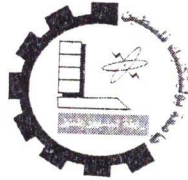


Palestine Polytechnic University



College of Engineering & Technology
Mechanical Engineering Department

Graduation Project

Design of Mechanical Systems for
Hospital in Hebron city

Mohammed Al-hmeidat

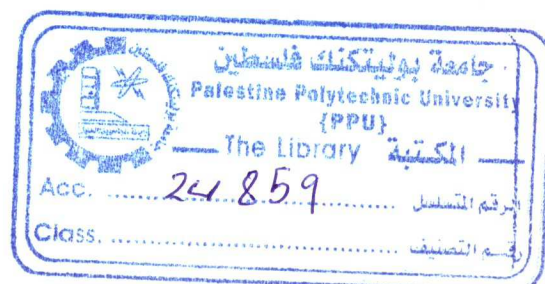
Project Team

Abed Al-hamid Mustafa

Project Supervisor
Eng.Kazem Osaily

Hebron – Palestine

June, 2009



Palestine Polytechnic University
Hebron-Palestine
College of Engineering & Technology
Mechanical Engineering Department

PROJECT NAME .

Design of Mechanical Systems for
Hospital in Hebron city

Project Team

Mohammed Al-hmeidat

Abed Al-hamid Mustafa

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 in engineering of Refrigeration and Air-conditioning

Supervisor Signature

.....

Examine community Signature



.....

Department Head Signature

.....

Dedication

We gift this graduation project
Firstly to our parents that supporting
Us till we reach to this stage

To our confreres in this university

To who appreciate the importance of science

To whom exist inside occupation prisons

To every person who makes every effort
to liberate our home

For all , we gift this done

Acknowledgement

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

We wish to thank the Dr: Ishaq Seder, eng. Mohammed Awed eng. Jamal Al-shweiki. We sincerely believe that this work would not exist without their inspiration.

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

Abstract

In this project it will make mechanical design for hospital building in Hebron city which consist from three stories with total area 3000m².

Mechanical design including water supply and drainage system, heating ventilating and air conditioning (HVAC system) .

This project discuss all theories that will be needed for designing any mechanical system . After that it will make all mechanical drawing based on the calculations , and select the suitable requirements for this purpose. Mechanical drawing should be contains pipes network for distribution water system also drainage network and ducts that using to distribute fresh and comfort air inside hospital , also ducts using for ventilation .

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CHAPTER ONE

INTRODUCTION

1-1 Introduction

Human still thinking how to improve his life for better , this is the cause of spread industry and technology , and life became more easier than previous mode .

Building technology is very important nowadays to satisfy comfort condition for occupants to make their life easier especially most of their time be inside building whether to be in homes, offices, factories, hospitals, universities, schools, etc...for this reason engineering who design any kind of building make it as possible to be suitable with occupants necessities or facilities. The most important design after architecture design for any kind of building is to supply this building by mechanical design which involves domestic water system, heating ventilating and air conditioning system (HVAC), fire suppression system, gas grid system, and drainage grid system.

Although some mechanical service are not necessary to be installed in every building , the existence of some other is basic mechanical system and very essential to be installed , for example domestic water system is forming the basic part of the building.

Some mechanical system such as air conditioning and ventilating are said to be luxuries; since they deal with a high level of technology from one side and their cost high relatively from another side.

But most application require to install them by many services such as some factories beside "domestic water, and drainage system" need ventilation system to exhaust polluted air that be produced from industrial process , to keep good climate for workers . other applications need HVAC system such as hospitals besides to fire suppression and domestic water, drainage systems and others because the different mechanical installations are not less important for the patients than the medical services itself so such installation must be in the best manner in addition to the continues maintenance needed to guarantee best performance .

Hospitals need accurate, special design in all application and many things that will take in consideration to guarantee the continuity and dynamic for all systems which hospitals contain , because hospitals are considered the essential and the important of all infrastructure in the country , for this reason it demands care from all designers participating in this project .

Mechanical design should satisfy all requirements inside hospitals also take into account the economic state on the level of long –range, so in this project effort is made to complete all requirements of mechanical design in the best way and accurate calculations, to select the best equipment and machines which are suitable for hospital`s use .

1-2 project objectives

- * The main objective of this project is to study all criteria for design any mechanical plan .
- * Design domestic water system and design grid of pipes to discard black and waste water outside the building to septic tank.
- * Design HVAC system for base floor only.
- *Select best system that satisfy requirements.

1-3 Project Benefits

- * The main benefit is to fulfill the graduation requirements of Palestine Polytechnic university , and be familiar with all mechanical design of systems installed in building to be ready in working in this field after graduating .
- * Hospitals form the difficult mechanical design because it need special care to make inside climate more comfortable and healthier, so this field was chosen to be expert and familiar with hospital requirements in one side and best selection for all mechanical systems in other side.
- * It forms a reference for other students where they desire to know more about mechanical design of hospitals .

1-4 Hospital Description

The hospital consists of three stories ; basement , ground , and first floor, each story has an area about 1000 m² and the total area of hospital with surrounding area is about 7500 m². And it contains the following administration departments:-

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

The hospital also has the following medical departments:-

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

In addition to these departments ,the hospital contains other service departments such as maintenance, food, laundry, stores, and offices. The number of beds are 50 bed.

1-5 First semester Budget

Table(1-1) Budget

<i>TASK</i>	<i>COST (NIS)</i>
USING INTERNET	100
PRINTING PAPERS	50
REPRINTING PAPER	100
Buying books	50
TOTAL	300

1-6 Second semester Budget

Table (1-2) Budget

<i>TASK</i>	<i>COST (NIS)</i>
USING INTERNET	100
PRINTING PAPERS	50
PRINTING DRAWING	250
REPRINTING FINAL COPY	300
TOTAL	700

1-7 The First Semester Time table

Table (1-3) Time table

WEEK #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Select project Name	█	█	█													
Gather information				█	█	█										
Writing introduction						█										
HVAC system							█	█	█	█						
Water supply and drainage											█	█	█			
Printing final copy														█	█	

1-8 The second Semester Time table

Table(1-4)Time table

WEEK #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Calculate plumbing																
Calculate HVAC load																
Design plumbing sys.																
Design HVAC system																
Selection Mech.systems																
Printing final copy																

1-9 Contents of the project

This project contain five chapters and are distributed as following:-

Chapter one:- Introduction

Includes the overview about project , project objectives and benefits.

Chapter two:- Plumbing System

Include overview about plumbing systems ,water distribution system(cold and hot water) and how potable water shall be reached inside hospital by using suitable pipes and how the pipes could be designed also this chapter contains the procedures to

calculate the required quantity of potable water for daily usage to know the quantity of containers that required to store this quantity, also components of drainage system and the procedures to design network drainage pipes , then overview about manhole design and about storm rain water drainage .

Chapter three :- The comfort conditions and heat transfer through building

Includes the comfort conditions inside hospital , the psychometric characteristics, then heat transfer through building and how heat is transmitted, finally calculation the overall heat transfer coefficient for all structure of hospital.

Chapter four:- Heating Ventilating and Air Conditioning.

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

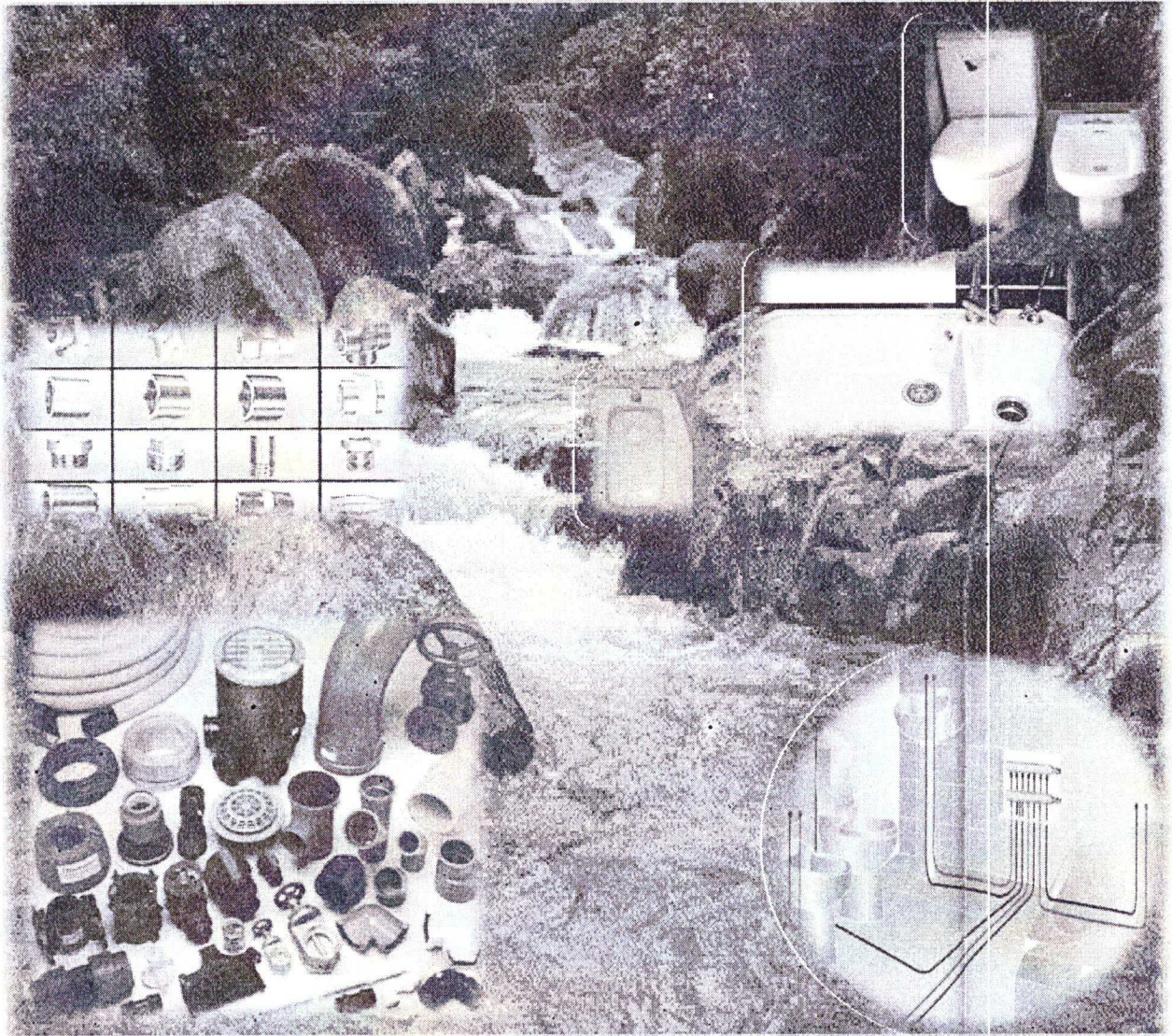
Chapter five:- Calculations and Selection

Includes all calculations are required for design mechanical system.

Includes selection for all systems are needed for installation inside hospital depending to accurate calculation.

CHAPTER TWO

PLUMBING SYSTEM



2.1 Introduction

Plumbing is a system of pipes, fitting and fixtures installed in a building for the distribution of potable water and remove waste water outside of building by established network of pipes and fitting suitable for this purpose .

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, , 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.

Modern plumbing engineering and design covers not only these areas, that is, water supply , sanitary and storm drainage and fire fighting , but also a host of other disciplines, which have piping as their common denominator . These include:

- Specialized water system (chilled , distilled).
- Gas system (oxygen , cooking gas , nitrogen , etc).
- Extended fire protection (standpipes).
- Compressed air .
- Decorative fountains and swimming pools .
- Irrigation system and...etc

In hospital , the design of plumbing system include all the previous systems and the details for some of them will be discussed separately in this chapter.

Section One:-

2.2 Water Supply System (Domestic water system)

Domestic water system is a comprehensive term for potable water supply system in residential ,commercial ,institutional, and industrial building . Potable water is drinking water , but is used in more quantities for operating fixtures that are used inside building.

building design needs to cold and hot water and the existence of hot water is vital for human usage . Cold water used in all fixtures which are installed in building such as lavatories, sink, shower bath and water closets(toilets),while hot water used in all fixtures too, besides to washing machines, dishwashers, except in water closet . Cold water can be heated by using solar energy by collectors and receiver or by using water heater which is usually known as boiler or geyser.

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

- (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 it should know the following:

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

2.2.1 Water and its use in hospitals

Water is very important for life , and without water there will be no life in the earth, so any building should be supplied with water for drinking , cooking , washing , cleaning and fire suppression.

2.2.2 Water properties

- The chemical composition of water is Hydrogen Oxygen(H₂O).
- In general potable water has no taste , color neither odors.
- On the contrary of other liquids , water expands when it freezes .
- When water is heated it changes its phase to vapor or steam.
- The specific heat of water is high compare to other substances ($C_p = 4.18 \text{ kJ/kg.}^\circ\text{C}$).
- The density of water = 1000 kg/m^3 .
- 70% of earth plane is covered by water , but 97% of this value is not suitable for direct use because of saltiness and being frozen .

2.2.3 Water sources

- Rain water which is the main source.
- Distilled water which is very expensive due to price increase of fuel.
- Ground water .
- Seas and rivers.

2.2.4 Water kinds

- Potable water : which is tested and corrected (treated) to be suitable for human .
- Non potable water: surface water , ground water, or collect rain water which contains some degree of impurity, this can be used for any purpose except human drinking , cooking , and bathing .
- Gray water : water discharged from dish washers , bath tubs , sinks and other fixtures.
- Black water : water containing toilets and urinals waste .
- Distilled water: pure water by using distillation it uses in laboratories , and not economical for the use in a water supply because of the high price .

2.2.5 Pipes And Fitting

Potable water supply system requires pipes to convey fluid from one location to another, while fitting some of them used to connect two or more pipes together, which are called unions , other used to control flow and pressure, which are called valves and safety valves , other used to change the direction of flow and they are called elbows and the others used to reduce the diameter of pipes and they are called reducers(*figure 2-1 shows the fittings and valves*) . It will require to supply the building by suitable and efficient type of pipe and fitting to avoid the problems which will be happened if we use incorrect type .

Pipes type

Characteristics of pipes is specified according their usage ,the pipes could be manufactured from many different materials which include iron , steel , cast iron , plastic, copper , glass , rubber , lead and concrete . The selection of the type of pipe is considerable factor in the design process of networks , and there are essential factors that related by physical principals for pipes, such as temperature , pressure ,reaction of chemical materials and coefficient of expansion . In general the iron , steal , cast iron , plastic, copper, are the most common in most applications.

From the previous, we can classify the pipes into two categories:-

- **Metal pipes**, which manufactured from different metals materials, and contains:
 1. Steel and iron pipes.
 2. Copper pipes .
 3. Stainless Steel pipes .
 4. Lead pipes .
 5. Aluminum pipes .
 6. Titanium pipes .
- **Non metal pipes** , which manufactured from different non metal materials, and contains :
 1. Plastic pipes, flexible plastic , confirm plastic (PVC, UPVC, HDPE, LDPE).
 2. Glass pipes .3- Concrete pipes

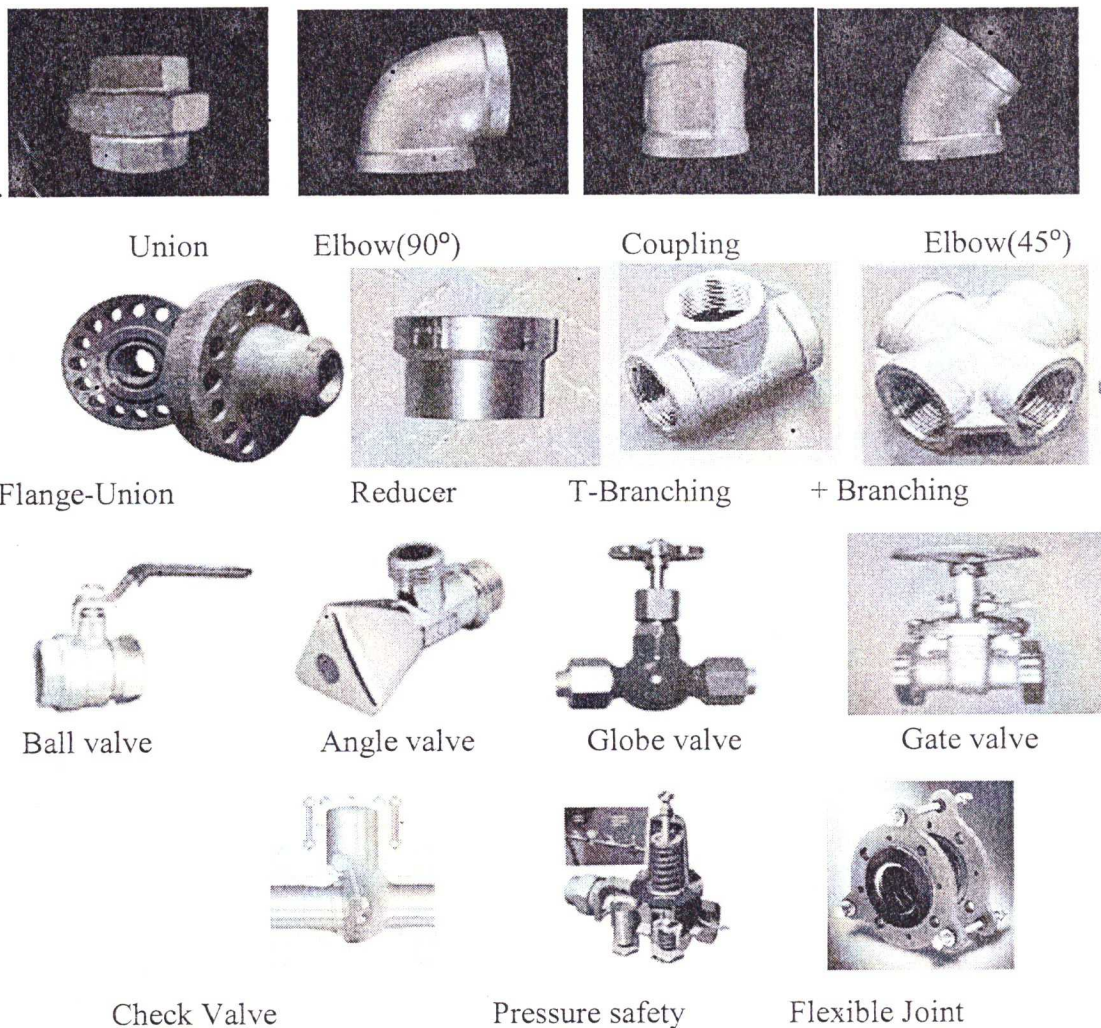


Figure (2-1) Fitting And Valves

2.2.6 Design procedure

- 1-Determine the pressure of the source, and decide whether to use the source directly , reduce the pressure or increase it.
- 2-Determine whether the structure will be treated as a single unit or whether it necessary to zone it.
- 3-Decide whether to use up feed or down feed system.
- 4-Determine the pressure and flow requirements of all fixtures and all continues water uses .
- 5-Determine maximum instantaneous water demand .
- 6-Determine the service size on the basis of maximum water requirement.
- 7- Determine minimum pipe sizes on basis of required flow rates and pressure for the water use device farthest from the service.
- 8-Decide of the method of supplying hot water. This includes hot water source and type of circulation system if any.
- 9-Determine water pipe sizes for the entire structure, pressure of hot and cold water should be equal at fixtures using both to prevent cross flow during mixing.
- 10-Design details of piping system including water service details , hot water supply details , all valving ,location of vacuum breakers , special support details and like.
- 11-Determine location of shock arresters (water hammer eliminators) and other special devices required.

2.2.7 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 it ranges from (30-60) psi. City mains larger than 80 psi can't be used directly, because it will damage the fixtures , for this reason 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) Inadequate pressure:- it is the city line pressure which is insufficient to provide the required minimum flow pressure. In the case of inadequate pressure a booster pump and pressure tank should be used.
- 2) Highest water fixture outlet in the hospital.
- 3) Minimum fixture pressure outlet.

* water velocity through piping should less than 8 fps and for sudden opening equipment such as flush valve water velocity should be around 4 fps .

At no flow condition:

Main pressure = static head

At flow condition:-

Main pressure = static head + friction head + minimum flow pressure (2-1)

static pressure :is caused by the weight of water above any point in the system [psi]

friction pressure: is caused by the carrying the water through pipes and elbows [psi]

flow pressure: is the pressure available at the fixture. [psi]

2.2.8 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 gallon 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.

2.2.9 Water pipe sizing

There are two types of water pipe sizing

1-Friction head loss

2-velocity limitations

In this project , Friction head loss method will be adopted .

Water pipe sizing by friction head loss procedures:-

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(2.1) (See in Appendix A).

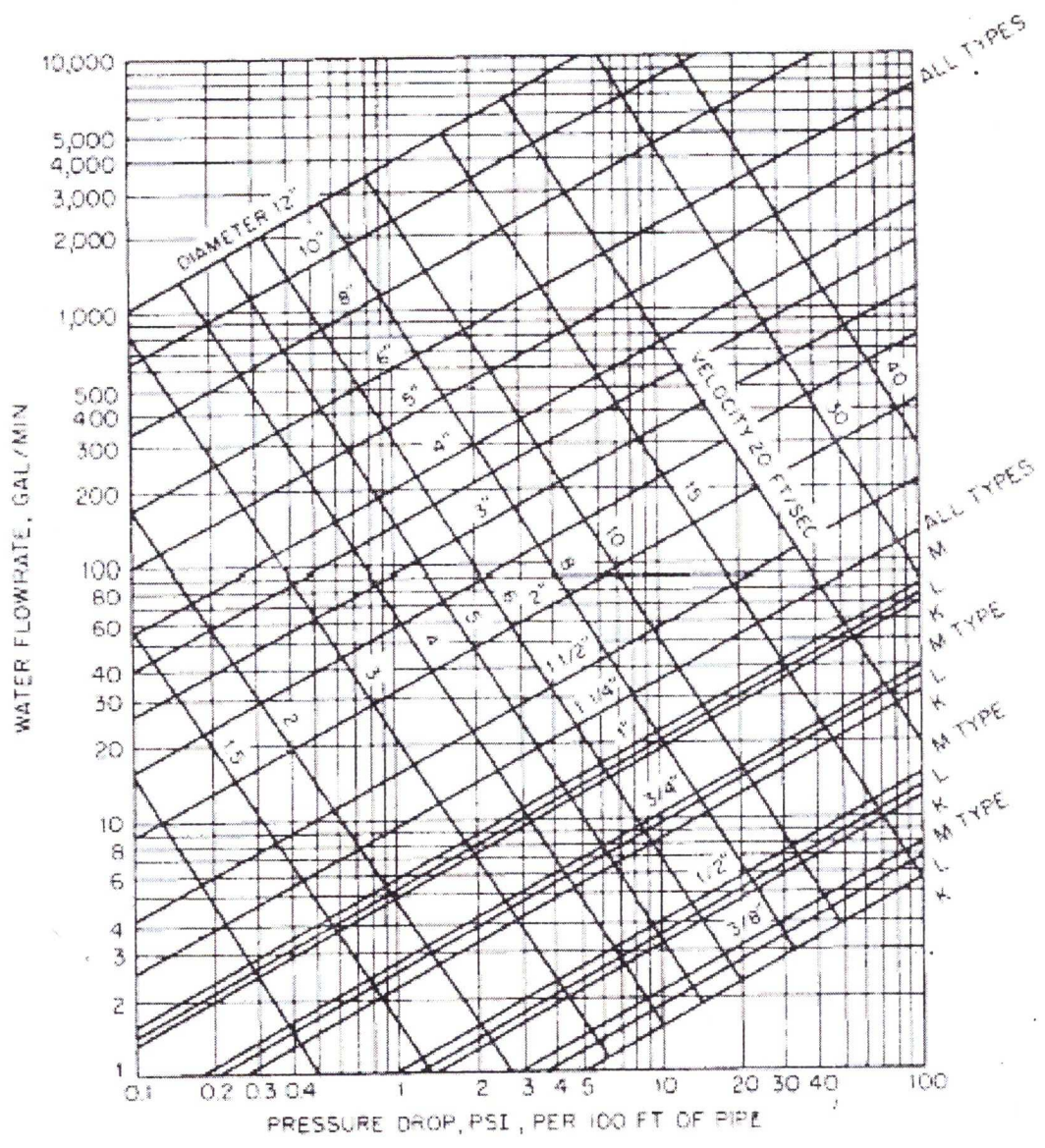
Step3: total the fixture unit in each branch of the system. Show both cold and hot water fixture units and then determine the water demand in gpm using table (2.2) (See in Appendix A).

Step4: show source pressure (minimum) and the minimum flow pressure required at the most remote outlet using table(2.2) (See in Appendix A).

Step5: Compute the equivalent length of pipe for each riser 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.

Note: - choose the pipe sizes from a chart like that in Fig.(2-2)or Fig.(2-3) or from the charts given in the plumbing charts.



Figure(2-2) chart for determination of flow in copper pipe tubing and other pipes

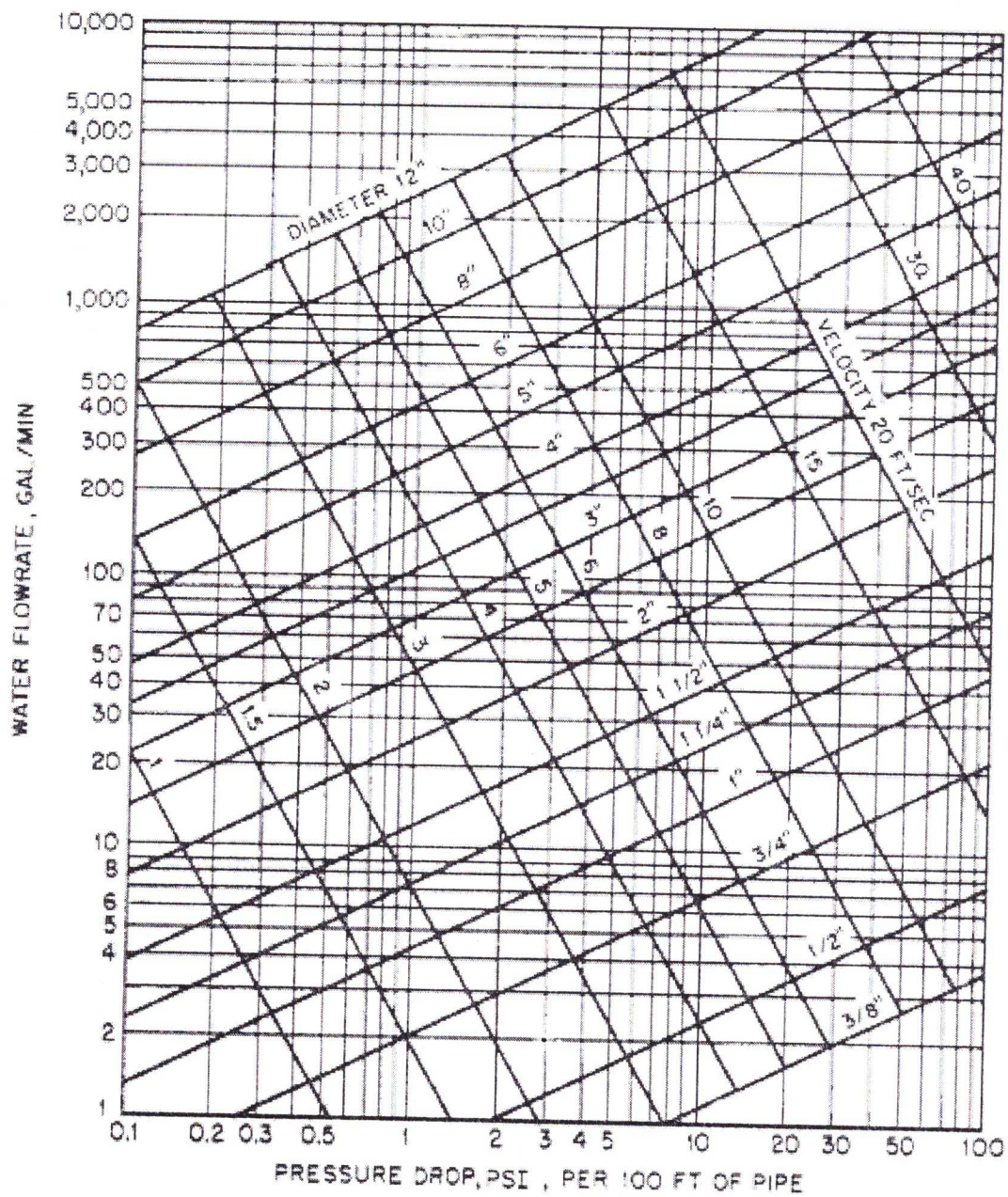


Fig (2-3) chart for determination of flow in pipes such as galvanized steel and wrought iron that will be fairly rough

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 .

2.2.10 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 2.3 lists minimum flow rates and pressures generally required at various water outlets. The pressure in table 2.3 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 8 ft / s .

Table(2.3) Required minimum flow rate and pressure during flow for fixture

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, 1/2-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

2.2.11 water supply systems

There are two basic types of water distribution systems for buildings:

1-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. Hence, in low buildings, cold water can be distributed by the up-feed method (Fig. 2-4), 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. (2-4), 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.

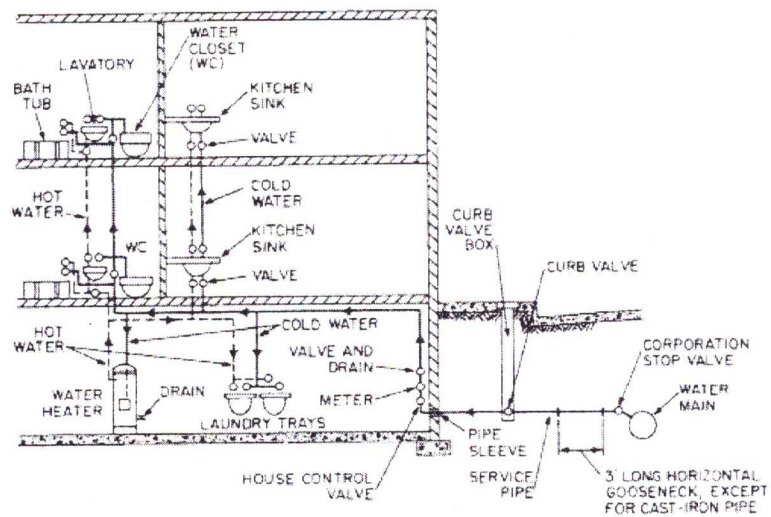


Figure (2-4) up feed system

2- 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. 2-5). Generally, also, 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(2-5) 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

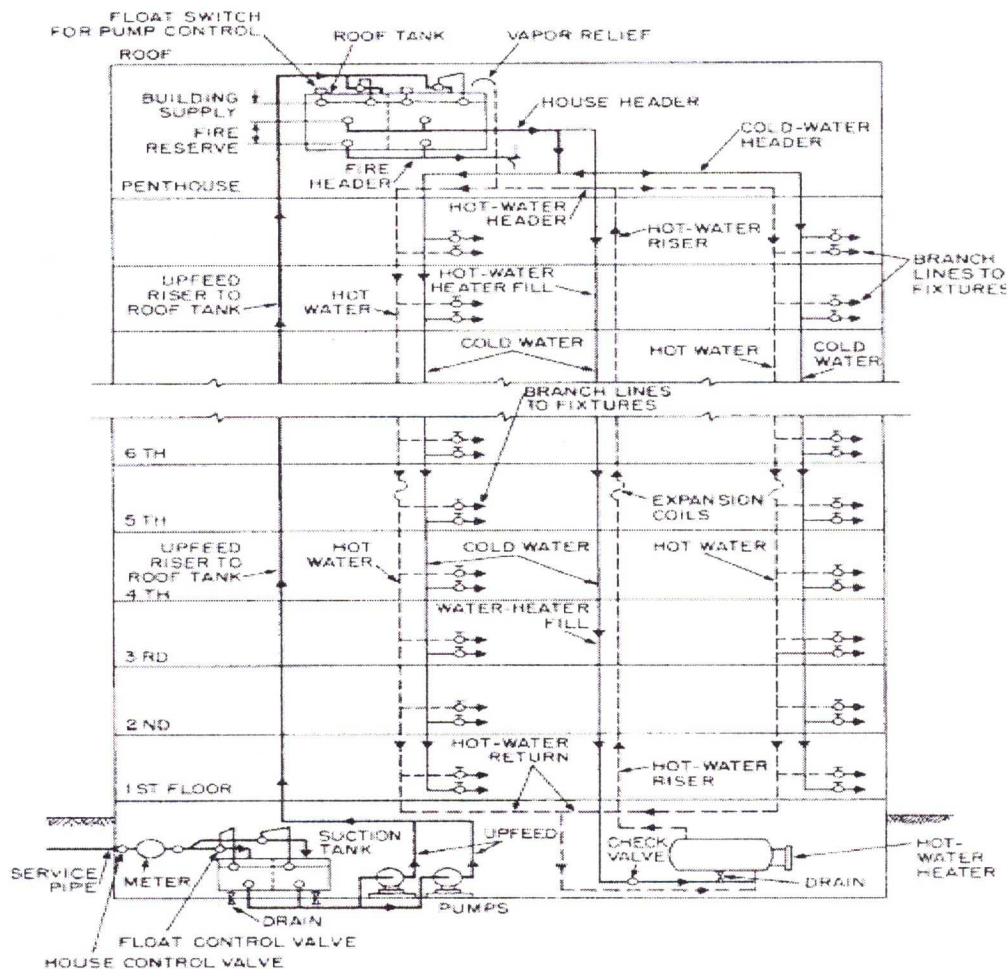


Figure (2-5) down feed system

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.(2-5).

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.

Section Two:

2.3 Sanitary Drainage and Waste Water Disposal

Its function to carries away the contaminated water and solids produced by domestic uses of water from lavatories, sinks, water closet, and other sanitary fixtures.

2.3.1 components of the drainage system

Drainage system consist from many components which will be illustrated below and appearing Obviously in the figure (2-6).

a- Drain pipe

It used to carry the waste water , and classify according to location and job as follows :-

- **Branch piping** : all horizontal drainage pipes that drain water from the fixtures to the stack. Branches are designed to run maximum 50% of it's complete fill with a recommended velocity 2 fps.
- **Stacks** :all vertical drainage pipe that drain water from branches to building pipes are

called stacks. Designed to run in the rang of 25% to 33% of fill maximum with velocity 16 fps.'

- **Soil pipe** : piping carrying effluent from water closets, urinals and bidets (black water).
- **Waste pipes** : piping carrying waste water from other fixtures (gray water).
- **Building piping:** piping connecting terminals of stacks to manhole.
- **Sewer piping** : piping between manholes.

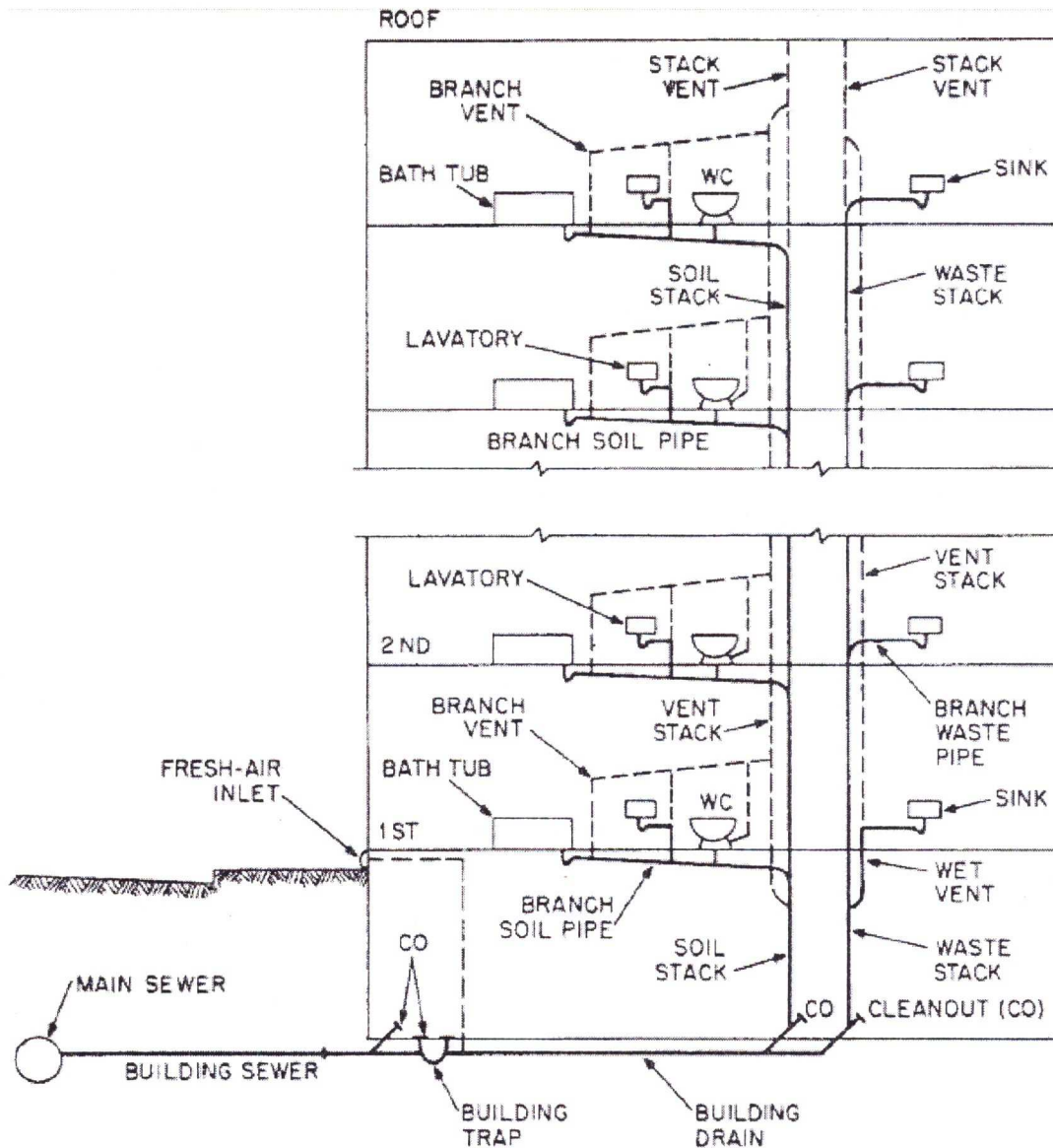


Figure (2-6) Wastewater-removal components for a multistory building

b- Traps

The basic function of the trap is to provide a water seal between the drainage

pipng that connects to the outside sewer and the fixture, this water seal prevents entry into the building of odors, sewer gas and vermin from the sewer via the fixture.

Every plumbing fixture must be trapped except for a few special cases such as fixtures with indirect (air-gap) and certain fixtures that discharge through interceptor. The only fixture that is self trapped is the water closet.

All traps operate on the principle of siphonage as water is added to the inlet end, an equal amount of water leaves the outlet end provided the pressure at both ends are approximately equal.

The maximum allowable pressure difference between inlet and outlet of the trap is (1 inch) water about (0.036 psi) , it cant be deeper because the trap will not self clean properly , it will retain foreign bodies and very soon become blocked.

There are many types of traps such as : integral trap , P - trap, drum trap, bell trap and S trap. The length of the trap arm may not exceed that shown in the table(2.4).

Table (2.4) Maximum length of the trap arm

Diameter of the trap arm (in)	Maximum trap arm (in)
1 ³ / ₄	3.5
1 ¹ / ₂	5
2	8
3	10
4	12

c-Vents

The importance of vents are:-

- Provide an air vent at each fixture trap, this ensure atmospheric pressure on the outlet side of the fixture trap (equalize the pressure at both side of the trap) so prevent the trap seal .
- Provides safe path to exhaust sewer gases and foul odors , building vent piping acts as a sewer vent in the absence of a building and street level fresh air vent.
- It fills the drainage piping with fresh air , that reduces odors , corrosion and formation of slime in piping.

There are some Rules governing vent piping and they are :-

- 1- The diameter of a vent pipe may not be less than (1 ½) or half the size of the drain pipe that it vents, which ever is large.
- 2- A relief vent may not be less than half the size of the drain pipe to which it is connected.
- 3- When fixtures other than water closets discharge down stream from a water closet in to a fixture shall be individually vented, this procedure called re-venting.

2.3.2 Hydraulics of gravity flow

Unlike water piping that flows fill in the pipe and under pressure , drainage flows at zero pressure and only partially full, the flow caused by gravity due to the slope of all drainage piping. For a given type of a pipe (friction) the variables in drainage flow are slope and depth of liquid.

When these two factors are known the flow velocity and flow quantity can be calculated, because the calculations are complex ,that required in plumbing design.

The code requires that horizontal drainage piping be installed with a uniform slope of not less than:

¼ inch/ ft (1.8%) for piping diameter less or equal 3 inch

1/8 inch/ft (1%) for piping diameter greater or equal 4 inch

The reason that large pipes can be installed at a less slope than small pipes is The greater diameter pipe has greater flow velocity, so it required less slope than small diameter pipe.

Horizontal branch drain are designed to run at a max(50%) fill.

- Stacks are designed to run at a max(25-30%) fill.
- Building drains and sewer drain may run at some what higher (over 50%) fill.

The flow in vertical pipes (stacks) depends on:-

a-pipe size.

b-Amount of fluid (flow rate).

c-Velocity.

d-Direction of the fluid entering the stack.

f-Pipe wall friction (roughness of the pipe wall)

At the base of a stack with a sharp 90 bend, waste water undergoes a rapid change in velocity . Within 10 stack pipe diameter, a horizontal jump occurs in which the water plies up causing large pressure variation , this condition can be avoided by using long radius elbows, or large horizontal drain , or additional vents.

2.3.3 Procedure of drainage piping sizing

Note :all tables required for this process are exist at appendix A.

Step 1 : Draw isometric of the entire system showing all fixtures.

Step 2: Assign drainage fixtures units to each fixture according to table (2.5) , if a fixture is not listed specifically , base the drainage fixture unit (dfu) requirements on its trap size. Minimum fixture trap sizes are listed in table (2.6).With respect to drainage requirements not due to fixture , such as non-recirculated cooling water or process water, use the conversion of (1gpm = 2 dfu) .

Step 3: Total the drainage fixture units in each drainage pipe and mark them on the drawing.

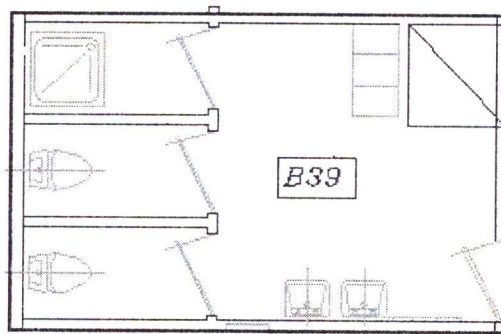
Step 4: Determine the required size of the horizontal fixture branches and stacks from table(2.7).

Step 5 : Determine the size and the slope of the building drain and its branches, and the building sewer using table (2.8).

Step 6:- Determine the size and slope found in step 5 meet the requirements of the code and of table (2.9). *Table(2-5)-Table(2-9)see AppendixA.*

2.3.4 A sample for design

As a calculation example, room B39, will be taken to explain design Procedure as following:-



Figure(2-7)bathroom #39 In base floor

From the above figure there is two water closet , two lavatories, and one shower

From table (2.5) the dfu for general WC is 6 dfu, and for lavatory is 1 dfu and for Shower is 2 dfu .

$$\text{Total dfu} = 2*6 + 2*1 + 2 = 16 \text{ dfu}$$

Since each 1 gpm = 2dfu, then total drainage rate is $16*0.5=8\text{gpm}$

Using table (2.7) , the horizontal branch diameter is 3 in. and the stack is 2.5 in. but in stack diameter should be at least equal to the branch that supplies it, so stack diameter is 3 in.

For building drain diameter is 4 in. from table(2.8) with slope 1%from table(2.9).

2.3.5 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 60 cm and then we calculate the height of the other manholes depending on the distance between manholes and the slope of drainage pipes between manholes 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.

Figure (2-8) in appendix A , show manhole.

Manholes are considered as clean-outs ,they are recommended to be installed around buildings, when there is an exterior drainage pipe from building, and on every edge of building , and the maximum horizontal distance between two manholes are not increases to 12 m , because after this distance there is a problem in the cleaning the manholes if there is difficulty in drain for example that request cleaning .

Some times there is high difference at the levels of ground when the manholes network are designed , that will make problems such as , increasing the pressure of drainage water when it transfer from ordinary level to deep one , also we hearing high voice for drainage water , and the small dirty that will collect in the wall of manhole and with time odors appear around building , and this is not healthy for occupants . In this case problems could be solved by using drop manhole, see *figure (2-9)* in appendix A show drop manhole .

It is preferable to separate drainage water (water from sinks , lavatories , showers and water from cleaning) about waste water(from water closet, urinals) by using two networks of manholes , in this case drainage manholes network lead drainage water to drainage water tank , and waste water to septic tank .

2.3.6 Septic Tank

Septic tank is a large hole that receives the wastewater from all sewer pipes and drains and the capacity of septic tank will be calculated after the drainage fixture units are calculated according to all fixtures were installed in hospital

Section Three:-

2.4 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.2-10 a), 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.2-10b) and parapet drains are available for different roof constructions and storm-water conditions.

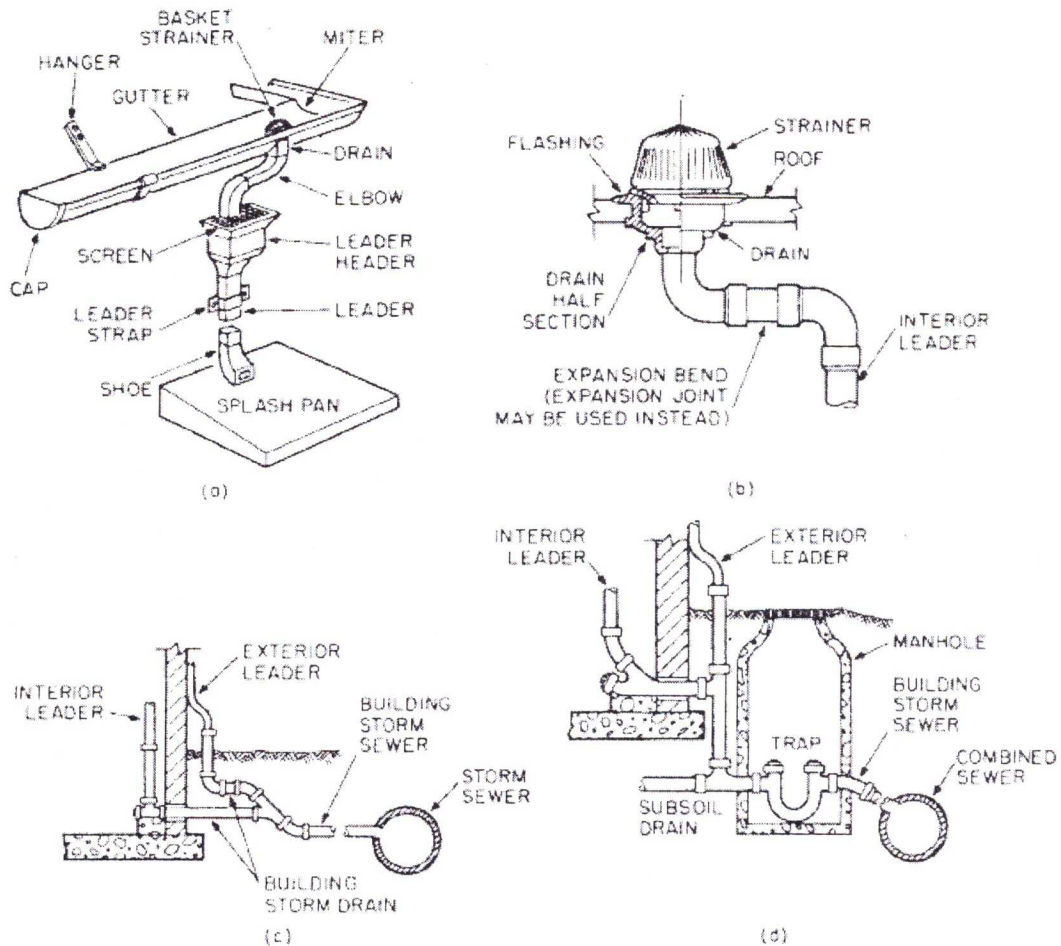


Figure (2-10) Elements of a storm-drainage system: (a) roof gutter, exterior leader, and splash pan; (b) roof drain and top portion of interior leader; (c) piping to a storm sewer; (d) piping to a combined sewer.

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 (2-10c) 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 Figure(2-10d)

Sizes of vertical leaders and horizontal storm drains depend on the roof area to be drained. Table(2.10) 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(2.11)shows how gutter capacity varies with diameter and pitch.

Table(2.10) Sizes of Vertical Leaders and Horizontal Drains

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					
	¼ 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(2.11) Sizes of Semicircular Roof Gutters

Gutter diameter, in	Maximum projected roof area, ft ² , and flow, gal/ min, for gutters of various slopes							
	1/8 in per ft slope		1/8 in per ft slope		1/4 in per ft slope		1/2 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

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 .

CHAPTER THREE

**COMFORT CONDITIONS AND HEAT TRANSFER
THROUGH BUILDING**

3.1 Heat and human comfort

The HVAC indoor design requirements are chosen to meet human body needs under the specific occupancy conditions of a space. In order to understand the basis of these conditions it is first necessary to understand the fundamentals of body temperature control and the physical principle of heat transfer.

3.1.1 Body temperature control

Human beings are constant-temperature (warm-blooded) creatures with a normal deep body temperature of 37 °C. We emphasize that this is an internal temperature because the external (skin) temperature can vary from a low of about 4.4 °C to a high of about 41.1 °C. These external can be maintained for a limited time without physiological damage. Indeed wide variation in skin temperature is one of the techniques used by body's highly sophisticated automatic temperature control system to regulate heat transfer to the environment.

The amount of heat generated by the body depends on the type of personal activity, this heat or energy is produced by metabolizing the food we eat there for referred to as the body metabolic rate. The entire process is known as metabolism. The body is only about 20% efficient in converting food to muscular energy, the other 80% is converted to heat that must be disposed of continuously to avoid overheating the body. The body disposes of heat by one or more of the four physical processes for heat transfer and exchange: conduction, convection, radiation and evaporation.

3.1.2 Body Heat Balance

The normal body temperature is 37.2 °C which is in most cases higher than the ambient temperature thus heat is continuously transferred from humans to their ambient air by virtue of this difference in temperature. For body thermal equilibrium to be maintained heat must be produced within the body in amount equal to the heat loss by the body. Metabolism is the biological process by which body cells generate heat from consumed food. The efficiency of this transformation is about 20%, the amount of heat produced by human body depends on the number of cells of the body.

Thus large animals produce more heat than can be dissipated through their limited skin area. Therefore they need to live near water to dip in and cool their bodies.

The metabolic rate (M) varies from one to another depending on age, sex, and type of activities, where the values of metabolic rate takes from special tables according to the type of activity, and could be calculated by using this equation:

$$M - P = E + R + C + S \quad (3-1)$$

Where, P is the power output of the individual, E is the rate of heat dissipated by evaporation from the body, R is the rate of heat dissipated by radiation from the body, C is the rate of heat dissipated by convection, and S is stored or the residual thermal power.

3.1.3 Heat and temperature

Heat is a form of energy. Temperature is simply an arbitrary scale invented in order to indicate the intensity of heat energy contained in an object. Many units are used to scale temperature such as, Fahrenheit and Celsius. Also the units of heat energy vary according to system used for example Watt (W) or British Thermal Unit (BTU).

3.1.4 Sensible heat and Latent heat

Sensible heat is the heat which causes a change in temperature when it is added or removed. *Latent heat* is that which causes a change of state or phase in the substance while the temperature remains constant.

3.1.5 Properties of atmospheric air

In order to figure out human comfort conditions we must first figure out the basic properties of atmospheric air which surrounds the body at all times. The study of the physical properties and thermal processes of atmospheric air is called Psychometrics, and the properties are:-

a-Dry Bulb(db) Temperature

The dry air is complex mixture of several gases such as Nitrogen(78%), Oxygen(21%), Carbon dioxide and other gases(1%) such as Argon, Carbon monoxide and Neon. It does not contain water vapor. The dry bulb temperature is the air temperature that is measured by a thermometer . This value indicate to the air temperature without wet or moisture.

b-specific and relative humidity

The amount of water vapor in the air can be specified in various ways. Probably the most logical way is to specify directly the mass of water vapor present in a unit mass of dry air. This called absolute or specific humidity or humidity ratio and is denoted by w .

$$w = \frac{m_v}{m_a} \quad (\text{kg water vapor/kg dry air}) \quad (3-2)$$

The amount of moisture in the air has a definite effect on how comfortable we feel in an environment. However, the comfort levels depends on more on the amount of moisture the air holds(m_v) relative to the maximum amount of moisture the air holds the same temperature (m_g) . the ratio of these two quantities is called the relative humidity(ϕ), and its value ranges from 0 to 1 for saturated air.

$$\phi = \frac{m_v}{m_g} \quad (3-3)$$

c-Wet Bulb Temperature(wb)

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

d-Dew-point temperature

The dew point temperature is the saturation temperature corresponding to the partial pressure of the water vapor in the surrounding air . when the dew-point water vapor in the surrounding air. When the dew point temperature is reached condensation start as the moist air is cooled at constant pressure. Further cooling results in more

condensation of water vapor. Moreover, the dew point temperature or below the air said to be saturated because the air is mixed with the maximum possible amount of water vapor.

According to the previous information about the body temperature control and the physical principles of heat transfer , we shall illustrate the ASHRAE comfort criteria.

3.1.6 ASHRAE comfort chart

ASHRAE is an abbreviation for the American Society of Heating Refrigerating and Air-conditioning Engineers. There is no rigid rule that indicates the best atmospheric condition for comfort for all individuals. This is because human comfort is affected by several factors such as health, age, activity, clothing, sex, food, etc.

Comfort condition are obtained as a result of tests for which people are subjected to air at various combinations of temperature and relative humidities. The result of such test indicate that a person will feel just about as cool at 24 °C and 60% RH as at 26 °C and 30%RH . Studies conducted by ASHRAE with relative humidity between (30%-70%)indicated that 98% of people feel comfort when the temperature and relative humidity combination fall in a comfort zones such as that indicated in figure(3.1) below.

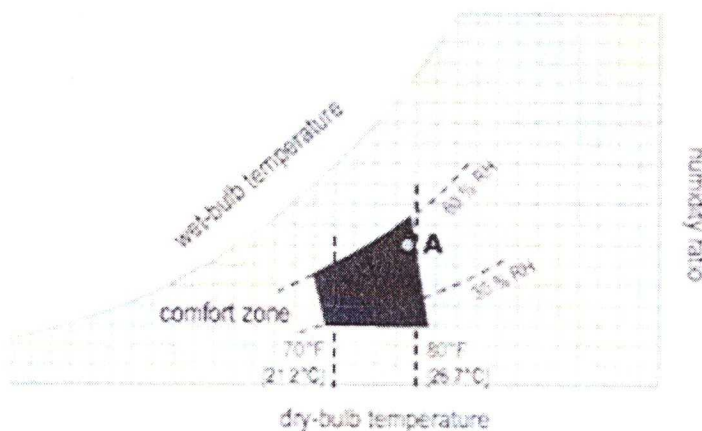


Figure (3-1) comfort zone for operating temperature and relative humidity

3.1.7 Thermal comfort criteria for inside design condition

The inside design conditions refer to temperature, humidity, air speed and quality of inside air that will induce comfort to occupants of the space at minimum energy consumption. There are several factor that control the selection of the inside design conditions and expenditure of energy to maintain those conditions:-

- 1-The outside design conditions.
- 2-The period occupancy of the conditioned space.
- 3-the level of activity of the occupants in the conditioned space.
- 4-the type of building construction and it`s use .

Usually the range of temperature difference between inside and outside is from 4 to 11 °C. Relative humidity range for the conditioned space varies from 30% to 60%.air velocity inside conditioned space it is desirable to keep it within the range of 0.1 to 0.35 m/s for comfort. A dry environment will be felt when the relative humidity falls below 30% and sickness will be felt at relative humidity above 60% .

When the inside design condition for a certain application are selected cost and energy (fuel, electricity ,etc) should be taken into consideration.

3.1.8 Comfort conditions inside hospital

All calculations (heating and cooling loads) will be made according to specified values for inside conditions of hospital design in the table (3.1) below refer to dry bulb temperature and relative humidity in both summer and winter seasons .

Table (3.1)Recommended inside design conditions for summer and winter*

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

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

Room or Area	Summer		Winter	
	Db Degrees °C (Degrees F)	RH %	Db Degrees °C (Degrees F)	RH %
Motor Vehicle Maintenance/Storage	Ventilation Only		21 (70)	--
MRI Units	24 (76)	50	25 (78)	30
Offices, Conference Rooms	25 (78)	50	22 (72)	30
Operating Rooms (O.R.s)	17-27 (62-80)	45-55	17-27 (62-80)	45-55
Operating Rooms (O.R.s) - Animal	22 (73)	50	22 (73)	50
Patient Rooms	24 (76)	50	25 (78)	30
Pharmacy	22 (72)	50	22 (72)	30
Radiation Therapy	24 (76)	50	25 (78)	30
Recovery Units	23 (75)	50	23 (75)	30
Smoking Area	25 (78)	50	22 (72)	30
SPECIAL PROCEDURE ROOMS*				
Bronchoscopy ■	24 (76)	50	25 (78)	30
Cardiac Catheterization ■	17-27 (62-80)	45-55	17-27 (62-80)	45-55
Colonoscopy/EGD ■	24 (76)	50	25 (78)	30
Cystoscopy ■	22 (72)	50	25 (78)	50
Endoscopy ■	24 (76)	50	25 (78)	30
Fluoroscopy ■	24 (76)	50	25 (78)	30
GI (Gastrointestinal) ■	24 (76)	50	25 (78)	30
Proctoscopy ■	24 (76)	50	25 (78)	30
Sigmoidoscopy ■	24 (76)	50	25 (78)	30
Spinal Cord Injury Units (SCIUs)	22 (72)	50	27 (82)	30
Supply Processing Distribution (SPD)	24 (76)	50	22 (72)	30
Ethylene Oxide (ETO) MERS ■	Ventilation only			
Steam Sterilizer MERS ■	Ventilation only			
Telephone Equipment Rooms	19(65)-23(75)	40-60	19(65)-23(75)	40-60
Therapeutic Pools	26(80)-29(85)	--	29 (85)	--
Transformer Rooms	39 (104)	(Maximum)		

Room or Area	Summer		Winter	
	Db Degrees °C (Degrees F)	RH %	Db Degrees °C (Degrees F)	RH %
Treatment Rooms	24 (76)	50	25 (78)	30
Warehouses	Ventilation Only		15 (60)	--

* was collected from "ASHRAE" books

3.1.9 Outside design conditions for Hebron city

The outside conditions due to dry bulb temperature , relative humidity(R.H) ,and wind speed are tabulated in below table (3.2), according to Palestinian code for Hebron city.

Table(3.2)outside conditions for Hebron city*

condition	summer		winter	
	Max. Value	Min. value	Max. Value	Min. value
Dry Bulb(°C)	37	19	13	4
R.H (%)	57	44	72	62
Wind Speed(m/s)	1.4		1.4	

* According to Palestinian code for Hebron city.

3.2 Heat Transfer In Building

Heat transfer is the transient flow of thermal energy from one system to another due to temperature difference between two system . There are three modes of heat transfer : Convection, Radiation, and Conduction. In most real life cases, the effect one mode dominates the other two . Each one of these modes is considered in detail in the following:-

1-Convection Heat Transfer

In this mode of heat transfer, heat is transferred from one system to another by means of moving fluid such as air or water. If the fluid is forced to move by fan or pump, then the convection process is called forced convection, otherwise called free

convection. The general equation for heat transfer by convection is given by the following relationship, which is known as Newton's Law of cooling.

$$\dot{Q} = h.A.(T_w - T_f) \quad (3 - 4)$$

Where \dot{Q} is the rate of heat transfer by convection, A is the heat transfer surface area, h is the convection heat transfer coefficient, or film conductance, T_w is the wall surface temperature, and T_f is the temperature of the fluid.

2- Radiation Heat Transfer

Heat transfer by convection and conduction require a medium for their existence, heat transfer by radiation can take place in complete vacuum. It is an electromagnetic radiation which is the same nature as solar radiation. The net heat exchange by radiation between two bodies is given by this equation:

$$\dot{Q}_r = \sigma.A_1.F_{1-2} \cdot \varepsilon (T_1^4 - T_2^4) \quad (3 - 5)$$

Where σ is the Stefan-Boltzmann constant. It equals to $5.669 \times 10^{-8} \text{W/m}^2\text{K}^4$, A_1 is the surface area of a body 1, F_{1-2} is the view or shape factor, which indicates the fraction of thermal energy leaving body 1 and reaching body 2, ε is the equivalent emissivity of the two objects, T_1 and T_2 are the absolute temperature of two bodies.

3-Conduction Heat Transfer

In conduction mode of heat transfer the system are in physical contact and heat is transferred from one molecule to the adjacent one. The heat transfer by conduction evaluated by using Fourier's equation of conduction as follows:

$$\dot{Q}_c = A \cdot \frac{k}{x} \cdot (T_1 - T_2) \quad (3- 6)$$

Where k is the thermal conductivity ($\text{W/m} \cdot ^\circ\text{C}$) of the material through which conduction takes place, x is the distance separating the two surfaces in meter, whose temperatures are T_1 and T_2 .

Thermal resistance due to conduction ($R_{\text{cond.}}$) $\text{m}^2 \cdot ^\circ\text{C}/\text{W}$ is define as follows:

$$R_{\text{cond.}} = \frac{x}{k} \quad (3 - 7)$$

For a wall composite from varies material, then the thermal resistance will be

$$R_{\text{cond.}} = \frac{x_1}{k_1} + \frac{x_2}{k_2} + \dots + \frac{x_n}{k_n} \quad (3-8)$$

In addition to the conduction thermal resistance of the various layers of the composite wall, the air in contact with the outside and inside surface of the wall from stagnant thin layers of the air adjacent to these surfaces so, the resistance of air layer given by $1/h$ where h is the air film heat transfer coefficient, the thermal resistance now be

$$R_{\text{th}} = R_o + \sum_{j=1}^n (R_{\text{cond.}})_j + R_i \quad (3-9)$$

$$R_i = 1/h_i, R_o = 1/h_o \quad (3-10)$$

Where i, o indicate to inside and outside respectively, and the eq.(3-8) could be written as:

$$\sum_{j=1}^n (R_{\text{cond.}})_j = R_1 + R_2 + \dots + R_n. \quad (3-11)$$

The overall heat transfer coefficient of the wall (U) is defined as follows:

$$U = \frac{1}{\sum R_{\text{th}}} \quad (3-12)$$

And the unit of U is $W/m^2 \cdot ^\circ C$. Then the final form of the Fourier's equation in conduction to be :

$$\dot{Q} = U.A.(T_i - T_o) \quad (3-13)$$

The previous equation is considered the important one for calculating thermal load besides other equation, according to the value of U for different material and the area of aspect that desired to calculate thermal load through it in addition to the temperature difference between inlet and outlet condition for the same aspect.

3.2.1 Basic Rules Of Thermodynamics

In all HVAC-work it is important to take into account several basic rules of thermodynamics such as:-

*Energy can be neither created nor destroyed and this rule is variously known as the law of conservation of energy. To the HVAC technologist it simply means that when heat transferred again in one place is balanced by an equal and opposite loss in another place, sensible heat can be converted to latent heat by evaporation and latent heat can be converted to sensible heat by condensation in other words the net change

of energy in a system is the difference between the energy added and the energy removed.

*Heat Flows (Downhill) Heat flows from an area or object of higher temperature to an area or object of lower temperature, heat transferred by temperature difference. In general the larger the temperature difference, the more rapid is the heat transfer.

*There Is No 100% Efficient Thermal Process. This is the essential meaning of the second law of thermodynamic. Energy heat transfer involves losses in the form of wasted heat . Two of the factors that increase losses, are large temperature difference and friction.

3.2.2 Calculation of The overall heat transfer coefficient(U)

Note :- all values of thermal conductivity and thermal resistance are taken from Heating and Air Conditioning book(for Mohammed A. Alsaad)

1-For outside walls:

The hospital-wall consist of the following materials as shown in the figure (3.2)and the

Table (3.3): overall heat transfer coefficient for the walls			
Material	k [W/m. ^o C]	x [m]	R_{th} [m ² . ^o C/W]
Outside air film	--	--	0.060
(1) Stone	1.53	0.06	0.039
(2) Concrete	1.75	0.20	0.1142
(3) Insulation(polyst.)	0.034	0.02	0.58
(4) Cement brick	1	0.07	0.07
(5) Plaster	1.2	0.02	0.0167
Inside Air film	--	--	0.120
$U = 0.992$ [W/m ² . ^o C]			

Figure(3-2) Wall Construction

values of thermal conductivity(k), thickness of wall(x), thermal resistance (R) are tabulated in the previous table (3.3). U could be calculated by using equation (3-13).

2-For ceiling

Ceiling constructs from the materials as in the figure (3-3).

Table (3.4): Overall heat transfer coefficient for the ceiling				Ceiling construction
Material	k [W/m ⁰ C]	x [m]	R_{th} [m ² °C/W]	
Outside air film	--	--	0.04	
(1) Mix asphalt	0.70	0.02	0.028	
(2) Reinforced concrete	1.75	0.10	0.029	
(3) Hollow block	0.95	0.17	0.179	
(4) Plaster	1.2	0.02	0.017	
Inside Air film	--	--	0.10	
$U = 2.38$ [W/m ² °C]				

3- For the floor

Floor constructs from the materials as in the figure (3-4).

Table 3.5: overall heat transfer coefficient for the floor				Floor construction
Material	k [W/m ⁰ C]	x [m]	R_{th} [m ² °C/W]	
Outside air film	--	--	
(1) Tiles	1.10	0.02	0.018	
(2) Mortar	1.20	0.02	0.017	
(3) Sand	0.70	0.10	0.143	
(4) Concrete	1.75	0.12	0.069	
(5) Rocks	1.05	0.5	0.476	
Inside Air film	--	--	0.15	
$U = 1.146$ [W/m ² °C]				

4-For inside wall

Inside wall constructs from the materials as shown in the figure(3-5).

Table (3.6): overall heat transfer coefficient for inside walls				Inside wall construction
Material	k [W/m ⁰ C]	x [m]	R_{th} [m ² °C/W]	
Inside air film	--	--	0.12	
(1) Plaster	1.2	0.02	0.017	
(2) Hollow block	0.95	0.10	0.105	
(3) Plaster	1.2	0.02	0.017	
Inside Air film	--	--	0.120	
$U = 2.64$ [W/m ² °C]				

Example explain the calculation of overall heat transfer.

For inside wall:

$$R_{th} = R_o + \sum_{j=1}^{n} (R_{cond.})_j + \quad (3-9)$$

$$R_{cond.} = +x_1/k_1 + x_2/k_2 + x_3/k_3 + \quad (3-8)$$

$$= 0.12 + 0.02/1.20 + 0.10/0.95 + 0.02/1.20 + 0.12$$

$$= 0.378 \text{ m}^2 \cdot ^\circ\text{C}/\text{W}$$

$$U = \frac{1}{\sum R_{th}} \quad (3-12)$$

$$U = 1/0.378 = 2.64 \text{ W/m}^2 \cdot ^\circ\text{C}$$

Now it will be summarize the overall heat transfer for all hospital structures in the following table (3.7) .

Table (3.7) Overall heat transfer for all structure of hospital.

Structure	$U(\text{W/m}^2 \cdot ^\circ\text{C})$
Outside wall	0.992
Inside wall	2.64
Ceiling of base floor	1.457
Ceiling of ground floor	1.457
Ceiling of first floor	2.38
Floor	1.146
Windows(double glass)with AL frame	3.2
(single glass) with AL frame	5.6
Wood door(35mm thickness)	3.1
Steal door	5.8

3.2.3 Heat loss from walls and floors below grade

The heat loss through basement walls and floors below grade depend on the value of overall heat transfer coefficient U , for all surfaces in contact with the soil and the temperature difference between the inside air and the ground .The overall heat transfer coefficient depends on the wall or floor depth below grade, and on thermal conductivity of the soil and the inside air film resistance . U for walls and floors below grade is given in the tables (3.8),(3.9) respectively .

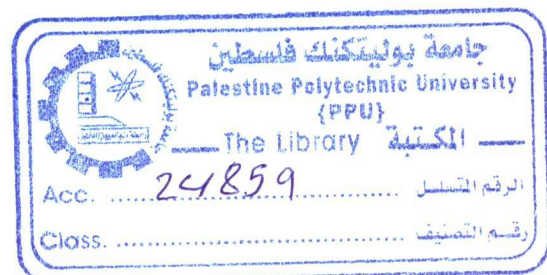
Table (3.8) Overall heat transfer coefficient (U_w) for basement walls below grade

Depth Below Grade(m)	$U_w (W/m^2 \cdot ^\circ C)$			
	Uninsulated	Insulation Resistance ($m^2 \cdot ^\circ C/W$)		
		0.715	1.430	2.145
0.0-0.3	2.328	0.863	0.528	0.380
0.3-0.6	1.261	0.559	0.449	0.335
0.6-0.9	0.880	0.534	0.386	0.301
0.9-1.2	0.676	0.449	0.341	0.273
1.2-1.5	0.545	0.392	0.301	0.250
1.5-1.8	0.449	0.341	0.273	0.227
1.8-2.1	0.392	0.307	0.250	0.210

Table(3.9) Overall heat transfer coefficient U_f , for basement floors below grade($W/m^2 \cdot ^\circ C$)

Depth Below Grade(m)	Narrowest width of the house(m).			
	6.1	3.7	8.5	9.8
	0.198	0.182	0.153	0.136
	0.182	0.165	0.148	0.131
	0.170	0.153	0.142	0.125
	0.165	0.148	0.131	0.119

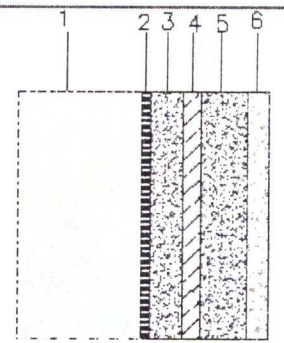
The temperature difference ΔT , which must be used when calculating the heat transfer through the below grade walls and floors is the inside design temperature T_i , minus the ground temperature T_g . Ground temperature is equal ambient temperature plus 5 to 10°C for moderate climate.



The hospital-wall below grade consist of the following materials as shown in the figure (3-6).

Table (3.10): overall heat transfer coefficient for the B/G

Material	k [W/m. ⁰ C]	x [m]	R_{th} [m ² . ⁰ C/W]
Outside air film	--	--	0.0
(1) Gravel	1.5	0.50	0.333
(2) Asphalt	1.1	0.002	0.002
(3) Concrete	1.75	0.10	0.057
(4) insulation	0.035	0.05	1.43
(5) Concrete	1.75	0.35	0.2
(6)plaster+Rin	1.2	0.0.2	0.017+0.120
$U = 0.463$ [W/m ² . ⁰ C]			



Figure(3-6) Wall B/G Construction

CHAPTER FOUR

HEATING VENTILATING AND AIR CONDITIONING

4.1 Introduction

Many of our homes and most offices and commercial facilities would not be comfortable without year-round control of the indoor environment .The "luxury label" attached to air conditioning in earlier decades has given way to appreciation of its practicality in making our lives healthier and more productive. Along with rapid development in improving human comfort came the realization that goods could be produced better, faster, and more economically in a properly controlled environment. In fact many goods today could not be produced if the temperature, humidity and air quality were not controlled within very narrow limits.

In hospitals room mechanical design also required good controlling for indoor climate to satisfying the comfort and healthy conditions for patients . This will happened by using special devices called Heating Ventilating and Air Conditioning systems(HVAC).

4.2 History of HVAC

In the early 20th century, Willis Carrier, discovered the "dew point control" an air conditioning unit based on the principle that cooled air reaches saturation and loses moisture through condensation . Carrier also discovered a system where in conditioned air was fed from the ceiling and exhausted at floor level . The first fully air conditioning office building , the Milam building in San Antonio, Texas U.S., was constructed in the late 1920s.

In the early 1930s an important step was occurred ,which is the development of highly efficient refrigerant gases of low toxicity known as Freon (carbon compound containing fluorine and chlorine or bromine). By the middle of that decade American railways had installed small air conditioning unit on their trains, and by 1950 compact units had become more common in the modern world. The system still improve and many technology entering to this system until now .

4.3 HVAC purpose

The basic purpose of HVAC system design in building and other applications is to provide a comfortable climate throughout the year since outdoor temperature and other climate factors vary widely with the season, it is apparent that the HVAC system must be dynamic to compensate for these changes . Similarly , the indoor comfort needs of occupant very greatly depending on the type of space occupancy. A residential , laboratory ,manufacturing application, hospitals and vehicles have widely different requirements which the HVAC system must satisfy to provide the conditions that will permit the space to be used as intended .

HVAC system could be called upon to do any or all of the following:-

- Maintain a uniformly warm indoor temperature in cold weather and maintain a uniformly cool indoor temperature during hot weather.
- Add humidity to the indoor air in winter and reduce it in summer.
- Assure that interior wall surfaces in winter will not have a chilling effect on nearby occupants.
- Recirculation interior air and filter out air-borne dust .
- Control the velocity of the recirculated air ; it should be first enough to provide freshness and slow enough to avoid drafts.
- Exhaust odor-laden air from rooms such as, kitchens , toilets and laboratories.

4.4 Heating System

In the hospital design, it should supply it by source of heating until to compensate the heat losses to satisfy comfort condition for occupants in the cold months.

Many systems are used for this purpose, such as heating by hot water (hydraulic system) or heating by warm air(duct system) and some time small heaters are used for this purpose but this method rarely used . And there are many criteria that will taken in the consideration to select the suitable system such as efficiency, flexibility, cost, installation, and the type of buildings.

4.4.1 Heating Load

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

1-Heat loss through all exposed walls, ceiling, floor, windows, doors, and walls between the space and an unheated space, and *equation (3-13)* will be used to calculate this load.

2-Heat load required to warm outside air infiltrated through cracks (clearances) of windows and doors, and air infiltrated due to opening and closing of doors . Equations used to calculate this type of load will be explained later.

3-Domestic hot water load.(If the system used for heating is central heating system).

4-Miscellaneous loads such as safety factor heat load , by multiplying the total load by factor as safety and will equal 10%.

4.4.2 Heat Loss By Infiltration

Infiltration is the leakage of outside air through cracks around the windows and doors, and due to door opening. The amount of air infiltrated depends mainly on the tightness of the windows and doors and on the outside wind velocity or the pressure difference between the outside and inside of the room .

The total heat load due to infiltration consists of two parts:

a-Sensible heat load , is the heat which raises the temperature of the moist air .

b-Latent heat load , is the heat associated with the evaporation or condensation of water vapor at the same temperature.

The sensible heat load $\dot{Q}_{s.f}$, due to infiltration is given by the following equation:

$$\dot{Q}_{s.f} = \dot{m}_f C_p (T_i - T_o) \quad (4-1)$$

Or,

$$\dot{Q}_{s.f} = \rho_o \dot{V}_f C_p (T_i - T_o) \quad (4-2)$$

Where , \dot{m}_f is the mass flow rate of infiltrated outside air , C_p is its specific heat at constant pressure and is equal to 1000 J/ kg.K , T_i and T_o are the inside and outside temperature of infiltrated air respectively , \dot{V}_f is the volumetric flow rate of infiltrated air (m^3/h) , ρ_o is the density of infiltrated air , and is taken as 1.25 kg / m^3

The total heat load $\dot{Q}_{t.f}$, due to infiltration is given by the equation.

$$\dot{Q}_{t.f} = \dot{m}_f (h_i - h_o) \quad (4-3)$$

Where, h_i and h_o are the inside and outside enthalpies of infiltrated air, respectively

The latent heat load $\dot{Q}_{L.f}$, is given by the equation.

$$\dot{Q}_{L.f} = \dot{m}_f (w_i - w_o) h_{fg} \quad (4-4)$$

Where, w_i and w_o are the inside and outside design humidity ratio, respectively, h_{fg} is the latent heat or the enthalpy of evaporation of water vapor.

But it will be calculate latent heat by using this equation

$$\dot{Q}_{L.f} = \dot{Q}_{t.f} - \dot{Q}_{s.f} \quad (4-5)$$

Two method are used to estimate the volumetric flow rate of infiltrated air into a space which are :

a- *The air change method (ACM).*

b- *The crackage method*, and this method it will be used to estimate the volumetric flow rate of infiltrated air, because it yields better accuracy than first method.

The crackage method is based on the length of the crack around window or door and the square root of pressure difference across the crack.

Equation (4-2) after compensate the density and specific heat value of air, becomes to

$$\dot{Q}_{s.f} = \rho_o \cdot V_f \cdot C_p (T_o - T_i) \quad (4-6)$$

$$\dot{V}_f = KL(\Delta P)^{2/3} \quad (4-7-a)$$

Where, K is the infiltrated air coefficient, and its value for different types of windows is given in table (4.1). See appendix B.

L is the crack length in meter, ΔP is the pressure difference between the inside and outside of the room (N/m^2) and is calculated by using the following equation.

$$\Delta P = 0.613(S_1 S_2 V_o)^2 \quad (4-8)$$

Where, S_1 is a factor that depends on the topography of the location of the building. S_2 is another coefficient that depends on the height of the building and the terrain of its location, S_1 , S_2 from table (4.2) and table (4.3) respectively. (See appendix B). V_o is the wind speed (m/s), in the design area. Or V_f calculated by this relation:-

$$V_f = L \cdot \text{infiltration rate in cubic meter per hour per meter of crack} (=L \cdot 7) \quad (4-7-b)$$

$7m^3/\text{hour}$ at $3m/s(10.8km/h)$ wind speed.

4.4.3 Infiltration Due To Door Opening

The amount of air entering each time a door is opened depends on the type of door , number of entrance passages and whether there are doors in one wall only or more than one wall .The amount of infiltrated air through various types of doors is given in table(4.4)for summer air conditioning. For winter heating infiltration amount of table (4.4) are increased by 50 percent. Table (4.5)gives the expect number of entrance passages per occupant per hour for different commercial establishments. If such information is not provide in table (4.5)then number of door opening for other types of establishments can be determined using the following equation.

$$\text{Door Opening /h} = \frac{NF}{nt} \quad (4.9)$$

Where N is the number of people in the establishments , F is the factor for arrivals and departure of occupants. Its value is equal to 2 for light traffic and 1.33 for heavy traffic, t is the average time of occupancy in hours, and n is the number of doors.

Tables mentioned above exist at app. B

4.4.4 Mechanical Ventilation Load

Mechanical ventilation is required for places in which the inside air is polluted due to activities that take place in these spaces such as laboratories , kitchens, toilets and closed parking areas. The sensible and latent heating load required to warm the ventilated air to the inside room temperature is calculated by using Eqs.(4-1) or (4-2), and Eq.(4-3). It should be noted that ventilation heat load is not apart of the space heating load. The ventilation heating load is carried out by the heating coil of the warm air heating system.

4.4.5 General Procedure For Calculating The Total Heating Load

When the total heating load is calculated it should following the below procedures:-

- 1- Select the design outdoor air conditions of temperature, humidity and wind speed

- 2- Select the comfort design indoor conditions of temperature and relative humidity
- 3- Estimate temperature in adjacent unheated spaces , if any.
- 4- Compute the overall transfer coefficients for all exposed surface of the hospital through which heat losses are to be calculated.
- 5- Determine all surface areas which heat is lost.
- 6- Compute heat loss for each type of walls, floor, ceiling, doors, windows by using Eq.(3-13).
- 7- Compute heat loss from bellow-grade walls and floor, if any.
- 8- Compute heat losses due to infiltrated air.
- 9- The sum of all previous loads represent the total heating load.
- 10- It will multiply the total load by 10% as safety factor.

4.4.6 A Sample For Calculations

For room # B26 from Base floor

1-For outside wall

$$\dot{Q}_{wall} = U.A.(T_i - T_o) \quad \text{Eq 3-13}$$

$$A_{wall} = [3.45*4 - (1.20*1)] = 12.6 \text{ m}^2$$

$$\blacktriangleright \dot{Q}_{wall} = 0.99*12.6*20 = 250 \text{ W}$$

2-For internal wall

$$\dot{Q}_{wall} = 2.64*(3.25*4)*10 = 343 \text{ W}$$

3-For ceiling

$$\dot{Q}_c = U.A.\Delta T_{adj}$$

$$\blacktriangleright \dot{Q}_c =$$

$$1.457*(3.45*3.25)*10 = 163 \text{ W}$$

4-For floor

$$\dot{Q}_f = 1.15*11.2*10 = 129 \text{ W.}$$

5-For window(single glass)

$$\dot{Q}_{glass} = U_g.A_g.(T_i - T_o)$$

$$= 5.6*(1.20*1)*20 = 134 \text{ W}$$

6-For infiltration due windows

$$L = (1.20*2 + 1*3) = 5.4 \text{ m.}$$

$$\dot{V}_f = 7*5.4 / 3600 = 0.0105 \text{ m}^3/\text{s}$$

\blacktriangleright from psychometric chart at $T_o = 37^\circ\text{C}$ & $\phi_o = 55\%$, then $v = 0.91 \text{ m}^3/\text{kg}$, $p_o = 1/v_o$



figure (4-1)storeB26

$$h_i = 48 \text{ kJ/kg}, h_o = 90 \text{ kJ/kg}$$

$$\dot{Q}_{s.f} = 1/0.91 * 0.0105 * 1000 * (37-24) = 150$$

$$\dot{Q}_{t.f} = \dot{m}_f (h_i - h_o)$$

$$\dot{m} = \dot{V}_f / v_o = 0.0115 \text{ kg/s}$$

$$\dot{Q}_{t.f} = 0.0115 * (90-48) * 1000 = 483 \text{ W}$$

$$\dot{Q}_{L.f} = \dot{Q}_{t.f} - \dot{Q}_{s.f}$$

$$\dot{Q}_{L.f} = 483 - 150 = 333 \text{ W}$$

$$\dot{Q}_{\text{total}} = 250 + 343 + 163 + 129 + 134 + 483 = 1502 \text{ W}$$

4.5 Air Conditioning System

Air conditioning system is expression of the controlling of the air temperature, wetness, purity and its flow, through a space to get a comfort medium without dust, added gases, stench for persons who live in that space for all seasons.

4.5.1 Need For Air Conditioning For Hospital Facilities

Proper air conditioning is helpful in the prevention and treatment of diseases. The factors determining the need for air conditioning in hospital facilities are:

- (a) The need to restrict air movement within and between various departments.
- (b) The specific requirements for ventilation and filtration to dilute and remove contaminants in the form of airborne microorganisms, viruses, odor, hazardous chemicals and radioactive substances.
- (c) Different types of temperature and humidity requirements for various areas.
- (d) Permit accurate control of environmental conditions.
- (e) Control of air quality and air movement.

4.5.2 Infection Sources And Control Measures

Infectious Bacteria are transported by air. Droplet or infectious agents of 5 Mm or less in size can remain airborne indefinitely . It has been shown that 90 to 95 per- cent effective filters remove 99.9 per cent of all bacteria present in hospitals.

4.5.3 Viral Infection

Epidemiological evidence and other studies indicate that many of the air borne viruses that transmit infections are sub micron in size, thus there is no known method to effectively eliminate 100 per cent of the viable particles. HEPA filters and/or Ultra-Low Penetration (ULPA) filters provide the greatest efficiency currently available. Therefore, the isolation rooms with appropriate ventilation pressure relationships are the primary means used to prevent the spread of airborne viruses in the hospital environment .

Outdoor air in comparison to room air is virtually free of bacteria and viruses. Infection control problems frequently involve a Bacterial or viral source within the hospital. Ventilation air dilutes the viral and bacterial contamination within the hospital. Properly designed, constructed and maintained ventilation systems preserve the correct pressure relationship between functional areas; they remove airborne infectious agents from hospital environment.

4.5.4 Cooling Load

In the summer the heat transferred from out of the building to inside by temperature difference .The rate at which heat energy must be removed from a space in order to maintain a given inside design condition is called cooling load. The heat gain of a given space or its cooling load can be removed by means of cooling equipment which supply cold air to the space in adequate amounts to maintain a given inside design temperature .

The cooling load of a given space consists of the following heat gains:-

1-Heat gains that are transmitted through building structure such as walls, floors, and ceiling .

2-Heat gains due to solar effect .

- 3- Sensible and latent heat gain due to infiltrated air through cracks of doors and windows.
- 4- Sensible heat gain due to lights , motors and other miscellaneous heat gain.
- 5- latent heat produced from cooking, hot baths, etc....
- 6- Sensible and latent heat produced by occupants. And every one of type heat gains is discus separately later.

The accurate calculation for cooling load is very important for the accurate design, and choosing the suitable system for air conditioning.

4.5.5 Factors influencing heat gain

1. Sources of heat ,external (walls, windows, doors ,ground, ceiling , and infiltration), and internal (lights , people , equipment).
2. Design air conditions:
 - Dry bulb temperature.
 - Relative humidity.
3. Building construction.

4.5.6 Heat gain by air ducts

Air ducts that transports conditioned air which placed on unconditioned areas gain heat from the surrounded air , see figure (4-2) .



Figure(4-2) Air ducts

The heat gained for duct calculated by the following equation:

$$\dot{Q} = UA(T_o - T_i) \quad (4-10)$$

Where

Q : the rate of heat transfer (W)

U : the over all heat transfer coefficient ($W/m^2 \cdot ^\circ C$)

A : the area of air duct (m^2)

T_o : temperature of out side air ($^\circ C$)

T_i : temperature of air in side ducts ($^\circ C$)

U for uninsulated ducts ($7 W/ m^2 \cdot ^\circ C$), and for insulated ducts ($1.25 W/ m^2 \cdot ^\circ C$).

4.5.7 Solar Radiation

Solar radiation received at the earth's surface on a plane perpendicular to the sun rays may reach at hourly value $900 (W/m^2)$ 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 $200 W/m^2$ on horizontal surface when the sun's altitude angle is 90 degrees.

4.5.8 Heat Gain By The Sun Rays

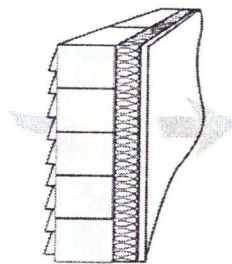


Figure (4-3) Heat conduction through surfaces

The sun is the main source of heat in the out side of the building , Direct and diffused radiation that is absorbed by walls and roofs result in raising the temperature of these surfaces .

Amount of radiation absorbed by walls and roofs depends on time of the day, building orientation, types of walls construction and presence of shading.

The sun's ray enters the building through the windows directly by radiation, and walls and ceilings by conduction, the seep of heat through glass affects the air inside the space, and we sense it directly as increasing of temperature, were the heat gained through walls and ceilings sense with its effect after 8 hours (after the sun set).

We can reduce the seep of heat through walls by insulation, and bright colors of the walls, and shading the outer walls.

On the other hand we can reduce the seep of heat through ceilings by insulations, and spraying ceilings with water, or making tow ceilings walking free or forced air between them.

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

$$\dot{Q} = U A \Delta T \quad (4-11)$$

ΔT the total equivalent temperature difference, which takes into consideration the increase of wall temperature due to absorption of solar radiation. The value of ΔT is called cooling load temperature difference CLTD, and can be obtained for roofs from table (4.6) see Appendix B.

The value of CLTD extracted from table (4.6) 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 :

$$(\text{CLTD})_{\text{corr}} = (\text{CLTD} + \text{LM})k + (25.5 - T_i) + (T_{0,m} - 29.4)f \quad (4.12)$$

Where

LM : latitude correction factor , which can be obtained from table (4.7 Appendix B)

k : the color factor adjustment ($k = 1$ for dark color, $k = 0.5$ for permanently light)

T_i : inside design temperature (C)

$T_{0,m}$: related to the outdoor design temperature (C)

f : the attic or roof fan factor ($f = 1$ if there is no attic or roof fan; $f = 0.75$ if there is an attic or roof fan).

If the roof construction details are not specified or construction is different from that specified in table (4.6 Appendix B) , approximate cooling load temperature difference can be obtained from table (4.8) , this simplified table gives the CLTD for sunlit roofs of light, medium, and heavy construction.

Table (4.8) CLTD for light, medium, and heavy sunlit roofs*.

solar Time	Roof construction		
	Light	Medium	Heavy
10	5	---	---
11	12	---	---
12	19	3	0
13	25	18	2
14	29	14	5
15	31	19	8
16	31	23	10
17	29	25	12
18	24	26	14
19	19	25	15
20	11	22	16

*From Heating and Air Conditioning book (for Mohammed A. Alsaad) .

The temperature difference ($25.5 - T_i$) is a correction value for indoor design temperature, T_i is the inside design temperature, on the other hand the temperature difference ($T_{0,m} - 29.4$) is a correction factor for out door mean temperature $T_{0,m}$. It is related to T_0 according to the relation.

$$T_{0,m} = T_0 - \frac{DR}{2} \quad (4-13)$$

Where DR : the daily range temperature (°C) which is given by the following equation:

DR = (the average maximum temperature - the average minimum temperature) for the warmest month of the summer season. Which equal for Hebron city at Aug. month

$$DR = (30-18) = 12 \text{ } ^\circ\text{C}$$

$$T_{0.m} = 37-12/2 = 31 \text{ } ^\circ\text{C}$$

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

$$\dot{Q} = UA(CLTD)_{corr}. \quad (4-14)$$

4.5.9 Heat Gain By Glass

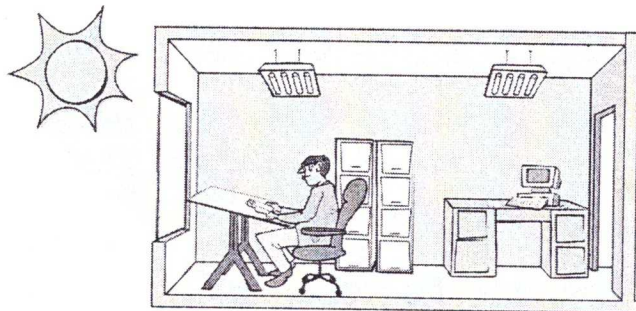


Figure (4-4) Heat gain by glass

The sun ray that transmitted through the windows increases the temperature of air inside the conditioned areas. Solar radiation which fall 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 – 87)% of incident solar radiation, depending on the glass transmissibility value.

1- Absorbed component : This component is absorbed by the glass itself and raises its temperature . About (5–50)% of solar radiation it absorbed by the glass, depending on the absorptivity value of the glass.

2- **Reflected component** : this component is reflected by the glass to the out side of the building . About 8% of the solar energy is reflected back by the glass.

The amount of solar radiation that can be transmitted through glass depends upon type of the glass (single , double, or insulating glass) , availability of shading (such as drapes, venetian blinds, construction overhang, wing walls) ,time of the day, the month of the year, orientation of the glass area , solar radiation intensity and incident angle, and latitude angle of the location.

4.5.9.1 Transmission heat gain

Heat gain due to solar transmission through glass windows and glass door is estimated by using tables (4.9 to 4.13 Appendix B) where the following factors are selected:

- **Solar heat gain factor (SHG)** . 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(4.9)
- **Shading coefficient (SC)** . This factor accounts for different shading effects of the glass wall or window and can be extracted from table (4.10) for single and double glass without inside shading or from table (4.11) for single and double glass as well as for insulating glass with internal shading see figure (4-5a).
- **Cooling load factor (CLF)** .This represents the effect of the internal walls, floor, and furniture on the instantaneous cooling load, and can be extracted from table (4.12) for glass without interior shading or from table (4.13) for glass with interior shading see figure (4-5b).



Figure (4-5a) Interior fins



Figure (4-5b) Exterior fins

The transmitted cooling load can be calculated from the relation

$$\dot{Q}_{tr} = A(SHG)(SC)(CLF) \quad (4-15)$$

4.5.9.2 Convection Heat Gain

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

$$\dot{Q}_{conv.} = UA(CLTD)_{corr.} \quad (4-16)$$

Where $CLTD$ is the temperature difference for the glass and can be extracted from table (4.14 Appendix B). Table (4.14) 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 $(25.5-T_i)$ will be added to the value of $CLTD$. On the other hand if $T_{0,m}$ is different from 29.4°C , then a correction value of $(T_{0,m}-29.4)$ is used.

4.5.9.3 Reducing The Seep Of Heat Through Glass

We note that the glass can permit four times than walls of transferring heat, we can reduce the seep of heat through of glass by using

- Double glass instead of single glass, this reduces 10-20 % of heat.
- Endothermic glass , reduces 25% of heat.
- Shelter for windows ,reduces 75% of heat.

- Use venetian blinds for windows, reduces 35% of heat.

4.5.10 Internal Source Of Heat

The internal source of heat consists of heat by people , equipments, and lights see figure(4-6)

Internal Heat Gains

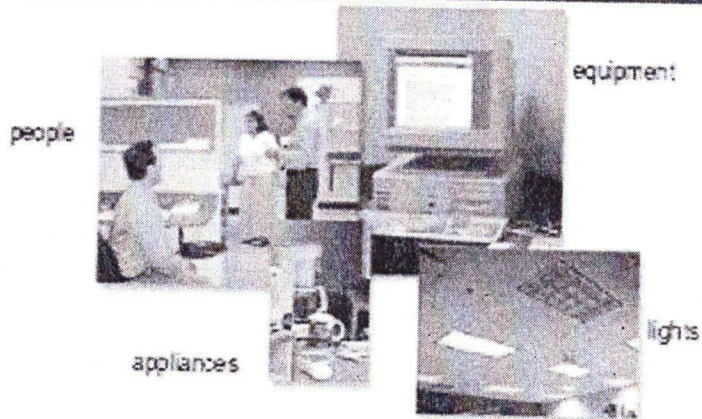


Figure (4-6) Internal Heat Gain

Cooling load for internal heat gain could be calculated by using this equation:

$$\dot{Q}_{in} = \dot{Q}_{people} + \dot{Q}_{light} + \dot{Q}_{equipment} \quad (4-17)$$

4.5.10.1 Heat Gain Due To Equipment

Energy released by equipments in the space, like electrical motors, the quantity of heat produced by machines and equipments in the room is calculated by the summing of its heat.

Sensible and latent heat loads arising from various equipments and appliances that are installed in a conditioned space are given in table (4.15 Appendix B). The indicated heat dissipation rates from such equipments and appliances should be included when the cooling load is estimated. Care must be taken when considering such dissipation rates as all sensible or latent or partly latent and party sensible.

4.5.10.2 Heat Gain Due To Lights.

Heat gains due to lights are sensible loads. The peak lighting heat gains for some applications such as hospitals, restaurants and offices will not occur simultaneously with the peak heat gain from other source. This fact should be considered when calculating the peak load for certain application.

When the exact lighting power is not known we can use the following equation

$$\dot{Q}_{light} = LI * A * F_b \quad (4-18)$$

Where:

LI : lighting intensity (W/m²), (10-30) W/m²for apartments, hospitals, hotels. (30-60) W/m² for class rooms, offices, barber shops , and similar applications.

A : area of the room (m²)

F_b : lamp factor (1.2 to fluorescent lamps, and 1 for an ordinary lamps).

The heat gain from lights is not an instantaneous load on the air walls, floor and furniture of the space, causing their temperature to increase with time. As time passes , heat is convicted from these surfaces . This results 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 lights.

$$\dot{Q}_{light} = P_{Lr} (F_u F_b) (CLF)_{lt} \quad (4-19)$$

Where:

P_{Lr} : the lamp rated power (W)

F_u : the fraction of lamp is used

F_b : lamp factor

(CLF)_{lt} : the light cooling load factor.

Table (4.16 Appendix B) gives the light cooling load factor for two types of fixture arguments.

4.5.10.3 Heat Gain Due To Motors

Electrical motors heat gains are estimated according to their rated out put power as indicated in table (4-15 Appendix B). In order to consider the heat gain of a motor driven machine as apart of the cooling load of a space, the motor and its load must be located inside the space.

4.5.10.4 Heat Gain Due To People

The heat gain due to people are sensible and latent heat, the heat of human body depends on the temperature , relative humidity, and the air movement

The following equation is used to calculate the heat due people

$$\dot{Q}_{people} = Z (\dot{Q}_{lat.} + \dot{Q}_{sen}) \quad (4-20)$$

Where

Z : number of expected people

$\dot{Q}_{lat.}$: Latent heat (W)

\dot{Q}_{sen} : Sensible heat (W)

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 values must be multiplied by a cooling load factor for people to compensate for the heat capacity effects of the occupants. Values of this factor are given in the table (4.17 Appendix B).

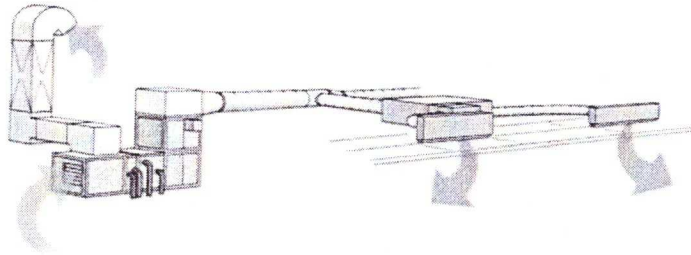
4.5.10.5 Diversity Factor

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 (4.18 Appendix B). Diversity factors can be applied when the peak cooling load is calculated for these applications. Values of diversity factors indicated in table (4.18

Appendix B) are approximate and must be used with care. However, diversity factors do not apply to applications, such as theaters, concert halls, etc.

4.5.11 Heat Gain Due To Ventilation

Ventilation is the air that we forced introduce into the space by fans to change the air inside the place, as shown in figure(4-7) . When air enter the space it will be heated inside space, and this is considered heat gains.



Figure(4-7) Ventilation System

The amount of the outside air needed for ventilation depends on the type of application. In hospitals for examples 100% fresh air is needed for operation room. In general, fresh outside air is required for one or more of the following reasons:

- Out air must be supplied to the inside space at a rate that ranges from 0.16 to 0.20 liters of air per second per person.
- Carbon dioxide must be removed or diluted such that it doesn't exceed 0.1% of the air volume.
- Body smells and other odors must be removed or diluted.

The amount of air needed for ventilation inside hospital can be computed by ventilation rates for person, or ventilation rates for place, which they represented in table (4-19).

Table (4.19) Outdoor air requirements for ventilation

Hospitals Room	Maximum Occupancy/100m ²	Outdoor Air Requirement	
		L/s/Person	L/s/m ²
Patient room	10	13	---
Medical procedure	20	8	---
Operating rooms	20	15	---
Recovery and ICU	20	8	---

Autopsy room	---	---	2.5
Physical therapy	20	8	---
Kitchens *	---	12	---
Bath ,toilets **	---	10	---
Corridors	---	---	0.25
Locker room	---	---	2.50
Smoking lounge	70	30	---

*or 50L/s intermittent or openable window

**or 25L/s intermittent or openable window

4.5.12 Heat Gain By Infiltration

Heat gain by infiltration is calculated by using Eqs.(4-6),(4-7),(4-8).

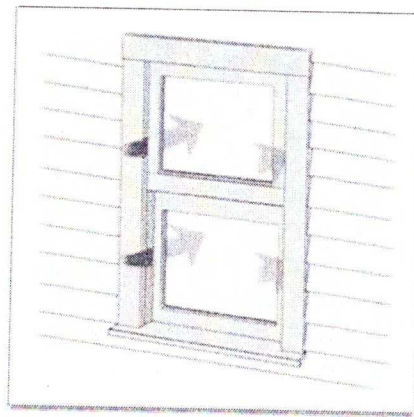


Figure (4-8) Infiltration Air Through Window

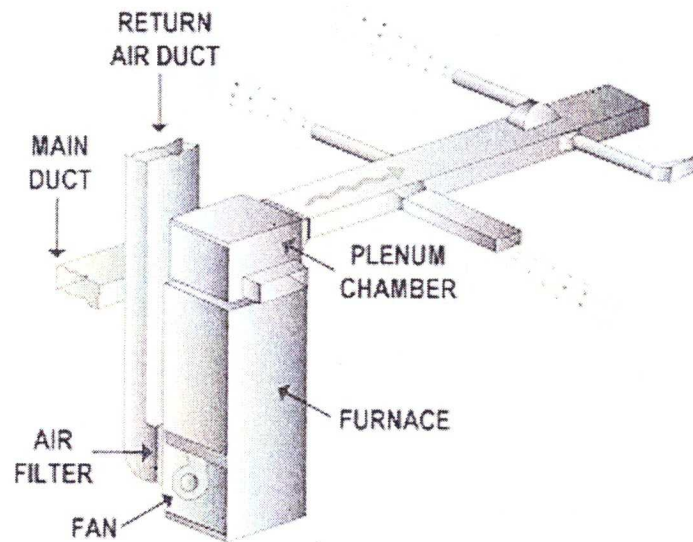
4.5.13 Ducts And Their Design

Ducts are used in heating, ventilation, and air conditioning systems to deliver and remove air. A duct system is often called ductwork see figure (4-9).

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(4-9) Duct Distribution

4.5.14 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.

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 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 (4.20) is a shortened version.

Table (4.20) Diameter Of Circular Ducts In Inches Equivalent To Rectangular 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		13.7	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	32.0	35.8	39.4					
42		18.3	23.4	29.4	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	34.5	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

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 (4.21) 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.

Table (4.21) Size of Round Ducts for Airflow

Friction in H ₂ O per 100 ft	0.05		0.10		0.15		0.20		0.25		0.30	
	Diam.	Velocity	Diam.	Velocity	Diam.	Velocity	Diam.	Velocity	Diam.	Velocity	Diam.	Velocity
	in	ft/min	in	ft/min	in	ft/min	in	ft/min	in	ft/min	in	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	11.3	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	17.5	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						

4.5.15 Central Air-conditioning System

It is used to Control of 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.

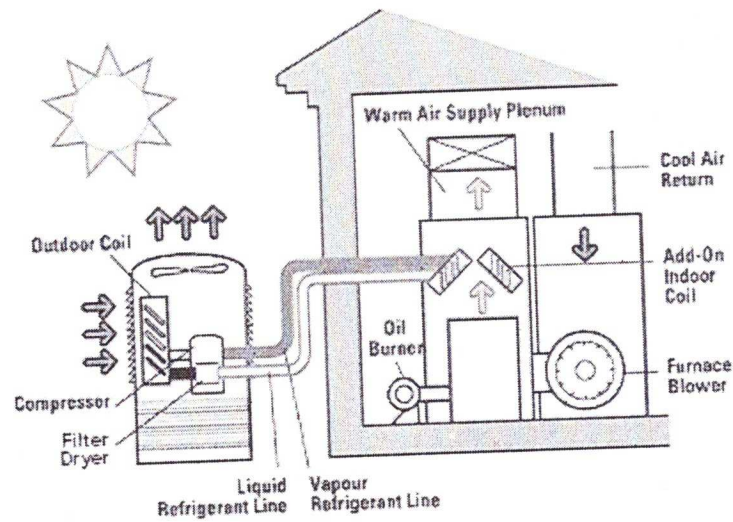


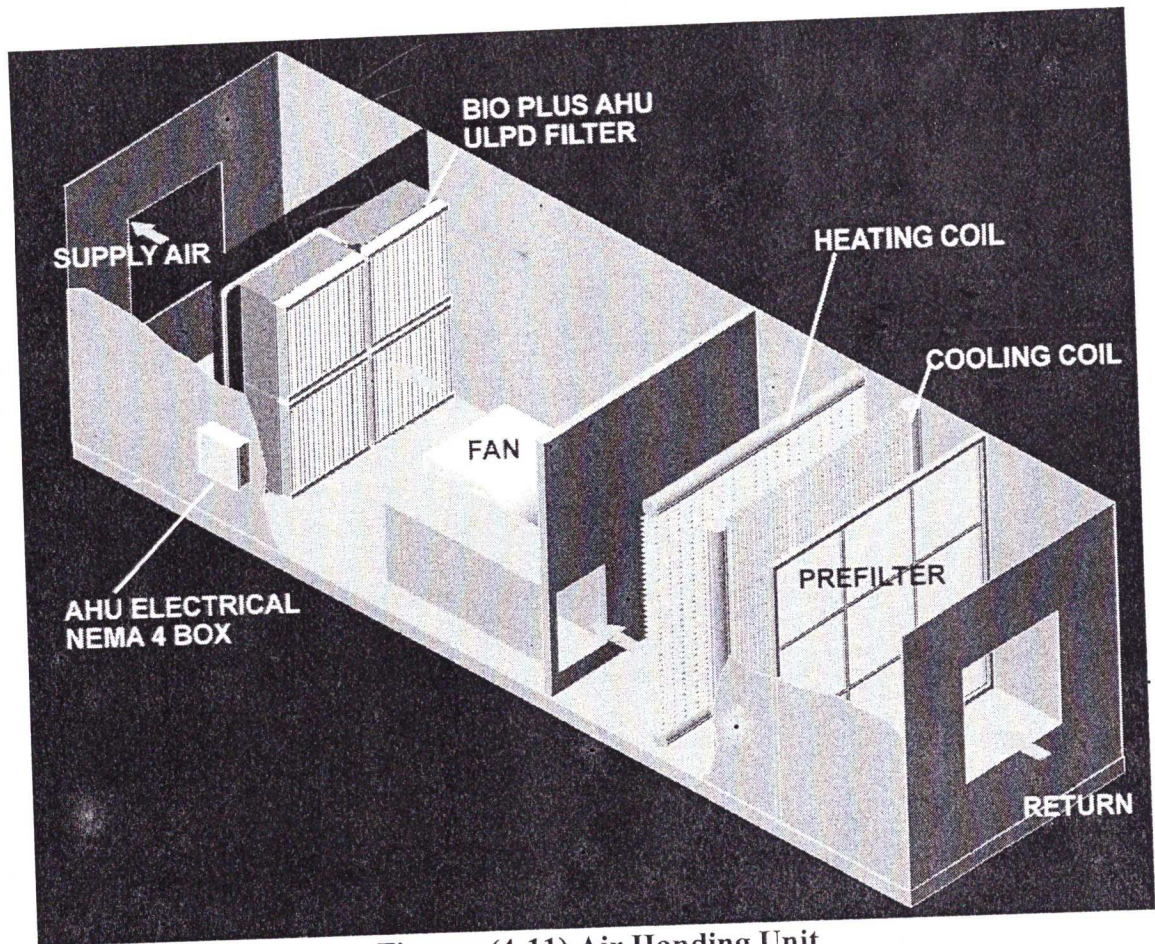
Figure (4-10) Central Air Conditioning Systems

4.5.16 Central Air-conditioning System Components That Suggested For Hospital

4.5.16.1 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 (4-11) 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.

4.5.16.2 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 .

4.5.16.3 Boiler

It is used to provide the coil in the air handling units through piping network with hot water which loses its heat to the air passing through the heating coil and then the hot air is pushed to the air conditioned space. This system is usually used in winter.

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.

Types of boilers:

- 1) Cast Iron sectional Boilers.
- 2) Steel Boilers.
- 3) Electrical Boilers
- 4) Steam Boilers.

4.5.16.4 Expansion tank selection:-

The volume of water increases 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.

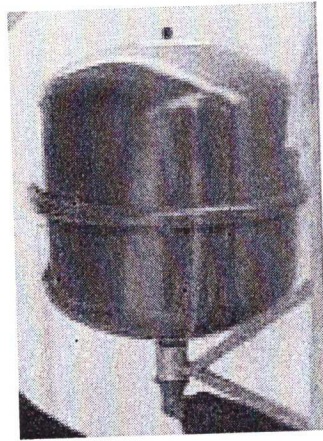


Fig.(4-12) Expansion tank

4.5.16.5 Circulating pump

A circulating is simply a small pump whose purpose is to circulate water inside pipes, centrifugal pumps are the type normally used as circulators.

The circulator can be installed either in the main supply line, outgoing from the boiler or from the chiller, or in the main return line coming back to the boiler or to chiller.

CHAPTER FIVE

CALCULATIONS AND SELECTION

5.1 Introduction

In this chapter it will make all calculations and selection for all mechanical systems were installed in the hospital building as the following:-

- 1- Heating load for base floor.
- 2- Cooling load for the same floor.
- 3- Air duct size(air supply, air return, and duct used for ventilation) and all duct-size will appears completely at design drawings .
- 4- Heating system .
- 5- Water quantity required for all fixtures inside hospital .
- 6- Pipes size used for domestic water and pipes used for sanitary drainage.
- 7- Calculations and selection of boilers, chillers, and pumps.
- 8- Calculations of septic tank , and seepage pit.

5.2 Domestic water calculations

5.2.1 Cold water calculations

In drawing of water riser diagram we calculate the WSFU of each riser and branch, the size of pipes, and the slope, according to tables in appendix A . Taking into the account that we use down feed system for supplying the hospital of cold water .and we use flush tanks, and the velocity shouldn't be more than 8FPS for flush tanks.

5.2.2 Cold water pipe size

Since we use down feed system, the equation of pressure (2-2) becomes as follow:-

$$\text{Static pressure} = \text{friction pressure} + \text{Flow pressure} \quad (5-1)$$

Where:

Static pressure : is caused by the weight of water above any point in the system [psi]

Friction pressure: is caused by the carrying the water through pipes and elbows [psi]

Flow pressure: is the pressure available at the fixture. [psi]

$$15 * 0.433 = \text{Friction pressure} + 8$$

$$\Rightarrow \text{Friction pressure} = -1.505 \text{ psi.}$$

Since the pressure is negative so its an adequate to supply the farthest fixture, so we will use a pump.

To calculate The size of pipes we must know the total equivalent length (232.5 ft), and then find the friction loss per 100ft length. After that and according to these information's we get the sizes of pipes from commercial steel pipe (schedule 40) chart.

$$232.5 \text{ ft} \rightarrow 1.505 \text{ psi.}$$

$$100\text{ft} \rightarrow ??$$

$$\Rightarrow \text{Friction loss (psi)/ 100ft} = 0.65 \text{ psi/100ft.}$$

Table 5.1 explain the calculations of pipes cold water sizes which we get from the chart of commercial steel pipe (schedule 40) chart.

Table (5.1) Data of cold water pipes

section	Friction Psi/100ft	Diameter (inch)	Velocity FPS	Actual Friction loss	TEL (ft)	Actual friction Pressure
Tank-2	0.65	4	2.5	0.27	24	0.0648
2-C1	0.65	2	2.2	0.51		
C1- C2	0.65	2	2	0.45		
C2-C3	0.65	1.5	1.9	0.45		
2-N1	0.65	2.5	2.3	0.45	16.73	0.075285
N1-C4	0.65	2.5	2.3	0.45	104.75	0.471375
C4-N2	0.65	2	2.9	0.4	23.81	0.09524

N2-C7	0.65	1.5	2.9	0.6	16.85	0.1011
C7-C8	0.65	1.5	2.9	0.6	17.023	0.102138
C8-C9	0.65	1.5	1.8	0.45	27.8	0.1251
N1-C10	0.65	2.5	1.6	2.8		
C10-C1	0.65	2	2.5	0.63		
C11-C12	0.65	2	2.5	0.65		
C12-C13	0.65	2	2.3	0.53		
C13-C14	0.65	2	1.9	0.4		
C14-C15	0.65	2	1.5	0.28		
2-3	0.65	5.3	3.2	0.65		
3-H1	0.65	1.25	1.9	0.65		
3-H2	0.65	3	2.5	0.35		
H2-N3	0.65	3	2.2	0.28		
N3-H3	0.65	2	2.6	0.65		
H3-H4	0.65	2	2	0.45		
H4-H5	0.65	1.5	2.1	0.65		
N3-H6	0.65	2.5	2.4	0.45		
H6-N4	0.65	2.5	2.5	0.45		
section	Friction	Diameter	Velocity	Actual	TEL	Actual
	Psi/100ft	(inch)	FPS	Friction	(ft)	friction
				loss		Pressure
N4-H7	0.65	2.5	2.9	0.65		
H7-H8	0.65	2	2.3	0.52		
N4-H9	0.65	2	2.3	0.52		
H9-H10	0.65	1.5	1	0.65		
H10-H11	0.65	1.5	2	0.5		
3-4	0.65	3	2.3	0.32		
4-N5	0.65	3	2.3	0.32		
N5-K2	0.65	2.5	2.1	0.38		
K2-K3	0.65	2.5	1.9	0.32		
K3-K5	0.65	2	2.5	0.64		
K5-K4	0.65	2	1.9	0.35		

The longest run from riser diagram of cold water is (tank- C9), so from calculating TEL of the longest pipe we find the friction pressure in the system.

Friction pressure = TEL (for each section in the longest run) * (Actual friction loss/100)

Friction pressure = 1.0351 psi.

The equation of pressure (5-1) becomes follow:-

pump pressure + Static pressure = friction pressure + Flow pressure

Pump pressure = Friction pressure + flow pressure – static pressure

Pump pressure = 2.54 psi

5.2.3 Pump selection of cold water

In order to select the pump we must know the head and the flow rate.

Pump head = 2.54psi / 0.433 (psi/ft) = 5.866ft/3.28 = 1.8m

The flow rate = 95.8 gpm = 21.8 m³/hr.

We select ASTRAL Victoria pump with code 20605.

5.3 Hot water calculations

In drawing of water riser diagram we calculate the WSFU of each riser and branch, the size of pipes, and the slope, according to tables in appendix A . Taking into the account that we use up feed system for supplying the hospital of hot water .and we use flush tanks, and the velocity shouldn't be more than 4FPS.

5.3.1 Hot water pipe size

Since we use up feed system, the equation of pressure (2-2) becomes follow:-

$$\text{Main} = \text{friction pressure} + \text{Flow pressure} \quad (5-2)$$

$$0 = \text{Friction pressure} + 8 \Rightarrow \text{Friction pressure} = - 8 \text{ psi.}$$

Since the pressure is negative so its an adequate to supply the farthest fixture, so we will use a pump.

320 ft → 8 psi.
 100ft → ??

Friction loss (psi)/ 100ft = 2.76 psi/100ft.

Table (5.2) explain the calculations of pipes hot water sizes which we get from the chart of commercial steel pipe (schedule 40) chart.

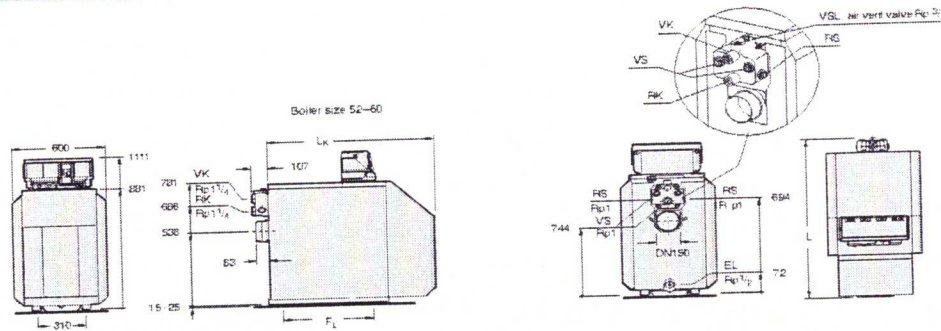
Table(5.2) Data of hot water pipes

section	Friction Psi/100ft	Diameter (inch)	Velocity FPS	Actual Friction loss	TEL (ft)	Actual friction Pressure
4-3	2.76	2.5	3.7	1.1	14.7	0.1617
Boier-4		3	2.9	0.48	19.2	0.09216
4-N5		2	3.5	1.25		
N5-K2		1.5	3.8	1.9		
K2-K3		1.5	3.9	2		
K3-K5		1.5	3.1	1.3		
K5-K4		1.25	2.9	1.4		
N5-K6		1.5	4	2.5		
K6-K7		1.5	3.9	2.1		
K7-K8		1.5	3.4	1.6		
K8-K9		1.5	3.1	1.3		
K9-K10		1.25	2.9	1.4		
K10-K11		1	3.1	2.3		
K11-K12		1	2.5	1.4		
3-H1		1	3.1	2.3		
3-H2		2	2.9	0.8		
H2-N3		2	2.8	0.7		
N3-H3		1.25	2.9	1.3		
H3-H4		1.25	2.5	0.8		
H4-H5		1	2.5	1.4		

Section	Friction Psi/100ft	Diameter (inch)	Velocity FPS	Actual Friction loss	TEL (ft)	Actual friction Pressure
N3-H6		1.5	3.9	2.3		
H6-N4		1.5	3.6	1.8		
N4-H7		1.25	3	1.8		
H7-H8		1.25	2.8	1.2		
N4-H9		1.5	2.9	1.2		
H9-H10		1.25	2.9	1.4		
H10-H11		1	2.8	1.9		
3-2		2.5	2.8	0.65	14.8	0.0962
2-C1		1.5	3.1	1.8		
C1-C2		1.25	3	1.6		
C2-C3		1.25	2.5	1		
2-N1		2	3.1	1.9	16.8	0.3192
N1-C4		1.5	3.1	1.3	104.75	1.36
C4-N2		1.5	3.9	1.25	23.8	0.297
N2-C5		1.25	2.6	1		
C5-C6		1	2.6	1.45		
N2-C7		1.25	2.6	1	16.5	0.165
C7-C8		1.25	2.5	0.9	17	0.153
C8-C9		1	2.6	1.45	28	0.406
C9-C10		1.5	3.9	2.1		
C10-C11		1.5	3.9	2.1		
C11-C12		1.5	3.5	2.7		
C12-C13		1.5	3.4	2.6		
C13-C14		1.5	3	1.4		
C14-C15		1.25	3.2	1.8		

The longest run from riser diagram of hot water is (boiler- C9), so from calculating TEL of the longest pipe we find the friction pressure in the system.

Friction pressure = 2*TEL (for each section in the longest run) * (Actual friction loss/100).



4

Boiler size			52	60
Boiler sections	Number		4	5
Rated output ⁴⁾	Full load	kW	45–52	55–60
Combustion output ⁴⁾	Full load	kW	45.5–56.6	59.5–66.3
Length	L	mm	1047	1167
	L _k	mm	927	1047
Transportation	Boiler block	mm	Width 460 mm/Height 820 mm/Depth L _k	
Combustion chamber	Length	mm	548	668
	Ø	mm	337	337
Burner door	Depth	mm		95
Centres-adjustable feet	F _L	mm	455	575
Net weight ¹⁾		kg	246	291
Water capacity		l	61	73
Gas capacity		l	68.8	85.1
Flue gas temperature ²⁾	Full load	°C	170–198	
	Partial load	°C		
CO ₂ content		%	12.5	
Required draught		Pa	0	
Permissible flow temperature ³⁾		°C	120	
Permissible working pressure		bar	4	
Boiler type test approval no.			Z-FDK-MUC-00-318-302-24	
CE Certification, product ID no.			CE-0032-BO KD1690	

¹⁾ Weight incl. packaging approx. 5-8 % higher.

²⁾ Acc. to DIN EN 303.

³⁾ High limit safety cut-out (safety temperature limiter). Max. possible flow temperature = safety limit (STB) – 18 K
Example: Safety limit (STB) = 100 °C; max. possible flow temperature = 100 – 18 = 82 °C

⁴⁾ Factory set to the upper output.

Figure (5- 1) Logano G215 WS boiler catalogue

5.3.3 Circulating pump calculations.

Taking the temperature difference in the cylinder equal (10 C⁰)

$$m = Q_{\text{boiler}} / 41.86 = 1.2146 \text{ kg/s.}$$

$$Q_{\text{pump}} = \frac{1.2146 * 3600}{1000} = 4.38 \text{ m}^3/\text{hr.}$$

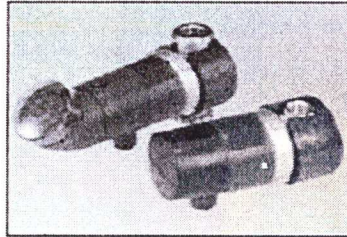
pressure of the pump = 11.9 psi.

The head of Circulating pump = $11.9 / 0.433 = 27.483 \text{ ft} / 3.28 = 8.38 \text{ m}$

Grundfoss UPS series 200 was selected for this purpose.



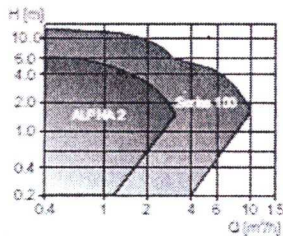
GRUNDFOS ALPHA2, UPS, UP Series 100
Circulator pumps, canned-rotor type



GRUNDFOS COMFORT UP-N, UP(S)-B Series 100
Circulator pumps, canned-rotor type



UPS Series 200
Circulator pumps, canned-rotor type



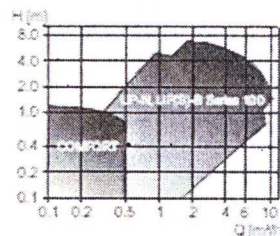
Technical data
Flow, Q: max. 10 m³/h
Head, H: max. 12 m
Liquid temp.: -25 °C to +110 °C
Operat. pressure: max. 10 bar.

Applications

- Heating systems
- Domestic hot-water systems
- Cooling and air-conditioning systems.

Features and benefits

- Low-energy
- Energy labelling class C to A
- Maintenance-free



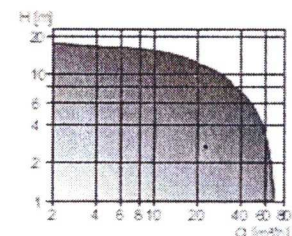
Technical data
Flow, Q: max. 10.5 m³/h
Head, H: max. 7 m
Liquid temp.: -25 °C to +110 °C
Operat. pressure: max. 10 bar.

Applications

- Heating systems
- Domestic hot-water systems
- Cooling and air-conditioning systems.

Features and benefits

- Maintenance-free
- Low-noise
- Low-energy



Technical data
Flow, Q: max. 70 m³/h
Head, H: max. 18 m
Liquid temp.: -10 °C to +120 °C
Operat. pressure: max. 10 bar.

Applications

- Heating systems
- Domestic hot-water systems
- Cooling and air-conditioning systems.

Features and benefits

- Maintenance-free
- Built-in thermal switch
- Low-noise

Figure (5-2) Grundfoss catalogue pump of USP series

5.3.4 Boiler chimney diameter

The boiler chimney diameter calculated due to the following equation:

$$A_c = m \cdot m_g / (\rho_g \cdot v) \tag{5-4}$$

Where

A_c : The chimney area (m)

m_g : mass flow of gas leaving the chimney .

v : velocity of gas leaving (3-5 m/s).

ρ_g : density of inside hot fuel gases.

$$m_f = Q_{\text{boiler}} / (\eta * C_v) \quad (5-5)$$

Where

m_f : mass flow of fuel consumed in boiler.

η : the efficiency of boiler.

C_v : calorific of diesel (39000 KJ/kg).

$$m_f = 0.00163 \text{ kg/s.}$$

Since every 1 kg of fuel produces 25.5 kg/s of fuel gas , so that 0.00163 kg produces 0.041 kg/s of fuel gases.

$$A_c = 0.041 / (1.1 * 3) = 0.01243 \text{ m}^2 .$$

The diameter of the chimney = 126 mm.

5.3.5 The expansion tank calculations.

From table (5.3) we determine expansion tank according to boiler capacity.

Table (5.3) Expansion tank capacity*

Boiler capacity(kW)	Tank volume(L)
Up to 29	100
58	200
87	250
116	500
175	750
233	1000

* from Heating and Air Conditioning book for Mohammed A. Alsaad

200 L expansion tank needed for 50.77 KW boiler capacity.

5.3.6 Storage tank capacity.

Referring to table (2 -14) in appendix A

Max hourly demand = $1/7 * (70 \text{ person} * 30) = 30 \text{ gal}$

Peak duration = 4 hr.

Total peak demand = $4 * 30 = 120 \text{ gal}$

Storage capacity = $1/5 * 210 = 45 \text{ gal} = 170 \text{ litre}$

Heating capacity (recovery) = $210 * 1/7 = 30 \text{ gph.}$

5.4 Drainage system calculations

All calculations are located on the riser diagram, which consists dfu, pipe sizes ,and slopes. Manholes design are predicted in drawing (08) of base ground drainage system in the drawings.

5.4.1 Septic tank calculations.

We assume that 70 person in the hospital, this number taken according to the number of beds, nursing rooms , doctor rooms.

From table (2-10) appendix A we select the septic tank capacity (3500 gallon) , and from code that we must take extra 25gal/fixture unit over 100dfu.

$$\text{Septic tank capacity} = 3500 + (462.5 * 25) = 11662.5 \text{ gallon} = 57 \text{ m}^3$$

5.4.2 Seepage pit calculations.

From table (2 – 11) , at porosity of the soil 3 minute for 1 inch drop, The sewage flow for general hospitals equal 150gal /day per person.

$$\begin{aligned} \text{The max sewage flow} &= \text{number of persons} * \text{sewage flow per person} && (5-6) \\ &= 70 * 100 = 7000 \text{ gpd} \end{aligned}$$

From table (2-12) ,the absorption area in the seepage pit for each 100 gallon /day equal to (45 ft^2)

The required absorption area = The max sewage flow * the absorption area/100gal.

$$= 7000 * \frac{45}{100} = 3150 \text{ } ft^2$$

Referring to table (2-13) Appendix (A) , with an 8ft diameter and 10ft depth has an absorption area 251.2 ft^2 .

$$7000 \text{ } ft^2 / (251.2 \text{ } ft^2 / \text{unit}) = 13 \text{ units.}$$

Spacing of seepage pits out side to out side 10ft or 1.5 times of the effective depth, which ever is greater up to 20 ft see table (2-14) appendix (A).

$$40ft * 1.5 = 60 \Rightarrow \text{use } 20 \text{ ft spacing.}$$

5.5 Heating load calculation

Heating load calculated according to losses of heat inside hospital as a result of temperature difference between inlet and outlet of building for the cold months .

By using the equations were mentioned previously starting by eq. (3-13) to eq.(4-7) as it detailed in the previous example for B26 and re arranged in table (5.4). The other heating load for all rooms in the base floor are explained at table (5-5).

Table(5.4)Heat load calculation form for specified room B26.

DESIGN CONDITION							
$\phi_i = 45\%$ $T_o = 4^\circ\text{C}$ $T_i = 24^\circ\text{C}$ $\phi_o = 65\%$ $T_{\text{ground}} = 14^\circ\text{C}$							
$T_{\text{adj}} = 9^\circ\text{C}$							
1-Due to outside wall For Room #B26							
surface	U (W/m ² °C)	A (m ²)	ΔT (°C)	Awa- Awin/ Adoor	Q(w) sensible	Q(w) latent	total Q(W)
wall	0.99	13.80	20.00	12.60	249.48		249.48
door	0.00	0.00	0.00	0.00	0.00	0.00	0.00
windows	5.60	1.20	20.00	0.00	134.40		134.40
wall	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Qtotal						0.00	383.88
2-Due to Tadj							
inside wall	2.64	13.00	10.00	13.00	343.20	0.00	343.20
inside wall	0.00	0.00	0.00	0.00	0.00	0.00	0.00
floor	1.15	11.21	10.00	11.21	128.94	0.00	128.94
ceiling	1.46	11.21	10.00	11.21	163.37	0.00	163.37
Qtotal						0.00	635.51
3-Due To infiltration							
surface	Qs,inf		Ql,inf		Sum		
windows	150.00		333.00		0.00		
door	0.00		0.00		0.00		
Total	150.00		333.00		483.00		
Total heating load for #B26 = 1.5 KW							

Table (5.5) Heat load for specified room

Room #	Qloss(W)	Qloss(kW)	Room #	Qloss(W)	Qloss(kW)
B1+B6	2835	2.835	B27	761	0.76
B2	5103	5.103	B32	1418	1.42
B3	1843	1.843	B33	2260	2.26
B4	1123	1.123	B34	1554	1.55
B9	305	0.305	B36	3969	3.97
B10	127	0.127	B37	1701	1.70

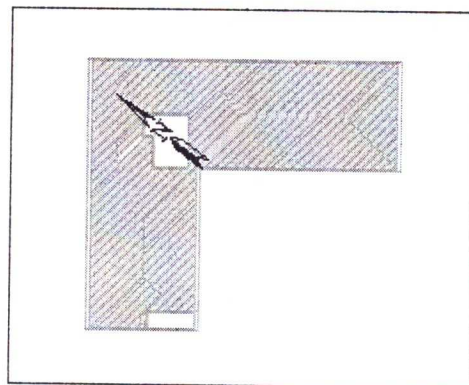
B11	1418	1.418	B41	2835	2.84
B15	1843	1.843	B42	992	0.99
B17	1418	1.418	B43	641	0.64
B19	1985	1.985	B44	1134	1.13
B20	515	0.515	B45	1701	1.70
B23	1985	1.985	B47	8505	8.51
B24	1701	1.701	B49	420	0.42
B26	2100	2.1	0.0	0.0	0.00
Total	24301	24.301	0.0	27891	27.89
tal Q = 52.19 kW					

5.6 Cooling load calculation

We calculate cooling load referring to equations (4-10) to (4-20) in chapter four. A sample example for room (B26) is illustrate cooling load, and the heat gain from structure and internal heat gain are clear in table (table5-6).

Required data for cooling load

- 1- Orientation:** as shown in the figure (5-3), the hospital building is oriented so that its walls are not directly exposed to the east, nor west. This kind of orientation is effective ;since walls are not facing the sun radiation with wide side. This will decrease the thermal lag and finally the total cooling load.



Figure(5-3) Building site orientation

2- **Time of day:** it is recommended in Palestine to calculate cooling load in August ,at 17:00 clock because this month is the warmest month in the summer season in Hebron city, and at 17:00 clock is the hour at which the heat gain reaches its greater value.

3- **Latitude:** Palestine lies at 32° N; so cooling load temperature difference (CLTD) calculated based on this latitude.

4- **CLTD** for all outside walls in the hospital and other data are shown in the table (5-6) .

Table (5.6) Design data

Wall direction	LM	K	f	CLTD(°c)	CLTDcorr (°c)
NE	-0.5	0.65	1	10	9.3
NW	-0.5	0.65	1	8	8
SE	0	0.65	1	14	12.2
SW	0	-----	-----	-----	$\Delta T=3$

5- Data for windows are shown in table (5-7)

Table (5.7) Windows design data

Wind. direction	CLTDcorr(°C)	SHG	SC	CLF
NE	9.6	445	0.95	0.22
NW	9.6	445	0.95	0.5
SE	10.1	471	0.95	0.27

Table (5.8) Cooling load calculation form.

DESIGN CONDITION							
Ti=24°C $\phi_i=45\%$ $v=0.91m^3$ / Tground=27°C							
To=37°C $\phi_o=55\%$ $h_i=48kJ/kg$ $\Delta t_{adj}=9°C$							
To,m=31°C $h_o=90kJ/kg$							
Due to CLTD For Room #B26				1-conduction			
surface	U (W/m ² °C)	A (m ²)	CLTDcor (°C)	Awa-Awi Adoor	Q(w) sensible	Q(w) latent	total Q(W)
wallNE	0.99	13.80	9.30	12.60	116.24		116.24
door	0.00	0.00	0.00	0.00	0.00	0.00	0.00
windows	5.60	1.20	9.60	1.20	64.51		64.51
			0.00	0.00	0.00	0.00	0.00
					Qtotal	0.00	180.75
2-Due to Tadj		ΔT					
inside wall	2.64	13.00	9.00	13.00	308.88	0.00	308.88
inside wall	0.00	0.00	0.00	0.00	0.00	0.00	0.00
floor	1.15	11.21	3.00	11.21	38.68	0.00	38.68
ceiling	1.46	11.21	9.00	11.21	147.03	0.00	147.03
					Qtotal	0.00	494.59
3-Due To Transmitted heat gain from glass							
glass dire.	A(m ²)	SHG	SC	CLF	Qtr.(W)	Qinf(sen.)	Qinf(lat.)
NE	1.20	445.00	0.95	0.22	111.61	150.00	333.00
NE	0.00	0.00	0.00	0.00	0.00	0.00	0.00
				Qtotal	111.61	150.00	333.00
4-Internal cooling load							
Item	sensible load			latent load		Qtotal	
occupants	#person*W/per.*CLF	1*70*0.95	66.50	1*40	40.00		106.50
lights	30*room area*CLF	30*11.21*	269.10	0.00	0.00		269.10
Equipment	0.82	100.00				100.00
Motor		0.00	0.00	0.00	0.00		0.00
							475.60
The total cooling load for Room #B26				1745.55 W	=	1.75 kW	

The other cooling load for all rooms in the base floor are explained at next table table(5.9).

Table (5.9) Cooling load for base floor rooms

Room#	kW	Room#	kW
B1+B6	7.23	B27	0.80
B2	7.51	B32	2.55
B3	1.49	B33	11.59
B4	3.00	B34	1.03
B9	0.99	B36	6.07
B10	0.26	B37	3.00
B11	1.78	B41	2.52
B15	2.39	B42	0.42
B17	1.07	B43	0.56
B19	1.99	B44	0.81
B20	1.29	B45+B46	2.94
B23	2.29	B47	11.68
B24	2.56	B49	0.81
B26	2.37
Total=81kW			
Qsensible		Qlatent	
65.5kW		15.5kW	

5.7 Duct sizing

Duct will be sized according to air flow inside it, so until calculate size of all duct system starting from main duct to last branch , first we should calculate the overall flow required inside hospital to satisfy comfort condition and by using the following equation

$$\dot{V} = v_s * \dot{m}_s \quad (5-7)$$

Where

\dot{V} : is the volumetric flow rate (m³/s) ,

v_s is specific volume of supply air(m³/kg)

\dot{m}_s : is mass flow rate of supply air(kg/s)

\dot{m}_s will be calculated by using the following equation,

$$\dot{Q}_t = \dot{m}_s (h_i - h_s) \quad (5-8)$$

Where

h_i & h_s : are enthalpy inside and supply air (KJ/kg dry air)

To determined supply condition first it will calculate Sensible heat ratio(SHR) and it calculate by using this relation,

$$\text{SHR} = \frac{Q_s}{Q_{total}} = \frac{Q_s}{Q_{sen} + Q_{lat}} \quad (5-9)$$

$$\text{Also, SHR} = \frac{T_i - T_s}{h_i - h_s} \quad (5-10)$$

$$\text{SHR} = 65.5\text{kW} / 65.5\text{kW} + 15.5\text{kW} = 0.81$$

After that it should draw the SHR-alignment point line at comfort point (@24°C dry bulb temperature, and 50% relative humidity) .

By try and error method it will determined h_s according to T_s , we suppose values for T_s less than T_i and by using eq.(5-10) h_s could be determine until its value close to its value from psychometric chart.

T_s & h_s determined as $T_s = 18^\circ\text{C}$, $h_s = 38.5\text{kJ/kg}$ then applying eq (5-8) to calculate mass flow rate.

$$\dot{m}_s = \dot{Q}_t / (h_i - h_s)$$

$$\dot{m}_s = 81 / (48 - 38.5)$$

$$\blacktriangleright \dot{m}_s = 8.53\text{kg/s}$$

$$\blacktriangleright \dot{V} = 0.835 * 8.53 = 7.12\text{m}^3/\text{s}$$

Note we using cooling load to determine SHR because design duct system depends on higher flow rate.

Heating load gives volumetric flow rate as:

$$\dot{V} = \frac{\dot{Q}}{cp \cdot \rho \cdot (T_s - T_i)} \quad (5-11)$$

Where T_s should ranges(60-65°C)

$$\blacktriangleright \dot{V} = \frac{52}{1.25 \cdot 1 \cdot (60 - 24)} = 1.15 \text{ m}^3/\text{s}.$$

So the main duct dimension will be calculated according to the supply flow rate equal 17.12 m³/s and velocity equal (6.5m/s) or according to the equal friction losses method.

we assign the value of friction losses from the following chart (fig5-3) at flow rate and velocity .



A DUCT FRICTION LOSS TABLES AND CHARTS

DUCT DESIGN TABLES AND CHARTS

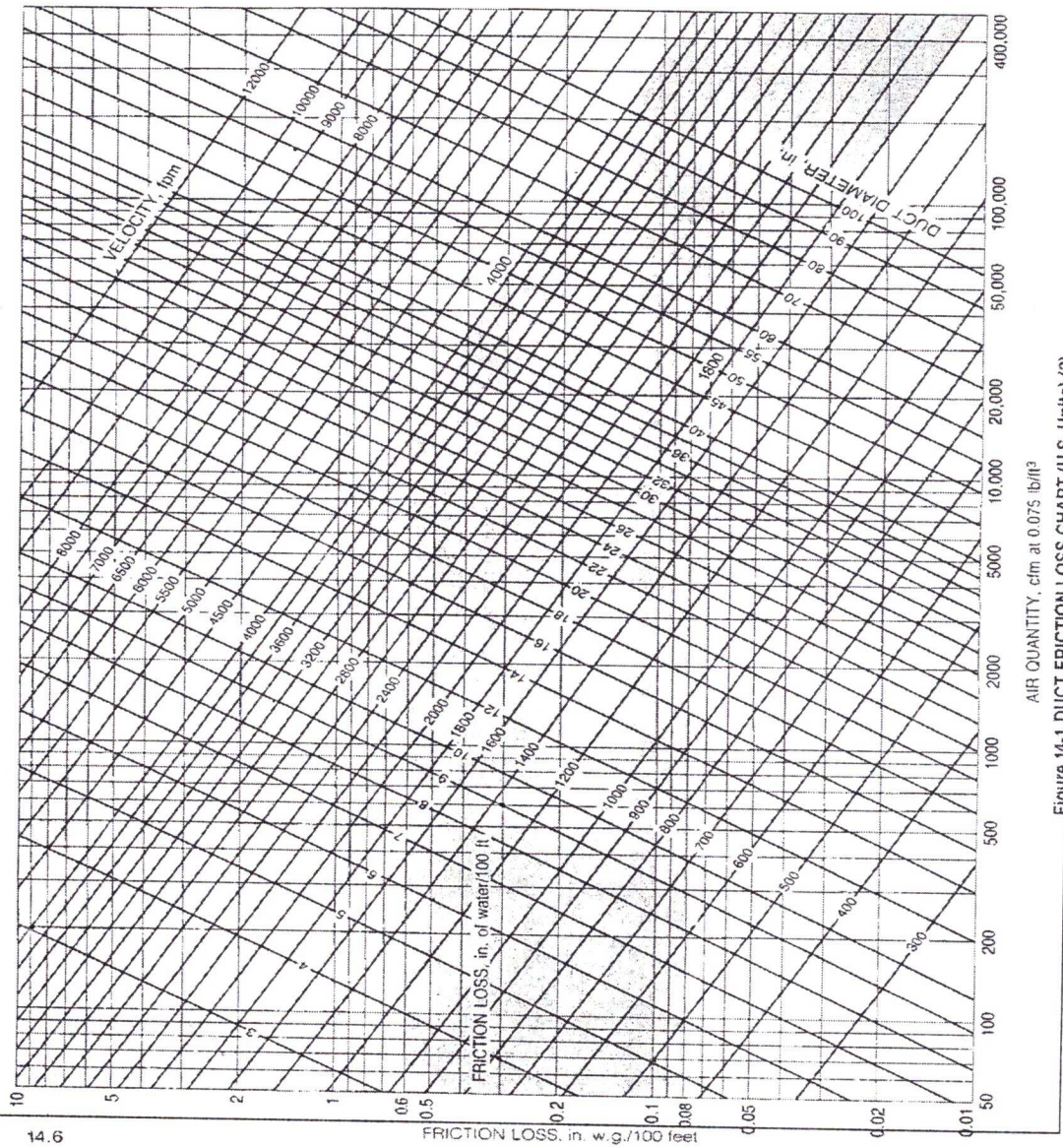


Figure 14-1 DUCT FRICTION LOSS CHART (U.S. Units) (2)

Note this chart based on ips(US unit) , until we can use this chart it should be convert all quantities used metric unit to US unit

Figure (5-4) Pressure drop($\Delta P/EL$) for air in galvanized steel duct ,based on round duct diameter

Duct system branches dimension established according to the following table which is show the volumetric flow rate for each room, and all dimension clear at duct layout drawing.

Table (5.10) Cooling and Heating flow rate

Room	Cooling load					Heating load			
	kW	kg/s	m ³ /s	L/s	CFM	kW	m ³ /s	L/s	CFM
B1+B6	7.23	0.76	0.64	635.48	1346.35	2.835	0.063	63.00	133.47
B2	7.51	0.79	0.66	660.09	1398.49	5.103	0.113	113.40	240.25
B3	1.49	0.16	0.13	130.96	277.46	1.843	0.041	40.96	86.77
B4	3.00	0.32	0.26	263.68	558.65	1.123	0.025	24.96	52.87
B9	0.99	0.10	0.09	87.02	184.36	0.305	0.007	6.78	14.36
B10	0.26	0.03	0.02	22.85	48.42	0.127	0.003	2.82	5.98
B11	1.78	0.19	0.16	156.45	331.47	1.418	0.032	31.51	66.76
B15	2.39	0.25	0.21	210.07	445.06	1.843	0.041	40.96	86.77
B17	1.07	0.11	0.09	94.05	199.25	1.418	0.032	31.51	66.76
B19	1.99	0.21	0.17	174.91	370.57	1.985	0.044	44.11	93.46
B20	1.29	0.14	0.11	113.38	240.22	0.515	0.011	11.44	24.25
B23	2.29	0.24	0.20	201.28	426.44	1.985	0.044	44.11	93.46
B24	2.56	0.27	0.23	225.01	476.72	1.701	0.038	37.80	80.08
B26	2.37	0.25	0.21	208.31	441.34	2.1	0.047	46.67	98.87
B27	0.80	0.08	0.07	70.32	148.97	0.761	0.017	16.91	35.83
B32	2.55	0.27	0.22	224.13	474.86	1.418	0.032	31.51	66.76
B33	11.59	1.22	1.02	1018.70	2158.26	2.26	0.050	50.22	106.40
B34	1.03	0.11	0.09	90.53	191.80	1.554	0.035	34.53	73.16
B36	6.07	0.64	0.53	533.52	1130.34	3.969	0.088	88.20	186.86
B37	3.00	0.32	0.26	263.68	558.65	1.701	0.038	37.80	80.08
B41	2.52	0.27	0.22	221.49	469.27	2.835	0.063	63.00	133.47
B42	0.42	0.04	0.04	36.92	78.21	0.992	0.022	22.04	46.70
B43	0.56	0.06	0.05	49.22	104.28	0.64	0.014	14.22	30.13
B44	0.81	0.09	0.07	71.19	150.84	1.134	0.025	25.20	53.39
B45+B46	2.94	0.31	0.26	258.41	547.48	1.701	0.038	37.80	80.08
B47	11.68	1.23	1.03	1026.61	2175.02	8.505	0.189	189.00	400.42
B49	0.81	0.09	0.07	71.19	150.84	0.42	0.009	9.33	19.77
total	81.00	8.53	7.12	7119.47	15083.63	52.19	1.160	1159.80	2457.20

5-8 Heating system calculation

1- Boiler:-

$$\begin{aligned}
 \text{Boiler capacity} &= \text{total heating load} * 1.1 && (5-12) \\
 &= 52\text{kW} * 1.1 = 57.2\text{kW}
 \end{aligned}$$

Base floor heating needs boiler with capacity 57.2 Kw.

We select Logano G215 WS boiler with 60 KW , size 60, see figure (5-1).

2- Expansion tank

From table (5-3) we determine expansion tank according to boiler capacity. We need 200 L expansion tank for 57.2 KW boiler capacity.

3- pipe length

All air conditioning system should exit at roofing so the pipe between boiler and AHU run for small distance (in other wise friction should be neglected).

The pipe equivalent length = 30m .

To size the pipe diameter first should know the mass flow rate from the following equation:-

$$\dot{m}_s = \dot{Q}_t / C_p \cdot \Delta T \quad (5-13)$$

Where :-

$$\dot{Q}_t = 52 \text{ kW}$$

$$C_{p \text{ water}} = 4.18 \text{ kJ/kg} \cdot \text{c}$$

ΔT :10°C (temperature difference)

$$\Rightarrow \dot{m}_s = 52 / 41.8 = 1.25 \text{ kg/s(L/s)}$$

$$\begin{aligned} \Delta p / EL &= 6000 / 30 \quad (\Delta p = 6000 \text{ from pump performance curve for pump model S25}) \\ &= 200 \text{ pa/m} \end{aligned}$$

From chart for steel pipe D =50mm(2in)main pipe. But we have three AHU and their heating load as following:-

Table (5.11) AHU supply hot water diameter

AHU#	Heating load (KW)	m(kg/s)or (L/s)	Pipe Ø mm(in)
AHU1	1.123	0.027	15(0.6)
AHU2	30	0.72	40(1.5)
AHU3	21	0.5	32(1.25)

5-9 Air handling units select to Hospital.

There are three air handling units selected to hospital and their specification and use as following:-

The 1st Air handling unit exists in the roofing of the base floor, which is used to supply fresh air for minor surgery room. And its specification as the following:-

Name: MCQUAY AHU with hepa filter.

AHU Capacity: 900 CFM with total cooling load 3kW .

Model :CAH 003 GDAC (see catalog).

The 2nd Air handling unit exists in the roofing which provided the lower zone (see drawing) of the base floor; which has the following specification:-

Name: MCQUAY AHU

AHU Capacity: 7924 CFM with total cooling load 42.61kW.

Return air capacity : 4300 CFM.

Model : CAH 010 GDAC

The 3d Air handling unit exists in the roofing which provided the upper area of the base floor which it has the following specification:-

NAME: MCQUAY AHU

AHU Capacity: 6590 CFM with total cooling load 35.39kW.

Return air capacity: 3600 CFM.

Model: CAH 010 GDAC

Quick Select Table

Quick Select Table

Table 2: Quick Select, Unit Sizes 003 to 021

Description	Unit size									
	003	004	006	008	010	012	014	017	021	
Airflow range: cfm	900-2500	1200-3100	1700-4600	2200-6000	2900-7700	3600-8700	4200-11200	5000-13500	6000-16000	
cfm @ 500 ft/min through large face area coil	1500	1800	2950	3750	4900	6050	7000	8400	10050	
Height x width (in)	26 x 38	30 x 40	30 x 52	34 x 58	36 x 64	42 x 66	42 x 74	46 x 80	58 x 82	
Cooling coil face area, sq ft										
Extended/staggered large	3.9	4.8	6.6	8.5	10.7	13.5	15.4	18.3	21.9	
Large	3.1	3.9	5.7	7.5	9.6	12.1	14.0	16.6	20.1	
Extended/staggered medium	2.6	3.4	4.7	6.4	8.3	9.8	11.2	13.7	17.2	
Medium	2.1	2.8	4.1	5.6	7.4	8.8	10.2	12.6	15.8	
Small	N/A	2.3	3.3	4.7	6.4	7.7	8.9	11.2	14.4	
Fan section—depth (in)										
Largest housed fan & motor avail. w/top hor. ducting	32	32	36	40	40	46	46	50	52	
Largest inline fan & motor available	N/A	N/A	N/A	N/A	N/A	44	44	50	54	
Largest belt drive plenum fan & motor available	N/A	N/A	N/A	N/A	34	42	42	48	52	
Largest direct drive plenum fan & motor available	N/A	N/A	N/A	20	20	54	54	54	54	
Largest twin fan & motor available	N/A	N/A	N/A	50	56	56	58	58	66	
Mixing box—depth (in)										
Mixing box only	20	20	20	20	22	24	24	26	30	
Mixing box with flat filter	24	24	24	24	26	26	28	30	34	
Mixing box with angular filter	42	42	42	42	44	46	46	48	52	
Economizer—depth (in)										
	40	40	40	40	44	48	48	52	60	
Blender—depth (in)										
Largest Klets	18	20	24	26	28	34	36	36	42	
Largest Blender Products (V)	18	22	26	30	34	38	40	46	48	
Side load filter sections—depth (in)										
Flat 2' and 4'	12	12	12	12	12	12	12	12	12	
2' angular	32	30	30	30	30	30	30	30	30	
Cartridge (12" deep w/2" pre-filter)	22	22	22	22	22	22	22	22	22	
Bag (36" w/2" pre-filter)	42	42	42	42	42	42	42	42	42	
Front load filter sections—depth (in)										
Cartridge (12" deep w/2" pre-filter)	16	16	16	16	16	16	16	16	16	
Bag (36" w/2" pre-filter)	40	40	40	40	40	40	40	40	40	
Face and bypass—depth (in)										
Internal	12	12	12	12	12	12	12	12	12	
External	18	18	18	20	22	24	24	26	30	
Coil sections—depth (in)										
Heating only (2-row water)	12	12	12	12	12	12	12	12	12	
Cooling only (4-row water)	18	18	18	18	18	18	18	18	18	
Cooling only (6-row water)	24	24	24	24	24	24	24	24	24	
Cooling & reheat (12-row cooling & 1-row heating)	36	36	36	36	36	36	36	36	36	
Vertical cooling only (6-row water)	30	30	30	30	36	36	36	36	42	
Multizone coil section—depth (in)										
3-deck horizontal with dampers	N/A	N/A	40	42	42	52	52	54	56	
Access sections—depth (in)										
10" deep	16	16	30	18	16	16	16	16	16	
24" deep	24	24	24	24	24	24	24	24	24	
30" deep	30	30	30	30	30	30	30	30	30	
36" deep	36	36	36	36	36	36	36	36	36	
42" deep	42	42	42	42	42	42	42	42	42	
48" deep	48	48	48	48	48	48	48	48	48	
54" deep	54	54	54	54	54	54	54	54	54	
Diffuse—depth (in)										
With housed fan	10	10	10	12	12	16	16	16	16	
With inline fan	N/A	N/A	N/A	N/A	N/A	16	16	16	18	
Attenuator—depth (in)										
Short	40	40	40	40	40	40	40	40	40	
Medium	52	52	52	52	52	52	52	52	52	
Long	64	64	64	64	64	64	64	64	64	
Supply or return plenum—depth (in)										
Top, bottom or end opening	14	16	16	18	20	22	22	24	28	

Note: Based on typical industry sizes. Vision air handler units are available in 2-inch increments of height and width to fit the exact space requirements.

Figure(5-5) AHU catalog

5.10 Calculation and selection of mass flow rate for chiller

Total cooling load = 81kW

Take water temperature inlet 7°C & outlet temperature 12.5°C so from eq.(5-13)

$$\dot{m}_s = \dot{Q}_t / C_p \cdot \Delta T$$

$$\begin{aligned} \blacktriangleright \dot{m}_s &= 1/4.18 \cdot (12.5-7) \\ &= 3.52 \text{kg/s} \end{aligned}$$

Chiller selection

The choices of the chiller according to the total heat gain (cooling load) .

Total cooling load = 81kW * 1.1 = 89kW (26TR).

Chiller select to Hospital:-

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

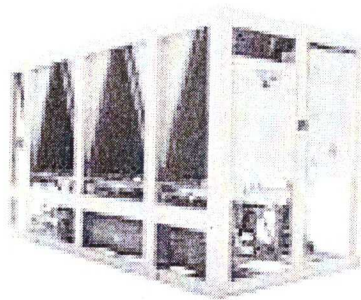


Figure (5-6) chillers

Chiller was selected has the following specification:-

Name MCQUAY Chiller

Model AGZ029BS

Chiller capacity 27.7TON/97KW

Air-Cooled Chillers

AGZ 020BS through 034BS, Packaged, R-22/R-407C

Physical data	AGZ model number			
	020BS	025BS	029BS	034BS
Basic data				
Unit capacity @ ARI conditions, tons (kW)*	20.6 (72.4)	22.7 (79.8)	27.7 (97.5)	34.0 (119.5)
No. of refrigerant circuits	1	1	1	1
Unit operating charge, R-22, lb (kg)	34.0 (15.4)	42.0 (19.1)	47.0 (21.3)	50.0 (22.7)
Cabinet dimensions, L x W x H, in (mm)	106.2 x 46.3 x 50.8 (2697 x 1176 x 1289)	106.2 x 46.3 x 50.8 (2697 x 1176 x 1289)	106.2 x 46.3 x 58.8 (2697 x 1176 x 1493)	106.2 x 46.3 x 58.8 (2697 x 1176 x 1493)
Unit operating weight, lb (kg)	1590 (723)	1635 (743)	1830 (832)	2315 (1052)
Unit shipping weight, lb (kg)	1570 (714)	1610 (732)	1800 (818)	2270 (1032)
Add'l weight if copper finned coils, lb (kg)	350 (159)	350 (159)	435 (197)	435 (197)
Compressors				
Type	Scroll	Scroll	Scroll	Scroll
Nominal tons per compressor	12.0 / 12.0	13.0 / 13.0	15.0 / 15.0	20.0 / 20.0
Oil charge per compressor of a tandem set, oz (g)	110 (3119)	110 (3119)	110 (3119)	158 (4479)
Capacity reduction steps—percent of compressor displacement				
Standard staging	0-50-100	0-50-100	0-50-100	0-50-100
Condensers—high efficiency fin and tube type with integral subcooling				
Coil face area, one of two sides, ft ² (m ²)	49.0 (4.5)	49.0 (4.5)	58.3 (5.4)	58.3 (5.4)
Finned height x finned length, in (mm)	84 x 84 (2134 x 2134)	84 x 84 (2134 x 2134)	100 x 84 (2545 x 2134)	100 x 84 (2545 x 2134)
Fins per inch x rows deep: R-22 and [R-407C]	16 x 2 [16 x 3]	16 x 3 [16 x 3]	16 x 3 [16 x 3]	16 x 3 [16 x 3]
Pumpdown capacity R-22 and [R-407C], lb (kg)	56.9 (25.9)	85.4 (38.8)	101.6 (46.2)	101.6 (46.2)
Condenser fans—direct drive propeller type				
No. of fans/circuit—fan dia., in (mm)	3-26 (660)	3-26 (660)	3-26 (660)	3-26 (660)
No. of motors—hp (kW)**	3-1.0 (0.75)	3-1.0 (0.75)	3-1.0 (0.75)	3-1.0 (0.75)
Fan and motor rpm, 60 Hz	1140	1140	1140	1140
60 Hz total unit airflow, cfm (L/s)	20,925 (9877)	20,925 (9877)	19,800 (9346)	19,800 (9346)
Direct expansion evaporator—braced plate-to-plate				
Connection size victaulic, in (mm)	2 (51)	2 (51)	2 (51)	2 (51)
Water volume, gallons (L)	2.16 (8.2)	3.05 (11.5)	4.00 (15.1)	5.55 (21.0)
Maximum refrigerant working pressure, psig (kPa)	450 (3103)	450 (3103)	450 (3103)	450 (3103)
Maximum water pressure, psig (kPa)	350 (2413)	350 (2413)	350 (2413)	350 (2413)

* Nominal capacity based on 95°F ambient air temperature and 54°F/44°F water range.

NOMENCLATURE

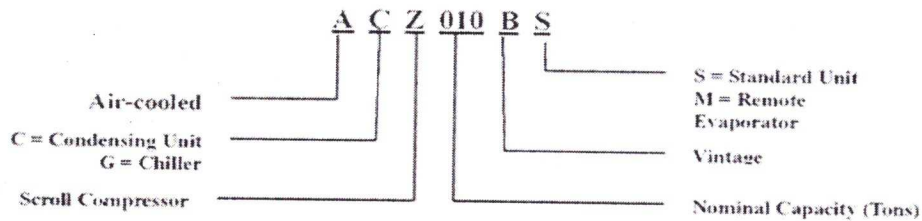


Figure (5-7) Chillers catalogue

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APPENDIX A

Table (2.1) 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 ^g , in.	0.25	1/2
Kitchen sink	Private	Faucet	2	1/2
Kitchen sink	General	Faucet	4	1/2
Laundry trays (1-3)	Private	Faucet	3	1/2
Lavatory	Private	Faucet	1	3/8
Lavatory	General	Faucet	2	1/2
Separate shower	Private	Mixing valve	2	1/2
Service sink	General	Faucet	3	1/2
Shower head	Private	Mixing valve	2	1/2
Shower head	General	Mixing valve	4	1/2
Urinal	General	Flushometer	5	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 Fixture Units	
	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 (2.2) water demand in gpm and minimum flow pressure

Minimum Pressure Required by
Typical Plumbing Fixtures

Fixture Type	Minimum Pressure, ψ
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	
$\frac{1}{2}$ -in. sill cock	15
$\frac{3}{4}$ -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
Bathtub	6
Laundry tray	5
Shower	3-10
Water closets	
tank type	3
flush valve*	15-40
Urinal flush valve	15
Garden hose	
$\frac{1}{2}$ -in. sill cock	3-6
$\frac{3}{4}$ -in. sill cock	5
Drinking fountain	$\frac{3}{4}$

Source: Data extracted from various sources

*Wide range of flows; depends on flow pressure.

Table for Estimating Demand

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

*Water Supply Fixture Units

Source: Reproduced with permission from The National Standard Plumbing Code, published by The National Association of Plumbing Heating Cooling Contractors.

Table (2.5) 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
Bathub group consisting of a water closet, lavatory and bathtub or shower stall;	6
Bathub (with or without overhead shower)*	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 1/4 in. or less	1
trap size 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

*A shower head over a bathtub does not increase the fixture unit value.
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Table (2.6) Maximum size of non integral traps

Plumbing Fixture	Trap Size, in.
Bathub (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*	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

*Separate trap required for wash tray and separate trap required for sink compartment with food waste grinder unit.
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Table(2.7) 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 (2.8)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 (2.9) Rain velocity an sloping drains

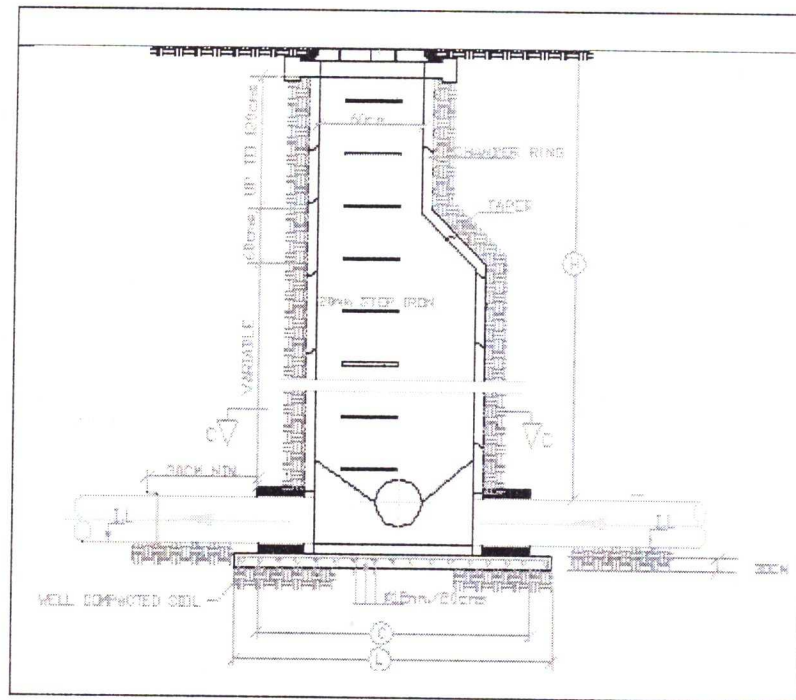
Actual Inside Diameter of Pipe, in.	$\frac{1}{16}$ in./ft Slope		$\frac{1}{8}$ in./ft Slope		$\frac{1}{4}$ in./ft Slope		$\frac{1}{2}$ in./ft Slope	
	Discharge, gpm	Velocity, fps	Discharge, gpm	Velocity, fps	Discharge, gpm	Velocity, fps	Discharge, gpm	Velocity, fps
$1\frac{1}{4}$							3.40	1.78
$1\frac{3}{8}$					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, $n = 0.015$.

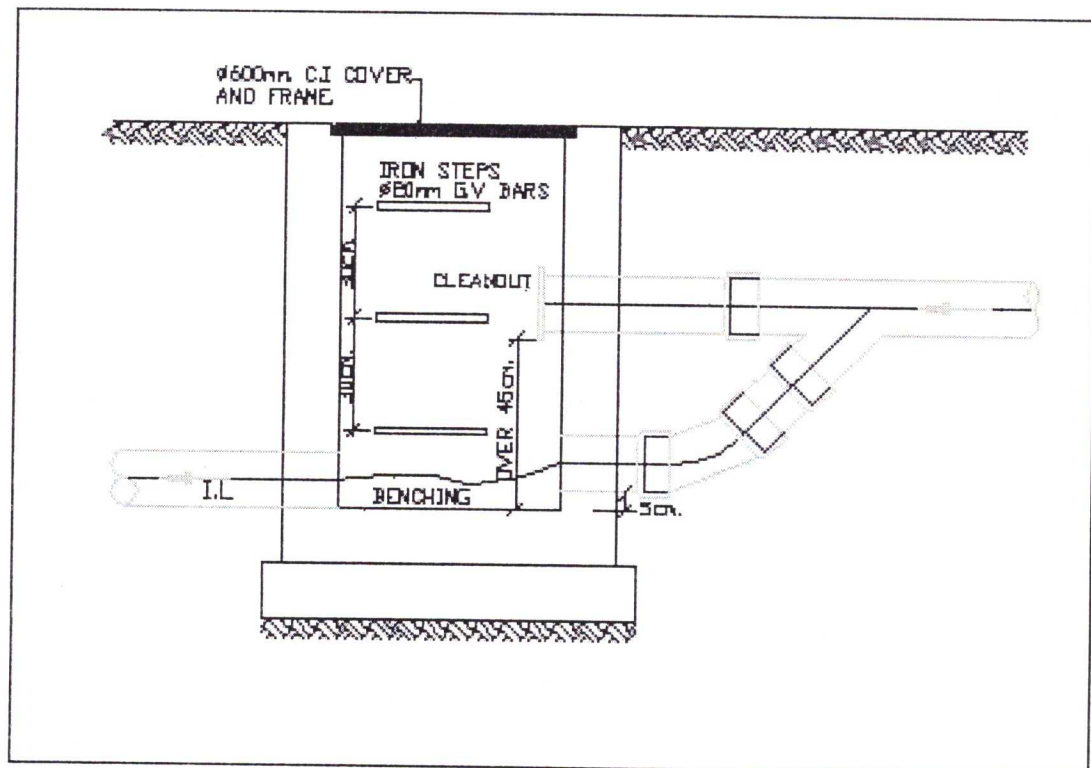
^bHalf full means filled to a depth equal to one-half the inside diameter.

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 and multiply velocity by 0.80. For $\frac{2}{3}$ 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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Figure(2-8) manhole



Figure(2-9) Drop manhol

APPENDIX B

Table (4.1) Values of infiltrated air coefficient K

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

Table (4.2) values of the factor S_1 of eq.(4-8)

#	Topography of Location	value of S_1
1	Protected location by hills or building	0.9
2	Unprotected location such as shores, hilltops	1.1
3	Location other than (1) or (2)	1.0

Table (4.3) Values of factor S_2 eq.(4-8).

Location class	Class 1			Class2			Class3			Class4		
	A	B	C	A	B	C	A	B	C	A	B	C
Building height												

Table (4.6) Cooling load temperature differences for calculating cooling load from sunlit roofs

Roof Description of No. Construction	U-value W/m ² .°C	Solar Time h																							
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Without Suspended Ceiling																									
1 Steel sheet with 25.4 mm (or 50.8 mm) insulation	1.209 (0.704)	0	-1	-2	-2	-3	-2	3	11	19	27	34	40	43	44	43	39	33	25	17	10	7	5	3	1
2 25 mm wood with 25.4 mm insulation	0.963	3	2	0	-1	-2	-2	-1	2	8	15	22	29	35	39	41	41	39	35	29	21	15	11	8	5
3 101.6 mm L.W. concrete	1.209 (0.704)	3	1	0	-1	-2	-2	-1	2	8	15	22	29	35	39	41	41	39	35	29	21	15	11	8	5
4 50.8 mm H.W. concrete with 25.4 mm (or 50.8 mm) insulation	1.170 (0.693)	3	3	2	1	0	0	2	2	11	19	25	30	35	37	37	35	31	25	20	16	12	10	8	
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	
8 203.4 mm L.W. concrete	0.715	20	19	14	12	10	8	6	5	4	5	7	10	14	18	22	25	28	30	30	27	25	22	19	
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	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	15	16	14	12	11	10	9	8	9	10	12	15	17	20	23	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 h																							
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
4 50.8 mm H.W. concrete with 25.4 mm insulation	0.744	15	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	0.522	22	20	18	16	15	14	11	10	9	8	8	9	11	14	16	19	21	23	25	25	25	24	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	15	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	12	12	12	12	13	13	15	16	17	18	18	19	19	19	18	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	13	14	15	16	18	19	20	20	20	20	10

Table (4.7) 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 (4.9) 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 (4.10) 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 ·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	3	—	0.90	—
Plate	6	—	0.83	—
Reflective	6	—	0.20-0.40	—
Insulating Glass				
Clear	3	0.71	0.88	0.88
	6	0.61	0.81	0.82
Heat absorbing	6	0.36	0.55	0.58

Table (4.11) 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 Dark	Translucent White
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
Heat absorbing	3	—	—	—	—
Pattern or Tinted	5.0-5.5	—	—	—	—
Heat absorbing	5.0-6.0	0.57	0.53	0.45	0.30
Pattern or Tinted	3.0-5.5	—	—	—	—
Heat Absorbing or Pattern Heat Absorbing	10	0.54	0.52	0.40	0.82
Heat Absorbing or Pattern	—	0.42	0.40	0.36	0.28
Reflective Coated Glass	—	0.30	0.25	0.23	—
	—	0.40	0.33	0.29	—
	—	0.50	0.42	0.38	—
	—	0.60	0.50	0.44	—
Double Glass					
Regular	3	0.57	0.51	0.60	0.25
Plate	6	0.57	0.51	0.60	0.25
Reflective	6	0.20-0.40	—	—	—
Insulating Glass					
Clear	2.5-6.0	0.57	0.51	0.60	0.25
Heat Absorbing	5.0-6.0	0.39	0.36	0.40	0.22
Reflective Coated	—	0.20	0.19	0.18	—
	—	0.30	0.27	0.26	—
	—	0.40	0.34	0.33	—

Table (4.12) Cooling load factor 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	0.43	0.42	0.37	0.33	0.28
	M	0.09	0.08	0.07	0.06	0.05	0.14	0.26	0.38	0.48	0.54	0.56	0.51	0.45	0.40	0.36	0.33	0.29
	H	0.11	0.10	0.10	0.09	0.08	0.17	0.28	0.40	0.49	0.53	0.53	0.48	0.41	0.36	0.33	0.30	0.27
SSE	L	0.07	0.05	0.04	0.04	0.03	0.06	0.15	0.29	0.43	0.55	0.63	0.64	0.60	0.55	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 (4.13) Cooling load factor for glass with interior shading, north latitudes

Penetration Facing	Solar Time <i>h</i>																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
N	0.03	0.03	0.04	0.04	0.04	0.04	0.05	0.05	0.06	0.06	0.07	0.07	0.08	0.08	0.09	0.09	0.10
NNE	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.05	0.05	0.06	0.06	0.07	0.07	0.08	0.08	0.09	0.10
NE	0.03	0.02	0.02	0.02	0.02	0.03	0.03	0.04	0.04	0.05	0.05	0.06	0.06	0.07	0.07	0.08	0.09
ENE	0.03	0.02	0.02	0.02	0.02	0.03	0.03	0.04	0.04	0.05	0.05	0.06	0.06	0.07	0.07	0.08	0.09
E	0.03	0.02	0.02	0.02	0.02	0.03	0.03	0.04	0.04	0.05	0.05	0.06	0.06	0.07	0.07	0.08	0.09
ESE	0.03	0.03	0.02	0.02	0.02	0.03	0.03	0.04	0.04	0.05	0.05	0.06	0.06	0.07	0.07	0.08	0.09
SE	0.03	0.03	0.02	0.02	0.02	0.03	0.03	0.04	0.04	0.05	0.05	0.06	0.06	0.07	0.07	0.08	0.09
SSE	0.04	0.03	0.03	0.03	0.02	0.12	0.31	0.54	0.72	0.81	0.81	0.71	0.54	0.38	0.32	0.27	0.22
S	0.04	0.04	0.03	0.03	0.03	0.09	0.16	0.23	0.38	0.58	0.75	0.83	0.80	0.68	0.50	0.35	0.27
SSW	0.05	0.04	0.04	0.03	0.03	0.09	0.14	0.18	0.22	0.27	0.43	0.63	0.78	0.84	0.80	0.66	0.46
SW	0.05	0.05	0.04	0.04	0.03	0.07	0.11	0.14	0.16	0.19	0.22	0.38	0.59	0.75	0.83	0.81	0.65
WSW	0.05	0.05	0.04	0.04	0.03	0.07	0.10	0.12	0.11	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	0.16	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	0.14	0.22	0.26	0.30	0.32	0.33	0.34	0.34	0.39	0.61	0.82
HORIZ.	0.05	0.05	0.04	0.04	0.03	0.12	0.27	0.44	0.59	0.72	0.81	0.85	0.85	0.81	0.71	0.58	0.42

Table (4.14) 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 (4.15) Heat gain rate from miscellaneous appliances

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 (4.16) Cooling load factor 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	0.00	0.19	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	0.86	0.90	0.98	0.98
13	0.87	0.91	0.99	0.99
14	0.88	0.92	0.99	0.99
15	0.89	0.93	0.99	0.99
16	0.90	0.94	0.99	0.99
17	0.91	0.94	0.99	0.99
18	0.92	0.95	0.99	0.99

^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 (4.17) 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	0.39	0.50	0.51	0.53	0.55	0.58	0.62
2	0.58	0.59	0.60	0.61	0.62	0.64	0.66	0.70
3	0.17	0.66	0.67	0.67	0.69	0.70	0.72	0.75
4	0.13	0.71	0.72	0.72	0.74	0.75	0.77	0.79
5	0.10	0.27	0.76	0.76	0.77	0.79	0.80	0.82
6	0.08	0.21	0.79	0.80	0.80	0.81	0.83	0.85
7	0.07	0.16	0.84	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(4.18) 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