Palestine Polytechnic University

College of Engineering & Technology

Department of Mechanical Engineering

Graduation Project

Survey and Evaluation of Mechanical Systems In Martyr Abu Al-Hassan Qasem Hospital – Yatta

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Dedication

We were hoping to dedicate this work to our fathers but all we can do now is dedicate it to their souls may they rest in peace ………………..

We dedicate it to the greatest, the strongest, the most precious, and most generous mothers in the world for all that they have given to us, we hope we will be able to make it up to them some day ……………………….

We dedicate it to our brothers and sisters for there understanding ……...

We dedicate it to all our teachers and colleagues for believing in us …….

We dedicate it to all those who value knowledge highly ……………….

Acknowledgment

We would like to express our genuine gratitude .First to the ministry of health for giving us the approval to work on our project at the hospital.

Then to Yatta municipality and the director of Martyr Abu Al – Hassan Qasem Hospital Mr. Mohammed Abu Sabha, for Mr. Mohammed Al – Masri, the technician and every employee at the hospital for all the help they provided to us.

Last but not least, we would like to thank our project supervisor Eng. Jamal Al – Shweiki for his highly appreciated guidance and support all through stages of this work.

Contents

SYMBOLS AND UNITS

Symbol	Meaning	Unit
A	Area	m^2
Cp	Specific heat capacity	kJ / kg.°C
Cυ	Choleric value of fuel	kW / kg
CLTD	Cooling Load Temperature Difference	°C
CLF	Cooling Load Factor	
D	Diameter	m
dfu	Drainage fixture unit	dfu
DR	Daily temperature range	°C
ΔT	Temperature difference	°C
EL	Equivalent Length	m
f	Friction factor for pipe losses	
f	Attic correction factor	
h_F	Fitting head losses	m
h_L	Friction head losses	m
h_{in}	Inside convection heat transfer coefficient	$W / m^2.°C$
h_{out}	Outside convection heat transfer coefficient	$W / m^2.°C$
K	Thermal conductivity	W / m.°C
κ	Fitting factor for pipe losses	
k	Color correction factor for walls	
LM	Latitude correction factor	°C
$\dot{m}$	Mass flow rate	kg / s
m	Mass	kg
μ	Factor to change kW to kcal / h	kcal / kW
$\dot{v}$	Volume flow rate	m^3 / s
Q	Heat load	W
Re	Renold's Number	
ρ	Density	kg / m^3
SHG	Solar Heat Gain factor for glass	

SC	Shading Coefficient for glass	
t_{in}	Inside design temperature	°C
t_{out}	Outside design temperature	°C
$T_{o,m}$	Outside mean temperature	°C
τ	Time interval	s
U	Overall heat transfer coefficient	$W / m^2.°C$
V	Volume	m^3
ν	Kinematic viscosity	m^2 / s
υ	Velocity	m / s
WSFU	Water Supply Fixture Unit	FU
η	Efficiency	%

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CHAPTER ONE

INTRODUCTION

1.1 Introduction

Human comfort is a function of the building in which he lives; even the development of buildings in any society indicates the level in which they live, this is related to any technology makes the life more comfortable. Services in the buildings are designed to achieve human's comfort; these services related to human comfort in the mechanical field are called mechanical services in the buildings.

Mechanical systems and technologies have started to spread by the beginning of the 1970 s, these technologies are improved more and more until they reach the current level and put under the title hi-tech or high technology.

Although some mechanical services are not necessary to be installed in every building, the existence of some other basic mechanical systems is a must; for example, domestic water system is as much important as the building itself, it is a basic part of the building.

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

However, in Palestine these mechanical systems appeared lately, but they still expensive, first since they are modern technologies that must take their time to be commonly used, and next because they are not known as basic requirements of the modern life.

Even the basic systems, such as domestic water and sanitary sewage systems are not designed based on engineering work. Most of technicians install these systems regardless of the designer (mechanical engineer) instructions and designs.

Some large projects that are executed in Palestine with a foreign administration and coordination are designed and installed following the designers considerations.

In spite of the limited spread of these systems generally, some regions in Palestinian territories such as Ram Allah city, the economical capital of Palestine, started to apply these systems with engineering designs. The slow spread of these systems in the other cities is a product of a kind of conventionalism; no one wants to change his way of life, even to the best. The main cause for using these systems is that when someone installs an air conditioner, for example in his house, his neighbors start to think about trying this air conditioner; by this way this system could spread faster than the results of advertisement.

The use of these systems could create job opportunities for the engineers who should be the real directors of designing and installing these systems.

1.2 Overview

Mechanical services in the buildings represent one of the basic requirements of them. These services deal with the daily life of people who use the building, for instance, cold and hot water, which are under the title water system, are used daily for drinking and cooking, cleaning and bathing, and for farming and hydroponics.

The system responsible for getting rid of the leavings of this system is called the sanitary sewage system; and it is called sanitary since if it is well designed, it will be healthy for human beings within the building.

The presence of the diversity of the mechanical systems differs according to the main purpose of the building in which they exist. Whereas all these buildings share some basic systems like the water system and the sewage system, such systems exist in the residential buildings, in addition to the possibility of having a central heating system, or an air conditioning system when the owners of the building can afford it.

In the public institutions the central heating system exists as a basic system in addition to the main two systems mentioned above. Where as at banks, the air conditioning system is as basic as the water and sewage systems. On the other hand a fire fighting system could exist in these institutions.

However, the hospitals in Palestine are different from other institutions in the sense that they have a group of comprehensive mechanical systems that may not exist together in any other institution.

Hospitals specialized in prohibitating different kinds of people; patients, visitors, and staff (managers, physicians, nurses, engineers, technicians, and other workers). On the other hand hospitals provide many services such as radiology, laboratories, surgery, laundry...etc. Hospitals in Palestine receive emergencies and a number of physicians and staff resides in the hospital which makes it highly important that these systems be designed at a high level of safety and accuracy.

From the forgoing it should be evident that our selection of this project to study a wide variety of building mechanical systems, which its design must meet the ever more demanding requirements of energy codes, laws delineating the needs of handicapped persons, environmental impact standards, and improved human comfort criteria. Also modern buildings especially hospitals not only must meet the complex technological needs of its occupants, but also must be designed for flexibility in order to meet the rapid technological changes in the society.

1.3 Difficulties in Palestine

Palestine faces a very critical and difficult economical and political situation. Because of the occupation from one side and the lack of domination and power of the state of Palestine that could support the institutions and control its inputs on the other side. Also the Palestinian authority's budget depends primarily on the aids from the donor countries which are conditional most of the times.

Depending on the Israeli side in exporting doubles the costumes and tariffs imposed on the technologies and the machineries used in their mechanical systems. The reason for exporting these machineries in the lack of a manufacture who is capable for producing them.

The difference in climate, and the difference of the altitude of sea level from one region to another causes the diversity of these systems in the West Bank, for example, the altitudes of sea level vary between 400 m BSL and 1020 m ASL.

The highest point in Hebron governorate is in Halhoul town at a level of 1020 m ASL and the lowest point is near AL-Dahryia town at a level of 400 m ASL. Such difference in climate causes the need for different mechanical systems.

1.4 Project Proposal

Yatta town

The word Yatta means the low point; Yatta lies in the southern part of Hebron governorate, it is about 12 km to the south of Hebron city, near to the northern borders of Alnaqab desert. Yatta is 820 m ASL, on the horizontal line of 159,000, and vertical line of 95,000. The average high temperature of Yatta is 30 °C, while the average low temperature is 5 °C, with an annual average rain falling of 300 mm.

The town of Yatta is one of the Hebron's Governorate's biggest towns in terms of population with about 75,000 citizens. Yatta town's area is about 24.5 km^2, while the total area of the town with neighborhoods is about 32 km^2. There is a number of clinics and two hospitals in Yatta; Al-E'timad hospital and Martyr Abu Al-Hassan Qasem Hospital. Figure (1 – 1) is the map of Yatta town, the site is shown on it.

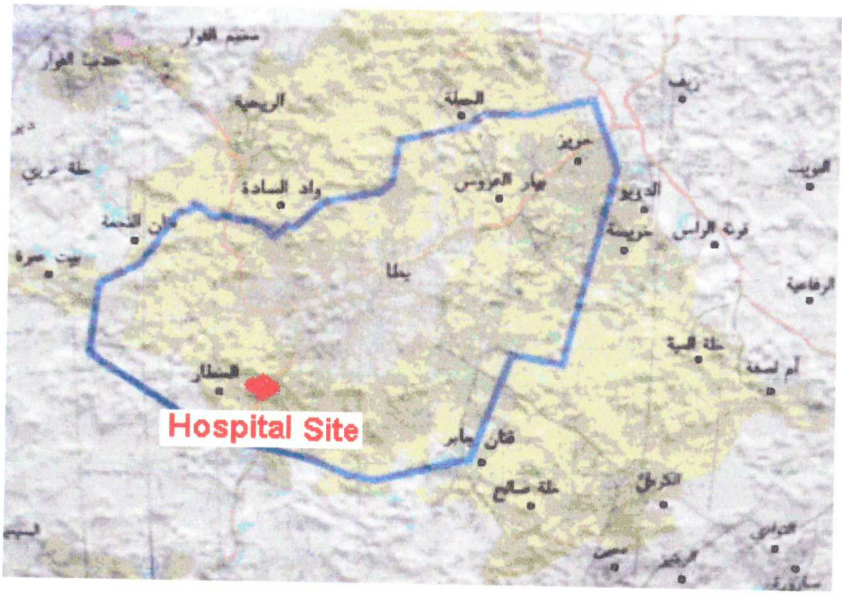

Figure (1 – 1) Yatta town

Martyr Abu Al-Hassan Qasem hospital

The hospital consists of three floors; basement, ground floor, and first floor, each one is about 1000 m^2 in area as shown in drawings (D – 1.1), (D – 1.2) and (D – 1.3). The total area of the hospital is about 7600 m^2.

Martyr Abu Al-Hassan Qasem Hospital provides medical services for the people of Yatta and to neighboring small villages. It contains administration departments that are:

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 tests
6. Pharmacy

In addition to these departments, the hospital contains other service departments such as maintenance, food, and laundry. It has only one ambulance and a mobile water tank. The number of physicians in Martyr Abu Al-Hassan Qasem Hospital is 15, and there are 15 nurses, all of them serve 50 beds.

Mechanical Systems in the Hospital

The mechanical systems are supervised by the maintenance department. Only one technician works in this department, and he is a PPU graduate specialized in mechanics who is in charge of all mechanical services maintenance.

Martyr Abu Al-Hassan Qasem Hospital comprises of a set of mechanical systems that serve it, these systems are:

1. Water system
2. Sewage system
3. Central heating system
4. Air conditioning system
5. Fire fighting system
6. Medical gases system
7. Elevator system
8. Ventilation system

1.5 Survey and Evaluation

Our project is concerned with the survey and evaluation of the mechanical systems in the hospital. The survey is concerned with studying the mechanical systems of the hospital which aims to:

1. Study the design and installation of the mechanical systems in the hospital.
2. Study the techniques of drawing preparation, and their software preparation.
3. To read and understand the bill of quantities and its relation to mechanical drawings and engineering specifications.
4. To be familiar with the most up-to-date mechanical systems used in hospitals.
5. To have knowledge of the well-known equipment manufacturers and hardware such as boilers, chillers, pumps, fans, pressure tanks, heat exchangers radiators, air handling units, softeners … etc.
6. The material inspection of piping networks of the mechanical systems and get knowledge of best quality of pipes and their fittings.
7. Study of the control systems associated with the mechanical systems within the hospital.
8. Survey of the problems associated with these mechanical systems through questioner delivered to employees, technicians, patients and visitors.

The evaluation which is the second part of our project is to study the defined problems we get from survey and provide solutions by analyzing these problems through:

1. The redesign and calculations of some mechanical systems and prepare the working drawings needed.
2. Field testing, adjusting and balancing of mechanical systems.
3. Providing better control systems.
4. Maintenance and field service plans.

The survey and evaluation process will be applied on the following systems:

1. Plumping system: this system contains two subsystems, both of them are basic requirements that should be exist in any building, and they are:
    a) Water system: the water in the hospital is used for many different purposes like drinking, bathing, cleaning, and general hygienes; such purposes require the existence of a water system that is built in a scientific design.
    b) Sanitary sewage system: in designing the sewage system it must be noted that there is no central sewage system in the cities in Palestine. This makes the build and design of an internal sewage system depend on the existence of a sewage hole (septic tank) for each building. Such fact causes a lot of pressure on the sewage system which requires a very will established study for the design of such system so as to reduce the pressure and make it safe.

2. Central heating: it must be taken into consideration the need for a stable and suitable temperature in all the departments of the hospital, which would mean that the central heating system must operate perpetually. Such considerations must be taken in the design of these systems.

3. Air conditioning system: Martyr Abu Al-Hassan Qasem Hospital contains air conditioning system that is only applied on the surgery and delivery rooms; a central conditioner with a ducting system serves these two rooms. The human comfort conditions require specific standards that must be used in the design and the build up of the air conditioning system.

1.6 The Importance of the Project

One of the main purposes of Palestine Polytechnic University is to help in building the society (a university that serves a society) is soundly applied in the institutions that render services to people like hospitals and care centers.

The existence of the hospital is extremely important in every city to achieve medical service coverage for citizens. The medical services vary from one hospital to another, but there are some basic services that are common for all hospitals; emergency service must exist in every hospital to deal with situations that can not wait for a long times to have a medical aid.

Delivery department is very important in the hospitals, especially in towns and villages that are far from the main cities; a fast aid should be given to women in this case. Also the surgery rooms are important in hospitals; a well timed surgery could save a human's life.

The importance of hospitals has a high level in countries having a war, an occupation or any kind of struggle such as Iraq, Sudan, Afghanistan and Palestine.

The importance of hospitals in Palestine rises from its capabilities of receiving a massive number of injured people who arrive there after being shot by the Israeli soldiers. That causes suffering for the Palestinians in every aspect of their lives, sociality, economically and heath aspects.

From here on, appears the need to study and evaluate all these systems in the institutions in general and specially in hospitals which would help improve and develop them as a means of supporting the survival and reducing the suffering.

This project represents an example on the cooperation between the educational institutions and the local society to benefit the, and to give a hand in building the free, strong and independent Palestinian state.

1.7 Contents and Description of the Project

As mentioned previously, this project will find out the technical problems in the mechanical systems of the hospital by a survey process. Then to suggest the solutions of these troubles by the evaluation which will lead to a list of recommendations to who is responsible for applying them according to this engineering study.

Most of troubleshootings in Martyr Abu Al-Hassan Qasem Hospital revolve around control issues; for instance controlling the work of domestic water pumps to achieve hospital needs, and to decrease the cost as much as possible, this can be satisfied by redesigning the critical water fixtures within the hospital.

Every system will be reviewed in one chapter as follows:

1. Chapter 2: Central heating system will be thoroughly explained and detailed with the design basics for all parts of the system, and a clear description for the heating system in the hospital. After that, and by the survey process using visits to the hospital and a questionnaire, troubleshootings will be determined, and then solutions will be designed.

2. Chapter 3: Plumping system, the domestic hot and cold water system, in addition to the sanitary sewage system will be studied; then some critical points will be designed to enhance the operation of these systems.

3. Chapter 4: Central air conditioning system for the surgery rooms will be put under a deep study to improve its performance using the layouts of the HVAC system, and by detecting the system on the ground.

CHAPTER TWO

SURVEY OF

CENTRAL HEATING SYSTEM

2.1 Introduction

Central Heating means heating from a central source. Even the Romans had central heating; this was in the form of an open fire under the floor. The heat from the fire was channeled through large ducts built into the floor giving a type of under floor heating.

Most modern central heating systems use water as the medium to get heat from the central source (boiler) to all the areas to be heated.

The correct term for a boiler is a heat generator because the water is not "boiled", although water in a modern central heating system can reach 100 deg °C and above, the normal running temperature is about 85 deg °C.

There is no such thing as a standard central heating system, you can tailor the system to suit your needs and, if working correctly, it should look after itself with regards to turning itself on and off automatically, should use no more fuel than necessary for your needs and always have the house at the correct temperature. It should also provide all the hot water you need, when you need it.

A centrally heated house will normally be cheaper to run than any other form of heating. For instance independent fires, even just one fire can be more expensive to run than a well designed central heating system with good quality controls.

Central heating using hot water heated by a central furnace, heat generator, or boiler (hot water central heatinmg) is the most common central heating type. It has being used inspite of existance of other modern types.

2.2 History of Central Heating

Central heating systems were used in northern Roman cities circa 100AD. Air heated by furnaces was led through empty spaces under the floors and out of pipes in the walls - this system being termed a hypocaust.

The Cistercian monks revived central heating using river diversions combined with indoor wood fired furnaces. An excellent example from the year 1202 of such an application is the well preserved Real Monasterio de Nuestra Senora de Rueda on the Ebro River in the Aragon region of Spain.

By the beginning of the 1700s Russian engineers were designing hydrological based systems for central heating. The best extant example is the Summer Palace of Peter the Great in St. Petersberg.

Slightly later in the year 1716, water was first used in Sweden to distribute heat in buildings. This system was used by Martin Triewald, a Swedish engineer, on a greenhouse at Newcastle upon Tyne. Bonnemain, a French architect, made its first industrial use on a Cooperative, at Château du Pêcq, near Paris.

Nowadays central heating takes many forms and designs, it is based on some basics and has its calculations. The principle is the same; i.e. to produce heat from a central source, all modern forms follow this principle.

2.3 The Principle of Central Heating

Central heating is a common method of providing warmth to the whole interior of a building, or portion of a building, from one point to multiple points or rooms. When combined with other systems in order to control the building climate the whole system may be referred to as HVAC (Heating, Ventilation and Air Conditioning).

Central heating differs from local heating in that the heat generation occurs in one place, such as a furnace room in a house or a mechanical room in a large building (which is not necessarily the "central" geometric point). The most common heat source is through combustion of fossil fuel in a furnace or boiler. The resultant heat is then distributed typically by forced air through ductwork, by water circulating through pipes or by steam fed through pipes. Of increasing use, the heat source may be solar powered, in which case the distribution system is normally by water circulation.

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

- Fuel supply tank and lines - represents a heat source
- Boiler - heats water in a closed water system
- Piping network - transfers hot water from boiler to heat transfer elements, and brings cold water back to boiler, and icludes control valces
- Pump - circulates the water in the closed system
- Heat exhangers - provides hot water for domestic uses
- Expansion tank - keeps pressure on a suitable average in the network
- Heat transfer elements such as radiators, and convectors - wall mounted panels through which the heated water passes in order to release heat into rooms
- Chimney - to get rid of smokes produced by burning the fuel

In this case, the heated water in a sealed system is allowed to flow through a heat exchanger in a hot water tank or hot water cylinder where water from the normal water supply is heated by it before being fed to hot water outlets in the house for domestic uses. These outlets could be hot water taps or appliances such as a washing machine or dishwasher.

Central heating systems are classified based on the form of piping network to:

- Single pipe system
- Double pipe system
- Three pipe system
- Four pipe system
- Radial pipe system

Although these forms differ from each other in water flow, connection way, and efficiency, the most common one now is radial system espicially in the last five years.

In radial pipe heating system each radiator has its own circuit, hot water enters the radiator coming from a hot water manifold, then and after heat transfer process is finished , slightly colder warter exits the radiator returning to a cold water manifold.

All foundations of radial pipe heating system are made under ground, these foundations are also based on calculations governed by the number of sections in each radiator.

Radial pipe heating system is widly used in Palestine, where hot water heating systems are the most common method for heating. Some other modern forms are used but they are rarely used, such as under floor heating or pannel heating. Even most of technicals in this field can easily deal with radial system.

2.4 Heating System in Martyr Abu – Alhassan Qasem Hospital

2.4.1 Radial piping system

The heating system in the hospital is based on the radial piping system. As shown in figure (2 – 1), the fuel tank supplies the burner with the diesel so as to start the burning process, the hot water exits the boiler as it is heated to about 85 °C to reach the supply manifold which gathers hot water and supplies all lines.

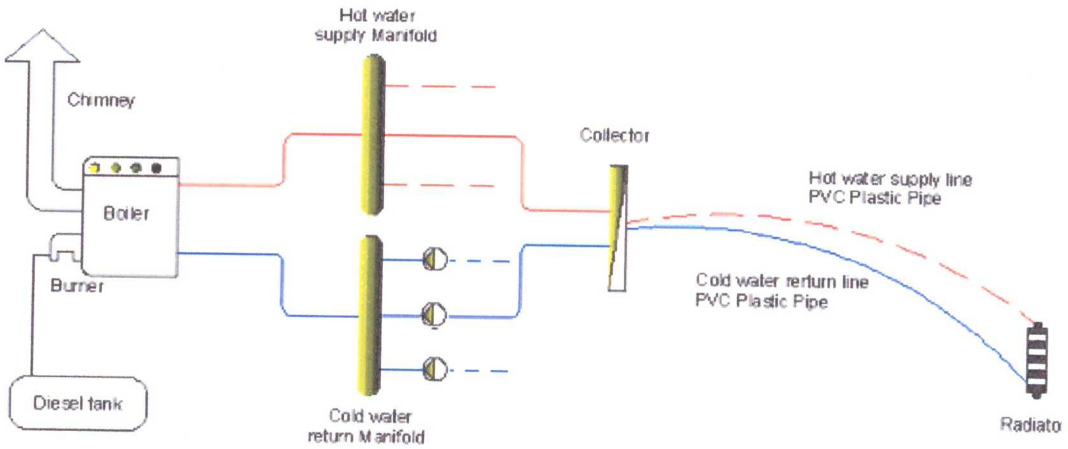

Figure (2 – 1): Radial piping system

The hot water of each line supplies a hot water collector, this collector, which is made of copper, distributes the hot water to the radiators, the heat transfer elements, by a plastic pipe embeded under the floor.

After heat transfer process the cold water returns to a cold water collector, then to the return manifold in its way to the boiler to be reheated. The pump takes the responsibility for circulating the water within the closed water cycle (water circuit).

The chimney exhausts the smoke resulted from burning the fuel. It has to be well insulated to decrease the losses.

2.4.2 Heating system equipment

Boilers

Boiler room of Martyr Abu – Alhassan Qasem Hospital, as shown in drawing number (D – 2.1), contains two steel boilers, CHAPEE type, each with a capacity of 320,000 kcal. One of the boilers is used for heating, the other is a stand by boiler. The two burners connected to the boilers are SICMA type. Above each burner there is an automatic fire fiting cylinder to deal with any emergency state. The burner flow rate is given by

$$\dot{V}_{Burner} = \frac{Q_{Boiler} \cdot \mu}{C\upsilon \cdot \rho \cdot \eta} \qquad \text{(E-2.1)}$$

Where:

H is the burner efficiency = 85 %

$C\upsilon$ is the choleric value of diesel = 11250 kcal / kg

ρ is the density of diesel = 840 kg / m^3

μ is the factor to change kW to kcal / h = 860 (kcal / kW)

Total boiler capacity is the result of all heat loads for all rooms and spaces within the hospital. It is common to multiply that total load by 1.25 to substitute the loss in piping system and chimney. The equation is

$$Q_{Boiler} = Q_{TOT} \times 1.25 \qquad \text{(E-2.2)}$$

Chimney

Each boiler has an exhuast (chimney) outlet of 300 mm, theses two outlets are collected by a larger steel chimney with a diameter of 600 mm. The stack of this large chimney rises with the building up to the roof, the chimney is insulated, as shown in figure (2 – 2), a 50 mm thickness fiber glass insulation is surrounding the chimney.

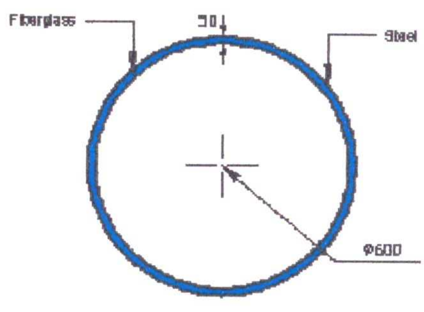

Figure (2 – 2): Insulation of chimney

At the bottom end of the chimney there is a drainage pool connected to a drain pipe ends above a drain trench with 2.5 m length, 0.4 m width, and 0.3 m depth in the ground, see drawing (D – 2.1).

Expansion tank

There are two expansion tanks within the boiler room; one for the heating system with a volme of 500 L, the other is 200 L volume, and used for the domestic hot water as shown in drawing (D – 2.1). Both of the two expansion vessles are ZILMET type. The volume of expansion tank is calculated using the relation

$$\text{Expansion tank volume} = \text{Water volume in the network} \times \text{Expansion factor} \qquad \text{(E-2.3)}$$

Hot water cylinders

To heat the domestic water for hospital use; there are two domestic hot water cylinders, with a volume of 750 L for each. The hot water from heating system enters the cylinder and makes a helical round to heat cold water within it, known that there is no mixing between the two waters.

Pumps and main piping lines are installed above the boilers, this piping system, which will be detailed in the next section, consists of the main hot and cold water pipes, and heating, domestic, and air conditioning water pumps and lines.

A pressure gauge and a thermometer are based on both supply and return headers, these measurment tools are used to detect the operation of the heating system.

Deisel tanks

There are two deisel tanks, 6500 L each, supply the burner with fuel. There is an equation related to the time of operation daily, and the time for filling the tank, this equation is also related to the volume flow rate of the burner, the equation is

$$V_{DT} = \dot{V}_{Burner} \times \text{Operating time} \qquad \text{(E-2.4)}$$

Piping system

The water mass flow rate of the system is calculated by the equation

$$\dot{m} = \frac{Q_{TOT}}{Cp \cdot \Delta T} \quad \text{(E-2.5)}$$

The friction head loss in pipes is

$$H_f = f \frac{L}{D} \cdot \frac{v^2}{2g} \quad \text{(E-2.6)}$$

Where f is the friction factor in pipes, L is the pipe length, D is the pipe diameter, υ is the water velocity, and g is the gravitational acceleration.

The head loss due to fittings is expressed as

$$H_T = n \cdot \kappa \cdot \frac{v^2}{2g} \quad \text{(E-2.7)}$$

Where κ is the fitting factor, n is the number of fittings (elbows and tees), υ is the water velocity, and g is the gravitational acceleration.

Selection of pump

After finding the flow rate, and the pressure drop (head loss), we can use the charts to select a pump. There are charts that are made by ARMSTRONG to select a pump for heating system.

As mentioned in describing the radial piping system, hot water leaves the boiler passing through a 150 mm diameter header, called supply header or supply manifold. The circulating pump, which has an other one stand by if a problem happens, supplies the hot water main line with diameter of 50 mm. The pumps are 1500 W ARMSTRONG ones. This line enters the domestic hot water cylinder with the same diameter.

These lines lead to the inside hot water manifolds (collectors), these collectors are made of copper, with a diameter of 16 mm as shown in figure (2 – 3).

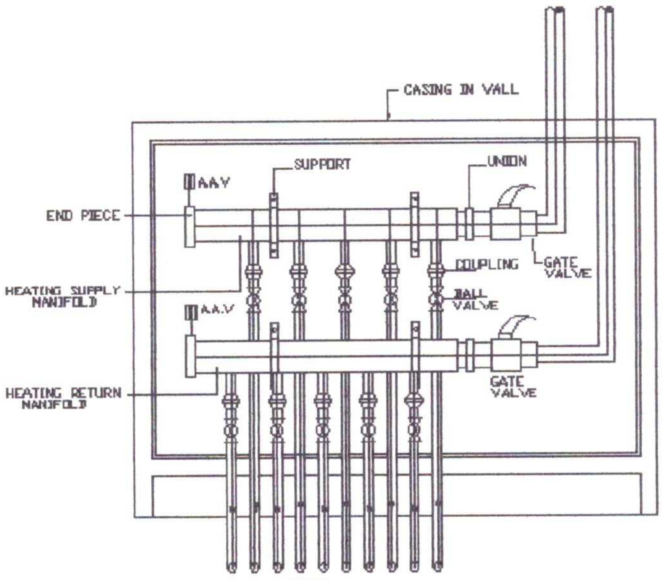

Figure (2 – 3): Inside copper collector

Flexible plastic pipes with 16 mm diameter carry the hot water from the collector to the radiator.

The return passage of the heating system is the same; the cold water, which is relatively cold to the supply water, with a temperature of 75 °C, returns from the radiator by a 16 mm plastic pipe to the collector in its way to the return manifold back to the boiler to be heated again to 85 °C.

Radiators

Radiators are the heat exchanging elements; although they are called radiators, they basically transfer heat by convection. The radiator receives hot water, makes the heat transfer process, and returns colder water.

Radiators are classified according to the material of which they are made to

- Steel radiators
- Cast iron radiators
- Aluminum radiators

Radiators give different thermal outputs according to their dimensions, number of sections, and the way of installation. Selection of radiators is based on the load of the space to be heated, this load determines the number of radiators to be installed in the room, also determines the number of elements per radiator.

In this hospital the radiators installed are cast iron radiators with a thermal output of 130 W, with total length of 69 cm. installed above the ground by 15 cm, given that the plastic PVC pipe has a hot water content that can give not more than 3500 W, so the maximum number of elements in each radiator is 27 elements.

2.5 Heat Load Calculations for The Hospital

Heat load for the hospital consists of:

1. Heat transmission through walls: walls of hospital building structure is shown in figure (2 – 4), we can see that the walls are insulated.

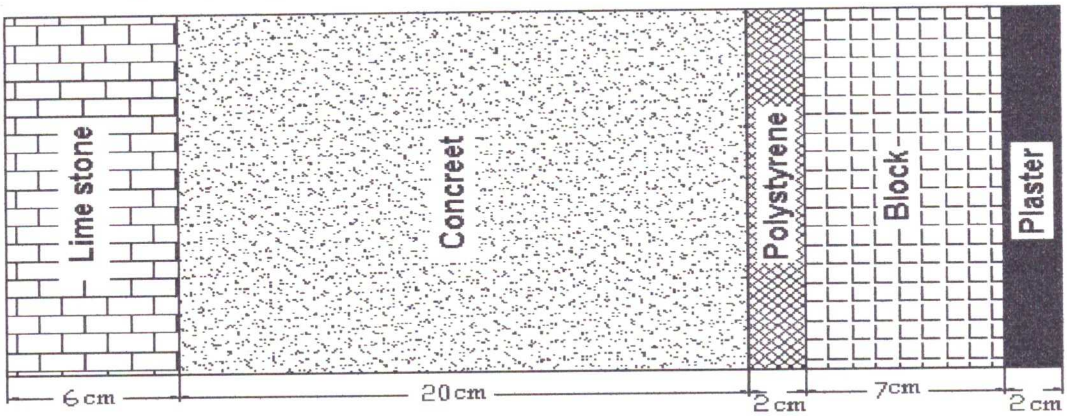

Figure (2 – 4): Wall construction

Table (2 – 1) illustrates the properties of wall layers.

Table (2– 1): Construction of the walls of the building.

Layer	Thickness t (mm)	k (W / m °C)
Lime stone	60	1.53
Concrete	200	1.72
Polystyrene	20	0.032
Block	70	0.77
Plaster	20	0.72

The overall heat transfer coefficient of walls is given by the equation

$$U_W = \left(R_i + \frac{t_1}{k_1} + \frac{t_2}{k_2} + \frac{t_3}{k_3} + \frac{t_4}{k_4} + \frac{t_5}{k_5} + R_o \right)^{-1} \qquad \text{(E-2.8)}$$

$$U_W = \left(0.12 + \frac{0.06}{1.53} + \frac{0.20}{1.72} + \frac{0.02}{0.032} + \frac{0.07}{0.77} + \frac{0.02}{0.72} + 0.06 \right)^{-1} = 0.9266\ W / m^2\ {}^0C$$

2. Heat loss through ceiling: ceiling of hospital has the structure shown in figure (2 – 5).

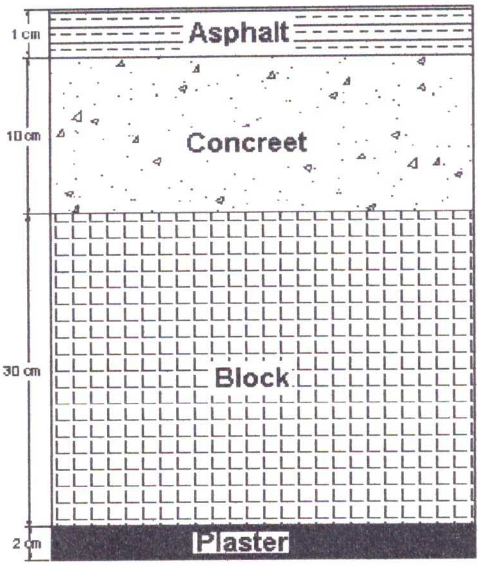

Figure (2 – 5): Ceiling construction

Table (2 – 2) illustrates the properties of ceiling layers.

Table (2 – 2): Construction of the ceiling

Layer	Thickness t (mm)	k (W / m °C)
Asphalt	10	0.37
Concrete	100	1.72
Block	300	0.52
Plaster	20	0.72

The overall heat transfer coefficient of ceiling is given by the equation

$$Uc = \left(R_i + \frac{t_1}{k_1} + \frac{t_2}{k_2} + \frac{t_3}{k_3} + \frac{t_4}{k_4} + R_o \right)^{-1} \qquad \text{(E-2.9)}$$

$$Uc = \left(0.12 + \frac{0.01}{0.37} + \frac{0.10}{1.72} + \frac{0.30}{0.52} + \frac{0.02}{0.72} + 0.06 \right)^{-1} = 1.1496 \text{ W / m}^2 \ {}^0\text{C}$$

3. Heat transmission through glass windows: since the windows are mono glass, according to Palestinian Code for Energy Efficient Buildings, conduction heat transfer coefficient of widows is k = 0.8 W / m °C. so the U value is

$$U_G = \left(R_i + \frac{t_1}{k_1} + R_o\right)^{-1} = \left(0.12 + \frac{0.004}{0.8} + 0.06\right)^{-1} = 5.4 \text{ W / m}^2 \text{ °C}$$

4. Heat loss through the floor: floor construction is shown in figure (2 – 6); table (2 – 3) gives the thermal conductivity values for floor layers.

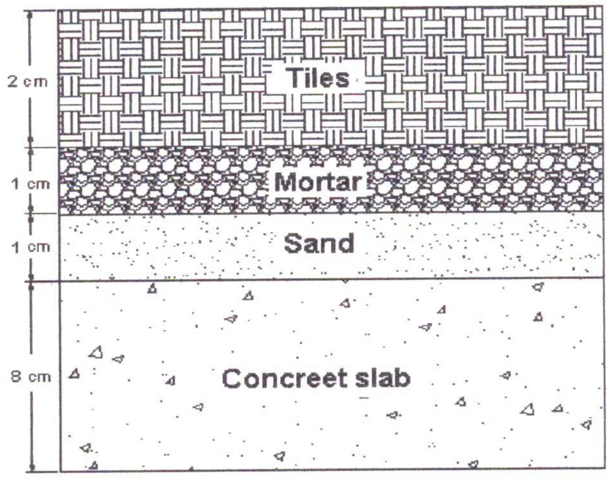

Figure (2 – 6): Construction of floor

Table (2– 3): Construction of the floor

Layer	Thickness t (mm)	k (W / m °C)
Concrete slab	80	1.72
Sand	10	0.70
Mortar	10	1.40
Tiles	20	1.20

The overall heat transfer coefficient of floor is given by

$$U_F = \left(\frac{t_1}{k_1} + \frac{t_2}{k_2} + \frac{t_3}{k_3} + \frac{t_4}{k_4} + R_o\right)^{-1} \qquad \text{(E-2.10)}$$

$$U_F = \left(\frac{0.08}{1.72} + \frac{0.01}{0.70} + \frac{0.01}{1.40} + \frac{0.02}{1.20} + 0.06\right)^{-1} = 6.4 \text{ W / m}^2 \text{ °C}$$

All parts mentioned above follow the heat equation

$$Q = U.A.\Delta T \qquad \text{(E-2.11)}$$

Where A is the area of heat transfer.

5. Heat loss by infiltration: infiltration is the leakage of outside air through cracks and clearances around windows and doors. It is divided into tow parts:

- Sensible heat loss: calculated by the relation

$$Q_S = \dot{m}.Cp.\Delta T \qquad \text{(E-2.12)}$$

Where Cp is the specific heat capacity of air, Cp = kJ / kg.°K

$\dot{m}$ is the mass flow rate of outside air, where

$$\dot{m} = \rho \dot{\upsilon} \qquad \text{(E-2.13)}$$

$\dot{\upsilon}$ is the volume flow rate of air, where

$\dot{\upsilon}$ = Volume of the room × number of air change per unit time (E-2.14)

- Latent heat loss: calculated by

$$Q_L = \dot{m}.(\omega_{in} - \omega_{out}).h_{fg} \qquad \text{(E-2.15)}$$

Where ω is the humidity content of air.

h_{fg} is the latent heat for evaporation of water.

Then the total infiltration heat loss is given by the equation

$$Q_{inf} = Q_S + Q_L \qquad \text{(E-2.16)}$$

The total heat load for the room is given by

$$Q_{TOT} = Q_W + Q_C + Q_F + Q_{inf}$$

$$\text{Number of elements for each radiator} = \frac{\text{Heat load of the room}}{\text{Thermal output of the section}} \qquad \text{(E-2.17)}$$

2.6 A Sample for Calculations

To explain the heat loss calculations, take one room as an example, as shown in building drawing (D – 2.4), room F19, the doctors' room, calculations will be applied on it.

$$Q_W = U\ A\ \Delta T = 0.9266 \times ((3.6 \times 3) - (1.2 \times 1)) \times (24 - 4) = 180\ W$$

$$Q_C = U\ A\ \Delta T = 1.1496 \times (3.6 \times 3.6) \times (24 - 4) = 298\ W$$

$$Q_G = U\ A\ \Delta T = 5.4 \times (1.2 \times 1) \times (24 - 4) = 129.6\ W$$

No heat loss through the floor since the ground floor is already heated and at the same temperature of the first floor.

$$\dot{\upsilon} = \text{Volume of the room} \times \text{number of air change per unit time}$$

$$= (3.6 \times 3.6 \times 3) \times \frac{1}{3600} = 0.0108\ m^3 / s$$

$$\dot{m} = \rho \dot{\upsilon} = 1.25 \times 0.0108 = 0.0135\ kg / s$$

$$Q_S = \dot{m}.Cp.\Delta T = 0.0135 \times 1 \times (24 - 4) = 270\ W$$

$$Q_T = \dot{m}.(h_{in} - h_{out}) = 0.0135 \times (48 - 13) = 472.5\ W$$

$$Q_L = Q_T - Qs = 470 - 270 = 202.5\ W$$

$$Q_{TOT} = 180 + 298 + 129.6 + 270 + 202.5 = 1080\ W$$

$$\text{Number of elements of cast iron radiator} = \frac{1080}{130} = 8\ \text{elements}$$

Drawings (D – 2.2), (D – 2.3), and (D – 2.4) illustrate the heating system for all floors of the hospital, collectors and radiators are clearly drawn, the heat load for each room is also shown on the drawings.

2.7 Troubleshooting in the Heating System

By discussing the system with the technician of the hospital we found some troubles. First, the two boilers have to be controlled so that the stand-by boiler could work automatically.

The situation now is if the boiler connected to the heating system (on-duty boiler) stops working; we have to divert the heating system to the stand-by boiler manually.

Another problem is that some of the rooms in the hospital are not warm enough; as mentioned previously, the water mass flow rate governs the heat transfer process, in other words, it determines the room temperature. When the flow rate is well adjusted, a perfect room temperature will be reached, which means controlling the heating process.

The overall heat transfer coefficient (U – value) of the glass windows is very high, since they are not doubled. The doubled glass window is better in that it has an air layer between the two plates of glass; this makes a kind of insulation and decreases the thermal conductivity of the window, which will finally decrease the heat transfer through it.

CHAPTER THREE

SURVEY OF

PLUMBING SYSTEM

3.1 Introduction

Plumbing, from the Latin for lead (plumbum), is the skilled trade of working with pipes, tubing and plumbing fixtures for potable water systems and the drainage of waste. Plumbing originated during the ancient civilizations such as Roman, Persian, Indian, and Chinese civilizations as they developed public baths and needed to provide potable water, and drainage of wastes.

A plumber is someone who installs or repairs piping systems, plumbing fixtures and equipment such as water heaters. The plumbing industry is a basic and substantial part of every developed economy due to the need for clean water, and proper collection and transport of wastes.

Plumbing is a system of pipes and fixtures installed in a building for the distribution of potable water and the removal of waterborne wastes. Plumbing is usually distinguished from water and sewage systems, in that a plumbing system serves one building, while water and sewage systems serve a group of buildings or a city. Improvement in plumbing systems was very slow, with virtually no progress made from the time of the Roman system of aqueducts and lead pipes until the 19th century. Eventually the development of separate, underground water and sewage systems eliminated open sewage ditches and cesspools.

3.2 History of Plumbing

The Roman Empire eventually encompassed all the countries along the Mediterranean Sea, Mesopotamia, the Balkans, and most of modern Europe, including Britain. With their plumbing engineers in tow, the Romans left in their wake large - and small - scale water systems that incorporated similar-style aqueducts, lead pipes, heated floors, dams and drains. From Rome's Cloaca Maxima, largest of the ancient sewers, to the famous spas of Aquae Sulis in Bath, England, and the colossal baths of Emperors Caracalla and Diocletian, the early Roman plumbers left indelible marks on civilization.

I n 79 A.D., Mount Vesuvius erupted and obliterated the ancient Roman resort towns of Pompeii and Herculaneum. Beneath the lava ruins rests a freeze - frame of high style Roman living, thanks in part to the plumberium, workers of lead.

Since 1758 when excavation began in Pompeii, palaces of the Caesars and private homes of the nouveau riche merchants and court hangers-on have emerged along with theaters, dance halls and circuses. In addition, grand-style temples and amphitheaters were uncovered, along with elaborate public baths for hundreds of people, and a water supply system for both private and public needs.

Water closets were in vogue in Pompeii, and archaeologists have found ancient closets in the back of one palace, including a cistern to flush water to the different seats. Near the palace kitchen they also found an arched recess approximately three feet deep. Although the actual wood had long disappeared, archaeologists say they could still see outlines of hinges for the privy seats. This bronze tub in figure (3 – 1) was buried when Vesuvius erupted in 79 A.D. It measures 6'4" long x 2' deep.

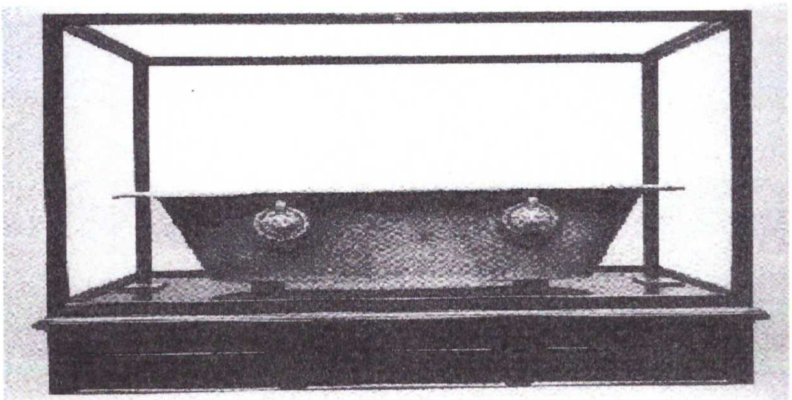

Figure (3 – 1): Bronze bathtub

The kitchen's brick oven sat four feet from the privy. To the efficient Romans who had no inkling of germs, the proximity allowed the easy disposal of both scraps and excrete. The women used the privy along side the kitchen; the men went around to the back and used their own.

Plumbing Galore: The famous Roman aqueducts supplied water to the town, the pipe used in siphons set in sections of 10 feet. The sections fit into a one-foot square block of stone servicing as an elbow, with connecting holes cut into the adjoining walls.

Water flowed continuously into a private home through a nozzle, the homeowner paying water rates according to the nozzle size. At the reservoir where the service pipe was attached, engineers installed a kind of ball float, resembling the modern type, to assure a reasonable steady flow of water. Each length of service pipe carried the subscriber's name to prevent any unpaying freeloaders from tapping into his neighbor's pipe.

The plumbers of Pompeii had a flourishing trade that included fashioning gutters of lead for the private homes. A Pompeiian house featured an atrium and open-roof design. Underneath a tank collected the rainwater which ran down from the roof tiles.

In Pompeii, this is how the plumber formed pipe: He poured molten lead into various sheets of thickness and dimension, and allowed them to cool. Then he shaped the sheets around a core of wood, leaving a V-shaped opening where the ends met. He fashioned a sand or clay mold around the channel, and poured hot lead into the opening. Typically the pipe was elliptical, or egg-shaped. According to present-day experts, the plumberium's efforts were crude, but workable.

The plumber made connecting joints in a like manner. He flared one end of the pipe into a cone - like shape, and fit the adjoining piece of lead into it. He soldered the two pieces together with pure hot lead.

Even Old Roman galleys were outfitted with regular plumbing, especially the ones used by emperors. It's reported that one old relic may have been used by Emperor Caligula for pleasure cruises. Expense unspared, it was outfitted with bronze pipe and ornaments, with running water provided in the lavish cabins.

3.3 Sanitary Sewage System

3.3.1 Function and components of sanitary sewage system

Sanitary sewage system (drainage system) functions to carry away the contaminated water and solids produced by domestic uses of water, and the use of water closets and other sanitary fixtures.

Sanitary sewage system consists of the following basic components:

1. Drainage piping to carry away the waste water.
2. Trap (siphon) to provide a water seal that prevent sewer gases such as methane, CO_2, odors, vermines, and any other sanitary substances from entering the building.
3. Vents to avoid self-siphoning of fixture traps and therefore loss the seal of trap.

3.3.2 Drainage fittings and pipes

Fittings are used in pipe and plumbing systems to connect straight pipe or tubing sections, to adapt to different sizes or shapes, and to regulate fluid flow, for example. Fittings, especially noncommmon types, can be expensive, and require time, materials, and tools to install, so they are a non-trivial part of piping and plumbing systems. Valves are technically fittings, but are usually discussed separately.

Materials of fittings

The 'bodies' of fittings for pipe and tubing are most often of the same base material as the pipe or tubing being connected, e.g., copper, steel, polyvinyl chloride (PVC), or other plastic. However, any material that is allowed by code may be used, but must be compatible with the other materials in the system, the fluids being transported, and the temperatures and pressures inside and outside of the system. For example, brass-bodied fittings are common in otherwise copper piping and plumbing systems. Fire hazards, earthquakes, and other factors also influence fitting materials.

Sanitary pipes are classified into four types as shown in figure (3 – 2).

1. Branch pipe: it is refer to as all horizontal drainage pipes that drain water from the fixtures to the stack. It is designed to have a minimum slope of $\frac{1}{4}$" per foot, in other expression 1.8 % of total length of the pipe. Branches are designed to run maximum of 50 % of its complete fill, with a recommended velocity of 2 Fps.
2. Stack pipe: all vertical drainage pipes that drain water from the branches to the building pipes are called the stacks. They should be designed to run in the range of 25 % - 33 % of fill maximum. Stacks should not deviate from the vertical, and the water velocity within them is 15 Fps.
3. Building pipe: a line that connecting terminal of stack toward the first manhole faces it. This pipe is designed so as not to exceed slightly more than 50 % of it fill, with a recommended flow velocity of 3 Fps, and a minimum slope of $\frac{1}{8}$" per foot (1 % of the total length of the pipe).
4. Sewer pipe: the pipes drain water between manholes are refer to as sewer pipes, these pipes are designed with a minimum slope of $\frac{1}{8}$" per foot (1 % of the total length of the pipe), with a recommended flow velocity of 4 Fps. The fill should be somewhat over 50 % of the total fill.
5. Manholes: these are exterior clean-outs, they are recommended to be installed each 4 m of sewer drain pipes.

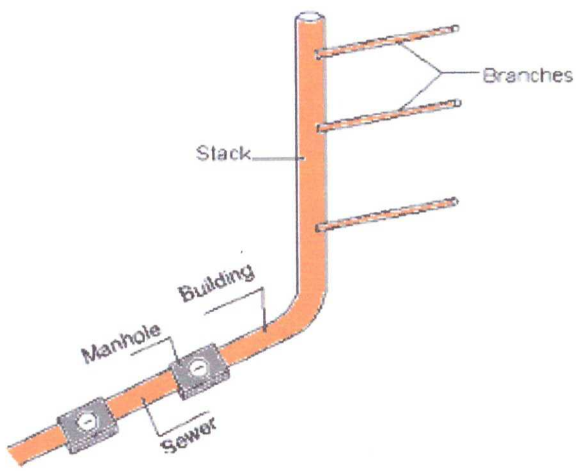

Figure (3 – 2): Drainage piping

Pipes are classified based on the water that they drain into:

1. Soil pipes: pipes that carry black water; wastewater resulted from the urinals and water closets.
2. Waste pipes: pipes carry gray water; wastewater resulted from sinks, lavatories, bathtubs … etc.

3.3.3 Septic tank

Septic tank is a large hole that receives the wastewater from all sewer pipes and drains and collects it in order to get rid of it or to treat it to reuse it.

As shown in figure (3 – 3) sewage fluids enter the septic tank, the solid sinks into the bottom of the tank, bacterial action breaks up the solids and aids in purifying liquids, very small amount of sludge accumulates at bottom with time and a scum forms at the top level surface of contents.

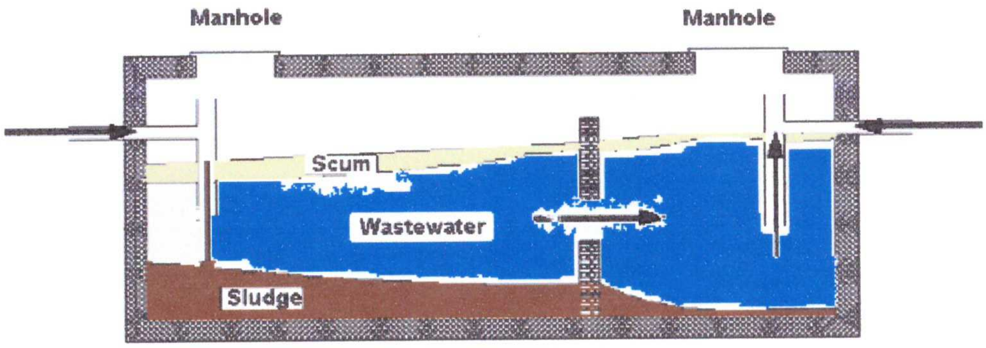

Figure (3 – 3): Septic tank

Septic tanks are designed according to some specifications that will be thoroughly explained in the evaluation part.

3.3.4 Traps

As water enters the inlet end of P-trap, an equal amount of water leaves the outlet end carrying all solid materials in the water, provided that an equal pressure is available at both ends with a maximum value of ±1 inch of water. The depth of the trap is in the range of 2 – 4 inches, the trap arm should be mostly as shown to prevent trap blow out due to sloping of drainage pipe, also to insure adequate air movement needed for venting and pressure equalizing.

If the trap is deeper, it will not become self scoring; in other words self cleaning, it will return solid material and cause blockage of trap.

Traps are classified based on shape to:

1. P – Trap: it is used when the vents are insufficient; especially in pipes drain both gray and black water, as shown in figure (3 – 4).

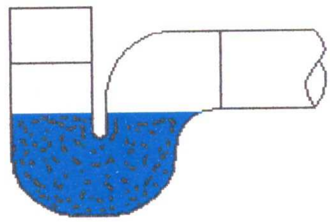

Figure (3 – 4): P - Trap

2. Drum Trap: as shown in figure (3 – 5), it has the tendency to collect foreign materials and cause blockage. This makes this trap not suitable.

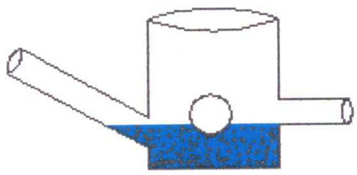

Figure (3 – 5): Drum Trap

3. Bell – Trap: a trap with moving parts tends to have fouling and causes blockage, and so it is not recommended to use this type of traps.
4. S- Trap: this type will siphon-out the trap as soon as the outer leg fills with water, as shown in figure (3 – 6), also it is not easy to connect the S – trap to the vents. So it is not commonly used.

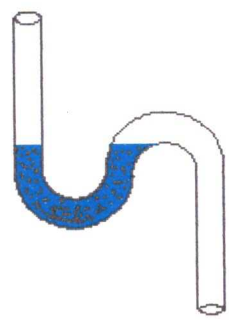

Figure (3 – 6): S - Trap

Siphonage phenomenon mentioned previously is caused by some factors related to the pressure and flow rate of wastewater. These factors are:

1. Pressure drop in stacks as a result of sucking air with water during flow from the top of the stack to the bottom.
2. High flow rate of water in branches especially in branches with small diameters.
3. Water evaporation when the users do not use the fixtures for long times.
4. Leakage of water from the connection points between pipes and fixtures.

3.3.5 Sanitary fixtures

Plumbing fixtures are the devices installed for the end-users. Some examples of fixtures include water closets (toilets), urinals, bidets, showers, bathtubs, lavatories, utility and kitchen sinks, drinking fountains, ice makers, humidifiers, air washers, fountains, eyewashes, floor drains, garbage disposers, and hosebibbs

Sanitary fixtures are made so that they could be easily installed and maintained, and comfortable in use. Fixtures also have to be well-shaped, and they should contain no cracks in order not to absorb moist.

Sanitary fixtures vary according to its use; they have many types and forms:

1. Water closets (WC): this fixture is responsible for drainage of solid and liquid human wastes. They are divided into two types

   a) Oriental water closet: it is healthier since there is no direct contact between the fixture and the human body, as shown in figure (3 – 7). An oriental WC consists of three independent parts:

Figure (3 – 7): Oriental WC

- The slab: the base installed on ground level, its dimensions are between 0.5 m × 0.5 m and 0.7 m × 0.9 m.
- Bowl: it is sloped downward with a width of 30 cm – 10 cm, installed between the slab and the siphon.
- Siphon: a turned pipe with a diameter of 4" installed under the bowel.

Figure (3 – 8): European WC

b) European water closet: it is more comfortable in use, see figure (3 – 8), and it consists of a bowl and a siphon. The seat above the bowel is made of plastic.

2. Urinals: these fixtures are installed in public buildings; they are special for men as shown in figure (3 – 9). Urinals have two types:
   a) Stall urinals.
   b) Urinal basin.

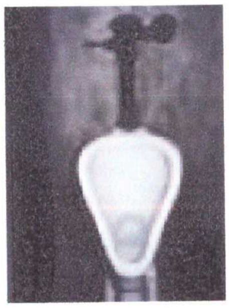

Figure (3 – 9): Urinal

3. Flush tanks: all WC's and urinals need an amount of water to clean them after using, this water is often stored in small tanks known as flush tanks shown in figure (3 – 10). These tanks can discharge all the water at once. Flush tanks have many forms:
   a) High flushing tank: used for both European and oriental WC's.
   b) Low flushing tank: installed only with European WC's.
   c) Automatic flush tank: used to clean urinals.
   d) Auto-flush tank: is used to clean drainage pipes that were not designed with an accurate slope.

Figure (3 – 10): Flush tank

4. Bidet: an elliptical sink put beside the European WC for washing. It is supplied by hot and cold water by a special mixer installed on the back top edge in specific holes.
5. Sinks: have many forms vary according to the use:
   a) Lavatory: a basin for washing hands shown in the figure beside. Lavatories have the many forms; rectangular, circular and elliptical. Installation of lavatories could take many forms; some of them installed on rods of stainless metal, others installed far from the wall by 5 cm, like those used in hospitals, and others lie on legs.

Figure (3 – 11): Lavatory

Lavatory receives two water lines; hot and cold, are founded at 100 cm height from the floor level if the faucet is wall fixed, but if it is fixed on the lavatory, it is founded on 50 cm, while the waste line is founded at 45 cm. Given that the lavatory itself is founded at a height of 85 cm.

b) Kitchen sink: also known as washing basin. Used for washing kitchen tools, it is installed commonly at 90 cm height. Kitchen sink receives two water lines; hot and cold, are founded at 105 cm height from the floor level. If the faucet is wall fixed, but if it is fixed on the sink, it is founded on 55 cm, while the waste line is founded at 50 cm.

Figure (3 – 12): Kitchen sink

c) Bathtub: a relatively large sink used for bathing, its faucet is founded at 70 cm above the floor; it may exist in many forms and dimensions.

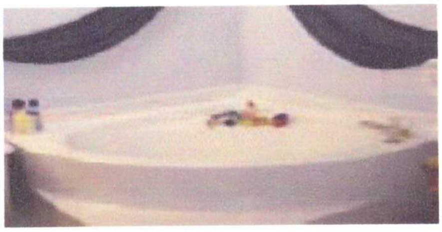

Figure (3 – 13): Bathtub

d) Shower basin: used for showering, it is supplied by hot and cold water the same as the bathtub.

Figure (3 – 14): Shower

3.3.6 Drainage accessories

The sanitary sewage system includes some other parts to complete the function of the system, these parts are called accessories, and they are:

1. Clean-out: blockage occurs most frequently in drainage piping where there is a change in the direction of flow, reduction in pipe sizing and at fittings. Clean-outs are installed in the following sites:
   a) Before P-trap or beside it using a Y-connection.
   b) At the end of the branch.
   c) At the base of every stack.
   d) At all changes in direction more than 45°.
2. Interceptors (separators): separate harmful materials such as oil, grease, hair, sand, flammable liquids … etc. from waste water which could cause blockage of drainage pipe.

3.3.7 Design of drainage pipes

To design a perfect drainage system, the following steps should be followed:

1. Draw a simple riser of the entire system showing all fixtures.
2. Assign drainage fixture units (DFU) for each fixture.
3. Find the total drainage fixture units in each drainage pipe.
4. Determine the required size of horizontal fixture branches and stacks.
5. Determine the size and slope of the building drain and its branches, and the building sewer.
6. Determine the size and slope found in 5 meet the requirements of the code.

3.3.8 Sanitary sewage system in Martyr Abu – Alhassan Qasem Hospital

The drainage system of the hospital is an ordinary system that considers all design specifications; each group of fixtures drains the wastewater by branches to stacks which lead to the building drain pipe to a number of manholes surrounding the building in their way to the septic tank.

The hospital drainage system also contains the other fittings such as, tees, elbows, traps and vents and the accessories such as, clean-outs and separators.

This drainage system differs from other common ones in that all fixtures have specific design considerations that should be followed especially in the case of handicapped fixtures and needs. Also in surgery department fixtures should be easily used and treated.

Sanitary sewage system in the hospital takes in consideration the architectural requirements in order to have a perfect design in the side of form and performance.

Drainage system details are shown in drawings (D – 3.1), (D – 3.2) and (D – 3.3).

3.3.10 Troubleshootings in the drainage system

The drainage system in the hospital has the following troubles:

1. There are some points that have leakage in the piping system, especially in fittings and around the fixtures.
2. Odors and sewer gases are not prevented from entering the building; because of the self-siphoning.

3.4 Domestic Water System

Domestic water supply or system (DWS) is a comprehensive term for the potable water supply systems in residential, commercial, institutional, and industrial buildings. Potable water is drinking water, but is used in more quantities for operating plumbing fixtures that are not intended for drinking or cooking. This article addresses the supply side of plumbing systems, where traps, drains, and vents, rainwater, surface, and subsurface water drainage, fire sprinklers, and other topics are addressed in related articles.

Most modern western water systems are directly fed from a municipal water system by a high-pressure pipe, usually located under the road or street. A water meter is installed to allow the supplier to charge appropriately for the water usage. Many houses in rural areas still use a cistern or a well where convenient water supply is not available; a pump and pressure tanks are used to create and maintain system pressure needed for operating the plumbing fixtures.

Any external water supply is almost always a 'cold' unheated or cooled water supply. The cold water supply system may include filter or water softener appliances. This cold water is then fed to plumbing fixtures that require cold water. The largest users of cold water are water closets (toilets) and outdoor hose bibbs, but cold potable water is needed at lavatories, sinks, bathtubs, showers, water fountains, humidifiers, and ice-makers too, for example. Cold water is also supplied to water heaters, if a building is so equipped.

3.4.2 Hot water

Domestic hot water is provided by means of water heater appliances. The hot water from these units is then piped to the various fixtures and appliances that require hot water, such as lavatories, sinks, bathtubs, showers, washing machines, and dishwashers.

Water heating is a thermodynamic process using a heating source to heat water above its initial temperature. Potable water is usually heated by a device known as a water heater or hot water system. (Hot water heater is an incorrect, redundant term). Water heaters for nonpotable use, both industrial and domestic, are also called hot water boilers. When a shell-and-tube heat exchanger is used for potable or nonpotable water heating, it is commonly called a hot water generator.

Most commonly, human-induced heating processes, such as combustion or electric-resistance, are relied upon to heat the water, but solar energy, or where possible, geothermal power may be used instead. Heat pumps and heat recovery may be used as well. Sometimes a combination is used, such as solar preheating, and then conventional combustion or electric heating.

In English-speaking countries, except in North America, water heaters are usually known as boilers, or "geysers" (though the latter term originally applied to a brand of tankless heaters). In cold climates, the water heating and hydronic space heating are commonly combined in one boiler; in much of North America, the water- and space-heating functions are through separate pieces of equipment.

Types of hot water heaters:

1. Instantaneous water heater: unit that heats water only when hot water faucet opens or other fixture demands hot water they are referred to as (tankless heaters) because don't use any sort of storage tank. They should be large enough to provide maximum hot water demand immediately to required temperature.
2. Tank-type water heater: is the most common used one. Its advantage that it makes a large quantity of heated water available on demand.

To determine the required of water heater, we should know the following:

1. Daily consumption.
2. Peak period.
3. Duration of peak period.

3.4.3 Up-feed system

Up-feed system: as shown in figure (3 – 15), this system is the system in which the city mains pressure is sufficient to overcome all friction in the building at calculated flow rate and still maintain minimum fixture pressure required the highest outlet.

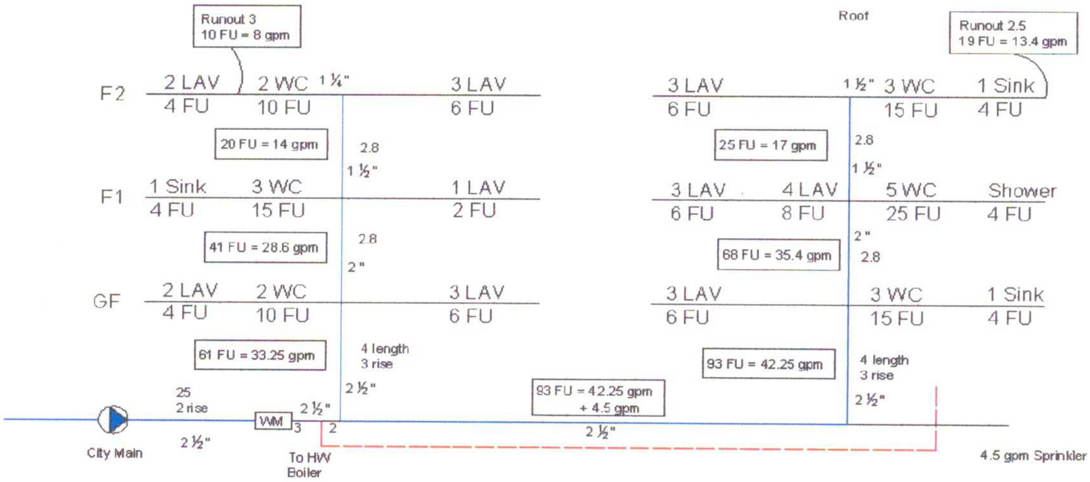

Figure (3 – 15): Up-feed water system

3.4.4 Down-feed system

Down-feed water: as shown in figure (3 – 16), this system operates by pumping water from city main or suction tank in the basement to a roof tank from which the building outlets are fed by gravity, the pump action is controlled by flout switches in roof tank suction tank if used. In this system the top floor outlet with minimum static head may be a problem.

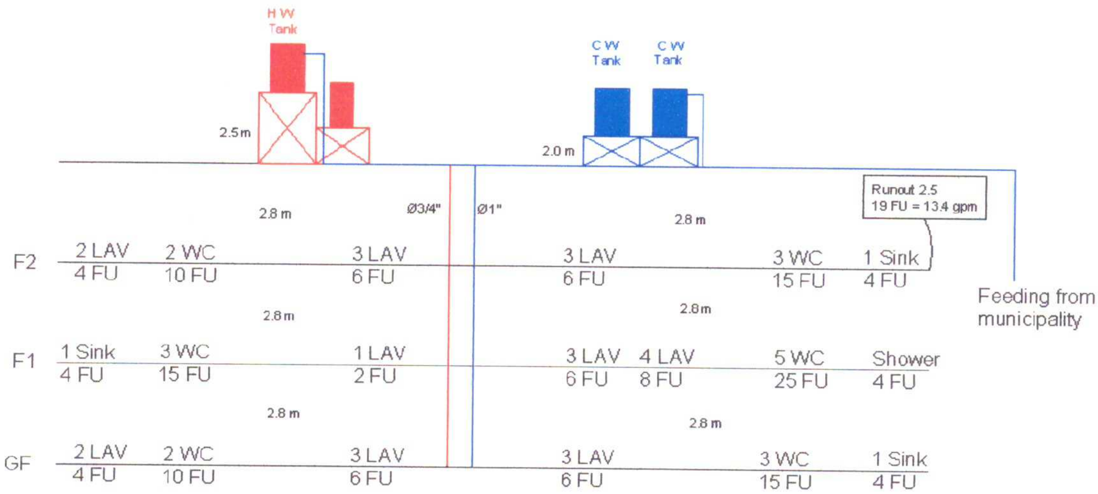

Figure (3 – 16): Down-feed water system

3.4.5 Pipes and fitting

Potable water supply systems require not only pipe, but also many fittings and valves which add considerably to their functionality as well as cost. The Piping and plumbing fittings and Valves articles discuss them further.

Within industry, piping is a system of pipes used to convey fluids, from one location to another. The engineering discipline of piping design studies the best and most efficient manner of transporting fluid to where it is most needed.[1][2]

Industrial process piping (and accompanying in-line components) can be manufactured from wood, glass, steel, aluminum, plastic and concrete. The in-line components, known as fittings, valves, and other devices, typically sense and control the pressure, flow rate and temperature of the transmitted fluid, and usually are included when one discusses the concept of piping design. Piping systems are documented in Piping and Instrumentation Diagrams. If necessary, pipes can be cleaned by the tube cleaning process

Plumbing is a piping system that most people are familiar with, as it constitutes the form of fluid transportation that is used to provide potable water and fuels to their homes and business. Plumbing pipes also remove waste in the form of sewage, and allow venting of sewage gases to the outdoors. Fire sprinkler systems also use piping, and may transport potable or nonpotable water, or other fire-suppression fluids.

Piping also has many other industrial applications, which are crucial for moving raw and semi-processed fluids for refining into more useful products. Some of the more exotic materials of construction are titanium, chrome-moly and various other steel alloys.

A valve is a device that regulates the flow of substances (either gases, fluidized solids, slurries, or liquids) by opening, closing, or partially obstructing various passageways. Valves are technically pipe fittings, but usually are discussed separately.

Valves are used in a variety of applications including industrial, military, commercial, residential, transportation. Plumbing valves are the most obvious in everyday life, but many more are used.

Some valves are driven by pressure only, they are mainly used for safety purposes in Steam engines and domestic heating or cooking appliances. Others are used in a controlled way, like in Otto cycle engines driven by a camshaft, where they play a major role in engine cycle control.

Fittings are used in pipe and plumbing systems to connect straight pipe or tubing sections, to adapt to different sizes or shapes, and to regulate fluid flow, for example. Fittings, especially noncommmon types, can be expensive, and require time, materials, and tools to install, so they are a non-trivial part of piping and plumbing systems. Valves are technically fittings, but are usually discussed separately

3.4.6 Pipe sizing

The main equation of pressure in the network is

Main pressure = Static head + Friction head + Minimum flow pressure

Static head is the total length of the vertical pipe that connects the source with the fixture has the maximum working pressure.

Friction head is calculated through finding the total equivalent length for the water passage from the source to the farthest outlet. The equivalent length is

$$\text{Equivalent length} = \text{Total length} \times 1.5$$

Minimum flow pressure is found from codes for each fixture.

3.4.7 Water system in Martyr Abu Al – Hassan Qasem Hospital

The two booster pumps dilevers the water to 7 roof tanks, each 2 m^3 volume, which are connected togather and supply the building with water by another booster pump system that consists of three prallel pumps cooprate to keep the network pressure at a suitable range. Electric floats adjust the water level in the tanks.

There are two water softeners, one is on duty and the other is stand by, they are connected to the main water source which means that all the water supplies the hospital is soft

Water system design is shown in drawings (D – 3.4), (D – 3.5) and (D – 3.6).

3.4.8 Troubleshootings in water system

The water system in the hospital has the following troubles:

1. All mechanical floats are damaged; since the pressure is higher than these floats can hold.
2. There is no need for water tanks on the roof; because the pump system can directly supply the building. The existence of roof tanks causes a need for another pump system to bring water from the tanks to the building.
3. The roof pump system works on a small range of pressure, which makes the pumps on duty all the time. This has the effect of disturbing the people within the hospital, especially that the pumps are not isolated with a vibration isolator.
4. There is no separation between the soft water and the normal domestic water; all water passes through the softener, this increase the cost because softeners waste a large amount of water for self-cleaning from one side, and the working time of the softeners will also increase from another side.

CHAPTER FOUR

SURVEY OF

AIR CONDITIONING SYSTEM

4.1 Introduction

"Air conditioning is life conditioning". This expression indicates how much air conditioning could change your life, and this change is certainly to the best.

In the broadest sense air conditioning can refer to any form of cooling, heating, ventilation or disinfection that modifies the condition of air, typically for thermal comfort. The more common use of air conditioning is to mean cooling and often dehumidification of indoor air, typically via refrigeration.

An air conditioner (AC or A/C) is an appliance, system, or mechanism designed to extract heat from an area using a refrigeration cycle. The most common uses of modern air conditioners are for comfort cooling in buildings and transportation vehicles.

4.2 History of Air Conditioning

While moving heat via machinery to provide air conditioning is a relatively modern invention, the cooling of buildings is not. The ancient Romans were known to circulate aqueduct water through the walls of certain houses to cool them. As this sort of water usage was expensive, generally only the wealthy could afford such a luxury.

In 1820, British scientist and inventor Michael Faraday discovered that compressing and liquefying ammonia, a powerful irritant, could chill air when the liquefied ammonia was allowed to evaporate.

In 1842, Florida physician Dr. John Gorrie used compressor technology to create ice, which he used to cool air for his patients in his hospital in Apalachicola, Florida He hoped eventually to use his ice-making machine to regulate the temperature of buildings. He even envisioned centralized air conditioning that could cool entire cities. Though his prototype leaked and performed irregularly, Gorrie was granted a patent in 1851 for his ice-making machine. His hopes for its success vanished soon afterwards when his chief financial backer died; Gorrie did not get the money he needed to develop the machine. According to his biographer Vivian M. Sherlock, he blamed the "Ice King," Frederic Tudor, for his failure, suspecting that Tudor has launched a smear campaign against his invention. Dr Gorrie died impoverished in 1855 and the idea of air conditioning faded away for 50 years.

Early commercial applications of air conditioning were manufactured to cool air for industrial processing rather than personal comfort. In 1902 the first modern electrical air conditioning was invented by Willis Haviland Carrier. Designed to improve manufacturing process control in a printing plant, his invention controlled not only temperature but also humidity. The low heat and humidity were to help maintain consistent paper dimensions and ink alignment. Later Carrier's technology was applied to increase productivity in the workplace, and The Carrier Air Conditioning Company of America was formed to meet rising demand. Over time air conditioning came to be used to improve comfort in homes and automobiles. Residential sales expanded dramatically in the 1950s.

In 1906, Stuart W. Cramer of Charlotte, North Carolina, USA, was exploring ways to add moisture to the air in his textile mill. Cramer coined the term "air conditioning," using it in a patent claim he filed that year as an analogue to "water conditioning", then a well-known process for making textiles easier to process. He combined moisture with ventilation to "condition" and change the air in the factories, controlling the humidity so necessary in textile plants. Willis Carrier adopted the term and incorporated it into the name of his company. This evaporation of water in air, to provide a cooling effect, is now known as evaporative cooling.

The first air conditioners and refrigerators employed toxic or flammable gases like ammonia, methyl chloride, and propane which could result in fatal accidents when they leaked. Thomas Midgley, Jr. created the first chlorofluorocarbon gas, Freon, in 1928. The refrigerant was much safer for humans but was later found to be harmful to the atmosphere's ozone layer. "Freon" is a trade name of Dupont for any Chlorofluorocarbon (CFC), Hydrogenated CFC (HCFC), or Hydrofluorocarbon (HFC) refrigerant, the name of each including a number indicating molecular composition (R-11, R-12, R-22, R-134). The blend most used in direct-expansion comfort cooling is an HCFC known as R-22. It is to be phased out for use in new equipment by 2010 and completely discontinued by 2020. R-11 and R-12 are no longer manufactured in the US, the only source for purchase being the cleaned and purified gas recovered from other air conditioner systems. Several non-ozone depleting refrigerants have been developed as alternatives, including R-410A, known by the brand name "Puron".

Innovation in air conditioning technologies continue, with much recent emphasis placed on energy efficiency and for improving indoor air quality.

4.3 Air Conditioning Systems

There are three basic air conditioning systems:

1. All – air system.
2. All – water system.
3. Air – and – water system.

4.3.1 All – air system

An all-air system provides complete sensible and latent cooling, preheating, and humidification capacity in the air supplied by the system. No additional cooling or humidification is required at the zone, except in the case of certain industrial systems. Heating may be accomplished by the same airstream, either in the central system or at a particular zone. In some applications, heating is accomplished by a separate heater. The term zone implies the provision or the need for separate thermostatic control, while the term room implies a partitioned area that may or may not require separate control.

All-air systems are classified in two basic categories:

- Single-duct systems, which contain the main heating and cooling coils in a series flow air path; a common duct distribution system at a common air temperature feeds all terminal apparatus.
- Dual-duct systems, which contain the main heating and cooling coils in parallel flow or series-parallel flow air paths with either
    1. A separate cold and warm air duct distribution system that blends the air at the terminal apparatus (dual-duct systems),
    2. A separate supply air duct to each zone with the supply air blended to the required temperature at the main unit mixing dampers (multizone).

All-air systems may be adapted to many applications for comfort or process work. They are used in buildings that require individual control of multiple zones, such as office buildings; schools and universities; laboratories; hospitals; stores; hotels; and even ships. All-air systems are also used virtually exclusively in special applications for close control of temperature and humidity, including clean rooms, computer rooms, hospital operating rooms, research and development facilities, as well as many industrial/manufacturing facilities.

Advantages of all – air system

All-air systems have the following advantages:

• The location of the central mechanical room for major equipment allows operation and maintenance to be performed in unoccupied areas. In addition, it allows the maximum range of choices of filtration equipment, vibration and noise control, and the selection of high quality and durable equipment.

• Keeping piping, electrical equipment, wiring, filters, and vibration and noise-producing equipment away from the conditioned area minimizes service needs and reduces potential harm to occupants, furnishings, and processes.

• These systems offer the greatest potential for use of outside air (free cooling) instead of mechanical refrigeration for cooling.

• Seasonal changeover is simple and adapts readily to automatic control.

• A wide choice of zoning, flexibility, and humidity control under all operating conditions is possible, with the availability of simultaneous heating and cooling even during off-season periods.

• Air-to-air and other heat recovery may be readily incorporated.

• They permit good design flexibility for optimum air distribution, draft control, and adaptability to varying local requirements.

• The systems are well suited to applications requiring unusual exhaust or makeup air quantities (negative or positive pressurization, etc.).

• All-air systems adapt well to winter humidification.

• By increasing the air change rate and using high-quality controls, it is possible for these systems to maintain the closest operating condition of ±0.25°F dry bulb and ±0.5% rh. Today some systems can maintain essentially constant space conditions.

Disadvantages of all – air system

All-air systems have the following disadvantages:

• They require additional duct clearance, which reduces usable floor space and increases the height of the building.

• Depending on layout, larger floor plans are necessary to allow enough space for the vertical shafts required for air distribution.

• Ensuring accessible terminal devices requires close cooperation between architectural, mechanical, and structural designers.

• Air balancing, particularly on large systems, can be more difficult.

• Perimeter heating is not always available to provide temporary heat during construction.

4.3.2 All – water systems

All – water systems for heating and cooling use either hot or chilled water for space conditioning, with the air in the space heated or cooled by conduction, convection, or radiation. The following are the principal types of all-water systems:

• Baseboard radiation

• Freestanding radiators and convectors

• Wall, floor, or ceiling panels

• Bare pipe (racked on wall)

• Fan-coil units

Advantages

A major advantage of the all-water system is that the delivery system (piping versus duct systems) requires less building space, a smaller or no central fan room, and little duct space. The system has all the benefits of a central water chilling and heating plant, while retaining the ability to shut off local terminals in unused areas. It gives individual room control with little crosscontamination of recirculated air from one space to another.

Extra capacity for quick pull down response may be provided. Because this system can heat with low-temperature water, it is particularly suitable for solar or heat recovery refrigeration equipment. For existing building retrofit, it is often easier to install the piping and wiring for an all-water system than the large ductwork required for an all-air system.

Disadvantages

All-water systems require much more maintenance than central all-air systems, and this work must be done in occupied areas. Units that operate at low dew points require condensate pans and a drain system that must be cleaned and flushed periodically. Condensate disposal can be difficult and costly. It is also difficult to clean the coil.

Filters are small, low in efficiency, and require frequent changing to maintain air volume. In some instances, drain systems can be eliminated if dehumidification is positively controlled by a central ventilation air system.

Ventilation is often accomplished by opening windows or by installing outside wall apertures.

Ventilation rates are affected by stack effect and wind direction and velocity.

Summer room humidity levels tend to be relatively high, particularly if modulating chilled water control valves are used for room temperature control. Alternatives are two-position control with variable-speed fans and the bypass unit variable chilled water temperature control.

4.3.3 Air – and – water system

Air – and – water systems condition spaces by distributing air and water sources to terminal units installed in habitable spaces throughout a building. The air and water are cooled or heated in central mechanical equipment rooms. The air supplied is called primary air; the water supplied is called secondary water. Sometimes a separate electric heating coil is included in lieu of a hot water coil.

Air-and-water systems apply primarily to exterior spaces of buildings with high sensible loads and where close control of humidity is not required. They may, however, be applied to interior zones as well. These systems work well in buildings such as office buildings, hospitals, hotels, schools, apartment buildings, and research laboratories.

In most climates, these systems are installed in exterior building spaces and are designed to provide:

1. All required space heating and cooling needs and
2. Simultaneous heating and cooling in different parts of the building during intermediate seasons.

Advantages

1. Individual room temperature control with the capability of adjusting each thermostat for a different temperature at relatively low cost.
2. Separate heating and cooling sources in the primary air and secondary water give the occupant a choice of heating or cooling.
3. Less space is required for the distribution system when the air supply is reduced by using secondary water for cooling and high-velocity air design. The return air duct system is reduced in size and can sometimes be eliminated or combined with the return air system for other building areas, such as the interior spaces.
4. The size of the central air-handling apparatus is smaller than that of other systems because little air must be conditioned.
5. Dehumidification, filtration, and humidification are performed in a central location remote from conditioned spaces.

6. Ventilation air supply is positive and may accommodate recommended outside air quantities.
7. Space can be heated without operating the air system via the secondary water system. Nighttime fan operation is avoided in an unoccupied building. Emergency power for heating, if required, is much lower than for most all-air systems.
8. System components are long-lasting. Room terminals operated dry have an anticipated life of 15 to 25 years. The piping and ductwork longevity should equal that of the building.
9. Individual induction units do not contain fans, motors, or compressors. Routine service is generally limited to temperature controls, cleaning of lint screens, and infrequent cleaning of the induction nozzles.

Disadvantages

1. Relatively low primary air quantities make the two-pipe changeover design for operating during intermediate seasons more critical than in alternate system types. The four-pipe changeover system overcomes this disadvantage.

2. The two-pipe changeover system has operating complexities not present in other systems. The operator must understand the cycles and changeover procedures. This disadvantage, and the need for heating at one time of the day and cooling at another, have effectively ruled out the two-pipe changeover system for modern buildings.

3. For most buildings, these systems are limited to perimeter space; separate systems are required for other building areas.

4. Controls tend to be more numerous than for many all-air systems.

5. Secondary airflow can cause the induction or fan-coil unit coils to become dirty enough to affect performance.

Lint screens or low-efficiency filters used to protect these terminals require frequent in-room maintenance and reduce unit thermal performance.

6. The primary air supply usually is constant with no provision for shutoff. This is a disadvantage in residential applications, where tenants or hotel room guests may prefer to turn off the air conditioning, or where management may desire to do so to reduce operating expense.

7. A low primary chilled water temperature is needed to control space humidity adequately.

8. The system is not applicable to spaces with high exhaust requirements (e.g., research laboratories), unless supplementary ventilation air is provided.

9. Central dehumidification eliminates condensation on the secondary water heat transfer surface under maximum design latent load. However, abnormal moisture sources (e.g., from open windows or people congregating) can cause condensation that can have annoying or damaging results.

10. Energy consumption for induction systems is higher than for most other systems due to the increased power required by the primary air pressure drop in the terminal units.

11. The initial cost for four-pipe induction systems is greater than that for most all-air systems.

4.4 Air Conditioners

Air conditioners employ the same operating principles and basic components as your home refrigerator. An air conditioner cools your home with a cold indoor coil called the evaporator. The condenser, a hot outdoor coil, releases the collected heat outside. The evaporator and condenser coils are serpentine tubing surrounded by aluminum fins. This tubing is usually made of copper. A pump, called the compressor, moves a heat transfer fluid (or refrigerant) between the evaporator and the condenser. The pump forces the refrigerant through the circuit of tubing and fins in the coils. The liquid refrigerant evaporates in the indoor evaporator coil, pulling heat out of indoor air and thereby cooling the home. The hot refrigerant gas is pumped outdoors into the condenser where it reverts back to a liquid giving up its heat to the air flowing over the condenser's metal tubing and fins.

4.4.1 Types of air conditioners

The basic types of air conditioners are room air conditioners, split-system central air conditioners, and packaged central air conditioners.

1. Room air conditioner

Room air conditioners, sometimes referred to as window air conditioners, cool rooms rather than the entire home or business. If they provide cooling only where they're needed, room air conditioners are less expensive to operate than central units, even though their efficiency is generally lower than that of central air conditioners. Window air conditioner uses R 410A, R 134a freons in the cycle.

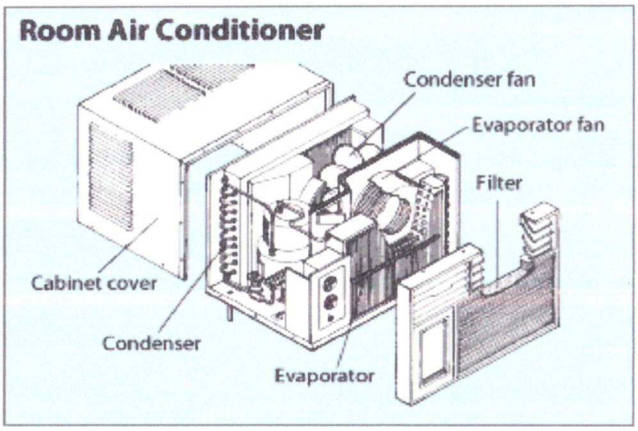

Figure (4 – 1): Room air conditioner

Room air conditioner has the following types:

1. Window-mounted types are available for installation in single-and double-hung windows, as well as for horizontal sliding windows and even casement windows.

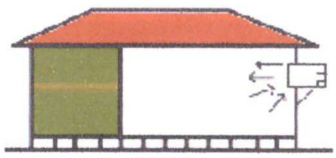

Figure (4 – 2): Window/Wall mountedair conditioner

2. Wall-mounted units use a sleeve to allow for through-the-wall mounting instead of window mounting.

3. Free-standing portable units are easily moved on casters; some require temporary ducting to the outdoors.

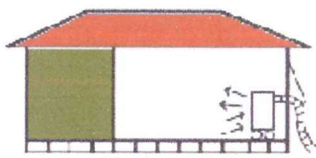

Figure (4 – 3): Portable air conditioner

2. Central Air Conditioners

Central air conditioners circulate cool air through a system of supply and return ducts. Supply ducts and registers (i.e., openings in the walls, floors, or ceilings covered by grills) carry cooled air from the air conditioner to the home. This cooled air becomes warmer as it circulates through the home; then it flows back to the central air conditioner through return ducts and registers. A central air conditioner is either a split-system unit or a packaged unit. Central conditioning has the following types:

- Single-package unit contains all the components and generally mounts through the wall or on the roof. Ducting to and from the unit conveys air to and from the rooms. This type is not commonly used in residential applications.

- A split-system unit consists of indoor and outdoor sections. The indoor heat exchanger, or coil, mounts above the furnace, inside the ducting. The outdoor section consists of the remaining components, and the two sections are joined by refrigerant lines connecting the indoor coil to the refrigeration components in the outdoor section, this type uses R 407C, R 410A freons.

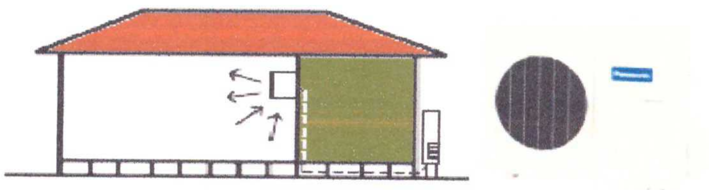

Figure (4 – 4): Split air conditioner

- A mini-split unit is similar to a split-system but contains more than one indoor coil connected to one outdoor unit. Some mini-split units have as many as three indoor units. These units are ideal for homes with new additions, as there is no need for ductwork. The indoor section simply mounts on an inside wall, the ceiling or the floor. The outdoor and indoor units generally have a very slim profile compared to conventional split-systems. The efficiency of mini-split units tends to be lower than other split-systems, which needs to be taken into account when considering such a unit, mini split uses R 407C, R 410A freons.

- A mini-duct unit is a central air conditioner where the indoor section is installed in the attic, and air is distributed through plastic pipes in partition walls to outlets and inlets. These units can be retrofitted in homes with electric or hydronic baseboard heating that have no ductwork.

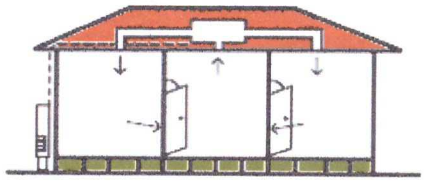

Figure (4 – 5): Ducted air conditioning

4.4.2 Construction of an air conditioner

The basic air conditioning cycle consist of the following parts:

1. A compressor.
2. An expansion valve.
3. A hot coil (on the outside).
4. A chilled coil (on the inside).
5. Two fans.
6. A control unit.

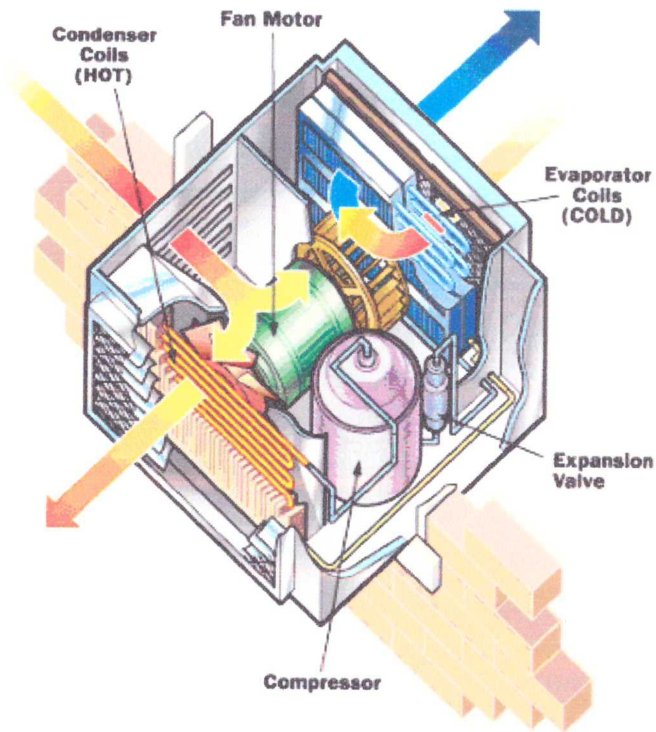

Figure (4 – 6): Inside air conditioner

4.5 Equipment of Air Conditioning

Air conditioning system requires a number of construction equipment that represents the parts that transfer the conditioned (heated or cooled) air to the building space, these parts are fan-coil units, ducting system, grilles and diffusers of air, and filters.

4.5.1 Fan – coil units

A fan coil unit is a device that withdraws or gives off heat to atmosphere by force convection; as shown in figure (4 – 7), it consists of condensation tray, filter, fan and coil.

Choice of fan coil depends on:

1. Heat output of fan coil: the heat output should be subdivided into many coils
2. Air flow rate of fan coil.
3. Temperature of outlet air.
4. Noise level.

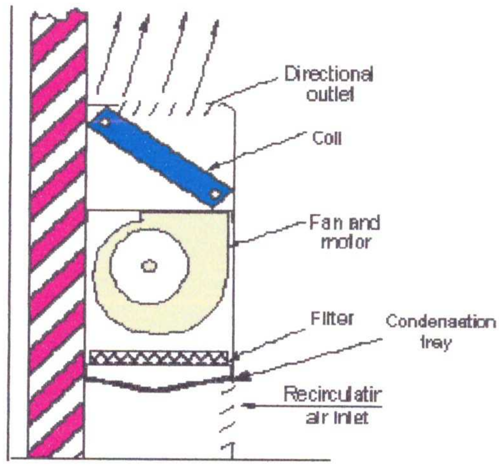

Figure (4 – 7) Fan – coil unit

It is recommended to use the fan-coil in open spaces; such as mosques, galleries and churches. It is also recommended to use the fan coil unit in hotels because of the ability of controlling each room.

4.5.2 Ducting system

This is the system which is responsible for distributing conditioned air to all spaces, most frequently by metallic ducts. Figure (4 – 8) illustrates the ducting system for a surgery room. Ducts should be insulated in order not to lose (or gain) heat by heat transfer with the surrounding. A duct system is often called ductwork. Planning ('laying out'), sizing, optimizing, detailing, and finding the pressure losses through a duct system is called duct design.

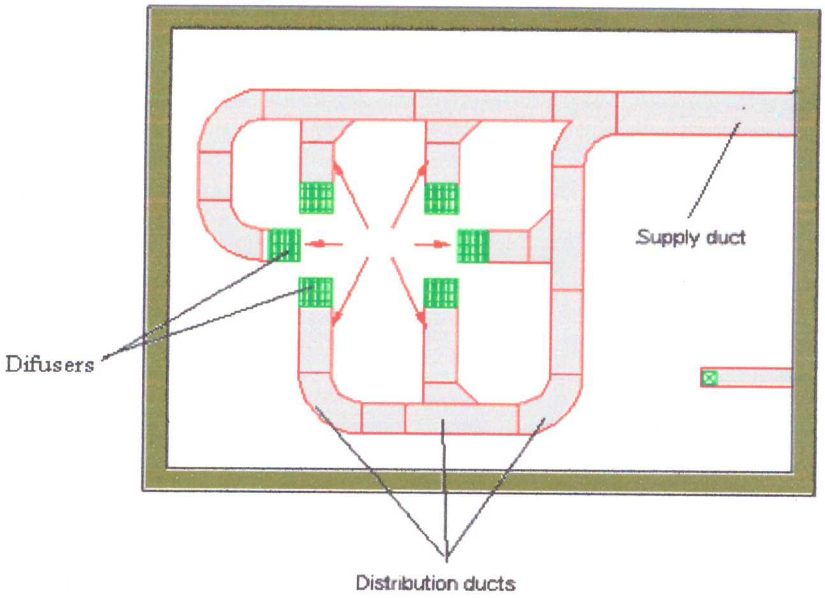

Figure (4 – 8): Ducting system

4.5.3 AC filters

There are three basic types of AC filters:

1. Dry filters: the most common one is HEPA (High Efficiency Particulate Air) filter, which is used in Yatta hospital.

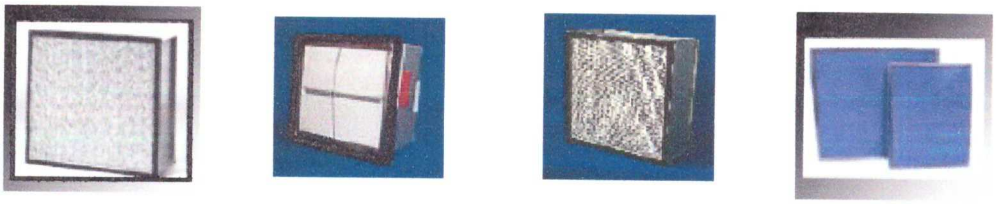

Figure (4 – 9): HEPA filters

2. Viscous filters: filters that make a seal to prevent the dusts and microbes from entering the conditioning space.

Figure (4 – 10): Viscous filter

3. Electronic filters: known as precipitators, and classified into two types; ionizing type and charged media type.

Figure (4 – 11): Electronic filter

4.5.4 Grilles and diffusers

They are used to diffuse (distribute) the conditioned air to the entire rooms and spaces. Grilles are used for return air ducts, and installed on the side walls of the room, as shown in figure (4 – 12).

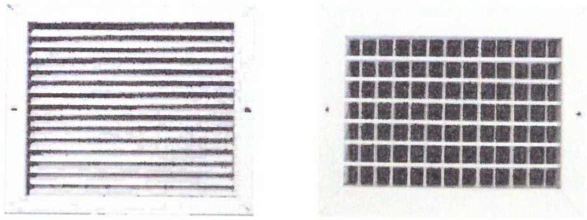

Figure (4 – 12): Grilles

Diffusers are used to supply spaces with the conditioned air, so they are installed at the ceiling as shown in figure (4 – 13).

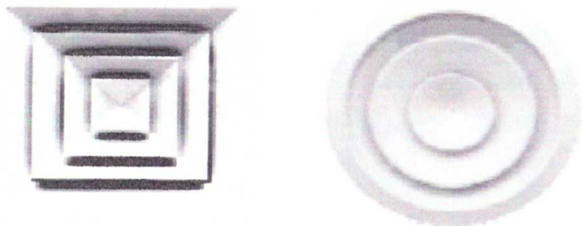

Figure (4 – 13): Ceiling diffusers

4.6 AC system in Martyr Abu – Al-hassan Qasem Hospital

As shown in drawing (D – 4.1), the roof semi-central unit distributes air as it is passed through a HEPA filter to the sergery department by the ducting system. This semi-central unit is produced by Petra company in Jordan, the basic component of which is a refrigeration cycle, with a reversed mode (heat pump), to provide both hot and cold air for conditioned space.

Large fans take the responsibility for pushing air that has been sucked from the back side of the unit. The AC system for surgery department is shown in drawing (D – 4.1).

4.7 Common Troubles in AC Systems

One of the most common air conditioning problems is improper operation. If your air conditioner is on, be sure to close your home's windows and outside doors.
Other common problems with existing air conditioners result from faulty installation, poor service procedures, and inadequate maintenance. Improper installation of your air conditioner can result in leaky ducts and low air flow. Many times, the refrigerant charge (the amount of refrigerant in the system) does not match the manufacturer's specifications. If proper refrigerant charging is not performed during installation, the performance and efficiency of the unit is impaired. Service technicians often fail to find refrigerant charging problems or even worsen existing problems by adding refrigerant to a system that is already full.

Air conditioner manufacturers generally make rugged, high quality products. If your air conditioner fails, it is usually for one of the common reasons listed below:

- Refrigerant leaks: if your air conditioner is low on refrigerant, either it was undercharged at installation, or it leaks. If it leaks, simply adding refrigerant is not a solution. A trained technician should fix any leak, test the repair, and then charge the system with the correct amount of refrigerant. Remember that the performance and efficiency of your air conditioner is greatest when the refrigerant charge exactly matches the manufacturer's specification, and is neither undercharged nor overcharged.
- Inadequate maintenance: if you allow filters and air conditioning coils to become dirty, the air conditioner will not work properly, and the compressor or fans are likely to fail prematurely.
- Electric control failure: the compressor and fan controls can wear out, especially when the air conditioner turns on and off frequently, as is common when a system is oversized. Because corrosion of wire and terminals is also a problem in many systems, electrical connections and contacts should be checked during a professional service call.

4.8 Trouble Shootings in AC System of The Hospital

The main trouble in air conditioning is that there is no water chiller or an air handling unit to use the cold water for air condition, this system has been alternated with a semi-central unit that is described previously.

Another problem appears in radiology department which is heated using the hot water central heating system; this permits the contact between the rays and the heating water.

The semi-central unit does not control the humidity; it only controls the temperature by heating and cooling processes.

According to the forgoing, this kind of applications should be heated using hot air by means of an air conditioning unit.

CHAPTER FIVE

EVALUATION OF

DOMESTIC WATER SYSTEM

5.1 Introduction

The evaluation process of the domestic water system is related to the troubleshootings appeared in the survey process of the system, the solutions of these troubles represent the evaluation of the system, in addition to the check of all parts of domestic water system.

As mentioned in the survey part (section 3.4.8), the main troubles are basically concentrated in the pump systems which control supplying the building with water, this problem will be solved regarding the pipe network calculations to achieve the best way of supplying without overshootings. The pump system will be edited so that it could supply the building with needed water without any kind of disturbance or oversizing.

In addition to the pumps, the two water softeners and their piping network must be redesigned in order not to make all water entering the hospital soft, since there are some applications within the building do not need soft water from one side, and to lower the cost of softening process from another side.

The evaluation process will also imply a check for the components of the water system such as diameters, velocities, and types of the pipes using the riser diagrams and charts. In addition, the hot water system will be checked and evaluated.

Finally, recommendations will be suggested to make the domestic water system as effective as possible.

5.2 Evaluation of cold water system

Cold water system in Yatta hospital was designed to be down-feed system, using two sets of pumps, and a copper piping network. Evaluation of cold water system will redesign it to be up-feed system.

5.2.1 Piping system

In order to evaluate the piping system, we should first draw the riser. The riser is a diagram shows the piping network in all parts of the building, including fixtures, diameters of pipes, pumps, and flow rates.

There are two types of water feeding systems:

1. Up – feed system, in which the building is supplied with water from a main supply pipe that carries water from a point at the bottom of the building (storage tank or city mains) toward the top of the building with a sufficient water flow for minimum fixture pressure.
2. Down – feed system, in which roof tanks supply the building with water.

There are three factors affect the main pressure required for the building:

1. Static head: which represents the sum of lengths of all vertical pipes from supplying point to the critical outlet. The critical outlet is not necessarily the farthest, it must have the greatest minimum fixture pressure.
2. Minimum fixture pressure: each fixture must have a minimum pressure to be available to the application in which it is used.
3. Friction head: the head loss through friction between water and the inside walls of the pipes and fittings.

The mathematical equation describes the relation among these parameters is:

Main pressure head = Static head + Friction head + Minimum fixture pressure (E-5.1)

5.2.2 Flow rate calculations and riser

Flow rate calculations aim to convert the system from down-feed system from tanks to up-feed system from storage well using pumps to the risers of the building. Figure (5 – 1) indicates the riser already installed for cold water system, and figure (5 – 2) shows the roof pump system used in down-feed water.

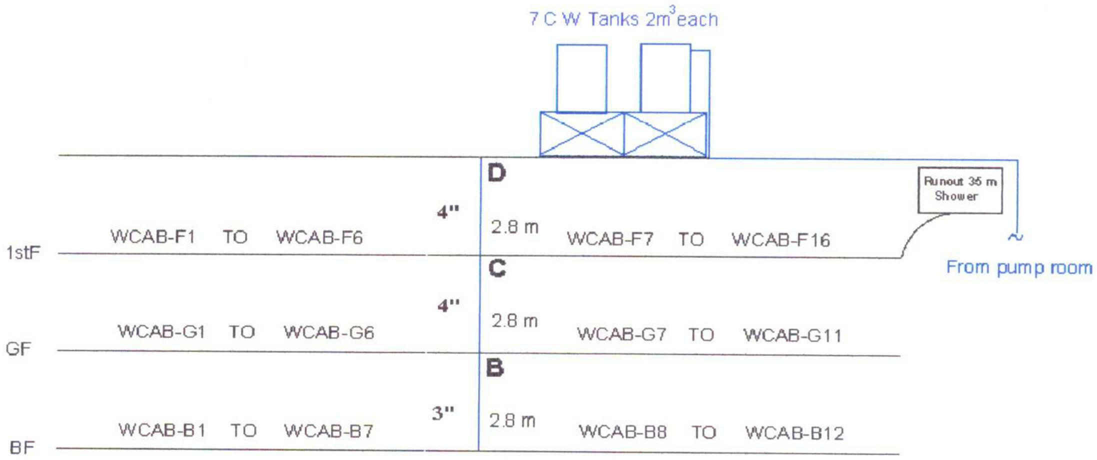

Figure (5 – 1): Riser installed in the hospital

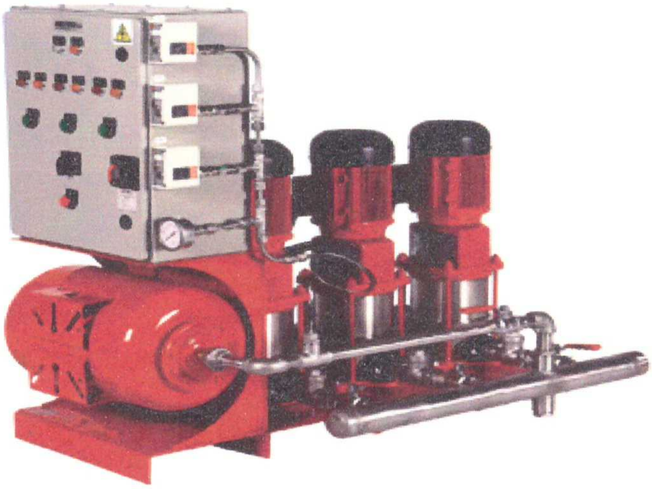

Figure (5 – 2): Roof pump system of the hospital

Figure (5 – 3) indicates the domestic water up-feed riser of the building, each floor contains a number of different fixtures related to the water collectors. Tables (5 – 1), (5 – 2), and (5 – 3) illustrate the water fixture units connected to each collector. Table (B-5.1) in appendix B shows the WSFU for each fixture, and table (B-5.2) in appendix B shows the conversions from WSFU to gpm, and table (B-5.3) shows the minimum pressure for each fixture.

Table (5 – 1): The total cold water fixture units for basement floor

Collector	WSFU (CW)
WCAB – B1	69 / 4
WCAB – B2	51 / 4
WCAB – B3	58 / 4
WCAB – B4	93 / 4
WCAB – B5	57 / 4
WCAB – B6	99 / 4
WCAB – B7	70 / 4
WCAB – B8	60 / 4
WCAB – B9	30 / 4
WCAB – B10	114 / 4
WCAB – B11	96 / 4
WCAB – B12	34 / 4
TOTAL	**207.75**

Table (5 – 2): The total cold water fixture units for ground floor

Collector	WSFU (CW)
WCAB – G1	73 / 4
WCAB – G2	24 / 4
WCAB – G3	134 / 4
WCAB – G4	120 / 4
WCAB – G5	68 / 4
WCAB – G6	34 / 4
WCAB – G7	18 / 4
WCAB – G8	18 / 4
WCAB – G9	99 / 4
WCAB – G10	84 / 4
WCAB – G11	84 / 4
TOTAL	**166.5**

Table (5 – 3): The total cold water fixture units for first floor

Collector	WSFU (CW)
WCAB – F1	81 / 4
WCAB – F2	66 / 4
WCAB – F3	78 / 4
WCAB – F4	54 / 4
WCAB – F5	70 / 4
WCAB – F6	133 / 4
WCAB – F7	64 / 4
WCAB – F8	118 / 4
WCAB – F9	34 / 4
WCAB – F10	70 / 4
WCAB – F11	54 / 4
WCAB – F12	54 / 4
WCAB – F13	54 / 4
WCAB – F14	54 / 4
WCAB – F15	54 / 4
WCAB – F16	54 / 4
TOTAL	**273**

The total WSFU values are shown in the table below.

Table (5 – 4): Total WSFU values for cold water in the building

Floor	WSFU (CW)
Basement	207.75
Ground	166.5
First	273
TOTAL	**647.25**

Using table (B- 5.2), the total flow rate for cold water of the hospital is 152 gpm.

Figure (5 – 3): UP-feed cold water riser

Applying equation (E-5.1), known that the pump used in the hospital is with a head of 30 m, then

$$\text{Main pressure head} = 30\ \text{m} \times 3.28\frac{\text{ft}}{\text{m}} \times 0.433\frac{\text{psi}}{\text{ft}} = 42.67\ \text{psi}$$

Static head = $2.8 \times 3 = 8.4$ m

$= 8.4 \times 3.28 \times 0.433 = 11.93$ psi

Using table (B-5.3) we can find that

Minimum fixture pressure = 8 psi (for the farthest shower)

Substituting the results above in equation (E-5.1)

$$\text{Main pressure head} = \text{Static head} + \text{Friction head} + \text{Minimum fixture pressure}$$

$$42.67 = \text{Friction head} + 11.93 + 8$$

$$\rightarrow \text{Friction head} = 22.67\ \text{psi}$$

To find the diameters we should first convert the friction head into psi per 100 ft so that we could use the charts to find the pipe characteristics.

$$\text{Friction per 100 ft} = \frac{\text{Available friction pressure loss (psi)}}{\text{Total equivalent length of pipes (ft)}} \times 100 \qquad \text{(E-5.2)}$$

The total pipe lengths from the source to the critical fixture are shown in table (5 – 5)

Table (5 – 5): Total pipe lengths of cold water system

Pipe	Length (m)
From pump room to riser	31
Riser length	8.4
Run out	35
From above false ceiling to collector	2.5
From collector to shower	3
TOTAL	**79.9**

$$\text{Total equivalent length} = 79.9 \times 1.5 = 119.85 \text{ m}$$

$$= 119.85 \times 3.28 = 393 \text{ ft}$$

$$\text{Friction per 100 ft} = \frac{22.67}{\frac{393}{100}} = 5.768 \text{ psi / 100 ft}$$

5.2.3 Diameters of pipes

Using chart (C-5.1) in appendix C we can find the diameters of pipes and cold water velocities in the pipes. Table (5 – 6) illustrates the results of piping system.

Table (5 – 6): Diameters of the up-feed cold water riser

Pipe	Flow rate (gpm)	Friction (psi)	Diameter (inch)	Velocity (fps)
A – B	152	5.8	2 ½	10.7
B – C	128	5.4	2 ½	10.1
C – D	80	5.6	2	8.8

It is recommended to install larger diameters in order to lower the velocity of water in pipes, then the pipes of riser are as shown in table (5 – 7).

Table (5 – 7): Diameters of the up-feed cold water riser for lower water velocity

Pipe	Flow rate (gpm)	Friction (psi)	Diameter (inch)	Velocity (fps)
A – B	152	2.3	3	6.9
B – C	128	1.9	3	6.2
C – D	80	1.8	2 ½	5.4

The above values represent the values have to be designed to have an up-feed water system, but the values already installed are shown in table (5 – 8). These values are designed for a down-feed water system.

Table (5 – 8): Pipes already installed in the hospital for up-feed cold water system

Pipe	Flow rate (gpm)	Friction (psi)	Diameter (inch)	Velocity (fps)
A – B	152	2.3	3	6.9
B – C	128	0.5	4	3.5
C – D	80	---	4	---

From the values above, we find that it is not possible to convert the water system to up-feed system considering the pipes already installed.

Conversion of the existing system to up-feed is possible if diameters in table (5 – 7) are installed. The installation of new pipes is easy; since there is a shaft shown in figure (5 – 4) which makes pipes alternating easier.

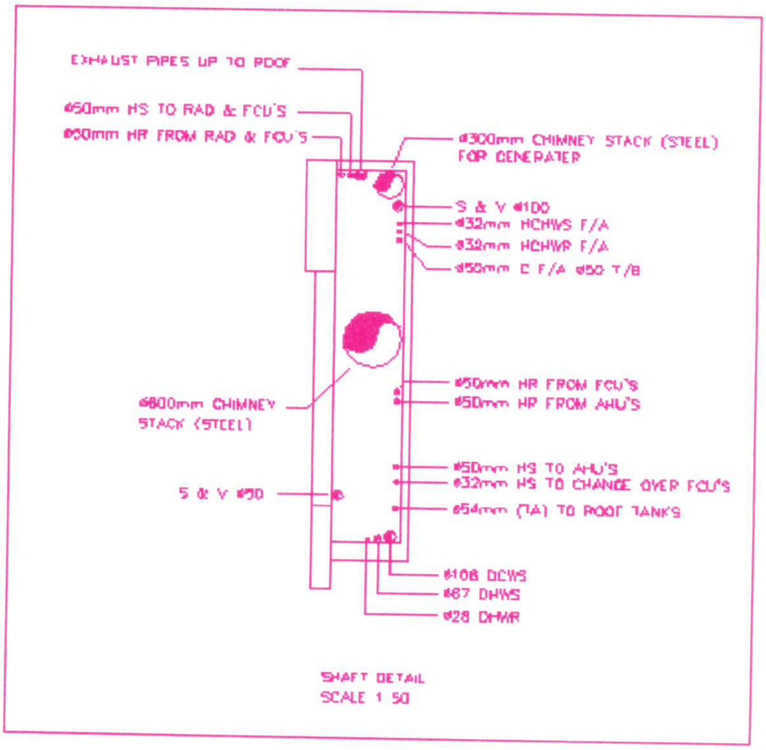

Figure (5 – 4): Shaft

5.3 Evaluation of hot water system

Hot water system in Yatta hospital was designed to be down-feed system, with a copper piping network. Evaluation of hot water system will redesign it to be up-feed system.

5.3.1 Piping system

Using equation (5 – 1), we can find out the friction head,

$$\text{Main pressure head} = 30\ \text{m} \times 3.28\frac{\text{ft}}{\text{m}} \times 0.433\frac{\text{psi}}{\text{ft}} = 42.67\ \text{psi}$$

Static head = 2.8 × 3 = 8.4 m

= 8.4 × 3.28 × 0.433 = 11.93 psi

Minimum fixture pressure = 8 psi (for the farthest shower)

$$\text{Main pressure head} = \text{Static head} + \text{Friction head} + \text{Minimum fixture pressure}$$

$$42.67 = \text{Friction head} + 11.93 + 8$$

$$\rightarrow \text{Friction head} = 22.67\ \text{psi}$$

$$\text{Total equivalent length} = 79.9 \times 1.5 = 119.85\ \text{m}$$

$$= 119.85 \times 3.28 = 393\ \text{ft}$$

Applying equation (5 – 2), according to values in table (5 – 5) we find

$$\text{Friction per 100 ft} = \frac{22.67}{\frac{393}{100}} = 5.768\ \text{psi / 100 ft}$$

5.3.2 Flow rate calculations and riser

Figure (5 – 5) indicates the domestic hot water up-feed riser of the building, each floor contains a number of different fixtures related to the water collectors.

Tables (5 – 9), (5 – 10), and (5 – 11) illustrate the water fixture units connected to each collector. Table (B-5.1) in appendix B shows the WSFU for each fixture, and table (B-5.2) in appendix B shows the conversions from WSFU to gpm. In addition, table (B-5.3) shows the minimum pressure for each fixture.

Table (5 – 9): The total hot water fixture units for basement floor

Collector	WSFU (HW)
WCAB – B1	33 / 4
WCAB – B2	15 / 4
WCAB – B3	6 / 4
WCAB – B4	21 / 4
WCAB – B5	9 / 4
WCAB – B6	27 / 4
WCAB – B7	18 / 4
WCAB – B8	12 / 4
WCAB – B9	30 / 4
WCAB – B10	42 / 4
WCAB – B11	24 / 4
WCAB – B12	18 / 4
TOTAL	**63.75**

Table (5 – 10): The total hot water fixture units for ground floor

Collector	WSFU (HW)
WCAB – G1	21 / 4
WCAB – G2	24 / 4
WCAB – G3	30 / 4
WCAB – G4	24 / 4
WCAB – G5	12 / 4
WCAB – G6	18 / 4
WCAB – G7	18 / 4
WCAB – G8	18 / 4
WCAB – G9	27 / 4
WCAB – G10	12 / 4
WCAB – G11	12 / 4
TOTAL	**54**

Table (5 – 11): The total hot water fixture units for first floor

Collector	WSFU (HW)
WCAB – F1	45 / 4
WCAB – F2	30 / 4
WCAB – F3	42 / 4
WCAB – F4	18 / 4
WCAB – F5	18 / 4
WCAB – F6	45 / 4
WCAB – F7	27 / 4
WCAB – F8	30 / 4
WCAB – F9	18 / 4
WCAB – F10	18 / 4
WCAB – F11	18 / 4
WCAB – F12	18 / 4
WCAB – F13	18 / 4
WCAB – F14	18 / 4
WCAB – F15	18 / 4
WCAB – F16	18 / 4
TOTAL	**126.75**

The total WSFU values for hot water are shown in the table below.

Table (5 – 12): Total WSFU values for the hot water in the building

Floor	WSFU (HW)
Basement	63.75
Ground	54
First	126.75
TOTAL	**244.5**

Using table (B- 5.2), the total flow rate for hot water of the hospital is 74 gpm.

As done in the cold water system, we first draw the riser diagram of the hot water system, it is shown in figure (5 – 5) including the pipes already installed in the hospital.

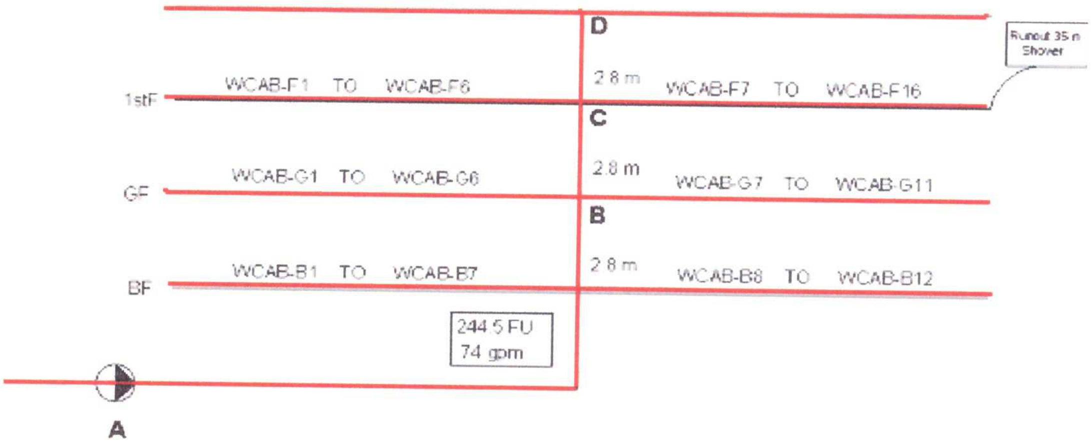

Figure (5 – 5): Up-feed hot water system

5.3.3 Diameters of pipes

Using chart (C-5.1) in appendix C we can find the diameters of pipes and hot water velocities in the pipes. Table (5 – 13) illustrates the results of piping system.

Table (5 – 13): Diameters of the up-feed hot water riser

Pipe	Flow rate (gpm)	Friction (psi)	Diameter (inch)	Velocity (fps)
A – B	74	4.4	2	7.8
B – C	61	3.1	2	6.1
C – D	50	2.3	2	5.2

It is recommended to install larger diameters in order to lower the velocity of water in pipes, then the pipes of hot water riser are as shown in table (5 – 14).

Table (5 – 14): Diameters of the up-feed hot water riser for lower water velocity

Pipe	Flow rate (gpm)	Friction (psi)	Diameter (inch)	Velocity (fps)
A – B	74	1.7	2 ½	5.4
B – C	61	1.1	2 ½	4.0
C – D	50	0.8	2 ½	3.4

The above values represent the values have to be designed to have an up-feed hot water system, but the values already installed are shown in table (5 – 15). These values are designed for a down-feed water system.

Table (5 – 15): Pipes already installed in the hospital for up-feed system

Pipe	Flow rate (gpm)	Friction (psi)	Diameter (inch)	Velocity (fps)
A – B	74	1.7	2 ½	5.4
B – C	61	1.1	2 ½	4.0
C – D	50	2.3	2	5.2

From the values above, we find that it is possible to convert the hot water system to up-feed system considering the pipes already installed. However, for better hot water system performance, diameters in table (5 – 14) have to be installed.

Conversion of the existing system to up-feed is possible if diameters in table (5 – 14) are installed. The installation of new pipes is easy; since there is a shaft that makes pipes alternating easier.

5.3.4 Heating coil capacity

The hospital contains 50 beds, and 50 employees, which means 100 persons, using table (B-5.4) in appendix B, we find that the maximum daily hot water demand is

$$30 \times 100 = 3000 \text{ L / day}$$

Using table (B-5.4) to find the peak demand, the hourly maximum hot water demand is calculated using the relation

$$\text{Maximum hourly demand} = \text{Maximum daily demand} \times \text{Peak demand} \qquad \text{(E-5.3)}$$

$$= 3000 \times \frac{1}{7} = 428.6 \text{ L / hr}$$

$$\text{The total peak demand} = \text{Maximum hourly demand} \times \text{Duration of peak load} \qquad \text{(E-5.4)}$$

$$= 428.6 \times 4 = 1714.4 \text{ L}$$

Using table (B-5.4), the storage capacity is calculated by the relation

$$\text{Storage capacity} = \text{Maximum daily demand} \times \text{storage factor}$$

$$= 3000 \times \frac{1}{5} \times 1.25 = 750 \text{ L}$$

$$\text{Recovery rate} = \frac{\text{Total peak demand - Storage capacity}}{\text{Duration of peak}} \qquad \text{(E-5.5)}$$

$$= \frac{1714.4 - \left(750 \times \frac{3}{4}\right)}{4} = 0.08 \text{ L / s}$$

$$\text{Then the heating coil capacity} = \text{Recovery rate} \times Cp_W \times \Delta T \qquad \text{(E-5.6)}$$

$$= 0.08 \times 4180 \times 50 = 16.72 \text{ kW}$$

According to table (B-5.5), we find that the boiler capacity needed for domestic hot water is about 35 kW.

Figure (5 – 6) represents a schematic diagram of the hot water cylinder with heating coil from boiler entering it. In Yatta hospital, there are two cylinders each of 750 L, which is compatible with the calculations done above.

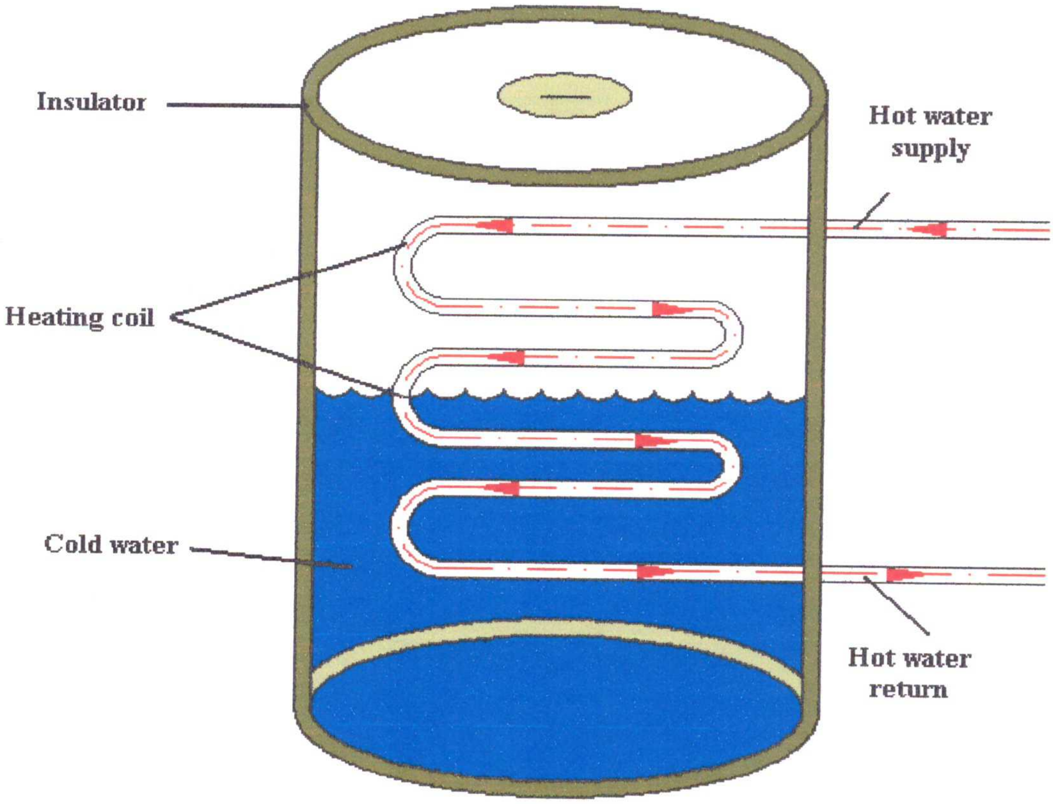

Figure (5 – 6): Domestic hot water cylinder

Recovery rate gives an indication about two main things; the first one is the storage capacity, which represents the water volume needed for continuous supply of hot water. And the second is the boiler capacity; the relation between the volume of cylinder and the boiler capacity is inverse; a large storage capacity needs smaller boiler capacity.

5.4 Evaluation of softeners

As mentioned in the survey part, all water enters the hospital is soft if softeners are used, which is a problem. However, if they are not, all water enters the hospital becomes not soft, and this is a greater problem. The solution is to separate between the soft water and normal domestic water (water which is not soft).

5.4.1 Separation between water lines

To avoid the situation mentioned above, there must be a separation between the soft water line, and the line of normal water. This process must be preceded with determining the areas that need soft water, which are two areas related to their collectors as shown in table (5 – 16)

Table (5 – 16): Areas need soft water

Area	Floor	Collector	WSFU (CW)
Washing area	Basement	WCAB – B5	57 / 4
Laundry	Basement	WCAB – B12	34 / 4

5.4.2 Soft water riser

We find that the two areas are in the basement floor, with total demand of 22.75 FU, and using table (B-5.2) we find that the soft water must be supplied to the hospital is 15.5 gpm. Using chart (C-5.1), and considering the head loss per 100 ft as previously calculated in domestic water (5.768 psi / 100 ft), we find that the diameter of soft water supply line is 1 inch. Riser of soft water supply is shown in figure (5 – 7).

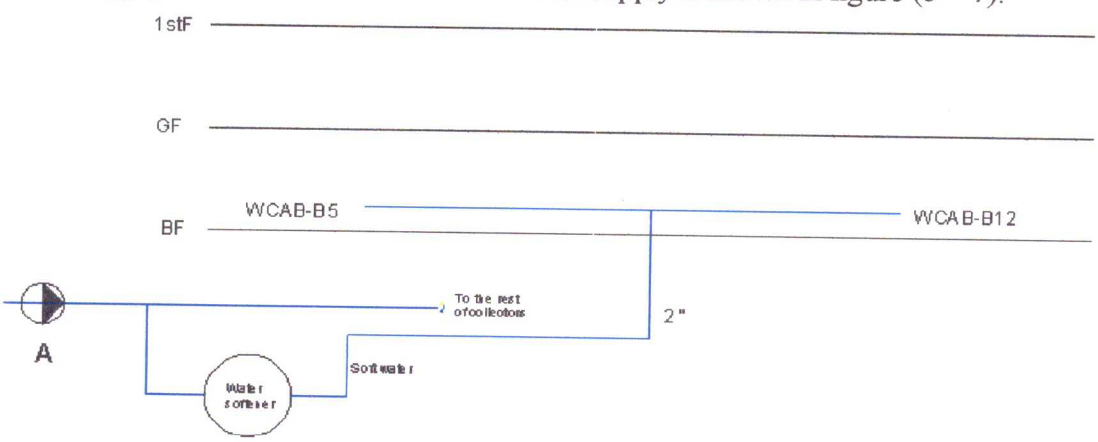

Figure (5 – 7): Soft water riser

5.5 Recommendations

According to all previous stages of evaluation, we can suggest the following evaluation recommendations to improve the water system performance:

1. To convert the water system to up-feed system, we should first install diameters in tables (5 – 7) and (5 – 14) for cold and hot water respectively. Existence of a shaft in the building could help so much in installing new pipes.

2. Pump that supplies the hospital with cold water from the well should be alternated with another one that has the same head (30 m), but with a flow rate of 10.5 L / s. in this case it is recommended to install 3 pumps in parallel with flow rate of 3.5 L / s for each.

3. Roof pumps and tanks have to be eliminated; with converting the system to up-feed, these elements become useless. This will eliminate the effect of disturbing resulted from the work of the roof pumps, and transfer this effect to the pump room, where no effects on hospital.

4. Separation between the soft water supply line and water for normal uses is essential; laundry and washing area have to be supplied with soft water to make devices within these areas work effectively.

5. All adjustments on domestic hot and cold water systems are shown in drawings (D-5.1) and (D-5.2).

CHAPTER SIX

EVALUATION OF

SANITARY SEWAGE SYSTEM

6.1 Introduction

Sanitary sewage system in Martyr Abu Al-Hassan Qasem Hospital is an ordinary sewage system that considers all design basics and specifications, it almost has no troubleshootings.

The evaluation of this system will be basically applied on two sides; first one is the septic tank, the evaluation will check and redesign the septic tank considering the universal standards. There are two main parts that will be checked; the capacity and the construction of the septic tank.

Manholes are the second side to be checked and evaluated; all manholes were perfectly designed, but on the ground things differ. The check will consider dimensions, levels, construction, and distribution of manholes, including the sewers connecting among them in cases of slopes and diameters.

The evaluation will also explain the internal drainage pipe network, i.e. the piping system inside the building, with an evaluation of the distribution of fixtures, cleanouts, siphons, and floor drains.

From all forgoing, a set of recommendations will be put forward to enhance the performance of the sanitary sewage system.

6.2 Evaluation of piping system

Sanitary sewage piping system was explained in survey part (section 3.3.2), with all its components, the evaluation of piping system will consider each one of these pipes and put the design standards and relations between all of them.

6.2.1 Riser of sewage system

To evaluate of the sanitary sewage piping, it is important to draw the riser of the system, it contains the diameters of stacks, the flow rates, the manholes, and the slopes of sewer pipes. Figures (6 – 1-a) and (6 – 1-b) illustrate the riser diagram of sanitary sewage system of the hospital, all the fourteen manholes are connected one by one with sewer drains having a diameter of 6 inch, and a slope of 1.5 %.

On the other hand, all stacks are 4 inch in diameter, receiving the sewage matters from all branches associated with fixtures, gutters, and floor drains. Branches vary in diameter according to the application of fixture related to it as shown in table (6 – 1).

Table (6 – 1): Diameters of branches in the hospital

Fixture	Branch diameter (mm)
WC	100
Lavatory	50
Sink	50
Bathtub	50
Floor drain	100

Using table (B-6.1) in appendix B, each fixture has a drainage fixture unit (dfu), related to the application and use of it, according to these values, the total drainage fixture unit dfu of the building is explained in table (6 – 2). Each stack is connected to a manhole; these manholes are connected with slopes so that they could finally lead to the septic tank.

Table (6 – 2): Total dfu for manholes and stacks

Manhole	Risers connected	Total dfu
MH - 1	---	46
MH – 2	S1, S2, S3	122
MH - 3	---	30
MH – 4	S4	67
MH – 5	S5	28
MH – 6	---	---
MH – 7	S6, S7	40
MH – 8	S8	47
MH - 9	S9	29
MH – 10	S9	58
MH – 11	S10	43
MH – 12	S11	102
MH – 13	S12	30
MH - 14	---	16
TOTAL		**658**

We note that manhole MH-6 has no dfu value; since it connects between two manholes without receiving any drainage pipes from the building, it does the work of an elbow, with its ability as a clean out. Manholes MH-1, MH-3, and MH-14 are not connected to any stack since they receive the sewage matters directly and only from the basement floor, but they are already connected to other vents.

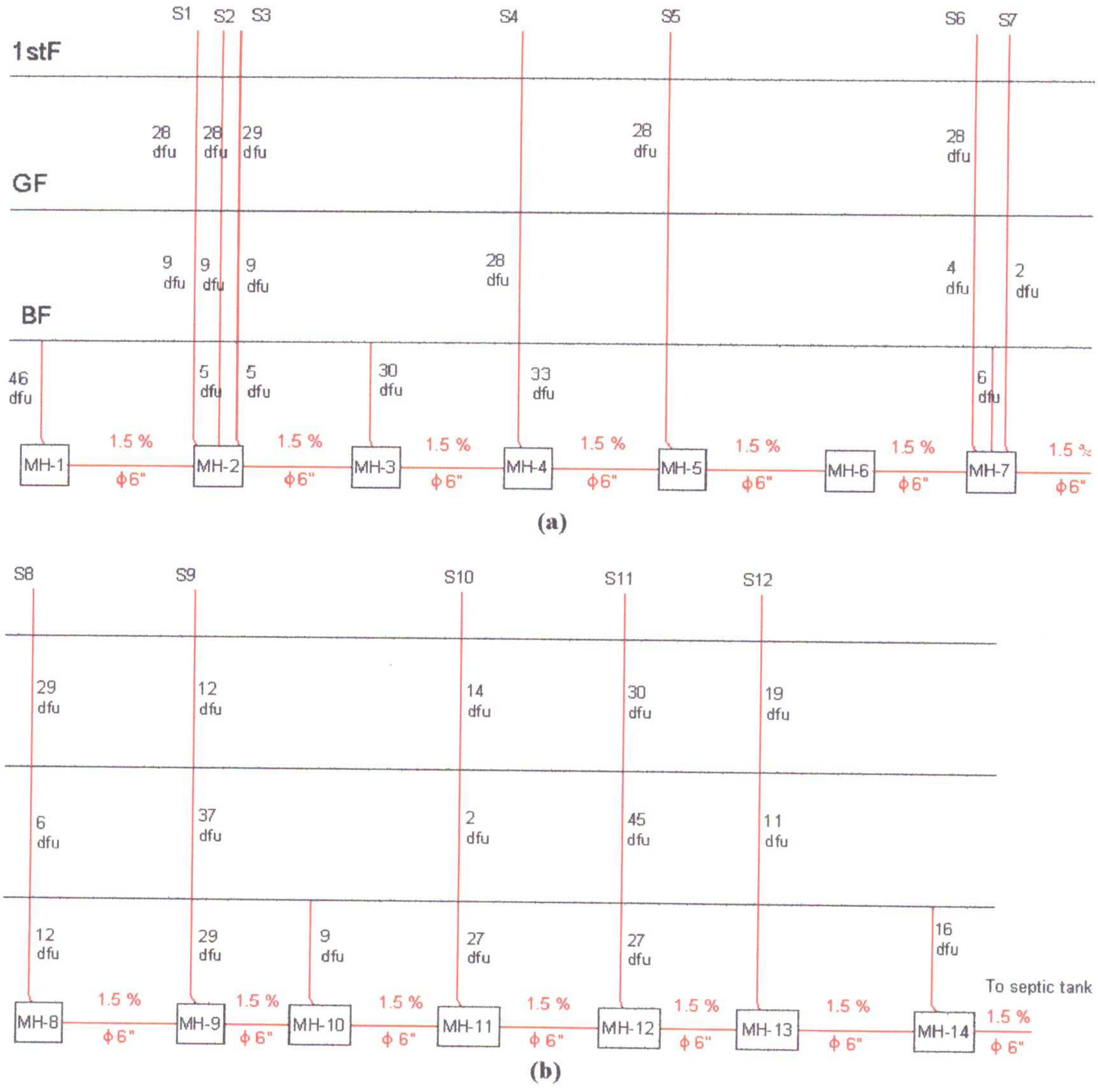

Figure (6 – 1): Sanitary sewage riser

6.2.2 Diameters and slopes

All installed stacks are 4" diameter, and to evaluate these diameters we take stacks named S4 and S5 as a sample. Table (6 – 3) gives the diameters of these two stacks related to the values of dfu.

Table (6 – 3): Diameters of stacks – already installed

Stack	dfu	Diameter (inch)
S4	48	4
S5	17	4

According to table (B-6.2) in appendix B, diameter of stack S4 according to its dfu is 3", but because the branch supplies it is 4" then stack S4 must be 4" diameter. Also the diameter of stack5 related to the dfu value is 2 ½ ", but since the branch supplies it is 3", then it must be designed at 3". So the diameters of stacks after evaluation are shown in table (6 – 4).

Table (6 – 4): Evaluation of stacks

Stack	Total dfu	Diameter installed (inch)	Diameter designed (inch)
S4	48	4	4
S5	17	4	3

Slopes of sewage system are designed to maintain a suitable flow velocity, diameter of sewage pipe governs the slope of it, table (6 – 5) shows the relation between them.

Table (6 – 5): Slopes of sewage pipes

	Minimum recommended slope	
Drainage pipe diameter	**Percentage of length**	**inch / ft**
Less than 3"	2 %	1 / 4
Greater than 4"	1 %	1 / 8

According to the riser, all sewer pipes are 6" diameters, then they must have a minimum slope of 1%, but they are installed with slopes of 1.5 %. This is right because minimum slopes are recovered.

6.3 Evaluation of internal drainage network

The internal drainage network has to be designed so that it could achieve the best drainage efficiency, with a minimum possible number of traps and floor drains. Also the internal drainage network has to be designed in an appropriate way that makes the flow of the sewage maters easier.

6.3.1 Bathrooms

Figure (6 – 2) describes the perfect internal connection of traps and floor drains with sewage pipes from fixtures to the stack of a bathroom

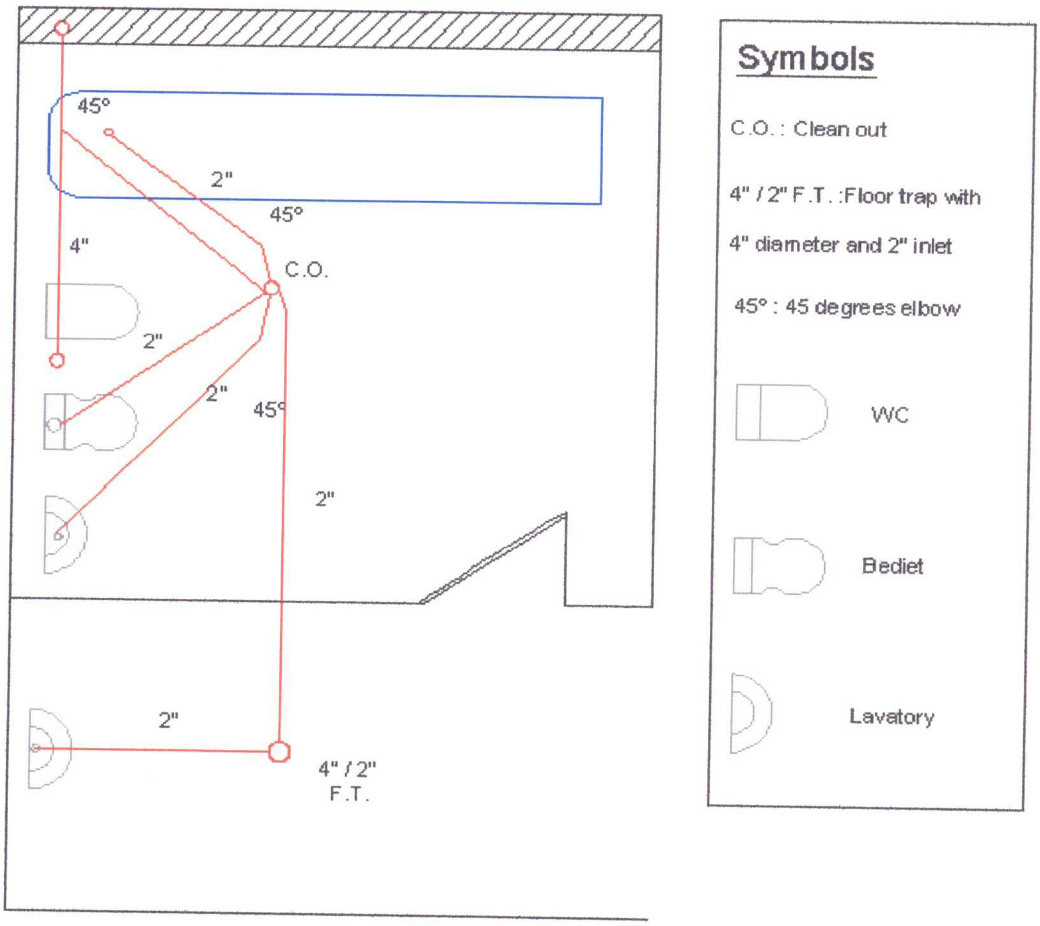

Figure (6 – 2): Design of bathroom sewage network

We note that it is more efficient for the stack to be installed so that the 4" sewage pipe from the WC goes straight to the stack, this makes the length of that pipe as small as possible and then the slope will not need a lot of digging.

6.3.2 Kitchens

In kitchens, the perfect way to connect the internal network is shown in figure (6 – 3), we can see that it is important to install a 4" diameter pipe in order to avoid the blockage due to oil and other materials used in kitchens.

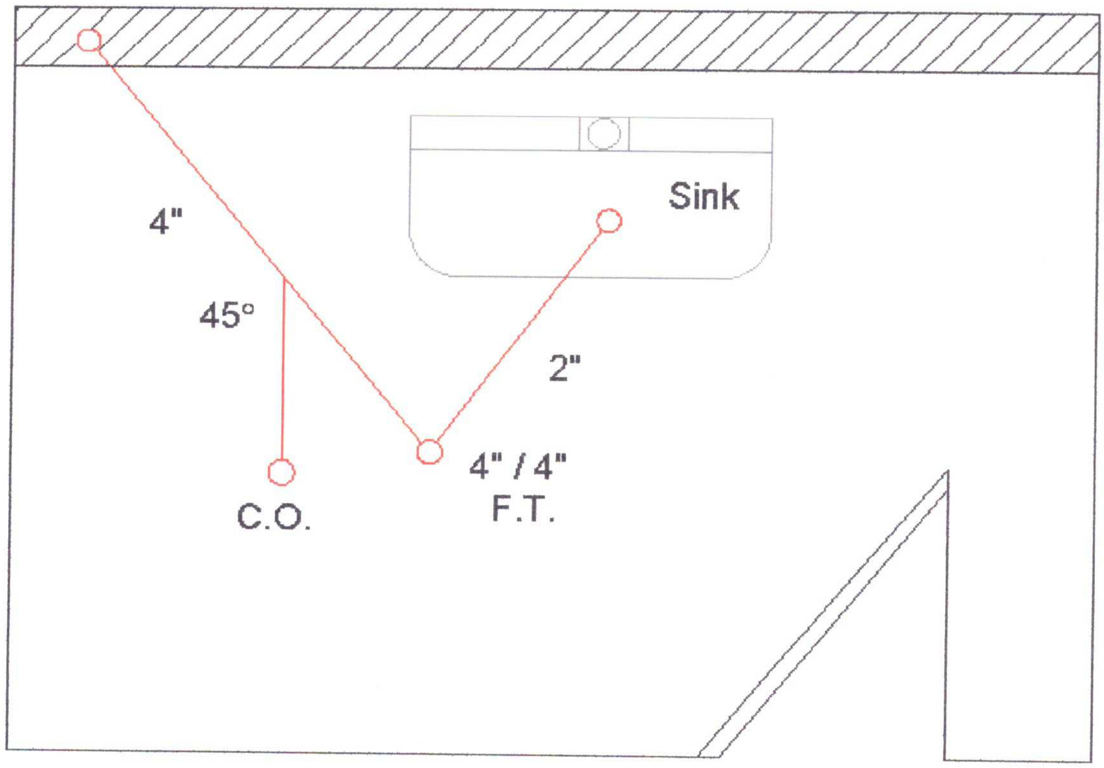

Figure (6 – 3): Design of kitchen sewage network

The internal sewage network in the hospital is designed as shown in figures (6 – 4) and (6 – 5), we can see that the installed diameters are as in table (6 – 6).

Table (6 – 6): Installed diameters compared with design aspects

Pipe	Installed diameter (inch)	Design diameter (inch)
From WC	4	4
From lavatory	2	2
From sink	4	4

Then we can judge that the installed diameters cope with the recommended ones, so the internal sewage network is correctly designed and installed.

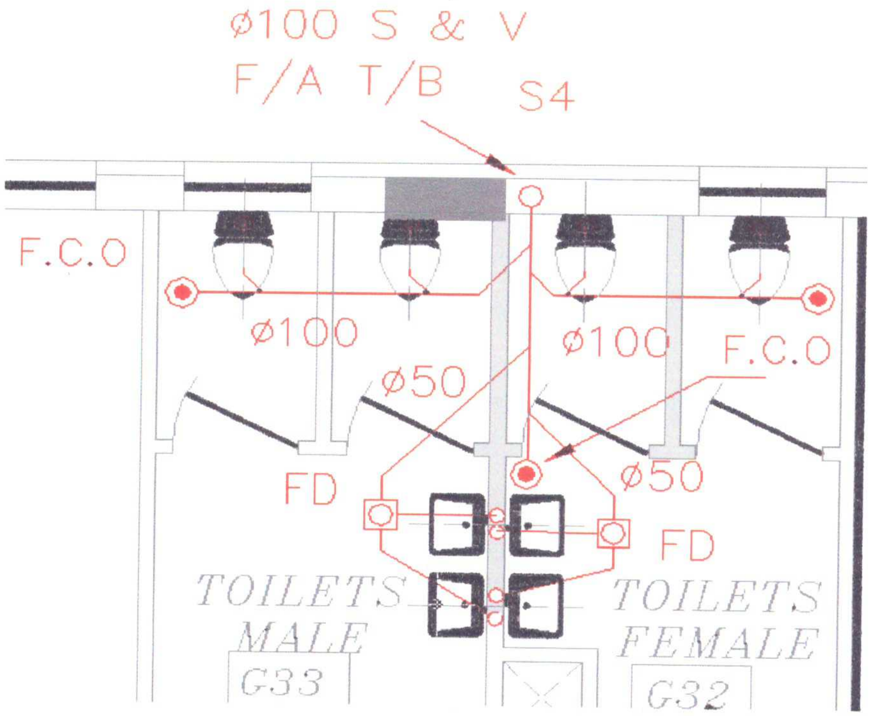

Figure (6 – 4): Internal sewage network in the hospital – bathrooms

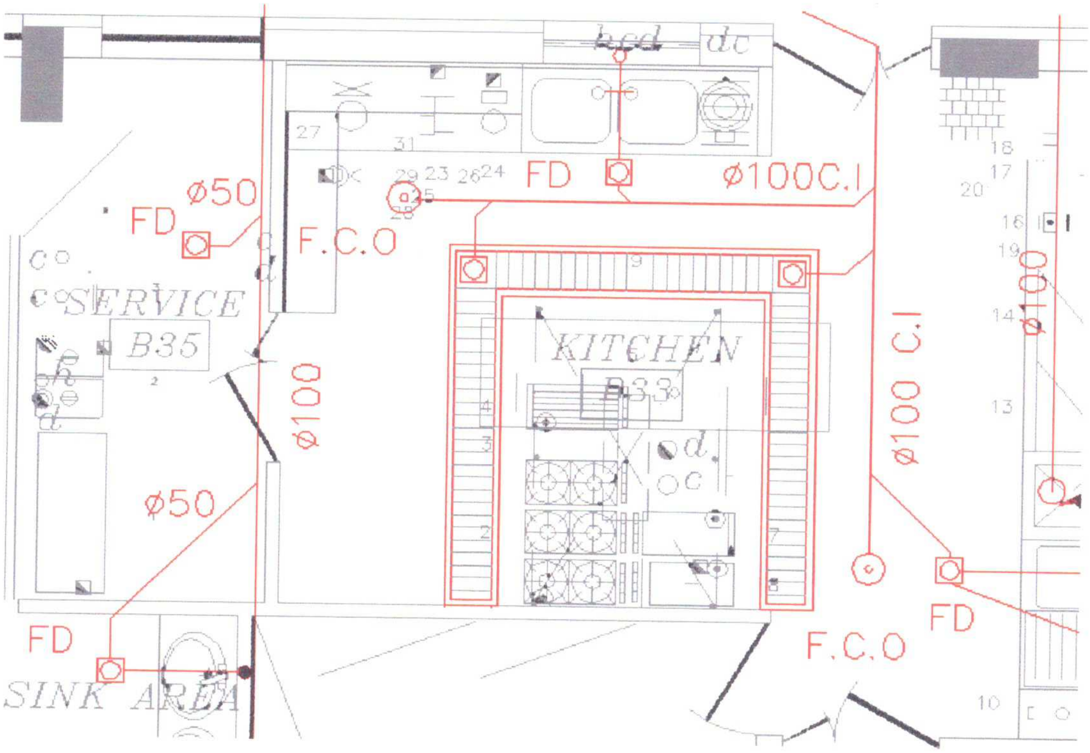

Figure (6 – 5): Internal sewage network in the hospital – kitchen

6.4 Evaluation of manholes

Manholes are those exterior clean out that installed each 4 m of sewer pipe length as recommended, installation of manholes depends on the design of sewer pipes between them. The evaluation of manholes will check all factors responsible for design process of manholes.

6.4.1 Construction of manholes

As shown in figure (6 – 6), a manhole is constructed of a body made of concrete, it may be cast or pre-cast rings. The drainage pipe has a slope (section A – A), this pipe is installed within the benching layer (section B – B). Benching consists of sand and concrete with similar quantities, with a little water added to them, this layer must be 20 cm at least.

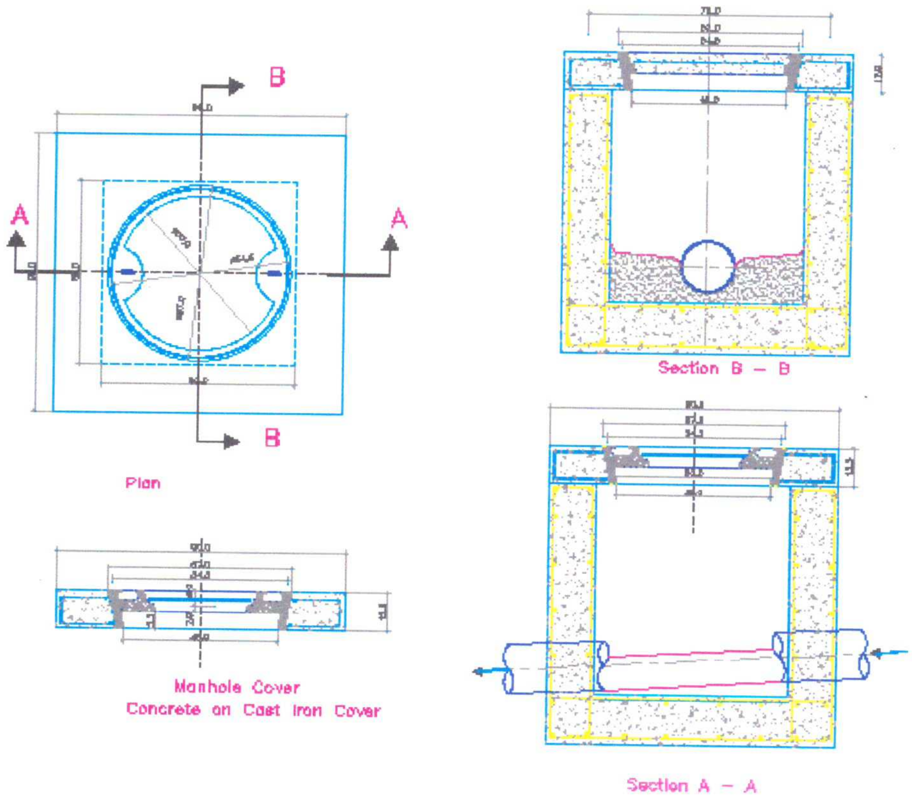

Figure (6 – 6): Construction of manhole

The manhole has a cast iron cover (plan), this cover differs according to the application of the manhole. Table (6 – 7) illustrates types of manhole covers associated to there applications.

Table (6 – 7): Types of manhole covers

Manhole cover	Weight can support (ton)	Application
Normal	2 – 4	Street for walking persons
Medium	8	Street for private cars
Heavy	24	Public street for large cars

Manhole often supported with a reinforced concrete base, consists of iron bars with 12 mm diameter, and 15 cm spacing ($\phi 12\ \text{mm} \bullet 15\ \text{cm}$). This layer is installed above another screed layer of 3 cm depth. Deep manholes are designed with galvanized iron steps so that maintenance workers could go down through the manhole to treat any blockage.

6.4.2 Drop manholes

Drop manhole is the manhole that places where there is a sudden change in the land level; figure (6 – 7) shows the drop manhole.

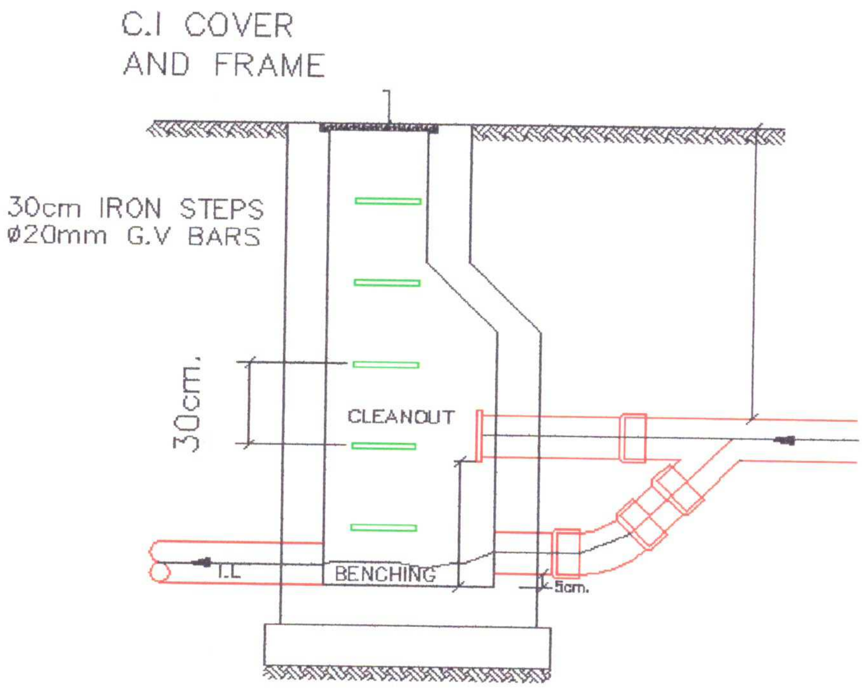

Figure (6 – 7): Drop manhole

Drop manhole is installed so that its cover level is the same as that for the preceding manhole, figure (6 – 8) shows the installation of the drop manhole.

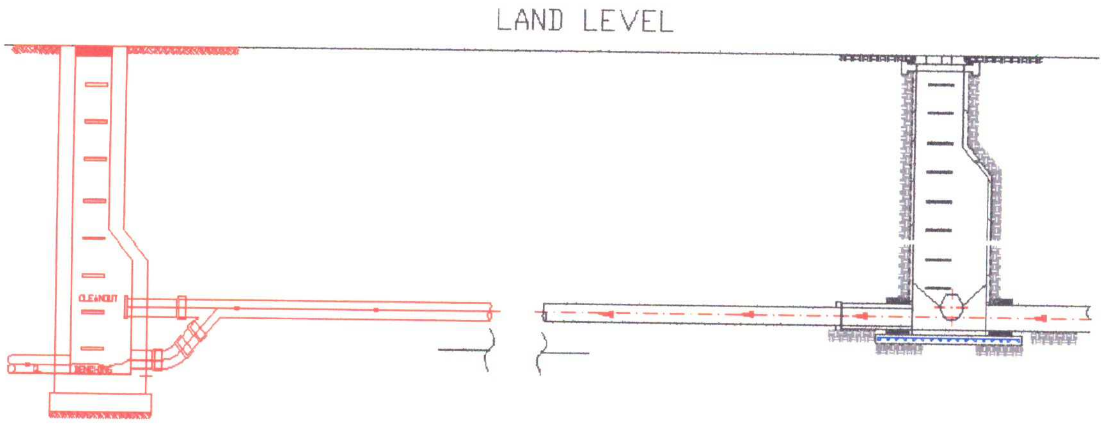

Figure (6 – 8): Installation of drop manhole

6.4.3 Design of manholes

In the design of manholes, there are some concepts related to manholes, and affect the design and installation of them, these concepts are:

- Top level or cover level: represents the land level in the manhole exists, the cover is installed so that it is at the same level with the land surface.
- Depth: the distance between the top level or the cover of the manhole and the center of its outlet.
- Invert level: the level of the bottom of the manhole.

Figure (6 – 9) and (6 – 10) illustrates these concepts, the equation that relates these factors is

$$\text{Top level} = \text{Invert level} + \text{Depth} \qquad \text{(E-6.1)}$$

$$\text{Invert level} = \text{Invert level of previous manhole} - (\text{Slope} \times \text{Length}) - 5\text{ cm} \qquad \text{(E-6.2)}$$

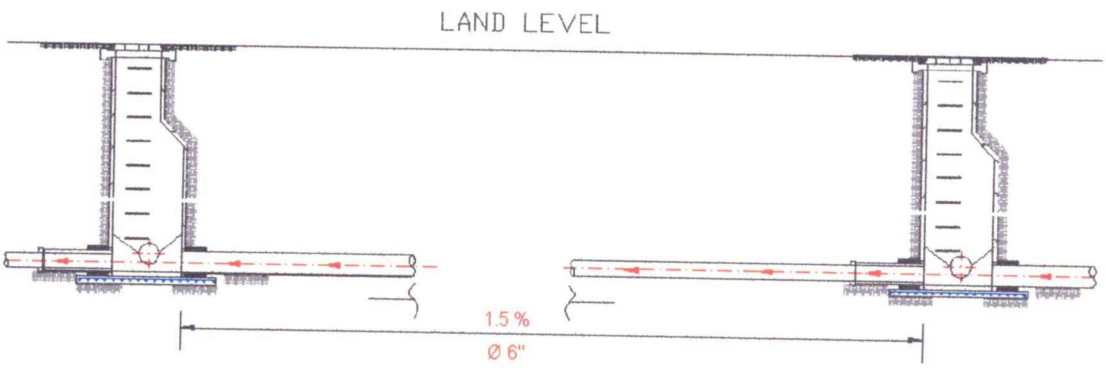

Figure (6 – 9): Installation of manholes

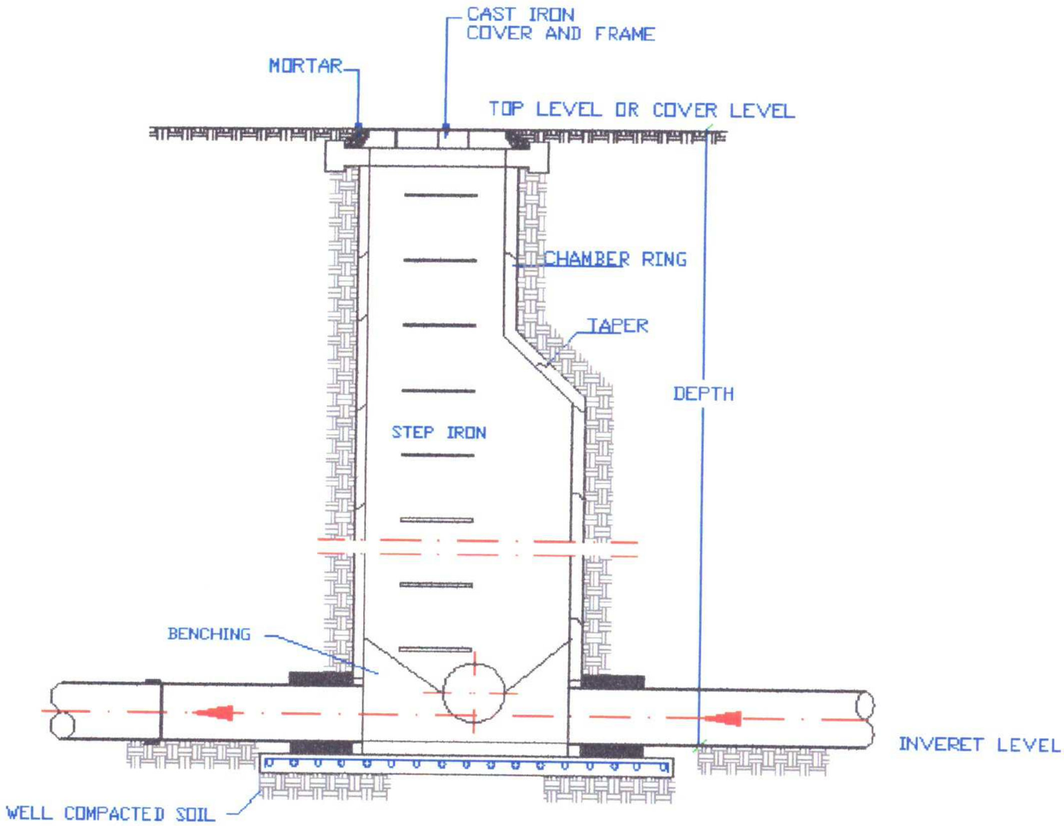

Figure (6 – 10): Manhole details

The value 5 cm represents the distance for benching; then to evaluate the manholes we apply this equation between each two manholes, for example MH-1 and MH-2, considering the values in table (6 – 8).

Table (6 – 8): Manholes details and evaluation

Manhole	Cover level (m)	Invert level (m)	Depth (mm)	Diameter (mm)	Type of cover	Remark
MH – 1	768.24	765.30	2940	900	Medium	Ordinary
MH – 2	767.50	765.17	2330	900	Medium	Ordinary
MH – 3	766.58	765.03	1550	900	Medium	Ordinary
MH – 4	766.00	764.90	1100	900	Medium	Ordinary
MH – 5	766.00	764.73	1270	900	Medium	Ordinary
MH – 6	766.00	764.65	1350	900	Medium	Drop
MH – 7	766.00	764.50	1500	900	Medium	Drop
MH – 8	766.00	764.39	1610	900	Medium	Drop
MH – 9	766.00	764.30	1700	900	Medium	Drop
MH – 10	766.00	764.25	1750	900	Medium	Drop
MH – 11	766.00	764.16	1840	900	Medium	Drop
MH – 12	766.00	764.10	1900	900	Medium	Drop
MH – 13	766.00	764.02	2480	900	Medium	Drop
MH – 14	766.00	763.92	3080	900	Medium	Drop

Invert level of MH-2 = Inert level of MH-1 – (Slope × Pipe MH-1_MH-2 length) – 5 cm

$= 765.30 - (0.015 \times 4.489) - 0.05$

$= 765.17$ m

Then,

Top level of MH-2 = 765.17 – 2.330 = 767.50 m

Applying this equation on all manholes gives the results in table (6 – 7), and then we can firmly judge that all manholes are correctly installed.

6.5 Evaluation of septic tank

Septic tank is a large hole that receives the wastewater from all sewer pipes and drains and collects it in order to get rid of it. The evaluation of septic tank will concentrate on capacity, absorption, and structure.

6.5.1 Capacity of septic tank

Total drainage fixture unit of the building as shown in table (6 – 1) is 658 dfu, according to table (B-6.3) in appendix B, each 100 dfu must have a septic tank of 3500 gal capacity. But we have 658 dfu then

$$\text{Capacity of septic tank} = 3500 + (658 - 100) \times 25$$
$$= 17{,}450 \text{ gal}$$

Or Yatta hospital septic tank must have a minimum capacity of about 66 m^3.

6.5.2 Absorption area

According to Palestinian Code mountain areas, like Yatta, have a time of 5 min for each 1 inch drop of water in the soil, according to table (B-6.4) in appendix B, the effective absorption area of septic tank is 56 ft^2 / 100 gal of capacity. Then

$$\text{Absorption area} = \frac{56 \times 17{,}450}{100} = 11{,}343 \text{ ft}^2$$

Or the septic tank of Yatta hospital must have an absorption area of 1054 m^2.

6.5.3 Structure of septic tank

Survey process (section 3.3.3) has explained the standard, perfect, and effective structure of the septic tank. Figure (6 – 11) shows a section of the construction of septic tank in Martyr Abu Al-Hassan Qasem Hospital. It consists of porous block. Pores in the block allow the sewage matters to be absorbed and make the absorption are more effective.

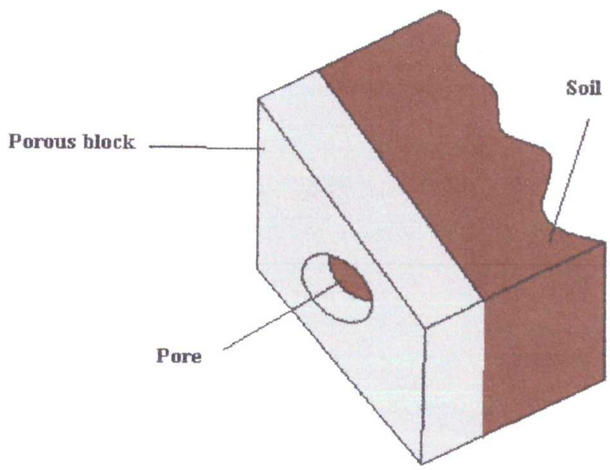

Figure (6 – 11): Section in septic tank

6.6 Recommendations

According to all forgoing steps of evaluation, we can put forward the following evaluation recommendations:

1. According to universal standards, stack diameter must cope with the largest diameter resulted from calculations. Plumbing is a technical art that depends on the skills of the plumber, so calculations only govern the basics of the plumbing system since they are simple. The technician must know all these basics, also the supervision engineer have to contact with all stages of installation.

2. Storm drainage, (rain water drainage), must not be drained to the septic tank; since this increases the sewage load on it. Rain water must have a special system of drainage that is independent of the sewage system.

3. Black and gray water must be separated from each other using special stacks for each one when there is a treatment plant. If there is no separation, another type of treatment plants must be used; this plant takes the responsibility for separating the black water from the grey water. The treated water is to be used in planting, and not for domestic uses.

4. Installing sewer pipes with 8" diameter and 1 % slope instead of 6" with 1.5 % slope will create an extra cost, but with better performance.

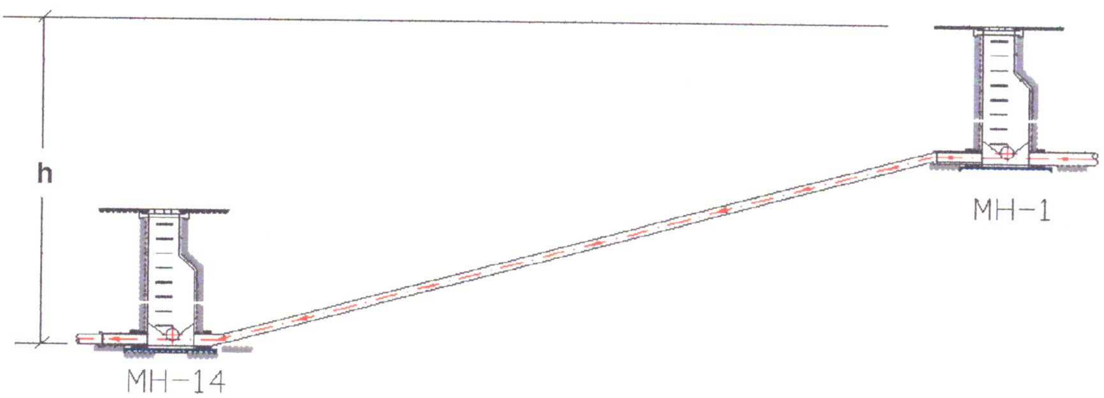

Figure (6 – 12): Evaluation of manholes

As shown in figure (6 – 12), the distance between MH-1 and MH-14 is 121 m, so using 6" sewer diameter with slope 1.5 % we find that the depth is

$$h_{6"} = 0.015 \times 121 = 1.815 \text{ m}$$

And using 8" sewer diameter with slope 1.0 % we find that the depth is

$$h_{8"} = 0.01 \times 121 = 1.21 \text{ m}$$

Then the difference between the two heights is

$$1.815 - 1.21 = 0.605 \text{ m}$$

The average of the depths for the total distance between MH-1 and MH-14 is

$$h_{avg} = \frac{0 + 0.605}{2} = 0.3025 \text{ m}$$

Then, the difference in volumes of crash that must be removed is

$$V_T = 121 \times 0.7 \times 0.3025 = 25.622 \text{ m}^3$$

Known that the cost per one cubic meter of digging is 40 NIS, then the saved costs for all digging is

$$C_D = 25.622 \times 40 = 1025 \text{ NIS}$$

Considered that the difference of cost between the 6" and 8" drainage pipes per one meter is 12 NIS, and then the extra cost for installing 8" pipes is

$$C_P = 121 \times 12 = 1452 \text{ NIS}$$

According to all forgoing, we find that installing 8" diameter sewer pipes with slope of 1 % instead of 6" with slope 1.5 % will create an extra cost of

$$1452 - 1025 = 427 \text{ NIS}$$

But this extra cost is relatively acceptable; since installing 8" diameter sewers could achieve easier maintenance without probable blockage.

Table (6 – 9): Evaluation of manholes' installation

Process	**Cost difference (NIS)**	**Advantage**
Alternating 1% slope instead of 1.5 %	+ 1025	Easier maintenance
Alternating 8" sewer pipes instead of 6"	– 1452	No probable blockage

CHAPTER SEVEN

EVALUATION OF

CENTRAL HEATING SYSTEM

7.1 Introoduction

Central heating system in Martyr Abu Al-Hassan Qasem Hospital was created considering the effective insulation of the building; this insulation will be evaluated so that it could be applied in other buildings since it is a good energy-saving system.

But as mentioned in survey (section 2.7), there are two main outshootings in the central heating system; the first one has been represented as a control case; the two boilers have to be connected to cooperate in such a way that could enhance their performance.

The second problem has appeared when the overall heat transfer coefficient (U-value) of the galss windows is calculated, it is very high. This increases the total heat transfer rate through windows and than the total load of the building will also increase. So the glass has to be changed so that it could save the energy, recommendations will explain this case.

Finally, evaluation will consider the piping system of the central heating, including the pumps, and the heating equipment including boiler, fancoil units, and radiators. A group of recommendations will be put after evaluation process.

7.2 Evaluation of piping system

Piping sytem of central heating system in Martyr Abu Al-Hassan Qasem Hospital has been designed using radial system, (section 2.4.1). This is the basis of evaluation process for piping system.

7.2.1 Radial system

Radial piping system used in the hospital is an effective method; flexible plastic PVC pipes, figure (7 – 1), are installed under the ground and connect the collectors with radiators.

It is known that all plastic PVC pipes used in radial heating system are 16 mm diameter, figure (7 – 2) is a schematic diagram of radial heating system, the two mains (supply and return) are designed so that they could supply all floors with hot water.

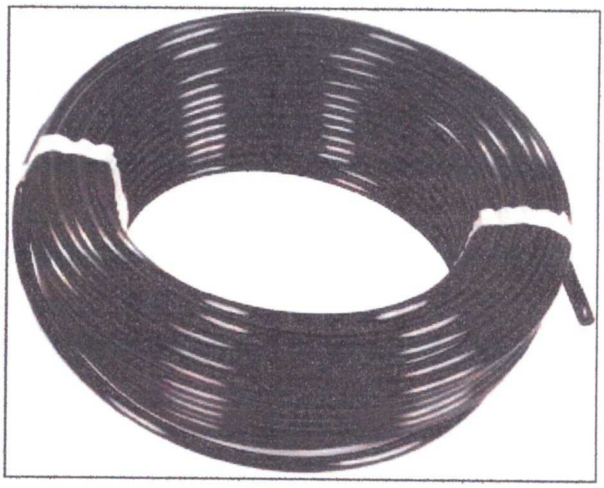

Figure (7 – 1): Plastic PVC flexible pipes

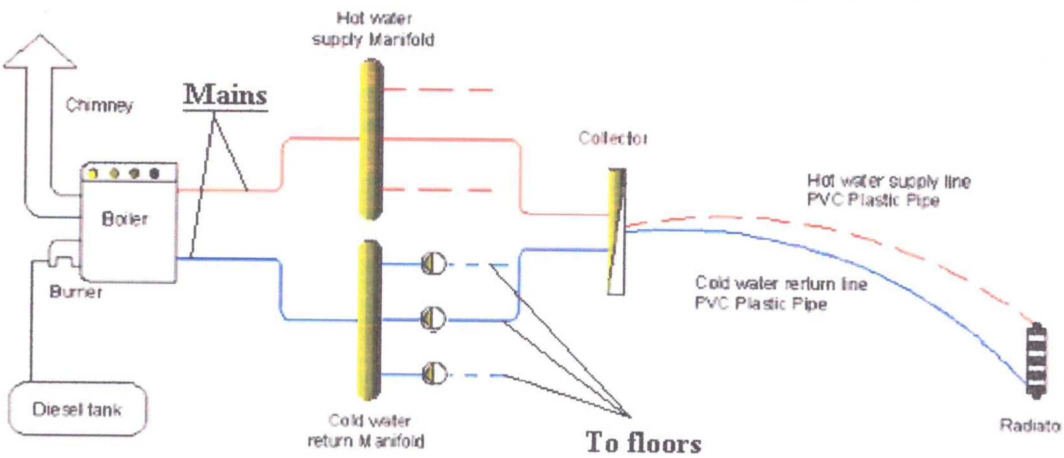

Figure (7 – 2): Radial system

7.2.2 Heating loads

In evaluation process we will take a sample of the building, according to building drawing (D – 2.4), rooms F1 to F31 will be evaluated as a central heating system. For instance, F19 loads are as follows

$$Q_W = U\ A\ \Delta T = 0.9266 \times ((3.6 \times 3) - (1.2 \times 1)) \times (24 - 4) = 180\ W$$

$$Q_C = U\ A\ \Delta T = 1.1496 \times (3.6 \times 3.6) \times (24 - 4) = 298\ W$$

$$Q_G = U\ A\ \Delta T = 5.4 \times (1.2 \times 1) \times (24 - 4) = 129.6\ W$$

No heat loss through the floor since the ground floor is already heated and at the same temperature of the first floor.

$$\dot{\upsilon} = \text{Volume of the room} \times \text{number of air change per unit time}$$

$$= (3.6 \times 3.6 \times 3) \times \frac{1}{3600} = 0.0108\ m^3 / s$$

$$\dot{m} = \rho \dot{\upsilon} = 1.25 \times 0.0108 = 0.0135\ kg / s$$

$$Q_S = \dot{m}.Cp.\Delta T = 0.0135 \times 1 \times (24 - 4) = 270\ W$$

$$Q_T = \dot{m}.(h_{in} - h_{out}) = 0.0135 \times (48 - 13) = 472.5\ W$$

$$Q_L = Q_T - Qs = 470 - 270 = 202.5\ W$$

$$Q_{TOT} = 180 + 298 + 129.6 + 270 + 202.5 = 1080\ W$$

$$\text{Number of elements of cast iron radiator} = \frac{1080}{130} = 8\ \text{elements}$$

Applying all forgoing calculations for all rooms from F1 to F31 gives the results shown in table (7 – 1).

Table (7 – 1): Heating loads for sample of evaluation

Room	Heating load (W)	Radiators × sections
F01	1080	1 × 8
F03	4050	2 × 15
F05	1485	1 × 11
F07	1350	1 × 10
F09	1350	1 × 10
F11	2565	1 × 19
F12	2025	1 × 15
F15	1755	1 × 13
F16	1890	1 × 14
F18	2295	1 × 17
F19	1080	1 × 8
F20	1350	1 × 10
F27	2295	1 × 17
F28	1890	1 × 14
F30	1890	1 × 14
F31	1890	1 × 14
Around elevator	2025 + 2900	1 × 15 + FCU-9

All rooms that are not mentioned above have special cases according to there application, so they are not heated. Table (7 – 2) illustrates the applications for unheated rooms.

Table (7 – 2): Unheated rooms

Room	Application
F02, F06, F08, F10, F13, F14, F17, , F29	Bathrooms and toilets
F25, F26	Toilets
F24	Kitchen
F21	Equipment store
F22	Equipment store
F23	Equipment store

7.2.3 Unheated rooms

As illustrated in table (7 – 2), bathrooms, toilets, kitchens, and equipment stores are not heated directly with a radiator inside them. However, they are, heated by the effect of heating from neighboring corridors.

The reason for which no radiators are installed within these rooms is that rooms with similar appliances do not contain people for long times from one side, and because of their very little load resulted from insulation of the building from another side.

Therefore, rooms have no radiators are heated in fact, but radiators do not need to be installed within them, especially if the building is insulated.

7.2.4 Overall heat transfer coefficient of glass

As said in survey process, glass of windows is single; therefore overall heat transfer coefficient is very high (5.4 W / m^2 °C). If doubled glass windows are used, with an overall heat transfer coefficient of 3.2 W / m^2 °C, then we can calculate the energy saved from this selection by finding the total area of glass in the hospital which is shown in table (7 – 3).

Table (7 – 3): Total area of glass windows in the hospital

Floor	**Glass area (m^2)**
Basement	88.8
Ground	22.4
First	10.5
TOTAL	**121.7**

Then the energy saved by installing double glass windows instead of single glass is

$$Q_{saved} = (U_{single} - U_{double})\ A\ \Delta T$$
$$= (5.4 - 3.2) \times 121.7 \times (30 - 5)$$
$$= 6693.5\ W$$

Then the energy saved is about 6.7 kW which can be converted to money, known that the cost per 1 kcal is about 1.25 NIS, then

$$\text{Saved cost} = 6.7 \times 860 \times 1.25 = 7202.5\ \text{NIS}.$$

7.2.5 Pumps and diameters of Pipes

Hot water flow rate is calculated by the equation

$$\dot{m}_w = \frac{Q}{Cp \cdot \Delta T} \qquad \text{(E-7.1)}$$

For main supply

$$\dot{m}_w = \frac{135.985}{4.18 \times 10} = 3.25 \text{ L / s}$$

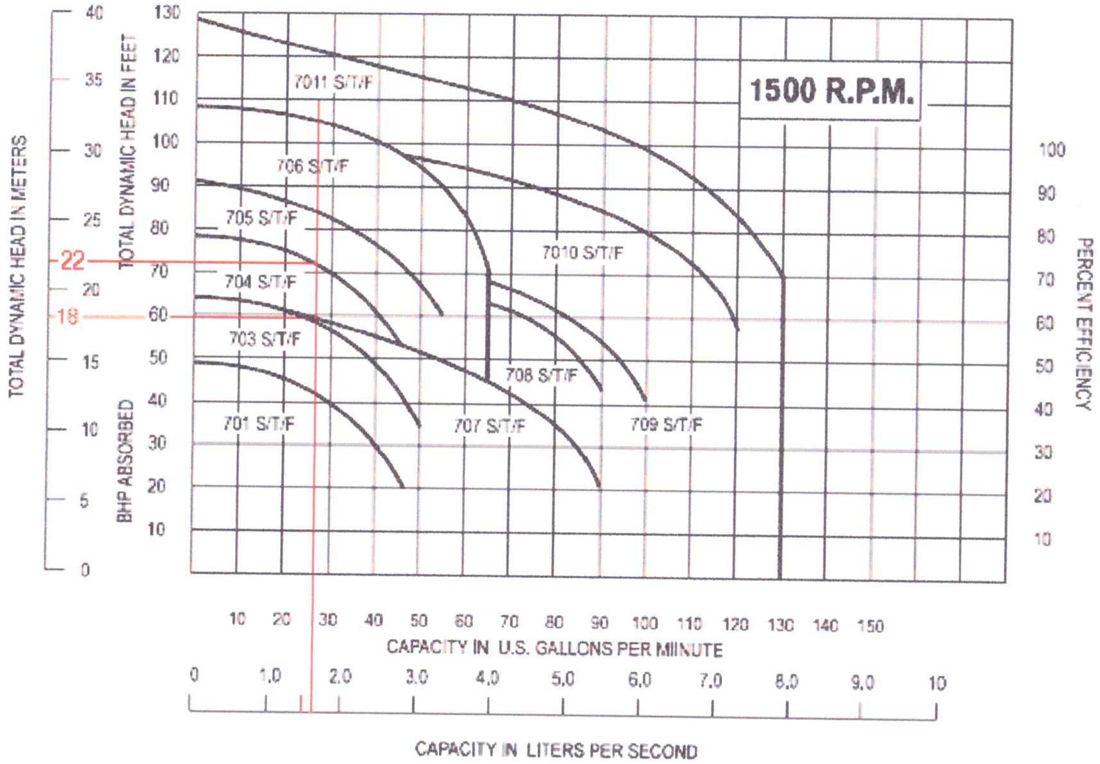

Figure (7 – 3): Capacity vs head pump chart

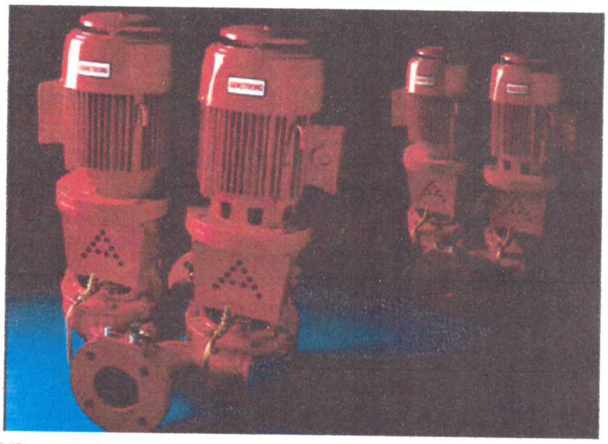

Figure (7 – 4): Pump used in the hospital

The pump head is 20 m if we use two pumps with flow rate of 1.625 L / s for each. The head is similar to the pumps installed within the central heating system in the hospital, and the flow rate for pumps installed is 1.8 L / s.

The recommended flow velocity in central heating is around 1.5 m / s, using chart in figure (7 – 4), we can find that the pressure drop is 425 Pa / m, and the inside pipe diameter is 60 mm.

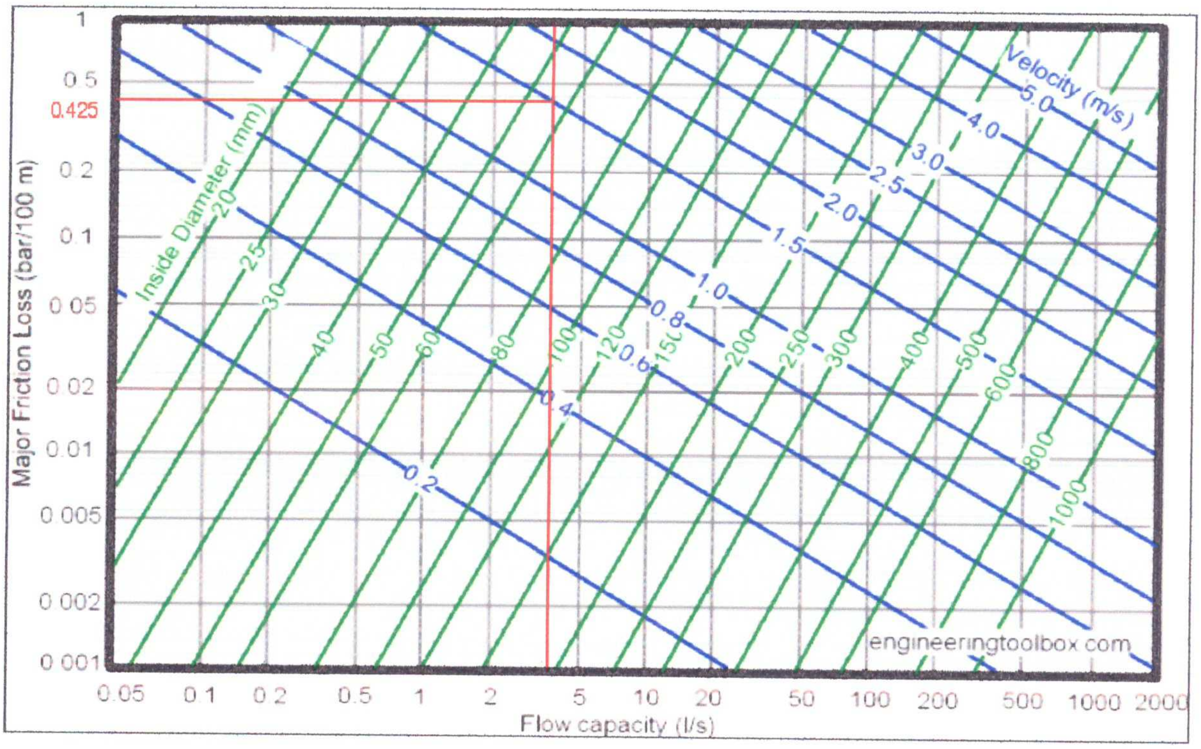

Figure (7 – 5): Flow rate vs friction chart

Then, the main supply diameter must be 2 ½ inch, the installed main supply pipe is 3 inch.

The recommended pressure loss in central heating is between 200 – 550 Pa / m, which is the range that our results lie in. Results for other pipes are shown in table (7 – 4).

Table (7 – 4): Design of pipes

Pipe	Load (kW)	Flow rate (L / s)	Designed diameter (mm)	Installed diameter (mm)
Main	135.985	3.25	67	76
HDC-1	14.85	0.355	25	32
HDC-2	9.45	0.226	20	32
HDC-3	7.965	0.191	20	25
FCU-9	2.9	0.069	15	20

7.3 Evaluation of heat transfer elements

Heat transfer elements in Martyr Abu Al-Hassan Qasem Hospital, like these in any heating system, are the radiators and fan-coil units. The evaluation of these elements will be an explanation for using them in this hospital, and a comparison between the used elements and other ones used for similar applications.

7.3.1 Radiators

Radiators used in the hospital are cast iron radiators, figure (7 – 6) shows this type of radiators from Chappee products with properties illustrated in table (7 – 5).

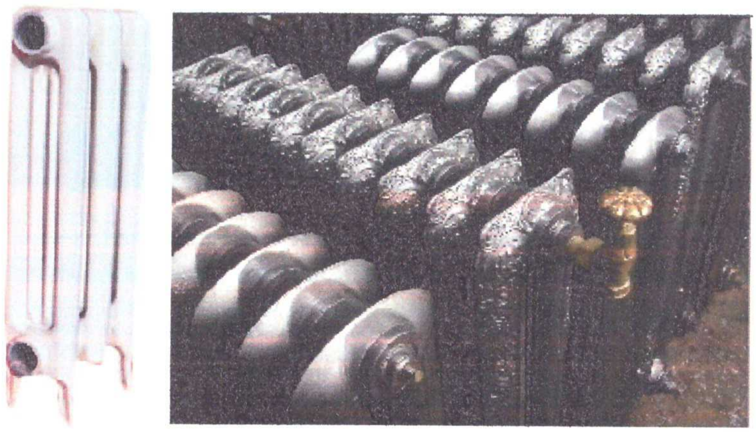

Figure (7 – 6): Cast iron radiator

Table (7 – 5): Cast iron radiators installed in the hospital

Thermal output	130 W
Height	68 cm
Width	6 cm
Depth	10 cm
Cost per section	7 $

Radiators in the hospital are installed above the floor level by 15 cm so that cold air could pass under the radiator and flows heated from the upper side of it as shown in figure (7 – 7).

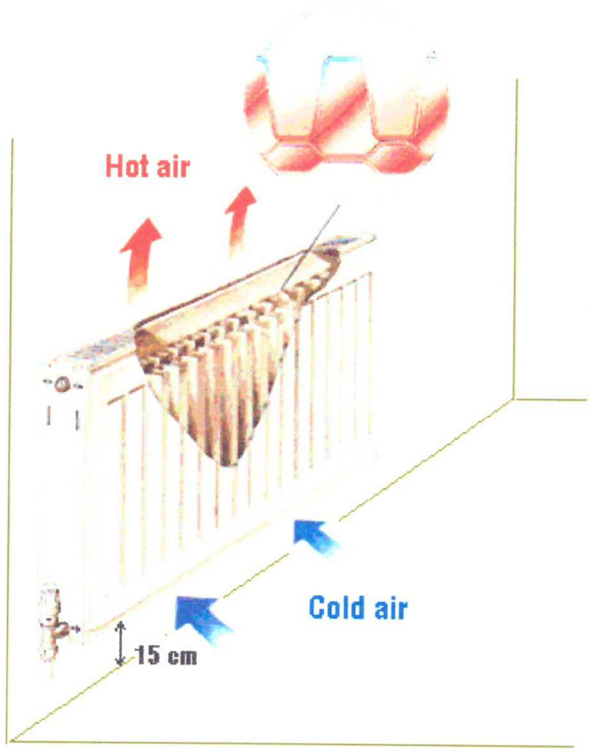

Figure (7 – 7): Air motion around radiator

7.3.2 Fan-coil units

Fan-coil units are used in the hospital where there is a large are that can not be heated with radiators, as shown in figure (7 – 8), the hot air leaves the fan-coil unit as it is heated by the hot water pipe.

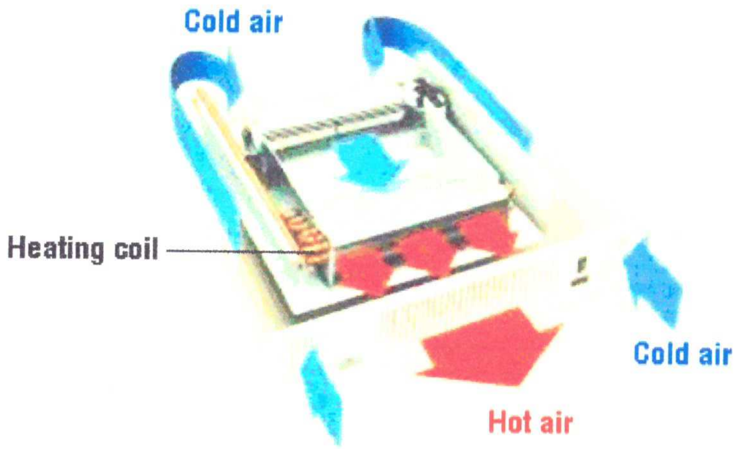

Figure (7 – 8): Fan-coil unit air circulation

7.4 Evaluation of boilers

Evaluation of boiler depends on the load of the building and the power needed for hot water demand. In addition, the type of boiler installed will be evaluated whether the selection of such type is correct or not.

7.4.1 Heating capacity of boilers

Total loads of the building are shown in table (7 – 6), the total value of these loads does not represent the boiler load; since the boiler heats all water needed for hot water applications.

Table (7 – 6): Heat loads for the hospital

Floor	Heat load (kW)
Basement	40.365
Ground	40.59
First	55.03
TOTAL	**135.985**

The hot water cylinders need 35 kW to heat water (section 5.3.4), then

$$\text{Required boiler capacity} = 135.985 + 35 = 170.985 \text{ kW}$$

However, boiler installed in the hospital is 320 kW; this is not a kind of oversizing because the boiler is installed not only for central heating, but also for air conditioning to supply air-handling units.

In addition, boilers in hospitals should be on duty for 24 hours a day; since heating is required all the time for domestic hot water uses, and to have a steady air temperature all the time.

7.4.2 Type of boilers

Boilers used in Yatta hospital are Chappee with SICMA burner; Figure (7 – 9) shows the Chappee steel boiler.

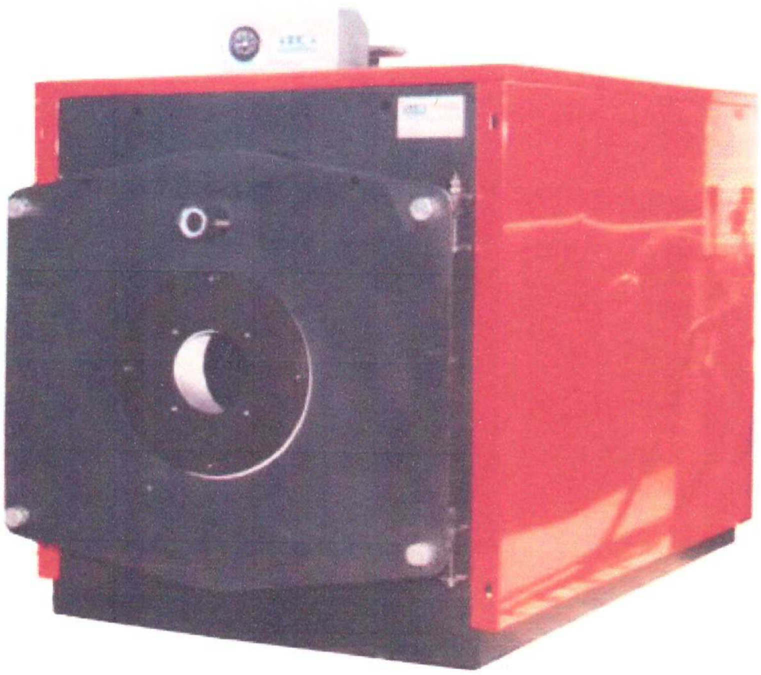

Figure (7 – 9): Chppee steel boiler

Boilers with similar capacity made by other industries are shown in table (7 – 7), all boilers have an efficiency of 92 %, and a capacity of 320 kW.

Table (7 – 7): Boilers and costs

Boiler	Cost ($)
De-Dietrich	5,500
Chappee	5,000
Fondital	3,500
Ferroli	3,500
Semi	3,000

Although using Chappee boiler relatively has high cost, but it has a high efficiency, and Chappee boiler is known as one of the best boilers around the world.

7.5 Recommendations

1. Overall heat transfer coefficient of glass has to be reduced; this may be obtained by installing double-plate glass with an air gap.

2. Boilers are oversized for central heating system; they are designed to overcome the heating system, domestic hot water system, and the central air conditioning system. But central air conditioning system has not been installed, so there will be a massive loss in energy.

3. Heating pumps are used as a booster system; one pump is on duty, and the other is standing by. This is a mistake; since the two pumps must work together to achieve the required flow rate of water.

4. Radiator must be removed from the X-ray room; because of the probable effect of radiation pollution. So room B41 has to be heated using any other type of heating.

CHAPTER EIGHT

EVALUATION OF

AIR CONDITIONING SYSTEM

8.1 Introduction

Air conditioning system in yatta hospital was designed to be a central system, but it has been alternated with a semi-central unit that only deals with the surgery department. This package unit controls only heating and cooling of air, without controlling of the relative humidity (RH). The evaluation of the air conditioning system will consider this situation to improve the performance of the air conditioning system.

As the air cinditioning system is only opplied on the surgery department, the evaluation will study the structure of this department in order to recalculate and control the load of it. Some factors that directly affect the cooling load of the building (surgery department) will be dicoused with their calculations and assumptions.

Evaluation will also explain the central air conditioning system that was designed for the hospital, and how to deal with the semi-central unit inm case of installation of the central system.

After evaluation process comes to an end, a set of recommendations will be suggested to make sure that the air conditioning system is an effective and succesfull system for health applications.

8.2 AC system components

The evaluation of the components of air conditioning system will be concerned only with the surgery room, since it is the only air conditioned space within the hospital. The factors affect air conditioning system are:

1. Orientation: determines which side of the building is exposed to the sun at a particular hour.
2. Time of day: the effect of direct solar radiation; eastern exposures have their maximum solar load in the morning, western exposures in afternoon, and roofs at noon.
3. Latitude: has a direct relation with the position of the sun during the day in addition to the time of day.
4. Heat gain through glass: which consists of direct solar radiation through unshaded glass exposed to the sun, and conductive heat gain through shaded glass and glass not directly exposed to the sun.
5. Type of construction (thermal lag): heat takes time to get through a structural element; this time depends on the specific heat of the structure.
6. External and internal shading: to avoid the large cooling load of glass, shading is made in different ways:
    - Coloring the glass or glazing it with heat-reflecting coating.
    - External shading: overhangs and baffles.
    - Internal shading: drapes and venetian blinds.
7. Internal sensible heat loads: these loads include:
    - Lighting.
    - Load for each space occupant, about 270 BTU / hr / person.
    - Electrical loads: motors, computers, and office equipment.
    - Kitchen applications or gas powered equipment.
8. Internal latent heat loads: occupants, showers, baths, laundries, infiltration, and ventilation of moist air.
9. Daily temperature range: the difference between the 24-hour high and low dry bulb temperatures.
10. Acceptable interior temperature swing: the range within which the inside temperature is allowed to change.

8.3 Evaluation of AC system components in the hospital

However, in Yatta hospital the air conditioning system components are:

1. Orientation: as shown in figure (8 – 1), 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 ends. This could decrease the thermal lag and finally the total cooling load. Orienting the building's narrow ends west and east reduces the solar heat gain and saves the energy.

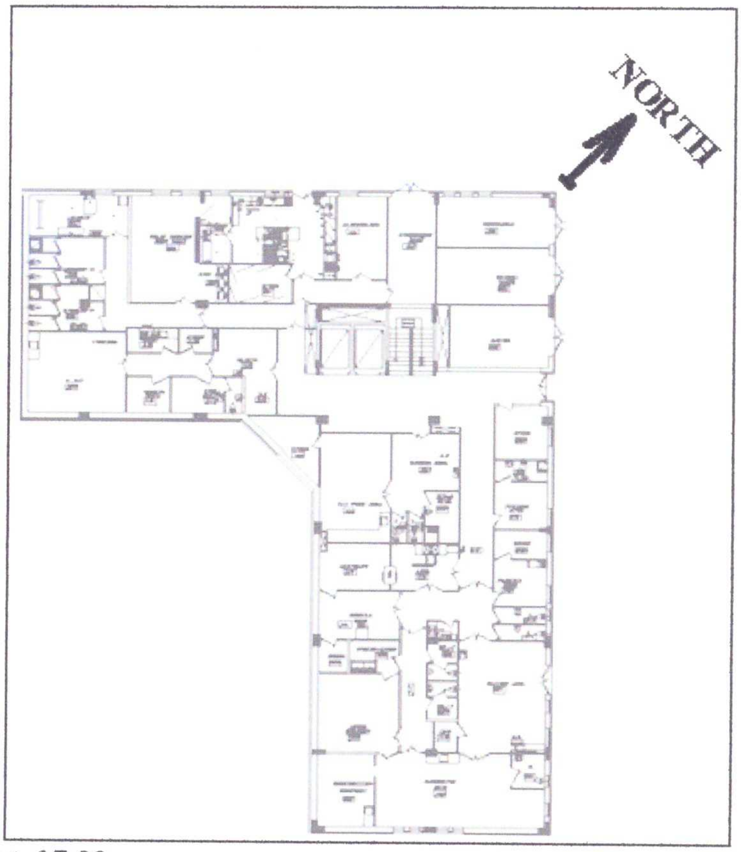

Figure (8 – 1): Orientation of the hospital

2. Time of day: it is recommended in Palestine to calculate the cooling load in August, exactly at 17:00 (5:00 pm). This is because August is the warmest month in our region is, and 17:00 is the hour at which the heat gain reaches its greater value.
3. Latitude: Cooling load in Palestine is designed considering that Palestine lies at 32° N; this gives information to determine heat gain from direct solar radiation, then to design shading and insulation.
4. Heat gain through glass: glass in Yatta hospital is single with overall heat transfer coefficient of 5.4 W / m^2 °C, which is calculated in heat loss calculations.

Heat gain through glass consists of two parts:

a) Transmitted solar radiation heat gain: the amount of solar energy received by the interior walls, floors, and furniture. It is calculated as

$$Q_{tr} = A \cdot (SHG) \cdot (SC) \cdot (CLF) \qquad \text{(E-8.1)}$$

Where, A is the area of glass, SHG is the solar heat gain factor that is obtained from table (B – 8.1) in appendix B. SC is the shading coefficient which is obtained from table (B – 8.2), and CLF is the cooling load factor that indicates the emitted energy from internal components and it is obtained from table (B – 8.3).

b) Transmission heat gain: by convection and conduction, and it is calculated by the equation

$$Q_{con} = U \cdot A \cdot (CLTD)_{cor} \qquad \text{(E-8.2)}$$

Where, U is the overall heat transfer coefficient of glass, and CLTD is the cooling load temperature difference that obtained from table (B – 8.4), where $(CLTD)_{cor}$ is

$$(CLTD)_{cor} = (CLTD + LM) + (25.5 - T_i) + (T_{o,m} - 29.4) \qquad \text{(E-8.3)}$$

Where, LM is the latitude correction factor, and can be obtained from table (B – 8.5), T_i is the inside design temperature, and $T_{o,m}$ is the mean outside temperature where

$$T_{o,m} = T_o - \frac{\text{Daily temp erature range}}{2} \qquad \text{(E-8.4)}$$

According to Palestinian code $T_{o,m}$ is 30.1 °C.

5. Daily temperature range (DR): it is the difference between the average maximum and average minimum temperatures for the warmest month of summer season. In Yatta according to Palestinian code DR is

   DR = 30 – 18 = 12 °C

6. External and internal shading: the building is not externally shaded; however, the surgery room is internally shaded using dark glazes.
7. Internal sensible heat loads: surgery room has the following sensible loads
   a. Lighting: there are 16 florescent lamps, 40 W each. Then the lighting load is calculated by the equation

$$Q_{light} = P_{light} \cdot \text{Number of lamps} \cdot (CLF_{light}) \qquad \text{(E-8.5)}$$

Where CLF of lights is obtained from table (B – 8.6).

   b. Load for each space occupant: there are five persons, each gives about 200 – 300 BTU / hr.
   c. Electrical loads: there is a sterilizer that is 2200 W.

8. Internal latent heat loads: ventilation and infiltration.

   a. Ventilation: calculated by the equation

$$Q_{T,v} = \dot{m}_f \cdot (h_o - h_i) \qquad \text{(E-8.6)}$$

Where, the air flow rate is obtained from table (B – 8.7) in appendix B.

   b. Infiltration: it is recommended in surgery rooms to consider the number of air change as 15 – 20 times per hour. Then equation (E-8.6) is used to calculate the infiltration load.

9. Acceptable interior temperature swing: surgery rooms are designed to have no more than 1 °C swing for inside temperature.

10. Thermal lag: heat gain through walls, roofs, floors, and doors follows the equation

$$Q_{lag} = U \cdot A \cdot (CLTD)_{cor} \qquad \text{(E-8.7)}$$

And,

$$(CLTD)_{cor} = (CLTD + LM)k + (25.5 - T_i) + (T_{o,m} - 29.4)f \qquad \text{(E-8.8)}$$

Where, CLTD for walls and roofs is obtained from tables (B – 8.8) and (B – 8.9) respectively, k is the color correction factor that is found in table (B – 8.10), and f is the attic roof fan factor. For flat walls and roofs f = 1.0, and f = 0.75for attic roofs and walls.

For walls and roofs that lie beside an area that has a constant temperature, we apply the equation using the temperature difference

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

Doors are treated the same as walls and roofs with the appropriate U value.

8.4 Cooling load calculations for surgery room

Cooling load calculations are based on the air conditioning system components that are previously mentioned, and using design tables mentioned in the previous section. The cooling load calculation will concerned with the surgery room F51 as a sample, considering wall, roof, and glass constructions.

8.4.1 Heat gain through walls, roof, and floor

Heat gain through walls must deal with each side of walls independently; northern wall may have specifications different from southern, western, and eastern walls. Since the building is oriented so that each straight wall is exposed to a position between the four orientations. Figure (8 – 2) illustrates these orientations.

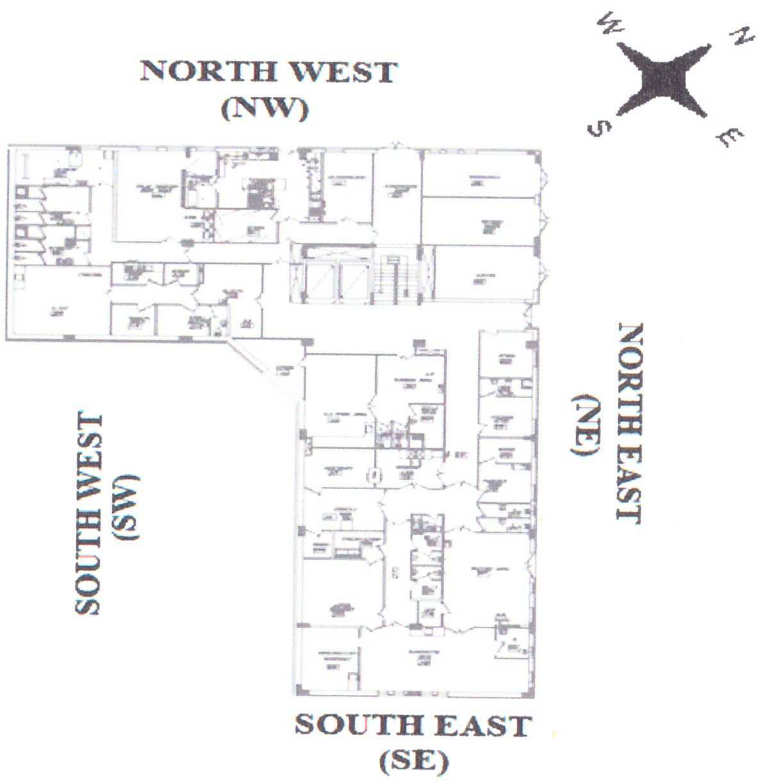

Figure (8 – 2): Orientation of straight walls of the hospital

Using tables we can find the values of LM, k, and *f* for all walls, roof, and floor. All values are illustrated in table (8 – 1). Heat gains through walls, roof, and floor are listed in table (8 – 2).

Table (8 – 1): LM, k, and *f* for walls, roof, and floor of the hospital

Wall	LM (°C)	k	*f*
NE	0.5	0.65	1
NW	0.5	0.65	1
SE	---	---	---
SW	---	---	---
Roof	0.5	0.5	1
Floor	---	---	---

Table (8 – 2): Heat gains through walls, roof, and floor of the hospital

Wall	$CLTD_{cor}$ or ΔT (°C)	Cooling load (W)
NE	10.875	144.35
NW	7.625	109.16
SE	5	76.44
SW	5	41.07
Roof	16.3	493.63
Floor	5	275.75

Heat gain	**1140.40**

8.4.2 Heat gain through glass

Using tables mentioned in section 8.3 we find values of SC, CLF, SHG, and $CLTD_{cor}$ for the glass, these values are listed in table (8 – 3). Then the heat gain through glass is also shown in the table.

Table (8 – 3): SC, CLF, SHG, and $CLTD_{cor}$ for glass

Factor	Value
SC	0.94
CLF	0.26
SHG	527
$CLTD_{cor}$	10.6

Heat gain	**195.34 W**

8.4.3 Heat gain through door

There are two doors for the surgery room, the heat gain through the first one is

$$Q_{d1} = U\ A\ \Delta T = 3.5 \times (1.8 \times 2.1) \times (29 - 24) = 66.15\ W$$

And for the second door the heat gain is

$$Q_{d2} = U\ A\ \Delta T = 3.5 \times (0.8 \times 2.1) \times (29 - 24) = 29.4\ W$$

Then, the total heat gain through doors is 95.55 W

8.4.4 Heat gain due to ventilation and infiltration

Applying equation (E-8.6), the heat gain due to ventilation is

$$Q_{T.v} = \frac{15 \times 5}{1000 \times 0.89}(83 - 48) = 2{,}949\ W$$

And the heat gain due to infiltration is calculated from equation (E-8.6) as

$$Q_{T.v} = \frac{4.775 \times 5.5 \times 3}{0.89} \times \frac{15}{3600} \times (83 - 48) = 12{,}910\ W$$

8.4.5 Heat gain due to lights and electrical equipment

Applying equation (E-8.5), the heat gain due to lighting is

$$Q_{light} = 40 \times 16 \times 0.78 = 499.2\ W$$

And there is a ventilator which is 2,200 W.

8.4.6 Heat gain due to occupants

Equations (E-8.9) and (E-8.10) are used to find the sensible and latent heat gains due to occupants, respectively.

$$Q_{O.s} = \text{Number of persons} \times \text{Sensible heat gain per person} \times \text{CLF} \qquad \text{(E-8.9)}$$

$$= 5 \times 78.5 \times 0.5 = 196.25\ W$$

$$Q_{O.l} = \text{Number of persons} \times \text{Latent heat gain per person} \qquad \text{(E-8.10)}$$

$$= 5 \times 78.5 = 392.5\ W$$

8.4.7 Total heat gain of the room

The total heat gain of the surgery room is the sum of all above heat gains, then

$$Q_{TOT} = 20{,}578.6\ W$$

8.5 Duct design

Air duct design in air conditioning systems depends on the total sensible and latent heat gains of the room, table (8 - 4) illustrates these loads.

Table (8 – 4): Sensible and latent heat gains of the room

Heat gain	Value W
Sensible	16,236.7
Latent	4,341.9

8.5.1 Supply air characteristics

To determine the air supply characteristics, we must draw the SHR – alignment point line, where the alignment point is at 24 °C dry bulb temperature, and 50 % RH. And SHR is found using the relation

$$SHR = \frac{T_i - T_s}{h_i - h_s} \qquad \text{(E-8.11)}$$

For the surgery room

$$SHR = \frac{Q_s}{Q_{TOT}} = \frac{16.2367}{20.5786} = 0.79$$

Applying equation (E-8.11), we can find the value h_s by assuming $T_s = 13$ °C, known that it is recommended to select a value of T_s between 12 °C and 16 °C. Then

$$0.79 = \frac{24 - 13}{46 - h_s} \Rightarrow h_s = 32 \text{ kJ/kg}$$

Trying values between 12 °C and 16 °C, comparing the value of h_s comparing it with the value on psychrometric chart, we fond $T_s = 13$ °C.

The supply air flow rate is calculated as follows

$$\dot{m} = \frac{Q_{TOT}}{h_i - h_s} = \frac{20.5786}{46 - 33} = 1.583 \text{ kg/s}$$

$$\dot{V} = \dot{m} \times \upsilon_o = 1.583 \times 0.82 = 1.3 \text{ m}^3\text{/s}$$

8.5.1 Duct sizing

Using table (B-8.13), we find the recommended velocity of air in the main supply duct which is 6.5 m / s. Then the duct diameter is calculated as

$$d = \sqrt{\frac{\dot{V} \times 4}{\pi \times v}} = \sqrt{\frac{1.3 \times 4}{\pi \times 6.5}} = 50.5 \text{ cm}$$

Using chart (C-8.2), the diameter of the main supply duct is 49 cm, and the pressure drop is 0.9 Pa / m.

Using equal friction method of duct sizing, we can determine the ducts' diameters and their equivalent rectangular sizes for all branches. Table (8 – 5) shows the results according to figure (8 – 3).

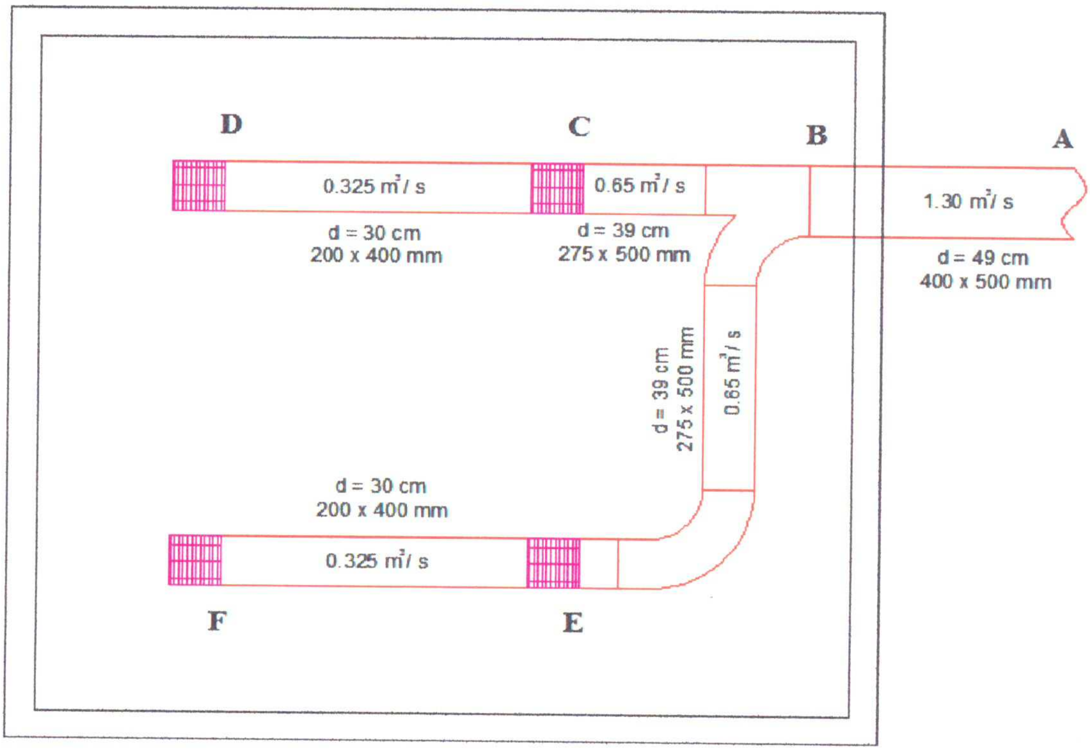

Figure (8 – 3): Duct layout

The ducts installed in the surgery room are shown in drawing (D – 4.3), in room F52.

8.6 Recommendations

1. The return air grilles are not connected to the return air duct, this situation is serious. It is a must to connect the return air duct, or at least connect only one of the return grilles. Temporarily; a fan must be installed at the external window of the corridor beside the surgery room.

2. It is important that a chiller must be installed to improve the AC system, especially that a central AC system was designed. The central AC system could improve RH controlling, since the package unit does not control it.

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APPENDIX A

BILL OF QUANTITY

Table (A – 1): Pumps schedule

Pump	Served area or equipment	Location	Flow L/Sseach	Head (m)	Electrical motor data				Quantity			Type	System
					RPM	Estim kW	Phase	Volt	Duty	Stand	Total		
FCWP	roof tank (transfer pump)	Pump room out side	1.5	30	2900	1.1	3	380	1	1	2	centrifugal base mounted end suction	Domestic cold water transfer
DCWP	Domestic cold &hot water system	Roof	3.0	20	1450	2.4	3	380	3	0	3	centrifugal base mounted end suction	Domestic cold &hot water
FFP	Fire fighting to serve hose feel fire hydrant &landing valve	Main pump room	31.5	7.5	2900	48.0	3	380	1	1	2	Centrifugal horizontal split case	Fire fighting system
FJP	Fire hockey pump	Main pump room	3.0	80	2900	5.0	3	380	1	0	1	Centrifugal multi stage	Fire fighting system
CHWP	Chillers	Roof plant room	8.5	25	1450	2.6	3	380		1	2	Centrifugal end suction base mounted	Chilled water system
HWP-1	AHU's &2-pipe change over FCU's	Boiler room	3.2	20	1450	1.6	3	380	1	1	2	Centrifugal end suction base mounted	Heating system
HWP-2	Domestic hot water cylinders	Boiler room	3.0	8	1450	0.6	1	220	1	1	2	Centrifugal in –line	Domestic hot water heating
HWP-3	Radiators &heating only FCUs	Boiler room	1.8	20	1450	1.6	3	380	2	0	2	Centrifugal in –line	Heating system
HWRP-1	Domestic hot water circulation	Boiler room	0.5	10	2900	1.3	1	220	2	0	2	Centrifugal in –line	Domestic hot water circulation

Table (A – 2): Hot water boilers schedule

Designation	title	location	Description	Quantity	Duty	Stand-by	Power supply			
							kW	Volts	Phase	Hz
HWB-1	Hot water boiler	Boiler room	-steel boiler -capacity =320kw -complete with:2stage burner &control panel -working pressure =7bar at 120C -fuel no.2	2	2	0	1.0	220	1	50

Table (A – 3): Fan coil units' schedule

Fan coil unit no.	Air (L/s)	Cooling capacity			Heating capacity	Qnt req	Type (as per York or equivalent)	Power (W)	Volts (V)
		Sensible load (kW)	Total load (kW)	Water (L/s)	Load (kW)				
Fcu-1	150	1.45	1.69	0.073	0.9	1	Concealed ceiling plenum ,ducted	250	230
Fcu-2	200	2.25	2.42	0.104	1.9	5	Concealed ceiling plenum, ducted	250	230
Fcu-3	250	3.00	3.40	0.147	1.97	1	Concealed ceiling plenum ,ducted	250	230
Fcu-4	350	4.00	4.40	0.19	1.52	1	Concealed ceiling plenum ,ducted	250	230
Fcu-5	350	4.40	5.60	0.24	1.6	1	Concealed ceiling plenum ,ducted	250	230
Fcu-6	550	6.80	8.80	0.38	305	1	Ceiling exposed cabinet heating only	250	230
Fcu-7	150	---	---	---	2.3	1	Ceiling exposed cabinet heating only	250	230
Fcu-8	200	---	---	---	2.8	2	Ceiling exposed cabinet heating only	250	230
Fcu-9	200	---	---	---	2.9	1	Ceiling exposed cabinet heating only	250	230
Fcu-10	100	---	---	---	0.97	1	Ceiling exposed cabinet heating only	250	230

Table (A – 4): Schedule of vessels tanks & heat exchangers

Ref./equipment Designation	Location	Description	Quantity	Capacity (L)	Working pressure (bar)	power		
						Estimated kW	Voltage	Phase
HWC-1 (domestic hot water cinders)	Boiler room (basement floor)	Volume =750liter each -type: vertical shell &tube storage -heating coil : heating water tin=80C tout=70C (tube side) coil capacity =140kw heating water flow=3L/S -domestic water tin=5tout =60C(shell side) recovery rate =0.6L/S	2	750	8	---	---	---
EXP-1(expansion tank for domestic hot water system)	Boiler room (basement floor)	-diaphragm closed type -working temperature=110C	1	150	10	---	---	---
EXP-2 (expansion tank for heating system)	Basement floor boiler room	-diaphragm closed type -working temperature=110C	1	500	10	---	---	---
SOF-1 (water softher)	Pump room (out side)	Type: duplex type of black steel epoxy lined -min grain :60000each -continuous service flow =1.5L/S	1	---	---	0.25	220	1
DIT (diesel tank)	Outside site	Material :black steel -thickness :6.0mm	2	7500	---	---	---	---
PV-1(pressure vessel for domestic cold water)	Roof	-Diaphragm type -working temperature 60C	1	250	10	---	---	---
EXP-3 expansion tank for (chilled water system)	Roof	Diaphragm type -working temperature 60C	1	250	10	---	---	---
GDT (generator daily tank)	Generator room	-black steel -thickness 3.0mm	1	1000	---	---	---	---

APPENDIX B

DESIGN TABLES

Table B-5.1: Water supply fixture units and fixture branch sizes

Fixture	Use	Type of supply control	Fixture units	Min. size of fixture branch in.
Bathroom	Private	Flushometer	8	---
Bathroom	Private	Flush tank for closet	6	---
Bathtub	Private	Faucet	2	½
Bathtub	General	Faucet	4	½
Clothes washer	Private	Faucet	2	½
Clothes washer	General	Faucet	4	½
Combination fixture	Private	Faucet	3	½
Dish washer	Private	Automatic	1	½
Drinking fountain	Offices ,etc	Faucet1/3 in.	0.25	½
Kitchen sink	Private	Faucet	2	½
Kitchen sink	General	Faucet	4	½
Laundry trays (1-3)	Private	Faucet	3	½
Lavatory	Private	Faucet	1	⅜
Lavatory	General	Faucet	2	½
Separate shower	Private	Mixing valve	2	½
Service sink	Private	Faucet	3	½
Shower head	General	Mixing valve	2	½
Shower head	Private	Mixing valve	4	½
Urinal	General	Flush ometer	5	¾
Urinal	General	Flush tank	3	½
Water closet	General	Flush ometer	6	1
Water closet	Private	Flush ometer /tank	3	½
Water closet	Private	Flush tank	3	½
Water closet	General	Flush ometer	10	1
Water closet	General	Flush ometer /tank	5	½
Water closet	General	Flush tank	5	½

Table B-5.2: Table for estimating demand

Supply systems predominantly for flush tanks	
Load, WSFU	Demand, gpm
6	5
10	8
15	11
20	14
25	17
30	20
40	25
50	29
60	33
80	39
100	44
120	49
140	53
160	57
180	61
200	65
225	70
250	75
300	85
400	105
500	125
750	170
1000	210
1250	240
1500	270
1750	300
2000	325
2500	380
3000	435
4000	525
5000	600
6000	650
7000	700
8000	730
9000	760
10000	790

Table B-5.3: Minimum pressure required by typical plumbing fixtures

Fixture type	Minimum pressure
Sink and tub faucets	8
Shower	8
Water closet – tank flush	8
Flush valve – urinal	15
Flush valve – siphon jet bowl	
floor – mounted	15
Wall – mounted	20
Flush valve – blowout bowl	
floor – mounted	20
Wall – mounted	25
Garden hose	
5/8-in sill cock	15
3/4 – in .sill cock	30
Drinking fountain	15

Table B-5.4: Hot water

Building type	Hot water per person gal day	Maximum hourly demand portion of daily use, gal	Duration of peak load, hr	Storage capacity portion of daily use, gal	Heating capacity portion of daily use, gph
Residences, apartments hotels	20 – 40	1/7	4	1/5	1/7
Office buildings	2 – 3	1/5	2	1/5	1/6
Factory buildings	5	1/3	1	2/5	1/8

Table B-6.1: Drainage fixture unit values for various plumbing fixtures

Type of fixture or group of fixtures	Drainage fixture unit value dfu
Automatic clothes washer (2-in standpipe and trap required direct connection)	3
Bathtub group consisting of a water closet lavatory and bathtub or shower stall	6
Bathtub (with or without overhead shower)	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 trop	2
Combination sink-and-tray with separate 1-in trop	3
Dental unit or cuspidor	1
Dental lavatory	1
Drinking fountain	½
Dish washer domestic	2
Floor drains with 2-in waste	3
Kitchen 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 (1or 2 compartments)	2
Shower stall domestic	2
Shower (group) per head sinks	2
Surgeons	3
Flushing rim (with valve)	6
Service (trap standard)	3
Service (p trap)	2
Pot scullery , act	4
Urinal , siphon 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
Fixtures not already listed trap size 1 ¼ in .or less	1
Trap size 1 ½ in	2
Trap size 2in	3
Trap size2 ½ in	4
Trap size 3 in	5
Trap size 4 in	6

Table B-6.2: Horizontal fixture branches and stacks

Diameter of pipe In	Any horizontal fixture branch ,dfu	One stack of three branch intervals or less ,afu	Stacks with more than three branch intervals	
			Total for Stack ,dfu	Total at one branch interval ,dfu
1 ½	3	4	8	2
2	6	10	24	6
2 ½	12	20	42	9
3	20	48	72	20
4	160	240	500	90
5	360	540	1100	200
6	620	960	1900	350
8	1400	2200	3600	600
10	2500	3800	5600	1000
12	3900	6000	8400	1500
15	7000			

Table B-6.3: Capacity of septic tanks

Single family dwellings, Number of bedrooms	Multiple dwelling units or apartments one bedroom each, Number of units	Other uses, maximum fixture units served	Minimum septic tank capacity in gal
1 – 3		20	1000
4	2	25	1200
5or6	3	33	1500
7or8	4	45	2000
	5	55	2250
	6	60	2500
	7	70	2750
	8	80	3000
	9	90	3250
	10	100	3500

Table B-6.4: Required absorption area in seepage pits for each 100 gal of sewage per day

Time for 1-indrop ,min	Effective absorption area ,ft2
1	32
2	40
3	45
5	56
10	75
15	96
20	108
25	139
30	167

Table B-6.5: Building drains and sewers

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			
	$\frac{1}{16}$ in	$\frac{1}{8}$ in	$\frac{1}{4}$ in	$\frac{1}{2}$ in
2			21	26
2 ½			24	31
3			42	50
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

Table B-7.1: Inside film resistance R_i

Element	Heat direction	Material type	Ri (m^2.°C / W)
Walls	Horizontal	Construction materials	0.12
		Metals	0.31
Ceilings and floors	Up ward	Construction materials	0.10
		Metals	0.21
	Down ward	Construction materials	0.15

Table B-7.2: Outside film resistance Ro

Wind speed		Less than 0.5 m/s	0.5-5.0 m/s	More than 5.0m/s
Element	Material type	Outside resistance R(m^2.°C / W)		
Walls	Construction Materials	0.08	0.06	0.03
	Metals	0.10	0.07	0.03
Ceilings	Construction Materials	0.07	0.04	0.02
	Metals	0.09	0.05	0.02
Exposed floors	Construction Materials	0.09	---	---

Table B-7.3: Air change per hours in residences and commercial application

Kind of room or building	Air changes per hour
Rooms with no windows or exterior doors	0.5
Rooms with windows or exterior doors on one side only	1.0
Rooms tithe windows or exterior doors on two sides	1.5
Rooms with windows or exterior doors on three sides	2.0
Entrance halls	2.0
Factories, machine shops	1.0 – 1.5
Recreation rooms, assembly rooms, gymnasium	1.5
Homes, apartments, offices	1.0 – 2.0
Class rooms, dining rooms, lounges toilets, hospital rooms	2.0
kitchens laundries, ballrooms, bath rooms	2.0
Stores, public buildings	2.0 – 3.0
Toilets, auditorium	3.0

Table B-8.1: Solar heat gain factor (SHG) W/m^2 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	781	69
NE/NW	91	205	338	461	536	555	527	445	325	199	91	69
ENE/WNW	331	470	577	631	565	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	861	861	836	770	672	552	498

Table B-8.5: Shading coefficient (SC) for single and double glass with indoor shading by Venetian blinds or roller shades

Type of glass	Nominal thickness (mm)	Type of shading				
		Venetian blinds		Roller shade		
				Opaque		Translucent
		Medium	Light	Dark	White	Light
Clear	2.5-6	---	---	---	---	---
Clear	6.0-12.0	---	---	---	---	---
Clear pattern	3.0-12.0	0.64	---	---	---	0.39
Heat absorbing	3	---	---	---	---	---
Patten or tinned	5.0-5.5	---	---	---	---	---
Heat absorbing	5.0-6.0	0.57	0.53	0.45	0.30	0.36
Pattern or tinted	3.0-5.5	---	---	---	---	---
Heat absorbing or pattern heat absorbing	10	0.54	0.52	0.40	0.82	0.32
Heat absorbing or pattern	---	0.42	0.40	0.36	0.28	0.31
Reflective coated glass	---	0.30	0.25	0.23	---	---
	---	0.40	0.33	0.29	---	---
	---	0.50	0.42	0.38	---	---
	---	0.60	0.50	0.44	---	---
Double glass						
Regular	3	0.57	0.51	0.60	0.25	---
Plate	6	0.57	0.51	0.60	0.25	---
Reflective	6	0.20-0.040	---	---	---	---

Table B-8.3: Cooling load factors (CLF) for glass with interior shading. North latitude

Facing	Solar time h												
	5	6	7	8	9	10	11	12	13	14	15	16	17
N	0.07	0.73	0.66	0.65	0.73	0.80	0.86	0.89	0.89	0.86	0.82	0.75	0.78
NNE	0.03	0.64	0.77	0.62	0.42	0.87	0.37	0.37	0.36	0.35	0.32	0.28	0.23
NE	0.02	0.56	0.76	0.74	0.58	0.87	0.29	0.27	0.26	0.24	0.22	0.20	
ENE	0.02	0.52	0.76	0.80	0.71	0.52	0.31	0.26	0.24	0.22	0.20	0.18	
E	0.02	0.47	0.72	0.80	0.76	0.62	0.41	0.27	0.24	0.22	0.20	0.17	
	0.02	0.41	0.67	0.79	0.80	0.72	0.54	0.34	0.27	0.24	0.21		
	0.02	0.30	0.57	0.74	0.81	0.79	0.68	0.49	0.33	0.26	0.25		
	0.02	0.12	0.31	0.54	0.72	0.81	0.81	0.71	0.54			0.77	
	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
	0.03	0.09	0.14	0.18	0.22	0.27	0.43	0.63	0.78	0.84	0.83	0.66	0.46
W	0.03	0.07	0.11	0.14	0.16	0.19	0.22	0.38	0.59	0.75	0.78	0.81	0.69
WSW	0.03	0.07	0.10	0.12	0.14	0.16	0.17	0.23	0.44	0.64		0.84	0.78
	0.03	0.06	0.09	0.11	0.13	0.15	0.16	0.17	0.31	0.53		0.82	
	0.03	0.07	0.10	0.12	0.14	0.16	0.17	0.18	0.22	0.43		0.80	
W	0.03	0.07	0.11	0.14	0.17	0.19	0.20	0.21	0.22	0.30	0.52	0.73	
NNW	0.03	0.11	0.17	0.22	0.26	0.30	0.32	0.33	0.34	0.34	0.69	0.61	0.82
Horiz	0.03	0.12	0.27	0.44	0.59	0.72	0.81	0.85	0.85	0.81	0.71	0.53	0.42

Table B-8.4: Cooling load temperature differences (CLTD) for glass convection

Solar Time	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
CLTD (°C)	-1	-1	-1	0	1	2	4	5	7	7	8	8	7	7	6	4

Table B-8.5: CLTD correction for latitude (LM) 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
	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
16	Mar/sept	-1.6	-1.6	-1.1	-1.1	-0.5	-0.5	0.0	0.0	0.0	-0.5
	Apr/aug	-0.5	0.0	-0.5	-0.5	-0.5	-1.6	-1.6	-2.7	-3.3	0.0
	May/jul	2.2	1.6	1.6	0.0	-0.5	-2.2	-2.7	-3.8	-3.8	0.0
	Jun	3.3	2.2	2.2	0.5	-0.5	-2.2	-3.3	-4.4	-3.8	0.0
	Dec	-2.7	-3.8	-5.5	-6.1	-4.4	-2.7	1.1	5.0	6.6	-9.4
	Jan/nov	-2.2	-3.3	-4.4	-5.0	-3.3	-1.6	-1.6	5.0	7.2	-6.1
	Feb/oct	-2.2	-3.3	-3.3	-3.3	-1.6	-0.5	1.6	3.8	5.5	-3.8
24	Mar/sept	-1.6	-2.2	-1.6	-1.6	-0.5	-0.5	0.5	1.1	2.2	-1.6
	Apr/aug	-1.1	-0.5	0.0	-0.5	-0.5	-1.1	-0.5	-1.1	-1.6	0.0
	May/jul	0.5	1.1	1.1	0.0	0.0	-1.6	-1.6	-2.7	-3.3	0.5
	Jun	1.6	1.6	1.6	0.5	0.0	-1.6	-2.2	-3.3	-3.3	0.5
	Dec	-2.7	-3.8	-5.5	-6.1	-4.4	-2.7	1.1	5.0	6.6	-9.4
	Jan/nov	-2.7	-3.8	-5.0	-6.1	-4.4	-2.2	1.1	5.0	6.6	-8.3
	Feb/oct	-2.2	-3.3	-3.8	-4.4	-2.2	-1.1	2.2	4.4	6.1	-5.5
32	Mar/sept	-1.6	-2.2	-2.2	-2.2	-1.1	-0.5	1.6	2.7	3.8	-2.7
	Apr/aug	-1.1	-1.1	0.5	-1.1	0.0	-0.5	0.0	5.0	0.5	-0.5
	May/jul	0.5	0.5	0.5	0.0	0.0	-0.5	-0.5	-1.6	-1.6	0.5
	Jun	0.5	1.1	1.1	0.5	0.0	-1.1	-1.1	-2.2	-2.2	1.1
	Dec	-3.3	-4.4	-5.5	-7.2	-5.5	-3.8	0.0	3.8	5.5	-11.6
	Jan/nov	-2.7	-3.8	-5.5	-6.6	-5.0	-3.3	0.5	4.4	6.1	-10.5
	Feb/oct	-2.7	-3.8	-4.4	-5.0	-3.3	-1.6	1.6	4.4	6.6	-7.7
40	Mar/sept	-2.2	-2.7	-2.7	-3.3	-1.6	0.5	2.2	3.8	5.5	-4.4
	Apr/aug	-1.1	-1.6	-1.6	-1.1	0.0	0.0	1.1	1.6	2.2	1.6
	May/jul	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5
	Jun	0.5	0.5	0.5	0.5	0.0	0.5	0.0	0.0	-0.5	1.1
	Dec	-3.3	-4.4	-6.1	-7.7	-7.2	-5.5	-1.6	1.1	3.3	-13.8
	Jan/nov	-3.3	-4.4	-6.1	-7.2	-6.1	-4.4	-0.5	2.7	4.4	-13.3
	Feb/oct	-2.7	-3.8	-5.5	-6.1	-4.4	-2.7	0.5	4.4	6.1	-10.0
48	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 B-8.6: Cooling load factors (CLF) for lighting

No of hours after lights are turned on	Hours of operation False ceiling 10	Hours of operation False ceiling 16	Hours of operation Normal ceiling 10	Hours of operation Normal ceiling 16
0	0.08	0.19	0.01	0.05
1	0.62	0.72	0.76	0.79
2	0.66	0.75	0.81	0.83
3	0.69	0.77	0.84	0.87
4	0.73	0.80	0.88	0.89
5	0.75	0.82	0.90	0.91
6	0.78	0.84	0.92	0.93
7	0.80	0.85	0.93	0.94
8	0.82	0.87	0.95	0.95
9	0.84	0.88	0.96	0.96
10	0.85	0.89	0.97	0.97
11	0.32	0.90	0.22	0.98
12	0.29	0.91	0.18	0.98
13	0.26	0.92	0.14	0.98
14	0.23	0.93	0.12	0.99
15	0.21	0.94	0.09	0.99
16	0.19	0.94	0.08	0.99
17	0.17	0.40	0.06	0.24
18	0.15	0.36	0.05	0.20

Table B-8.7: CLTD for light, medium, and heavy weight walls

Solar Time	Light N	Light E	Light S	Light W	Medium N	Medium E	Medium S	Medium W	Heavy N	Heavy E	Heavy S	Heavy W
8	---	61	---	---	---	---	---	---	---	---	---	---
9	---	20	---	---	---	6	---	---	---	---	---	---
10	---	21	2	---	---	11	---	---	---	---	---	---
11	---	18	7	---	---	14	---	---	---	3	---	---
12	---	12	12	---	---	15	---	---	---	5	---	---
13	2	9	15	5	---	14	5	---	---	7	---	---
14	3	7	16	13	---	12	9	1	---	8	---	---
15	3	7	14	21	1	10	11	6	---	8	1	---
16	4	6	11	27	2	9	12	12	---	8	3	---
17	4	5	7	30	2	8	11	17	---	8	5	3
18	5	3	4	27	3	7	9	22	---	8	6	7
19	2	1	1	17	3	5	7	23	---	7	6	10
20	---	---	---	6	3	3	5	20	1	7	6	12

Table B-8.8: CLTD for light, medium, and heavy weight sunlit roofs

Solar time	Roof construction		
	Light	Medium	Heavy
10	5	---	---
11	12	---	---
12	19	3	0
13	25	8	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

Table B-8.9: Color correction factor k

Type of structure	Color correction factor k
Dark colored roof and wall	1.0
Permanently light colored roof	0.5
Permanently medium colored wall	0.83
Permanently light colored wall	0.65

Table B-8.10: Air requirements for ventilation in hospitals

Application	Maximum occupancy per 100 m^2	L / s / Person
Patient rooms	10	13.0
Medical procedure	20	8.0
Operating rooms	20	15.0
Recovery and ICU	20	8.0
Physical therapy	20	8.0

Table B-8.11: Recommended inside design conditions for summer and winter

<table>
<tr><th rowspan="4">Type of application</th><th colspan="4">Summer</th><th colspan="3">Winter</th></tr>
<tr><th colspan="2">Deluxe</th><th colspan="2">Commercial practice</th><th colspan="3">Humidification</th></tr>
<tr><th rowspan="2">T (°C)</th><th rowspan="2">RH %</th><th rowspan="2">T (°C)</th><th rowspan="2">RH %</th><th colspan="2">With</th><th>Without</th></tr>
<tr><th>T (°C)</th><th>RH %</th><th>T (°C)</th></tr>
<tr><td>General comfort apartment, house, hotel, office, hospital, school, etc</td><td>23-24</td><td>50-45</td><td>25-26</td><td>50-45</td><td>23-24</td><td>35-30</td><td>24-25</td></tr>
</table>

Table B-8.12: Sensible heat cooling load factors (CLF) for people

Hours after each entry into space	Total hours in space							
	2	4	6	8	10	12	14	16
1	0.49	0.49	0.50	0.51	0.53	0.55	0.58	0.62
2	0.58	0.59	0.60	0.61	0.62	0.64	0.72	0.70
3	0.17	0.66	0.67	0.67	0.69	0.70	0.77	0.75
4	0.13	0.71	0.72	0.72	0.74	0.75	0.80	0.79
5	0.10	0.27	0.76	0.76	0.77	0.79	0.83	0.82
6	0.08	0.21	0.79	0.80	0.80	0.81	0.85	0.85
7	0.07	0.16	0.34	0.82	0.83	0.84	0.86	0.87
8	0.06	0.14	0.26	0.85	0.85	0.86	0.88	0.88
9	0.05	0.11	0.21	0.87	0.87	0.88	0.89	0.90
10	0.04	0.10	0.18	0.89	0.89	0.89	0.90	0.91
11	0.04	0.08	0.15	0.42	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

Table B-8.13: Equivalent length for various fittings in air ducts

Duct fitting	Equivalent length (m)
45° round elbow	1.5
90° four pieces elbow	3.0
Gradual reduction	6.0
45° round Tee	
Main run	1.5
Branch	11.0
90° round Tee	
Main run	1.5
Branch	15.0
90° rectangular elbow	5.0
Abrupt round contraction or expansion	11.0

Table B-8.14: Performance data for circular and rectangular diffusers

Diameter for circular (cm) 25	Neck velocity (m/s)							
	Datum	3.5	4.0	4.5	5.0	5.5	6.0	6.5
	$\dot{V}$,L/s	170	195	220	245	270	295	320
	Thr ,m	1.5-3.0	1.8-3.6	1.8-3.9	2.1-4.2	2.1-4.5	2.4-4.5	2.4-5.1
	ΔP ,Pa	12.5	17.5	22.4	27.4	32.4	39.8	47.3

Size for rectangular (cm) 30 × 15	Neck velocity (m/s)							
	Datum	2.00	2.25	2.50	2.75	3.00	3.25	3.50
	$\dot{V}$,L/s	90	100	110	125	135	145	155
	Thr ,m	1.8-3.7	2.4-4.3	2.4-5.0	3.0-5.5	3.0-6.1	3.0-6.7	3.7-7.3
	ΔP ,Pa	10.0	12.2	14.7	17.2	20.4	22.9	26.9

APPENDIX C

DESIGN CHARTS

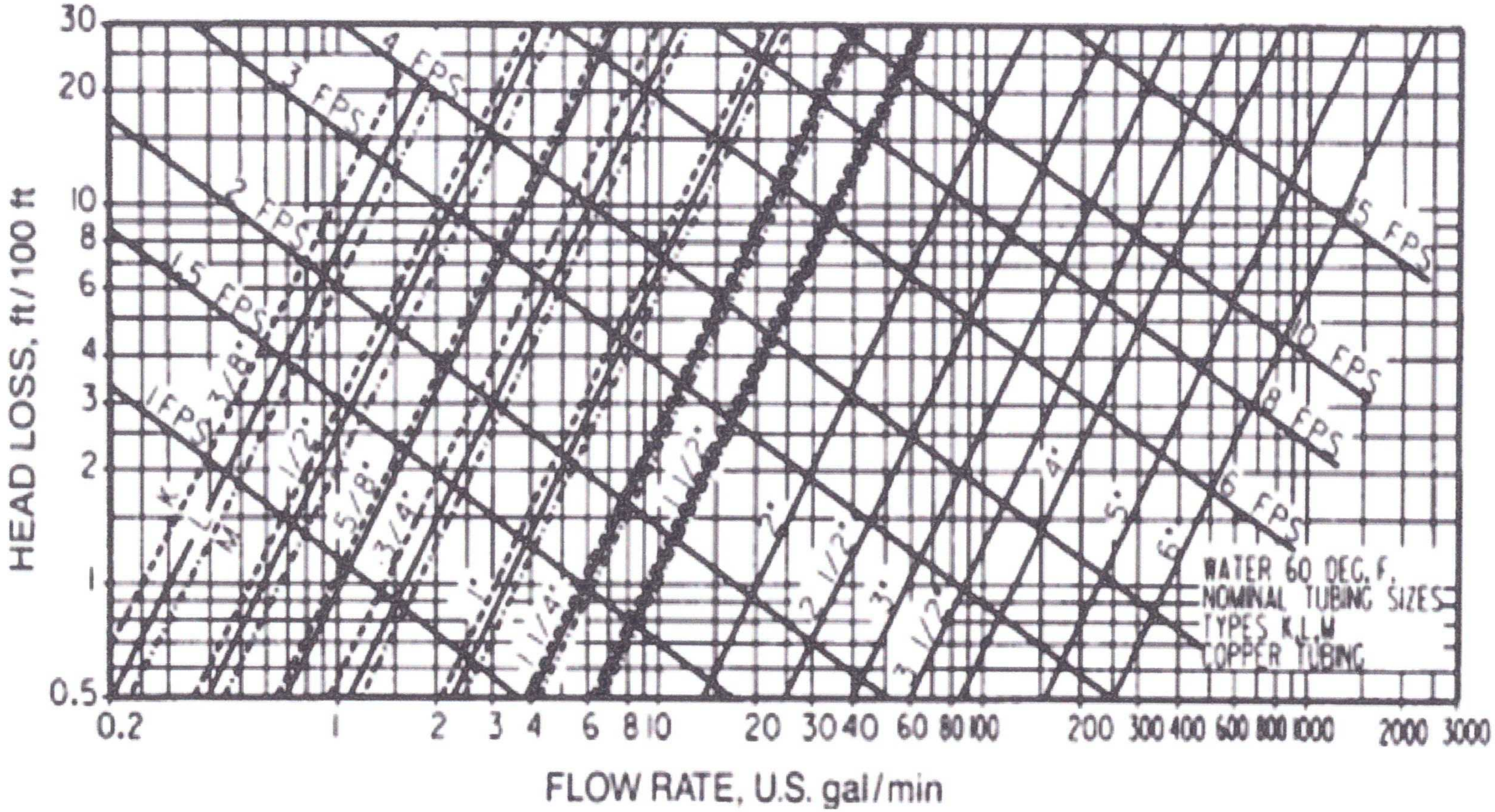


Chart C – 5.1: Friction loss for water in copper pipes

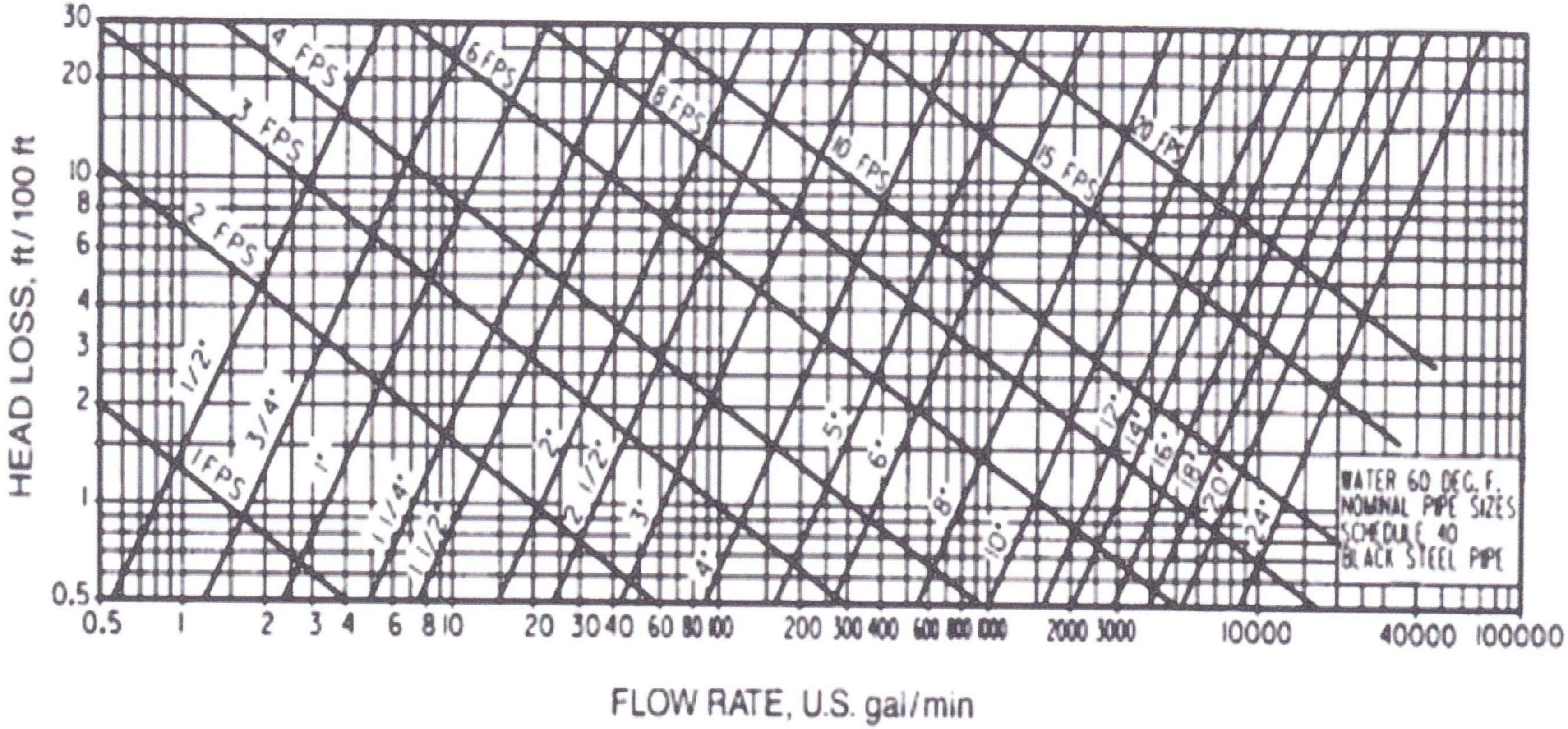


Chart C – 5.2: Friction loss for water in steel pipes

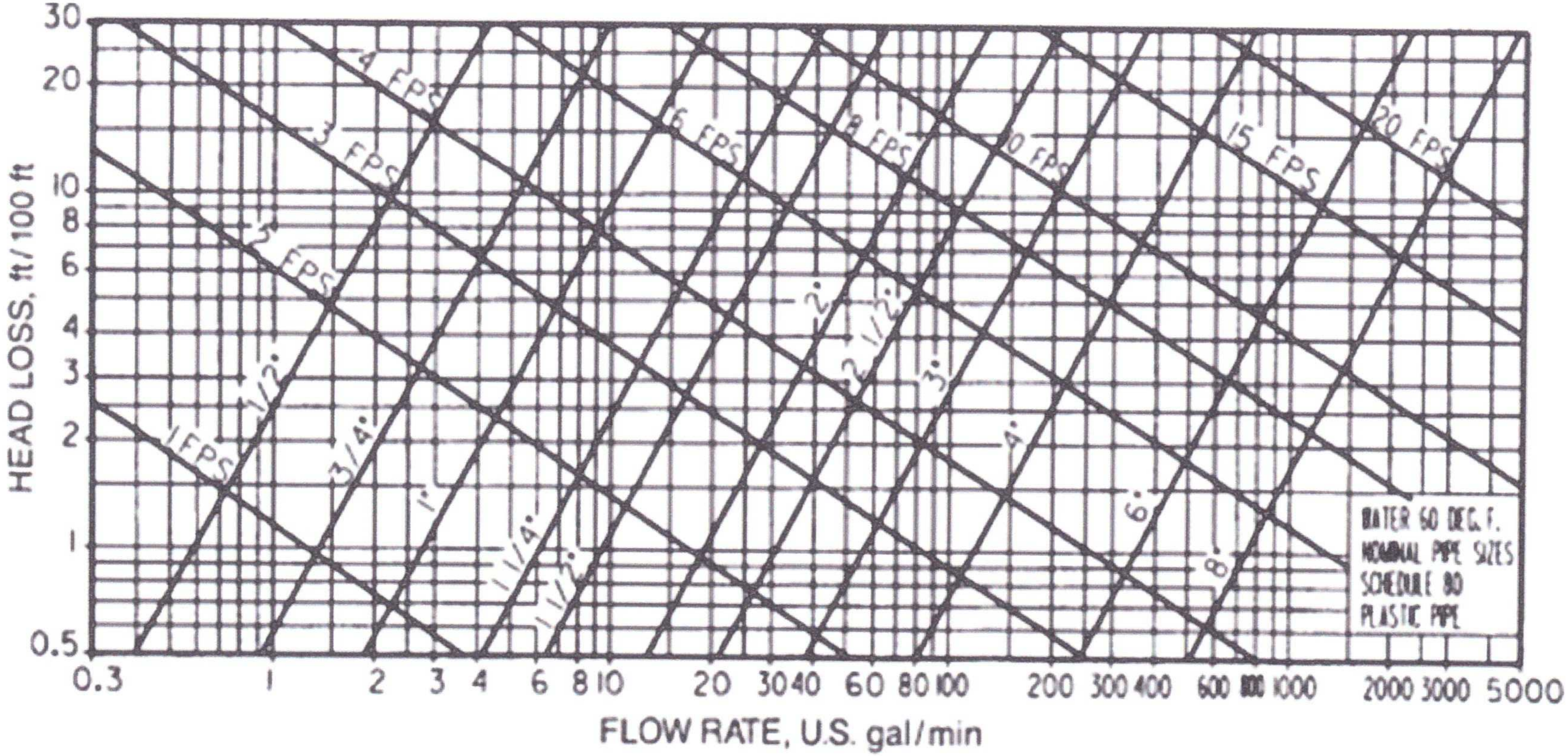


Chart C – 5.3: Friction loss for water in plastic pipes

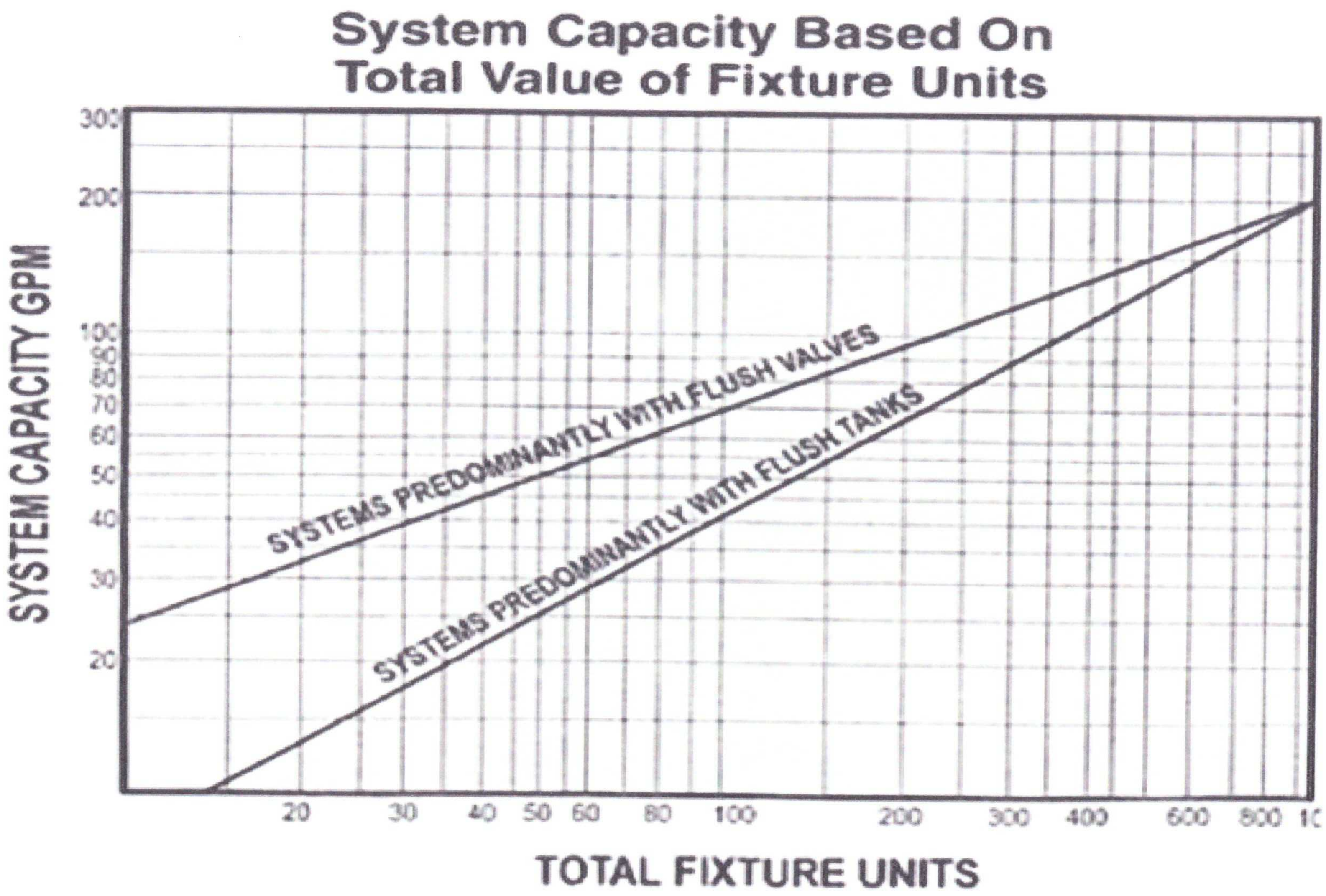


Chart C – 5.4: Water system capacity based on total fixture units

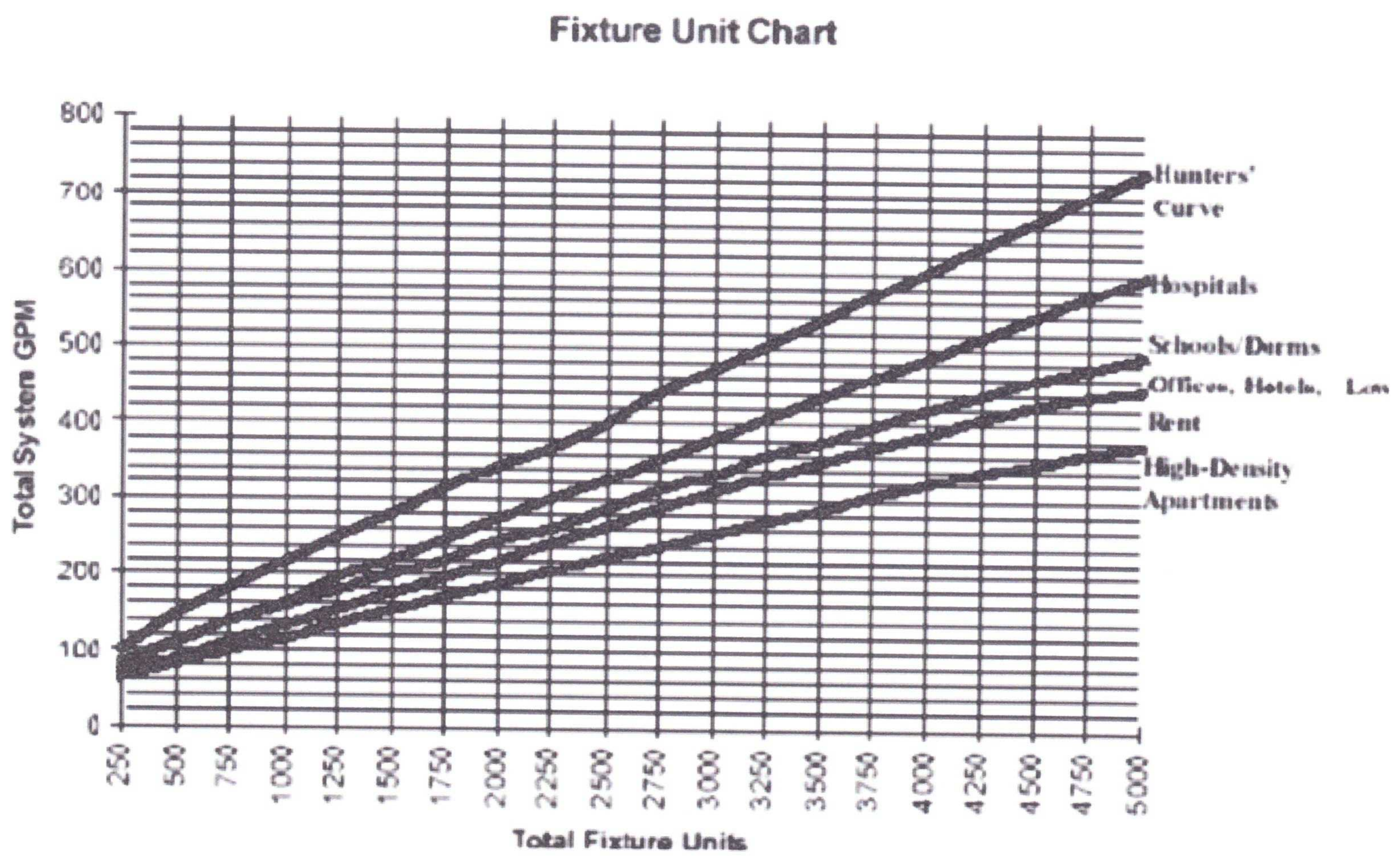


Chart C – 5.5: Water system capacity – total fixture units for different applications

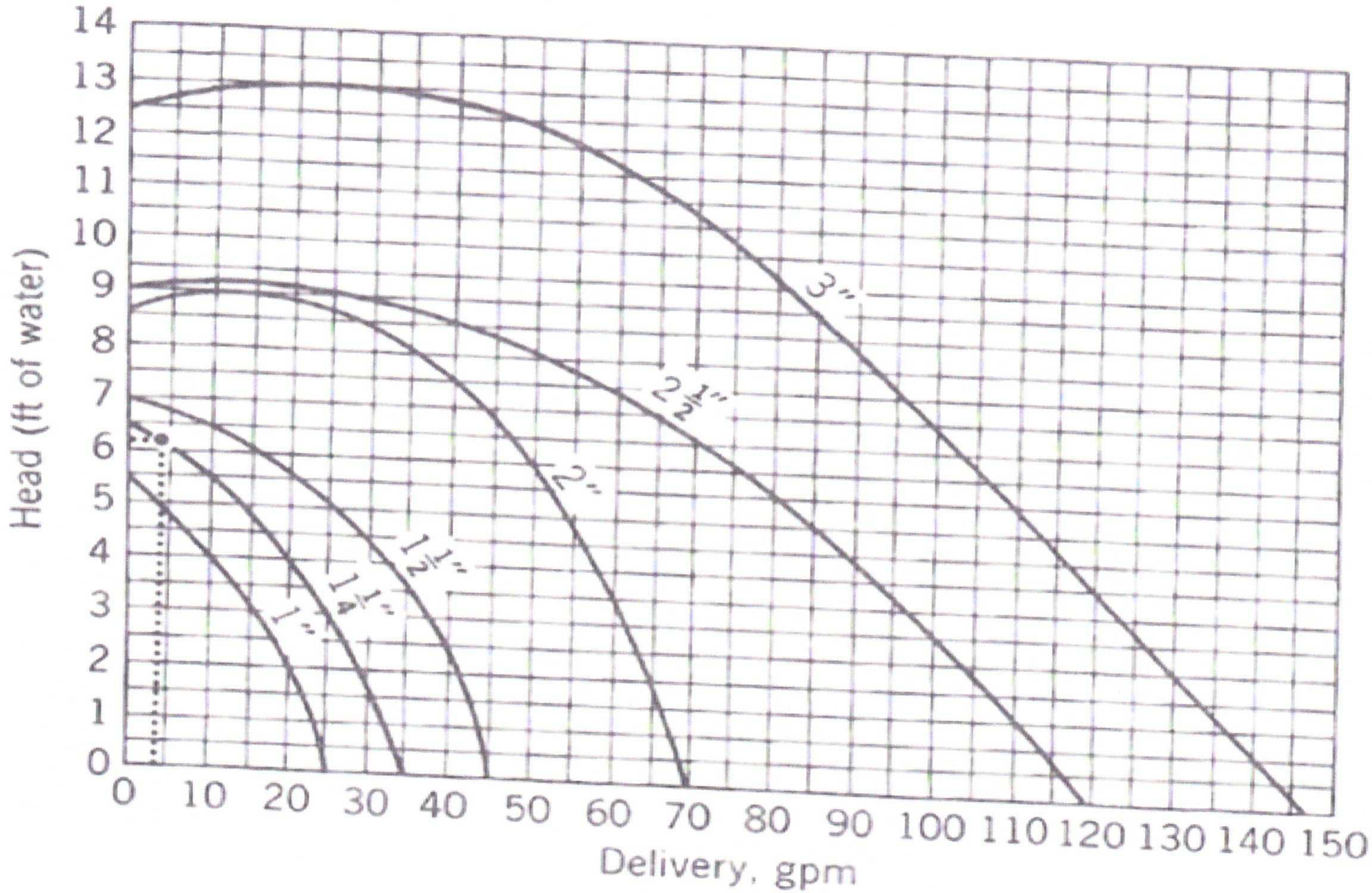


Chart C –7.1: Performance chart of circulating pumps commonly used in hot water heating system

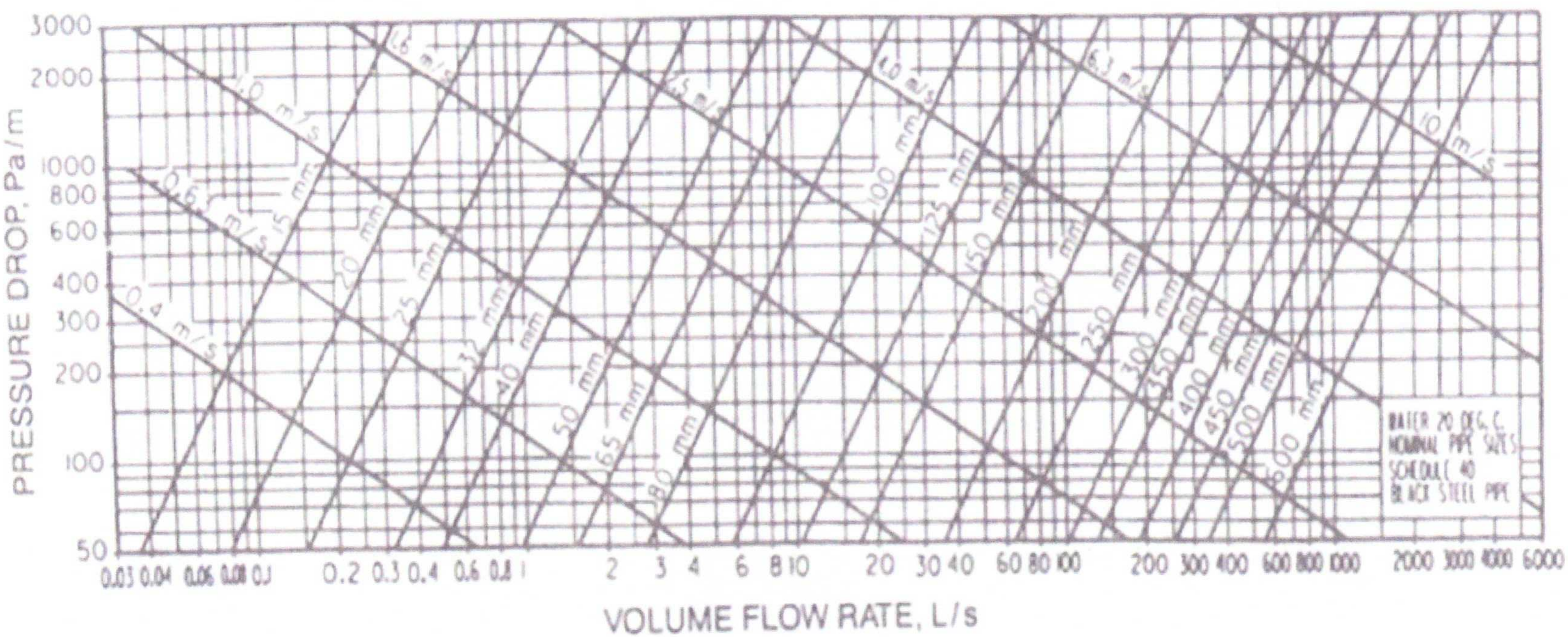


Chart C – 7.2: Pressure drop per unit length for water in steel pipes

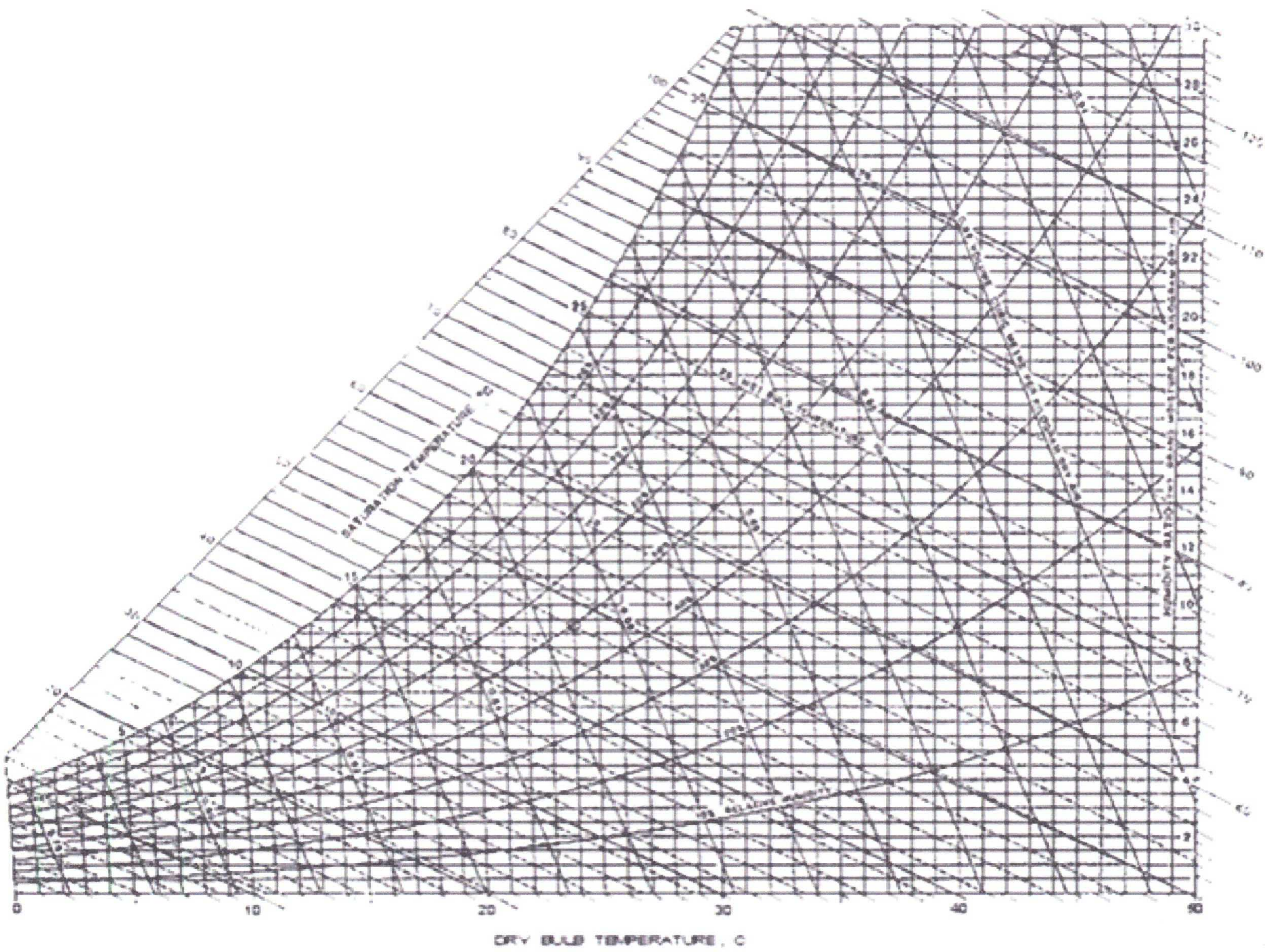


Chart C – 8.1: Psychrometric chart

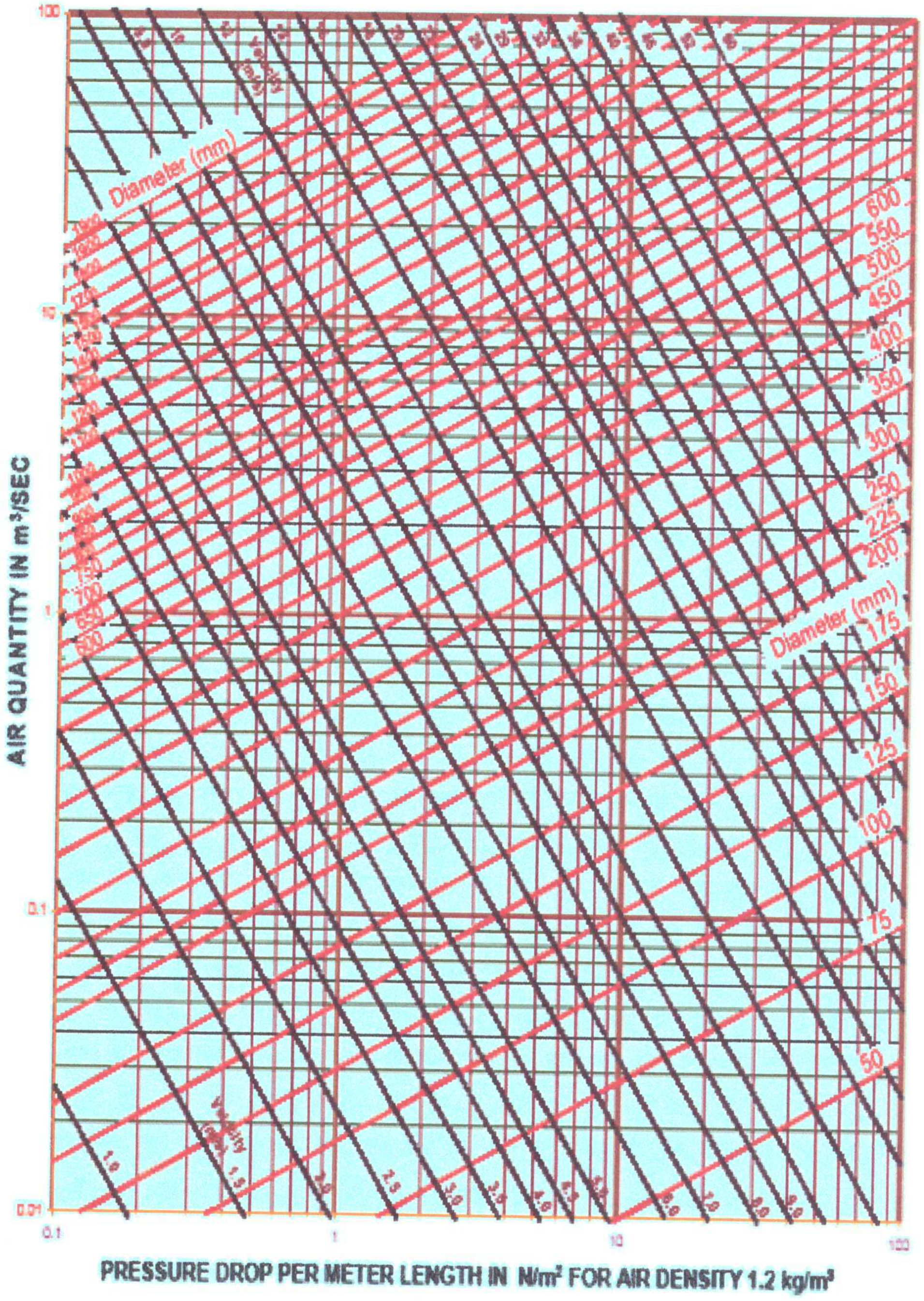
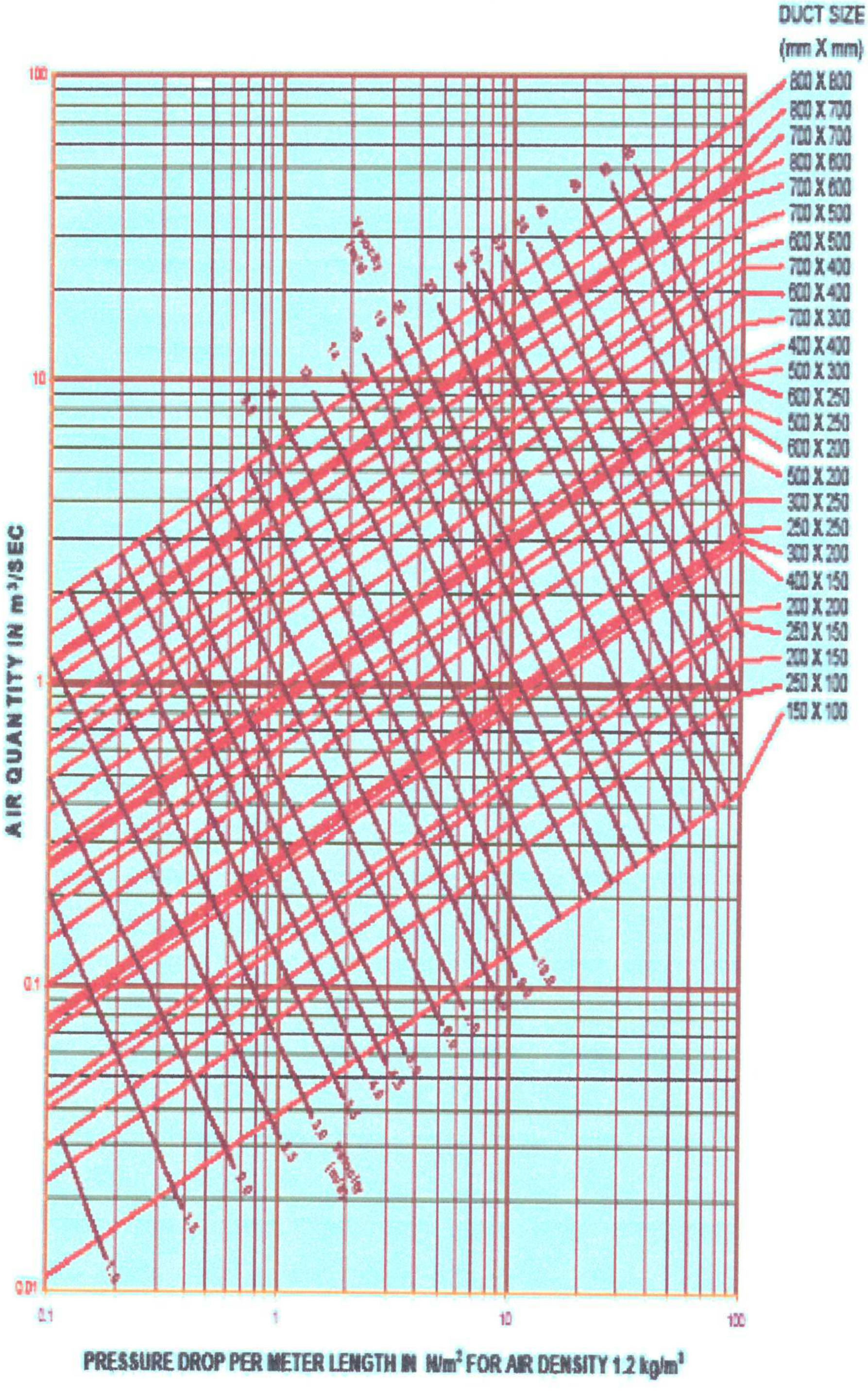


Chart C – 8.2: Pressure drop per meter length in Pa / m for circular ducts

Chart C – 8.3: Pressure drop per meter length in Pa / m for rectangular ducts



Dimensions in mm

Side Rectangular Duct	100	125	150	175	200	225	250	275	300	350	400	450	500	550	600	650	700	750	800	900	Side Rectangular Duct
100	109																				100
125	122	137																			125
150	133	150	164																		150
175	143	161	177	191																	175
200	152	172	189	204	219																200
225	161	181	200	216	232	246															225
250	169	190	210	228	244	259	273														250
275	176	199	220	238	256	272	287	301													275
300	183	207	229	248	266	283	299	314	328												300
350	195	222	245	267	286	305	322	339	354	383											350
400	207	235	260	283	305	325	343	361	378	409	437										400
450	217	247	274	299	321	343	363	382	400	433	464	492									450
500	227	258	287	313	337	360	381	401	420	455	488	518	547								500
550	236	269	299	326	352	375	398	419	439	477	511	543	573	601							550
600	245	279	310	339	365	390	414	436	457	496	533	567	598	628	656						600
650	253	289	321	351	378	404	429	452	474	515	553	589	622	653	683	711					650
700	261	298	331	362	391	418	443	467	490	533	573	610	644	677	708	737	765				700
750	268	306	341	373	402	430	457	482	506	550	592	630	666	700	732	763	792	820			750
800	275	314	350	383	414	442	470	496	520	567	609	649	687	722	755	787	818	847	875		800
900	289	330	367	402	435	465	494	522	548	597	643	686	726	763	799	833	866	897	927	984	900
1000	301	344	384	420	454	486	517	546	574	626	674	719	762	802	840	876	911	944	976	1037	1000
1100	313	358	399	437	473	506	538	569	598	652	703	751	795	838	878	916	953	988	1022	1086	1100
1200	324	370	413	453	490	525	558	590	620	677	731	780	827	872	914	954	993	1030	1066	1133	1200
1300	334	382	426	468	506	543	577	610	642	701	757	808	857	904	948	990	1031	1069	1107	1177	1300
1400	344	394	439	482	522	559	595	629	662	724	781	835	886	934	980	1024	1066	1107	1146	1220	1400

Chart C – 8.4: Circular equivalents of rectangular ducts