

# Chapter One

## **Introduction**

The balance between thermal comfort and air quality in healthcare facilities to optimize the Indoor Air Quality (IAQ). This research will present the balance from the viewpoint of the air conditioning design. It was found that the design of the HVAC airside systems plays an important role for achieving the optimum air quality beside the optimum comfort level. This research highlights the importance of the proper airside design on the IAQ. The present research introduces some recommendations for airside designs to facilitate the development of optimum HVAC systems. This research also stresses on the factors that improve the thermal comfort and air quality for the already existed systems (for maintenance procedure).

Merely lowering or raising the temperature does not provide comfort in general to the machines or its components and living beings in particular. In case of the machine components, along with temperature, humidity (moisture content in the air) also has to be controlled and for the comfort of human beings along with these two important parameters, air motion and cleanliness also play a vital role. Air conditioning, therefore, is a broader aspect which looks into the simultaneous control all mechanical parameters which are essential for the comfort of human beings or animals or for the proper performance of some industrial or scientific process. The precise meaning of air conditioning can be given as the process of simultaneous control of temperature, humidity, cleanliness and air motion. In some applications, even the control of air pressure falls under the purview of air conditioning. It is to be noted that

refrigeration that is control of temperature is the most important aspect of air conditioning.

Depending upon the requirement, air conditioning is divided into the summer air conditioning and the winter air conditioning. In the summer air conditioning, apart from cooling the space, in most of the cases, extra moisture from the space is removed, whereas in the winter air conditioning, space is heated and since in the cold places, normally the humidity remains low, moisture is added to the space to be conditioned. The summer air conditioning thus uses a refrigeration system and a dehumidifier. The winter air conditioning uses a heat pump (refrigeration system operated in the reverse direction) and a humidifier. Depending upon the comfort of the human beings and the control of environment for the industrial products and processes, air conditioning can also be classified as comfort air conditioning and industrial air conditioning. Comfort air conditioning deals with the air conditioning of residential buildings, offices spaces, cars, buses, trains, airplanes, etc. Industrial air conditioning includes air conditioning of the printing plants, textile plants, photographic products, computer rooms, etc.

- **Research problem:-**

The project is aiming to provide health care hospital with the best air conditioning system to satisfy the requirements.

- **Research objectives:-**

To calculate and select the best air conditioning system for **Health Care Hospital**.

**Research methodology:-**

- Determining the basic international standards of HVAC systems required for each departments of the hospital.
- Making a survey for the hospitals in Sudan to see if it's applying the standards of basic international.
- gathering the data from the hospital and determine the weather conditions of Sudan.
- calculating the heat load of (health care)hospital according to the inside specification.
- selecting HVAC systems.

# Chapter Two

## **Literature review**

The balance between thermal comfort and air quality in healthcare facilities to optimize the Indoor Air Quality (IAQ) is the main aim of this research. The present research will present this balance from the viewpoint of the air conditioning design. It was found that the design of the HVAC airside systems plays an important role for achieving the optimum air quality beside the optimum comfort level.

This research highlights the importance of the proper airside design on the IAQ. The present research introduces some recommendations for airside designs to facilitate the development of optimum HVAC systems. This research also stresses on the factors that improve the thermal comfort and air quality for the already existed systems (for maintenance procedure).

To design an optimum HVAC airside system that provides comfort and air quality in the air-conditioned spaces with efficient energy consumption is a great challenge. The present research defines the current status, future requirements, and expectations. Based on this analysis and the vast progress of computers and associated software, the artificial intelligent technique will be a competitor candidate to the experimental and numerical techniques.

Finally, the researches that relate between the different designs of the HVAC systems and energy consumption should

concern with the optimization of airside design as the expected target to enhance the indoor environment.

Health considerations and hygiene requirements necessitate the following:-

- To restrict air movement in and between the various departments.
- to use appropriate ventilation and filtration to dilute and reduce contamination in the form of odors, air-borne micro organisms, viruses and, hazardous chemicals.
- To regulate different temperature and humidity requirements for various medical areas.
- To maintain accurate control of environmental conditions.

## **2.1 Environmental Control:**

### **2.1.1 Temperature & Relative Humidity Control:**

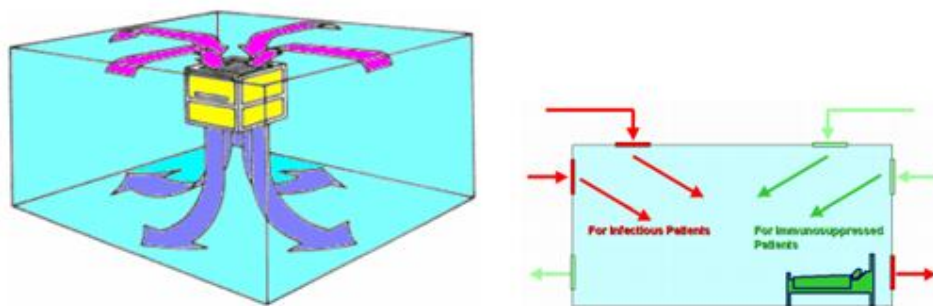
Codes and guidelines specify temperature range criteria in some hospital areas as a measure for infection control as well as comfort. Local temperature distributions greatly affect occupant comfort and perception of the environment. Temperature should be controlled by change of supply temperature without any airflow control; the temperature difference between warm and cool regions should be minimized to decrease airflow drift. Efficient air distribution is needed to create homogenous domain without large difference in the temperature distribution. The laminar airflow concept developed for industrial clean room use has attracted the

interest of some medical authorities. There are advocates of both vertical and horizontal laminar airflow systems.

For high contaminated areas, the local velocity should be greater than or at least equal to 0.2 m/s. For patient rooms 0.1 m/s is sufficient in the occupied area. The unidirectional laminar airflow pattern is commonly attained at a velocity of  $0.45 \pm 0.10$  m/s (ASHRAE standards 55-1966).

### **2.1.2 Air Change and Filtration:**

Three basic filtration stages are usually incorporated namely: Primary filter, second stage filter (the high efficiency particulate bag filter) and a third stage filter which is the high efficiency particulate filter located at the air supply outlets. Air Change per Hour (ACH) plays an important role to provide a free contamination place. The patient rooms are served by (2 ACH – 6 ACH) in usual. Some critical rooms could be served by value up to 12 ACH. The critical rooms, such as the surgical operating theatres, are supplied by (15 ACH – 25 ACH) in usual. (AIA, 2006)



**Figure 2-1: air flow movement in rooms**

The negative pressure is obtained by supplying less air to the area than is exhausted from it. This induces a flow of air into the area around the perimeters of doors and prevents an outward airflow.

The operating room offers an example of an opposite condition. This room, which requires air that is free of contamination, must be positively pressurized relative to adjoining rooms or corridors to prevent any airflow from these relatively highly contaminated areas.

In general, outlets supplying air to sensitive ultraclean areas and highly contaminated areas should be located on the ceiling or on sidewalls closing to ceiling, figure 1, with perimeter or several exhaust inlets near the floor.

The bottoms of return or exhaust openings should be at least 0.075 m above the floor (ASHRAE HOSPITAL 2003).

## **2.2 Design Specifications:**

### **2.2.1 Hospital Facilities:**

As, perfect air conditioning system is helpful in the prevention and treatment of disease, the construction of air conditioning system for health facilities presents many precautions not encountered in the usual comfort air conditioning systems.

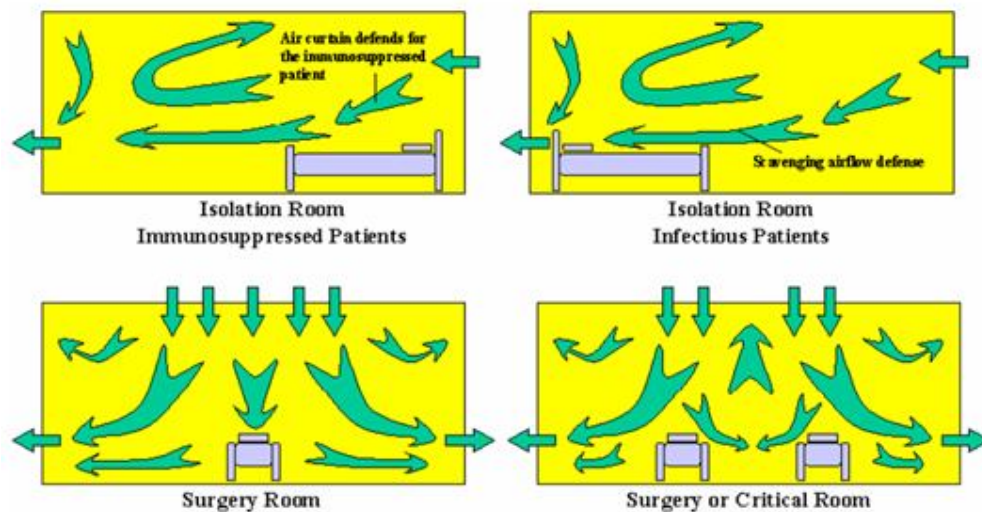
### **2.2.2 Critical Care and Isolation Rooms:**

In the isolation rooms for infectious patients, the patient bed should be located close to the extract ports. The infectious isolation rooms should be maintained at negative pressure.

The immunosuppressed patient's bed should be located in the side of supplied air, or close to the supply outlets, figure 2. Previous predictions of local velocity profiles, air temperatures, relative humidity distributions were reported by Kameel and Khalil,(2002,2003), using a finite difference computer package, Khalil (1994,2000), that solves the governing equations of mass, three momentum, energy, relative humidity and age equations in three dimensional configuration of rooms as indicated by (Khalil ,2004).

### 2.2.3 Protective Isolation Units:

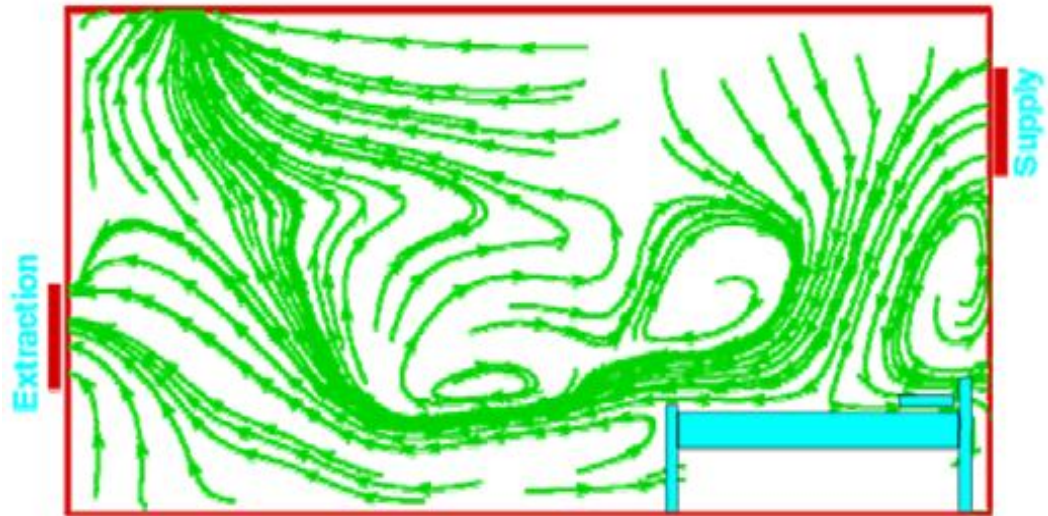
Immunosuppressed patients are highly susceptible to diseases. An air distribution of 15 air changes per hour supplied through a non aspiration. (ASHRAE HOSPITAL 2003).



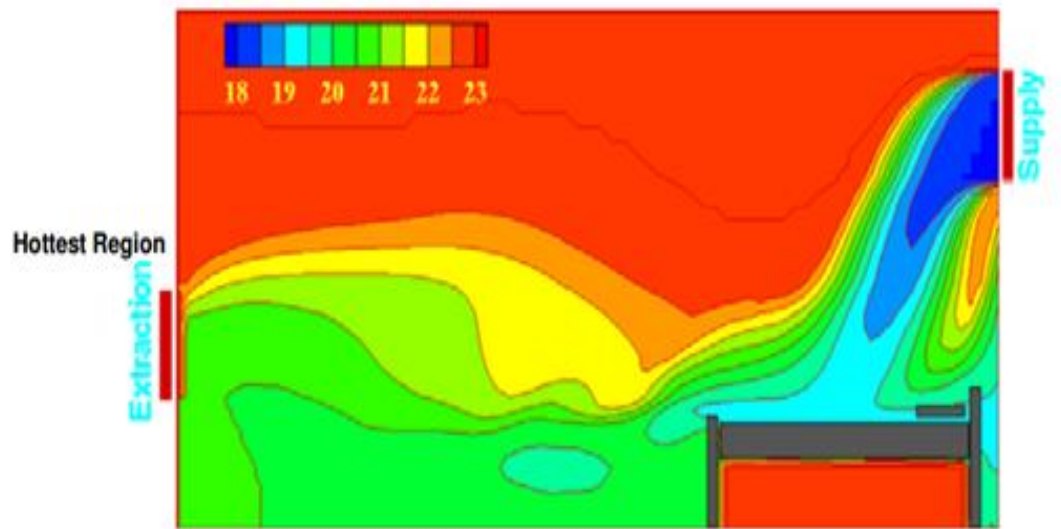
**Fig 2-2airflow configuration for critical areas**

Diffuser is recommended. When the patient is immunosuppressed but not contagious, a positive pressure should be maintained between the patient room and adjacent area. Figure 3 shows the

velocity, air temperatures and relative humidity contours in an immunosuppressed patient room.



**Figure 2-3a** predicted velocity contours immunosuppressed patient room.



**Figure 2-3b**: temperature contours in immunosuppressed patient room.

## 2.2.4 Surgical Operating Rooms:

Operating room air distribution systems that deliver air from the ceiling, with a downward movement to several exhaust inlets located on opposite walls, is probably the most effective air movement pattern, figure 4.

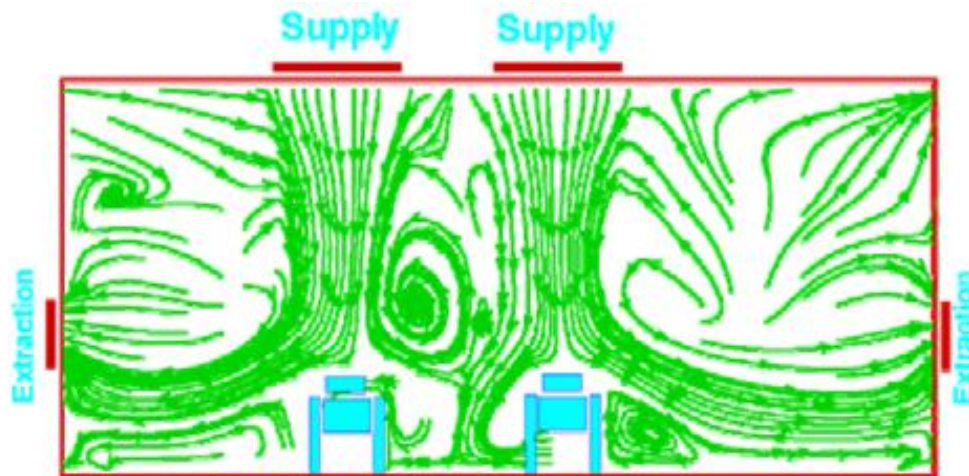


Figure 2-4a: air flow distribution in operating theatre open heart surgery

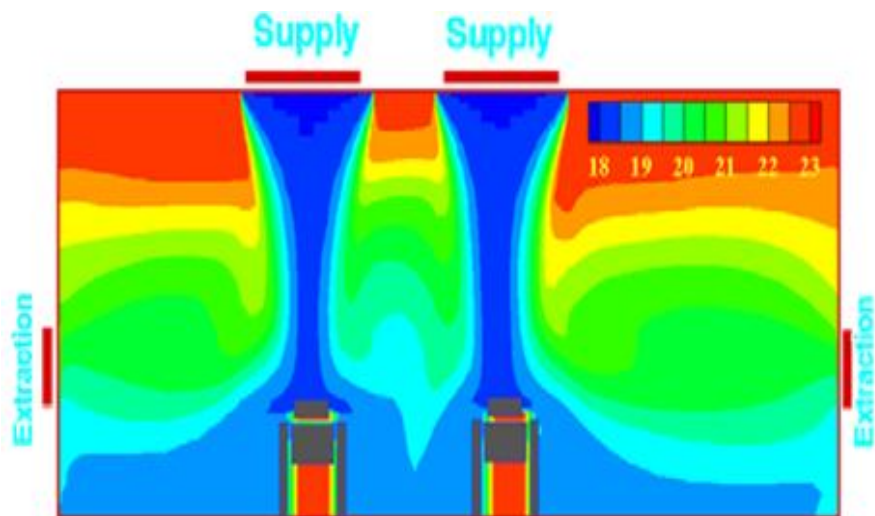
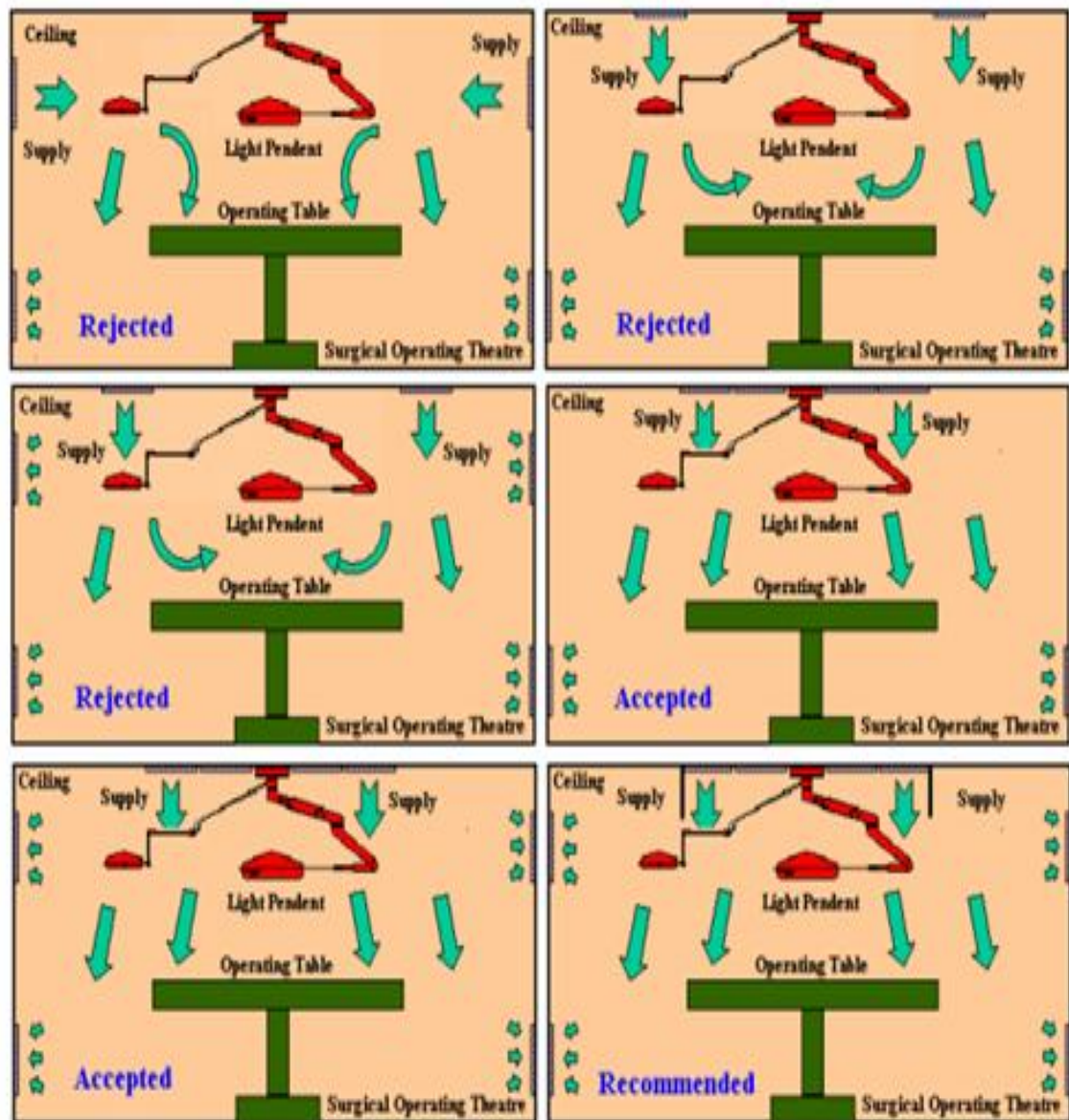


Figure 2-4b: temperature in operating theatre open heart surgery

Based on the above analyses, the following design conditions are recommended for operating, catheterization, cystoscopy, and fracture rooms, figure 5:-

There should be a variable range temperature capability of 20 °C to 24°C.

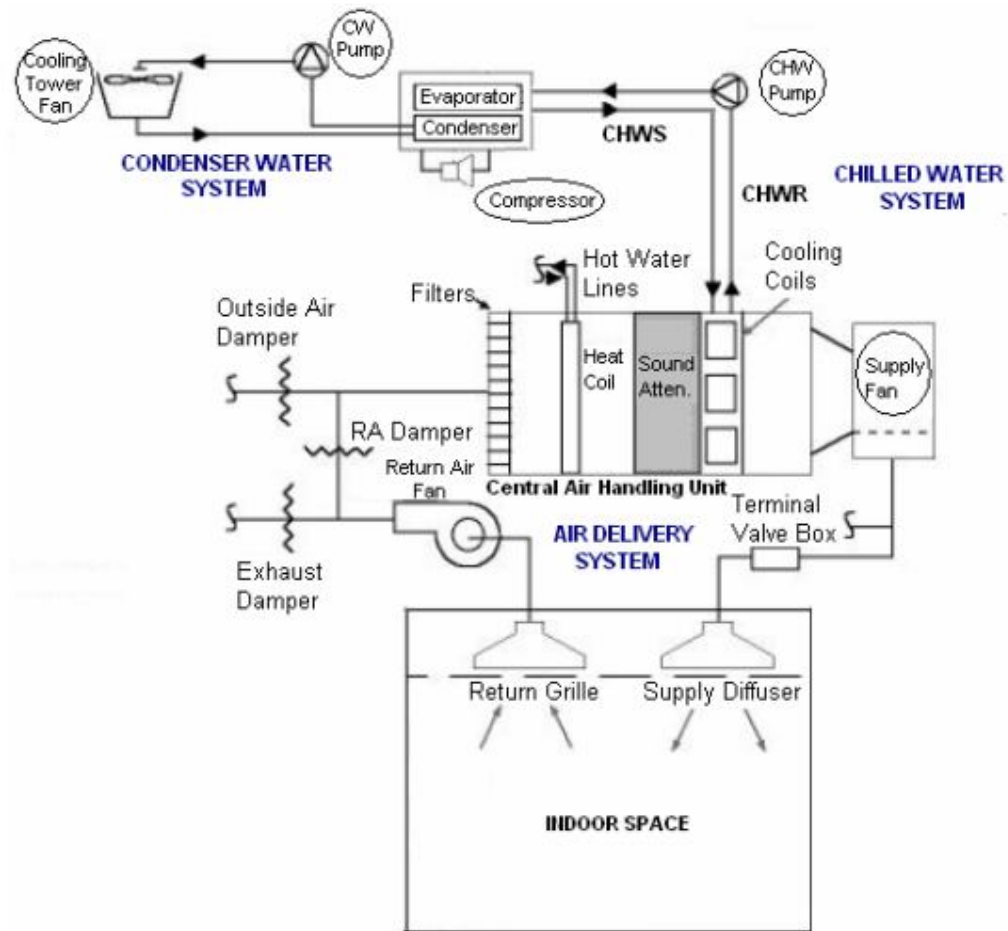
2. Relative humidity should be kept between 50% and 60%.
3. Positive air pressure should be maintained by supplying about 15% excess air.
4. Differential pressure indicating device should be installed.
5. Humidity indicator and thermometers should be located for easy observation.
6. Filter efficiencies should be in accordance with codes
7. Entire installation should conform to NFPA Standard 99, Health Care facilities.
8. All air should be supplied at the ceiling and exhausted from at least two locations near the floor.
9. Control centers that monitor and permit adjustment of temperature, humidity, and air pressure may be located at the surgical supervisor's desk.



**Figure 2-5: different configuration of surgical operating theatres**

The surgical operating suite should be located in complete floor in the hospital, to be separated from the other suites and patient rooms. The above design features were strongly supported by the predicted air flow pattern, temperature contours and relative humidity as

obtained in different operating theatres as discussed by Kameel and Khalil (2003) and Khalil (2004).



**Fig 2-6 typical chilled water**

### **2.3 Chilled Water System:**

The chilled water system supplies chilled water for the cooling needs of all the building's air-handling units (AHUs). The system includes a chilled water pump which circulates the chilled water through the chiller's evaporator section and through the cooling coils of the AHUs. The system may have primary and secondary chilled water pumps in order to isolate the chiller(s) from the building; the primary pumps

ensure constant chilled water flow through the chiller(s), while the secondary pumps deliver only as much chilled water is needed by the building AHUs.

Three most common chillers options are - reciprocating compressors (up to 200 TR\*), screw compressors (100 to 750 TR) and centrifugal compressors (200 to 2000 TR). The centrifugal compressors offer the best peak load efficiency while screw chillers give better part load and the off-design performance.

[**TR\*** stands for Ton of Refrigeration and is defined as the ability of the air-conditioning equipment to extract heat. 1TR is equal to heat extraction rate of 12000 Btu/h].

## **2.4 Condenser Water System:**

A refrigeration system must also reject the heat that it removes. There are two options for heat rejection:

- 1) Air cooled.
- 2) Water cooled.

- **Air cooled units** Absorb heat from the indoor space and rejects it to ambient air.

Air cooled units incorporate a condensing unit comprising of condenser, compressor, propeller fans and controls assembled in one unit and located outdoors. These are the most common system used in residential and light commercial applications.

- **Water cooled units** absorb the heat from the indoor space and rejects that heat to water which in turn may either reject heat via fluid coolers or cooling towers, or dry air coolers with adiabatic kits. Due to the lower refrigerant condensing temperatures compared to air cooled systems, water cooled chillers have higher coefficient of performance (COP). These are most common where good quality water is available and for large buildings such as multistory offices, hotels, airports and shopping complexes.

## **2.5 Air Delivery System:**

Air is drawn into a building's HVAC system through the air intake by the air handling unit (AHU). Once in the system, supply air is filtered to remove particulate matter (mold, allergens, and dust), heated or cooled, and then circulated throughout the building via the air distribution system, which is typically a system of supply ducts and registers.

In most buildings, the air distribution system also includes a return air system so that conditioned supply air is returned to the AHU ("return air") where it is mixed with supply air, re-filtered, re-conditioned, and re-circulated throughout the building. This is usually accomplished by drawing air from the occupied space and returning it to the AHU by:

1-ducted returns, wherein air is collected from each room or zone using return air devices in the ceiling or walls that are directly connected by ductwork to the air-handling unit.

2- Plenum returns, wherein air is collected from several rooms or zones through return air devices that empty into the negatively pressurized ceiling plenum (the space between the drop ceiling and the real ceiling); the air is then returned to the air-handling unit by ductwork or structural conduits. Finally, some portion of the air within is exhausted from the building. The air exhaust system might be directly connected to the AHU and/or may stand-alone.

## 2.6 System Types:

The Central system category could be further broken down into the following:

- Central systems with CAV air-handling units.
- Central systems with VAV air-handling units.
- Central systems with fan-coil units (All- Water systems).
- **Constant air volume (CAV) system:** is an all-air system which accomplish cooling and heating by varying the supply air temperature and keeping the air volume constant. The system works well and maintains comfortable conditions in spaces with uniform heating and cooling requirements.
- **Variable Air Volume (VAV) system:** is an all air system which can satisfy the individual cooling requirements of multiple thermal zones. This is achieved by supplying air at a constant temperature from central plant to one or more VAV terminal units in each zone and adjusting the amount of supply air to meet required cooling loads. The primary benefit of VAV over constant

volume systems (CV) is its ability to simultaneously provide the required level of cooling to any number of zones within a building.

**Key points:**

- Used in buildings with multiple zones to match the particular cooling/heating demands of each zone.
- Can be relatively energy efficient due to the ability to reduce the speed of the supply/extract fan(s) during periods of low to moderate loads.

**Limitations:**

- Design and commissioning is particularly important if good system performance is to be achieved in terms of comfort and energy efficiency.
- Fan-assisted terminal units generally have higher capital and maintenance costs and the potential for increased noise levels.
- The designer needs to ensure adequate outside air is provided when the VAV terminal is regulated down to offset moderate thermal cooling loads.
- The designer needs to take care with the air distribution equipment to ensure dumping of supply air does not occur when the VAV terminal is regulated down to suit moderate cooling loads.
- Fan assisted VAV units do not adequately filter the recirculated air.

### ●All-Water Systems:

Central all-water systems with fan-coil units use un-ducted arrangement. Here chilled water is pumped from the central plant through pipes to the fan coil terminal units placed inside the conditioned space. The room air is re-circulated through the unit and is cooled by the coil. Fan coils are available in a range of sizes, but can be broadly divided between the perimeter under-window console type and ducted units generally installed in a ceiling space. Fan coils offer many benefits including good environmental control and air movement however have increased maintenance requirements compared with a “all-air” ducted system and require maintenance access to the occupied space. Each unit contains a filter which requires regular cleaning/changing. Generally, fan coils are quiet, but noise can be a problem in some situations where the fans are close to the conditioned space, and appropriate acoustic treatment needs to be considered.

### Limitations:

- Each fan coil unit incorporates a filter which requires regular cleaning/changing which can be difficult to access.
- There is a risk of water leaking from overhead fan coils into the space below.
- Floor mounted perimeter fan coils can occupy valuable floor space.
- Potential noise issues due to short duct runs from the supply air fan to the air conditioning outlets.

### Typical Applications of Central Systems:

Centralized systems are mostly used in mid to high rise buildings, which are structures with 5-7+ floors. Commercial buildings commonly choose several types of systems based on the space conditioning needs of different systems. A constant-volume (CV) system might cool the interior, which has relatively uniform cooling requirements while a VAV system conditions perimeter areas, which have variable requirements. Table below shows some typical applications for various types of systems.

Table (2.1) Applications

<b>Building Type</b>	<b>Type of System</b>
Office Buildings (low rise)	VAV; or CV in the core, and hydraulic at perimeter
Office Buildings (high-rise)	Central CV system for core and VAV or hydraulic at perimeter
Department Stores	Multiple CV or VAV air handlers
Universities	CV, VAV or combined air-water systems at each building
Schools	CV or VAV air handlers serving individual common areas, and hydraulic or combined air-water systems in classrooms
Hospitals	Separate CV systems for critical areas; CV or VAV for common areas; hydraulic and combined air-water in

	patient rooms
Hotels	VAV for common areas like lobbies, restaurants, ball rooms & banquets; fan-coil units in guest rooms for individual temperature and humidity control
Assembly, Theatres	Multiple VAV air handlers
Libraries, Museums	Multiple CV air handlers, with precise humidity and temperature control

Central systems are also available as DX systems but in true sense these are large split systems. For example in a multistory building above 6 floors, chilled water system can work with chillers located at one central location (in basement or ground level) and the cooling is achieved by circulating chilled water through various air handling units located at multiple floors. For DX system there is limit to the length of refrigerant piping and the best configuration may be achieved by incorporating individual localized DX system for each floor. We will discuss this further in subsequent sections.

## **2.7 DECENTRALIZED SYSTEMS:**

Decentralized air conditioning systems commonly known as by various generic names viz. local systems, individual systems, floor-by-floor systems, unitary systems or packaged systems provide cooling to single room/spaces rather than the building. These are also referred to as “Direct Expansion” or DX types since the cooling is delivered by exchanging heat directly with a refrigerant type cooling coil and these do not use chilled water as an intermediate cooling

medium. These units are factory designed modular units all assembled into a package that includes fans, filters, heating source, cooling coil, refrigerant coils, refrigerant side controls and condenser. All cooling and heat rejection occur within the envelop of the unit. Each component is matched and assembled to provide specific performance specifications.

## 2.8 Window Air Conditioner:

Window air conditioner provides cooling only when and where needed and is less expensive to operate. In this air conditioner all the components, namely the compressor, condenser, expansion valve or coil, evaporator and cooling coil are enclosed in a single box which is fitted in a slot in the wall of the room, or often a window sill. Room air conditioners are generally available in capacities varying from about 0.5 TR to 3 TR.

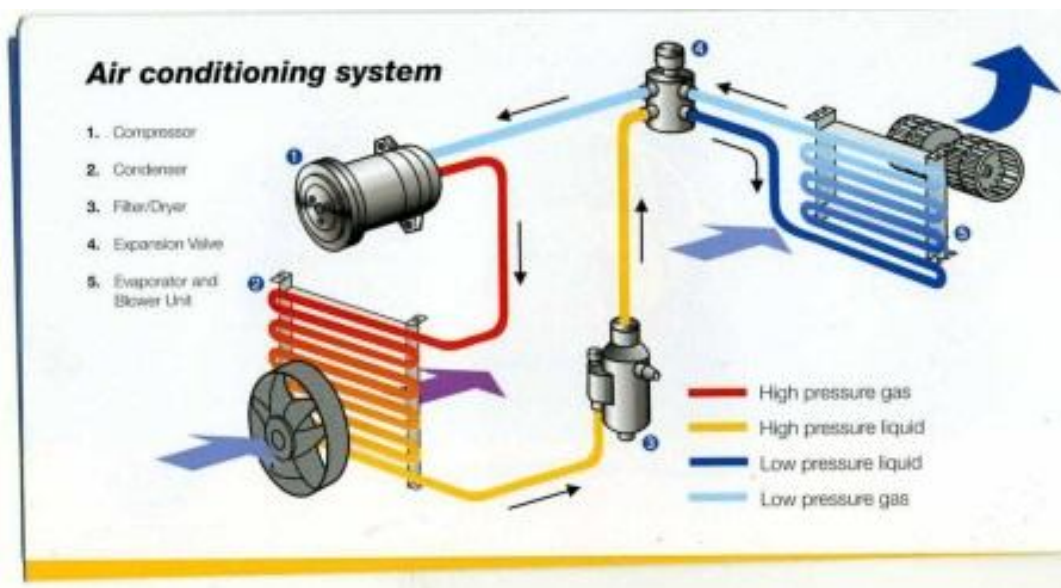
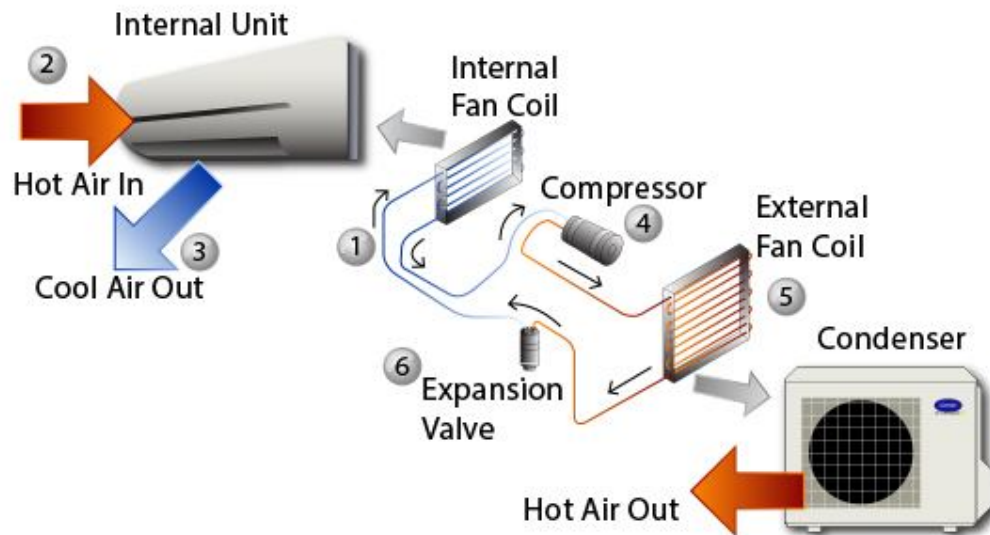


Fig 2-7 Typical Window Unit

## 2.9 Split Air conditioning Systems:

The split air conditioner comprises of two parts: the outdoor unit and the indoor unit. The outdoor unit, fitted outside the room, houses components like the compressor, condenser and expansion valve. The indoor unit comprises the evaporator or cooling coil and the cooling fan. The indoor and outdoor units are connected by refrigerant pipe that transfers the refrigerant. Separation distance between exterior and interior elements is usually limited to around 100 feet. Split-systems are popular in small, single-story buildings. For this unit you don't have to make any slot in the wall of the room.



**Fig 2-8 Typical Split Unit Arrangement**

Flexibility is the overriding advantage of a split system. Because a split system is connected through a custom designed refrigerant piping system, the engineer has a large variety of possible solutions available to meet architectural and physical requirements particularly for buildings with indoor and/or outdoor space constraints. For example, the evaporator unit might be located in a

basement; interior closet or attic while the compressor/ condenser unit might be located on the side, rear or roof of a building.

### **2.10 Variable Refrigerant Flow (VRF) Split System:**

A VRF air-conditioning system is essentially a sophisticated split system with an added ability to provide cooling on an individual basis to multiple rooms from a common condenser. Central to VRF control is their ability to automatically vary refrigerant flow in response to the heating/cooling load of the building. Occupant control is very simple, with easy to use wall-mounted key pads or hand held remote controllers providing individual control of room units. This is particularly useful in applications such as office blocks, hotels and large retail stores etc. which may need cooling in some areas and heating in other areas.

VRF systems are complex and contain microprocessor-based electronics, which ensure efficient operation and simple individualized control. Drawback is that these systems can have longer refrigerant piping runs and significant amount of refrigerant passes through occupied spaces. This could potentially cause a problem if a leak occurs.

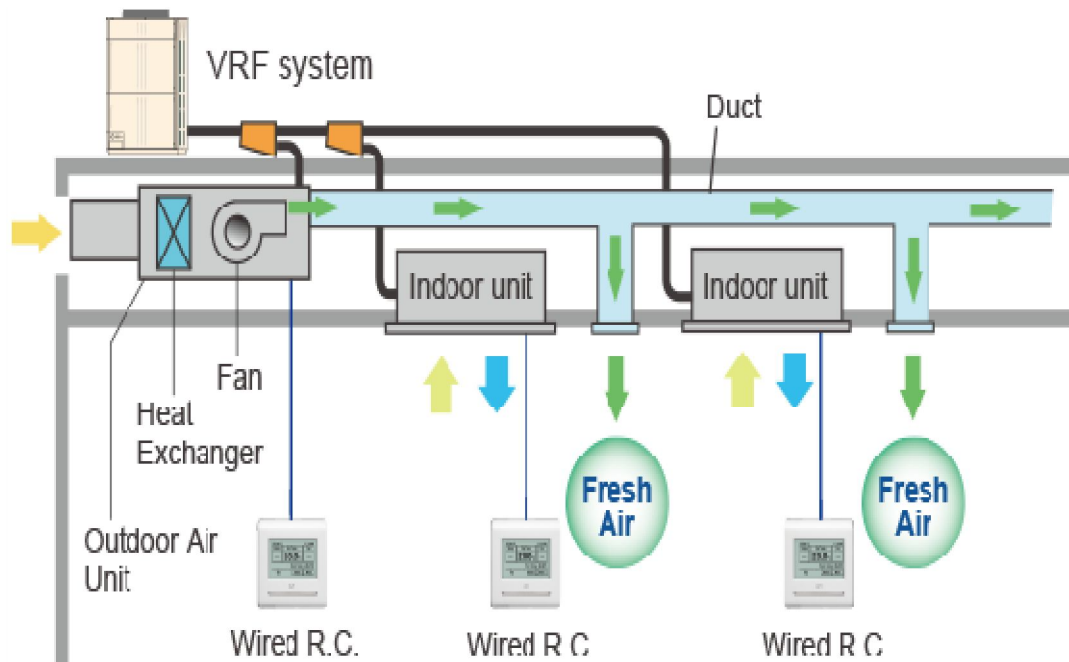
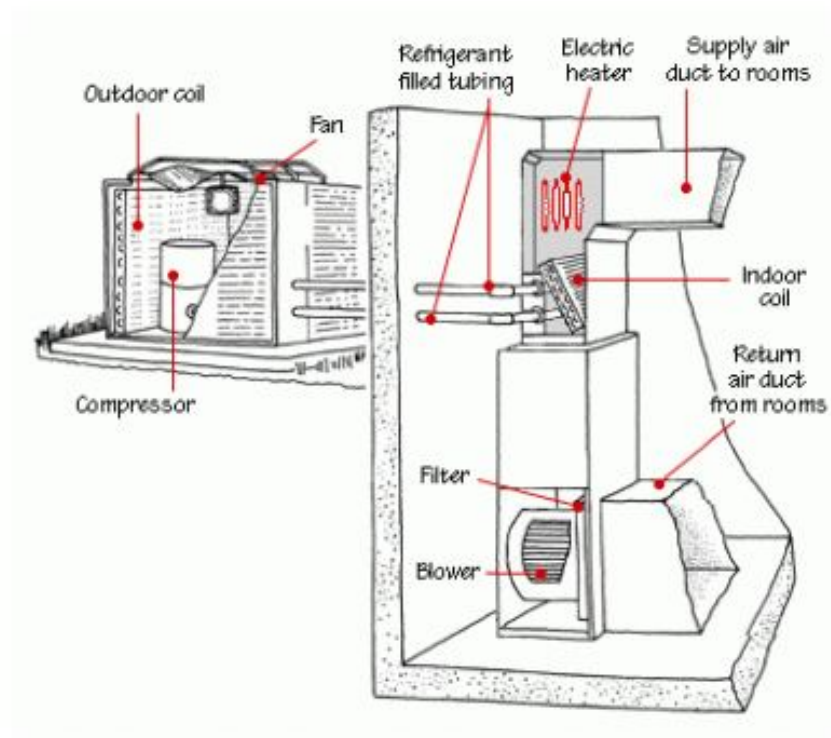


Fig (2-9) VRF System

## 2.11 Packaged Air Conditioners:

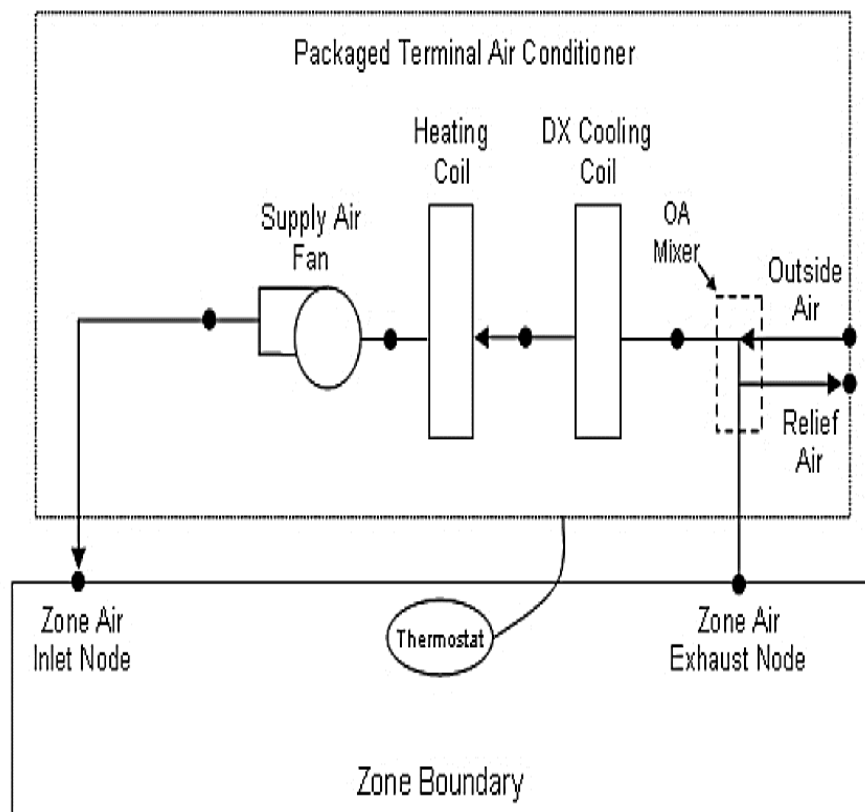
Packaged HVAC systems consist of pre-assembled, off-the-shelf equipment that provides space heating, cooling, and ventilation to small and medium spaces. An HVAC designer will suggest package type of air conditioner if you want to cool more than two rooms or a larger space at your home or office. Packaged air conditioning systems are available in capacities ranging from about 5 TR to up to about 100 TR and a standard package unit is typically rated at 400 CFM (cubic feet per minute) supply air flow rate per ton of refrigeration. Obviously the larger the tonnage, the larger will be the airflow and it will require ductwork to cover all spaces and to reduce noise.



**Fig (2-10) Package Type Split System**

## 2.12 Package terminal air conditioners (PTAC):

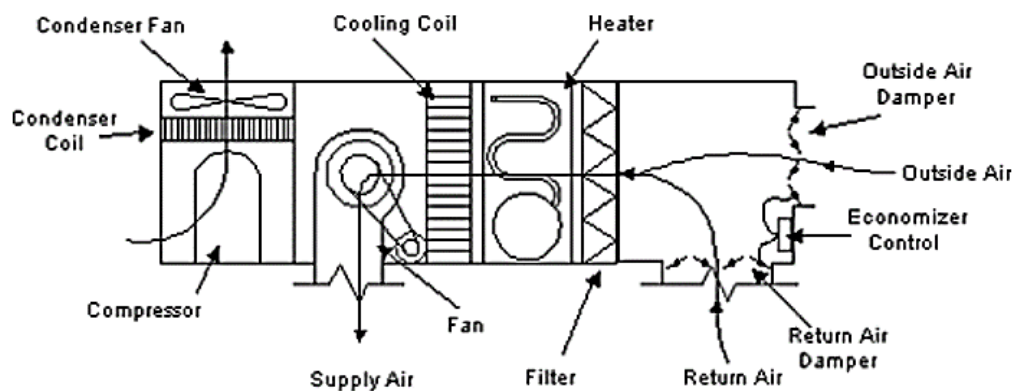
Package terminal air conditioners (PTAC) also called "through-the-wall" air conditioners are relatively small systems typically below 7.5 TR and require no external ductwork. They are like a commercial quality version of residential window-mounted air conditioners (although they are actually mounted at floor level in a sleeve passing through the building wall). Ductless products are fundamentally different from ducted systems in that heat is transferred to or from the space directly by circulating refrigerant to evaporators located near or within the conditioned space. In contrast, ducted systems transfer heat from the space to the refrigerant by circulating air in ducted systems.



**Fig (2-11) Package terminal air conditioners**

### 2.13 Single package rooftop systems:

These systems consist of a single rooftop-mounted unit that contains all mechanical elements of the HVAC system, including compressors, condensers, and evaporators. The units also include a supply fan and filter system that connects to the ductwork to provide air to the conditioned space. These units can be used with air distribution ductwork. Space can be used with air distribution ductwork.



**Fig (2-12) Typical Single-Package Rooftop System**

The typical capacity for a rooftop-packaged unit is 5 to 130 tons. Rooftop units work well for single-story buildings, but don't fit into multi-storey schemes. These units are popular for general air-conditioning of stores, residences, schools, offices, etc. particularly suitable for single flat building with extensive floor areas.

### 2.14 Heat Pumps:

Heat pumps are similar to cooling only systems with one exception. A special 4-way valve in the refrigeration piping allows the refrigeration cycle to reverse so that heat is extracted from outside air and rejected into the building. Heat pumps provide both heating

and cooling from the same unit and due to added heat of compression, the efficiency of heat pump in heating mode is higher compared to the cooling cycle. In the summer heat pumps work like a standard air conditioner removing heat from inside your home and transferring it to the outside through the condenser coil. In the winter heat pumps run in reverse removing heat from the outdoor air and transferring into the home by the evaporator coil, which now becomes a condenser coil in the heating mode. As the temperature drops outside, the unit must work harder to remove heat from the air, lowering its efficiency. At this point, a heat pump system will use supplemental electric resistive heaters to warm the air to the proper temperature, similar to the heating elements in a toaster.

### **2.15 Heat Rejection:**

Most decentralized systems use air-cooled finned tube condensers to expel heat. The larger packaged air conditioners may be water cooled or air cooled.

### **2.16 Typical Applications:**

Decentralized systems are used in most classes of buildings, particularly where low initial cost and simplified installation are important, and performance requirements are less demanding.

**Table (2-13) Typical Applications**

<b>Building Type</b>	<b>Type of System</b>
Residences, Dormitories	Window or Split Units, Heat Pumps or Package Units.
Office Buildings (low rise)	Split Units, Package Units, Roof top Units
Department Stores	Rooftop Units, Package Units
Restaurants	Package Units
Motels	Package Units, Split Units, Heat Pumps, Roof top Units
Small commercial complexes	Package Units, Rooftop Units
Cinema Halls, Theatre	Rooftop Units, Package Units, Custom built DX Units
Library	Rooftop Units, Package Units, Custom built DX Units
Medical centers, clinics	Rooftop Units, Package Units, Custom built DX Units

**Note on Roof top and Package Units:**

Decentralized systems are considered as standard off shelf catalogue products, which include large split system, the roof top units and the cabinet package units. Despite not being distant from the rooms they have to cool (no pipes, no ducts), these are sometimes defined as central systems because they do not work on a room-by-room basis. Moreover their cooling capacity is often much higher exceeding 20TR.

For the purpose of this course, the author defines the central system as those systems which are intended to condition multiple spaces from one base location and are essentially field assembled equipment comprising chillers, air handling units, ductwork, chilled water and condenser water distribution and engineered control system.

# Chapter Three

## **Description of health care hospital**

This research interested in air conditioning for hospitals and compliance international standards, to provide thermal comfort required within the hospital.

We have done study and a survey for air conditioning systems for hospitals in Sudan, and we selected **Health Care** hospital for this study.

### **3.1Hospitals Survey:**

#### **3.1.1Al Baraha Hospital:**

An interview was conducted with the deputy director of the hospital Mr.AlameenTaha on February 15, 2012.He said that all department of hospital are running with split air conditioner system (indoor outdoor units), even the operation rooms are work with the same system and rely on UV light for sterilization, the administration of hospital is building an additional building to expand the hospital and they sections because of hospital preoccupation.

#### **3.1.2 Al Zaytona Hospital:**

An interview was conducted with air-conditioning engineer who designed the air conditioning system of the hospital Mr. Ahmed Albadawi, on February 17,2012.He said that all department of the hospital working on VRV system with air handling unit mixing outside fresh air with return air in rate of 70% return air, the air is drawn from a height of 60 centimeters above the floor, the operation rooms have especial air handling units equipped with HEPA filters

and these rooms are positive pressure room, and the heat load of the building is 500 T.R.

### **3.1.3 Fideal Hospital:**

An interview was conducted with maintenance engineer at the hospital Mr. Alzubair Hashim on February 17, 2012. He said that all hospital departments working on split units and they are using the UV light for sterilization in operation rooms.

### **3.1.4 Al Faisal Hospital:**

An interview was conducted with maintenance engineer at the hospital Mr. Khalafalla Abas on February 17, 2012. He said that all hospital departments working on the window type air conditioner with expect for places that are difficult to install such units on it a split air conditioner was installed there, there are two split unit and one window type in the operation rooms.

He said he was not quite sure of the heat load of the building , but the building has four 48000 BTU units every unit equipped with two compressor.

### **3.1.5 Sharq Al Neel National Hospital:**

An interview was conducted with maintenance engineer at the hospital Mr. Ahmed Abdalla on February 23, 2012.

He said that air conditioning system used in this hospital is packages with air handling units mixing 70% of return air, the operation rooms are equipped with special air handling unit 100%

outside fresh air with HEPA filters and the room is positive pressure room with ultraviolet light of sterilization and split units are used for the administrative offices.

### **3.1.6Makkah Hospital:**

An interview was conducted with maintenance engineer at the hospital Mr. Altahir Ali on February 25, 2012.

This hospital was using split unit in air conditioning system. There are (package unit) on the roof of the hospital to supply some parts of the hospital. There are no using of HEPA or ULPA filters in the hospital.

### **3.1.7Royal Care Hospital:**

An interview was conducted with maintenance engineer at the hospital Mr. Osman Mohammed Ali on February 25, 2012. He said that the hospital has a heat load and the third one is used as a standby. But recently they have installed a special 100% fresh air handling unit for the operation rooms with HEPA filters with some split units to deal with the outlying areas and administration offices.

## **3.2Description of health care hospital:**

### **3.2.1Location:**

The hospital is located in the north west direction of the Sudan university for science and technology collage of engineering, in the intersection of AL-SHAFA street with the 61th street.

### 3.2.2Construction:

It consists of a five floors and basement, the external wall contains three layers (two plaster layers (30 mm for each) and a common brick (200 mm)), and the roof consist of three layers (common plaster layer (20 mm), ceramic layer (7 mm) and a concrete (200 mm), the building color is beige, and it faces the east direction.

### 3.2.3Floors description:

**Basement floor:** This floor contains a X-RAY room, a laboratory, two offices, a hall, a medicine store, and X-RAY device, 12 lamp (4ft), 28 lamp (2ft), 15 roof fan, 2 LCD screens, 2 receivers, 1 computer, 1 water cooler, 4 widows(1\*1.7 m<sup>2</sup>, glass and aluminum) and 2 doors(2.9\*1 m<sup>2</sup>, aluminum).

**Ground floor:** This floor contains a laboratory, pharmacy, office, 3 bathrooms and a clinic. and 12 lamp (4ft), 28 lamp(2ft), 15 roof fan, 2 LCD screens, 2 receivers, 2 water coolers, 3 refrigerators (6ft), 3computers, 1sampling device, 3 evaporative air conditioners, 2 split type air conditioners, 4 widows and 2 doors (2.9\*1 m<sup>2</sup>).

**First floor:** This floor contains are 3 clinics, Doctors rest room, ultrasound room, hall, nurse room and 7 bathrooms. Also it contains 12 lamp (4ft), 28 lamp (2ft), 15 roof fan, 2 LCD screens , 2 receiver, 1 water cooler, 2 computers,1 ultrasound 2 refrigerators , 7 split type air conditioners, and 6widows and 14 doors(2.9\*1 m<sup>2</sup>).

**Second floor:** This floor contains 3 birth rooms, patient room, office, hall, incubation room and 7 bathrooms.

Also it contains 12 lamp (4ft), 28 lamp (2ft), 15 roof fan, 2 LCD screens, 2 receivers, 1 computer, 2 water coolers, other operation devices, 2 refrigerators, 7 split type air conditioners, and 6 widows(1.7\*1 m2) and 14 doors(2.9\*1 m2).

**Third floor:** This floor contains an intensive care unit(ICU), coronary care unit(CCU), 2 surgery rooms, doctors rest room, 2 bathrooms, changing room, sterilization room, Also it contains 12 lamp (4ft), 28 lamp (2ft), 15 roof fan, 1 water cooler, 2 refrigerators, 5 computers, other operation devices, 7 split type air conditioners, 6 widows(1.7\*1m2) and 14 doors(2.9\*1m2).

**Fourth floor:** This floor contains a 7 patient rooms, hall, 4 bathrooms, Also it contains 12 lamp (4ft), 28 lamp (2ft), 15 roof fan, 7 LCD screens, 7 receivers, 2 water coolers, 7 refrigerators, 7 split type air conditioners, 7 widows(1.7\*1m2) and 11 doors(2.9\*1m2).

**Fifth floor:** This floor contains a washing room , ironing room, cafeteria store, 2 washers, 2 ironers, 2 furnaces, 3 refrigerators, 2 LCD screens, 2 receivers, 2 water coolers ,(note: the roof of this floor is horizontal and made of zinc).

**Table (3-1)Number of equipments for each floor**

	No of lamps		Roof fans	Other Equipments
	4ft	2ft		
<b>Basement</b>	12	28	15	7
<b>Ground</b>	12	28	15	13
<b>First</b>	12	28	15	10
<b>Second</b>	12	28	15	14
<b>Third</b>	12	28	15	13
<b>Fourth</b>	12	28	15	23
<b>Fifth</b>	20	-	15	20
<b><math>\Sigma</math></b>	<b>92</b>	<b>140</b>	<b>105</b>	<b>80</b>

**Table (3-2)The overall heat transfer coefficient for materials**

<b>spaces</b>	<b>U –value-w/m2.c</b>
Roof	1.775
Floor	2.232
Wall	1.621
Glass	1.67
Aluminum	1.73

**Table (3-3) Capacity of equipment's.**

<b>Equipment</b>	<b>Capacity (watt)</b>
Roof fan	300
Lamp (4ft)	36
Lamp (2ft)	18
Refrigerator	500
Window A.C	1200
Split A.C	1200
Desktop computer	1500
LCD screen (42 inch)	230
receiver	420
ironer	1200
washer	1150
microwave	1200
Mixer fruits	300
X-Ray device	500

**Table (3-4) number of people and Activity level for each floor**

<b>Spaces</b>	<b>No.patient</b>	<b>No.visitor</b>	<b>No.worker</b>	<b>No.doctor</b>	<b>No.nurse</b>	<b>No.lenient</b>	<b>total</b>
<b>Basement floor</b>	5	0	3	6	8	10	26
<b>Ground floor</b>	6	30	4	6	8	6	60
<b>First floor</b>	15	20	2	8	3	15	63
<b>Second floor</b>	18	20	4	2	8	18	70
<b>Third floor</b>	5	0	4	8	8	0	25
<b>Fourth floor</b>	8	16	4	4	8	8	48
<b>Fifth floor</b>	0	0	10	0	0	0	10
<b>Activity level</b>	No activity	Seated rest	Heavy work	Sedentary work	Medium work	Seated rest	

**Table (3-5) Conductional heat transfer coefficient and thickness for each material**

<b>material</b>	<b>K (kJ/kg. k)</b>	<b>X (mm)</b>
Aluminum (door, window)	237	60
Steel (door, window)	80	50
water	0.613	-
brick	0.72	100
Concrete (roof)	0.84	200
Concrete (basement)	0.84	300

material	K (kJ/kg. k)	X (mm)
plaster	1.34	20
Glass (door, window)	0.78	10

K=conductional heat transfer coefficient (kJ/kg. k).

X=thickness (mm).

### **(3.3)Outside design conditions:**

The outside design had been taken as:

$T_{d.b}= 45^{\circ}\text{C}$  (Dry bulb temperature).

$T_{w.b}=28^{\circ}\text{C}$  (Wet bulb temperature).

$\Phi = 30\%$  (relative humidity).

**\*note: These conditions are Constant for all departments.**

### **3.4Inside Design Conditions:**

Below table recommended inside design parameter for each department of hospital:

**Table (3-4) Inside design parameter for each department of hospital**

<b>Department</b>	<b>T<sub>d.b</sub>(C°)</b>	<b>T<sub>w.b</sub>(C°)</b>	<b>R.H %</b>	<b>Supply air speed m/s</b>	<b>Pressure deference with the surrounding space</b>
<b>Surgery and operation rooms</b>	25	19	55	0.38	+25 pa
<b>Nursing and intensive care</b>	25	20	60	0.28	N
<b>X-rays and laboratories</b>	25	19	55	0.3	P
<b>Diagnosis and treatment</b>	25	19	55	0.3	P
<b>sterilization</b>	25	19	55	0.28	N
<b>Hospital administration</b>	25	19	55	0.25	O
<b>Services (kitchen, laundry, ...)</b>	25	19	55	0.3	N

### **3.5Heat load calculation equations:**

#### **3.5.1 Estimation of external loads:**

##### **a) Heat transfer through opaque surfaces (Q):**

This is a sensible heat transfer process. The heat transfer rate through opaque surfaces such as walls, roof, floor, doors etc is:

$$Q_{\text{glass}} = U_g \cdot A \cdot \Delta T \dots\dots\dots (1)$$

$U_g \equiv$  overall heat transfer coefficient for glass (KJ/Kg. k)

$A \equiv$  heat transfer area (m<sup>2</sup>)

$\Delta T \equiv$  cooling load temperature difference (K)

$$Q_{\text{wall}} = U_w \cdot A \cdot \Delta T \dots\dots\dots (2)$$

$U_w \equiv$  overall heat transfer coefficient for wall (KJ/Kg. k)

$A \equiv$  heat transfer area (m<sup>2</sup>)

$\Delta T \equiv$  cooling load temperature difference (K)

$$Q_{\text{roof}} = U_r \cdot A \cdot \Delta T \dots\dots\dots (3)$$

$U_r \equiv$  overall heat transfer coefficient for roof (KJ/Kg. k)

$A \equiv$  heat transfer area (m<sup>2</sup>)

$\Delta T \equiv$  cooling load temperature difference (K)

$$Q_{\text{ground}} = U_b \cdot A \cdot \Delta T \dots\dots\dots (4)$$

$U_g \equiv$  overall heat transfer coefficient for ground (KJ/Kg. k)

$A \equiv$  heat transfer area (m<sup>2</sup>)

$\Delta T \equiv$  cooling load temperature difference (K)

### 3.5.2 Estimation of internal loads:

The internal loads consist of load due to occupants, due to lighting, due to equipment and appliances and due to products stored or processes being performed in the conditioned space.

#### a) Load due to occupants:

$$Q_{s, \text{occupants}} = n \times (\text{Sensible heat gain/person}) \dots\dots\dots (1)$$

$Q_{s, \text{occupants}}$  Sensible heat transfer to the conditioned space due to the occupants. (W)

$n$   $\equiv$  number of people.

$$Q_{l, \text{occupants}} = n \times (\text{Latent heat gain}) \dots\dots\dots (2)$$

#### b) Load due to lighting:

$$Q_{s, \text{lighting}} = (\text{installed wattage}) (\text{usage factor}) (\text{ballast factor}) \dots (3)$$

$Q_{s, \text{lighting}}$   $\equiv$  Lighting adds sensible heat to the conditioned space. (W)

#### c) Internal loads due to equipment and appliances:

$$Q_{s, \text{appliances}} = (\text{installed wattage}) \times (\text{wattage factor}) \dots (4)$$

$$Q_{l, \text{appliance}} = (\text{installed wattage}) \times (\text{latent heat gain}) (W) \dots (5)$$

#### D) Heat transmitting through the air:

$$Q_{a, s} = m_a c_{pa} \Delta T_a \dots\dots (6)$$

$Q_{a, s}$   $\equiv$  sensible heat transmitting through the air. (W)

$\dot{m}_a \equiv$  mass of air over one second. (kg/s)

$c_{pa} \equiv$  specific heat for air. (kJ/kg.k)

$\Delta T_a \equiv$  cooling load temperature difference.

$$Q_{a,L} = \dot{m}_a \Delta W \cdot h_{fg} \dots (7)$$

$Q_{a,L} \equiv$  latent heat transmitting through the air (W)

$\dot{m}_a \equiv$  mass of air over one second (kg/s).

$\Delta W \equiv$  Specific humidity.

$h_{fg} \equiv$  latent heat of vaporization.

Calculating of ( $\dot{m}_a$ ) value:

$$\dot{m}_a = \rho \cdot v \dots (8)$$

$\dot{m}_a \equiv$  mass of air over one second. (Kg/s)

$\rho \equiv$  density of air (Kg/m<sup>3</sup>)

$v \equiv$  volume of air over one second (m<sup>3</sup>/s)

Calculating of ( $v$ ) value:

$$v = \frac{V \times n}{3600} \dots (9)$$

$V \equiv$  volume of the space (m<sup>3</sup>)

$n \equiv$  air changing times per hour = 12

e) Sensible heat factor (SHF):

$$Q_{S.H.F} = \frac{Q_S}{Q_S + Q_L} \dots (10)$$

$Q_{S.H.F}$   $\equiv$  sensible heat factor (W).

$Q_S$   $\equiv$  sensible heat (W).

$Q_L$   $\equiv$  latent heat (W).

Overall heat transfer coefficient (U):

$$\frac{1}{U} = \frac{1}{h_o} + \sum \frac{x}{K} + \frac{1}{h_i} \dots (11)$$

$U$   $\equiv$  the Overall heat transfer coefficient (kJ/kg. K).

$h_o$   $\equiv$  Convective heat transfer coefficient for outside surface (kJ/kg.K).

$x$   $\equiv$  Thickness (mm).

$K$   $\equiv$  Conductive heat transfer coefficient (kJ/kg. K).

$h_i$   $\equiv$  Convective heat transfer coefficient for inside surface (kJ/kg. K).

# Chapter Four

## **Heat load calculations**

Thermal load has been calculated by using **Hourly Analysis Program (HAP)** version 4.6, as inside and outside design condition had been adopted as instructed by Dr. Hassan Abdel-Lateef Osman.

### **4.1 Introduction for Hourly Analysis Program ( HAP):**

Carrier's **Hourly Analysis Program** is two powerful tools in one package - versatile features for designing HVAC systems for commercial buildings AND powerful energy analysis capabilities for comparing energy consumption and operating costs of design alternatives.

By combining both tools in one package, significant time savings are achieved. Input data and results from system design calculations can be used directly in energy studies.

HAP is designed for consulting engineers, design/build contractors, HVAC contractors, facility engineers and other professionals involved in the design and analysis of commercial building HVAC systems.

In addition, HAPs 8760 hour energy analysis capabilities are very useful for green building design. For instance, HAP energy analysis results are accepted by the US Green Building Council for its LEED®<sup>1</sup> (Leadership in Energy and Environmental Design) Rating System

The program is a powerful tool for designing systems and sizing system components. HAP can easily handle projects involving

- Small to large commercial buildings;

- Systems including rooftops, central air handlers, WSHPs, GSHPs, fan coils, VRF, chilled water and hot water plants and more;
- Many types of constant volume and VAV system controls;
- Small office buildings, retail stores, strip shopping centers, schools, churches, restaurants, large office buildings, hotels, malls, hospitals, factories, and multi-use buildings; and
- New design, retrofit or energy conservation work.

#### **4.2 Load calculations:**

Uses ASHRAE Transfer Function cooling load calculation procedures, ASHRAE design heating load calculation procedures, ASHRAE design weather data, ASHRAE design solar calculation procedures.

- Calculates space and zone loads 24-hours a day for design days in each of the 12 months. In doing so it calculates heat flow for all room elements such as walls, windows, roofs, skylights, doors, lights, people, electrical equipment, non-electrical equipment, infiltration, floors and partitions considering time of day and time-of-year factors.
- Performs detailed simulation of air system operation to determine cooling coil loads and heating coil loads and other aspects of system performance 24-hours a day for design days in each of the 12 months.
- Analyzes plenum loads.

- Considers any operating schedule for HVAC equipment from 1 hour to 24 hours in duration.
- Permits hourly and seasonal scheduling of occupancy, internal heat gains, and fan and thermostat operation.

**4.3 The following tables show heating and cooling load calculation:**

# Chapter Five

## **Conclusion& recommendations**

Air conditioning systems that meet the standards of the hospital air conditioning can be costly in all respects, But human health is not measured by money and these standards of hospital complexity had been designed carefully after that proved to meet the basic needs of optimum diagnosis and treatment, so we are clear to say that the first treatment for patient at hospitals is the healthy air conditioning which meet the healthy need of patient, and because the hospital is the place which relieve our diseases not increase it , so by application of the fundamental standards of hospital air conditioning systems we are sure the spread of diseases will be under control with the willing of ALLAH.

### **5.1 Conclusion:**

- According to heat loads results we calculated cooling load , then we select the proper central air-conditioning system (air-water)type.
- according to selection of central air conditioning we cannot install it in health care hospital.
- Health care** hospital does not match the American institute architectures (AIA) standards.
- The requirements of ventilation for surgery rooms in **Health care hospital** does not match American society of heating and refrigeration air- conditioning engineers (ASHRAE).

- **Health care hospital** does not have many basic departments like (infection room, isolation room).

- Health care hospital** does not match American society of heating and refrigeration air- conditioning engineers (ASHRAE).

- As result of this project we found that the central air conditioning system cannot be applied in **health care hospital**.

## **5.2 Recommendations:**

- To apply the selection system, the recommendation is to install insulation external ducts and insulation pipe water

- The recommendation of this project is to verify from the ministry of health to force any hospital to commit to standards of (ASHRAE&AIA).

- The recommendation of this project is to make a study that aim to minimize the consumption of energy in central air conditioning in hospitals...

- The recommendation of this project is to continue research in this subject

.

## REFERENCES

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# Appendixes

