

Palestine Polytechnic University



College of Engineering & Technology
Mechanical Engineering Department

Graduation Project

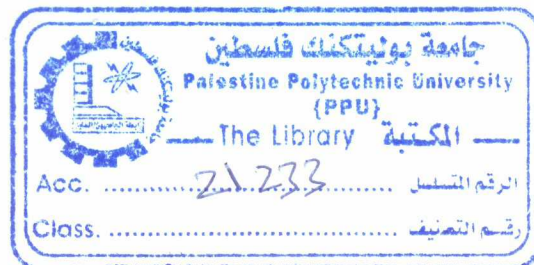
Survey and Evaluation of Mechanical Systems In
Al Amra Alia Hospital

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جامعة بوليتكنك فلسطين



Palestine Polytechnic University
(PPU)
Hebron-Palestine

PROJECT NAME
Survey and Evaluation of Mechanical Systems In
Al Amra Alia Hospital

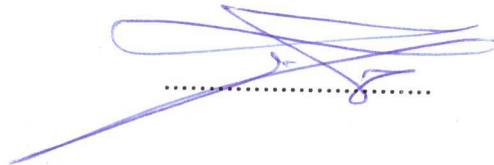
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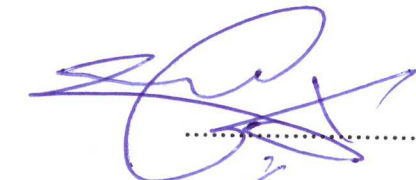
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According to the project supervisor and according to the agreement of the Testing committee members, this project is submitted to the Department of Mechanical Engineering at college of engineering and technology in partial fulfillment of the requirements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

Supervisor Signature



Examine community Signature



Department Head Signature



Dedication

We gift this graduation project
To who carry candle of science
To light his avenue
Of live

To all students & who
Wish to look for
The future

To who love the knowledge &
Looking for all is new
In this world

Acknowledgement

Our thanks go first to our advisor Dr: Jamal Shweiki. His guidance and support made this work possible. His constant encouragement, intuitive wisdom, and resolute Leadership was instrumental in completing this work.

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Abstract

In this project we will make survey and study the design of some mechanical systems in the new part of AL AMEERA ALIA HOSPITAL which include air conditioning system, heating system, water supply distribution system and drainage distribution system.

Also we will study and discuss problems in the hospital and make an evaluation of these systems and give a new and supposed solving for the problem in that part.

The different mechanical installations including central heating system, air conditioning system, water supply distribution system, drainage distribution system , and medical gas systems are not less important for the patients' than the medical service itself, so such installations must be in the best manner in addition to the continuous and maintenance of it.

Our project will contains soft ware discuss these problems and contains presentation to expose our study to the doctors and discuss them after we will finish from this project.

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CHAPTER ONE

INTRODUCTION

1 Introduction

1.1 Introduction

The Governmental hospitals in Palestine had an essential and vital rule in promoting the general health of the Palestinians people.

Alia hospital is a good example, where about half million of people in Hebron city receive treatment regularly in the different hospital departments, the health service include dealing with urgent cases specially gunshots during the Intifada.

Also thousands of people every year receive treatment and medical service in the different sections of the hospital including internal medicines, pediatrics, orthopedics, surgery ,Gynecology, obstetrics, lab investigation, x-ray and ultra sound in addition to out patient clinics and E.N.T and mother care clinics.

The importance of Alia Hospital and other governmental hospitals is that such hospitals introduce the full medical care and treatments for free since the penitents are covered by the health insurance.

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

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

1.2 General description for project idea

Princess Alia hospital was established by the Hashemite kingdom of Jordan in 1959 in Hebron city under the name of princess Alia hospital and it is the unique government hospital in Hebron city. This hospital is located at the center of Hebron city in the region called "Hapayel Alreyah".

The total area of this hospital is about 14000 m² and about 400 employees' work in this hospital, also it provides services to 450,000 persons in Hebron city.

The hospital contains several departments that offer services as shown in this table:

No #	The department	No of beds
1	Pediatric Department	45
2	Internal Department	25
3	Surgery Department	22
4	Obstetrics & Gynecology Department	28
5	ICU Department	5
6	CCU Department	5
7	NICU Department	3
8	Urology Department	10
9	Orthopedic Department	10
10	Hematology Department	4
11	Neonatal Unit	17
12	industrial college Department	14
13	Otolaryngology Department	10

Table 1.1 the departments of Alia Hospital

Besides on the ground floor there are out patient clinics, Radiology Department, Department of Physical therapy, Registration and Archive, The kitchen, maintenance, laundry unit and mechanical room.

Public administration exists in the east wing and the emergency exists in the north wing.

In this project we will study the mechanical systems which consist of central heating system, air conditioning system, plumbing system. Of the North Wing which contains three floors and its area is about 6800 m².

1.3 Project Objectives

our project consist of two steps the first step is to make a survey for central heating system, central air conditioning system, water supply system, drainage supply system.

The second step is to evaluate these mechanical systems and Give recommendation for trouble shooting of these systems and provide maintenance program for them.

This projects aims to achieve the following objectives:

Survey

The main aims of the survey step are:-

- 1- Analytical review of the design of the above mentioned mechanical systems
 - To be familiar with mechanical drawing for all systems such as central heating system, Air conditioning system and plumbing system.
 - To be familiar with the equipments used of these systems.
 - To be familiar with the different types pipe and their fittings used in all mechanical systems.
- 2- To have an idea about the most recent control system for the above network.
- 3- To get data about the problems concerted these system through Questionnaire

Evaluation

The evaluation step of this project aims to:

- 4- To study the problems those have been identified.

- 5- To study the mechanical systems In terms of design and the type of equipment and control devices and the method of installation.
- 6- To work processes measurements and tests to find the cause of problems.
- 7- To compare the devices and equipment on the ground with the existing schemes in the mechanical drawing

1.4 Project Benefits

We are choose this project for its importance for our society, also include a revision of all building mechanical systems, we was study at our university and as it represent a first step to our practical live that we will deal with after we will graduate as it provides us a knowledge of mechanical drawing, equipment, piping and control systems needed in our future carrier.

Also in our country "Palestine" the universities concern with its cooperation with its society it in all fields that possible. So one of these fields is our project in which our great Palestine polytechnic university cooperates with Alia hospital engineering's and its staff hopping to improve the work of the mechanical systems and give recommendations about the using of this system in this hospital.

Therefore as a result of these reasons our great Palestine polytechnic university takes care of this project because of its importance for the society, people, patients and wonders in our beloved city Hebron.

1.5 Budget

TASK	COST (NIC)
USING INTERNET	100
TRANSPORTATION FROM AND INTO ALIA HOSPITAL	300
OTHER TRANSPORTATION TO COPY FROM LIBRARY	150
PRINTING PAPERS	50
REPRINTING PAPER	100
PRINTING DRAWING	50
TOTAL	400
	1150

Table 1.2 Budget

1.6 Project lay out

This proposal composed of four chapters as follows:-

Chapter one: - Introduction

Include an overview about the project, and the importance of the mechanical systems. And the reason to work with it, and the previous studies.

Chapter Two: - Central Heating System

Include an overview about Central Heating System and the importance of it as a mechanical system also a survey of the Central Heating System in the hospital and the properties of this mechanical system

Chapter Three: - Air Conditioning System

Include an overview about Air Conditioning System and the importance of it as a mechanical system also a survey of the Air Conditioning System in the hospital and the properties of this mechanical system

Chapter Four: - Plumbing System

Include an overview about Plumbing System including water supply system and drainage distribution system and the importance of it as a mechanical system also a survey of the Plumbing System in the hospital and the properties of this mechanical system

1.7 Time Planning

The project plan follows the following time schedule, which includes the related tasks of study and system analysis.

The following time plan is for the first semester

1.7.1 The First Semester Time Plan

Task/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Collecting Information about the project	■	■	■													
Survey central heating system				■	■											
Survey central Air-Condition system						■	■	■								
Survey water supply system							■	■	■							
Survey drainage supply system									■	■	■					
Project Documentation	■	■	■	■	■	■	■	■	■	■	■	■	■	■		

Figure 1.1 The First Time Plan

1.7.2 The Second Semester Time Plan

Task/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Study central heating system	■	■	■													
Study central Air-Condition system				■	■											
Study water supply system						■	■	■								
Study drainage supply system							■	■	■							
Evaluate the project									■	■	■					
Project Documentation	■	■	■	■	■	■	■	■	■	■	■	■	■	■		

Figure 1.2 The Second Time Plan

CHAPTER TWO

CENTRAL HEATING SYSTEM

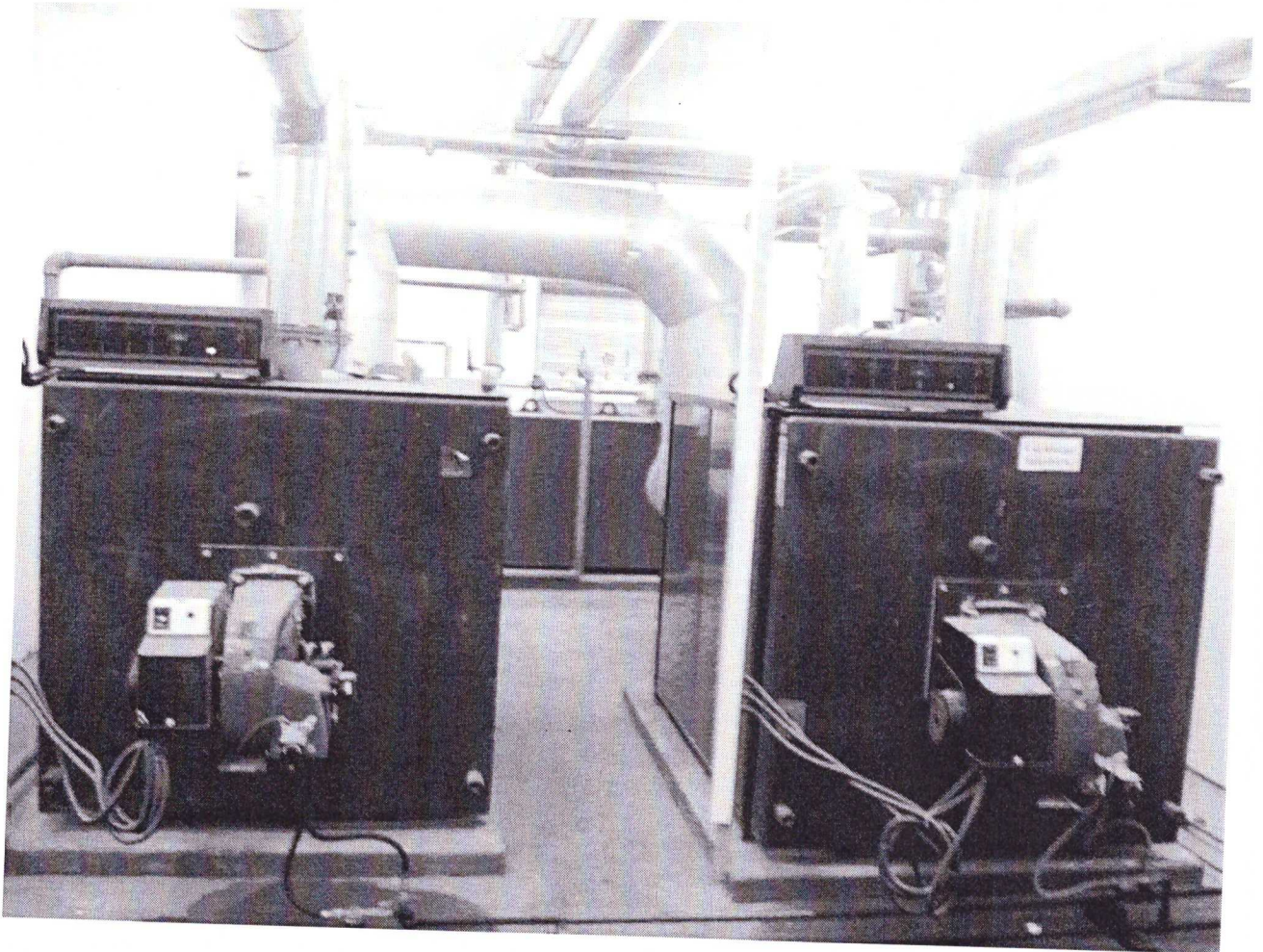
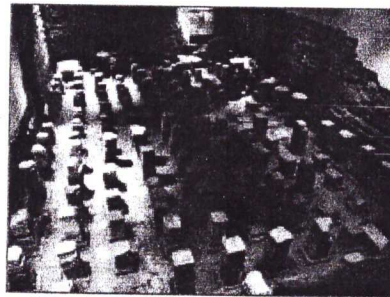


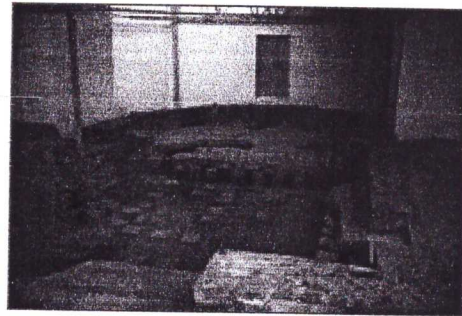
Figure 2.1 Boiler room in Alia hospital

2.1 INTRODUCTION

Central heating systems were used in northern Roman cities circa 100AD. Air heated by furnaces was led through empty spaces under the floors and out of pipes in the walls - this system being termed a hypocaust which that Roman engineers devised this ingenious system for heating public baths and private houses. The floor was raised off the ground by pillars and spaces were left inside the walls so that hot air from a furnace (praefurnium) could circulate through these open areas. Rooms requiring the most heat were placed closest to the furnace, whose heat could be increased by adding more wood.



Caldarium from the Roman Baths at Bath, England. The floor has been removed to reveal the empty spaces which the hot air would flow through.



Ruins of the hypocaust under the floor of a Roman villa. The part under the exedra is covered.

Figure 2.2 Under floor heating of a Roman villa

A derivation of hypocaust, the gloria, had been in use in Castile until the arrival of modern heating. After the fuel (straw, paper, refuse) has been reduced to ashes, the air intake is closed to keep hot air inside and slow combustion.

By the beginning of the 1700s Russian engineers were designing hydrological based systems for central heating. The best extant example is the Summer Palace of Peter the Great in St. Petersburg. Slightly later in the year 1716, water was first used in Sweden to distribute heat in buildings. This system was used by Martin Triewald, a Swedish engineer, on a greenhouse at Newcastle upon Tyne. Bonne main, a French architect, made its first industrial use on a Cooperative, at Château du Pêcq, near Paris.

2.2 What is Central Heating?

Central Heating means heating from a central source.

A central heating system consists of all the pipe work and radiators that are connected to the boiler. The **boiler** provides the **heat** but, it's the **pump** (Circulator) that moves the heated water from the boiler through the pipe work to the radiators, and back to the boiler for re-heating. There are many types of systems that can be installed, and which may be tailored to your own preferences. But a carefully designed and installed system will give many years of trouble free running and will not waste heat, therefore keeping fuel costs low.

2.3 Heating load calculation

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

- a) Heat loss through all exposed walls, ceiling, floor, windows, doors and walls between the space and unheated space.

This load is due to the transient flow of thermal energy from one system to another due to temperature difference between the two systems, there are two modes of heat transfer: conduction and convection "neglected the effect of radiation since it is too small"

This heat transfer by conduction is calculated using Fourier law of conduction:

$$Q = -K.A.[\delta T / \delta X]$$

Where:

Q: Heat flow through the walls, ceiling, floor, by conducting. (Watt).

K: conduction heat transfer coefficient (W/m.K)

A: Area of heat conductive. (m²).

[\delta T / \delta X]: Temperature gradient (°C/m).

Note: The negative sign in Fourier's law that represent the concept of heat transfer (second law of thermodynamic) "actual process occur in the direction of decreasing temperature".

The heat transfer by convection is given by the following relationship which is known as Newton's law:

$$Q = h.A. [T_w - T_\infty]$$

Where:

Q: Heat flow through the air by convection. (Watt).

h: convection heat transfer coefficient (W/m².C)

A: Area of heat convection. (m²).

T_w: Temperature of wall (C).

T_∞: temperature of space (C).

By merging the conduction and convection equations we obtained this equation:

$$Q = U.A.\Delta T$$

Where:

Q: Heat flow through the walls, floors, ceiling and air (Watt).

U: Overall heat transfer coefficient

$$U = \frac{1}{\frac{1}{h_{in}} + \frac{L_1}{K_1} + \frac{L_2}{K_2} + \frac{L_3}{K_3} + \frac{1}{h_{out}}}$$

A: Area of heat transfer. (m²).

ΔT: different between inside temperature and outside temperature

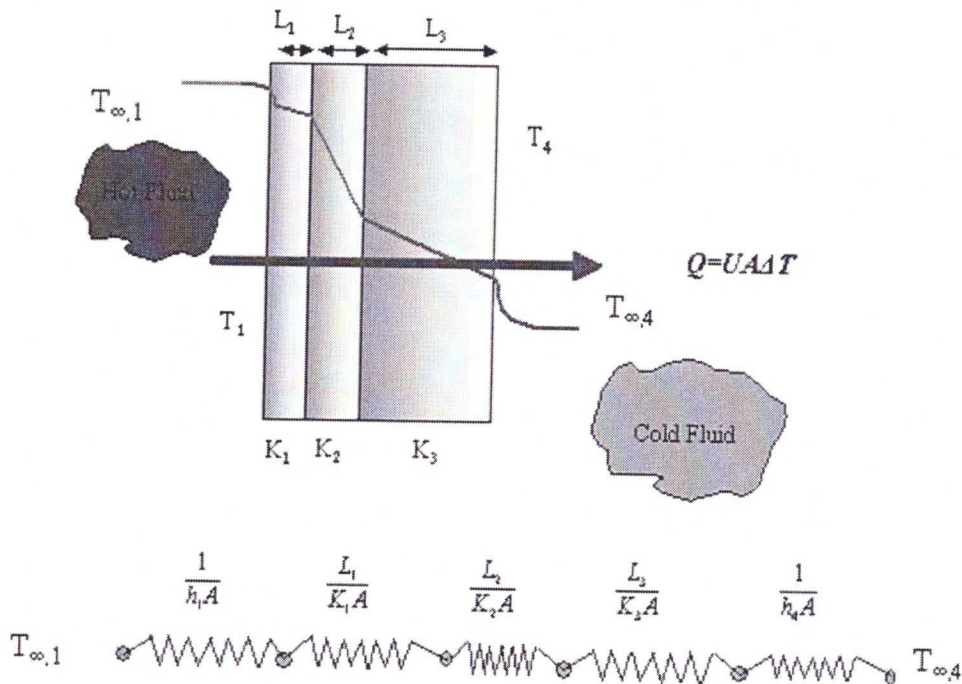


Figure 2.3 Convection and conduction heat transfer

2.3.1 Overall heat transfer coefficient In Alia hospital

- 1) Walls consist of 5cm stone, 9cm concrete, 3cm randopan, 20cm hollow blocks, 2cm plaster.
- 2) Ceiling consists of 6cm concrete, 46cm light weight blocks, 2cm plaster and 100cm air gap after false ceiling.
- 3) Floors consist of 60cm pascorce and 10cm concrete.

	Element	Overall heat transfer coefficient U (w/m ² .°C)
1	walls	0.51
2	Ceilings	0.0248
3	Floors	0.89

Table 2.1 walls, ceilings and floors overall heat transfer coefficient

- b) Heat load required to warm outside air infiltrated through cracks of windows and doors and air infiltrated due to opening and closing of doors to the temperature of the space.

Infiltration

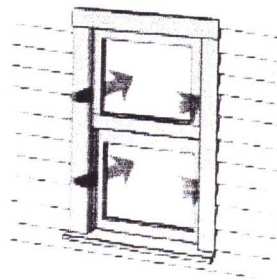


Figure 2.4 Infiltration

Infiltration heat load is divided in two parts:

- 1) Sensible heat loss: the heat increase the temperature of moist air

$$Q_s = m. cp. \Delta T$$

- 2) Latent heat transfer: heat associated with evaporation or condensation of water
Vapor at the same temperature

$$Q_L = m \cdot (w_i - w_o) h_{fg}$$

$$Q_{total} = Q_s + Q_L = m \cdot (h_o - h_i)$$

Where:

Q_s: Sensible heat loss (Watt).

Q_L: Latent heat transfer (Watt).

m: Flow rate of Air (kg/s).

cp: Specific heat for air =1.21 (KJ/Kg.K)

ΔT: Difference between inside temperature and outside temperature (C)

w_i: Specific humidity inside room (kg/kg dry air)

w_o: Specific humidity outside room (kg/kg dry air)

h_{fg}: latent heat of vaporization

h_i: Enthalpy inside room (kj/kg dry air)

h_o: Enthalpy outside room (kj/kg dry air)

c) Domestic hot water load

2.4 Hot water heating system components:

The main components of a central heating system using water circulation are:

- 1) Room heating elements (radiators or fan coils).
- 2) Boilers.
- 3) Piping network.
- 4) Circulating pump.
- 5) Expansion tank.
- 6) Oil tank.
- 7) Chimney.
- 8) Hot water cylinder.

Device and fitting are required in a hot water heating system, these include the following:

- 1) Air elimination device such as automatic air vent and manual air vents for room heating elements.
- 2) Flow control devices such as non-return valves.
- 3) Pressure relief valve.
- 4) Pressure reducing valves for balancing the piping network of the different room or balancing different zones.
- 5) Provision for pipe expansion and elimination of vibration.

2.4.1 Room heating elements

Heat transfer elements facilitate the transfer of heat between the hot water and space to be heated, heating elements that are in common use in hot water heating system are:-

2.4.1.1 Radiators:

Radiators are made of cast iron, aluminum or steel plates.

1) **Cast iron radiators:** this type of radiators are made from cast iron

Cast iron radiators contains two types

- a) Panel type
- b) Column type

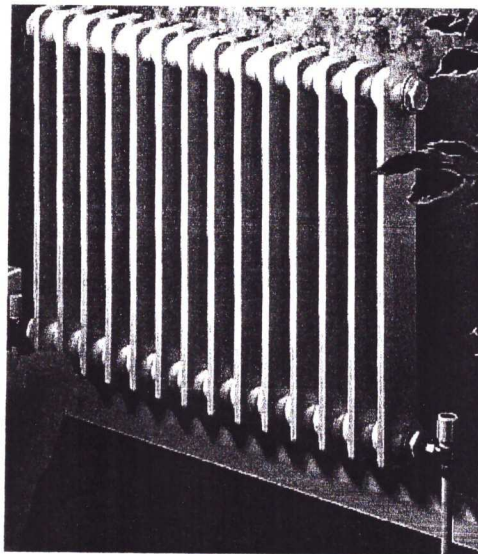


Figure 2.5 cast iron radiator

Positive features of cast iron radiators

- 1) This type of radiators is resistive to corrosion provided it good painted and that is not free of water.
- 2) They are made of sections so could be lengthened and shortened easily.
- 3) Plugging in public institutions because it bears the bruises and trauma.
- 4) Long life.

Negative features of cast iron radiators

- 1) high weight of its sections near 4.5 kg for one section
- 2) relatively high cost
- 3) brittleness
- 4) high thermal inertia

2) **Aluminum radiators:** this type of radiators are made from aluminum alloy

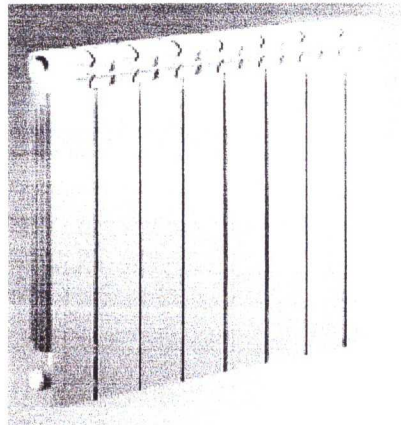


Figure 2.6 Aluminum radiator

Positive features of Aluminum radiators

- 1) This radiators has low cost.
- 2) Light weight construction near 1.5 kg for one section.
- 3) Limited thermal inertia.
- 4) They are made of sections so could be lengthened and shortened easily.

Negative features of Aluminum radiators

- 1) This type can be able to corrosion.

3) **Steel radiators:** this type of radiators is made from steel.

Steel radiators contain four types:

- a) Tube type.
- b) Blade type.
- c) Column type.
- d) Panel type.

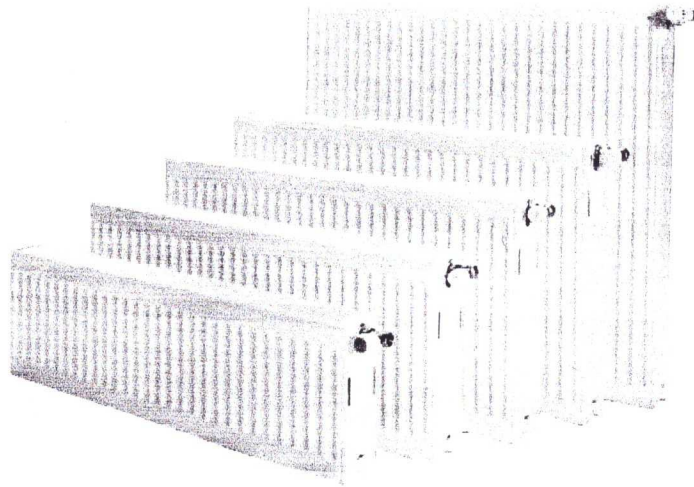


Figure 2.7 steel radiators

Positive features of steel radiators

- 1) Low cost: they are the most economical panel and column type radiators.
- 2) Low weight: they weight approximately 65 to 70 % less than cast iron radiators with the same heat out put.
- 3) Low thermal inertia on the panel type.
- 4) They blend in easily with their surrounding.

Negative features of steel radiators

- 1) High thermal inertia of the column and tube type
- 2) Thy are not assembled from sections.

3) Possible corrosion: - these radiators are easily affected by external corrosion unless they have suitable surface coatings.

2.4.1.2 Radiators used in Alia Hospital:

In Alia hospital they are used steel radiators **CHAPPEE C22/600** and these tables represent the radiators Distribution and its length in the ground floor and first floor. (see 2.1 catalogue of radiator in Appendix A)

Radiators table in ground floor:

Radiator no in dwg	Radiator C22/600 size in cm
R-1	110
R-2	50
R-3+R-4	130
R-5	90
R-6	90
R-7	150
R-8	150
R-9	50
R-10	50
R-11	70
R-12	50
R-13	50
R-14	110
R-15	50
R-16	50
R-17	50
R-18	40
R-19	130
R-20	130
R-21	110
R-22	110
R-23	120
R-24	110
R-25	110
R-26 + R-27 + R-28	120
R-29 + R-30 + R-31 + R-32	120

Table 2.2 Distribution of radiators in Ground floor

Radiators table in First floor:

Radiator no in dwg	Radiator C22/600 size in cm
R-1	40
R-2	50
R-3+R-4	40
R-5	50
R-6	70
R-7	40
R-8	90
R-9	40
R-10 + R-11 + R-12 + R-13 + R-14	40
R-15	130
R-16	40
R-17	100
R-18	110
R-19 + R-20 + R-21 + R-22	140
R-23	40
R-24	40
R-25	40
R-26 + R-27 + R-28	100
R-29	40
R-30	150
R-31	40

Table 2.3 Distribution of radiators in first floor

2.4.2 Boilers

Boilers are constructed of cast iron or steel sheets in various capacities and sizes, they may be low pressure "200 kpa" or high pressure boilers "3200 kpa".

Boilers are classified in a number of ways as follows:-

- a) They may be classified on the basis of material out of which they are made as cast iron boilers or steel sheet boilers.
- b) They may be classified on the basis of the operation pressure for example low pressure or high pressure boilers.
- c) they may be also classified on the basis of raw energy they use, for example, gas boiler, diesel boilers, or any other energy boiler.
- d) type of construction may be used for classification for example, fire tube or water tube boilers.

The boiler package contains, in addition to the boiler body, the burner, the safety control and jacket, the safety devices associated with boilers include relief valves, water level cut-off device, switch on-off device, and outlet and inlet temperature control thermostat.

2.4.2.1 Types of boilers:

- 1) Cast Iron sectional Boilers
- 2) Steel Boilers
- 3) Electrode Boilers
- 4) Steam Generators

2.4.2.2 Steel Boilers

In fire-tube boilers, the gases of combustion pass through the tubes and the water circulates around them. In water-tube boilers, the gases of combustion circulate around the tubes and the water passes through them. Either the fire-tube or water-tube type may be shipped in one package, ready for piping connections.

A packaged boiler is a boiler unit including the burner, boiler, controls, and auxiliary equipment. Medium-sized units are usually of a modified scotch marine type. Smaller units are usually of the firebox type (integral water-jacketed furnaces). A packaged boiler may be ordered as a steam or hot-water generator. Steel boilers

range in size from small residential units to those with gross heat outputs of 23,500 MBH (6883 kW).

For steel boilers, both residential and commercial, the SBI rating has been adopted by the Steel Boiler Industry Division of the Hydraulic Institute. The rating code shows the SB! gross outputs and net SB! ratings for steel boilers. The factors used to determine gross I = B = R ratings are also used to determine gross SBI ratings. Steel gas- and oil-fired boilers normally operate in an efficiency range of 70 to 80%.

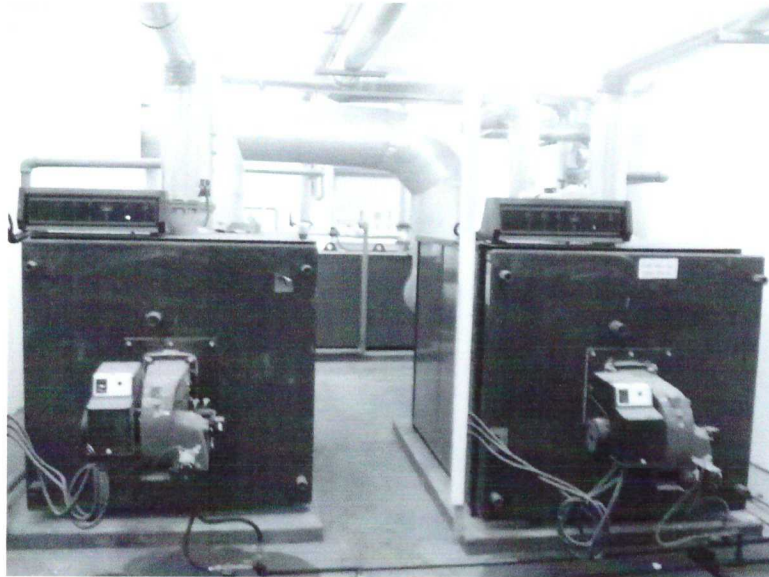


Figure 2.8 Steel boilers

2.4.2.3 Boilers used in Alia Hospital:

There are three steel boilers with oil burner exists in mechanical room in Alia hospital and there specification and use as following

1) Two boilers are used for central heating that connected with collector .One boiler every year is used and the other is standing by. They have the following specification:-

Name: CHAPEE ARIZONA CX 1210

Boiler Capacity: 1210 kw

T_{max}: 110 C

PMS: 10 bar

Burner model: SIKMA MS 130 25

Code: CS0113801GB

Flow rate: 130 kg/h

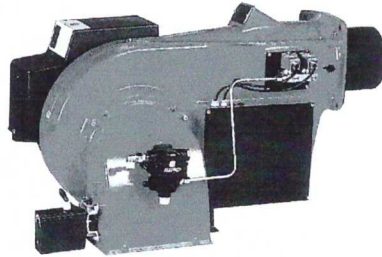


Figure 2.9 Burner

2) The third boiler is used to provide the hospital with the domestic hot water needed.

It has the following specification:-

Name: CHAPEE ARIZONA CX 385

Boiler Capacity: 385 kw

T_{max}: 110 C

PMS: 10 bar

Burner model: CAPPEE CF4825

Code: CS2148801GB

Flow rate: 47.2 kg/h

(see 2.1 catalogue of boilers in Appendix A)

2.4.3 Piping network

A distribution piping system is an arrangement of one or more pipes. The proper piping arrangement is usually selected to meet the needs of the system. Piping systems may be classified as follows:

- 1) Single pipe system
- 2) double pipe system

- 3) 3-pipe system
- 4) 4-pipe system
- 5) Radial pipe system

2.4.3.1 Radial pipe system

This pipe system uses plastic pipe instead of metal pipe for circulating the hot water throughout the heating system.

the supply pipes of a certain number of radiators are connected to a single supply manifold, using special brass coupling, the return pipes are also connected to single return manifold as shown in figure 2.6 the supply and return manifold are respectively connected to the main supply and main return pipes of boiler which may be made from plastic or metal pipes.

Alia hospital adopts this system of piping.

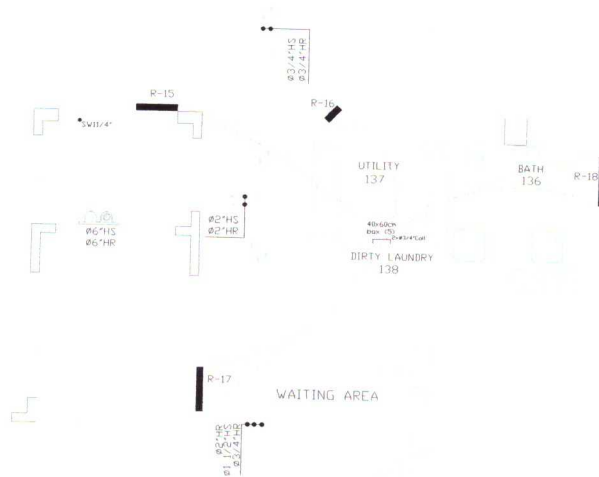


Figure 2.10 Radial pipe system

2.4.3.2 Pipe sizing

flow in pipes suffers from the friction losses between the flowing fluid and the internal walls of the pipe and from other losses associated with the flow, the parameters in which influence the magnitude of the friction losses or pressure head losses are the flow velocity, mass flow rate, fluid type, diameter of the pipe and the

inner surface roughness of the pipe, the relationship between these parameters are complex, for the purposes pipe network of the hot water heating system design, the relation between the above parameters are given in graphical forms and charts such as shown in figure 2.11

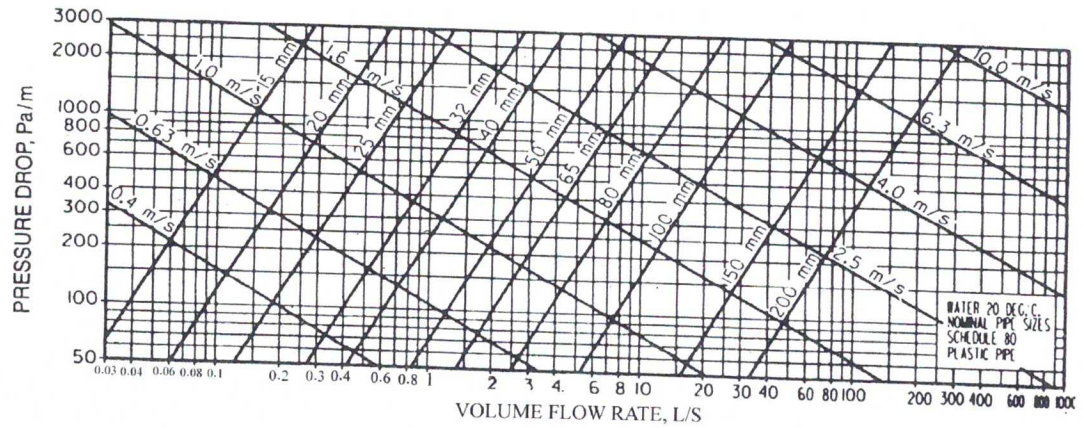


Figure 2.11 Pressure drop per unit pipe length for water flowing in commercial steel pipe.

The chart represent the relationship between the pressure drop per meter of pipe length in unit of pa/m, volume flow rate and velocity of flow and pipe diameter for water flowing in commercial steel pipes.

2.4.3.3 Pipe system design

The following items must be observed when the design procedure of the heating system piping network is carried out:-

- 1) The design temperature drop of hot water in each radiator is about 10°C.
- 2) The design water velocity in the piping network should be in range of 0.6 to 1.2 m/s, this is related to the allowable noise ratings and water hummer occurrence.
- 3) The design hot water inlet temperature to radiators is normally about 80°C.
- 4) The recommended value of the pressure drop per equivalent unit length of pipe ranges from 200 to 550 pa/m.

3) The hot water flow rate is computed from the known heating load of each circuit branch using the following equation:

$$Q = \dot{m} \cdot c_p \cdot (T_{wi} - T_{wo})$$

Where:

Q: heat required to be delivered by room radiator (KW)..

\dot{m} : mass rate of water flowing through radiator (kg/s).

c_p : Specific heat of water 4.186= (KJ/Kg.C)

T_{wi} : temperature of hot water entering the radiator (°C)

T_{wo} : temperature of hot water leaving the radiator (°C)

4) Select the circulating pump of the heating system based on the calculated values of total rate of hot water and the total pressure drop through the longest pipe run, performance curves of pumps supplied by the pump manufacture catalogues can be used for this purpose, the selection procedure is as follows:-

Let the selected pump has a pressure of ΔP " in unit of Pascal" when operates at the calculated flow rate of the pump, the value of the pressure drop per unit meter of pipe length for the selected is obtained by dividing ΔP by the total equivalent length EL, of the longest pipe run.

If obtained value of $\Delta P/EL$ turned out to be in the range of 200 to 500 Pa/m, then the selected pump is acceptable if not another selection of the pump must be made.

5) the diameter of each pipe section of the heating system is determine as follows

The hot water flow rate is known for each pipe section of the pipe network, the pressure drop per unit length is also known "from step 4" thus the chart in figure can be used to determine the pipe diameter for each pipe section.

2.4.4.2 Pumps used in Alia Hospital:

There are two pump one is used and the other is stand by

NAME	GRANDFOS
TYPE	NB80-200/222-F-A-BAOE
MODEL	OD5311B9J
Bar / C max.	16/140

Q	97 m ³ /h
H	14.5 M
N	1440 min ⁻¹

2.4.5 Expansion tank

In a closed recirculating system (hot-water heat, chilled water, combined heating and cooling), a given amount of air or gas space is required to accommodate water expansion and pressurization. Since water expands when heated and contracts when cooled in direct proportion to the temperature change, and since water is incompressible, a lack of expansion space means that any volume increase due to heating will cause an immediate and definite pressure increase. This is true even of chilled-water systems, which have limited expansion owing to their relatively narrow operating temperature range. An airtight expansion tank is the primary device used to accommodate fluctuations in water volume within a closed system while maintaining a predetermined range of pressures, from the minimum cold-fill pressure up to (but not more than) the maximum working pressure of the system. The expansion tank acts as a spring on the system, keeping the pressure on it at all times.

The location of the pump relative to the expansion-tank connection determines whether the pump head is added to or subtracted from the system static pressure. This is because the expansion tank's point of connection in the system is the point of no pressure change for the system with regard to the pressures produced by pump.

Pump

The point of connection of the expansion tank to a closed system is usually selected so that the pump discharges away from the expansion tank and the pump head adds to system pressures at all points

The necessary volume of a closed expansion tank can be expressed as

$$V_{et} = 2 V_w [(v_1 / v_0) - 1] / [(p_a / p_0) - (p_a / p_1)] \quad (2)$$

p_a = atmospheric pressure - (psia)

p_0 = system initial pressure - cold pressure (psia)

p_1 = system operating pressure - hot pressure (psia)

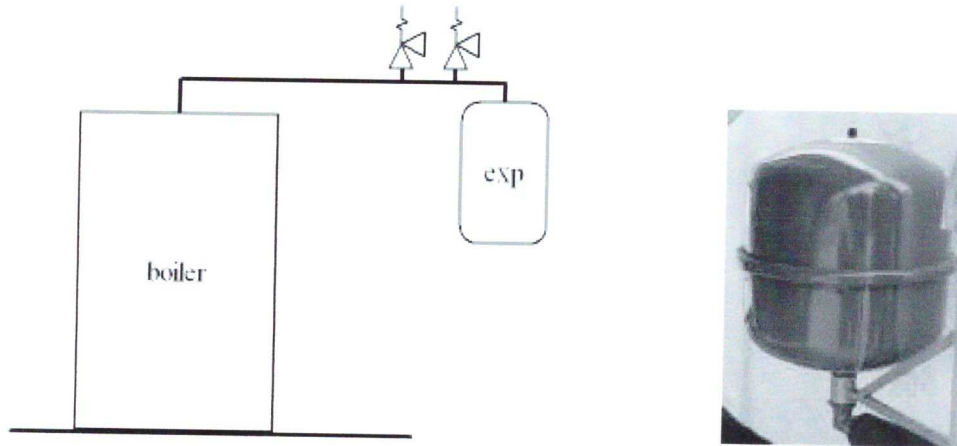


Figure 2.13 Close expansion tank

2.4.5.1 Expansion tank used in Alia hospital:-

There are four closed expansion tank in Alia hospital it have the following specification:-

NAME	CAIT
MODEL	HL-200
CAPACITY	200 L
PRECHARGE PRESSURE	1.5bar
PRESSUR MAX.	10 bar
TEMPRETUARE MAX.	110C

2.4.6 Oil tank.

A fuel storage tank can be an underground storage tank (UST) or an above ground storage tank (AST).

UST stands for **Underground Storage Tank**. A UST may contain petroleum products or certain hazardous substances. A UST is defined as a tank and any of its associated piping that has at least 10% of its combined volume underground.

Buried oil tanks raise increasing environmental, safety, legal and economic concerns because oil leaks underground or even within buildings can lead to both environmental damage and very costly cleanup operations. While we've found them lasting longer, a common life expectancy of buried oil tanks is 10-15 years. At about

20 years, the risk of leaks from buried steel oil tanks becomes significant. Leaks can occur earlier if a tank was damaged at installation or was not properly piped

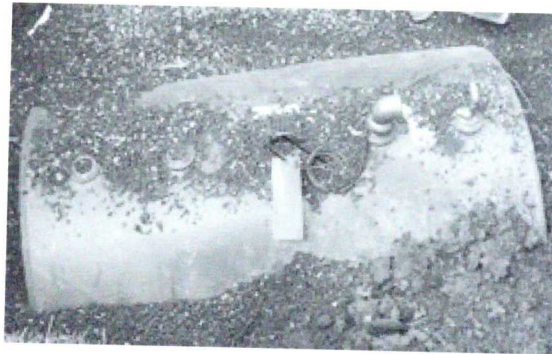


Figure 2.14 Underground oil tank

2.4.6.1 Oil tank used in Alia Hospital:

In Alia hospital there is one oil tank its capacity 20000 liter

2.4.7 Chimney

A vertical hollow structure of masonry, steel, or reinforced concrete, built to convey gaseous products of combustion from a building or process facility. A chimney should be high enough to furnish adequate draft and to discharge the products of combustion without causing local air pollution. The height and diameter of a chimney determine the draft. For adequate draft, small industrial boilers and home heating systems depend entirely upon the enclosed column of hot gas. In contrast, stacks, which are chimneys for large power plants and process facilities, usually depend upon force-draft fans and induced-draft fans to produce the draft necessary for operation, and the chimney is used only for removal of the flue gas

2.4.7.1 Types of chimney:

Cast-in-place concrete lining systems. This is the most expensive option, and the best option for a chimney that needs structural reinforcement. You can often avoid rebuilding the entire chimney by installing a cast lining system. These systems can be used for any type of fuel, but if your chimney is structurally sound, you may be able to use a less expensive metal liner.

Stainless steel. These lining sleeves are recommended for coal and oil systems because they resist corrosive acid emissions these fuels generate. They can be used in chimneys that are structurally sound.

Galvanized or aluminum sleeves. Similar in construction and function to stainless, this least expensive option can only be used if both the furnace and the water heater are natural gas. Never use galvanized or aluminum with a coal or oil system, because the metal will rapidly corrode.

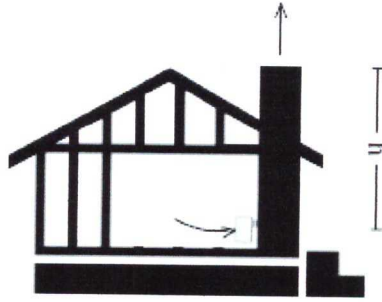


Figure 2.15 Chimny

2.4.7.2 Chimneys used in Alia Hospital:

In Alia hospital there are three steel chimneys for boilers

For central heating boilers there is chimney for each boiler has a diameter 20"

For domestic hot water boiler there is a chimney has a diameter 10"

2.4.8 Hot water cylinder

Hot water cylinders are the key component in most Central heating systems, boilers are designed to produce sufficient quantities of hot water to service the central heating system and produce instantaneous hot water for domestic use.

The principle of its work is charge of hot water from boiler entry to the coil within the cylinder and its re-entry into the boiler.

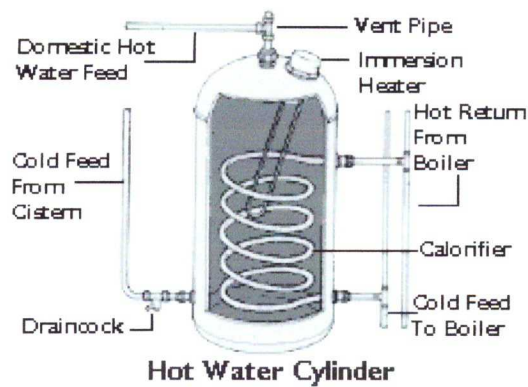


Figure 2.16 Hot water cylinder

2.4.8.1 Hot water cylinder used in Alia Hospital:

In Alia hospital there are two hot water cylinders one is used and the other is stand by Each one has 3000 liter capacity.

2.5 Problems in central heating system in Alamera Alia hospital

During our survey in the heating system at Alia Hospital we found that the main problems existing in the system is summarized in the following:

- 1) The farthest radiator in each section is remaining cold.
- 2) The pipe which connecting the boiler with diesel pump is impairing constantly.
- 3) Failure to respond the boiler to the thermostat signals in the commencement of the work or work stoppages.

CHAPTER THREE

CENTRAL AIR CONDITIONING SYSTEM

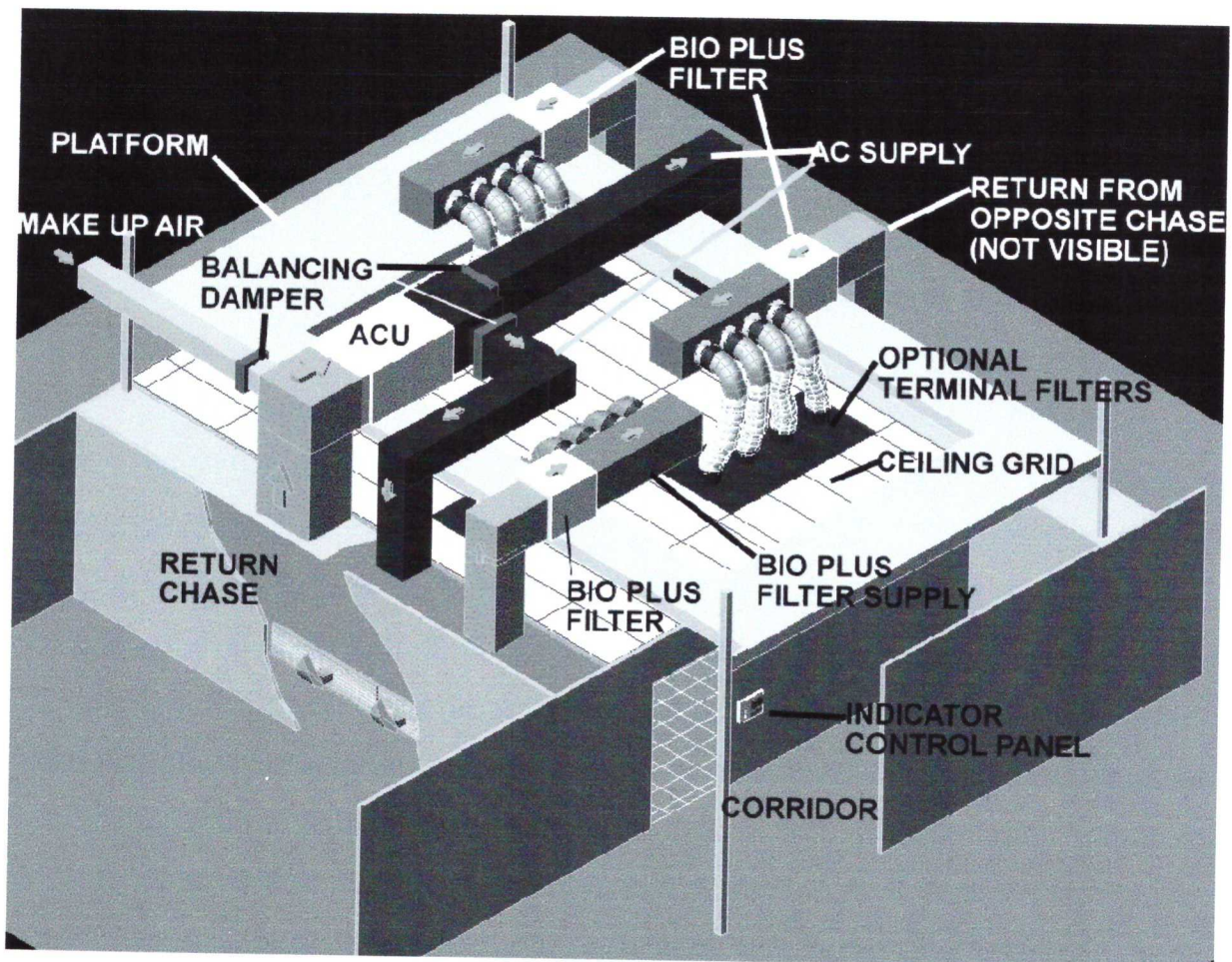


Figure3.1 Central Air Conditioning System

3.1 INTRODUCTION:-

"Air conditioning" means the control, within a space, of the different properties of the air within that space. These properties include temperature, humidity, air speed and the cleanliness of the air (amount of dust, odour and other contaminants).

The first air conditioning probably started with early man when he moved inside a cool, dark cave to escape the summer heat and to protect himself from the winter cold.

Humans have continually searched for ways to keep cool in the summer, from indulging in Roman baths to siting castles for cross-ventilation to using cardboard hand fans during many summer church services.

In the late 1800s, mechanical refrigeration was used to preserve meat and perishable foods. In some large cities, cold air was piped from a central station to surrounding buildings for cold storage to preserve food, chill beer and protect special documents.

An early pioneer who did much to promote "controlled air" was Willis Carrier, a mechanical engineer who worked at the Buffalo Forge Company in Buffalo, New York. Subsequent subsidiary companies carrying his name helped conquer the temperature-humidity relationship, marrying theory with practicality. Starting in 1902, he designed a spray-type temperature and humidity controlled system. His induction system for multi-room office buildings, hotels, apartments and hospitals was just another of his air-related inventions. Many industry professionals and historians consider him the "father of air conditioning."

Air conditioning has had an incredible impact on the way we live, giving us the option to work, play and relax in controlled environments. We live in air conditioned homes, travel to our air conditioned workplaces in air conditioned cars, shop in air conditioned stores and malls and enjoy sports in air conditioned arenas. We have year-round choices of fresh or preserved foods kept cool or frozen and benefit from advances in medical services that are made possible through air conditioning. We see new frontiers open up in space exploration because controlled environments are possible.

3.2 THERMAL LOAD CALCULATION:-

Thermal load in air conditioning system consist of two type

- 1) Cooling load: it is in summer and it 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.
- 2) Heating load: it is in winter and it is the rate at which heat must be added to a space in order to maintain the desired conditions in the space

3.3 Cooling load sources:-

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

- (1) Heat gains that transmitted through building structures such as walls, floors and ceiling that are adjacent to unconditioned spaces .The heat transmitted is caused by temperature difference that exists on both sides of structures
- (2) Heat gain due to solar effect which include:
 - (a)Solar radiation transmitted through the glass and absorbed by inside surfaces and furniture.
 - (b) Solar radiation absorbed by walls, glass windows, glass doors and roofs that are exposed to solar radiation
- (3)Sensible and latent heat gains brought into the space as a result of infiltration of air through windows and doors

Infiltration

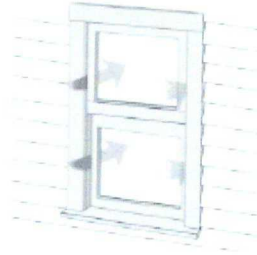


Figure 3.2 Infiltration

(4) Sensible heat produced in space by lights, appliances, motors and other miscellaneous heat gains.

(5) Latent heat produced from cooking, hot baths, or any other moisture producing equipment

(6) Sensible and latent heat produced by occupants

The cooling load sources that affect on the air conditioning system design can be made-up of many components, including the follow:

1. External sources.

2. Internal sources.

✓ External sources: the external source in this project represent as follow:

Cooling Load Components

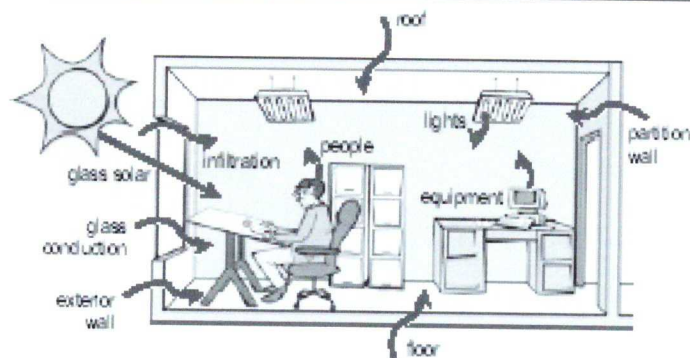


Figure 3.3 cooling load components

3.4 Solar Radiation:-

Solar radiation received at the earth's surface on a plane perpendicular to the sun rays may reach at hourly value 900 W/m² on a clear day. This value of solar radiation intensity occurs when the sun is directly over head. Solar radiation intensity decreases as the sun's angle of altitude α , decreases. The altitude angle is the angle that the sun rays make with horizontal line in a vertical plane.

Time of the day and altitude of the location are also factors that affect the direct radiation. Some radiation occurs from the sky itself even through the direct rays of the sun don't strike the surface in question. This sky radiation called diffused radiation. Diffused radiation may be incident upon north walls or windows which never receive direct solar radiation. Sky or diffused radiation can reach an intensity of about 200 W/m² on horizontal surface when the sun's altitude angle is 90 degree.

3.5 Heat gain through sunlit walls and roofs:-

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

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

$$Q = UA\Delta T$$

Heat Conduction through Surfaces

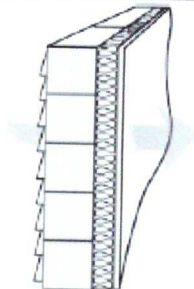


Figure 3.4 Heat Conduction through surfaces

→Where:

Q: Heat flow through the walls, ceiling, floor, by conduction. (Watt)

U: Over all heat transfer coefficient (W/m².K).

A: Out door Area of heat conduction. (m²)

ΔT: the total equivalent temperature difference which take in consideration the increase of wall temperature due to Absorption of solar radiation

Note: - the value of ΔT is called cooling load temperature difference **CLTD**

And can be obtained for roofs from tables 3-1 (See Appendix B)

The value **CLTD** extracted from tables 3-1 (See Appendix B) needs to be corrected so that the actual value is found for different cases, and hence it will be called corrected **CLTD** and can be calculated from the following equation

$$(\text{CLTD}) \text{ corr} = (\text{CLTD} + \text{LM}) K + (25.5 - T_i) + (T_o, m - 29.4) f$$

→Where:

LM: Latitude correction factor which can obtain from table 3-2 (See Appendix B) for horizontal and vertical surfaces

K: colour adjustment factor such that k=1.0 for dark coloured roof, and k=0.5 for permanently light coloured roofs

(25.5-T_i): a correction factor for indoor design temperature where T_i is The room design temperature °c

(T_{o, m} -29.4): a correction factor for outdoor mean temperature T_{o, m}

It is related to the out door design temperature T_o, according to the relation

$$T_{o, m} = T_o - DR / 2$$

DR: the daily temperature range which equal to the difference between the Average maximum and Average minimum temperature for the Warmest month of the summer season

f: attic or roof fan factor such that $f=1.0$ if there is no attic or roof fan & $f = 0.75$ if there is an attic or roof fan

Over all heat transfer coefficient depends on the layers which the building is consist of and the indoor and outdoor convection heat transfer coefficient

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

$$\frac{1}{U} = \frac{1}{h_o} + \frac{1}{h_i} + \sum \frac{x}{k}$$

→Where:

K: conduction heat transfer coefficient (W/m.K).

X: Layer thickness (m).

hi: Indoor convection heat transfer coefficient (W/m².K).

ho: Outdoor convection heat transfer coefficient (W/m².k)

3.6 Heat transfer through glass:

Solar radiation which falls on glass has **three components** which are:

(1) **Transmitted component:** it represents the largest component, which is transmitted directly into the interior of the building or the space. This component

represents about 42 to 87% of incident solar radiation, depending on the glass transmissibility value.

(2) **Absorbed component:** This component is absorbed by the glass itself and raises its temperature. About 5 to 50% of solar radiation is absorbed by the glass depending on the absorptivity value of 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 the 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 factor:

- (1) Type of glass. (Single, double or insulation glass)
- (2) Availability of shading (such as drapes, Venetian blinds, construction overhang, wing walls, etc)
- (3) Time of the day
- (4) Orientation of glass area (north, northeast, east orientation, etc)
- (5) Solar radiation intensity and incident angle
- (6) Latitude angle of the location

3.7 Transmission Heat Gain:-

Heat gain due to solar transmission through glass windows and doors is estimated by using tables 3-3 to 3-7 (See Appendix B) where the following factors are selected:

- (a) Solar heat gain factor (SHC): this factor represents the amount of solar energy that would be received by floor, furniture and the inside walls of the room and can be extracted from table 3-3 (See Appendix B)
- (b) Shading coefficient (SC): this factor accounts for different shading effects of the glass wall or window and can be extracted from tables 3-4 (See Appendix B) for single and double glass without inside shading or from table 3-5 (See Appendix B) for single and double glass as well as for insulating glass with internal shading
- (c) Cooling load factor (CLF): this represent the effects of the internal walls, floor, and furniture on the instantaneous cooling load, and can be extracted from table 3-6 (See Appendix B) for glass without interior shading or from table 3-7 (See Appendix B) for glass with interior shading.

The transmitted cooling load can be calculated from the relation

$$Q_{tr} = A (SHC) (SC) (CLF)$$

3.8 Convection Heat Gain:-

The value of the convected cooling load by the glass can be calculated from the equation

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

Where CLTD is the temperature difference for the glass and can be extracted from table 3-8 (See Appendix B). Table 3-8 (See Appendix B) is designed for inside room temperature of 25.5°C and outside mean temperature of 29.4°C if room temperature is different from 25.5°C then the difference (25.5-Ti) will be added to the value of CLTD. On the other hand if (To, m -29.4) is different from 29.4°C then a correction value of (To, m -29.4) is used.

- ✓ Internal sources: The next component of the space cooling load is the heat that is generated within the space. Typical sources of internal heat gain are people, lights, cooking processes, and other heat-generating equipment, such as motors, appliances, and office equipment. While all of these sources contribute sensible heat to the space, people, cooking processes, and some appliances (such as a coffee maker) also contribute latent heat to the space.

The internal source in this project represent as follow:

Internal Heat Gains

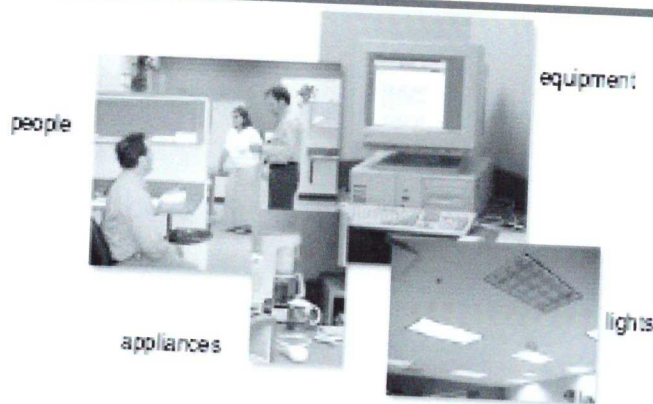


Figure 3.5 internal heat gains

3.9 Heating Gain Due To Equipment:

Sensible and latent heat loads arising from various equipment and appliances that are installed in a conditioned space are given in table 3-9(See Appendix B). The indicated heat dissipation rates from such equipments and appliances should be inclined when the cooling load is estimated. Care must be taken when considering such dissipation rates all sensible or latent or partly sensible and partly latent

3.10 Heating Gain Due To Lights:

Heat gains due to light are sensible loads. Such loads must be carefully analyzed specially for supermarkets, department stores and other commercial applications that

are usually brightly illuminated. The peak lighting heat gains for some application such as hospitals, restaurants and office will not occur simultaneously with the peak heat gain from other source. This fact should be considered when calculating the peak load for a certain application.

The heat gain due to fluorescent lamps is obtained by multiplying the rated voltage of lamp by 1.2 while that for ordinary lamp is obtained from its rated voltage directly.

Lighting intensity differs from one application to another. It ranges from 10 to 30 W/m² of floor area for apartments, hospitals, hotels etc. and from 30 to 60 W/m² for class rooms, offices, barbershop and similar application. These lighting intensities can be used to estimate the heat gain from lights if the exact lighting power is not known.

The heat gain from lights is not an instantaneous load on the air conditioning equipment. The radiant energy from lights is first absorbed by walls, floor and furniture of the space causing there temperature to increase with time. As time passes, heat is convected from these surfaces. This result in a time delay between turning the light on and the energy from the light to have an effect on the cooling load. To accommodate for this fact, the following equation can be used to calculate the heat gain due to the lights

$$Q_{Lt} = P_{Lt} (F_u F_b) (CLF)_{Lt}$$

→Where:

P_{Lt}: the lamp rated power in watts

F_u: fraction of lamp that are in use

F_b: the ballast factor that equal 1.2 for fluorescent lamp and 1.0 for Ordinary lamp

CLF_{Lt}: the light cooling load factor

Table 3-10 (See Appendix B) gives the light cooling load factor for two types of fixture arguments.

3.11 Heating Gain Due To Motors

Electrical motors heat gains are estimated according to their rated out put power as indicated in table 3-9(See Appendix B). In order to consider the heat gain of a motor driven machine as a part of the cooling load of a space, the motor and its load must be located inside the space

3.12 Diversity Factor

For some application such as office buildings, hotels and department stores, it is reasonable to assume that some occupants of such application will be on holiday or absent. Also, it is reasonable to assume that some lights and motors are switched off for certain period of time during the day. Diversity factors for such applications are shown in table 3-11 (See Appendix B). Diversity factors can be applied when the peak cooling load is calculated for these applications. Values of diversity factors indicated in table 3-11 (See Appendix B) are approximate and must be used with care. However, diversity factors do not apply to applications, such as theaters, concert halls, etc

The heat gain due to occupants is influenced by the number of hours after each entry to the space and the total hours of residency in the space. Thus, the sensible heat gain value by table must be multiplied by a cooling load factor for people to compensate for the heat capacity effect of occupants. Values of this factor are given in table 3-12 (See Appendix B).

3.13 Miscellaneous heat gains:

These heat gains include the following:

- (1) Supply and return duct if they are located outside the conditioned space. All ducts must be well installed to minimize this heat gain and to prevent moisture condensation on the duct surface.
- (2) Supply duct air leakage into non –conditioned space. It occurs due to poor construction and workmanship of duct connections.

(3) Heat generated by fans and blowers .Such heat gains are added to the air stream if the fan is located on the exist side of the cooling coil. Thus the above heat gains are considered part of the total cooling load.

3.14 Load Calculation Form:

The calculation of various components of cooling load of the hospital must be carried out on a room by room basis, as the case of heating load calculation.

The cooling load components for each room or space of the hospital is computed separately and tabulated in a form such as the one shown below. The total heat gain of the hospital is obtained by adding the cooling loads of all the rooms and spaces in the hospital.

Cooling load form

Item	value
Project Name	
Date	
Room NO.	
Inside design condition T_i	
Outside design condition T_o	
Outside mean condition T_o, m	
Adjacent space temperature T_{adj} .	
Inside Relative humidity ϕ_i	
Inside Relative humidity ϕ_o	

(1) external cooling load

(a) Conduction due to $(T_{adj} - T_i)$

Surface	Area (m ²)	U(W/m ² .°C)	$\Delta T(^{\circ}C)$	Q(w)
Wall				
Wall				
Glass				
Glass				
Door				
Ceiling				
Floor				
				TOTAL

(b) Solar effects

1. Transmitted heat gains

Surface	Area (m ²)	SHG	SC	CLF	Q(w)
Glass					
Glass					
Glass					
					TOTAL

2. conduction due to CLTD:

$(25.5 - T_i) = \quad ^{\circ}C,$

$(T_o, m - 29.4) = \quad ^{\circ}C$

Surface	Area (m ²)	CLTD ($^{\circ}C$)	LM	$(CLTD)_{corr.}$ ($^{\circ}C$)	Q (w)
Wall					
Wall					
Wall					
Glass					
Glass					
Glass					
Ceiling					
					TOTAL

(c) Internal cooling loads

Item	Sensible Load	Latent heat
Occupants		
Lights		
Equipment		
Motors		
	TOTAL	TOTAL

Computer programs, such as carrier 89E20-I I Program, are designed to calculate all components of the cooling load of large floor area buildings. Such programs are used by air conditioning engineers to obtain the sensible and total cooling loads, ventilation cooling load, mixes air stream condition, supply air flow rate, supply air temperature, cooling coil capacity, apparatus dew point temperature, cooling coil bypass factor, resulting relative humidity of the space and other important out put data.

3.15 Central air-conditioning system

It is used to Control the temperature, humidity, purity, and motion of air in an enclosed space, independent of outside conditions.

In a self-contained air-conditioning unit, air is heated in a boiler unit or cooled by being blown across a refrigerant-filled coil and then distributed to a controlled indoor environment. Central air-conditioning in a large building generally consists of a main plant located on the roof or mechanical floor and intermittently spaced air-handling units, or fans that deliver air through ducts to zones within the building. The air then returns to the central air-conditioning machinery through spaces called plenums to be re cooled (or reheated) and re circulated. Alternate systems of cooling use chilled water, with water cooled by a refrigerant at a central location and circulated by pumps to units with fans that circulate air locally.

In air conditioning systems, heated water is distributed to coils, in air handling units, and used water is returned to the boiler. These heating coils transfer sensible and latent heat from the heated water to the air, thus heating and usually humidifying the air stream

In air conditioning systems, chilled water is distributed to coils, in air handling units, and used water is returned to the chiller. These cooling coils transfer sensible

and latent heat from the air to the chilled water, thus cooling and usually dehumidifying the air stream.

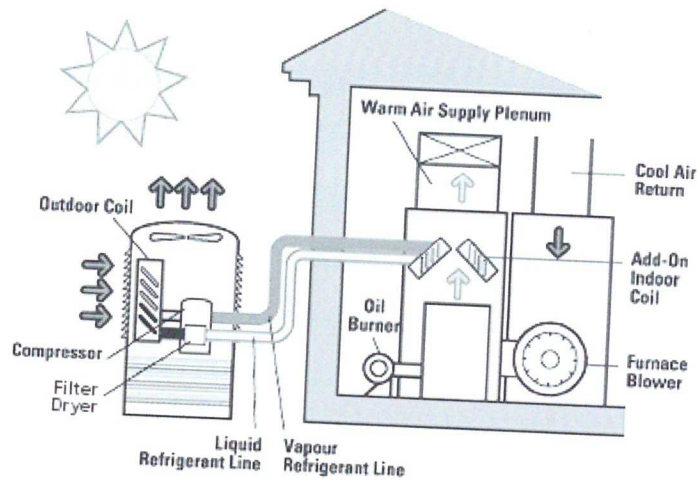


Figure 3.6 Central air conditioning systems

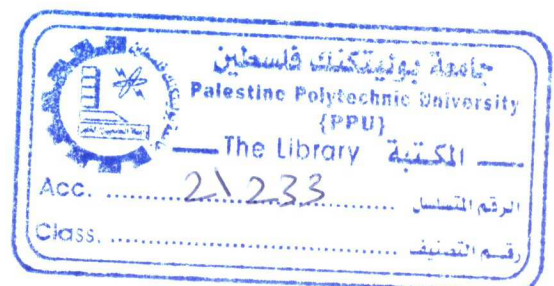
3.16 Central air-conditioning system in Alia Hospital:-

In Alia Hospital they use air handling units in central air conditioning system to blow air through ducts to the air conditioned space. **Two-pipe system** (see two pipe system in 3.17) for a closed water system is used in which a cold-water supply, a cold-water return, a hot-water supply, and a hot-water return is used

Air handling units may be connected to one of these components' during its operation:

- 1) **Boiler:** it is use to provide the coil in the air handling units through piping network with hot water which loss its heat to the air passing through the heating coil and then the hot air is drawn to the air conditioned space . This system usually used in winter.
- 2) **chiller :** it is use to provide the coil in the air handling units through piping network with cold water which take off heat from the air passing through the cooling coil and then the cold air pushed to the air conditioned space. This system usually used in summer.

Air handlers connect to ductwork that distributes the conditioned air through the hospital, and returns it to the AHU.



3.17 Two Pipe System:

Hot water is pumped from the boiler through one pipe (Flow) to the heating coil, which then gives up its heat to the air and the cooled water is pumped back to the boiler via a second pipe (Return). Also coldwater is pumped from the chiller through one pipe (Flow) to the cooling coil, which then take heat from the air and the hot water is pumped back to the chiller via a second pipe (Return)

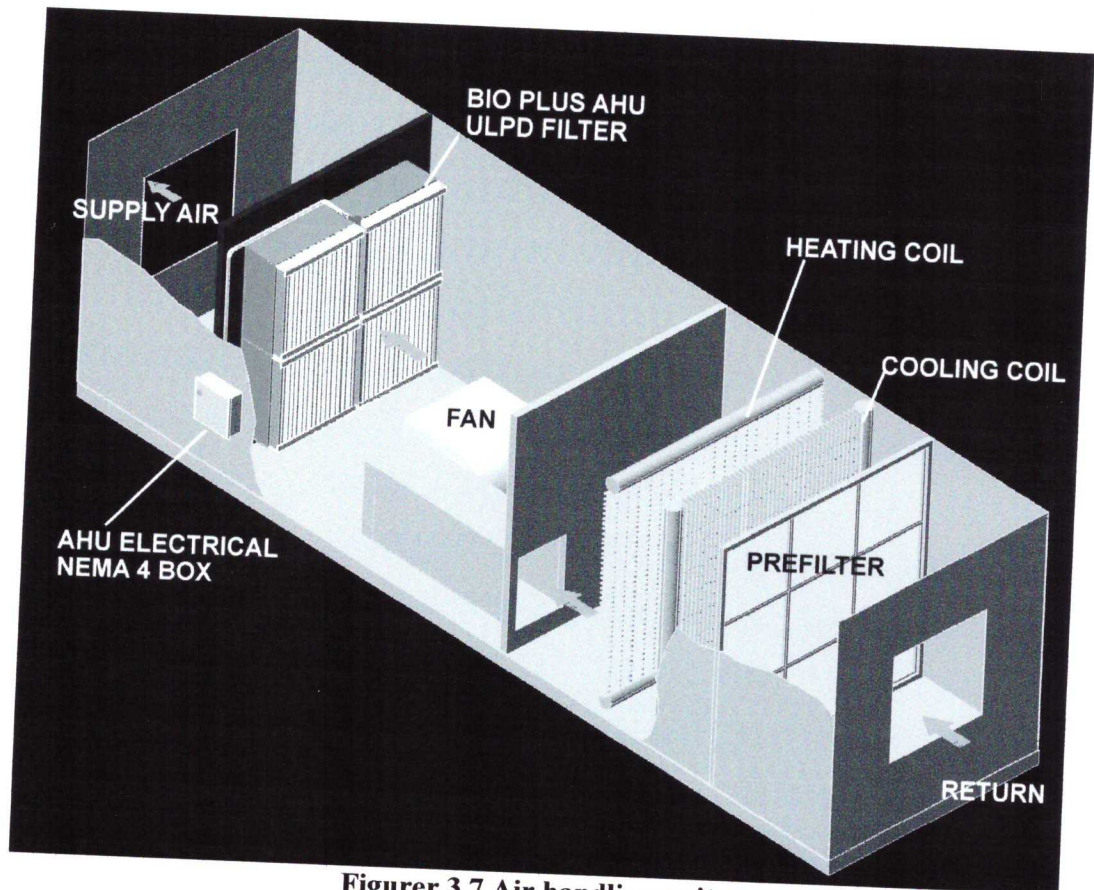
Note:-there is a point on the piping network where the lines that come from boiler and chiller are meeting. At that point there are valves on the lines of both boiler and chiller that used to control the opening and closing of the valves in order to use ether boiler or chiller.

3.18 Equipments used in Central air conditioning systems:-

3.18.1 Air handling unit

Air handling unit (AHU), is a device used as part of a heating, ventilating, and air-conditioning (**HVAC**) system. Usually, an air handler is a large metal box containing the following components:-

- 1 - Supply and Return Ducts
- 2 - Fan compartment
- 3 - Vibration isolator
- 4 - Heating and/or cooling coil
- 5 - Filter compartment
- 6 - Mixed (re circulated + outside) air duct



Figurer 3.7 Air handling unit

If used to supply heat, the air handler may contain a fuel burning heater or it may simply contain heat exchanger coils that are heated using circulating water or steam with the heat provided by a central boiler. Electric resistance and heat pumps are used too.

If used for cooling, the unit may a refrigeration evaporator, or simply a coil cooled by chilled water provided by a central chiller. Evaporative cooling is possible in dry climates too.

Air filtration may be via simple low-MERV pleated media, HEPA, Electrostatic, or a combination of techniques. Gas-phase and ultraviolet air treatments may be employed as well.

3.18.2 Air handling units used in Alia Hospital:-

There are eight air handling units exists in Alia hospital and there specifications are as flows

The **FIRST** Air handling unit exists in the **GROUNG FLOOR** which provided the **Physiotherapy** at the hospital which has the following specification:-

NAME: PETRA AIR HANDLING UNIT

AHU CAPACITY: 3600 CFM

RETEURN AIR FAN INCLUDING SHOCK ABSORBER: 2300 CFM

The **SECOND** Air handling unit exists in the **GROUNG FLOOR** which provided the **Pharmacy** at the hospital which has the following specification:-

NAME: PETRA DUAL ZONE AIR HANDLING UNIT

AHU CAPACITY: 4250 CFM

RETEURN AIR FAN INCLUDING SHOCK ABSORBER: 3450 CFM

The **THIRD** Air handling unit which it is a combined of two airs handling units exists in the **GROUND FLOOR** which provided the **CCU** at the hospital and has the following specifications:-

NAME: PETRA AIR HANDLING UNIT

AHU CAPACITY: 8000 CFM

RETEURN AIR FAN INCLUDING SHOCK ABSORBER: 6600 CFM

The **FOURTH** Air handling unit which it is a combined of two air handling units exists in the **GROUND FLOOR** which provided the **Emergency** at the hospital and has the following specifications:-

NAME: PETRA DUAL ZONE AIR HANDLING UNIT

AHU CAPACITY: 6200 CFM

RETURN AIR FAN INCLUDING SHOCK ABSORBER: 5000 CFM

The **FIFTH** Air handling unit which it is a combined of two air handling units exists in the **GROUND FLOOR** which provided the **Emergency** at the hospital and has the following specification:-

NAME: PETRA DUAL ZONE AIR HANDLING UNIT

AHU CAPACITY: 7500 CFM

RETURN AIR FAN INCLUDING SHOCK ABSORBER: 6450 CFM

The **SIXTH** Air handling unit which it is a combined of two air handling units exists in the **FIRST FLOOR** which provided the Operating room at the hospital and has the following specification:-

NAME: PETRA AIR HANDLING UNIT

AHU CAPACITY: 1600 CFM

RETURN AIR FAN INCLUDING SHOCK ABSORBER: CFM

3.18.3 Chiller

A chiller is a machine that removes heat from a liquid via a vapor-compression or absorption refrigeration cycle. Most often water is chilled, but this water may also contain ~20% glycol and corrosion inhibitor. Other fluids such as thin oils can be chilled as well.

Chilled water is used in Air conditioning cool most chillers are designed for indoor operation, but a few are weather-resistant. Chillers are precise machines that are very expensive to purchase and operate, so great care is needed in their selection and maintenance.

3.18.4 Chiller selection:-

The choices of the chiller according to the total heat loss including in the hospital. By using the following equation

$$Q_{\text{chiller}} = Q_{\text{transmission}}$$

So from Catalogs we can select the useful chiller

3.18.5 Chiller used in Alia Hospital:-

One Petra chiller is used for air conditioning system exists at the roof of Alia hospital. It is connected with air handling units to provide cold air for air conditioned space.

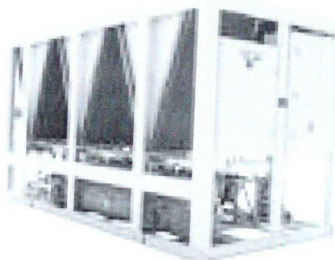


Figure 3.8 Petra chillers

Chiller in Alia Hospital has the following specification:-

NAME	PETRA CHILLER		
MODEL	APS 90-25L		
CHILLER CAPACITY	85 TON/300KW		
COND.FAN MOTOR CAPACITY	2.2KW		
NOMINAL POWER SUPPLY	Volt /Hz /Ph	380 /50 /3	
REFREGERANT	R 22		
MAX. AMPER	128A		
COIL TEST PRESSURE	450psig		

TYPE	QTY.	VOLT	HZ	PH
COMPRESSOR MOTOR	2	380	50	3
CONDENSER FAN MOTOR	4	380	50	3

3.18.6 DUCT S

Ducts are used in heating, ventilation, and air conditioning systems to deliver and remove air. A duct system is often called ductwork.

Ducts are most often made of galvanized steel in rectangular, round, and oval cross-sectional shapes. Steel ducts are commonly wrapped or lined with fiberglass thermal insulation, both to reduce heat loss or gain through the duct walls and water vapor from condensing on the exterior of the duct when the duct is carrying cooled air. Insulation, particularly duct liner, also reduces duct-borne noise. Both types of noise reduce 'breakout' noise through the ducts' sidewalls.

While galvanized steel is still very common, many rectangular and even round ducts are manufactured from "duct board", a rigid form of fiberglass that can easily be shop- or field-fabricated to make custom shapes and sizes. The fiberglass provides built-in thermal insulation and the interior surface absorbs sound, helping to provide quiet operation of the HVAC system.

Flexible ducts, known as flex, have a variety of configurations, but for HVAC applications, they are typically flexible plastic over a metal wire coil to make round, flexible duct. Most often a layer of fiberglass insulation covers the duct, and then a thin plastic layer protects the insulation. Flexible duct is very convenient for attaching supply air outlets to the rigid ductwork.

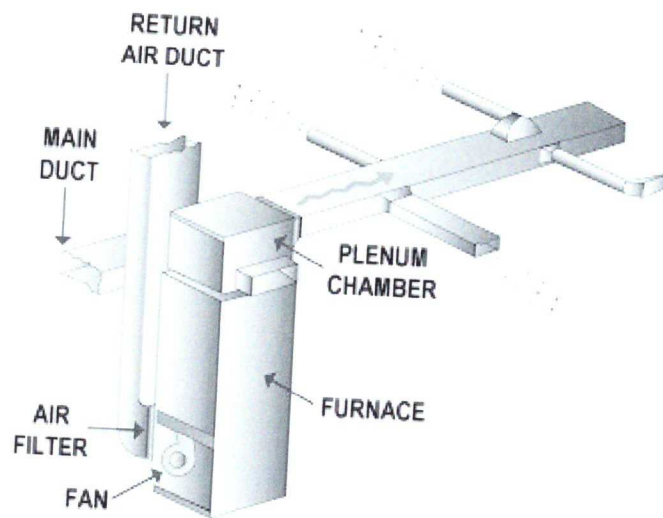


Figure 3.9 Duct distribution

3.18.7 DUCT DESIGN

After air discharge grilles and the air handler, this consists of a heat exchanger and blower, have been located, it is advisable to make a single-line drawing showing the duct layout and the air quantities each branch and line must be able to carry.

Of the methods of duct design in use, the equal-friction method is the most practical. It is considered good practice not to exceed a pressure loss of 0.15 in of water per 100 ft of ductwork by friction. Higher friction will result in large power consumption for air circulation. It is also considered good practice to stay below a starting velocity in main ducts of 900 ft /min in residences; 1300 ft /min in schools, theaters, and public buildings; and 1800 ft /min in industrial buildings. Velocity in branch ducts should be about two-thirds of these and in branch risers about one half. Too high a velocity will result in noisy and panting ductwork. Too low a velocity will require uneconomical, bulky ducts.

Side	4	8	12	18	24	30	36	42	48	60	72	84
3	3.8	5.2	6.2									
4	4.4	6.1	7.3									
5	4.9	6.9	8.3									
6	5.4	7.6	9.2									
7	5.7	8.2	9.9									
12		10.7	13.1									
18		12.9	16.0	19.7								
24		14.6	18.3	22.6	26.2							
30		16.1	20.2	25.2	29.3	32.8						
36		17.4	21.9	27.4	32.9	35.8	39.4					
42		18.3	23.1	29.1	34.4	38.6	42.4	45.9				
48		19.6	24.8	31.2	36.6	41.2	45.2	48.9	52.6			
60		21.4	27.3	34.3	40.4	45.8	50.4	54.6	58.5	65.7		
72		23.1	29.5	37.2	43.8	49.7	54.9	59.6	63.9	71.7	78.8	
84				39.9	46.9	53.2	58.9	64.1	68.8	77.2	84.8	91.9
96					49.5	56.3	62.4	68.2	73.2	82.6	90.5	97.9

Table 3.13 diameter of circular ducts in Inches equivalent to rectangular ducts

The shape of ducts usually installed as rectangular, because dimensions can easily be changed to maintain the required area. However, as ducts are flattened, the increase in perimeter offers additional resistance to airflow. Thus a flat duct requires an increase in cross section to be equivalent in air-carrying capacity to one more nearly square.

A 12 * 12-in duct, for example, will have an area of 1 ft² and a perimeter of 4 ft, whereas a 24 * 6-in duct will have the same cross-sectional area but a 5-ft perimeter and thus greater friction. Therefore, a 24 * 7-in duct is more nearly equivalent to the 12*12. Equivalent sizes can be determined from tables, such as those in the "ASHRAE Handbook—Fundamentals," where rectangular ducts are rated in terms of equivalent round ducts (equal friction and capacity). Table 13.6(See Appendix B) is a shortened version.

Charts also are available in the ASHRAE handbook giving the relationship between duct diameter in inches, air velocity in feet per minute, air quantity in cubic feet per minute, and friction in inches of water pressure drop per 100 ft of duct. Table 13.7 (See Appendix B) is based on data in the ASHRAE handbook.

In the equal-friction method, the equivalent round duct is determined for the required air flow at the predetermined friction factor.

Friction, in H ₂ O per 100 ft	0.05		0.10		0.15		0.20		0.25		0.30	
	Diam. in	Velocity, ft/min	Diam. in	Velocity, ft/min	Diam. in	Velocity, ft/min	Diam. in	Velocity, ft/min	Diam. in	Velocity, ft/min	Diam. in	Velocity, ft/min
	Airflow, cfm											
50	5.3	350	4.6	450	4.2	530	3.9	600	3.8	660	3.7	710
100	6.8	420	5.8	550	5.4	640	5.1	720	4.8	780	4.7	850
200	8.7	480	7.6	650	6.9	760	6.6	860	6.3	940	6.1	1020
300	10.2	540	8.8	730	8.2	850	7.7	960	7.3	1050	7.1	1120
400	11.5	580	9.8	770	9.0	920	8.5	1040	8.2	1130	7.8	1200
500	12.4	620	11.8	820	9.8	970	9.3	1080	8.8	1160	8.6	1270
1000	15.8	730	13.7	970	12.8	1140	12.0	1280	11.5	1400	11.2	1500
2000	20.8	870	18.0	1150	16.6	1370	15.7	1520	15.0	1660	14.5	1780
3000	24.0	960	21.0	1280	19.7	1500	18.3	1680	17.3	1850		
4000	26.8	1050	23.4	1360	21.6	1600	20.2	1800				
5000	29.2	1100	25.5	1460	23.7	1700	22.2	1900				
10000	37.8	1310	33.2	1770	30.3	2000						

Table 3.14 size of round ducts for airflow

3.18.8 Centrifugal PUMPS:-

The centrifugal pump is a machine that adds energy in the form of velocity to flowing water. All centrifugal pumps are built with the suction entrance directed toward the center of the pump.

In heating and cooling systems, water flow is normally produced by pumps. Centrifugal pumps are most commonly used in heating and cooling systems.

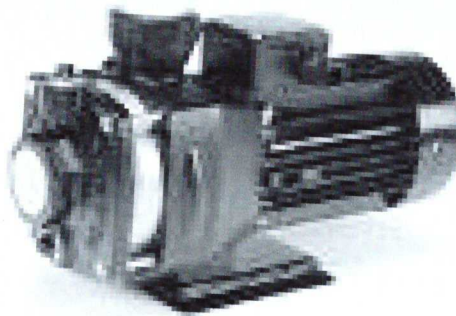


Figure 3.10 Centrifugal pump

3.18.9 Pump selection:

Pump selection is depending on the head losses (hL) against flow rate (m).

In alia hospital we have four pumps for conditioning system. Two pumps for chiller and the other two for boilers.

Pumps in Alia Hospital for chiller have the following specifications:-

NAME	GRANDFOS
TYPE	NB65-315309A-F-A-BAOE
MODEL	AD4511BBJP203-430001
Bar / C max.	16/120
Q	85 m ³ /h
H	28.8 M
N	1450 min ⁻¹

Made in Hungary

3.18.10 Expansion tank selection:-

The volume of water increase when the temperature is increased and this may cause high pressure on the system parts (such as pipes) and then cause exploding of the pipe, so; expansion tank should be in the system to conserve constant volume of water, the expansion tank volume is approximately 8% Of the total volume of the water in the system.



Figure 3.11 Expansion tank

Total volume of the water in the system=Boiler capacity (output)*12
Expansion tank volume = 0.08 * total volume of water

3.18.11 Expansion tank used in Alia hospital:-

In **Alia Hospital** expansion tank have the following specification:-

NAME	CAIT
MODEL	HL-50
CAPACITY	50 L
PRECHARGE PRESSURE	1.5bar
PRESSUR MAX.	10 bar
TEMPRETUARE MAX.	110C

3.19 Ventilation:-

It is the supplying of air motion in a space by circulation or by moving air through the space. Ventilation may be produced by any combination of natural or mechanical supply and exhaust. Such systems may include partial treatment such as heating, humidity control, filtering or purification.

Natural ventilation may be provided by wind force, convection, or a combination of the two. Although largely supplanted by mechanical ventilation and air conditioning, natural ventilation still is widely used in homes, schools, hospitals, and commercial and industrial buildings.

Mechanical supply ventilation may be of the central type consisting of a central fan system with distributing ducts serving a large space or a number of spaces, or of the unitary type with little or no ductwork, serving a single space or a portion of large space. Outside air connections are generally provided for all ducted systems. Outside air is needed in controlled quantities to remove odors and to replace air exhausted from the various building spaces and equipment.

Exhaust ventilation is required to remove odors, fumes, dust, and heat from an enclosed occupied space. Such exhaust may be of the natural variety or may be mechanical by means of roof or wall exhaust fans or mechanical exhaust systems.

3.20 Ventilation used in Alia Hospital

In Alia Hospital the following things is used in ventilation system

- 1) Roof top exhaust for toilets ventilation with capacity of 5000 CFM including Shock absorbers and water proof disconnect switch. Made by Greenheck
- 2) Kitchen ventilation fan, including shock absorber for delivering 15500 CFM, With 2 speed motors and disconnect switch. Made by Greenheck
- 3) Toilets ventilation fan for delivering 19400 CFM, with 2 speed motors, shock. Absorber, disconnect switch. Made by Greenheck

3.21 Problems in central air conditioning system in Alamera Alia hospital

During our survey in the heating system at Alia Hospital we found that the main problems existing in the system are summarized as follows:-

- 1) The central air conditioning is very cold at summer and very hot at winter in berth portion
- 2) Gas exist at the chiller is quickly discharged
- 3) Ventilation fan is quickly stopped as a result of dust and other things and so need cleaning every small time

CHAPTER FOUR

PLUMPING SYSTEM

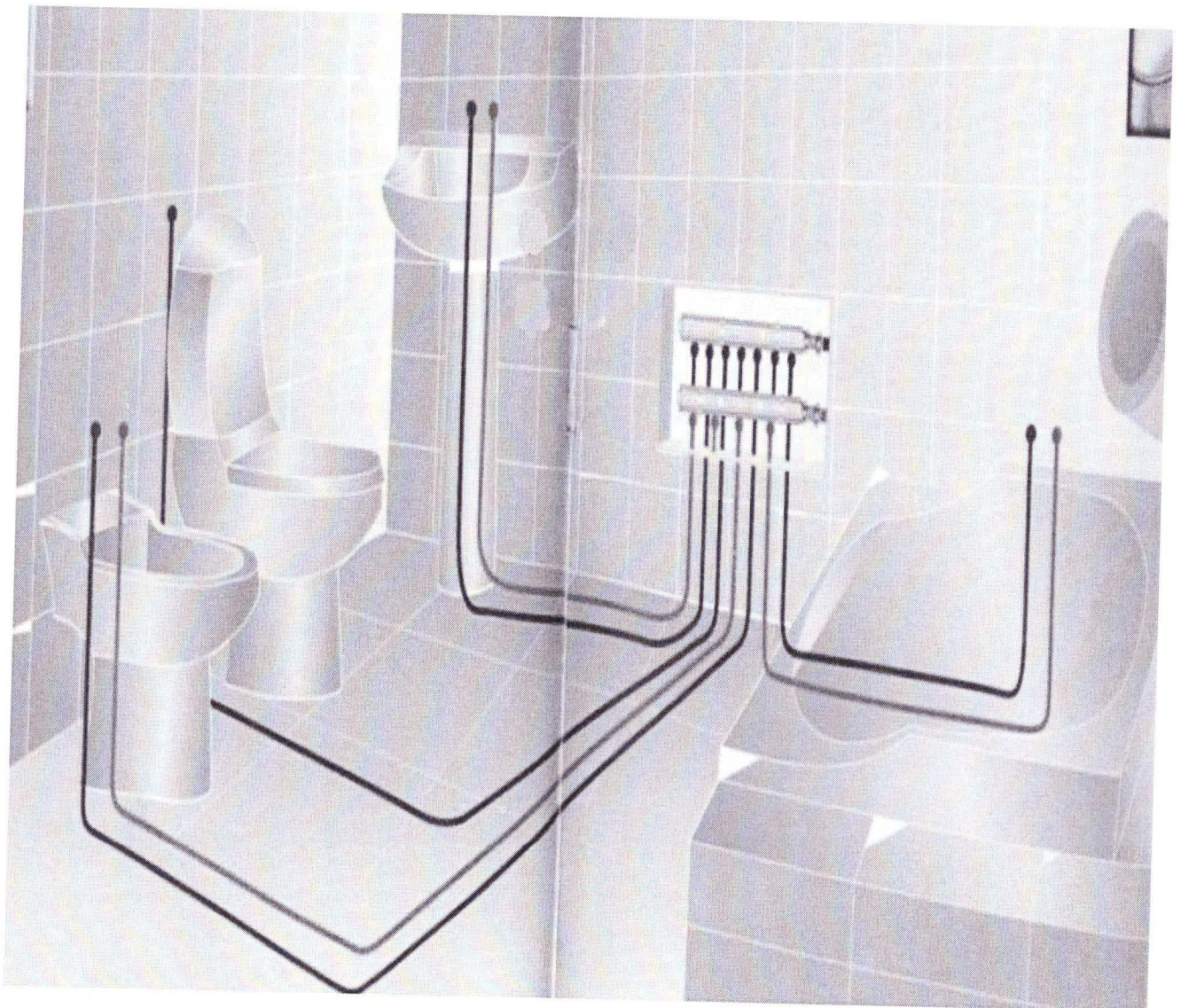


Figure 4-1 hot and cold water piping

4.1 INTRODUCTION:-

Plumbing consist of two things which is water supply system and drainage distribution system

It is one of the most essential and vital subject that its problems face us every day and need a fast solution to treat it

Most dwellings and buildings, including those in rural areas are supplied with water from a public water supply, otherwise known as the mains supply. The design of a mains water supply needs to consider present demand and anticipated future demand, the size of the water mains, and the pressure of water in the mains which is known as the 'head', the height to which the water would rise in a vertical pipe.

The connection to the mains water supply is usually taken to the boundary of the site and finished with a stop valve or stop cock, housed in a suitable box or purpose chamber. This chamber may be fitted with a hinged cast iron cover. The cold water supply for the dwelling is taken from the stop valve to the building, 750 mm below ground level. A second stop valve should be fitted on the service pipe where it enters the building. Where possible this should be at the kitchen sink, although the location is not critical. Inside the house a drain cock should be fitted above the stop valve to allow the cold water system to be drained down.

4.2 HEALTH REQUIREMENTS FOR PLUMBING:-

Plumbing codes place strict constraints on plumbing installations in the interest of public health. Following are typical basic provisions:

All buildings must be provided with potable water in quantities adequate for the needs of their occupants. Plumbing fixtures, devices, and appurtenances should be supplied with water in sufficient volume and at pressures adequate to enable them to function properly. The pipes conveying the water should be of sufficient size to provide the required water without undue pressure reduction and without undue noise under all normal conditions of use.

The plumbing system should be designed and adjusted to use the minimum quantity of water consistent with proper performance and cleansing of fixtures and appurtenances.

Devices for heating and storing water should be designed, installed, and maintained to guard against rupture of the containing vessel because of overheating or over pressurization.

The wastewater system should be designed, constructed, and maintained to guard against fouling, deposit of solids, and clogging. Provision should be made in every building for conveying storm water to a storm sewer if one is available.

Recommended tests should be made to discover any leaks or defects in the system. Pipes, joints, and connections in the plumbing system should be gastight and watertight for the pressure required by the tests. Plumbing fixtures should be located in ventilated enclosures and should be readily accessible to users.

Plumbing fixtures should be made of smooth, nonabsorbent materials. They should not have concealed fouling surfaces. Plumbing fixtures, devices, and appliances should be protected to prevent contamination of food, water, sterile goods, and similar material by the backflow of wastewater. Indirect connections with the building wastewater system should be provided when necessary

Every fixture directly connected to the wastewater system should be equipped with a liquid-seal trap. This is a fitting so constructed that passage of air or gas through a pipe is prevented while flow of liquid through the pipe is permitted.

Foul air in the wastewater system should be exhausted to the outside, through vent pipes. These should be located and installed to minimize the possibility of clogging and to prevent sewer gases from entering the building

If a wastewater system is subject to the backflow of sewage from a sewer, suitable provision should be made to prevent sewage from entering the building. The structural safety of a building should not be impaired in any way as a result of the installation, alteration, renovation, or replacement of a plumbing system. Pipes should be installed and supported to prevent stresses and strains that would cause malfunction of or damage to the system. Provision should be made for expansion and contraction of the pipes due to temperature changes and for structural settlements that might affect the pipes.

Where pipes pass through a construction that is required to have a fire-resistance rating, the space between the pipe and the opening or a pipe sleeve should not exceed 1.2 in. The gap should be completely filled with code-approved, fire-stopping material and closed off with close-fitting metal escutcheons on both sides of the construction.

Pipes, especially those in exterior walls or underground outside the building, should be protected, with insulation or heat, to prevent freezing. Underground pipes should be placed below established frost lines to prevent damage from heaving. And in high traffic areas should be encased in concrete or installed deep enough so as not to be damaged by heavy traffic. Pipes subject to external corrosion should be protected with coatings, wrappings, cathodic protection, or other means that will prevent corrosion. Dissimilar metals should not be connected to each other unless separated by a dielectric fitting. Otherwise, corrosion will result.

Each plumbing system component, such as domestic water, natural gas, and wastewater pipes and fixtures, should be tested in accordance with the plumbing code. All defects found during the test should be properly corrected and the system retested until the system passes the requirements of the test.

4.3 Water Supply:-

Enough water to meet the needs of occupants must be available for all buildings. Further water needs for fire protection, heating; air conditioning, and possibly process use must also be met.

4.4 Water Quality:-

Sources of water for buildings include public water supplies, groundwater, and surface water. Each source requires careful study to determine if a sufficient quantity of safe water is available for the building being designed.

Water for human consumption, commonly called potable water, must be of suitable quality to meet local, state, and national requirements. Public water supplies generally furnish suitably treated water to a building, eliminating the need for treatment in the building. However, ground and surface waters may require treatment prior to distribution for human consumption.

4.5 Water pipe sizing by friction head loss

Step1: draw a riser on this riser show floor to floor heights, run out distance to farthest fixture on each floor and length of piping from the service point to floor takeoff points Indicating the number and the type of fixtures served, together with the required flow

Step2: show the WSFU for each fixture and fixture unit total on each piping run out using table 4.1 (See Appendix C)

Step3: total the fixture unit in each branch of the system. Show both cold and hot water fixture units and then determine the water demand in gal /mm using table 4-2 (See Appendix C)

Step4: show source pressure (minimum) and the minimum flow pressure required at the most remote outlet using table 4-2 (See Appendix C)

Step5: Compute the equivalent length of pipe for each stack in the system, starting from the street main and determine the pressure available for friction head loss from the service point to final outlet.

Step6: determine the required pipe size in each section using the friction head loss data calculated in step 5 and the friction head charts

Note: - choose the pipe sizes from a chart like that in Fig. 4-2or 4-3 or from the charts given in the plumbing code being used

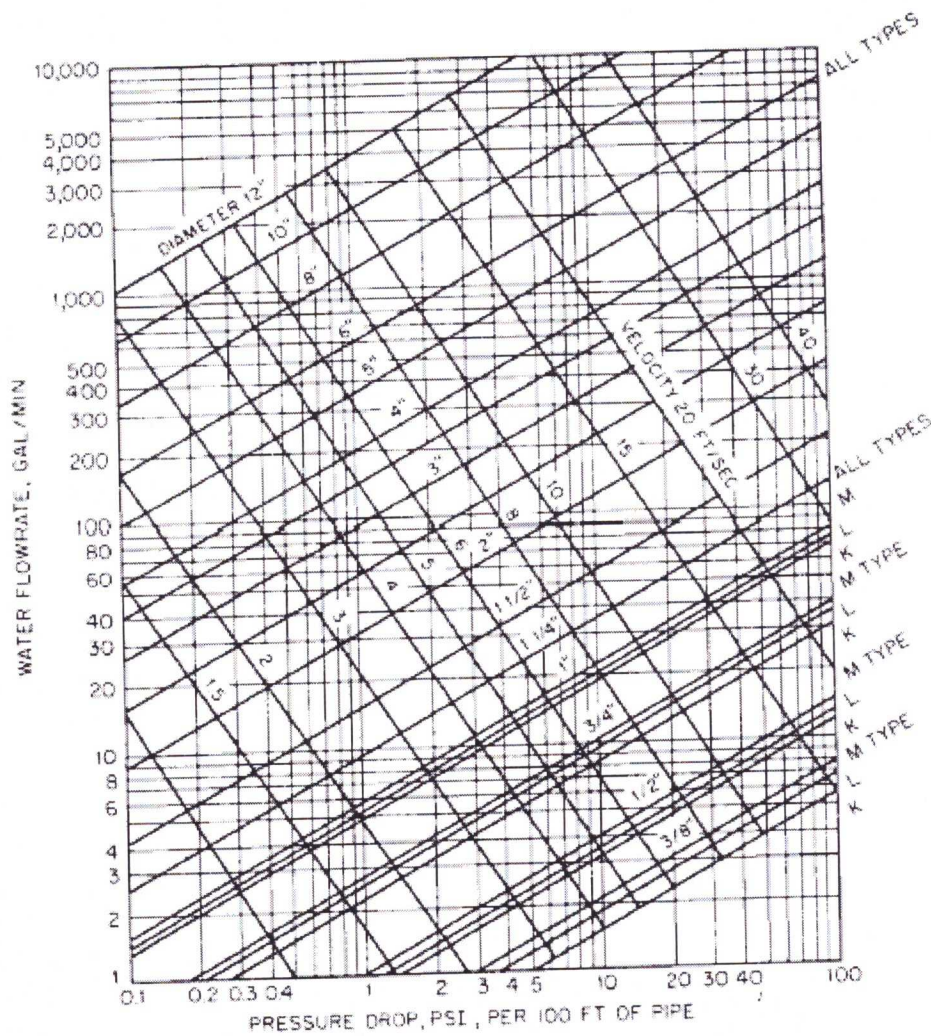


Fig 4-2 chart for determination of flow in copper pipe tubing and other pipes that will be smooth after 15-20 year of use

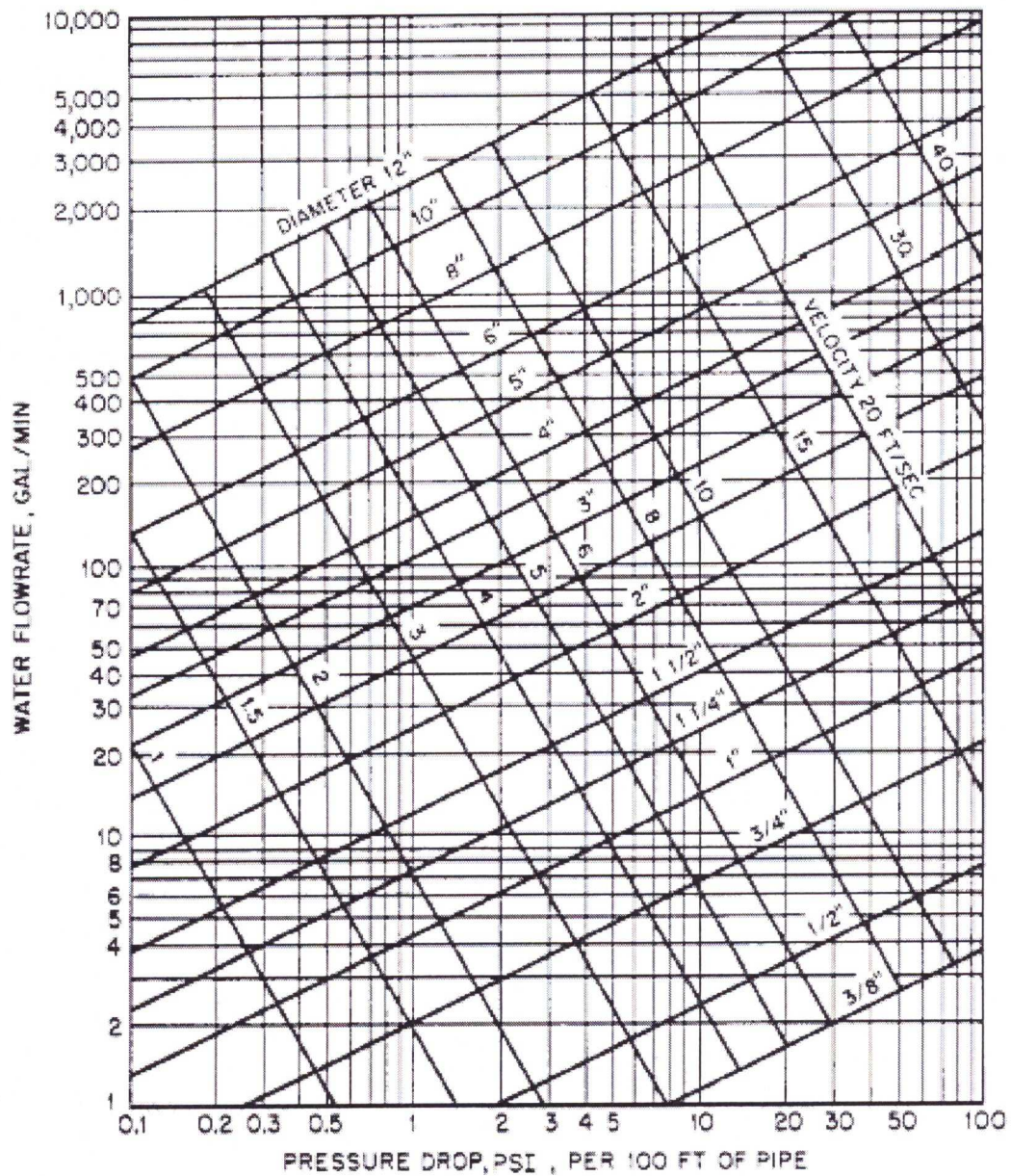


Fig 4-3 chart for determination of flow in pipes such as galvanized steel and wrought iron that will be fairly rough after 15-20 year of use

Selection is normally based on uniform friction head loss per foot through out and a maximum water velocity usually 8 fps except that branches feeding quick closing devices such as flush valve should be limited to about 4 fps to avoid water hummer

4.6 Water supply design procedure:-

- 1) determine the pressure of the source, decide wither to use source directly , reduce the pressure or increase it
- 2) determine wither to treat the structure as one unit or its necessary to zone it
- 3) decide wither to use up feed system or down feed system
- 4) determine the pressure and flow rate for all fixture and all continuous water use
- 5) determine the instantaneous maximum water demand (WSFU)
- 6) determine the size of water service based on the maximum water requirement
- 7) determine the minimum pipe size based on the pressure and flow requirement of water .use the farthest from the main source

4.7 Water pressure:-

The design of hospital water supply depends on:-

- 1) supply water pressure
 - a) City mains: - it is the pressure of the water source from municipality and its range from (30-60) psi. City mains larger than 80 psi cant be use directly , a pressure reducing valve should be used
 - b) Flow pressure: - it is the pressure available at the fixture when the outlet is wide open and it must equal or exceed minimum fixture pressure.
 - c) In adequate pressure:- it is the city line pressure which is insufficient to provide the required minimum flow pressure

In the case of in adequate pressure a booster pump and pressure tank should be used

- 2) highest water fixture outlet in the hospital
- 3) higher minimum fixture pressure outlet

At non flow condition:-

Main pressure = static head

At flow condition:-

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

4.8 Water service sizing:-

It is straight forward just to count the number of each type of fixture in the hospital.

Water service sizing depends on:-

- 1) Factor demand (use factor):- such that the fixture is not in continuous use it depends on duration of use, frequency, and flow.
- 2) Diversity factor between fixture: - such that not all fixture are used at the same time

The above two factors are called over all diversity factor

Water supply fixture unit (WSFU):- It is used to calculate the probable maximum water demand and then converted to gpm.

It is more accurate as its number is increases, for small building such as residences and small offices we use the unit of bath room group.

4.9 Hot Water System:-

The heater is designed to provide hot water at the minimum required temperature in order to:-

- (1) Lower heat loss in piping
- (2) Slower scale formation in piping
- (3) Avoidance of scalding temperature

To determine the required size of hot water heater we must know the following:

- (1) daily consumption
- (2) peak period
- (3) Duration of peak period

We have two types of hot water heaters:

(1) Instantaneous water heater: - it is a unit that heat water only when hot water faucet opens or other fixture demands hot water. They are referred to as tank less heater because they don't use any sort of storage tank. They should be large enough to provide maximum hot water demand immediately at required temperature

A gas burner or an electric element heats the water when there is a demand or a need for hot water. Hot water never runs out, as long as you don't exceed its designed "flow rate," and the temperature may be relatively low, around 105°F. Energy is saved, or more accurately, not wasted as there are almost no standby losses.

(2) Tank type water heater: - are the most common one used. Its advantages that it makes a large quantity of heated water available on demand

Typical units range in size from 30 to 80 gallons, but smaller and larger tank available. Most are fueled by electricity, natural gas, propane or oil. Storage water heaters heat the water in the tank to the set temperature, turn off, and then turn on and off as needed to keep it hot, ready for use. When you use hot water, the unit comes on to heat the incoming cold water that replaces what you use.

The figure below shows the hot water storage tank and its connection with the solar collector that are used for heating water.

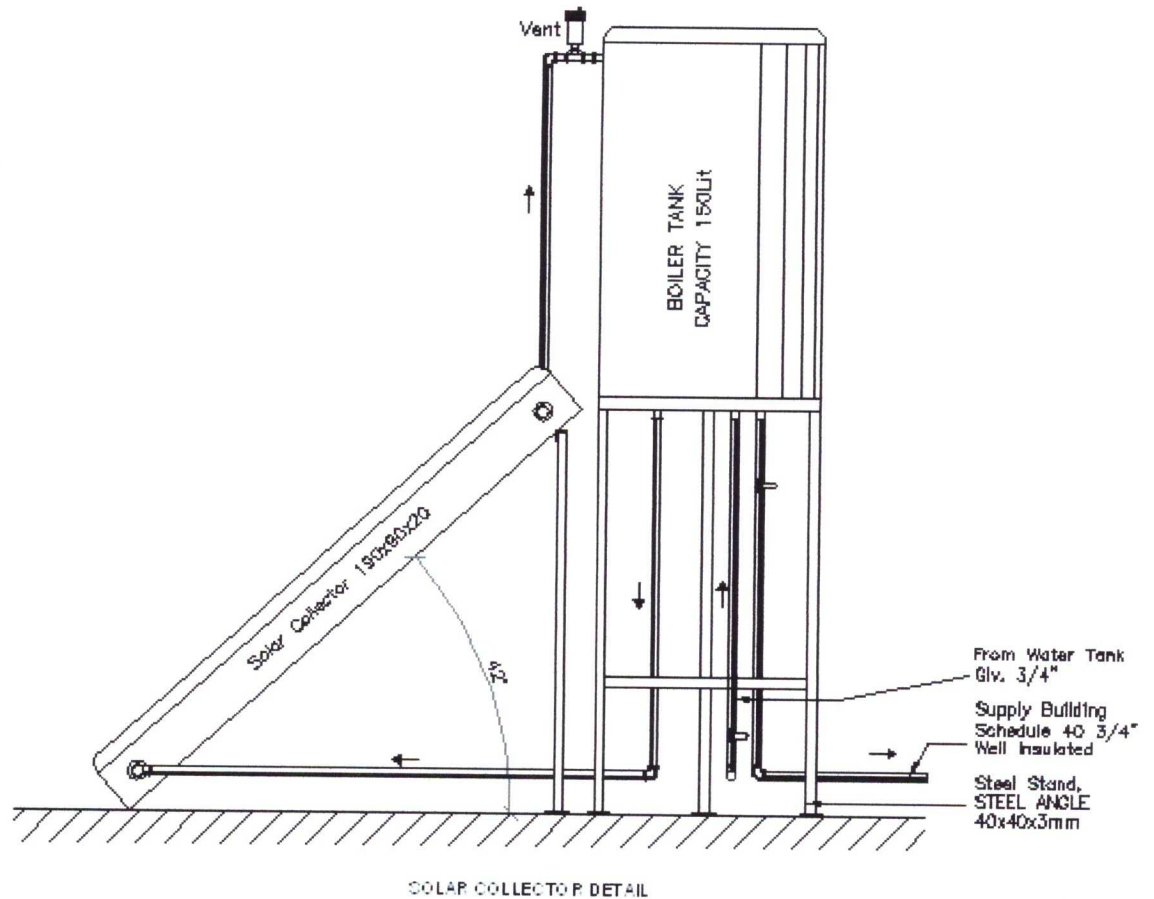


Fig 4-4: solar collector detail

4.10 Water Quantity and Pressure

Quantity of water supplied must be adequate for the needs of occupants and processes to be carried out in the building. The total water demand may be calculated by adding the maximum flows at all points of use and applying a factor less than unity to account for the probability that only some of the fixtures will be operated simultaneously

In addition, the pressure at which water is delivered to a building must lie within acceptable limits. Otherwise, low pressures may have to be increased by pumps and high pressures decreased with pressure-reducing valves. Table 4.1 lists minimum flow rates and pressures generally required at various water outlets. The pressure in Table 4.1 is the

pressure in the supply pipe near the water outlet while the outlet is wide open and water is flowing.

In delivery of water to the outlets, there is a pressure drop in the distribution pipes because of friction. Therefore, water supplied at the entrance to the distribution system must exceed the minimum pressures required at the water outlets by the amount of the pressure loss in the system. But the entrance pressure should not exceed 80 psi, to prevent excessive flow and damage to system components. Velocity of water in the distribution system should not exceed 10 ft / s.

A separate supply of water must be provided for fire-fighting purposes. This supply must be of the most reliable type obtainable. Usually, this requirement can be met with water from a municipal water supply. If the municipal water supply is not adequate or if a private water supply is utilized, pumps or storage in an elevated water tank should be provided to supply water at sufficient quantities and pressures. Generally, such water should be provided at a pressure of at least 15 psi residual pressure at the highest level of fire-sprinkler protection for light hazard occupancies and 20 psi residual pressure for ordinary-hazard occupancies. Acceptable flow at the base of the supply riser is 500 to 700 gpm for 30 to 60 minutes for light-hazard occupancies and 850 to 1500 gpm for 60 to 90 minutes for ordinary-hazard occupancies.

Fixture	Pressure, psi*	Flow, gpm
Basin faucet	8	3
Basin faucet, self-closing	12	2.5
Sink faucet, 3/8-in	10	4.5
Sink faucet, 1/2-in	5	4.5
Dishwasher	15-25	†
Bathtub faucet	5	6
Laundry tub cock, 1/4-in	5	5
Shower	12	3-10
Water closet ball cock	15	3
Water closet flush valve	15-20	15-40
Urinal flush valve	15-20	15
Garden hose, 50 ft, and sill cock	30	5

Table 4.3 required minimum flow rate and pressure during flow for fixture

4.11 Water Distribution in Building

Cold and hot water may be conveyed to plumbing fixtures under the pressure of a water source, such as a public water main, by pumps, or by gravity flow from elevated storage tanks.

The water-distribution system should be so laid out that, at each plumbing fixture requiring both hot and cold water, the pressures at the outlets for both supplies should be nearly equal. This is especially desirable where mixing valves may be installed, to prevent the supply at a higher pressure from forcing its way into the lower-pressure supply when the valves are opened to mix hot and cold water. Pipe sizes and types should be selected to balance loss of pressure head due to friction in the hot and cold-water pipes, despite differences in pipe lengths and sudden large demands for water from either supply.

Care should be taken to assure that domestic water piping is not installed in a location subject to freezing temperatures. When piping is installed in exterior walls in cold climate areas, the piping should be insulated and should be installed on the building side of the building wall insulation. Piping installed in exterior cavity walls or chases may require heat tracing, although the installation of high and low wall mounted grilles, which allow heated air from the building to naturally flow through the cavity, will usually prevent the temperature in the cavity from falling below a temperature where water in the piping will freeze. Designers should thoroughly investigate local climatic conditions and building methods to assure proper installation. Designers should also specify freeze-proof-type hydrants (hose bibs) for exterior applications.

4.12 Up-Feed Water Distribution

It is the system in which the city mains pressure is sufficient to overcome all friction in building at the calculated flow rate and still maintain the minimum fixture pressure required at the highest outlet

To prevent rapid wear of valves, such as faucets, water should only be supplied to building distribution systems at pressures not more than about 80 psi. This pressure is large enough to raise water from 8 to 10 stories upward and still retain desired pressures at plumbing fixtures (Table 4.1). Hence, in low buildings, cold water can be distributed by the up-feed method (Fig. 4.1), in which at each story plumbing fixtures are served by branch pipes connected to risers that carry water upward under pressure from the water source.

In Fig. 4.5, cold water is distributed under pressure from a public water main. The hot-water distribution is by a discontinuous system. Hot water rises from the water heater in the basement to the upper levels under pressure from the cold-water supply to the water heater.

When an up-feed distribution system is desired, but the city water pressure is not sufficient to provide adequate water pressure, the water pressure may be boosted to desired levels by the installation of a packaged, domestic water-booster pump system. This equipment usually consists of a factory-built system with multiple pumps, a pressure tank, and all operating controls to maintain the required water pressure. This type of system may also be used in buildings in excess of 10 stories by proper zoning and the use of pressure-reducing valves at each zone

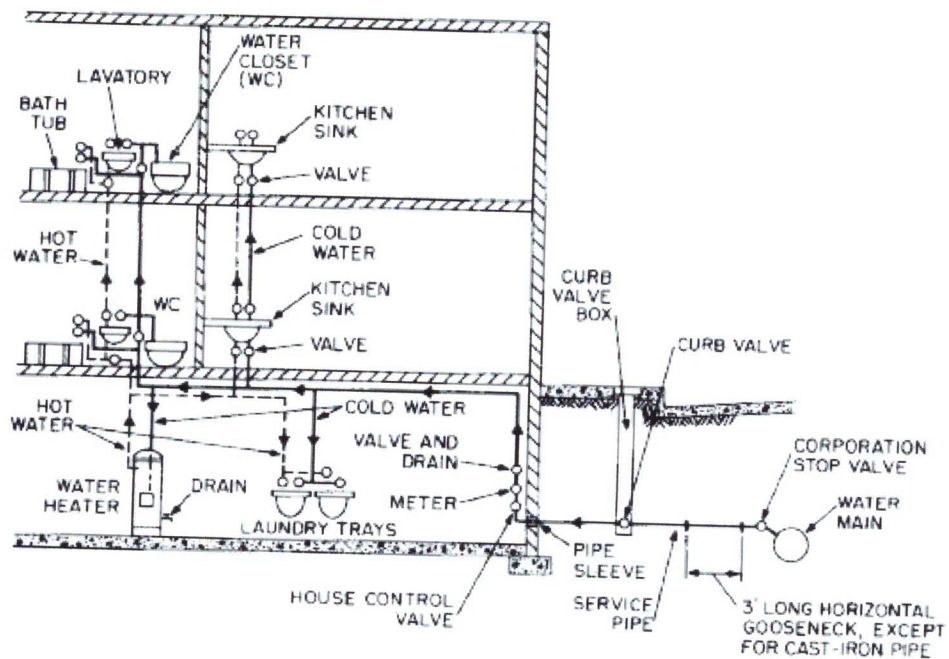


Figure 4.5 up feed system

4.13 Down-Feed Water Distribution

This system operates by pumping water from city mains or suction tank in the basement up to a roof tank from which the building outlets are fed by gravity. The pump action is controlled by float switch in roof tank and suction tank if used in this system the top floor outlet with minimum static head may be a problem.

For buildings more than 8 to 10 stories high, designers have the option to pump water to one or more elevated storage tanks, from which pipes convey the water downward to plumbing fixtures and water heaters. Water in the lower portion of an elevated tank often is reserved for fire-fighting purposes (Fig. 4.2). Generally, the tank is partitioned to provide independent, side-by-side chambers, each with identical piping and controls. During hours of low demand, a chamber can be emptied, cleaned, and repaired, if necessary, while the other chamber supplies water, as needed. Float-operated electric switches in the chambers control the pumps supplying water to the tank. When the water level in the tank falls below a specific elevation, a switch starts a pump, and when the water level becomes sufficiently high, the switch stops the pump.

Usually, at least two pumps are installed to supply each tank. One pump is used for normal operation. The other is a standby, for use if the first pump is inoperative. For fire-fighting purposes, a pump must be of adequate size to fill the tank at the rate of the design fire flow.

When a pump operates to supply a tank, it may draw so much water from a public main that the pressure in the main is considerably reduced. To avoid such a condition, water often is stored in a suction tank at the bottom of the building for use by the pumps. The tank is refilled automatically from the public main. Because refilling can take place even when the pumps are not operating, water can be drawn from the public main without much pressure drop.

Figure 4.6 is a simplified schematic diagram of a down-feed distribution system of a type that might be used for buildings up to 20 stories high.

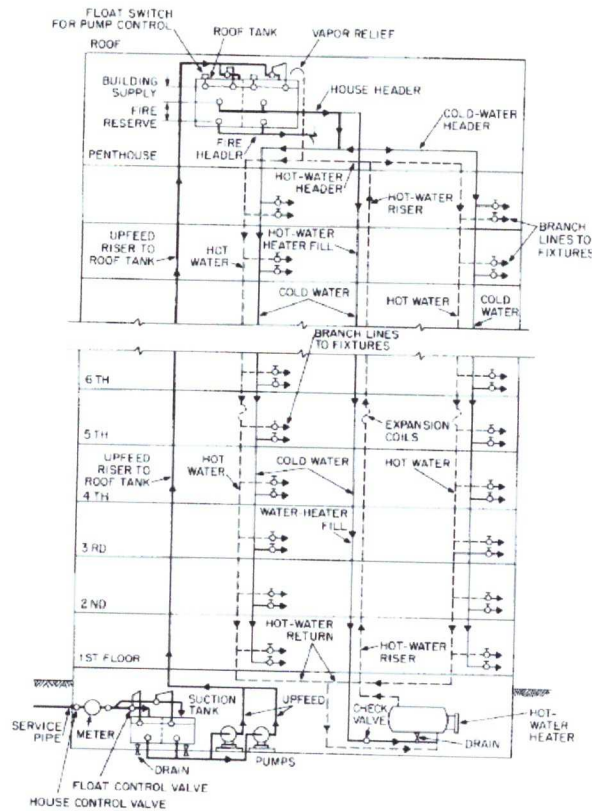


Figure 4.6 down feed system

Tall buildings may be divided into zones, each of which is served by a separate down-feed system. (The first few stories may be supplied by an up-feed system under pressure from a public main.) Each zone has at its top its own storage tank, supplied from its own set of pumps in the basement. All the pumps draw on a common suction tank in the basement. Also, each zone has at its base its own water heater and a hot-water circulation system. In effect, the distribution in each zone is much like that shown in Fig. 4.6.

If space is not available to install storage tanks at the top of each zone, the main water supply from a roof-mounted storage tank may be supplied to the zones if pressure-reducing valves are utilized to reduce the supply-water pressure to an acceptable level at each zone.

4. 14 Water Distribution System Used In Alia Hospital

In Alia Hospital the water that provided from city main is carried away to a storage tank that exists in the ground floor and then the water is pumped through GRANDFOSS PUMPS to another storage tank at the roof then the water goes down to the first floor which then pumped through GRANDFOSS PUMPS to the outlets of the hospital.

Note: - we see that the system used in Alia hospital is a mixing between down feed and up feed systems.

4.15 Pumps used in Alia Hospital:

There are two pumps one is used and the other is stand by to distribute the water to the outlets of the hospital.

NAME	GRANDFOS
TYPE	NB40-200/210A-F-A-BAQE
MODEL	OD2311BB2
Bar / C max.	16/140
Q	64 m ³ /h
H	47.6 M
N	2920 min ⁻¹

There are two pumps one is used and the other is stand by using to rise water to the storage tank at the roof

NAME	GRANDFOS
TYPE	NB65-255/265A-F-A-BAQE
MODEL	A D4411B9JP2 05430003
P/T	16/120 Bar / C max
Q	71 m ³ /h
H	18.8 M
N	1450 min ⁻¹

4.16 Expansion tank used in Alia hospital:-

There are six closed expansion tank in Alia hospital they have the following specifications:-

NAME	CAIT
MODEL	HL-200
CAPACITY	200 L
PRECHARGE PRESSURE	1.5bar
PRESSUR MAX.	10 bar
TEMPRETUARE MAX.	110C

And there is one closed expansion tank in Alia hospital it have the following specifications:-

NAME	CAIT
MODEL	HL-500
CAPACITY	500 L
PRECHARGE PRESSURE	1.5bar
PRESSUR MAX.	10 bar
TEMPRETUARE MAX.	110C

4.17 Sanitary Drainage

Its function to carries away the contaminated water and solids

The drainage or waste system is the most complex member of a well-designed plumbing installation. It is composed of two parts: the pipes which convey solid and liquid wastes to the house sewer, and the venting system, which facilitates the rapid removal of odors and gases from, and allows air to circulate within, the drainage system. That portion of the drainage system which convoys liquid and solid wastes to the house sewer begins with the fixture trap, which is usually located directly behind and below the fixture. Traps are constructed to prevent the back passage of air or gas through a pipe or fixture without materially reducing the flow of sewage and waste water. As the fixture discharges, a portion of the fluid is retained in the trap where it remains to form a liquid seal that prevents the gases that circulates within the drainage system from entering the room. Water closets have built-in traps.

Piping that carries the discharges of water closets is called soil pipe. Pipes receiving the discharge of other fixtures are called waste pipes. Indirect wastes are those not directly connected to the house drain, soil, or waste stack, such as that which draws off refrigerator drippings. The term stack is used to describe any vertical line of soil, waste, or vent piping.

The main of any drainage system of horizontal, vertical, or continuous piping is that part which receives the wastes, vents, or back vents from outlets or traps, either directly or through branch pipes which extend from the main to the fixture outlet. The house drain is normally the lowest piping of the drainage system. It receives the discharge from soil, waste, and other drainage pipes, and extends to the outside of the house foundation wall, where the house sewer begins.

As stated above, the drainage system allows air to enter and circulate within, and gases to escape from the drainage system, this portion of piping is known as the venting system. To obtain some idea of its importance, perform the following, experiment. Fill an empty cardboard milk container with water, invert it, and allow the water to drain. Notice the time required for the container to empty. Refill the container and repeat the

procedure. Once the water begins to flow, punch several holes in the container bottom. Notice how rapidly and easily the water flows out.

Similarly, the venting system allows the air ahead of a discharge in the drainage pipes to escape. Moreover, the air that reenters the system behind the discharge helps to speed it to the house sewer. Furthermore, the circulation of air within the drainage system helps to reduce corrosion.

The primary importance of the vent system is to prevent siphonage of the fixture vent traps by supplying air near the trap so there will be an equal supply of air on both sides of it. The water in the trap prevents sewer gas from going through the trap and out the fixture. The next most important function of the venting system is to allow air to be pushed ahead of a discharge without building up back pressure in the drainage system.

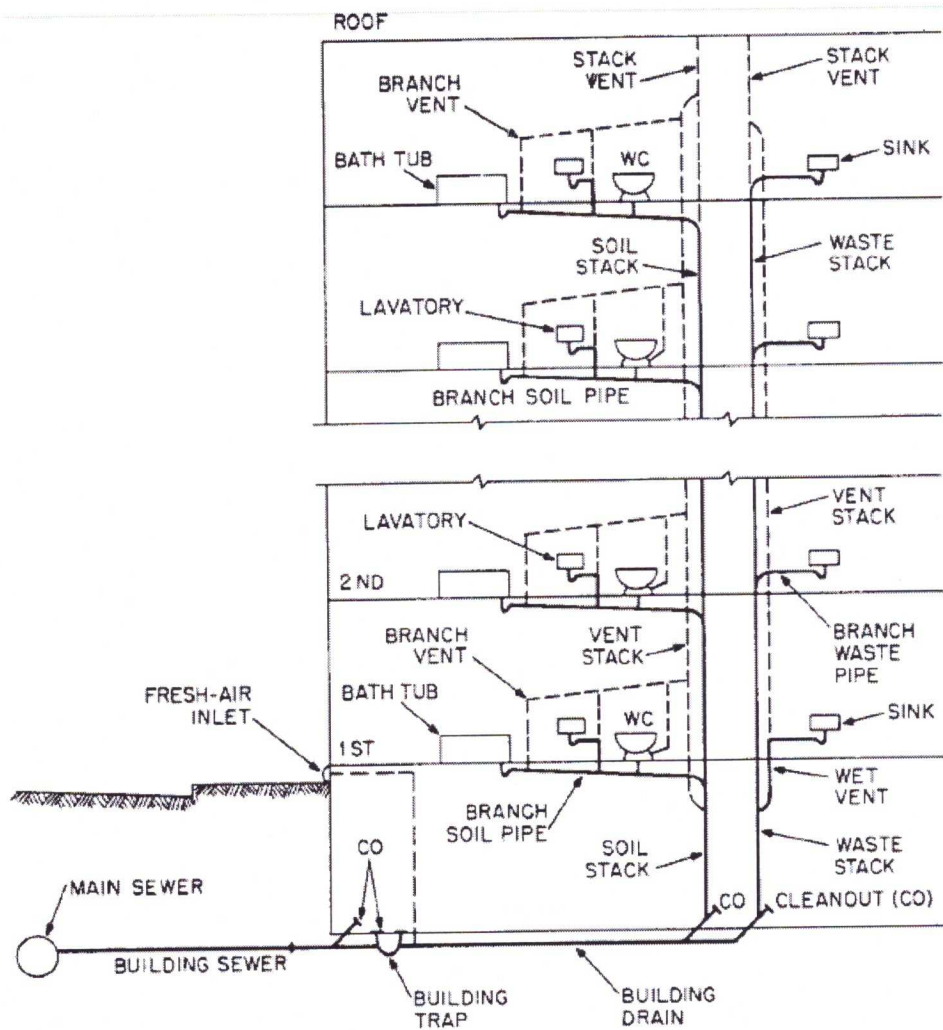


Figure 4-7 Wastewater-removal systems for a multistory building

Drainage piping fill

- 1) Branches are designed to run maximum of 50% fill.
- 2) Stacks are designed to flow between 25-33% maximum.
- 3) Building drains and sewer drains may be designed over 50% fill

Drainage piping velocity

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

Velocity of water flow through drainage piping depends on

- 1) Pipe diameter
- 2) Slope

For the same diameter large pipe diameter required lower slope

For pipes of diameter $\leq 3''$ the minimum slope is 1/4 in/ft

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

4.18 Drainage pipe sizing procedure

- 1) Draw a simple riser of the entire system showing all fixtures.
- 2) Assign drainage fixture units to each fixture according to table 4.4 (See Appendix C), if a fixture is not listed specifically, base the dfu requirement on its trap sizes are listed in table 4.5 (See Appendix C) with respect to drainage requirement not due to fixture, such as non re circulated cooling water or process water, use the conversion of (1gpm = 2dfu).

Thus, For instance, 2 gpm of process water at any drain should be counted as 4 dfu, and so forth.

- 3) Total the drainage fixture units in each drainage pipe and mark them on the drawing.
- 4) Determine the required size of horizontal fixture branches and stacks from table 4.6 (See Appendix C).
- 5) Determine the size and slope of the building drain and its branches, and the building sewer using table 4.7 (See Appendix C).
- 6) Determine the size and slope found in step 5 meet the requirement of the code and of table 4.8 (See Appendix C).

4.19 Rainwater Drainage

Exterior sheet-metal **gutters** and **leaders** for rainwater drainage are not normally included as part of the plumbing work. Interior leaders or storm-water drains, however, are considered part of the plumbing work. Depending on local codes or ordinances in the locality, rainwater from various roof areas may or may not be led into the sanitary sewer. Where separate rainwater leaders or storm drains are used, the building drains are then called **sanitary drains** because they convey only the wastes from the various plumbing fixtures in the building.

Interior storm-water drain pipes may be made of cast iron, steel, plastic, or wrought iron. All joints must be tight enough to prevent gas and water leakage. When a combined system is utilized, it is common practice to insert a cast-iron running trap between the storm drain and the building drain to maintain a trap seal on the storm drain at all times. Use of a combined system does not eliminate the need for separate drains and vents for wastewater. All codes prohibit use of storm drains for any type of wastewater.

Water falling on the roof may be led either to a gutter, from where it flows to a downspout (Fig.4.8a), or it may be directed to a roof drainage device by means of a slope in the roof surface. Many different roof drainage devices, such as roof drains (Fig. 4.8b) and parapet drains are available for different roof constructions and storm-water conditions.

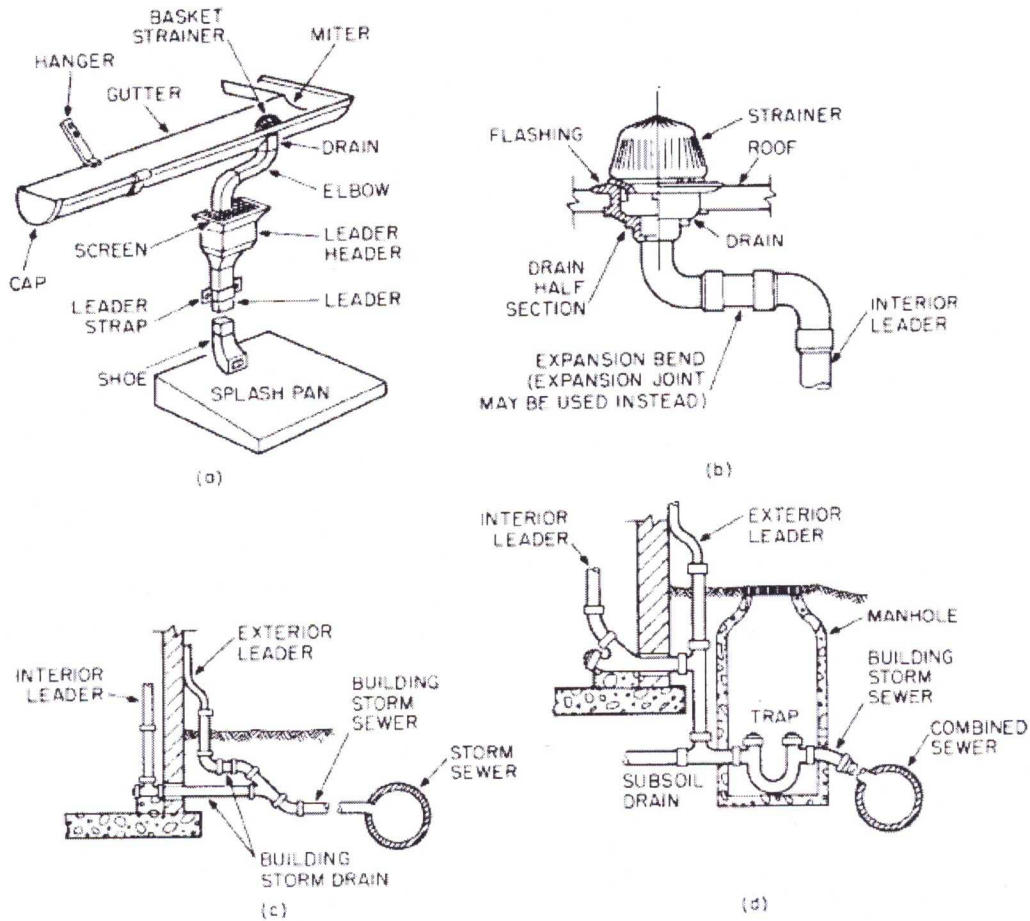


Figure 4-8 Elements of a storm-drainage system: (a) roof gutter, exterior leader, and splash pan; (b) roof drain and top portion of interior leader; (c) piping to a storm sewer; (d) piping to a combined sewer.

Most plumbing codes include provisions to prevent the collapse of the building structure due to water pounding on the roof because of a clogged storm drainage system. In most cases, these codes require installation of overflow roof drains or parapet overflow scuppers to relieve water from the roof in the event of such a condition. Local authorities should be contacted to determine what requirements apply in their jurisdiction.

When vertical leaders are extremely long, it is common practice to install an expansion joint between the leader inlet and the leader itself. Figure 4.8c shows an example of a connection of a building storm drain to a storm sewer. When the drain must be connected

to a combined sanitary-storm sewer, a trap should be installed before the connection to the sewer (Fig. 4.8d).

Sizes of vertical leaders and horizontal storm drains depend on the roof area to be drained. Table 4.9 indicates the maximum horizontal projection of roof area permitted for various sizes of leaders and horizontal storm drains. Semicircular gutters are sized on the basis of the maximum projected roof area served. Table 4.10 shows how gutter capacity varies with diameter and pitch.

Vertical conductors and leaders

Size of leader or conductor, in†	Maximum projected area, ft ²	Flow, gal/min
2	2,176	23
2½	3,948	41
3	6,440	67
4	13,840	144
5	25,120	261
6	40,800	424
8	88,000	913

Horizontal building storm drains and building storm sewers

Drain diameter, in	Maximum projected roof area, ft ² , and flow, gal/min, for various slopes					
	⅛ in per ft slope		¼ in per ft slope		½ in per ft slope	
	Area	Flow	Area	Flow	Area	Flow
3	3,288	34	4,640	48	6,576	68
4	7,520	78	10,600	110	15,040	156
5	13,360	139	18,880	196	26,720	278
6	21,400	222	30,200	314	42,800	445
8	46,000	478	65,200	677	92,000	956
10	82,800	860	116,800	1,214	165,600	1,721
12	133,200	1,384	188,000	1,953	266,400	2,768
15	238,000	2,473	336,000	3,491	476,000	4,946

*Roof areas and flows are based on a maximum rainfall intensity of 1 in/hr for a duration of 1 hr. For regions with different maximum rainfall intensity in storms with a 100-year recurrence interval, divide tabulated areas and flows by that intensity, in/hr.

†The area of rectangular leaders should equal or exceed that of the circular leader required. The ratio of width to depth of rectangular leaders should not exceed 3 to 1.

Table 4-9 Sizes of Vertical Leaders and Horizontal Drains

Gutter diameter, in	Maximum projected roof area, ft ² , and flow, gal/min, for gutters of various slopes							
	1/8 in per ft slope		1/4 in per ft slope		1/2 in per ft slope		3/4 in per ft slope	
	Area	Flow	Area	Flow	Area	Flow	Area	Flow
3	680	7	960	10	1,360	14	1,920	20
4	1,440	15	2,040	21	2,880	30	4,080	42
5	2,500	26	3,520	37	5,000	52	7,080	74
6	3,840	40	5,440	57	7,680	80	11,080	115
7	5,520	57	7,800	81	11,040	115	15,600	162
8	7,960	83	11,200	116	14,400	165	22,400	233
10	14,400	150	20,400	212	28,800	299	40,000	416

Table 4-10 Sizes of Semicircular Roof Gutters

Where maximum rainfall is either more than, or less than, 1 in/hr, refer to the plumbing code for suitable correction factors.

Drains for building yards, subsoil drainage systems, and exterior areaways may also be connected to the storm drainage system. Where this is not possible, these drains may be run to a dry well. When a dry well is used, only the discharge from these devices may be run to the dry well

4.20 Manhole Design:-

We design the manholes around the building so as that the sewage comes from the stacks flows in , then the sewage flows from one manhole to another so as reaching the septic tank.

The design of the manholes depend on the ground and its nature around the building, and so as the first manhole height should not be less than 50 cm. and then we calculate the height of the other manholes depending on the spacing between manholes and the slope of drainage pipes between manhole to be 1.5 % .

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

- Φ60 cm for manhole depth (50-100)cm.
- Φ80 cm for manhole depth (100-150) cm.
- Φ100 cm for manhole depth (150-250) cm.
- Φ120 cm for manhole depth > 250 cm.

4.21 Manholes in Alia hospital

Most manholes used in Alia hospital are the rectangular type which has a soft cover made from cast iron which bears a weight of 8 ton, 25 ton.

For the sewage manholes (see table 4.11 in appendix C).

For the rain table (see table 4.12, table 4.13 in appendix C).

CHAPTER FIVE

CENTRAL HEATING CALCULATIONS

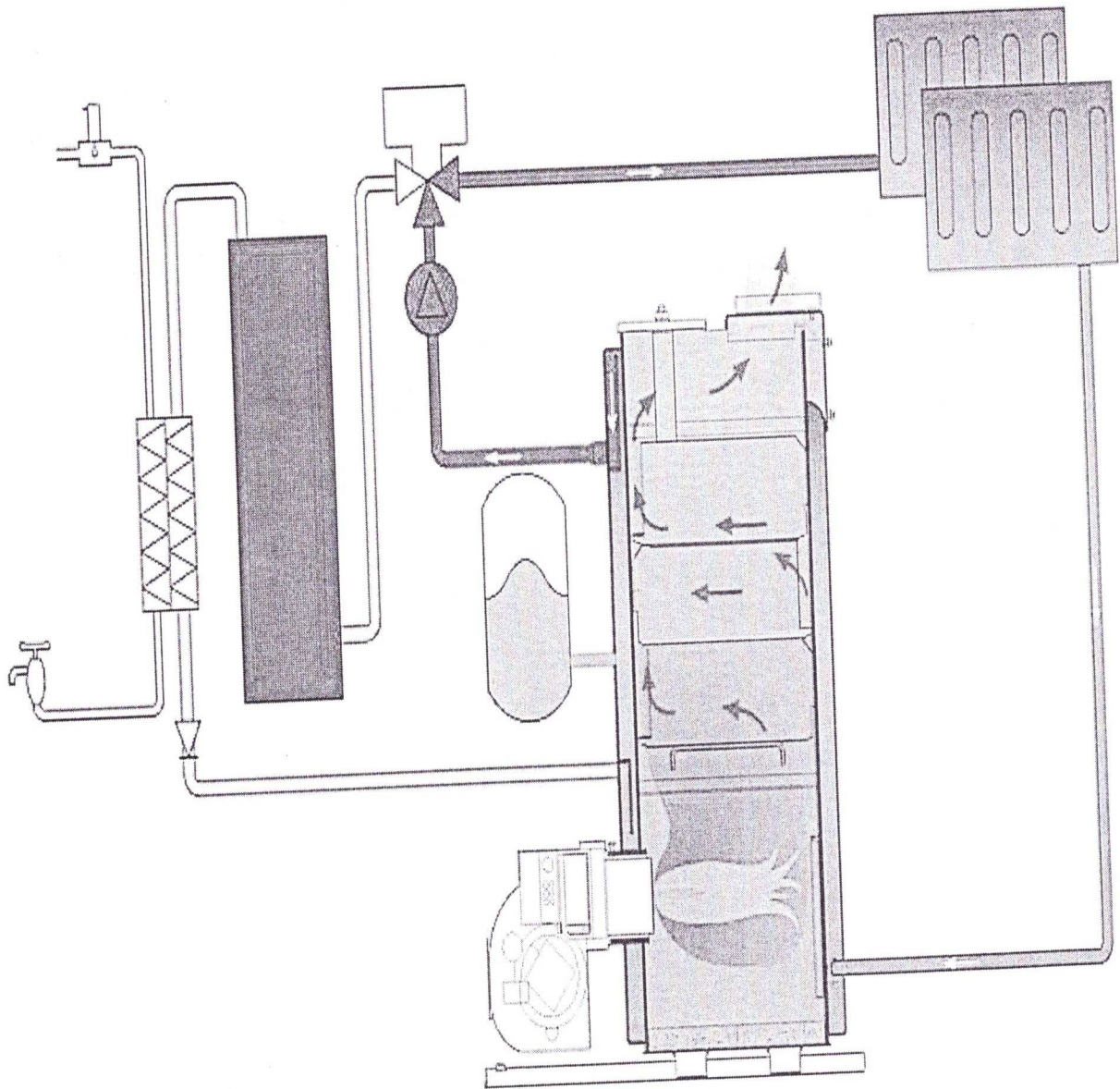


Figure 5-1 Central heating system

5.1 Heating load calculation in the Obstetrics & Gynecology Department as following:

The total area of the first floor = 3900 m² and the total area of Obstetrics & Gynecology Department of the hospital = 510 m² and the height is 3.35 m

In the Obstetrics & Gynecology Department in Alia hospital the heating system exist consist of steel radiators and two air handler with the following value:

5.1.1 Heat gain from radiators

By using steel radiator catalogue the heat outputs at all radiators at ΔT 60°C as follows:-

Radiators table in First floor:

Radiator no in drawing	Radiator C22/600 size in cm	Q _{Rad.} in watt
R-1	40	929
R-2	50	1161
R-3+R-4	40	929
R-5	50	1161
R-6	70	1625
R-7	40	929
R-8	90	2090
		Total load = 8.83kW

Table 5.1 Distribution of radiators in the Obstetrics & Gynecology Department

5.1.2 Heat gain from air handling units

The first air handler has a flow rate = 7460 CFM that provides rooms and corridor

With mixing 21% fresh air and 79% return air

And so

$$Q = m * C_p * \Delta T$$

As the outside has a temperature = 2°C & relative humidity = 70%

Also the inside has a temperature = 22°C & relative humidity = 50%

So from psychometric chart and as there is a mixing so by using the following equation

$$m_1 * T_1 + m_2 * T_2 = (m_1 + m_2) * T_3$$

m_1 = percentage flow rate for fresh air (kg/s).

m_2 = percentage flow rate for return air (kg/s).

T_1 = inside temperature (°C)

T_2 = outside temperature (°C)

T_3 = mixing temperature (°C)

ΔT = temperature difference between design temperature and mixing temperature

m = flow rate of the first air handler (°C)

C_p = Specific heat for air = 1.0 (KJ/Kg.K)

And so

$$21 * 2/100 + 79 * 22/100 = 100 * T_3/100$$

So $T_3 = 17.8^\circ\text{C}$

Then

$$\Delta T = 22 - 17.8 = 4.2^{\circ}\text{C}$$

$$Q = m \cdot C_p \cdot \Delta T$$

$$Q = 7460 \cdot 1.28 / 2119 \cdot 1.0 \cdot 4.2 = 19.0 \text{ KW}$$

The second air handler has a flow rate = 1600 CFM that provides surgery operation rooms with 100% fresh air

So the total load of the two air handler can be calculated from the following

Then

$$Q = m \cdot C_p \cdot \Delta T$$

$$Q = 1600 \cdot 1.28 / 2119 \cdot 1.0 \cdot 20 = 19.30 \text{ KW}$$

And so the total heating load from radiators and the two air handler

$$Q_{\text{total}} = 19.0 + 19.30 + 8.83 = 47.13 \text{ KW}$$

5.1.3 Heat loss through walls, ceiling, floor, glass and doors:

For walls

	Material	Distance (CM)	Thermal Conductivity
1	Stone	5	2.2
2	Concrete	9	1.7
3	Randopan	3	0.12
4	Concrete Block	20	1
5	Plaster	2	1.2

Table 5.2 Walls components in the Obstetrics & Gynecology Department

$$U = \frac{1}{\frac{1}{8.34} + \frac{0.02}{1.2} + \frac{0.2}{1} + \frac{0.03}{12} + \frac{0.9}{1.7} + \frac{0.05}{2.2} + \frac{1}{12.5}}$$
$$= 1.347 \text{ w/m}^2 \cdot \text{°C}$$

For first side of wall:

$$Q_1 = U \cdot A \cdot \Delta T$$
$$= 1.347 * 106.2 * 20 = 2861.028 \text{ W}$$

For second side of wall:

$$Q_2 = U \cdot A \cdot \Delta T$$
$$= 1.347 * 94.785 * 20 = 2553.5 \text{ W}$$

For internal walls:

	Material	Distance (CM)	Thermal Conductivity
1	Concrete Block	14	1
2	Plaster	6	1.2

Table 5.3 Internal Walls components in the Obstetrics & Gynecology Department

$$U = \frac{1}{\frac{1}{8.34} + \frac{0.06}{1.2} + \frac{0.14}{1} + \frac{1}{8.34}}$$

$$= 2.326 \text{ w/m}^2 \cdot \text{°C}$$

$$Q_3 = U.A.\Delta T$$

$$= 2.326 * 117.25 * 12 = 3272.6$$

For glass

$$Q = U.A.\Delta T$$

$$= 3.2 * 29.16 * 20 = 1866.24 \text{ W}$$

For door

	Material	Distance (CM)	Thermal Conductivity
1	PVC	6	0.15
2	Wood	5	0.16

Table 5.4 Door components in the Obstetrics & Gynecology Department

$$U = \frac{1}{\frac{1}{8.34} + \frac{0.06}{0.15} + \frac{0.05}{0.16} + \frac{1}{8.34}}$$

$$= 1.05 \text{ w/m}^2 \cdot \text{°C}$$

$$Q = U \cdot A \cdot \Delta T$$

$$= 1.05 * 3.57 * 12 = 44.982 \text{ W}$$

For floor

	Material	Distance (CM)	Thermal Conductivity
1	Tiles	3	0.69
2	Mortar	2	0.16
3	Sand fill	10	0.27
4	R.C Slab	45.7	1.85
5	Plaster	1.5	1.2

Table 5.5 Floor components in the Obstetrics & Gynecology Department

$$U = \frac{1}{\frac{1}{6.6} + \frac{0.015}{1.2} + \frac{0.457}{1.85} + \frac{0.1}{0.27} + \frac{0.02}{0.16} + \frac{0.03}{0.69} + \frac{1}{10}}$$

$$= 0.952 \text{ w/m}^2 \cdot \text{°C}$$

$$Q = U.A.\Delta T$$

$$= 0.952 * 510 * 12 = 5826.24 \text{ W}$$

For Ceiling

	Material	Distance (CM)	Thermal Conductivity
1	Water Proofing		
2	Foam concrete screed	12.5	0.2
3	Reinforced slab	50	1.85
4	Plaster	1.5	1.2
5	Air gap	100	0.026

Table 5.6 Ceiling components in the Obstetrics & Gynecology Department

$$U = \frac{1}{\frac{1}{6.6} + \frac{0.015}{1.2} + \frac{0.5}{1.85} + \frac{0.125}{0.2} + \frac{1}{36.91} + \frac{1}{0.026} + \frac{1}{10}}$$

$$= 0.0252 \text{ w/m}^2 \cdot \text{°C}$$

$$Q = U.A.\Delta T$$

$$= 0.0252 * 510 * 12 = 154.22 \text{ W}$$

$$Q \text{ total for all walls, ceiling...} = 16578.81 \text{ w} = 16.579 \text{ KW}$$

5.1.4 Infiltration calculations:-

From Palestinian code number of air change per hour for hospital rooms and kitchen and toilets = 2

For windows

$$Q = m \Delta h$$

$$m = V * \rho$$

Δh = enthalpy change between inside and outside of the building (kJ/Kg)

ρ = 1.28 kg/m³ (at outside temperature 2°C and relative humidity 70%) (Kg / m³)

V = Volumetric flow rate (m³/s)

V = Number of air changes per hour * room volume

NO.	Using type	Q inf.
1	Toilets	338
2	Room106	2176
3	kitchen	606
4	Room104	1700
5	Room5	1478
6	Room4	1066
7	Room3	1066
8	Room2	1066
9	Room1	1502
10	Room144	1033
11	Room145	606
12	Room146	916

13	Room148+149	6806
14	Room152	1455
		TOTAL LOAD for windows =21.82 kw

Table 5.7 Infiltration value in the Obstetrics & Gynecology Department

For main door at the first floor

We assume that the number of hospital staff is 100 persons and we assume that the number of Patients and visitors that this part service are 100 persons.

$$Q = m \Delta h$$

$$m = V * \rho$$

Δh = enthalpy change between inside and outside of the building (kJ/Kg)

ρ = 1.28 kg/m³ (at outside temperature 2°C and relative humidity 70%) (Kg / m³)

V = Volumetric flow rate (m³/s)

V = Number of air changes per hour * room volume

The number of passage per hour = 200 persons

Entrance passage per occupant per hour = 4 from table (6-6)

Infiltration rate due to door opening = 4.757 m³/passage from table (6-5)

Total Infiltration rate = 4.757*4*200 = 3806 m³/h

$$m = V * \rho = 3806 * 1.28 / 3600 = 1.354 \text{ kg/s}$$

$$Q = m \Delta h = 1.354(43-10) * 103 = 44.70 \text{ kW}$$

By using the percentage of area

The total area of this first floor of the hospital = 3900 m² and the Obstetrics & Gynecology Department in Alia hospital its area = 510 m².

Q inf. For main door = Q total for door * area of Obstetrics & Gynecology Department / total area of the first floor

$$Q \text{ inf. For main door} = 44.70 * 510 / 3900 = 5.84 \text{ kW}$$

So the total infiltration from windows and doors

$$Q \text{ inf.} = Q \text{ inf. door} + Q \text{ inf. windows} = 21.82 + 5.84 = 27.66$$

$$Q \text{ total} = Q \text{ total for all walls, ceiling, ...} + Q \text{ inf.} = 44.24 \text{ KW}$$

5.2 Pump Calculations

$$Q_T = \dot{m} \cdot c_p \cdot \Delta T$$

$$Q \text{ from old hospital} = 120 \text{ KW}$$

$$Q \text{ from Radiators} = 124.925 \text{ KW}$$

$$\begin{aligned} Q \text{ from AHU} &= Q \text{ from AHU1} + Q \text{ from AHU2} + Q \text{ from AHU3} + Q \text{ from AHU4} + \\ &\quad Q \text{ from AHU5} + Q \text{ from AHU6} + Q \text{ from AHU7} + Q \text{ from AHU8} \\ &= 101.23 \text{ Ton} \\ &= 101.23 * 3.516 = 355.924 \text{ KW} \end{aligned}$$

$$Q \text{ from second floor} = 125 + 355 = 480 \text{ KW}$$

$$\begin{aligned} Q_{\text{Total}} &= Q \text{ from Radiators} + Q \text{ from old hospital} + Q \text{ from AHU} + Q \text{ from second} \\ &\quad \text{Floor (expected)} \\ &= 124.925 + 120 + 355.924 + 480 \\ &= 1080.849 \text{ KW} \end{aligned}$$

$$\Delta T = 10 \text{ }^\circ\text{C}$$

$$C_p = 4.18 \text{ (KJ/Kg.K)}$$

$$\dot{m} = Q_{\text{Total}} / (C_p \cdot \Delta T)$$

$$\begin{aligned} \dot{m} &= 1080.849 / (4.18 * 10) \\ &= 25.85 \text{ kg/s} \\ &= 93.06 \text{ m}^3/\text{h} \end{aligned}$$

$$\text{Total length from pump to farther radiator (supply + return)} = 144.8 * 2 = 289.6 \text{ m}$$

$$\text{Total Equivalent length} = 289.6 * 1.5 = 434.4 \text{ m}$$

From the grandffoss catalogue (see figure A 2.1(a) in appendix A) at the intersecting between flow rate = 93.06 m³/h with the curve at the catalog we see that the head =15 kpa.

$\Delta P/EL$ must be in the range of 200 to 500 Pa/m

From the catalog at head 15 kpa we have $\Delta P = 150$ kpa

$$\Delta P/EL = 150000 / 434.4 = 345.3 \text{ Pa/m}$$

5.3 pipe sizing

In this case we will to calculate the diameter of main pipe in **Obstetrics & Gynecology Department** which carry hot water from boiler to radiators.

Q total from radiators = 8.83 kw

$$Q_T = \dot{m} \cdot c_p \cdot \Delta T$$

$$\dot{m} = 8.83 / (4.18 \cdot 10) = 0.2112 \text{ kg/s}$$

By using chart in figure 2.11

We have flow rate = 0.2112 kg/s and pressure drop = 345.4 pa/m

So the main pipe diameter = 25 mm

CHAPTER SIX

AIR CONDITIONING CALCULATIONS

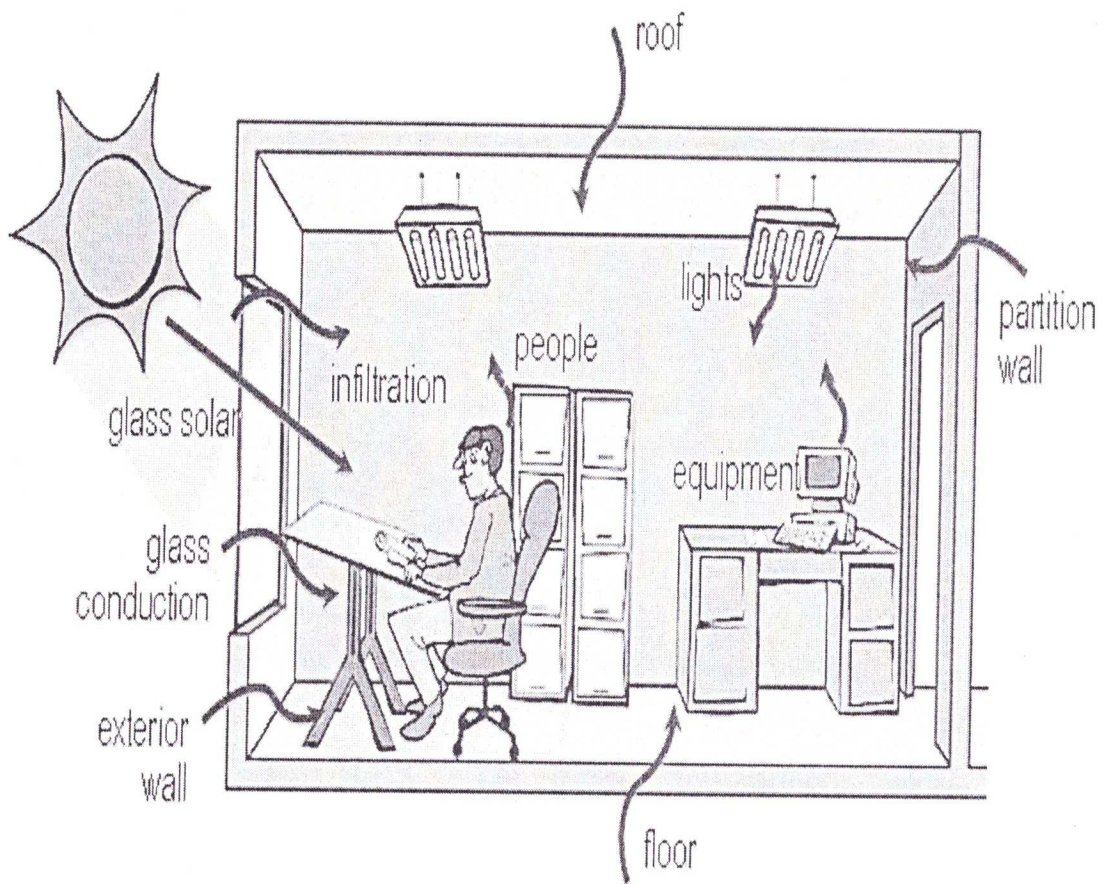


Figure 6-1 cooling load component

6.1 Cooling load calculation in the Obstetrics & Gynecology

Department as following:

The total area of the first floor = 3900 m² and the total area of Obstetrics & Gynecology Department of the hospital = 510 m² and the height is 3.35 m

In the Obstetrics & Gynecology Department in Alia hospital the cooling system exists consist of tow air handler the first Air handling unit using in delivery room of Obstetrics & Gynecology Department of the hospital and the second Air handling unit using in operation room

6.1.1 Heat Gain Due To walls, ceiling, floor, glass and doors:

For walls

$$U = \frac{1}{\frac{1}{8.34} + \frac{0.02}{1.2} + \frac{0.2}{1} + \frac{0.03}{12} + \frac{0.9}{1.7} + \frac{0.05}{2.2} + \frac{1}{12.5}}$$
$$= 1.347 \text{ w/m}^2 \cdot \text{°C} \text{ (see table 5.2)}$$

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

$$Q = U * A * (CLTD)_{CORR}$$

→Where:

Q: Heat flow through the walls, ceiling, floor, by conducting. (Watt)

U: Over all heat transfer coefficient (W/m².K).

A: Out door Area of heat conductive. (m²)

CLTD: the total equivalent temperature difference which take in

Consideration the increase of wall temperature due to
Absorption of solar radiation

Note: - the value of **CLTD** is called cooling load temperature difference

The value **CLTD** extracted from tables 3-13 (See Appendix B) needs to be corrected so that the actual value is found for different cases, and hence it will be called corrected **CLTD** and can be calculated from the following equation

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

→Where:

CLTD: is called cooling load temperature difference which can obtain from table 3-13 (See in Appendix B) for walls and roofs

LM: Latitude correction factor which can obtain from table 3-2 (See Appendix B) for horizontal and vertical surfaces

K: colors adjustment factor such that $k=1.0$ for dark coloured roofs

And $k=0.65$ for Permanently Light coloured walls

$(25.5 - T_i)$: a correction factor for indoor design temperature where T_i is the room design temperature °c and = 24°C

$T_{o,m}$ = the out door design temperature °c and = 35°C

$(T_{o,m} - 29.4)$: a correction factor for outdoor mean temperature $T_{o,m}$

It is related to the out door design temperature T_o , according to the relation

$$T_{o,m} = T_o - DR / 2$$

DR: the daily temperature range which equal to the difference between the Average maximum and Average minimum temperature for Warmest month of the summer season

Note: - Average maximum and Average minimum temperature for the Warmest month of the summer season = 35°C, 23 °C Respectively

f: attic or roof fan factor such that $f=1.0$ if there is no attic or roof fan & $f = 0.75$ if there is an attic or roof fan

For east wall:

$$Q = U * A * (CLTD)_{CORR}$$

So we must do the following calculations

$$T_{o, m} = T_o - DR / 2$$

$$T_{o, m} = 35 - (35 - 23) / 2 = 29 \text{ }^\circ\text{C}$$

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

$$(CLTD)_{corr \text{ for east wall}} = (9 + -1.1) 0.65 + (25.5 - 24) + (29 - 29.4) * 1 = 6.235 \text{ }^\circ\text{C}$$

$$Q = U * A * (CLTD)_{CORR}$$

$$Q_{\text{east wall}} = 1.347 * 81.92 * 6.235 = 688.0 \text{ w}$$

For west walls:

As a result that these walls besides an unconditioned spaces so the temperature of these spaces are uniform and = 35°C

$$Q = U * A * \Delta T$$

$$Q_{\text{west wall}} = 1.347 * 93.98 * (35 - 24) = 1392.50 \text{ w}$$

For internal south and north walls:

$$U = \frac{1}{\frac{1}{8.34} + \frac{0.06}{1.2} + \frac{0.14}{1} + \frac{1}{8.34}}$$

$$= 2.326 \text{ w/m}^2 \cdot ^\circ\text{C} \text{ (see table 5.3)}$$

$$Q = U \cdot A \cdot \Delta T$$

$$Q_{\text{ south internal wall}} = 2.326 \cdot 56.73 \cdot (35-24) = 1451.50 \text{ w}$$

$$Q_{\text{ north wall}} = 2.326 \cdot 24.62 \cdot (35-24) = 629.93 \text{ w}$$

For floor

As a result that the ground floor below this floor is unconditioned space so the temperature of the unconditioned space are uniform and = 35 °C and so we can use the following equation to calculate heat flow from floor:-

$$Q = U \cdot A \cdot \Delta T$$

$$U = \frac{1}{\frac{1}{6.6} + \frac{0.015}{1.2} + \frac{0.457}{1.85} + \frac{0.1}{0.27} + \frac{0.02}{0.16} + \frac{0.03}{0.69} + \frac{1}{10}}$$
$$= 0.952 \text{ w/m}^2 \cdot ^\circ\text{C} \text{ (see table 5.5)}$$

Then we can calculate heat flow as following:-

$$Q = U \cdot A \cdot \Delta T$$

$$Q_{\text{ floor}} = 0.952 \cdot 466.5 \cdot (35-24) = 4885.20 \text{ W}$$

For Ceiling

As a result that this ceiling exposed to the outside air so the temperature difference can be calculated using cooling load temperature difference (CLTD) and so we can use the following equation to calculate heat flow from ceiling:-

$$Q = U * A * (CLTD)_{CORR}$$

$$U = \frac{1}{\frac{1}{6.6} + \frac{0.015}{1.2} + \frac{0.5}{1.85} + \frac{0.125}{0.2} + \frac{1}{36.91} + \frac{1}{0.026} + \frac{1}{10}}$$
$$= 0.0252 \text{ w/m}^2 \cdot \text{ }^\circ\text{C} \quad (\text{see table 5.6})$$

Then we can calculate heat flow as following:-

$$Q = U * A * (CLTD)_{CORR}$$

So we must do the following calculations

$$T_{o, m} = T_o - DR / 2$$

$$T_{o, m} = 35 - (35 - 23) / 2 = 29 \text{ }^\circ\text{C}$$

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

$$(CLTD)_{corr \text{ for roof}} = (10 + -0.5)1.0 + (25.5 - 24) + (29 - 29.4) * 1 = 10.60 \text{ }^\circ\text{C}$$

$$Q = U * A * (CLTD)_{CORR}$$

$$Q_{\text{roof}} = 0.0252 * 466.5 * 10.60 = 124.62 \text{ kW}$$

So the total heat flow through walls as follow

$$Q_{\text{total for walls}} = Q_{\text{east wall}} + Q_{\text{west wall}} + Q_{\text{north wall}} + Q_{\text{south internal wall}} + Q_{\text{floor}} + Q_{\text{roof}}$$

$$Q_{\text{total for walls}} = 688.0 + 1392.50 + 629.93 + 1451.50 + 4885.20 + 124.62 = 9.17 \text{ kW}$$

For glasses:-

We have glasses on east and west walls and no glasses on north and south walls and so we can use the following equation to calculate heat flow from glasses:-

$$Q_{\text{TOTAL east}} = Q_{\text{CONV.}} + Q_{\text{TR.}}$$

$$Q_{\text{CONV.}} = U * A * (\text{CLTD})_{\text{CORR}}$$

$$Q_{\text{TR.}} = A (\text{SHG}) * (\text{SC}) * (\text{CLF})$$

→Where:

SHC: Solar heat gain factor this factor represents the amount of solar Energy that would be received by floor, furniture and the inside walls Of the room and can be extracts from table 3-3 (See Appendix B)

SC: Shading coefficient this factor accounts for different shading effects of the glass wall or window and can be extracted from tables 3-4 (See Appendix B) for single and double glass without inside shading or From table 3-5 (See Appendix B) for single and double glass as Well as for insulating glass with internal shading

CLF: Cooling load factor this represent the effects of the internal walls, Floor and furniture on the instantaneous cooling load, and can be Extracted from table 3-6 (See Appendix B) for glass without Interior shading or from table 3-7 (See Appendix B) for glass with Interior shading

CLTD: is called cooling load temperature difference which can obtain From table 3-8 (See Appendix B) for glass convection

For east glass

$$Q_{\text{TOTAL east}} = Q_{\text{CONV.}} + Q_{\text{TR.}}$$

$$Q_{\text{CONV.}} = U * A * (CLTD)_{\text{CORR}}$$

$$Q_{\text{CONV.}} = 3.2 * 14.76 * 8 = 377.86 \text{ W}$$

$$Q_{\text{TR.}} = A (\text{SHG}) * (\text{SC}) * (\text{CLF})$$

$$Q_{\text{TR.}} = 14.76 * 615 * 0.25 * 0.20 = 453.87 \text{ W}$$

$$Q_{\text{TOTAL east}} = Q_{\text{CONV.}} + Q_{\text{TR.}} = 377.86 + 453.87 = 831.73 \text{ W}$$

For west glass

$$Q_{\text{TOTAL west}} = Q_{\text{CONV.}} + Q_{\text{TR.}}$$

$$Q_{\text{CONV.}} = U * A * \Delta T$$

$$Q_{\text{CONV.}} = 3.2 * 14.40 * (35 - 24) = 506.88 \text{ W}$$

$$Q_{\text{TR.}} = A (\text{SHG}) * (\text{SC}) * (\text{CLF})$$

$$Q_{\text{TR.}} = 14.40 * 663 * 0.25 * 0.84 = 2005.0 \text{ W}$$

$$Q_{\text{TOTAL west}} = Q_{\text{CONV.}} + Q_{\text{TR.}} = 506.88 + 2005.0 = 2511.88 \text{ W}$$

So the total heat flow through walls as follow

$$Q_{\text{total for glasses}} = Q_{\text{TOTAL east}} + Q_{\text{TOTAL west}}$$

$$Q_{\text{total for glasses}} = 831.73 + 2511.88 = 3.34 \text{ kW}$$

For doors:-

We have one door on south wall and no doors on other walls and as a result that these door beside an unconditioned space so the temperature of the unconditioned space are uniform and = 35 °C and so we can use the following equation to calculate heat flow from door:-

$$Q = U * A * \Delta T$$

$$U = \frac{1}{\frac{1}{8.34} + \frac{0.06}{0.15} + \frac{0.05}{0.16} + \frac{1}{8.34}}$$

$$= 1.05 \text{ w/m}^2.\text{°C} \text{ (see table 5.4)}$$

→Where:

Q: Heat flow through the door by conducting. (Watt)

U: Over all heat transfer coefficient (W/m².K).

A: Out door Area of heat conductive. (m²)

ΔT: the total equivalent temperature difference between air-conditioned Space and the unconditioned space which temperature = 35°C

Then we can calculate heat flow as following:-

$$Q = U * A * \Delta T$$

$$Q_{\text{total door}} = 1.05 * 3.57 * (35 - 24) = 41.23 \text{ W}$$

6.1.2 Heat Gain Due To Ventilation:-

The total cooling load due to ventilation consists of two parts sensible cooling load and latent cooling load and so

From psychometric chart:-

As the outside has a temperature = 35°C & relative humidity = 60% Then outside enthalpy = 90.0 KJ/Kg

Also the inside has a temperature = 24°C & relative humidity = 45% Then inside enthalpy = 45.0 KJ/Kg

So for the Obstetrics & Gynecology Department in Alia hospital as following:

$$Q_t = m \cdot (h_2 - h_1)$$

$$Q_t = 8 \cdot 95 / 0.901 \cdot 1000 \cdot (90.0 - 45.0) = 37.96 \text{ KW}$$

→Where:

$Q_{\text{ventilation}}$ = Total load for ventilation in the Gynecology Department and operation Room in Alia hospital

Q_{GYN} = Total load for ventilation in the Gynecology Department in Alia hospital

Q_{opera} = Total load for ventilation in operation room in Alia hospital

m = total flow rate for fresh air (kg/s)

h_1 = inside enthalpy (KJ/kg)

h_2 = outside enthalpy (KJ/kg)

6.1.3 Heating Gain Due To Lights:

$Q_{\text{Lt.}}$ = lighting intensity * A * CLF * Diversity Factor

$$Q_{\text{Lt}} = 20 \cdot 466.5 \cdot 0.36 \cdot 0.4 = 1.34 \text{ Kw}$$

→Where:

Lighting intensity: 10-30 w/ m² for hospitals so we will take 20W/ m²

A: area of the Obstetrics & Gynecology Department in Alia hospital

CLF Lt: the light cooling load factor from tables3-10 (See in Appendix B)

Diversity factor: 0.4 for lights from tables3-11 (See in Appendix B)

6.1.4 Heating Gain Due To occupants:

$$Q_{\text{total for occupant}} = Q_{\text{sensible}} + Q_{\text{latent}}$$

$$Q_{\text{latent}} = \text{heat gain latent} * \text{No. of people} * \text{Diversity Factor}$$

$$Q_{\text{latent}} = 57.0 * 95 * 0.5 = 2707.50 \text{ W}$$

$$Q_{\text{sensible}} = \text{heat gain latent} * \text{No. of people} * \text{CLF} * \text{Diversity Factor}$$

$$Q_{\text{sensible}} = 71.5 * 95 * 0.39 * 0.5 = 1324.54 \text{ W}$$

So the total cooling load from people in the hospitals

$$Q_{\text{total for occupant}} = Q_{\text{sensible}} + Q_{\text{latent}}$$

$$Q_{\text{total for occupant}} = 1324.54 + 2707.50 = 4.03 \text{ Kw}$$

→Where:

Heat gain latent and sensible: from tables 3-16 (See in Appendix B)

A: area of the Obstetrics & Gynecology Department in Alia hospital

Diversity factor: 0.5 for peoples from tables3-11 (See in Appendix B)

6.1.5 Heating Gain Due To equipments and motors:

In the Obstetrics & Gynecology Department in Alia hospital we have the following devices and its outputs:

Type	Total Number of devices	Output (w)
Ultrasound	3	70
Table lamp	4	50
television	1	100
Coffee boiler	1	1779
Refrigerator	1	180
Restator	4	200
computer	1	100
CTG	6	50
microwave	1	300
Ultracasional	1	55
Cooking gas	1	100
		Total =4.129 kw

Table 6.1 Equipments in the Obstetrics & Gynecology Department

And so the total flow rate in the Obstetrics & Gynecology Department in Alia hospital as following:

$$Q_{\text{total for load}} = Q_{\text{for all walls}} + Q_{\text{all glasses}} + Q_{\text{all doors}} + Q_{\text{ventilation}} + Q_{\text{all lights}} \\ + Q_{\text{all occupants}} + Q_{\text{equipments and motor}}$$

$$Q_{\text{total for load}} = 9.17 + 3.34 + 0.041 + 37.96 + 1.34 + 4.03 + 4.129 = 60.01 \text{ kW}$$

We usually use units that operate at 80% from total load in order to make it in continuous operation of the units to maintain a certain relative humidity and temperature range

So

$$Q_{\text{operation}} = Q_{\text{total}} * 80\%$$

$$Q_{\text{operation}} = 60.01 * 80\% = 48.0 \text{ kW}$$

6.2 Cooling load calculation in the operation room

6.2.1 Heat Gain Due To walls, ceiling, floor, glass and doors

For east wall:

It is near unconditioned space so we use ΔT instead of CLTD because the temperature is uniform and not exposed to sun light and As a result that these walls besides an unconditioned spaces so the temperature of these spaces are uniform and = 35°C

$$Q = U * A * \Delta T$$

$$Q_{\text{east wall}} = 1.347 * 7.71 * (35 - 24) = 114.20 \text{ w}$$

For west walls:

As a result that these walls besides an unconditioned spaces so the temperature of these spaces are uniform and = 35°C

$$Q = U * A * \Delta T$$

$$Q_{\text{west wall}} = 1.347 * 14.40 * (35 - 24) = 213.37 \text{ W}$$

For internal south and north walls:

$$Q = U * A * \Delta T$$

$$Q_{\text{north wall}} = 2.326 * 27.64 * (35 - 24) = 679.83 \text{ W}$$

Note: - As a result that these walls besides an conditioned spaces so the temperature of these spaces are uniform and = 24°C and so there is no heat transfer between these space and operation room because $\Delta T = \text{zero}$

For Floor

$$Q_{\text{floor}} = U * A * \Delta T$$

$$Q_{\text{floor}} = 0.952 * 43.5 * (35 - 24) = 455.53 \text{ W}$$

For Ceiling

$$Q = U * A * (\text{CLTD})_{\text{CORR}}$$

$$Q_{\text{roof}} = 0.0252 * 43.50 * 10.60 = 11.62 \text{ kW}$$

So the total heat flow through walls as follow

$$Q_{\text{total for walls}} = Q_{\text{east wall}} + Q_{\text{west wall}} + Q_{\text{north wall}} + Q_{\text{south internal wall}} + Q_{\text{floor}} + Q_{\text{roof}}$$

$$Q_{\text{total for operation room}} = 114.20 + 213.37 + 679.83 + 55.53 + 11.62 = 1.075 \text{ kW}$$

Note: there is no glasses or doors that in direct contact with operation room

6.2.2 Heating Gain Due To Ventilation:-

The total cooling load due to ventilation consists of two parts sensible cooling load and latent cooling load and so

From psychometric chart:-

As the outside has a temperature = 35°C & relative humidity = 60% Then outside enthalpy = 90.0 KJ/Kg

Also the inside has a temperature = 24°C & relative humidity = 45% Then inside enthalpy = 45.0 KJ/Kg

So for the operation room in Alia hospital as following:

$$Q_t = m \cdot (h_2 - h_1)$$

$$Q_t = 15 \cdot 5 / 0.901 \cdot 1000 \cdot (90.0 - 45.0) = 3.75 \text{ KW}$$

6.2.3 Heating Gain Due To Lights:

$$Q_{Ll} = \text{lighting intensity} \cdot A \cdot \text{CLF} \cdot \text{Diversity Factor}$$

$$Q_{Ll} = 20 \cdot 43.5 \cdot 0.36 \cdot 0.4 = 125.28 \text{ W}$$

6.2.4 Heating Gain Due To occupants:

$$Q_{\text{total for occupant}} = Q_{\text{sensible}} + Q_{\text{latent}}$$

$$Q_{\text{latent}} = \text{heat gain latent} \cdot \text{No. of people} \cdot \text{Diversity Factor}$$

$$Q_{\text{latent}} = 57.0 \cdot 5 \cdot 0.5 = 142.50 \text{ W}$$

$$Q_{\text{sensible}} = \text{heat gain latent} \cdot \text{No. of people} \cdot \text{CLF} \cdot \text{Diversity Factor}$$

$$Q_{\text{sensible}} = 71.5 * 5 * 0.39 * 0.5 = 70.0 \text{ W}$$

So the total cooling load from people in the operation room

$$Q_{\text{total for occupant}} = Q_{\text{sensible}} + Q_{\text{latent}}$$

$$Q_{\text{total for occupant}} = 70.0 + 142.5 = 212.50 \text{ w}$$

6.2.5 Heating Gain Due To equipments and motors:

In the operation room in Alia hospital we have the following devices and its outputs:

type	Total Number of devices	Output (w)
Table lamp	1	50
Another equipments	6	507
		Total = 557w

Table 6.2 Equipments in the operation room

6.2.6 Heating Gain Due To infiltration:-

We must change the air of the operation rooms between (15 to 20) once per hour
In order to maintain the condition of the operation room healthy

$$Q_{\text{infiltration}} = m_o * (h_o - h_i)$$

Therefore,

$$m_{\text{inf}} = N * V / v_o$$

$$m_{\text{inf}} = 20 * (43.5 * 3.35) / 3600 = 0.81 \text{ m}^3 / \text{sec}$$

$$m_{\text{inf}} = 0.81 / 0.901 = 0.90 \text{ kg / s}$$

$$Q_{\text{INF}} = 0.90 (90.0 - 45.0) = 40.50 \text{ kW}$$

$$Q_s = 0.90 (35.0 - 24.0) = 9.90 \text{ Kw}$$

And so

$$Q_L = Q_{INF} - Q_S$$

$$Q_L = 40.50 - 9.90 = 30.60 \text{ kW}$$

→Where:

m_{Inf} = flow rate for return air (kg/s).

h_i = inside enthalpy (KJ/kg)

h_o = outside enthalpy (KJ/kg)

Q_{INF} = total load of infiltration from outside air (KW)

Q_S = sensible load of infiltration from outside air (KW)

Q_L = latent load of infiltration from outside air (KW)

N = number of air change for operation room we use 15 once per hour

$$Q_{\text{total for load}} = Q_{\text{for all walls}} + Q_{\text{all glasses}} + Q_{\text{all doors}} + Q_{\text{ventilation}} + Q_{\text{all lights}} \\ + Q_{\text{all occupants}} + Q_{\text{equipments and motor}} + Q_{\text{ventilation}} + Q_{\text{infiltration}}$$

$$Q_{\text{total for load}} = 1.075 + 3.75 + 0.12528 + 0.2125 + 0.557 + 40.50 = 46.22 \text{ kW}$$

We usually use units that operate at 80% from total load in order to make it in continuous operation of the units to maintain a certain relative humidity and temperature range

So

$$Q_{\text{operation}} = Q_{\text{total}} * 80\%$$

$$Q_{\text{operation}} = 46.22 * 80\% = 36.98 \text{ kW}$$

6.3 Calculation for air handling units

6.3.1 Air handling unit in the Obstetrics & Gynecology Department

In the Obstetrics & Gynecology Department in Alia hospital the cooling system exists consist of tow air handler with the following value:

The first air handler has a flow rate = 7460 CFM that provides rooms and corridor with mixing 21% fresh air and 79% return air

And so

As the outside has a temperature = 35°C & relative humidity = 60%

Also the inside has a temperature =24°C & relative humidity = 45%

From psychometric chart by using mixing properties then:-

As the outside has a temperature = 35°C & relative humidity = 60% Then outside enthalpy = 90.0 KJ/Kg

Also the inside has a temperature =24°C & relative humidity = 45% Then inside enthalpy = 45.0 KJ/Kg

The component of the cooling load of the Obstetrics & Gynecology Department in Alia hospital are summarized as follows

For first air handler

Item	Q _{for} all walls	Q _{all} glasses	Q _{all} doors	Q lights	Q _{all} occupants	Q equipments and motor	Q total for load
Q _{sensible(kw)}	9.11	3.34	0.041	1.29	1.33	4.23	19.34
Q _{latent (kw)}	-----	-----	-----	-----	2.70	-----	2.70

Table 6.3 Cooling load in the first air handler

We have cooling and dehumidification process suggested for air conditioning the Obstetrics & Gynecology Department in Alia hospital

The flow rate of fresh air m_o is obtained as follows

$$m_o = V_o / v_o$$

$$m_o = 8 \times 95 / 1000 \times 0.901 = 0.844 \text{ kg/s}$$

→Where:

m_o = flow rate for supply air (kg/s).

v_o = Specific volume for fresh air (m^3 / kg)

V_o = volumetric flow rate for fresh air (m^3 / s)

The flow rate of supply air m_s is obtained as follows

$$Q_t = m_s * (h_i - h_s)$$

→Where:

Q_t = total cooling load (kW)

m_s = flow rate for supply air (kg/s).

h_i = inside enthalpy (KJ/kg)

h_s = supply enthalpy (KJ/kg)

To obtain h_s we have to determine state (s) by using try and error method and calculating the space **SHR** as follows

$$\text{SHR} = Q_s / (Q_s + Q_L)$$

$$\text{SHR} = 19.34 / (19.34 + 2.70)$$

$$\text{SHR} = 0.88$$

And by using try and error method by assuming that $T_s = 17.0^\circ\text{C}$ and using the SHR line so

$$\text{SHR} = (T_i - T_s) / (h_i - h_s)$$

$$0.88 = (24 - 17) / (45.0 - h_s)$$

Then

$$h_s = 37.0 \text{ KJ/kg}$$

Also From psychometric chart the enthalpy of state (s) $h_s = 37.0(\text{KJ/kg})$ and $h_i = 45.0(\text{KJ/kg})$

So

$$Q_s = m_s * (T_i - T_s)$$

$$19.34 = m_s * (24.0 - 17.0)$$

$$m_s = 2.76 \text{ (kg/s)}$$

→Where:

SHR = sensible heat ratio

Q_s = total sensible cooling load (kW)

h_i = inside enthalpy (KJ/kg)

h_s = supply enthalpy (KJ/kg)

T_i = inside temperature (KJ/kg)

T_s = supply temperature (KJ/kg)

The volumetric flow rate V_s , for supply air is

$$V_s = m_s * v_s$$

Where $v_s = 0.83 \text{ m}^3 / \text{kg}$ (From psychometric chart) therefore

$$V_s = 2.76 * 0.83$$

$$V_s = 2.30 \text{ m}^3 / \text{s}$$

→Where:

m_s = flow rate for supply air (kg/s).

v_s = Specific volume for supply air (m^3 / kg)

V_s = volumetric flow rate for supply air (m^3 / s)

To calculate the capacity of the required cooling coil Q c.c,

So

$$Q_t = m_s * (h_{mix} - h_s)$$

Where h_{mix} , is obtained from mixing process as follows

$$m_i * h_i + m_o * h_o = m_s * h_{mix}$$

$$(2.76 - 0.844) * 45.0 + 0.844 * 90.0 = 2.76 * h_{mix}$$

Then

$$h_{mix} = 58.76 \text{ KJ/kg}$$

Then

$$Q_{c.c.l} = m_s * (h_{mix} - h_s)$$

$$Q_{c.c.l} = 2.76 * (58.76 - 37.0) = 60.01 \text{ kW}$$

→Where:

m_i = flow rate for fresh air (kg/s).

m_o = flow rate for return air (kg/s).

m_s = flow rate for supply air (kg/s).

h_i = inside enthalpy (KJ/kg)

h_o = outside enthalpy (KJ/kg)

h_{mix} = mixing enthalpy (KJ/kg)

h_s = supply enthalpy (KJ/kg)

v_o = Specific volume for outside air (m^3 / kg)

V_o = volumetric flow rate for outside air (m^3 / s)

$Q_{c.c}$ = total load for cooling coil (kW)

A direct expansion cooling coil with capacity of (60.01) kW may be selected for this application. Such selection is made from the manufacture catalogues of such equipment. It should be noted that the difference in value between the cooling coil capacity (60.01) kW and the total cooling load of the Obstetrics & Gynecology Department in Alia hospital (22.04) kW is due to cooling the ventilation air from its outside conditions to the inside design conditions where

$$Q_v = m_o * (h_o - h_i)$$

Therefore,

$$Q_v = 0.844 (90.0 - 45.0) = 37.98 \text{ kW}$$

→Where:

m_o = flow rate for return air (kg/s).

h_i = inside enthalpy (KJ/kg)

h_o = outside enthalpy (KJ/kg)

Q_v = total load for ventilation fro outside air (kW)

Equal pressure drop method is used for sizing the duct system with main duct velocity of 6.5 m/s from tables 3-17 (See in Appendix B).

We will use two supply ducts for the first air handler one for rooms at east and the other for room at west and one return duct will pass between the two supply ducts which will return air from the corridor and rooms at east and west.

6.3.2 Air handling unit in the operation room

The second air handler has a flow rate = 1600 CFM that provides operation rooms with 100% fresh air.

For second air handler

Item	Q _{for} all walls	Q _{all} glasses	Q _{all} doors	Q _{all} lights	Q _{all} occupants	Q _{equipments} and motor	Q _{total} for load
Q _{sensible(W)}	1502.05	-----	-----	125.28	70.0	145.0	1842.33
Q _{latent (W)}	-----	-----	-----	-----	142.50	-----	142.50

Table 6.4 Cooling load in the second air handler

We have cooling and dehumidification process suggested for air conditioning the Obstetrics & Gynecology Department in Alia hospital.

And so

The flow rate of fresh air m_o is obtained as follows

$$m_o = V_o / v_o$$

$$m_o = 15 \times 5 / (1000 \times 0.901) = 0.0832 \text{ kg/s}$$

→Where:

m_o = flow rate for supply air (kg/s).

v_o = Specific volume for fresh air (m^3 / kg)

V_o = volumetric flow rate for fresh air (m^3 / s)

And so

The flow rate of supply air m_s is obtained as follows

$$m_s = m_o + m_{inf}$$

$$m_s = 0.0832 + 0.90 = 0.983 \text{ kg/s}$$

→Where:

m_s = flow rate for supply air (kg/s).

m_o = flow rate for supply air (kg/s).

m_{inf} = flow rate for return air (kg/s).

To obtain h_s we have to determine state (s) by using the following equation and calculating the space **SHR** as follows:

$$Q_t = m_s * (h_o - h_s)$$

$$46.22 = 0.983 * (90.0 - h_s)$$

$$h_s = 42.98 \text{ KJ/kg}$$

And so

$$Q_s = m_s * (T_o - T_s)$$

$$12.66 = 0.983 * (35.0 - T_s)$$

$$T_s = 22.12$$

→Where:

Q_t = total cooling load (kW)

m_s = flow rate for supply air (kg/s).

h_o = out side enthalpy (KJ/kg)

h_s = supply enthalpy (KJ/kg)

Q_s = total sensible cooling load (kW)

T_o = outside temperature (KJ/kg)

T_s = supply temperature (KJ/kg)

Also by using construction line (SHR line) as flows

$$\text{SHR} = Q_s / (Q_s + Q_L)$$

$$\text{SHR} = 1842.33 / (1842.33 + 142.5)$$

$$\text{SHR} = 0.93$$

So

→Where:

SHR = sensible heat ratio

Q_s = total sensible cooling load (kW)

Q_L = total latent cooling load (kW)

Also by using psychometric chart at SHR = 0.93 & $h_s = 42.98$ So $T_s = 22.12^\circ\text{C}$

And so

The volumetric flow rate V_s , for supply air is

$$V_s = m_s * v_s$$

Where $v_s = 0.901 \text{ m}^3 / \text{kg}$ (From psychometric chart) therefore

$$V_s = 0.983 * 0.901$$

$$V_s = 0.886 \text{ m}^3 / \text{s}$$

→Where:

m_s = flow rate for supply air (kg/s).

v_s = Specific volume for supply air (m^3 / kg)

V_s = volumetric flow rate for supply air (m^3 / s)

To calculate the capacity of the required cooling coil Q c.c,

So

$$Q_t = m_s * (h_o - h_s)$$

$$Q_{c.c1} = 0.983 * (90.0 - 42.98) = 46.22 \text{ kW}$$

→Where:

m_s = flow rate for supply air (kg/s).

h_o = outside enthalpy (KJ/kg)

h_s = supply enthalpy (KJ/kg)

v_o = Specific volume for outside air (m^3 / kg)

$Q_{c.c}$ = total load for cooling coil (kW)

A direct expansion cooling coil with capacity of (46.22) kW may be selected for this application. Such selection is made from the manufacture catalogues of such equipment It should be noted that the difference in value between the cooling coil capacity (46.22) kW and the total cooling load of the Obstetrics & Gynecology Department in Alia hospital (1.985) kW is due to cooling the ventilation and infiltration air from its outside conditions to the inside design conditions where

$$Q_v = m_o * (h_o - h_i)$$

Therefore,

$$Q_v = 0.0832 (90.0 - 45.0) = 3.744 \text{ kW}$$

&

$$Q_{inf} = m_{inf} (h_o - h_i)$$

$$Q_{inf} = 0.90 (90.0 - 45.0) = 40.50 \text{ kW}$$

And so

$$Q_{c.c.l} = Q_{inf} + Q_v + Q_{total \text{ load}}$$

$$Q_{c.c.l} = 3.744 + 40.5 + 1.985$$

$$Q_{c.c.l} = 46.22 \text{ kW}$$

→Where:

m_o = flow rate for return air (kg/s).

h_i = inside enthalpy (KJ/kg)

h_o = outside enthalpy (KJ/kg)

Q_v = total load for ventilation from outside air (kW)

Q_{inf} = total load for ventilation from outside air (kW)

$Q_{total \text{ load}}$ = total load for from walls, lights, equipments, occupant, (kW)

Equal pressure drop method is used for sizing the duct system with main duct velocity of 5.0 m/s from tables 3-17 (See in Appendix B)

6.4 Ducts distribution

We use two supply ducts above for ceiling in the Obstetrics & Gynecology Department in Ali hospital one near the east wall and one near the west wall and one return duct will pass between them at the middle of them

We will use one supply ducts above for ceiling in the in the operation room in Alia hospital and one return duct

6.4.1 Ducts distribution in the Obstetrics & Gynecology Department

We will use the percentage of load to calculate the flow rate for the two supply ducts as follows:

The total load at east side $Q_e = 32.79$ kW and at the west $Q_w = 27.22$ kW and the total load for the Obstetrics & Gynecology Department in Alia hospital = 60.01 KW

$$m_e = m_s * Q_e / Q_t$$

$$m_e = 2.76 * 32.79 / 60.01$$

$$m_e = 1.51 \text{ kg/s}$$

so

$$m_w = m_s - m_e$$

$$m_w = 2.76 - 1.51 = 1.25 \text{ kg/s}$$

→Where:

m_e = flow rate for supply air at east side (kg/s).

m_w = flow rate for supply air at west side (kg/s).

m_s = total flow rate for supply air (kg/s).

Q_e = total load for rooms at east side (kW)

Q_w = total load for rooms at west side (kW)

Q_t = total load for the Obstetrics & Gynecology Department (kW)

For east duct

The volumetric flow rate V_e , for duct supply air at east side is

$$V_e = m_e * v_s$$

Where $v_s = 0.83 \text{ m}^3 / \text{kg}$ (From psychometric chart) therefore

$$V_s = 1.51 * 0.83$$

$$V_s = 1.25 \text{ m}^3 / \text{s}$$

→Where:

m_e = flow rate for supply air at east side (kg/s).

v_s = Specific volume for supply air (m^3 / kg)

V_e = volumetric flow rate for duct supply air at east side (m^3 / s)

For first duct section 1-1 $V = 1.25 \text{ m}^3 / \text{s}$ & $v = 5.0 \text{ m/s}$.

And so

$$V = v * (\pi/4) d^2$$

$$1.25 = 5 * (\pi/4) d^2$$

$$d = 564.33 \text{ m}$$

From figure B 3-2(b) (See in Appendix B) at $V = 1.25 \text{ m}^3 / \text{s}$ & $v = 5.0 \text{ m/s}$, then $(\Delta P / \text{EL}) = 0.50 \text{ Pa/m}$

→Where:

v = velocity at the main duct (m/ s)

V = flow rate at the main duct (m^3 / s)

d = diameter of the main duct (m)

The other duct sections are sized following the same procedure. The result as shown

Room no.	Duct section	Total load for rooms(kw)	Volumetric flow rate (m ³ / s)	Diameter by calculation (mm)	Diameter from chart (mm)	For rectangular Duct(a*b) (mm)	Velocity (m/s)	Friction loss (Pa/m)
Main duct	1-1	32.79	1.25	564.33	600.0	500.0*600.0	5.0	0.50
Preparation ward	1-2	4.39	1.25	564.33	600.0	500.0*600.0	5.0	0.50
104	1-3	4.69	1.08	529.88	550.0	450.0*600.0	4.90	0.50
5	1-4	2.72	0.90	488.0	500.0	350.0*600.0	4.80	0.50
4	1-5	2.60	0.80	470.69	500.0	350.0*600.0	4.60	0.50
103	1-6	10.26	0.70	450.18	450.0	300.0*600.0	4.40	0.50
3	1-7	2.60	0.31	331.20	350.0	200.0*600.0	3.60	0.50
2	1-8	2.60	0.21	286.90	300.0	200.0*400.0	3.25	0.50
1	1-9	2.93	0.11	223.70	225.0	200.0*225.0	2.80	0.50

Table 6.5 Distribution of flow rate of duct sizing for east duct

To select the required size for round ceiling diffuser, we refer to table 3-22 (See in Appendix B) and select 8.0 round ceiling diffuser each has throw range from 1.20 to 2.10 m and a diameter of 20.0cm which give a volumetric flow rate 0.11 m³ / s the diffuser pressure drop is 14.90 Pa and noise criteria NC of 19.0 which is consistent with the application considered in the Obstetrics & Gynecology Department in Alia hospital.

If square diffusers are to be selected then from table 3-23 (See in Appendix B) indicates that a diffuser size of (23.0*23.0) cm gives a volumetric flow rate 0.112 m³ /s which has throw ranging from 1.80 to 4.30 m with pressure drop is 13.90 Pa.

For west duct

The volumetric flow rate V_w , for duct supply air at west side is

$$V_w = m_w * v_s$$

Where $v_s = 0.83 \text{ m}^3 / \text{kg}$ (From psychometric chart) therefore

$$V_s = 1.25 * 0.83$$

$$V_s = 1.04 \text{ m}^3 / \text{s}$$

→Where:

m_w = flow rate for supply air at west side (kg/s).

v_s = Specific volume for supply air (m^3 / kg)

V_w = volumetric flow rate for duct supply air at west side (m^3 / s)

For first duct section 1-1 $V = 1.04 \text{ m}^3 / \text{s}$ & $v = 5.0 \text{ m/s}$.

And so

$$V = v * (\pi/4) d^2$$

$$1.04 = 5.0 * (\pi/4) d^2$$

$$d = 514.75 \text{ mm}$$

From figure B 3-2(b) (See in Appendix B) at $V = 1.04 \text{ m}^3 / \text{s}$ & $v = 5.0 \text{ m/s}$, then $(\Delta P / \text{EL}) = 0.55 \text{ Pa/m}$

→Where:

v = velocity at the main duct (m/ s)

V = flow rate at the main duct (m^3 / s)

d = diameter of the main duct (m)

The other duct sections are sized following the same procedure. The result as shown

Room no.	Duct section	Total load for rooms (kw)	Volumetric flow rate (m ³ / s)	Diameter by calculation (mm)	Diameter from chart (mm)	For rectangular Duct(a*b) (mm)	Velocity (m/s)	Friction loss (Pa/m)
Main duct	1-1	27.22	1.04	514.75	550.0	400.0*650.0	5.0	0.55
144	1-2	3.40	1.04	514.75	550.0	400.0*650.0	5.0	0.55
147	1-3	2.47	0.91	486.40	500.0	400.0*550.0	4.90	0.55
146	1-4	2.37	0.82	466.50	500.0	400.0*550.0	4.80	0.55
149	1-5	4.09	0.73	449.62	450.0	400.0*450.0	4.60	0.55
corridor	1-6	2.47	0.58	409.78	450.0	400.0*450.0	4.40	0.55
151	1-7	5.09	0.49	390.02	400.0	300.0*450.0	4.10	0.55
152	1-8	2.37	0.30	325.82	350.0	300.0*350.0	3.60	0.55
158	1-9	2.47	0.21	280.05	300.0	250.0*300.0	3.40	0.55
161	1-10	1.26	0.11	219.82	225.0	150.0*300.0	2.90	0.55
154	1-11	1.23	0.062	177.74	200.0	150.0*225.0	2.50	0.55

Table 6.6 Distribution of flow rate of duct sizing for west duct

To select the required size for round ceiling diffuser, we refer to table 3-22 (See in Appendix B) and select 10.0 round ceiling diffuser each has throw range from 0.90 to 1.80 m and a diameter of 15.0 cm which give a volumetric flow rate 0.070 m³ / s the diffuser pressure drop is 22.40 Pa and noise criteria NC of 22.0 which is consistent with the application considered in the Obstetrics & Gynecology Department in Alia hospital.

If square diffusers are to be selected then from table 3-23 (See in Appendix B) indicates that a diffuser size of (15.0*15.0) cm gives a volumetric flow rate 0.065 m³ /s which has throw ranging from 2.40 to 6.0 m with pressure drop is 17.9 Pa.

6.4.2 Ducts distribution in the operation room

For first duct section A-B $\dot{V} = 0.886 \text{ m}^3 / \text{s}$ & $v = 5.0 \text{ m/s}$. since

$$\dot{V} = v * (\pi/4) d^2$$

$$0.886 = 5 * (\pi/4) d^2$$

$$d = 475.11 \text{ mm}$$

From figure B 3-2(b) (See in Appendix B) at $\dot{V} = 0.886 \text{ m}^3 / \text{s}$ & $v = 5.0 \text{ m/s}$, then

$$(\Delta P / EL) = 0.60 \text{ Pa/m}$$

→Where:

v = velocity at the main duct (m/ s)

\dot{V} = flow rate at the main duct (m^3 / s)

d = diameter of the main duct (m)

The other duct sections are sized following the same procedure. The result as shown

Room no.	Duct section	Total load for rooms (kw)	Volumetric flow rate (m^3 / s)	Diameter by calculation (mm)	Diameter from chart (mm)	For rectangular Duct(a*b) (mm)	Velocity (m/s)	Friction loss (Pa/m)
Main duct	1-1	46.22	0.886	475.11	500.0	400.0*550.0	5.0	0.60
preparation room	1-2	2.20	0.886	475.11	500.0	400.0*550.0	5.0	0.60
Operation room	1-3	44.02	0.85	470,0	500.0	400.0*550.0	4.90	0.60

Table 6.7 Distribution of flow rate of duct sizing for operation room

To select the required size for round ceiling diffuser, we refer to table 3-22 (See in Appendix B) and select 4.0 round ceiling diffuser each has throw range from 4.50 to 9.10 m and a diameter of 45.0 cm which give a volumetric flow rate $0.875 \text{ m}^3 / \text{s}$ the diffuser pressure drop is 19.90 Pa and noise criteria NC of 38.0 which is

consistent with the application considered in the Obstetrics & Gynecology Department in Alia hospital.

If square diffusers are to be selected then from table 3-23 (See in Appendix B) indicates that a diffuser size of (53.0*53.0) cm gives a volumetric flow rate 0.895 m³ /s which has throw ranging from 7.90 to 12.20 m with pressure drop is 31.40 Pa.

Note: - in the operation room we can use two diffusers instead of the one chosen which must give a total volumetric flow rate as the same as the one chosen.

Note: - the design of return ducts is based on many methods usually equal friction method is used. For the return duct system, air flows through branches into the main duct and back to the fan. The total pressure drop of the return system must not exceed the allowable negative suction pressure of the fan

And so the total cooling load from the two air handler

$$Q_{\text{total for air handlers}} = Q_{c.c1} + Q_{c.c2}$$

$$Q_{\text{total for air handlers}} = 60.01 + 36.05 = 96.06 \text{ KW}$$

6.6 In Alia hospital:-

In the Obstetrics & Gynecology Department in Alia hospital the cooling system exists consist of tow air handler with the following value:

First Air handling unit using in delivery room which it gives =25.23 ton = 88.73 kW

Second Air handling unit using in operation room which it gives = 6 ton = 21.10 kW

Then the total cooling load used in Alia hospital from First and second Air handling units =88.73 + 21.10 = 109.83 kW

CHAPTER SEVEN

PLUMBING SYSTEM CALCULATIONS

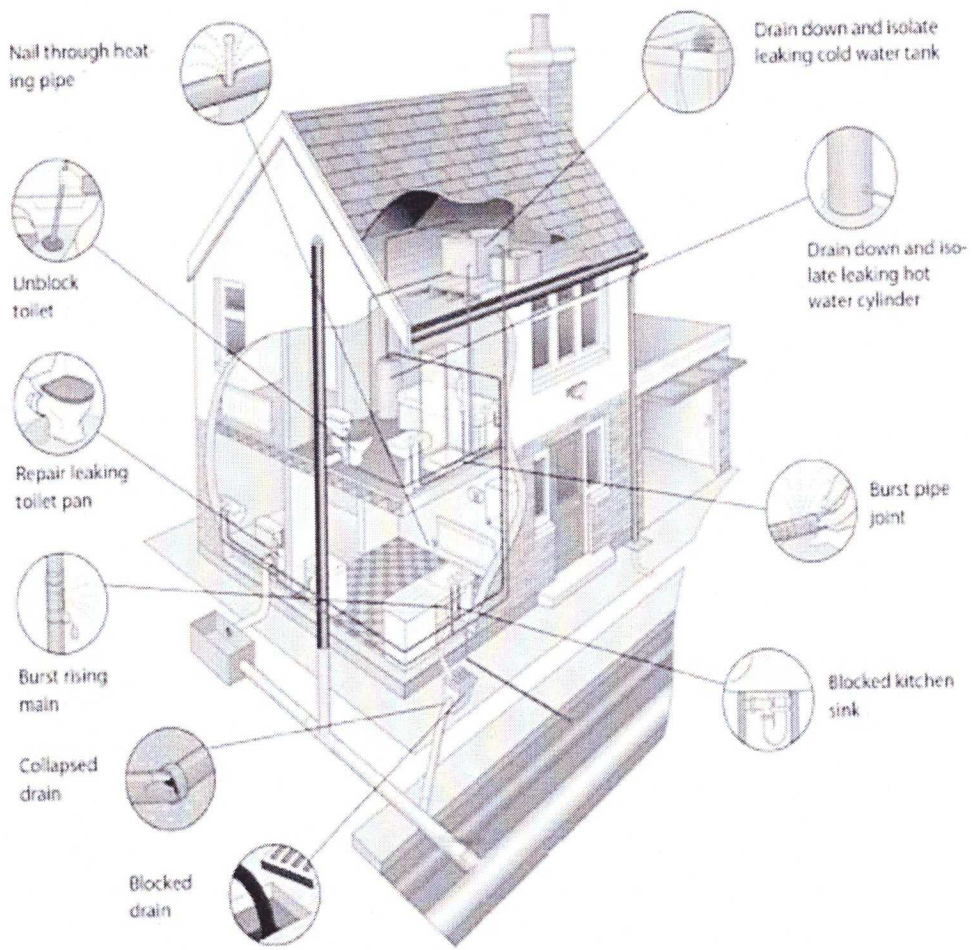


Figure 7-1 Plumbing System

7.1 Water System

7.1.1 Calculations For hot and cold water:-

To determine the pipe size for cold and hot water we must calculate the water supply fixture unit (WSFU) for each fixture and fixture unit total on each piping run out and determine the minimum flow pressure required at the most remote outlet.

We can determine the required pipe in each section using the friction head loss data calculated and the friction head chart as follows:-

Floor name	total Lavatory	Total sink	Total Water closet / flush valve	Total Water closet /flush tank	Total Separate Shower	Pipe diameter	Total Water closet White flush pipe	Total Another things
Ground floor	at right =10& at left =5 Total =15	at right =1& at left =9 Total =10	at right =8& at left =1 Total =9	-----	at right =3 Total =3	at right =2(Ø1.25) & at left =1(Ø3/4) Total = 2*(Ø1.25) (Ø3/4) *1	at right =8& at left =1 Total =9	-----
First floor	at right =26& at left =10 Total =36	at right =10& at left =12 Total =22	at right =10& at left =5 Total =15	at right =5& at left =4 Total =9	at right =6& at left =6 Total =12	at right =3(Ø3/4)&1 (Ø1)& 1(Ø1.25) at left = 2(Ø3/4)& 3(Ø1) Total = 5*(Ø3/4) 4*(Ø1) 1*(Ø1.25)	at right =15 & at left =9 Total =24	-----
Basement	-----	-----	-----	-----	-----	at right 4*(Ø3/4) Total =4*(Ø3/4)	-----	-----
CONTENIO US FLOW AT GARDEN	-----	-----	-----	-----	-----	at right 3*(Ø1/2) 1*(Ø2) Total= 3*(Ø1/2) 1*(Ø2)	-----	-----

Table 7-1 Total number for water supply fixture unit for cold and hot water

So WSFU for each floor as in the following table:

Fixture Unit	No. of Units	WSFU From table (9.3)	Total no. of WSFU For Cold Water	Total no. of WSFU For hot Water	Total no. of WSFU For hot Water Cold Water &
BASMENT FLOOR	-----	-----	-----	-----	-----
4*OUT LET FOUCET (GENERAL) (3/4")	4	$\frac{3}{4} * 6$	18	18	24
GROUND FLOOR	-----	-----	-----	-----	-----
Lavatory (general)	15	$\frac{3}{4} * 2$	22.5	22.5	30
Kitchen Sink(general)	10	$\frac{3}{4} * 4$	30	30	40
Water Closet FLUSH VALVE (general)	9	10	90	-----	90
SHOWER (PRIVAITE)	3	$\frac{3}{4} * 2$	4.5	4.5	6
Spray Bibb (general)(Ø3/4)	9	$\frac{3}{4} * 6$	40.5	-----	56
1* DEVICE (3/4") + 2* DEVICE (1.25")(GENERAL)	3	$\frac{3}{4} * 6 +$ $\frac{3}{4} * 12.5$	23.25	23.25	31
FIRST FLOOR	-----	-----	-----	-----	-----
Lavatory (general)	36	$\frac{3}{4} * 2$	54	54	72
Kitchen Sink(general)	22	$\frac{3}{4} * 4$	66	66	88
Water Closet FLUSH VALVE (general)	15	10	150	-----	150
Water Closet FLUSH TANK (general)	9	5	45	-----	45
SHOWER (PRIVAITE)	12	$\frac{3}{4} * 2$	18	18	24

Spray Bibb (general)(Ø3/4)	24	¾ *6	108	-----	144
5* DEVICE (¾") +	10	¾ *6	22.5+ 30+9.375	22.5+	82.5
4* DEVICE (1")+ 1*		+ ¾ *10 +	=61.88	30+9.375	
DEVICE (1.25") (GENERAL)		¾ *12.5		=61.88	
-----	-----	-----	Σ =731.63	Σ =298.13	Σ =882.50
			WSFU	WSFU	WSFU

Table 7-2 Water supply unit for cold and hot water

7.1.2 Flow rate calculations

To calculate flow rate in gpm:-

By using table 4-2 (See in Appendix C) for supply system predominantly for flush meter (flush valve) the estimating demand in gpm for cold water = 731.63 WSFU.

So by using interpolation =172.43gpm

By using table 4-2 (See in Appendix C) for supply system predominantly for flush meter (flush valve) the estimating demand in gpm for hot water = 298.13 WSFU.

So by using interpolation =109.63gpm

By using table 4-2 (See in Appendix C) for supply system predominantly for flush meter (flush valve) the estimating demand in gpm for hot & cold water 882.50 WSFU.

So by using interpolation =197.79 gpm

Note: - For supply outlets likely **to impose continuous demand**, we estimate continuous separately and add to the total demand for fixture

We have 3 faucets ($\text{Ø}1/2$) & 1 faucet ($\text{Ø}2$) so from table 4-2(See in Appendix C)

The total flow in gpm = $3*3.34 + 1*13.36 = 23.38$ gpm

So the total cold and hot water demand needed = $197.79 + 23.38 = 221.17$ gpm

7.1.3 Pumps pressure at the hospital:-

We can see Pumps pressure for water system used at the hospital from the pressure gauge installed at the discharge line (discharge pipe)

Pump indicate a pressure = 4.0 bar

Pump has a pressure = $4.0 * 14.50 = 58.0$ psi

To calculate static head:-

Floor to floor height = 4.00m

Water closet with flush valve outlet above ground level = 0.70 m

& Pump outlet above first floor level = 0.70

So there is no static head in this case and goes to zero

To calculate the equivalent length:-

Pumps at first floor transfer the water through pipes to the boiler room at the ground floor from which it distribute the water through pipes to the collectors at the ground floor and the riser at the riser room from which it distribute the water through pipes to the collectors at the first floor and to the basement floor.

So we will calculate the equivalent length from the pumps to the farthest outlet at the first floor (water closet with flush valve) at farthest collector no (15).

FOR COLD WATER

Total length from first floor (from pumps) to the boiler room in the ground floor = 4.50 m

Total length in the ground floor from boiler room to the riser = 80.0m

Total length through shaft room from ground floor to the first floor = 4.0m

Total length in the first floor from riser at the shaft room to farthest out let (water closet with flush valve) at farthest collector no (15) = 52.80m

So the total length from pumps to the farthest outlet at the first floor (water closet with flush valve) at farthest collector no (15)

$$\text{Total length} = 4.50 + 80.0 + 4.0 + 52.80 = 141.30 \text{ m}$$

To calculate the equivalent length we assumed 50% additional equivalent length to account for fittings there for the total developed length or the equivalent length as follows:

$$\text{Equivalent length} = \text{Total length} * 1.5$$

$$\text{Equivalent length} = 141.3 * 1.5 = 211.95 \text{ m}$$

$$\text{Equivalent length} = 211.95 * 3.28 = 695.20 \text{ ft}$$

FOR HOT WATER

Total length in the ground floor from boiler room to the riser = 78.30m

Total length through shaft room from ground floor to the first floor = 4.0m

Total length in the first floor from riser at the shaft room to farthest out let (water closet with flush valve) at farthest collector no (15) = 52.80m

So the total length from pumps to the farthest outlet at the first floor (water closet with flush valve) at farthest collector no (15).

$$\text{Total length} = 78.30 + 4.0 + 52.80 = 135.10 \text{ m}$$

To calculate the equivalent length we assumed 50% additional equivalent length to account for fittings there for the total developed length or the equivalent length as follows:

$$\text{Equivalent length} = \text{Total length} * 1.5$$

$$\text{Equivalent length} = 135.1 * 1.5 = 202.65 \text{ m}$$

$$\text{Equivalent length} = 202.65 * 3.28 = 664.70 \text{ ft}$$

The minimum required flow pressure:-

The minimum required flow pressure at the most remote outlet on the first floor (water closet with flush valve) is **15.0 psi** from table 4-2 (See in Appendix C).

To calculate the friction head

After calculating the above requirement we can calculate the friction head from the following equation:

$$\text{Main pressure} = \text{static head} + \text{minimum required flow pressure} + \text{friction head}$$

$$58.0 = 0.0 + 15.0 + \text{friction head}$$

$$\text{So friction head} = 58.0 - 15.0 = 43.0 \text{ psi}$$

Note:-

$$\text{Main pressure} = \text{pumps pressure} = 58.0 \text{ psi}$$

The usual design aims for uniform friction loss along the entire pipe length to do this we establish a friction loss per 100 ft by dividing total loss by total length and then size the pipe accordingly.

Uniform design friction loss in psi/100ft is:-

FOR COLD WATER

Friction /100 ft = available friction head/ total equivalent length

$$\text{Friction /100 ft} = 43.0 \text{ psi} / 695.20 * 100 \text{ ft} = 6.19 \text{ psi} / 100\text{ft}$$

So for flow rate 221.17 gpm and friction head loss 6.19 psi / 100ft from figure 4-9 (See in Appendix C) the diameter of the pipe from the pumps to the riser 4" and the velocity is 5.5 fps and the friction head is 2.9 psi / 100ft

FOR HOT WATER

Friction /100 ft = available friction head/ total equivalent length

$$\text{Friction /100 ft} = 43.0 \text{ psi} / 664.70 * 100 \text{ ft} = 6.47 \text{ psi} / 100\text{ft}$$

So for flow rate 109.63 gpm and friction head loss 6.47 psi / 100ft from figure 4-9 (See in Appendix C) the diameter of the pipe from the pumps to the riser 3" and the velocity is 4.70 fps and the friction head is 3.0psi / 100ft

Note: - branches supplying mainly flush valve load should be limited to a water velocity of 4 fps to avoid water hummer

Now we can determine pipe size, velocity of water and friction head for each pipe in the hospital as shown:-

Pipe section	Equivalent length in (ft)	Pipe size in (inch)	Friction (psi/100ft)	Velocity(fps)	Section friction(psi)
From pumps to hot water tap (221.17 gpm)	22.14	4.0	2.90	5.50	0.64
Hot water tap off to first riser (195.81 gpm)	393.60	4.0	2.40	5.0	9.45
First riser section(140 gpm)	19.68	3.0	4.90	6.20	0.96
Run out (91.32 gpm)	259.78	2.50	6.20	6.0	16.10

Table 7-3 Pipe size, velocity of cold water and friction head for each pipe in Alia Hospital

Pipe section	Equivalent length in (ft)	Pipe size in (inch)	Friction (psi/100ft)	Velocity(fps)	Section friction(psi)
Hot water tap off to first riser (109.63gpm)	385.24	3.0	3.0	4.70	11.56
First riser section (106.03 gpm)	19.68	3.0	2.85	4.50	0.56
Run out (91.0gpm)	259.78	2.50	6.20	6.10	16.10

Table 7-4 Pipe size, velocity of cold water and friction head for each pipe in Alia Hospital

Note: - the total friction to drop for cold water of 27.15psi is considerably less than the permissible maximum of 43.0 psi

Note: - the pipe size could be reduced considerably by using water closet with flush tank

7.1.4 Boiler calculations:-

From table we chose consumption of hot water per person for the hospital as for hotels and we take the mean value as 15 gal /day/ person

Number of persons at hospital =800 person

Water consumption = 15 gal /day/ person

Total consumption= Number of persons at hospital * Water consumption

Total consumption (daily consumption) for person = $15 \times 800 = 12000$ gal / day

But we have two clothes washer each have additional 40 gal /day

So Total consumption (daily consumption) =12080

Maximum peak hourly demand = $(1/7) * 12080 = 1725.72$ gal / hour

Duration of peak demand = 4 hours

Total peak load = Duration of peak demand*Maximum peak hourly demand

Total peak load = $4 * 1725.72 = 6902.88$ gal

Storage capacity = $(1/5) * 12080 = 2416$ gal

Heat capacity = $(1/7) * 12080 = 1725.72$ gal / hour

Recover rate = Total peak load - (3/4)* Storage capacity/ Duration of peak demand

Recover rate = $(6902.88 - (3/4) * 1725.72) / 4 = 1199.65$ gal / hour

So

$$Q = \dot{m} \cdot C_p \cdot \Delta T$$

Q: heat flow through water (KW)

\dot{m} : Flow rate of water (liter/s).

Cp: Specific heat for water = 4.18 (KJ/Kg.K)

ΔT: Different between inlet temperature and outlet temperature (°C)

Note: - **Note: - 1gallon = 3.7854 liter** &we will take **ΔT = 50°C**

So

$$Q = m \cdot Cp \cdot \Delta T$$

$$Q = (1199.65 \cdot 3.7854 / 3600) \cdot 4.18 \cdot 50 = 263.64 \text{ Kw}$$

We will take 25% as safety factor so

$$Q \text{ TOTAL} = Q + Q \cdot \text{Safety factor}$$

$$Q \text{ TOTAL} = 263.64 + 263.64 \cdot 25/100$$

$$Q \text{ TOTAL} = 329.55 \text{ kW}$$

So we need a boiler that its output gives 329.55 kW

In the hospital they use a boiler that its out put gives 385.0 kW

7.2 Drainage system

7.2.1 Drainage fixture unit calculations

In order to calculate the diameter for branches and sewer building in Alia hospital we must first calculate the total number of (DFU) from tables then from the total number of (DFU) we calculate we can chose the pipe diameters.

By using table 4-4 and 4-5 in Appendix C the Drainage fixture unit value as follow:

Basement floor

Manhole number	total Lavatory	Total sink	Total Water closet / flush valve	Total Separate Shower	Pipe diameter	Total Floor Drain	Total DFU
through pumps to manholes 39	3	0	0	0	0	2	7

Table 7-5 Fixture unit in each manhole in basement floor

Ground floor

Manhole number	total Lavatory	Total sink	Total Water closet / flush valve	Total Separate Shower	Pipe diameter	Total Floor Drain	Total DFU
1	0	0	0	0	0	1	2
2	0	0	0	0	0	1	2
3	1	0	1	1	0	3	15
5	3	1	1	1	0	3	19
6	2	1	4	0	1	3	37

7	2	0	2	1	0	2	20
8	4	0	0	0	0	2	8
10	0	0	0	0	0	1	2
11	0	0	0	0	0	1	2
12	0	0	0	0	0	4	8
14	0	0	0	0	0	3	6
15	0	0	0	0	0	2	4
29	0	0	0	0	0	1	2
33	2	0	1	0	0	1	10
34	0	0	0	0	0	1	2
35	0	2	0	0	0	2	8
36	0	0	0	0	0	4	8
38	0	0	0	0	0	1	2
39	1	0	0	0	0	4	9
42	0	2	0	0	0	1	4

Table 7-6 Fixture unit in each manhole in ground floor

First floor

Manhole number	total Lavatory	Total sink	Total Water closet / flush valve	Total Separate Shower	Pipe diameter	Total Floor Drain	Total DFU
1	0	0	0	0	0	1	2
3	1	2	0	0	0	3	9
4	4	1	3	2	1	2	39
5	0	1	2	1	1	2	21
6	3	0	3	1	0	0	23
7	0	0	0	0	0	2	4

8	3	0	3	1	0	3	29
9	0	1	0	0	0	1	4
10	3	2	1	1	0	3	21
11	0	2	0	0	1	2	9
12	1	2	1	1	0	2	17
15	0	0	0	0	0	2	4
21	2	0	2	0	0	1	16
24	0	2	0	0	0	2	8
25	3	0	1	0	0	3	15
26	5	1	2	2	0	2	25
27	0	0	0	0	0	4	8
31	2	0	1	1	0	3	12
32	1	4	0	0	1	3	16
36	1	0	0	0	0	1	3
37	2	0	2	2	0	2	22
38	0	2	0	0	0	1	6
39	1	0	1	1	1	2	14
40	1	0	0	0	0	1	3
42	3	2	1	0	1	3	20

Table 7-7 Fixture unit in each manhole in first floor

Note: we take 2 dfu for each floor drain

7.2.2 Pipe sizing Calculations

By using table 4-6 Appendix C the branch diameter in ground floor as following:

Manhole number	Total DFU	Branch Diameter
1	2	1.5"
2	2	1.5"
3	15	3"
5	19	3"
6	37	4"
7	20	3"
8	8	2.5"
10	2	1.5"
11	2	1.5"
12	8	2"
14	6	2"
15	4	2"
29	2	1.5"
33	10	2.5"
34	2	1.5"
35	8	2.5"
36	8	2.5"
38	2	1.5"
39	9	1.5"
42	4	2"

Table 7-8 Branch diameters in ground floor

By using table 4-6 and 4-7 and 4-8 in Appendix C the branch, stack, building diameters in first floor as following:

Manhole number	Total DFU	Branch Diameter	Stack Diameter	Building Diameter
1	2	1.5"	1.5"	2.5" Slope 4%
3	9	3"	3"	3" Slope 4%
4	39	4"	4"	4" Slope 1.8%
5	21	3"	3"	3" Slope 4%
6	23	4"	4"	4" Slope 1.8%
7	4	2"	2"	2.5" Slope 4%
8	29	4"	4"	4" Slope 1.8%
9	4	2"	2"	2.5" Slope 4%
10	21	3"	3"	3" Slope 4%
11	9	3"	3"	3" Slope 4%
12	17	3"	3"	3" Slope 4%
15	4	2"	2"	2.5" Slope 4%
21	16	3"	3"	3" Slope 4%
24	8	2.5"	2.5"	2.5" Slope 4%
25	15	3"	3"	3" Slope 4%
26	25	4"	4"	4" Slope 1.8%
27	8	2.5"	2.5"	2.5" Slope 4%
31	12	2.5"	2.5"	2.5" Slope 4%
32	16	3"	3"	3" Slope 4%
36	3	1.5"	1.5"	2.5" Slope 4%
37	22	4"	4"	4" Slope 1.8%
38	6	2"	2"	2.5" Slope 4%
39	14	3"	3"	3" Slope 4%
40	3	1.5"	1.5"	2.5" Slope 4%
42	20	3"	3"	3" Slope 4%

Table 7-9 Branch, stack, building diameters in first floor

All branches piping in the hospital is 4" PVC

All stacks piping in the hospital is 4" PVC

We take all sewer pipes 8" at Slope 1%

CHAPTER EIGHT

Conclusions

And

RECOMMENDATIONS

8.1 Recommendations of Central heating system

No.	Description	Result of calculations	Installed in hospital
1	Heating load at the Obstetrics & Gynecology Department (kW)	47.13	44.24
2	Pump flow rate (m ³ /h)	93.06	97
3	Pump head (kpa)	15	14.7
4	Main pipe diameter in the Obstetrics & Gynecology Department	1"	1"

According to the above comparison table we notice that:

1) Heating load calculated is nearly the same as the load of radiators installed, which means that it is sufficient.

According to our questioner we noticed that there are no complains from employers, visitors and patient.

2) Pump specification: the selected pump and the installed pump have the same Specification either from flow rate or head.

But from our questioner, the employees complain that the farthest radiator does not give the required heat, since the pump is sufficient, then mostly the reason For that is air leak to that radiator.

3) The pipe diameter calculated is nearly the same as the pipe diameter installed, This means that it is sufficient

8.2 Recommendations of Air conditioning system

No.	DESCRIPTION	INSTALLED IN THE HOSPITAL	RESULT FROM CALCULATION	RESULT FROM CHART
1	Dimension, diameter, flow rate of Main supply duct near east wall in Obstetrics & Gynecology Department	(85*35) Ø = 58.2 cm 3250.0 cfm	(60*50) Ø = 56.4 cm 2650.0 cfm	(60*50) Ø = 60.0 cm 2650.0 cfm
2	Dimension, diameter, flow rate of Main supply duct near west wall Obstetrics & Gynecology Department	(95*40) Ø = 65 cm 4210.0 cfm	(65*40) Ø = 51.4 cm 2204.0 cfm	(65*40) Ø = 55.0 cm 2204.0 cfm
3	Dimension, diameter, flow rate of Main supply duct in operation room	(55*30) Ø = 43.9 cm 1600.0 cfm	(55*40) Ø = 47.51 cm 1877.43 cfm	(55*40) Ø = 50.0 cm 1877.43 cfm

Table 8.1 Comparison between the result of calculation and the installed in Hospital in air conditioning system

1) Heating load calculated for the first air handler in the Obstetrics & Gynecology Department in Alia hospital is 60.01 kW which is less than that installed which has 88.73 kW which means that there is an extra cooling and heating in the Obstetrics & Gynecology Department which it is not necessary, also this will means extra cost

According to our questioner we noticed that there is complains from employers, visitors and patient. That in the winter season they feel of an excess heat in the conditioned space and in the summer season they feel of an excess cold.

- 2) Heating load calculated for the second air handler in the operation room in Alia hospital is 46.22 kW which is more than that installed which is 21.10 kW and this means that there is a lack in there cooling and heating load calculation, mostly due to a lack in there infiltration calculation which is necessary and very important in the operation room
- 3) In Alia hospital if we see the AutoCAD drawing we noticed that there is a return duct from the operation room which will return the air to the air handler and this is not true because operation room need 100% fresh air and don't use any quantity of return air or mixing
- 4) For the first air handler used in the Obstetrics & Gynecology Department in Alia hospital the percentage of mixing used is 20% fresh air and 80% return air which is insufficient to the ventilation requirement in Alia hospital so from our calculation we see that a mixing with 30% fresh air and 70% return air is sufficient and more comfortable for employers, visitors and patients
- 5) From our questioner, we see that the employees in the winter season complain from feeling of excess heat in there body and this is a result of an excessive latent heat which will rise the relative humidity in the conditioned space and cause un comfortable sense, so it is better to increase the ventilation quantity by increasing the quantity of fresh air mixed which will give more comfortable sense
- 6) Usually in air conditioning system it is advices to use an undersized units in order to operates continually and this will maintain a certain temperature and relative humidity in the conditioned space as desired which will mean more comfort for the occupancy, using an over sized unit will means stopping of the unit several time through the day and this will cause a change in the temperature and relative humidity of the conditioned space which will mean un comfort for the occupancy

8.3 Recommendations of plumbing system

8.3.1 Recommendations of hot and cold water system

- 1) In Alia hospital the water system operates by pumping water from a suction tank in the ground floor up to a roof tank, from which the building outlets are fed by another pumps at first floor, and this case will cause fluctuation in the quantity of water which will arrive to the outlets of the building also this system is expensive, and so it is better to use pumps to pump water from the suction tank in the ground floor up to the building outlets (using up feed system) also it is more economic system than that used in the hospital
- 2) Pump specification: the selected pump and the installed pump have the same Specification either from flow rate or head.

But from our questioner, the employees complain that there is fluctuation of Water at the building outlets.

- 3) in Alia hospital they use two pumps in the first floor to distribute water to the building outlets (one pump operates and one stand by) and so this will cause a height fluctuation in the pressure inside the pipes which will cause a fluctuation in the quantity of water which will arrive to the outlets of the building and so its better to use three pumps instead of the one used which will give the same flow rate and head used in ali hospital, but they will controlled to operates proportional to the required quantity of water in the building and so this system is more better and will reduce the fluctuation of water at the building outlets.
- 4) Pipe diameter calculated is nearly the same as the pipe diameter installed, which means that it is sufficient

- 5) The Boiler capacity calculated for hot water gives 329.55 kW heat out in order to be sufficient to the building requirement and it is nearly the same as The Boiler capacity installed, which gives 385.0 kW which means that the boiler installed is sufficient and safe.

8.3.2 Recommendations of sanitary system

- 1) Most of our branches and stacks pipe selections as noticed from table (7-8 & 7-9) are less than 4"

- 2) Most applied diameters are 4" this due to that the available pipes and fitting in the total market are 4" diameter which safe

For what concerning economical aspect we find that there is no much difference in the price of pipe and fitting as long as we are taking a bout diameter $\leq 4''$

- 3) Building drains: according to the hospital network it seems that the pipe diameter between manholes is 6" with 1.5 % slope; we did calculation for pipe 8" at slope 1% since we find that the price of pipe is less than the price of excavication

- 4) for building drains the recommended velocity is 3 fps and if we use a pipe diameter between manholes 6" with 1.5 % slope, as built in Alia hospital the velocity will be 2.52 fps from table 4-8 (See in Appendix C) which may be in some cases insufficient to carry the solids such as sand and human waste along the flow, instead they will stele out in the piping, actually building up to cause blockage of the piping ,so we did our calculation for pipe diameter 8" at slope 1% and from table 4-8 (See in Appendix C) the velocity will be 3.07 fps which is sufficient and safe and as recommended

Reference

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- [5] **Deh.gov site,**
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APPENDIX A

2.1 catalogue of radiator

HEAT OUTPUTS OF ALL RADIATORS AVAILABLE IN SIMPLE HORIZONTAL RANGE, AT $\Delta T 60^{\circ}C$

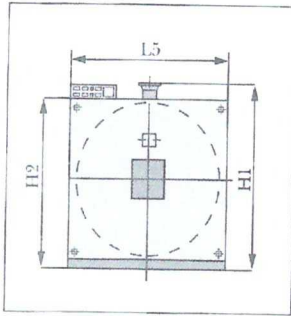


MODEL	Number of sections	Length (mm)	OUTPUTS IN W							APPROX. OUTPUTS IN BTU/h						
			Height (mm)							Height (mm)						
			300	400	500	600	720	800	1000	300	400	500	600	720	800	1000
C10	12	400		222	274	325	386	427	528		757	935	1109	1317	1456	1801
	15	500		278	342	407	483	534	660		948	1167	1388	1647	1821	2251
	18	600		333	410	488	580	641	792		1136	1398	1665	1978	2186	2701
	21	700		389	479	569	676	748	924		1327	1634	1941	2306	2551	3152
	24	800		444	547	650	773	854	1056		1514	1866	2217	2637	2913	3602
	27	900		500	616	732	869	961	1188		1705	2101	2497	2964	3278	4052
	30	1000		555	684	813	966	1068	1320		1893	2333	2773	3295	3643	4502
	33	1100		611	752	894	1063	1175	1452		2084	2565	3049	3626	4008	4953
	36	1200		666	821	976	1159	1282	1584		2272	2800	3329	3953	4373	5403
	39	1300		722	889	1057	1256	1388	1716		2463	3032	3605	4284	4734	5853
	42	1400		777	958	1138	1352	1495	1848		2650	3268	3882	4612	5099	6303
	45	1500		833	1026	1220	1449	1602	1980		2841	3500	4161	4942	5464	6754
	51	1700		944	1163	1382	1642	1816	2244		3220	3967	4714	5601	6194	7654
	57	1900		1055	1300	1545	1835	2029	2508		3599	4434	5270	6259	6921	8555
	60	2000		1110	1368	1626	1932	2136	2640		3786	4666	5546	6590	7286	9005
63	2100		1166	1436	1707					3977	4898	5823				
72	2400		1332	1642	1951					4543	5601	6655				
81	2700		1499	1847	2195					5113	6300	7487				
90	3000		1665	2052	2439					5769	6999	8319				
C11	12	400	252	329	404	480	568	628	773	860	1122	1378	1637	1937	2142	2637
	15	500	315	411	505	600	710	785	966	1074	1402	1723	2047	2422	2678	3295
	18	600	378	493	607	720	851	941	1159	1289	1682	2070	2456	2903	3210	3953
	21	700	441	575	708	840	993	1098	1352	1504	1961	2415	2865	3387	3745	4612
	24	800	504	658	809	960	1135	1255	1546	1719	2244	2759	3275	3871	4281	5273
	27	900	567	740	910	1080	1277	1412	1739	1934	2524	3104	3684	4356	4816	5932
	30	1000	630	822	1011	1200	1419	1569	1932	2149	2804	3448	4093	4840	5352	6590
	33	1100	693	904	1112	1320	1561	1726	2125	2364	3083	3793	4502	5325	5887	7248
	36	1200	756	986	1213	1440	1703	1883	2318	2579	3363	4137	4912	5809	6423	7907
	39	1300	819	1069	1314	1560	1845	2040	2512	2794	3646	4482	5321	6293	6958	8568
	42	1400	882	1151	1415	1680	1987	2197	2705	3008	3926	4827	5730	6778	7494	9227
	45	1500	945	1233	1516	1800	2129	2354	2898	3223	4206	5171	6140	7262	8029	9885
	51	1700	1071	1397	1719	2040	2412	2667	3284	3653	4765	5863	6958	8227	9097	11202
	57	1900	1197	1562	1921	2280	2696	2981	3671	4083	5328	6552	7777	9196	10168	12522
	60	2000	1260	1644	2022	2400	2838	3138	3864	4288	5608	6897	8186	9680	10704	13180
63	2100	1323	1726	2123	2520	2980			4513	5887	7242	8596	10165			
72	2400	1512	1973	2426	2880	3406			5157	6730	8275	9824	11618			
81	2700	1701	2219	2730	3240	3831			5802	7569	9312	11052	13067			
90	3000	1890	2466	3033	3600	4257			6447	8411	10346	12280	14521			
C12	12	400	506	652	792	929	1090	1195	1452	1726	2224	2701	3169	3718	4076	4953
	15	500	633	815	990	1161	1362	1494	1815	2159	2780	3377	3960	4646	5096	6191
	18	600	760	977	1188	1393	1624	1793	2178	2592	3332	4052	4751	5539	6116	7429
	21	700	886	1140	1386	1625	1907	2092	2541	3022	3888	4728	5543	6505	7136	8667
	24	800	1013	1303	1584	1858	2179	2390	2904	3455	4444	5403	6338	7433	8152	9905

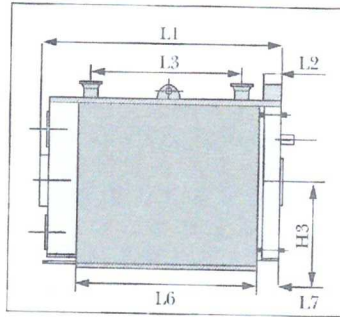
2.2 catalogue of boilers

STEEL BOILER FROM CHAPPÉE

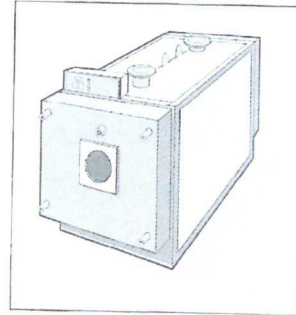
ARIZONA



Dist. draining system: 10 x 19



Dist. condensats: 32 (smooth)



Boiler HR2 model		Weight kg	Reconnectings		L1 mm	L2 mm	L3 mm	L5 mm	L6 mm	L7 mm	H1 mm	H2 mm	H3 mm	OIL*	GAS*
CE	CX		water mm	flux gas mm										BURNER burner nose ML	BURNER burner nose ML
200	220	780	50/60	200	1289	250	810	900	1010	150	1025	950	500	CF 28 1A	CG 28 1A
250	275	1230	50/60	200	1579	250	1100	900	1300	150	1025	950	500	CF 28 2A	CG 28 2A
290	319	1250	80	300	1962	350	1200	1100	1500	200	1300	1150	600	MS 38 2A	GS 38 2A
350	385	1270	80	300	1962	350	1200	1100	1500	200	1300	1150	600	MS 48 2A	GS 48 2A
405	445	1290	80	300	1962	350	1200	1100	1500	200	1300	1150	600	MS 68 2A	GS 68 2A
465	511	1320	80	300	1962	350	1200	1100	1500	200	1300	1150	600	MS 80 2A	GS 80 2A
520	572	1790	100	400	2240	350	1500	1250	1800	200	1450	1300	675	MS 130 2A	GS 130 2A
580	638	1830	100	400	2240	350	1500	1250	1800	200	1450	1300	675	MS 130 2A	GS 130 2A
640	704	1840	100	400	2240	350	1500	1250	1800	200	1450	1300	675	MS 130 2A	GS 130 2A
700	770	1870	100	400	2240	350	1500	1250	1800	200	1450	1300	675	MS 130 2A	GS 130 2A
800	880	1930	100	400	2255	400	1500	1450	1800	250	1650	1466	766	MS 130 2A	GS 130 2A
900	990	2130	125	500	2255	400	1500	1450	1800	250	1650	1466	766	MS 130 2A	GS 130 2A
1100	1210	2350	125	500	2255	400	1500	1450	1800	250	1650	1466	766	MS 151 2A	GS 151 2A
1400	1540	2780	125	550	2680	450	1750	1750	2150	250	1950	1800	925	MS 151 2A	GS 151 2A
1650	1815	3000	125	550	2680	450	1750	1750	2150	250	1950	1800	925	MS 240 2A	GS 191 2A
1850	2035	3650	150	600	2900	450	2000	1900	2400	250	2125	1970	1020	MS 240 2A	GS 240 2A
2100	2310	3870	150	600	2900	450	2000	1900	2400	250	2125	1970	1020	MS 245 2A	GS 245 2A
2350	2585	4100	150	600	3100	450	2200	2175	2600	250	2225	2175	1112	MS 350 2A	GS 350 2A
2500	2750	5200	200	650	3335	450	2250	2350	2735	250	2545	2400	1225	MS 350 2A	GS 350 2A
	2900	5200	200	650	3335	450	2250	2350	2735	250	2545	2400	1225	-	-

* For ARIZONA, CE version

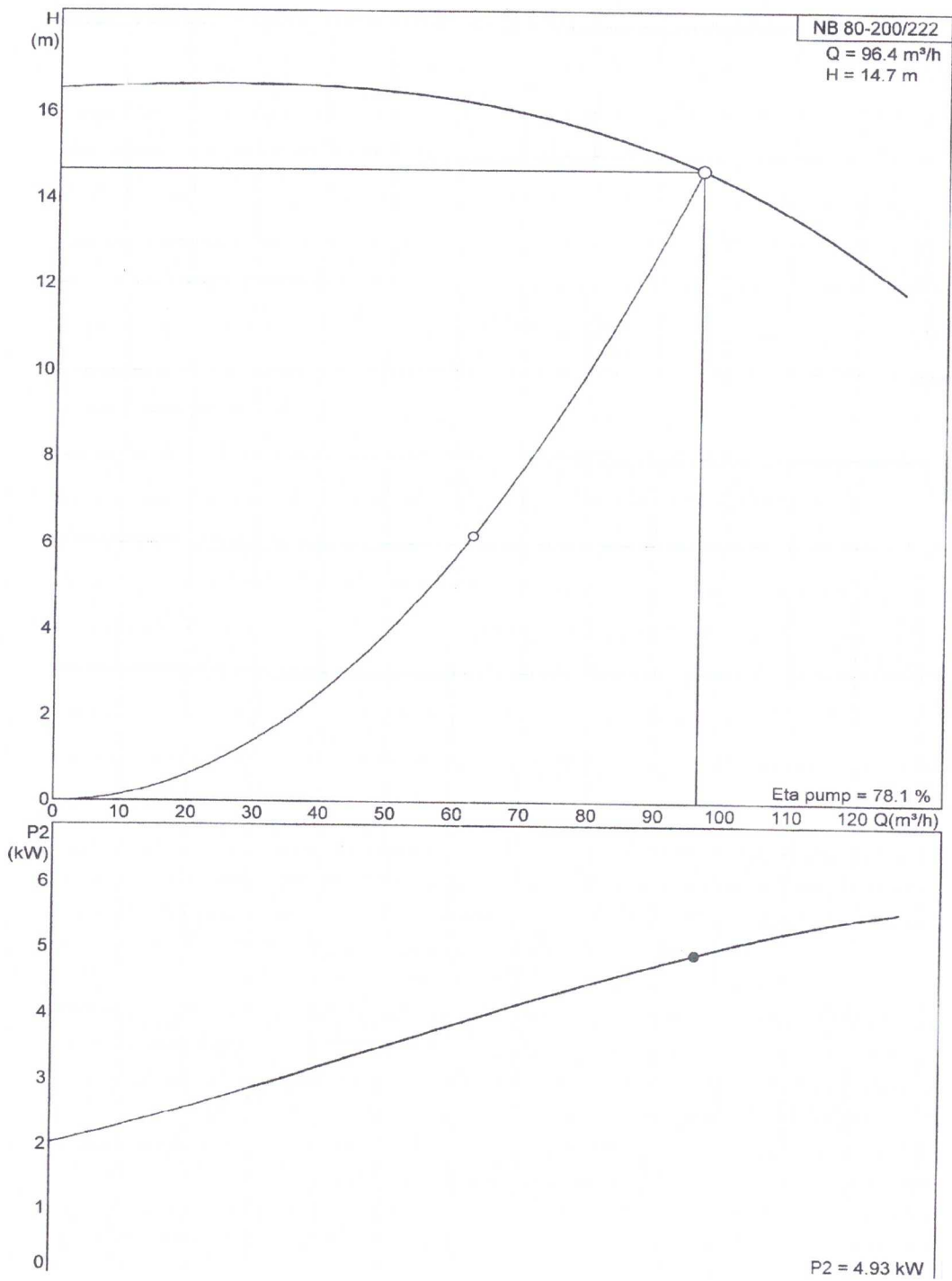
TECHNICAL FEATURES

HR2 ARIZONA model		Combustion chamber CE/CX			Smoke circuit volume (combustion chamber included) CE/CX m ³	Combustion chamber pressure		Water volume Nom. CE/CX m ³	Water circuit resistance Mini CE/CX mbar	Water flow rate CX		Smoke (Tf-Ta) CX (°)	Smoke temperature flow rate CX		Standing loss (Δt = 50°C) CX %
		Output	dia.	L		Volume	CE			CX	Δt = 20		P/45	Gas	
CE kW	CX kW	mm	mm	m ³	CE/CX m ³	CE mbar	CX mbar	m ³	mbar	m ³ /h	m ³ /h	°C	m ³ /h	m ³ /h	%
200	220	440	939.5	0.143	0.235	1.0	1.7	0.257	10	9.46	4.2	190	300	280	0.40
250	275	440	1238	0.188	0.291	1.5	2.6	0.255	10	11.83	5.3	190	375	350	0.40
290	319	600	1385	0.392	0.602	2.3	2.5	0.433	10	13.7	6.1	190	435	486	0.40
350	385	600	1385	0.392	0.602	2.2	3.6	0.433	11	16.5	7.4	190	525	490	0.30
405	445	600	1385	0.392	0.615	3.2	2.7	0.415	11	19.1	8.5	190	607	566	0.24
465	511	600	1385	0.392	0.615	2.4	3.6	0.415	12	21.9	9.8	190	697	650	0.24
520	572	750	1685	0.744	0.998	3.2	5.0	0.639	12	24.6	11.0	190	780	728	0.22
580	638	750	1685	0.744	0.998	4.5	6.2	0.639	14	27.4	12.2	190	871	812	0.20
640	704	750	1685	0.744	1.010	5.6	6.9	0.618	14	30.3	13.5	190	961	896	0.20
700	770	750	1685	0.744	1.010	5.4	7.2	0.618	16	33.1	14.7	190	1051	980	0.18
800	880	800	1684	0.846	1.231	6.5	5.0	1.143	16	37.8	16.8	190	1201	1120	0.18
900	990	800	1684	0.846	1.287	4.5	5.5	1.100	17	42.6	18.9	190	1351	1260	0.18
1100	1210	800	1684	0.846	1.327	5.0	5.5	1.060	17	52.0	23.1	190	1651	1540	0.15
1400	1540	950	2030	1.439	2.281	5.0	5.5	2.100	18	66.0	29.4	190	2102	1960	0.15
1650	1815	950	2030	1.439	2.377	5.0	6.1	2.780	18	78.0	35.0	190	2477	2310	0.14
1850	2035	1050	2275	1.970	3.026	5.5	6.1	2.780	18	87.5	39.0	190	2777	2590	0.12
2100	2310	1050	2275	1.970	3.047	5.5	6.1	2.750	18	99.3	44.0	190	3153	2940	0.12
2350	2585	1300	2480	3.292	4.516	5.5	6.1	2.650	18	111.0	50.0	190	3528	3290	0.12
2500	2750	1400	2600	4.000	4.700	5.5	6.1	3.100	20	129.7	58.0	190	3740	3492	0.10
	2900	1400	2600	4.000	4.700	-	6.7	3.100	20	148.0	65.4	190	3958	3690	0.10

normal output smoke temperature, air excess = 20%, secondary (60/80)

Figure 2.1 Grandfoss NB 80-200/222 pump catalog

96125134 NB 80-200/222



APPENDIX B

TABLE 3.1 Cooling load temperature differences for calculating cooling load from sunlit roofs.

Roof Description of No. Construction	U-value W/m ² ·°C	Solar Time <i>h</i>																							
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Without Suspended Ceiling																									
1 Steel sheet with 25.4 mm (or 50.8 mm) insulation	1.209 (0.704)	0	-1	-2	-2	-3	-2	3	11	19	27	34	40	43	44	43	39	33	25	17	10	7	5	3	1
2 25 mm wood with 25.4 mm insulation	0.963	3	2	0	-1	-2	-2	-1	2	8	15	22	29	35	39	41	41	39	35	29	21	15	11	8	5
3 101.6 mm L.W. concrete	1.209 (0.704)	5	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4 50.8 mm H.W. concrete with 25.4 mm (or 50.8 mm) insulation	1.170 (0.693)	5	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5 25.4 mm wood with 50.8 mm 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	18	18	11	9	7	6	4	3	4	5	8	11	15	19	23	27	29	31	31	27	25	22	19	16
8 203.4 mm L.W. concrete	0.715	20	19	14	12	10	8	6	5	6	7	10	13	16	20	22	25	28	30	30	26	24	21	19	16
9 101.6 mm H.W. concrete with 25.4 mm (or 50.8 mm) insulation	1.136 (0.681)	14	12	10	8	7	5	4	4	6	8	11	15	18	22	25	28	29	30	29	27	24	21	19	16
10 63.5 mm wood with insulation	0.528	18	15	13	11	9	8	6	5	5	5	7	10	13	17	21	24	27	28	29	29	27	25	23	20
11 Roof terrace system	0.602	19	17	15	14	12	11	9	8	7	8	8	10	12	15	18	20	22	24	25	26	25	24	22	21
12 152.4 mm H.W. concrete with 25.4 mm (or 50.8 mm) insulation	0.664	18	16	14	12	11	10	9	8	8	9	10	12	15	17	20	22	24	25	25	25	24	22	20	19
13 101.6 mm wood with 25.4 mm (or 50.8 mm) insulation	0.602 (0.443)	21	20	18	17	15	14	13	11	10	9	9	9	10	12	14	16	18	20	22	23	24	24	23	22
With Suspended Ceiling																									
1 Steel sheet with 25.4 mm (or 50.8 mm) insulation	0.761 (0.522)	1	0	-1	-2	-3	-3	0	5	13	20	28	35	40	43	43	41	37	31	32	15	10	7	5	3
2 25-mm wood with 25.4 mm insulation	0.653	11	8	6	5	3	2	1	2	4	7	12	17	22	27	31	33	35	34	32	28	24	20	17	14
3 101.6 mm L.W. concrete	0.761	10	8	6	4	2	1	0	0	2	6	10	16	21	27	31	34	36	36	34	30	26	21	17	13

-Continued-

Roof Description of No. Construction	U-value W/m ² ·°C	Solar Time <i>h</i>																							
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
4 50.8 mm H.W. concrete with 25.4 mm insulation	0.744	16	14	13	11	10	8	7	7	8	9	11	14	17	19	22	24	25	26	26	25	24	21	20	18
5 25.4 mm wood with 50.8 mm insulation	0.471	14	11	9	7	5	4	3	3	4	6	10	14	18	23	27	30	31	32	31	29	26	22	19	16
6 152.4 mm L.W. concrete	0.619	18	15	13	11	9	7	6	4	4	4	6	9	12	16	20	24	27	29	30	30	28	26	23	20
7 63.5 mm wood with 25.4 mm insulation	0.545	19	18	16	14	13	12	10	9	8	8	9	10	12	14	17	19	21	23	24	25	24	23	22	21
8 203.4 mm L.W. concrete	0.528	22	20	18	16	15	13	11	10	9	8	8	8	9	11	14	16	19	21	23	25	25	24	23	23
9 101.6 mm H.W. concrete with 25.4 mm (or 50.8 mm) insulation	0.727 (0.511)	17	16	15	14	13	13	12	11	11	11	12	13	15	16	18	19	20	21	21	21	21	20	19	18
10 63.5 mm wood with 50.8 mm insulation	0.409	19	18	17	16	14	13	12	11	10	10	10	11	12	14	16	18	19	21	22	23	23	22	22	21
11 Roof terrace system	0.466	17	16	16	15	15	14	13	13	13	12	12	13	13	14	16	16	16	17	18	18	19	18	18	18
12 152.4 mm H.W. concrete with 25.4 mm (or 50.8 mm) insulation	0.710 (0.449)	16	16	15	15	14	13	13	12	12	12	12	13	13	15	16	17	18	18	19	19	19	18	18	18
13 101.6 mm wood with 25.4 mm (or 50.8 mm) insulation	0.465 (0.363)	20	19	19	18	17	16	15	14	14	13	12	12	12	12	13	14	15	16	18	19	20	20	20	10

TABLE 3.2 CLTD correction for latitude and month applied to walls and roofs, north latitudes.

Lat.	Month	N	NNE NNW	NE NW	ENE WNW	E W	ESE WSW	SE SW	SSE SSW	S	Horiz.
16	Dec	-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/Jul	2.2	1.6	1.6	0.0	-0.5	-2.2	-2.7	-3.8	-3.8	0.0
	Jun	3.3	2.2	2.2	0.5	-0.5	-2.2	-3.3	-4.4	-3.8	0.0
24	Dec	-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/Jul	0.5	1.1	1.1	0.0	0.0	-1.6	-1.6	-2.7	-3.3	0.5
	Jun	1.6	1.6	1.6	0.5	0.0	-1.6	-2.2	-3.3	-3.3	0.5
32	Dec	-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/Jul	0.5	0.5	0.5	0.0	0.0	-0.5	-0.5	-1.6	-1.6	0.5
	Jun	0.5	-1.1	-1.1	0.5	0.0	-1.1	-1.1	-2.2	-2.2	1.1
40	Dec	-3.3	-4.4	-5.5	-7.2	-5.5	-3.8	0.0	3.8	5.5	-11.6
	Jan/Nov	-2.7	-3.8	-5.5	-6.6	-5.0	-3.3	0.5	4.4	6.1	-10.5
	Feb/Oct	-2.7	-3.8	-4.4	-5.0	-3.3	-1.6	1.6	4.4	6.6	-7.7
	Mar/Sept	-2.2	-2.7	-2.7	-3.3	-1.6	0.5	2.2	3.8	5.5	-4.4
	Apr/Aug	-1.1	-1.6	-1.6	-1.1	0.0	0.0	1.1	1.6	2.2	1.6
	May/Jul	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5
	Jun	0.5	0.5	0.5	0.5	0.0	0.5	0.0	0.0	-0.5	1.1
48	Dec	-3.3	-4.4	-6.1	-7.7	-7.2	-5.5	-1.6	1.1	3.3	-13.8
	Jan/Nov	-3.3	-4.4	-6.1	-7.2	-6.1	-4.4	-0.5	2.7	4.4	-13.3
	Feb/Oct	-2.7	-3.8	-5.5	-6.1	-4.4	-2.7	0.5	4.4	6.1	-10.0
	Mar/Sept	-2.2	-3.3	-3.3	-3.8	-2.2	-0.5	2.2	4.4	6.1	-6.1
	Apr/Aug	-1.6	-1.6	-1.6	-1.6	-0.5	0.0	2.2	3.3	3.8	-2.7
	May/Jul	0.0	-0.5	0.0	0.0	0.5	0.5	1.6	1.6	2.2	0.0
	Jun	0.5	0.5	1.1	0.5	1.1	0.5	1.1	1.1	1.6	1.1

TABLE 3.3 Solar heat gain factor (SHG), W/m², for a latitude angle of 32°.

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
Horiz.	555	685	795	855	874	871	861	836	770	672	552	498

TABLE 3.4 Shading coefficient (SC), for single, double and insulating glass without interior shading.

Type of Glass	Nominal Thickness (mm)	Solar Trans.	Shading Coefficient ($W/m^2 \cdot K$)	
			$h_o = 22.7$	$h_o = 17.0$
Single Glass				
Clear	3	0.86	1.00	1.00
	6	0.78	0.94	0.95
	10	0.72	0.90	0.92
	12	0.67	0.87	0.88
Heat absorbing	3	0.64	0.83	0.85
	6	0.46	0.69	0.73
	10	0.33	0.60	0.64
	12	0.42	0.53	0.58
Double Glass				
Regular Plate	3	—	0.90	—
	6	—	0.83	—
Reflective	6	—	0.20-0.40	—
Insulating Glass				
Clear	3	0.71	0.88	0.88
	6	0.61	0.81	0.82
Heat absorbing	6	0.36	0.55	0.58

TABLE 3.5 Shading coefficient for single, double and insulating glass with indoor shading by venetian blinds or roller shades.

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

TABLE 3.6 Cooling load factors for glass without interior shading, north latitudes.

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

-Continued-

Fenestration Facing	Room Construction	Solar Time h																
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
SE	L	0.05	0.04	0.04	0.03	0.03	0.13	0.28	0.43	0.55	0.62	0.63	0.57	0.48	0.43	0.37	0.33	0.28
	M	0.09	0.08	0.07	0.06	0.05	0.14	0.26	0.38	0.48	0.54	0.56	0.51	0.45	0.40	0.36	0.33	0.29
	H	0.11	0.10	0.10	0.09	0.08	0.17	0.28	0.40	0.49	0.53	0.53	0.48	0.41	0.36	0.33	0.30	0.27
SSE	L	0.07	0.05	0.04	0.04	0.03	0.06	0.15	0.29	0.43	0.55	0.63	0.64	0.60	0.55	0.45	0.40	0.35
	M	0.11	0.09	0.08	0.07	0.06	0.08	0.16	0.26	0.38	0.58	0.55	0.57	0.54	0.48	0.43	0.39	0.35
	H	0.12	0.11	0.11	0.10	0.09	0.12	0.19	0.29	0.40	0.49	0.54	0.55	0.51	0.44	0.39	0.35	0.31
S	L	0.08	0.07	0.05	0.04	0.04	0.06	0.09	0.14	0.22	0.34	0.48	0.59	0.65	0.65	0.59	0.50	0.43
	M	0.12	0.11	0.09	0.08	0.07	0.08	0.11	0.14	0.21	0.31	0.42	0.52	0.57	0.58	0.53	0.47	0.41
	H	0.13	0.12	0.12	0.11	0.10	0.11	0.14	0.17	0.24	0.33	0.43	0.51	0.56	0.55	0.50	0.43	0.37
SSW	L	0.10	0.08	0.07	0.06	0.05	0.06	0.09	0.11	0.15	0.19	0.27	0.39	0.52	0.62	0.67	0.65	0.58
	M	0.14	0.12	0.11	0.09	0.08	0.09	0.11	0.13	0.15	0.18	0.25	0.35	0.46	0.55	0.59	0.59	0.53
	H	0.15	0.14	0.13	0.12	0.11	0.12	0.14	0.16	0.18	0.21	0.27	0.37	0.46	0.53	0.57	0.55	0.49
SW	L	0.12	0.10	0.08	0.06	0.05	0.06	0.08	0.10	0.12	0.14	0.16	0.24	0.36	0.49	0.60	0.66	0.66
	M	0.15	0.14	0.12	0.10	0.09	0.09	0.10	0.12	0.13	0.15	0.17	0.23	0.33	0.44	0.53	0.58	0.59
	H	0.15	0.14	0.13	0.12	0.11	0.12	0.13	0.14	0.16	0.17	0.19	0.25	0.34	0.44	0.52	0.56	0.56
WSW	L	0.12	0.10	0.08	0.07	0.05	0.06	0.07	0.09	0.10	0.12	0.13	0.17	0.26	0.40	0.52	0.62	0.66
	M	0.15	0.13	0.12	0.10	0.09	0.09	0.10	0.11	0.12	0.13	0.14	0.17	0.24	0.35	0.46	0.54	0.58
	H	0.15	0.14	0.13	0.12	0.11	0.11	0.12	0.13	0.14	0.15	0.16	0.19	0.26	0.36	0.46	0.53	0.56

TABLE 3.7 Cooling Load factors for glass with interior shading, North latitude.

Fenestration Facing	Solar Time <i>h</i>																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
N	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
NNE	0.03	0.03	0.02	0.02	0.02	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
NE	0.03	0.02	0.02	0.02	0.02	0.05	0.06	0.06	0.05	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
ENE	0.03	0.02	0.02	0.02	0.02	0.05	0.06	0.06	0.05	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
E	0.03	0.02	0.02	0.02	0.02	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
ESE	0.03	0.03	0.02	0.02	0.02	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
SF	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
SSF	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	0.65
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	0.69	0.72	0.81	0.85	0.85	0.81	0.71	0.58	0.42

TABLE 3.8 Cooling load temperature differences for glass convection.

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

TABLE 3.9 heat gain rate from miscellaneous appliances (W).*

Appliance	Without Hood			With Hood
	Sensible	Latent	Total	All Sensible
Hair dryers (Blower type)	675	120	795	—
Hair dryers (Helmet type)	550	100	650	—
Coffee brewer (electrical)	225	65	290	95
Coffee brewer (gas)	490	210	700	415
Water heater	1,130	335	1,465	—
Coffee urn (electrical)	1,075	350	1,425	440
Coffee urn (gas)	1,460	625	2,085	415
Deep fat fryer (electrical)	820	1,930	2,750	730
Deep fat fryer (gas)	2,080	2,080	4,160	830
Toaster	1,055	705	1,760	440
Domestic gas oven	2,430	1,200	3,630	—
Roasting oven	500	320	820	—
Food warmer (gas)	1,550	400	1,950	400
Egg boiler	335	220	555	—
Frying griddle	13,600	7,200	20,800	4,150
Hotplate	1,550	1,060	2,610	780
Neon sign, per meter length	56	—	56	—
Sterilizer	190	350	640	—
Laboratory burner	470	120	690	—
Small copy machine	1,760	—	1,760	—
Large copy machine	3,515	—	3,515	—
Motors				
400–2,000 W	1,100	—	1,100	—
2,000–15,000 W	2,430	—	880	—

TABLE 3.10 Cooling load factors for lighting.†

No of hours after lights are turned on	Fixture X ^c hours of operation		Fixture Y ^c hours of operation	
	10	16	10	16
1	0.08	0.15	0.01	0.05
2	0.62	0.72	0.76	0.79
3	0.66	0.75	0.81	0.83
4	0.69	0.77	0.84	0.87
5	0.73	0.80	0.88	0.89
6	0.75	0.82	0.90	0.91
7	0.78	0.84	0.92	0.93
8	0.80	0.85	0.94	0.94
9	0.82	0.87	0.95	0.95
10	0.84	0.88	0.96	0.96
11	0.85	0.89	0.97	0.97
12	0.32	0.90	0.22	0.98
13	0.29	0.91	0.18	0.98
14	0.26	0.92	0.14	0.98
15	0.23	0.93	0.12	0.99
16	0.21	0.94	0.09	0.99
17	0.19	0.94	0.08	0.99
18	0.17	0.40	0.06	0.24
18	0.15	0.36	0.05	0.20

^c Fixture description: X, recessed lights which are not vented. The supply and return air registers are below the ceiling or through the ceiling space and grille. Y, vented or free-hanging lights. The supply air registers are below or through the ceiling with the return air registers around the fixtures and through the ceiling space.

TABLE 3.11 Diversity factor for selected applications.‡

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

TABLE 3.12 Sensible heat cooling load factors for people.§

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	0.51	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	0.46	0.93	0.94
14	0.02	0.06	0.10	0.15	0.23	0.36	0.94	0.95
15	0.02	0.05	0.08	0.13	0.20	0.30	0.47	0.95
16	0.02	0.04	0.07	0.12	0.17	0.25	0.38	0.96
17	0.02	0.04	0.06	0.10	0.15	0.21	0.31	0.49
18	0.01	0.03	0.06	0.09	0.13	0.19	0.26	0.39

TABLE 3.15 CLTD for light medium and heavy weight walls

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

TABLE 3.16 CLTD corrections for latitude and month applied to walls and roof,
North latitude

Month	N	NNE NNW	NE NW	ENE WNW	E W	LSE WSW	SE SW	SSE SSW	S	Horiz.
Dec	-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/Jul	2.2	1.6	1.6	0.0	-0.5	-2.2	-2.7	-3.8	-3.8	0.0
Jun	3.3	2.2	2.2	0.5	-0.5	-2.2	-3.3	-4.4	-3.8	0.0
Dec	-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/Jul	0.5	1.1	1.1	0.0	0.0	-1.6	-1.6	-2.7	-3.3	0.5
Jun	1.6	1.6	1.6	0.5	0.0	-1.6	-2.2	-3.3	-3.3	0.5
Dec	-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/Jul	0.5	0.5	0.5	0.0	0.0	-0.5	-0.5	-1.6	-1.6	0.5
Jun	0.5	1.1	1.1	0.5	0.0	-1.1	-1.1	-2.2	-2.2	1.1
Dec	-3.3	-4.4	-5.5	-7.2	-5.5	-3.8	0.0	3.8	5.5	-11.6
Jan/Nov	-2.7	-3.8	-5.5	-6.6	-5.0	-3.3	0.5	4.4	6.1	-10.5
Feb/Oct	-2.7	-3.8	-4.4	-5.0	-3.3	-1.6	1.6	4.4	6.6	-7.7
Mar/Sept	-2.2	-2.7	-2.7	-3.3	-1.6	0.5	2.2	3.8	5.5	-4.4
Apr/Aug	-1.1	-1.6	-1.6	-1.1	0.0	0.0	1.1	1.6	2.2	1.6
May/Jul	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5
Jun	0.5	0.5	0.5	0.5	0.0	0.5	0.0	0.0	-0.5	1.1
Dec	-3.3	-4.4	-6.1	-7.7	-7.2	-5.5	-1.6	1.1	3.3	-13.8
Jan/Nov	-3.3	-4.4	-6.1	-7.2	-6.1	-4.4	-0.5	2.7	4.4	-13.3
Feb/Oct	-2.7	-3.8	-5.5	-6.1	-4.4	-2.7	0.5	4.4	6.1	-10.0
Mar/Sept	-2.2	-3.3	-3.3	-3.8	-2.2	-0.5	2.2	4.4	6.1	-6.1
Apr/Aug	-1.6	-1.6	-1.6	-1.6	-0.5	0.0	2.2	3.3	3.8	-2.7
May/Jul	0.0	-0.5	0.0	0.0	0.5	0.5	1.6	1.6	2.2	0.0
Jun	0.5	0.5	1.1	0.5	1.1	0.5	1.1	1.1	1.6	1.1

TABLE 3.17 Recommended and maximum air velocities for warm air heating system

Description	Recommended Velocity (m/s)			Maximum Velocity (m/s)		
	Residence Buildings	Public Buildings	Industrial Buildings	Residence Buildings	Public Buildings	Industrial Buildings
Outside air intake	2.5	2.5	2.5	4.0	4.5	6.0
Heating coils	2.3	2.5	2.8	2.5	2.8	3.8
Cooling coils	2.3	2.5	3.0	2.5	2.8	3.8
Fan section	3.5	4.0	5.0	4.5	5.0	6.0
Fan outlet	5.0-8.0	6.5-10.0	8.0-12.0	3.5	4.0-5.0	5.0-6.0
Main ducts	4.0-4.5	5.0-6.5	6.0-9.0	4.0-5.0	5.5-8.0	6.0-10.0
Branch ducts	3.0	3.0-4.5	4.0-5.0	3.5-5.0	4.0-6.5	5.0-9.0
Branch riser	2.5	3.0-3.5	4.0	3.5-4.0	4.0-6.0	5.0-8.0

TABLE 3.18 Recommended values of noise criteria (NC)

No	Application	NC
1	Concert halls, studios, opera halls	22
2	Offices, private rooms	25
3	Theaters	27
4	Conference rooms, houses, villas	30
5	Lecture rooms, hotels, libraries	35
6	Restaurants, recreation halls	40
7	Supermarkets, cafeterias	45
8	Accounting offices, coliseums	50
9	Factories, machine rooms	60-65

TABLE 3.19 circular equivalent of rectangular duct for equal friction and capacity

Lgth. Adj.	Length of One Side of Rectangular Duct , mm																			
	100	125	150	175	200	225	250	275	300	350	400	450	500	550	600	650	700	750	800	900
100	109																			
150	133	150	164																	
200	152	172	189	204	219															
250	169	190	210	228	244	259	273													
300	183	207	229	248	266	283	299	314	328											
400	207	235	260	283	305	325	343	361	378	409	437									
500	227	258	287	313	337	360	381	401	420	455	488	518	547							
600	245	279	310	339	365	390	414	436	457	496	533	567	598	628	656					
700	261	298	331	362	391	418	443	467	490	533	573	610	644	677	708	737	765			
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
1200	324	370	413	453	490	525	558	590	620	677	731	780	827	872	914	954	993	1030	1066	1133
1400	344	394	439	482	522	559	595	629	662	724	781	835	886	934	980	1024	1066	1107	1146	1220
1600	362	415	463	508	551	591	629	665	700	766	827	885	939	991	1041	1088	1133	1177	1219	1298
1800	379	434	485	533	577	619	660	698	735	804	869	930	988	1043	1096	1146	1195	1241	1286	1371
2000	395	453	506	555	602	646	688	728	767	840	908	973	1034	1092	1147	1200	1252	1301	1348	1438
2200	410	470	525	577	625	671	715	757	797	874	945	1013	1076	1137	1195	1251	1305	1356	1406	1501
2400	424	486	543	597	647	695	740	784	826	905	980	1050	1116	1180	1241	1299	1355	1409	1461	1561
2600	437	501	560	616	668	717	764	810	853	935	1012	1085	1154	1220	1283	1344	1402	1459	1513	1617
2800	450	516	577	634	688	738	787	834	879	964	1043	1119	1190	1259	1324	1387	1447	1506	1562	1670

Lgth. Adj. ^b	Length of 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
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								
2200	1591	1676	1756	1833	1906	1977	2044	2110	2173	2233	2292	2350	2405							
2300	1623	1710	1793	1871	1947	2019	2088	2155	2220	2283	2343	2402	2459	2514						
2400	1655	1744	1828	1909	1986	2060	2131	2200	2266	2330	2393	2453	2511	2568	2624					
2500	1685	1776	1862	1945	2024	2100	2173	2243	2311	2377	2441	2502	2562	2621	2678	2733				
2600	1715	1808	1896	1980	2061	2139	2213	2285	2355	2422	2487	2551	2612	2672	2730	2787	2842			
2700	1744	1839	1929	2015	2097	2177	2253	2327	2398	2466	2533	2598	2661	2722	2782	2840	2896	2952		
2800	1772	1869	1961	2048	2133	2214	2292	2367	2439	2510	2578	2644	2708	2771	2832	2891	2949	3006	3061	
2900	1800	1898	1992	2081	2167	2250	2329	2406	2480	2552	2621	2689	2755	2819	2881	2941	3001	3058	3115	3170

^a Table based on $D_e = 1.30(ab)^{0.625}/(a + b)^{0.25}$.
^b Length of adjacent side of rectangular duct , mm.

TABLE 3.20 equivalent lengths L_e , of various fitting

Fitting	L_e (m)
45° Round elbow	1.5
90° Four pieces elbow	3.0
Gradual reduction	6.0
45° Round Tee	
Main run	1.5
Branch	11.0
90° Round Tee	
Main run	1.5
Branch	15.0
90° Rectangular elbow	5.0
Abrupt round contraction or expansion	11.0

TABLE 3.21 Pressure drop of dividing flow fittings (pa).

V_u m/s	V_d (m/s)									
	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	12.5	15.0
3.0	0.25	0.75	1.00							
4.0	0.75	0.50	2.00	2.50	2.50					
5.0	1.00	0.75	0.75	1.25	2.50	2.50				
6.0	1.75	1.50	1.25	1.25	2.50	2.50	2.75	3.00		
7.0	2.50	2.50	2.00	2.00	1.50	2.50	2.75	3.25		
8.0	4.25	3.75	3.50	2.50	2.00	3.00	2.75	3.25		
9.0	5.50	5.00	4.50	3.00	2.75	3.00	3.00	3.25		
10.0	6.75	5.00	4.75	4.50	4.25	4.25	3.75	2.50	5.0	7.5
12.5								7.50	5.0	5.0
15.0								10.00	7.5	7.5

TABLE 3.22 Performance data for round diffusers

Dia. (cm)	Neck Velocity (m/s)	3.5	4.0	4.5	5.0	5.5	6.0	6.5
		\dot{V} , (L/s)	45	50	55	60	70	75
12.5	Thr, (m)	0.9-1.5	0.9-1.5	0.9-1.5	0.9-1.8	0.9-1.8	0.9-2.1	1.2-2.1
	ΔP , (Pa)	17.4	22.4	29.9	37.4	44.8	52.3	62.3
	NC	18	22	25	28	31	34	36
	\dot{V} , (L/s)	60	70	80	90	95	105	115
15.0	Thr, (m)	0.9-1.5	0.9-1.8	0.9-1.8	0.9-2.1	1.2-2.1	1.2-2.4	1.2-2.7
	ΔP , (Pa)	17.4	22.4	27.4	34.9	39.8	49.8	59.8
	NC	18	22	26	29	31	34	36
	\dot{V} , (L/s)	110	125	140	160	175	190	205
20.0	Thr, (m)	1.2-2.1	1.2-2.4	1.2-2.7	1.5-3.0	1.5-3.3	1.5-3.6	1.8-3.6
	ΔP , (Pa)	14.9	19.9	24.9	32.4	39.8	47.3	54.8
	NC	19	23	29	30	33	35	37
	\dot{V} , (L/s)	170	195	220	245	270	295	320
25.0	Thr, (m)	1.5-3.3	1.8-3.6	1.8-3.9	2.1-4.2	2.1-4.5	2.4-4.5	2.4-5.1
	ΔP , (Pa)	12.5	17.5	22.4	27.4	32.4	39.8	47.3
	NC	21	25	29	32	34	37	39
	\dot{V} , (L/s)	250	285	320	355	390	425	460
30.0	Thr, (m)	2.1-4.2	2.1-4.5	2.4-5.0	2.4-5.0	2.7-5.4	2.7-5.7	3.9-6.0
	ΔP , (Pa)	12.5	14.9	19.9	24.9	29.9	34.9	42.3
	NC	23	26	30	33	36	38	41
	\dot{V} , (L/s)	390	440	495	555	610	660	720
37.5	Thr, (m)	2.4-5.1	2.7-5.4	2.7-5.7	3.0-6.3	3.3-6.6	3.6-7.2	3.9-7.8
	ΔP , (Pa)	10.0	12.5	15.9	19.9	22.4	27.4	32.4
	NC	24	28	32	35	38	40	41
	\dot{V} , (L/s)	560	635	715	795	875	955	1035
45.0	Thr, (m)	3.3-6.6	3.6-7.5	3.9-7.8	4.2-8.4	4.5-9.1	4.5-9.6	4.8-9.9
	ΔP , (Pa)	7.5	10.0	12.5	14.9	19.9	22.4	27.4
	NC	26	30	32	35	38	41	43

TABLE 3.23 Performance data for square diffusers

Size (cm)	Neck Velocity (m/s)	2.00	2.25	2.50	2.75	3.00	3.25	3.50
	15 × 15	\dot{V} , (L/s)	45	50	55	60	65	70
Thr, (m)		1.2-3.0	1.2-3.7	1.5-4.3	1.8-5.5	2.4-6.0	2.4-6.1	2.4-6.7
ΔP , (Pa)		8.7	10.5	13.4	14.9	17.9	20.2	23.2
23 × 23	\dot{V} , (L/s)	100	112	125	135	150	160	175
	Thr, (m)	1.8-3.7	1.8-4.3	2.4-4.9	3.0-5.5	3.0-6.1	3.0-6.7	3.0-7.3
	ΔP , (Pa)	10.7	13.9	15.7	18.4	21.7	22.4	28.6
30 × 30	\dot{V} , (L/s)	180	200	225	250	270	295	315
	Thr, (m)	2.4-4.3	3.0-4.9	3.7-5.5	4.3-6.7	4.3-7.3	4.9-7.9	4.9-8.5
	ΔP , (Pa)	11.5	13.7	17.2	20.4	23.7	24.4	31.6
38 × 38	\dot{V} , (L/s)	280	315	350	380	415	455	495
	Thr, (m)	3.1-6.1	4.3-6.7	4.9-7.3	4.9-7.9	6.1-8.5	6.1-9.1	6.1-9.8
	ΔP , (Pa)	12.0	15.9	19.2	21.7	25.2	28.9	33.6
46 × 46	\dot{V} , (L/s)	405	455	505	560	610	660	700
	Thr, (m)	4.9-7.3	5.5-7.9	6.1-9.1	6.1-9.3	6.1-10.4	6.1-11.0	6.1-11.6
	ΔP , (Pa)	13.2	16.2	19.2	25.4	26.2	30.6	35.1
53 × 53	\dot{V} , (L/s)	550	620	690	755	825	895	970
	Thr, (m)	5.5-9.1	6.1-9.8	7.3-10.4	7.3-11.0	7.3-11.6	7.9-12.2	7.9-12.8
	ΔP , (Pa)	13.7	16.7	19.9	27.4	27.6	31.4	35.9
61 × 61	\dot{V} , (L/s)	720	810	900	990	1080	1215	1305
	Thr, (m)	6.7-10.4	7.3-11.0	7.3-11.6	7.9-12.2	8.5-14.0	9.1-14.6	9.1-15.2
	ΔP , (Pa)	14.7	17.4	20.5	27.6	27.9	31.9	36.6
91 × 91	\dot{V} , (L/s)	1620	1800	2025	2250	2475	2700	2925
	Thr, (m)	9.1-15.2	10.4-16.5	11.0-17	12.2-18.3	12.8-19	14.0-20.7	14.6-21.0
	ΔP , (Pa)	15.9	20.5	23.9	32.1	35.6	40.6	45.3

TABLE 3.24 Performance data for rectangular diffusers

Size (cm)	Neck Velocity (m/s)	2.00	2.25	2.50	2.75	3.00	3.25	3.50
		\dot{V} , (L/s)	65	70	75	90	100	110
15 × 23	Thr, (m)	1.2-3.0	1.8-3.7	2.4-4.3	2.4-4.9	2.4-4.9	2.4-6.0	2.4-6.7
	ΔP , (Pa)	8.5	10.2	12.5	14.4	14.4	19.7	22.4
15 × 30	\dot{V} , (L/s)	90	100	110	125	135	145	155
	Thr, (m)	1.8-3.7	2.4-4.3	2.4-5.0	3.0-5.5	3.0-6.1	3.0-6.7	3.7-7.3
	ΔP , (Pa)	10.0	12.2	14.7	17.2	20.4	22.9	26.9
23 × 30	\dot{V} , (L/s)	135	145	165	185	205	215	230
	Thr, (m)	2.4-4.3	3.0-4.9	3.7-5.5	3.7-6.0	4.3-6.7	4.3-7.3	4.3-7.8
	ΔP , (Pa)	10.7	13.2	15.7	18.4	21.4	24.7	28.1
23 × 38	\dot{V} , (L/s)	165	190	210	230	250	275	295
	Thr, (m)	3.0-4.9	3.7-5.5	4.3-6.0	4.3-6.7	4.3-7.3	4.3-8.0	4.3-8.5
	ΔP , (Pa)	10.7	13.2	15.2	16.4	22.2	25.9	29.1
23 × 46	\dot{V} , (L/s)	200	225	250	275	305	350	360
	Thr, (m)	3.1-5.5	4.3-6.0	4.3-6.7	4.3-7.3	4.3-7.9	4.3-8.5	4.3-9.1
	ΔP , (Pa)	12.2	15.2	18.7	21.4	27.6	28.6	33.4
18 × 53	\dot{V} , (L/s)	230	270	295	330	350	385	405
	Thr, (m)	3.7-6.1	4.3-6.7	4.3-7.3	4.9-7.9	4.9-8.5	4.9-9.1	5.5-11.0
	ΔP , (Pa)	12.7	15.7	18.9	22.2	28.4	29.4	33.9
30 × 38	\dot{V} , (L/s)	225	250	270	305	340	360	390
	Thr, (m)	3.7-6.7	4.3-7.5	4.3-7.9	4.3-8.5	4.9-9.0	4.9-9.8	4.9-11.6
	ΔP , (Pa)	12.2	15.7	18.9	21.7	27.6	28.9	33.6
30 × 46	\dot{V} , (L/s)	270	305	340	370	405	440	485
	Thr, (m)	4.3-6.7	4.3-8.0	4.9-8.5	4.9-9.1	5.5-10.4	5.5-11.0	5.5-11.6
	ΔP , (Pa)	12.5	15.2	18.7	21.9	27.4	29.1	33.9
30 × 61	\dot{V} , (L/s)	360	405	450	495	540	585	630
	Thr, (m)	4.9-7.9	5.5-8.9	5.5-11.0	6.1-11.6	6.1-12.2	6.1-13.0	6.1-13.7
	ΔP , (Pa)	13.2	16.2	19.4	22.7	26.6	30.4	35.1

TABLE 3.25 Performance data for return air diffusers

Face Velocity (m/s)	0.50	0.75	1.00	1.25	1.50	1.75	2.00	2.25	2.50	2.75
ΔP (Pa)	2.0	4.0	7.5	12.5	17.4	22.4	29.9	39.8	49.8	69.7
Size (cm)	Volumetric Flow Rate (m ³ /s)									
15 × 15	18	23	30	36	45	47	54	65	74	77
15 × 23	23	32	43	54	63	74	85	97	108	117
15 × 30	27	40	54	68	83	97	110	124	137	150
23 × 23	32	45	60	77	92	108	125	140	155	170
23 × 30	38	60	77	97	117	135	155	173	195	212
23 × 38	47	70	92	115	140	162	185	207	230	254
30 × 30	50	72	97	122	145	170	195	218	243	268
30 × 46	70	105	137	173	207	240	276	310	345	378
30 × 53	80	120	160	198	240	280	320	358	395	437
38 × 53	97	145	195	243	293	340	390	435	485	535
38 × 61	110	165	220	275	330	387	440	495	550	603
46 × 61	120	170	230	288	347	403	465	522	567	637
53 × 61	150	225	304	378	456	530	603	684	765	837
61 × 61	170	260	350	437	518	612	702	783	873	954

TABLE 3.26 Circular equivalents of rectangular duct for equal friction and capacity

Side Rectangular Duct	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400	2500	2600	2700	2800	2900	Side Rectangular Duct
1000	1093																				1000
1100	1146	1202																			1100
1200	1196	1256	1312																		1200
1300	1244	1306	1365	1421																	1300
1400	1289	1354	1416	1475	1530																1400
1500	1332	1400	1464	1526	1584	1640															1500
1600	1373	1444	1511	1574	1635	1693	1749														1600
1700	1413	1486	1555	1621	1684	1745	1803	1858													1700
1800	1451	1527	1598	1667	1732	1794	1854	1912	1968												1800
1900	1488	1566	1640	1710	1778	1842	1904	1964	2021	2077											1900
2000	1523	1604	1680	1753	1822	1889	1952	2014	2073	2131	2186										2000
2100	1558	1640	1719	1793	1865	1933	1999	2063	2124	2183	2240	2296									2100
2200	1591	1676	1756	1833	1906	1977	2044	2110	2173	2233	2292	2350	2405								2200
2300	1623	1710	1793	1871	1947	2019	2088	2155	2220	2283	2343	2402	2459	2514							2300
2400	1655	1744	1828	1909	1986	2060	2131	2200	2266	2330	2393	2453	2511	2568	2624						2400
2500	1685	1776	1862	1945	2024	2100	2173	2243	2311	2377	2441	2502	2562	2621	2678	2733					2500
2600	1715	1808	1896	1980	2061	2139	2213	2285	2355	2422	2487	2551	2612	2672	2730	2787	2842				2600
2700	1744	1839	1929	2015	2097	2177	2253	2327	2398	2466	2533	2598	2661	2722	2782	2840	2896	2952			2700
2800	1772	1869	1961	2048	2133	2214	2292	2367	2439	2510	2578	2644	2708	2771	2832	2891	2949	3006	3061		2800
2900	1800	1898	1992	2081	2167	2250	2329	2406	2480	2552	2621	2689	2755	2819	2881	2941	3001	3058	3115	3170	2900
Side Rectangular Duct	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400	2500	2600	2700	2800	2900	Side Rectangular Duct

Equation for Circular Equivalent of a Rectangular Duct:

$$D_e = 1.30 [(ab)^{0.625}/(a + b)^{0.250}]$$

where

a = length of one side of rectangular duct, mm.

b = length of adjacent side of rectangular duct, mm.

D_e = circular equivalent of rectangular duct for equal friction and capacity, mm.

TABLE 3.27 Circular equivalents of rectangular duct for equal friction and capacity

Dimensions in mm

Side Rectan- gular Duct	Dimensions in mm																		Side Rectan- gular Duct		
	100	125	150	175	200	225	250	275	300	350	400	450	500	550	600	650	700	750		800	900
100	109																				100
125	122	137																			125
150	133	150	164																		150
175	143	161	177	191																	175
200	152	172	189	204	219																200
225	161	181	200	216	232	246															225
250	169	190	210	228	244	259	273														250
275	176	199	220	238	256	272	287	301													275
300	183	207	229	248	266	283	299	314	328												300
350	195	222	245	267	286	305	322	339	354	383											350
400	207	235	260	283	305	325	343	361	378	409	437										400
450	217	247	274	299	321	343	363	382	400	433	464	492									450
500	227	258	287	313	337	360	381	401	420	455	488	518	547								500
550	236	269	299	326	352	375	398	419	439	477	511	543	573	601							550
600	245	279	310	339	365	390	414	436	457	496	533	567	598	628	656						600
650	253	289	321	351	378	404	429	452	474	515	553	589	622	653	683	711					650
700	261	298	331	362	391	418	443	467	490	533	573	610	644	677	708	737	765				700
750	268	306	341	373	402	430	457	482	506	550	592	630	666	700	732	763	792	820			750
800	275	314	350	383	414	442	470	496	520	567	609	649	687	722	755	787	818	847	875		800
900	289	330	367	402	435	465	494	522	548	597	643	686	726	763	799	833	866	897	927	984	900
1000	301	344	384	420	454	486	517	546	574	626	674	719	762	802	840	876	911	944	976	1037	1000
1100	313	358	399	437	473	506	538	569	598	652	703	751	795	838	878	916	953	988	1022	1086	1100
1200	324	370	413	453	490	525	558	590	620	677	731	780	827	872	914	954	993	1030	1066	1133	1200
1300	334	382	426	468	506	543	577	610	642	701	757	808	857	904	948	990	1031	1069	1107	1177	1300
1400	344	394	439	482	522	559	595	629	662	724	781	835	886	934	980	1024	1066	1107	1146	1220	1400
1500	353	404	452	495	536	575	612	648	681	745	805	860	913	963	1011	1057	1100	1143	1183	1260	1500
1600	362	415	463	508	551	591	629	665	700	766	827	885	939	991	1041	1088	1133	1177	1219	1298	1600
1700	371	425	475	521	564	605	644	682	718	785	849	908	964	1018	1069	1118	1164	1209	1253	1335	1700
1800	379	434	485	533	577	619	660	698	735	804	869	930	988	1043	1096	1146	1195	1241	1286	1371	1800
1900	387	444	496	544	590	633	674	713	751	823	889	952	1012	1068	1122	1174	1224	1271	1318	1405	1900
2000	395	453	506	555	602	646	688	728	767	840	908	973	1034	1092	1147	1200	1252	1301	1348	1438	2000
2100	402	461	516	566	614	659	702	743	782	857	927	993	1055	1115	1172	1226	1279	1329	1378	1470	2100
2200	410	470	525	577	625	671	715	757	797	874	945	1013	1076	1137	1195	1251	1305	1356	1406	1501	2200
2300	417	478	534	587	636	683	728	771	812	890	963	1031	1097	1159	1218	1275	1330	1383	1434	1532	2300
2400	424	486	543	597	647	695	740	784	826	905	980	1050	1116	1180	1241	1299	1355	1409	1461	1561	2400
2500	430	494	552	606	658	706	753	797	840	920	996	1068	1136	1200	1262	1322	1379	1434	1488	1589	2500
2600	437	501	560	616	668	717	764	810	853	935	1012	1085	1154	1220	1283	1344	1402	1459	1513	1617	2600
2700	443	509	569	625	678	728	776	822	866	950	1028	1102	1173	1240	1304	1366	1425	1483	1538	1644	2700
2800	450	516	577	634	688	738	787	834	879	964	1043	1119	1190	1259	1324	1387	1447	1506	1562	1670	2800
2900	456	523	585	643	697	749	798	845	891	977	1058	1135	1208	1277	1344	1408	1469	1529	1586	1696	2900
Side Rectan- gular Duct	100	125	150	175	200	225	250	275	300	350	400	450	500	550	600	650	700	750	800	900	Side Rectan- gular Duct

Figure B 3.1 Duct friction loss chart

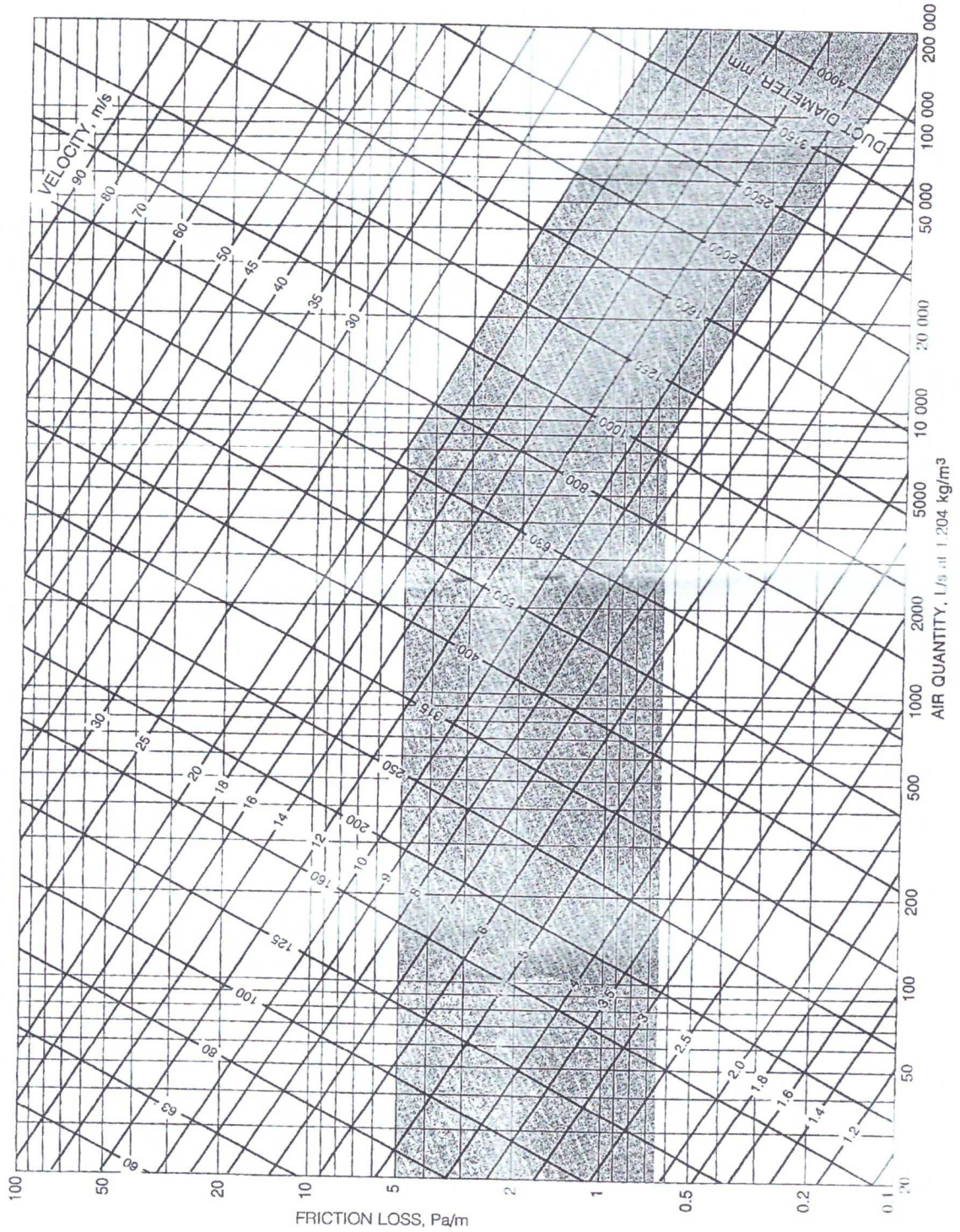


Figure B 3.2 (a) pressure drop ($\Delta P/El$). For air in galvanized steel duct, based in round Duct diameter

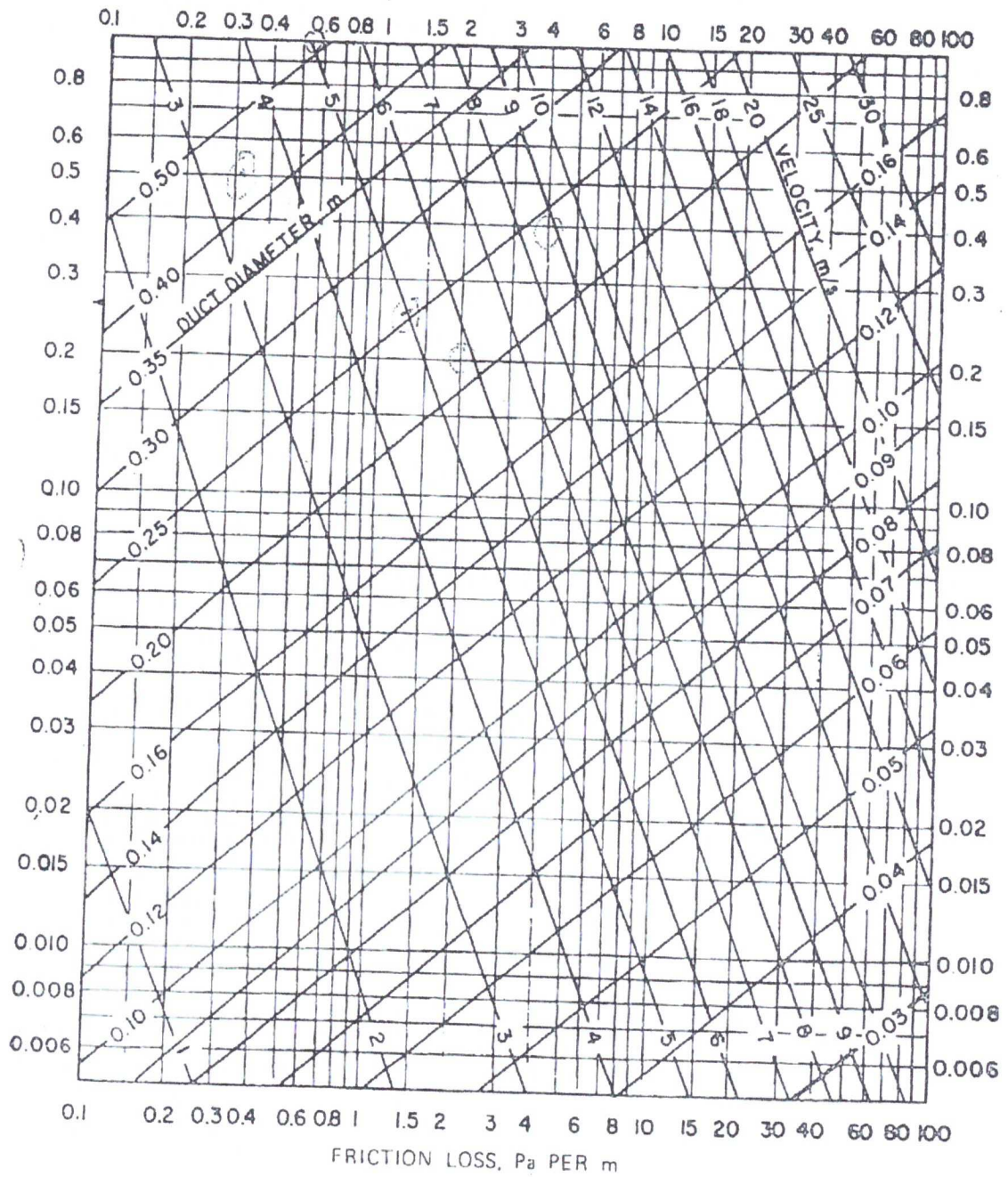


Figure B 3.2 (b) pressure drop ($\Delta P/El$). For air in galvanized steel duct, based in round Duct diameter

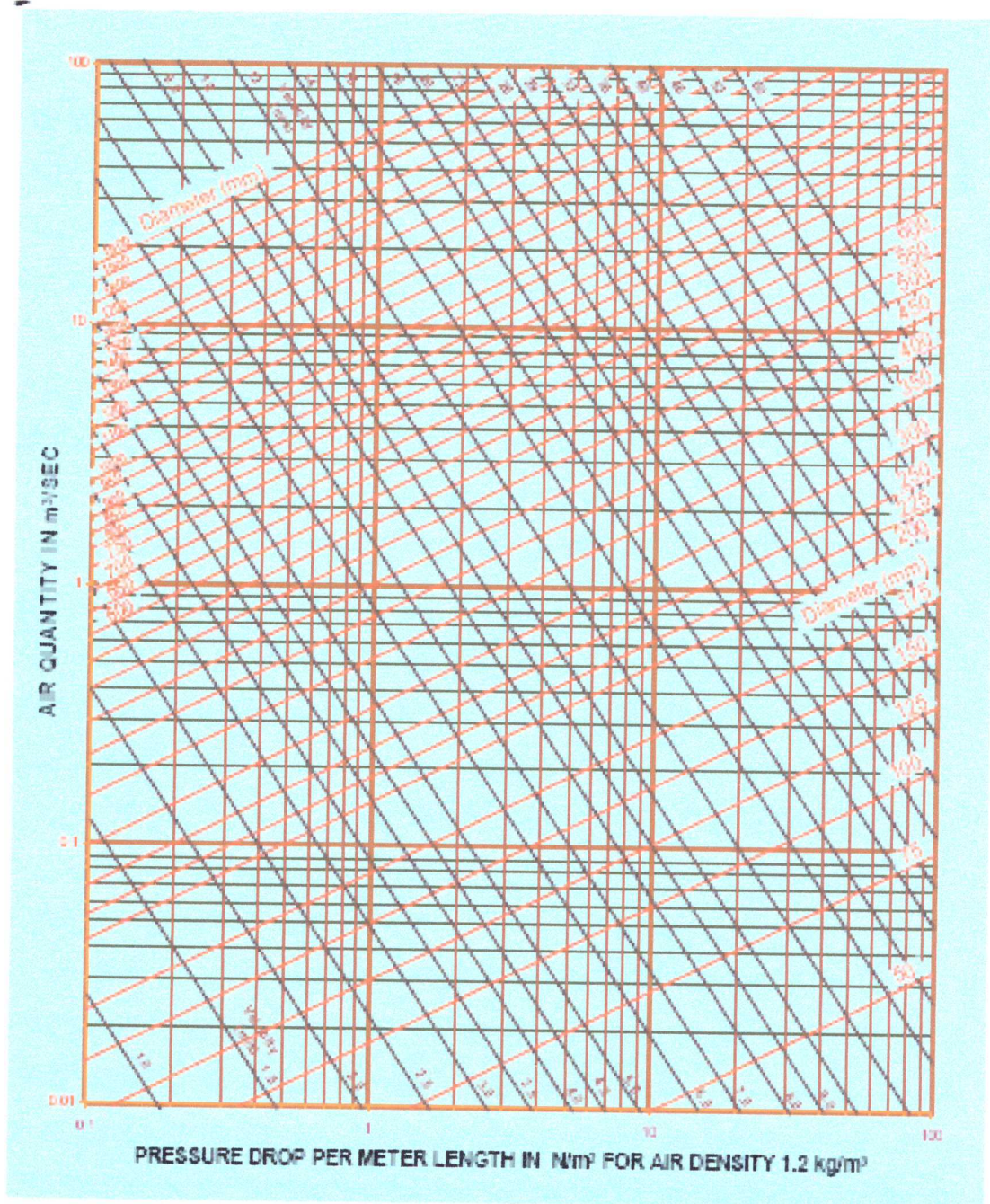
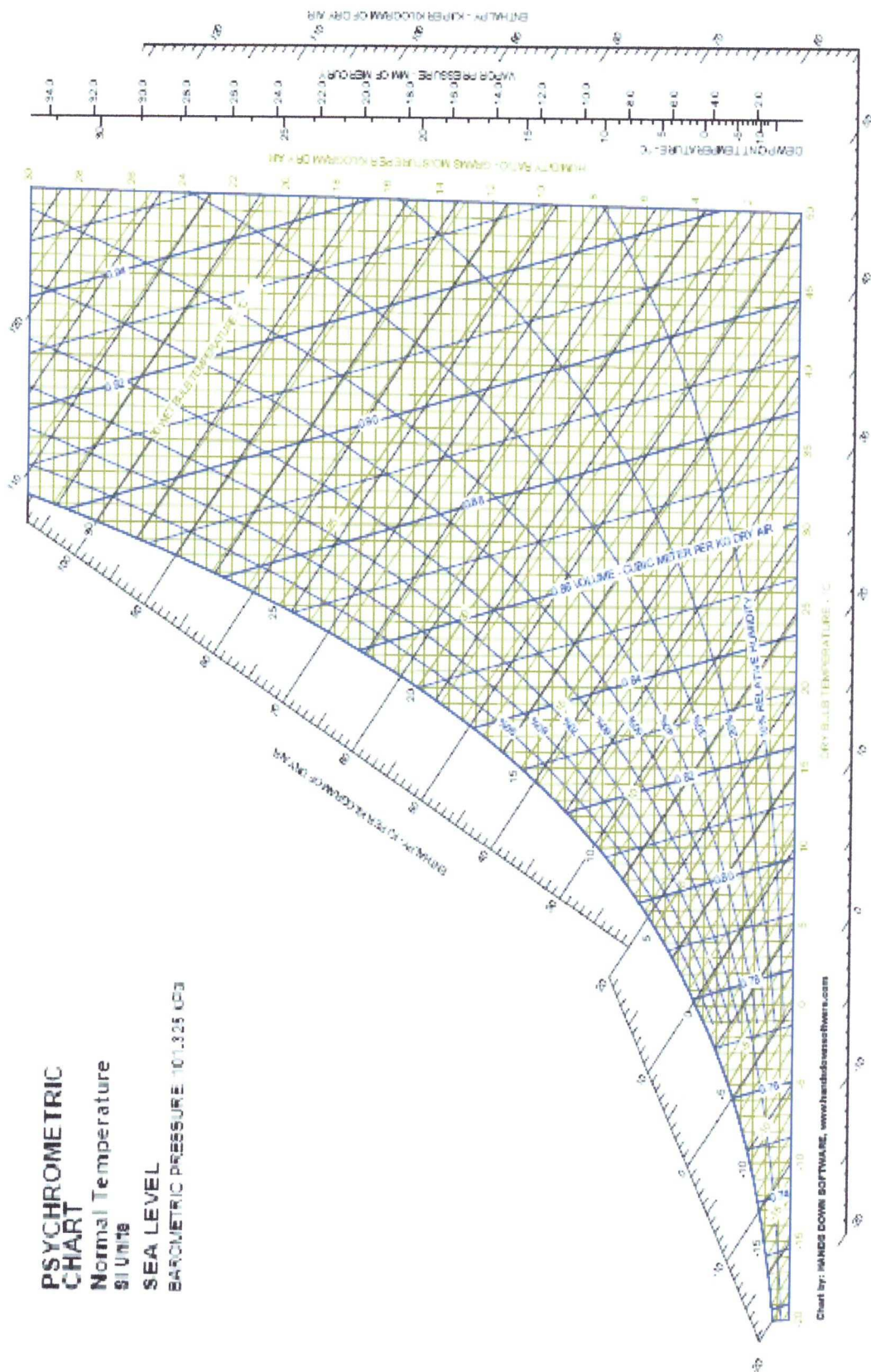


Figure B 3.3 Psychrometric Chart



APPENDIX C

Table 4.1 Water supply fixture unit and fixture branch size

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

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

Fixture Branch ^d	Number of Fixtures ^e	
	Private Use	General Use
1/2	1	2
3/4	2	4
1	3	6
1	6	10

^aFor supply outlets likely to impose continuous demands, estimate continuous supply separately and add to total demand for fixtures.

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

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

^dNominal I.D. pipe size.

^eSome may require larger sizes—see manufacturer's instructions.

^fData extracted from Code Table B.5.2.

Source. Reproduced with permission from The National Standard Plumbing Code, published by The National Association of Plumbing Heating Cooling Contractors.

Table 4.2

Minimum Pressure Required by
Typical Plumbing Fixtures

Fixture Type	Minimum Pressure, psi
Sink and tub faucets	8
Shower	8
Water closet—tank flush	8
Flush valve—urinal	15
Flush valve—siphon jet bowl	
floor-mounted	15
wall-mounted	20
Flush valve—blowout bowl	
floor-mounted	20
wall-mounted	25
Garden hose	
3/8-in. sill cock	15
1/2-in. sill cock	30
Drinking fountain	15

Source: EPA Manual of Individual Water Supply Syst. 1975 and manufacturers' data

Recommended Flow
Rates for Typical Plumbing
Fixtures

Fixture Type	Flow, gpm
Lavatory	3
Sink	4.5
Bathub	9
Laundry tray	5
Shower	3-10
Water closets	
tank type	3
flush valve ^a	15-40
Urinal flush valve	15
Garden hose	
3/8-in. sill cock	3-5
1/2-in. sill cock	5
Drinking fountain	1/4

Source: Data extracted from various sources

^aWide range of flows; depends on flow pressure.

Table for Estimating Demand

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

^aWater Supply Fixture Units

Source: Reproduced with permission from The National Standard Plumbing Code, published by The National Association of Plumbing Heating Cooling Contractors.

Table 4.4 Drainage fixture unit value

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

^aA shower head over a bathtub does not increase the fixture unit value.

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Table 4.5 Maximum size of non integral traps

Plumbing Fixture	Trap Size, in.
Bathtub (with or without overhead shower)	1 1/2
Bidet	1 1/4
Clothes washing machine standpipe	2
Combination sink and wash (laundry) tray	1 1/2
Combination sink and wash (laundry) tray with food waste grinder unit ^a	1 1/2
Combination kitchen sink, domestic, dishwasher, and food waste grinder	1 1/2
Dental unit or cuspidor	1 1/4
Dental lavatory	1 1/4
Drinking fountain	1 1/4
Dishwasher, commercial	2
Dishwasher, domestic (nonintegral trap)	1 1/2
Floor drain	2
Food waste grinder, commercial	2
Food waster grinder, domestic	1 1/2
Kitchen sink, domestic, with food waste grinder unit	1 1/2
Kitchen sink, domestic	1 1/2
Kitchen sink, domestic, with dishwasher	1 1/2
Lavatory, common	1 1/4
Lavatory (barber shop, beauty parlor or surgeon's)	1 1/2
Lavatory, multiple type (wash fountain or wash sink)	1 1/2
Laundry tray (1 or 2 compartments)	1 1/2
Shower stall or drain	2
Sink (surgeon's)	1 1/2
Sink flushing rim type (flush valve supplied)	3
Sink (service type with floor outlet trap standard)	3
Sink (service trap with P trap)	2
Sink, commercial (pot, scullery, or similar type)	2
Sink, commercial (with food grinder unit)	2

^aSeparate trap required for wash tray and separate trap required for sink compartment with food waste grinder unit.

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Table 4.6 Horizontal Fixture branches and stacks

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

^aDoes not include branches of the building drain.

^bNot more than two water closets or bathroom groups within each branch interval nor more than six water closets or bathroom groups on the stack.

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

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Table 4.7 Building drain and sewer

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

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

^bNot over two water closets or two bathroom groups, except that in single family dwellings, not over three water closets or three bathroom groups may be installed.

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Table 4.8 Rain velocity an sloping drains

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

^aComputed from the Manning Formula for $\frac{1}{2}$ -full pipe, $n=0.015$.

^bHalf full means filled to a depth equal to one-half the inside diameter.

Note: For $\frac{1}{4}$ full, multiply discharge by 0.274 and multiply velocity by 0.701. For $\frac{1}{3}$ full, multiply discharge by 0.408 and multiply velocity by 0.80. For $\frac{3}{4}$ full, multiply discharge by 1.82 and multiply velocity by 1.13. For full, multiply discharge by 2.00 and multiply velocity by 1.00. For smoother pipe, multiply discharge and velocity by 0.015 and divide by n value of smoother pipe.

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Table 4.11 Sewage Manholes

Table of Sewage Manholes

S.M. No.	S.M. Diam. cm	S.M. Depth cm	Distance m.	Size of pipe		Cover tons	B.O.Q Item.
				in.			
1	80	50		7.05	6	8t.	7.2.12
2	80	60	6.8		6	8t.	7.2.12
3	80	75		5	6	8t.	7.2.12
4	80	87	0.66		6	8t.	7.2.12
5	80	100		7.5	6	8t.	7.2.12
6	100	105	6.1		6	8t.	7.2.13
7	100	116		5.65	6	8t.	7.2.13
8	100	120	5.7		6	8t.	7.2.13
9 1D*	100	140		7.3	8	8t.	7.2.14
10 1D*	100	155	6.2		8	8t.	7.2.15
11 1D*	100	165		6.45	8	8t.	7.2.15
12 1D*	100	180	8.6		8	8t.	7.2.15
13	100	204		7.2	8	8t.	7.2.16
14 1D*	100	210	2.75		8	8t.	7.2.16
15 1D*	100	235		16	8	8t.	7.2.16
17	100	100	-		8	25t.	7.2.13
18	80	100		2.9	6	25t.	7.2.12
19	80	105	4.95		6	25t.	7.2.12
20	80	150		-	-	25t.	7.2.13
21	100	340	1.6		6	8t.	7.2.17
22	100	280		4.2	6	8t.	7.2.17
23	100	265	6.6		6	8t.	7.2.17
24	100	235		-	-	8t.	7.2.16
25	100	205	4.3		6	8t.	7.2.16
26	100	210		3.2	6	8t.	7.2.16
27	100	160	3.4		6	8t.	7.2.15
28	100	115		-	-	8t.	7.2.13
29	100	80		-	-	8t.	7.2.13
-	-	-	-	-	-	-	-
31	100	60	3.35		6	8t.	7.2.13
32	100	70		2.5	6	25t.	7.2.13
33	100	80	3.8		6	25t.	7.2.13
34	100	75		2.95	6	25t.	7.2.13
35	100	95	1.4		6	25t.	7.2.13
36	100	100		12	6	25t.	7.2.13
37 1D*	100	105	7		8	25t.	7.2.13
38 2D*	100	185		6.5	8	8t.	7.2.15
39	100	194		-	-	8t.	7.2.15
40	100	70		4.7	6	8t.	7.2.13
41	100	66	1.35		6	8t.	7.2.13
42	100	72		1.35	6	8t.	7.2.13
O.I							
39			25		8		7.2.13
43	100	70		24.5	8	25t.	7.2.13
17							7.2.13
43			16.5		10		7.2.13
44	100	75		5.5	8	25t.	7.2.13
E7				10.5	10	25t.	
E8						25t.	

+1 External Drop for connecting on existing manhole

D* : Drop Manhole

Manhole Cover =25ton at traffic points , int. diam. of cover =50cm for S.M of diam.80cm

Manhole Cover =25ton at traffic points , int. diam. of cover =60cm for S.M of diam.100c

Manhole Cover =25ton at no traffic points , int. diam. of cover =500 for S.M of diam.10c

Manhole Cover =8ton at no traffic points , int. diam. of cover =500 for S.M of diam.80cm

Table 4.12 Rain Manholes

Slab+49.8														
R.M. No.	Gr. Level	I.L. Pipe in			I.L. Pipe out	R.M. Diam. cm	R.M. Depth cm	Distance		Slope%		Size of pipe		Cover tons
		P1 <small>(branch)</small>	P2 <small>(branch)</small>	P3 <small>(bet. R.M.s)</small>				m	m	%	%	in.	in.	
1	+54.00	+53.58			+53.23	60	77	7.5		2%		6"		25t.
2	+54.00	+53.58			+53.06	80	94	7.5	7.5	2%	2%	6"	6"	25t.
3	+54.00	+53.58			+52.89	80	111	7.5		2%		6"		25t.
4	+54.00	+53.58			+52.72	80	128	7.5	7.5	2%	2%	6"	6"	25t.
5	+54.00	+53.58			+52.55	80	145	7.5		2%		8"		25t.
6	+54.00	+53.58			+52.38	80	162	7.5		2%	2%	8"	8"	25t.
7	+54.00	+53.58			+52.21	80	179	13	7.5	2%	2%	10"		25t.
8	+54.00	-			+51.92	100	208		9.5	2%	2%	10"	10"	25t.
9	+53.70	+53.16			+51.69	100	201	11		2%		10"		25t.
10	+53.20	+52.76			+51.46	100	174			2%				25t.
11	+52.00	+51.58			+51.23	60	77	8.5		5.6%		6"		8t.
12	+51.60	+51.18			+50.84	60	76		8.5	3.2%		6"	6"	8t.
13	+51.30	+50.88			+50.60	80	70	7.5		9.2%		6"		8t.
14	+50.70	+50.27			+50.00	80	70			5.6%				8t.
15	+49.98	+50.23			+49.28	80	70							
16	+49.90	+49.46			+49.09	80	81		8		2%		6"	25t.
17	+49.90	+49.46			+48.90	80	100	7		2%		6"		25t.
18	+49.80	+49.35			+48.79	80	101		10	2%	1.5%	8"	8"	25t.
19	+49.80	+48.43			+48.38	100	142	8		2%				25t.
20	+49.40	+48.67			+48.15	100	125		8		2.3%		10"	25t.
21	+49.20	+49.33			+47.96	100	124	6.5				10"		8t.
23	+48.70	+49.33			+47.26	100	144							
22	+48.85	+49.33			+47.43	100	142							8t.

Table 4.13 Rain Manholes

Slab+49.8	R.M. No.	Gr. Level	I.L. Pipe in			I.L. Pipe out	R.M. Diam. cm	R.M. Depth cm	Distance m		Slope%	Size of pipe in.		Cover tons	B.O. Q Item
			P1 (branch)	P2 (branch)	P3 (both R.M.s)										
	24	+54.00					100	65	10.30			6"	6"	Gill 25t	7.2.13
	1	+54.00	+53.58			+53.23	60	77		6.3		6"	6"	25t	7.2.11
	2	+54.00	+53.58			+53.06	80	130	7			6"	6"	25t	7.2.13
	3	+54.00	+53.58			+52.89	80	120		6.45		6"	6"	25t	7.2.13
	4	+54.00	+53.58			+52.72	80	128	6.35			6"	6"	25t	7.2.13
	5	+54.00	+53.58			+52.55	80	170		7		8"	8"	25t	7.2.13
	6	+54.00	+53.58			+52.38	80	190	6			8"	8"	25t	7.2.13
	7	+54.00	+53.58			+52.21	80	185		10.35		10"	10"	25t	7.2.16
	8	+54.00	-			+51.92	100	200	8.5			10"	10"	25t	7.2.16
	9	+53.70	+53.16			+51.69	100	215		9.40		10"	10"	25t	7.2.16
	10	+53.20	+52.76			+51.46	100	240	-			-	10"	25t	7.2.16
	11	+52.00	+51.58			+51.23	60	70		6.20		6"	6"	8t	7.2.11
	12	+51.60	+51.18			+50.84	60	110	7.30			6"	6"	8t	7.2.12
	13	+51.30	+50.88			+50.60	60	100		7.20		6"	6"	8t	7.2.13
	14	+50.70	+50.27			+50.00	80	130	-			-	6"	8t	7.2.12
	15	+49.98	+50.23			+49.28	80	70		-		6"	6"	25t	7.2.12
	16	+49.90	+49.46			+49.09	80	70	7.4			6"	6"	25t	7.2.12
	17	+49.90	+49.46			+48.90	80	75		3		6"	6"	25t	7.2.13
	22						100	90	1.65			6"	6"	25t	7.2.13
	18	+49.80	+49.35			+48.79	100	100		9		8"	8"	25t	7.2.13
	19	+49.80	+48.43			+48.38	100	100	6.8			8"	8"	25t	7.2.13
	20	+49.40	+48.87			+48.15	100	110		6.6		10"	10"	8t	7.2.16
	21	+49.20	+49.33			+47.96	100	200	6.3			10"	10"	8t	7.2.16
	23	+48.70	+49.33			+47.26	100	214		-		-	-	25t	7.2.12
	25						80	60		12		6"	6"		
	14														
	26														
	15														

+1 External Drop for connecting on existing manhole
 Manhole Cover = 25ton at traffic points , int. diam. of cover = 50cm for S.M of diam. 80cm
 Manhole Cover = 25ton at traffic points , int. diam. of cover = 60cm for S.M of diam. 100cm
 Manhole Cover = 8ton at no traffic points , int. diam. of cover = 500 for S.M of diam. 60cm & 80cm