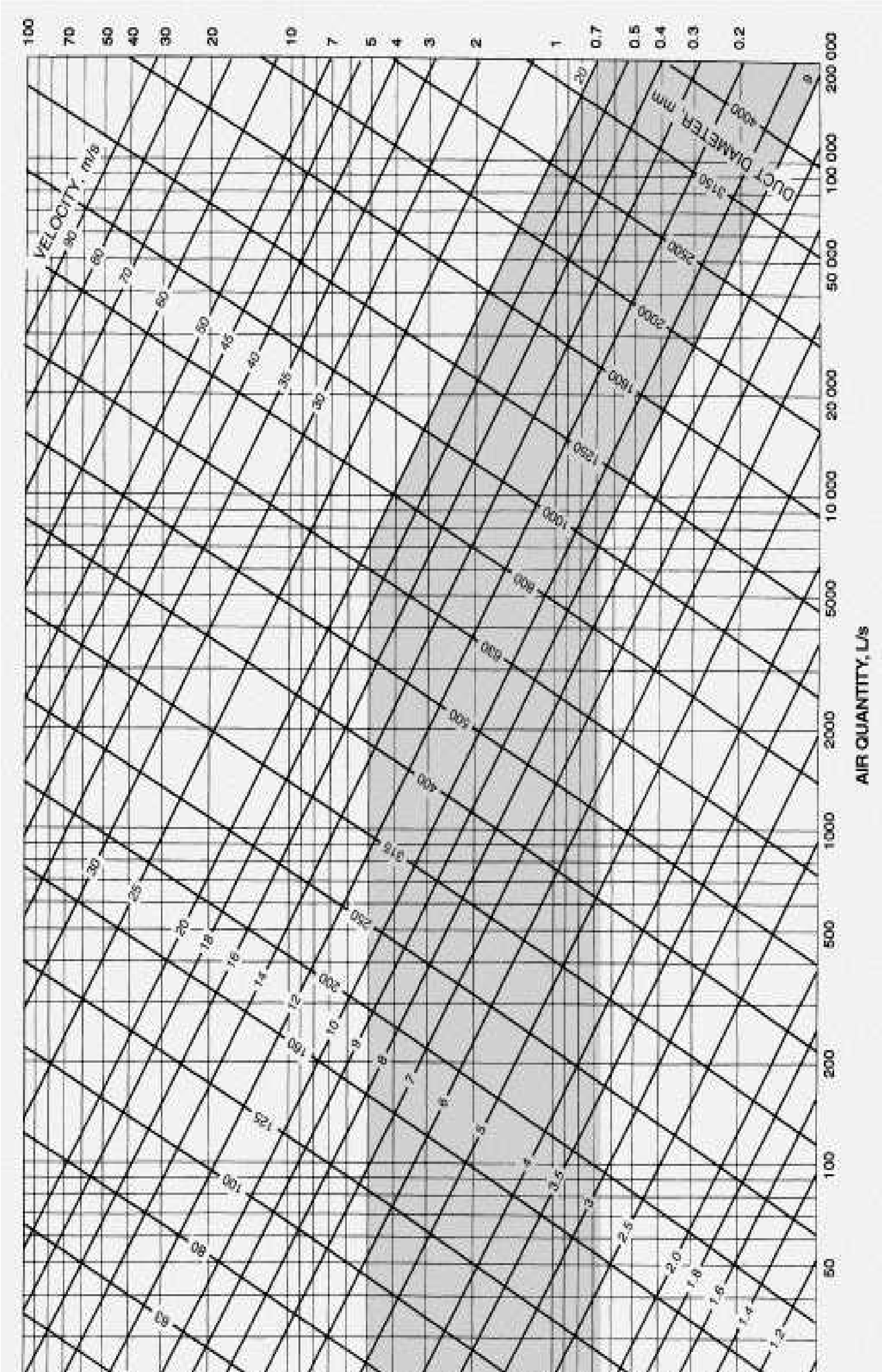


Fig. 9 Friction Chart for Round Duct ($\rho = 1.20$ kg/m^3 and $\varepsilon = 0.09$ mm)

A-10 Cercular Equivelant Rectangular Duct For Equal Friction and Capacity

Lgth Adj.[b]	Length of One Side of Rectangular Duct (a), mm																			
	100	125	150	175	200	225	250	275	300	350	400	450	500	550	600	650	700	750	800	900
	Circular Duct Diameter, mm																			
100	109																			
125	122	137																		
150	133	150	164																	
175	143	161	177	191																
200	152	172	189	204	219															
225	161	181	200	216	232	246														
250	169	190	210	228	244	259	273													
275	176	199	220	238	256	272	287	301												
300	183	207	229	248	266	283	299	314	328											
350	195	222	245	267	286	305	322	339	354	383										
400	207	235	260	283	305	325	343	361	378	409	437									
450	217	247	274	299	321	343	363	382	400	433	464	492								
500	227	258	287	313	337	360	381	401	420	455	488	518	547							
550	236	269	299	326	352	375	398	419	439	477	511	543	573	601						
600	245	279	310	339	365	390	414	436	457	496	533	567	598	628	656					
650	253	289	321	351	378	404	429	452	474	515	553	589	622	653	683	711				
700	261	298	331	362	391	418	443	467	490	533	573	610	644	677	708	737	765			
750	268	306	341	373	402	430	457	482	506	550	592	630	666	700	732	763	792	820		
800	275	314	350	383	414	442	470	496	520	567	609	649	687	722	755	787	818	847	875	
900	289	330	367	402	435	465	494	522	548	597	643	686	726	763	799	833	866	897	927	984
1000	301	344	384	420	454	486	517	546	574	626	674	719	762	802	840	876	911	944	976	1037
1100	313	358	399	437	473	506	538	569	598	652	703	751	795	838	878	916	953	988	1022	1086
1200	324	370	413	453	490	525	558	590	620	677	731	780	827	872	914	954	993	1030	1066	1133
1300	334	382	426	468	506	543	577	610	642	701	757	808	857	904	948	990	1031	1069	1107	1177
1400	344	394	439	482	522	559	595	629	662	724	781	835	886	934	980	1024	1066	1107	1146	1220
1500	353	404	452	495	536	575	612	648	681	745	805	860	913	963	1011	1057	1100	1143	1183	1260
1600	362	415	463	508	551	591	629	665	700	766	827	885	939	991	1041	1088	1133	1177	1219	1298
1700	371	425	475	521	564	605	644	682	718	785	849	908	964	1018	1069	1118	1164	1209	1253	1335
1800	379	434	485	533	577	619	660	698	735	804	869	930	988	1043	1096	1146	1195	1241	1286	1371
1900	387	444	496	544	590	663	674	713	751	823	889	952	1012	1068	1122	1174	1224	1271	1318	1405
2000	395	453	506	555	602	646	688	728	767	840	908	973	1034	1092	1147	1200	1252	1301	1348	1438
2100	402	461	516	566	614	659	702	743	782	857	927	993	1055	1115	1172	1226	1279	1329	1378	1470
2200	410	470	525	577	625	671	715	757	797	874	945	1013	1076	1137	1195	1251	1305	1356	1406	1501
2300	417	478	534	587	636	683	728	771	812	890	963	1031	1097	1159	1218	1275	1330	1383	1434	1532
2400	424	486	543	597	647	695	740	784	826	905	980	1050	1116	1180	1241	1299	1355	1409	1461	1561
2500	430	494	552	606	658	706	753	797	840	920	996	1068	1136	1200	1262	1322	1379	1434	1488	1589
2600	437	501	560	616	668	717	764	810	853	935	1012	1085	1154	1220	1283	1344	1402	1459	1513	1617
2700	443	509	569	625	678	728	776	822	866	950	1028	1102	1173	1240	1304	1366	1425	1483	1538	1644
2800	450	516	577	634	688	738	787	834	879	964	1043	1119	1190	1259	1324	1387	1447	1506	1562	1670
2900	456	523	585	643	697	749	798	845	891	977	1058	1135	1208	1277	1344	1408	1469	1529	1586	1696

Lgth Adj.[b]	Length One Side of Rectangular Duct (a), mm																			
	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400	2500	2600	2700	2800	2900
	Circular Duct Diameter, mm																			
1000	1093																			
1100	1146	1202																		
1200	1196	1256	1312																	
1300	1244	1306	1365	1421																
1400	1289	1354	1416	1475	1530															
1500	1332	1400	1464	1526	1584	1640														
1600	1373	1444	1511	1574	1635	1693	1749													
1700	1413	1486	1555	1621	1684	1745	1803	1858												
1800	1451	1527	1598	1667	1732	1794	1854	1912	1968											
1900	1488	1566	1640	1710	1778	1842	1904	1964	2021	2077										
2000	1523	1604	1680	1753	1822	1889	1952	2014	2073	2131	2186									
2100	1558	1640	1719	1793	1865	1933	1999	2063	2124	2183	2240	2296								