Sudan University of Science and Technology

Collage of Engineering

Mechanical Engineering

# Design of Air Conditioning System for Sport Hall for 1000 Occupant

# تصميم نظام تكييف لصالة رياضية سعة ١٠٠٠ متفرج

**A Project Submitted in Partial Fulfillment for the Requirement of the Degree of B.Eng. (HONOR) In Mechanical Engineering**

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# الاية

# DEDICATION

For their countless sleepless nights filled with prayer and hopes for our Success in life, the least we could do is to dedicate the fruit of our Efforts to the two most influential people in our life mother and father.

…This is for you.

For providing us with constant encouragement to complete this journey, And for believing in our ability to always do our best, we would like to Dedication this project to our teachers who have been with us all the Step of the way.

We are truly blessed to have them by our side.

Experience also, we predict the effort to the kindness person, who provides us with his knowledge Experience studies tell this see the light. And the respectful college teachers who take our hands since our

Entrance to the college till this step.

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# Abstract

The aim of this study is calculate cooling load for sport hall (1000 occupant) by mathematical relation, software program and select proper air conditioning devices and equipment.

Cooling load have been calculated by relation by using cooling load temperature difference (CLTD) and it founded 116TR, and software program by Hourly Analysis Program (HAP) and it founded 103TR then air duct dimension have been calculated by using McQuay duct sizer design tools by using constant head loss method.

Five air conditioning unit package (50Z030) 30TR capacity have been selected from CARRIER product CatLog.

## المستخلص

الهدف من هذا المشروع هو حساب الاحمال الحرارية لصالة رياضية سعة الف متفرج باستخدام العلاقات الرياضية وباستخدام برنامج حاسوب، ومن ثم اختيار اجهزة التكييف المناسبة على ضوء الاحمال الحرارية.

تم حساب الاحمال الحرارية باستخدام العلاقات الرياضية بطريقة فرق درجة الحرارة لحمل التبريد ووجد انه يساوي 116 طن تبريدي وباستخدام برنامج الحاسوب 103 طن تبريدي ومن ثم تم حساب ابعاد مجاري الهواء باستخدام برنامج McQuay Duct Sizer بطريقة ثبات فرق الضغط.

تم اختيار خمس وحدات تكييف Package سعة 30 طن تبريدي من نوع (50Z030 CARRIER). من منتجات شركة كاريير الامريكية.

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# Table of Abbreviations

| | |
|---|---|
| HVAC | Heating and ventilating air conditioning |
| TOR | Ton of refrigeration |
| ASHRAE | American Society of Heating and Refrigeration and Air Conditioning Engineers. |
| TFM | Transfer Function Method |
| DBT | Dry bulb temperature |
| WBT | Wet bulb temperature |
| Φ | Relative humidity |
| $w$ | Humidity ratio |
| H | Enthalpy |
| CLF | Cooling Load Factor |
| CLTD | Cooling Load Temperature Differential |
| $U$ | Heat transfer coefficient |
| $A$ | Area |
| $SC$ | Shading coefficient |
| $SCL$ | Solar cooling load factor with no interior shade or with shade |
| $W$ | Watts input from electrical plans or lighting fixture data |
| $P$ | Horsepower rating from electrical plans or manufacturer’s data |
| $F_{ul}$ | Special allowance factor, as appropriate |
| $E_F$ | Efficiency factors and arrangements to suit circumstance |
| $F_U$ | Usage factors, |
| $F_R$ | Radiation factors |
| $F_L$ | Load factor |
| $Q$ | Ventilation from ASHRAE Standard 62 |
| HAP | Hourly Analysis Program |

| | |
|---|---|
| cfm | Cubic feet per minute |
| FPM | Feet per minute |

# List of Appendix

# Chapter One

# Introduction

## 1.1 Introduction

The American Society of Heating& Refrigerating and Air-Conditioning engineers ASHRAE defines air conditioning as: "The process of heating air so as to control simultaneously its temperature, humidity, cleanliness, and distribution to meet the requirements of the conditioned space." as the definition indicates, the important actions involved in the operation of an air conditioning system [1]

- Temperature control.
- Humidity control.
- Air filtering & cleaning and purification.
- Air movement and circulation.

The purpose of air conditioning is to provide a comfortable temperature for human beings and machines and equipment to be protected. Air conditioning can either be for cooling or heating. This project is dealing with conditioning the air within certain areas to keep it in the range of Human comfort. The human beings will feel more comfortable when he is in an atmosphere of a reasonable temperature and humidity.

## 1.2 Problem Statement

Estimate Cooling load for sport hall and select proper air conditioning devices and equipment.

## 1.3 Objective

- Calculate the thermal load manually.
- Calculate the thermal load by HAP application.
- Select suitable air conditioning equipment.

## 1.4 Significant of Study

The importance of this research and its essence in preserving both the two methods (manual and software) of calculating Air Conditioning cooling load for sizing cooling equipment and a general procedure for calculating cooling load, for nonresidential applications.

## 1.5 Scope of Study

Estimate the cooling load calculation for nonresidential building according to The American Society of Heating& Refrigerating and Air-Conditioning engineers ASHRAE Stander.

# CHAPTER TWO

# LITERATURE REVIEW

## 2.1 Introduction

Air-conditioning is a process that simultaneously conditions air; distributes it combined with the outdoor air to the conditioned space, and at the same time controls and maintains the required space's, temperature, humidity, air movement, air cleanliness, sound level, and pressure differential within predetermined limits for the health and comfort of the occupants, for product processing, or both[2]

As mentioned earlier, the term "air conditioning," when properly used, now means the total control of temperature, moisture in the air (humidity), supply of outside air for ventilation, filtration of airborne particles, and air movement in the occupied space. There are seven main processes required to achieve full air conditioning and they are listed and explained below:

### This processes are:

**1- Heating:** the process of adding thermal energy (heat) to the conditioned space for the purposes of raising or maintaining the temperature of the space

**2- Cooling:** the process of removing thermal energy (heat) from the conditioned space for the purposes of lowering or maintaining the temperature of the space.

**3- Cleaning:** the process of removing particulates, (dust etc.,) and biological contaminants, (insects, pollen etc.,) from the air delivered to the conditioned space for the purposes of improving or maintaining the air quality.

**4- Humidification**

This as its name implies, means that the moisture content of the air is increased. This may be accomplished by either water or steam in air conditioning system Humidification can be obtained by direct injection of water drops of aerosol size into the room being conditioned.(A variant of this last technique is to inject aerosol-sized droplets into an airstream moving through a duct.)

**5- Dehumidification**

There principal methods whereby moist air can be dehumidified in application of air conditioning system cooling to a temperature below the dew point, Cooling to a temperature below the dew point is done by passing the moist air over a cooler coil or through an air washer provided with chilled water[3]

**6- Ventilating:**

The process of exchanging air between the outdoors and the conditioned space for the purposes of diluting the gaseous contaminants in the air and improving or maintaining air quality, composition and freshness. Ventilation can be achieved either through natural ventilation or mechanical ventilation. Natural ventilation is driven by natural draft, like when you open a window. Mechanical ventilation can be achieved by using fans to draw air in from outside or by fans that exhaust air from the space to outside

**7- Air Movement**: the process of circulating and mixing air through conditioned spaces in the building for the purposes of achieving the proper ventilation and facilitating the thermal energy transfer. [4]

## 2.2 Classification of air conditioning systems

Based on the fluid media used in the thermal distribution system, air conditioning systems can be classified as [5]

### 2.2.1 All air systems

As the name implies, in an all air system air is used as the media that transports energy from the conditioned space to the A/C plant. In these systems air is processed in the A/C plant and this processed air is then conveyed to the conditioned space through insulated ducts using blowers and fans. This air extracts (or supplies in case of winter) the required amount of sensible and latent heat from the conditioned space. The return air from the conditioned space is conveyed back to the plant, where it again undergoes the required processing thus completing the cycle. No additional processing of air is required in the conditioned space. All air systems can be further classified into:

### 2.2.2 All water systems

In all water systems the fluid used in the thermal distribution system is water, i.e., water transports energy between the conditioned space and the air conditioning plant. When cooling is required in the conditioned space then cold water is circulated between the conditioned space and the plant, while hot water is circulated through the distribution system when heating is required. Since only water is transported to the conditioned space, provision must be there for supplying required amount of treated, outdoor air to the conditioned space for ventilation purposes. Depending upon the number of pipes used, the all water systems can be classified into a 2-pipe system or a 4-pipe system

### 2.2.3 Air-water systems

In air-water systems both air and water are used for providing required conditions in the conditioned space. The air and water are cooled or heated in a central plant. The air supplied to the conditioned space from the central plant is called as primary air, while the water supplied from the plant is called as secondary water. The complete system consists of a central plant for cooling or heating of water and air, ducting system with fans for conveying air, water pipelines and pumps for conveying water and a room terminal. The room terminal may be in the form of a fan coil unit, an induction unit or a radiation panel.

## 2.3 Unitary refrigerant based systems

Unitary refrigerant based systems consist of several separate air conditioning units with individual refrigeration systems. These systems are factory assembled and tested as per standard specifications, and are available in the form of package units of varying capacity and type. Each package consists of refrigeration and/or heating units with fans, filters, controls etc. Depending upon the requirement these are available in the form of window air conditioners, split air conditioners, heat pumps, ductable systems with air cooled or water cooled condensing units etc. The capacities may range from fraction of TR to about 100 TR for cooling. Depending upon the capacity, unitary refrigerant based systems are available as single units which cater to a single conditioned space, or multiple units for several conditioned spaces.

### 2.3.1 Window Type

Type of Window air conditioners are one of the most commonly used and cheapest type of air conditioners. Window air conditioners are comprised of components like the compressor, condenser, expansion valve or expansion coil, and the evaporator or the cooling coil, all housed in a single box. There is also a motor which has shafts on both sides. On one side of the shaft the blower is connected, which sucks hot air from the room and blows it over the cooling coil, thus cooling it and sending it to the room. On the other shaft the fan is connected, which blows the air over Freon gas passing through the condenser.

One of the complaints that window air conditioners have had is that they tend to make noise inside the room. But this problem has been greatly overcome by the present day efficient and less noisy rotary compressors, which also consume less electricity. Today a number of fancy and elegant looking models of window air conditioners are available that enhance the beauty of your rooms

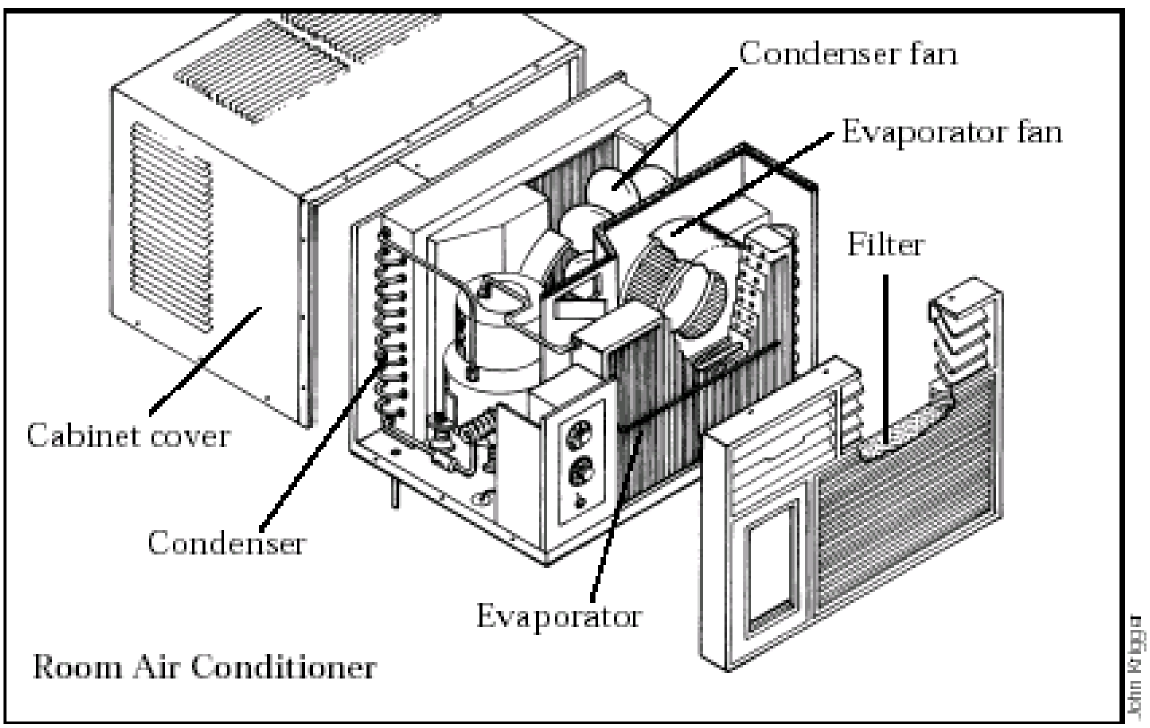


**Figure (2 – 1) : Window Type**

## 2.3.2 Split Type

Split air conditioners are used for small rooms and halls, usually in places where window air conditioners cannot be installed. However, these days many people prefer split air conditioner units even for places where window air conditioners can be fitted.

The split air conditioner comprises of two parts: the outdoor unit and 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. For this unit you don't have to have to make any slot in the wall of the room. A split air conditioner can be used to cool one or two rooms.

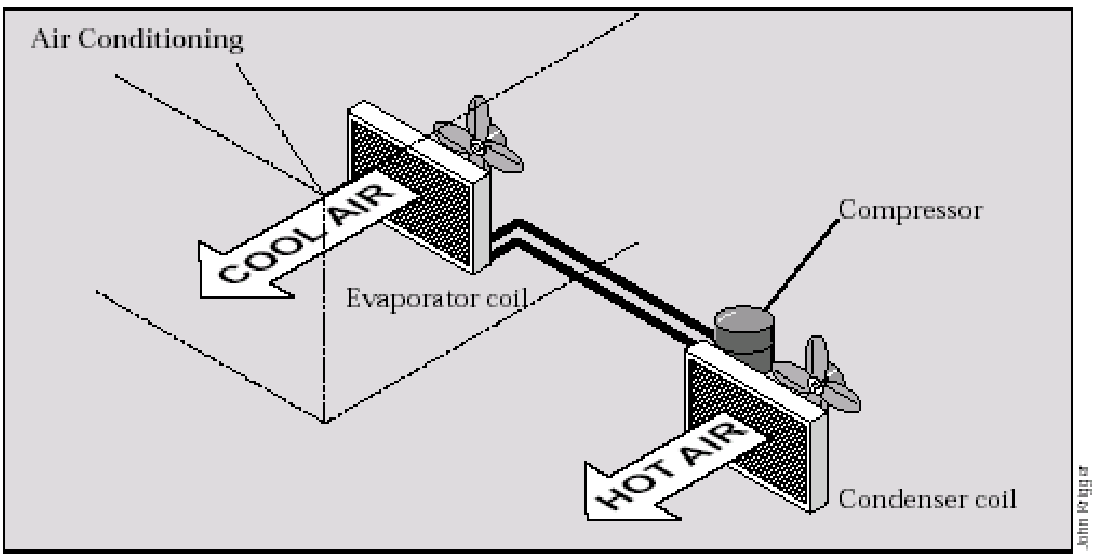


**Figure (2 – 2) : Split Type**

## 2.3.3 Packaged Air Conditioner

Package air conditioner use when we want to cool more than two rooms or large space at your home or office. There are two possible arrangements with package unit.

In the first one, all components namely the compressor, condenser, expansion valve and evaporator are housed in single box. The cooled air is shown by the high capacity blower and it flow through the duct laid through various rooms

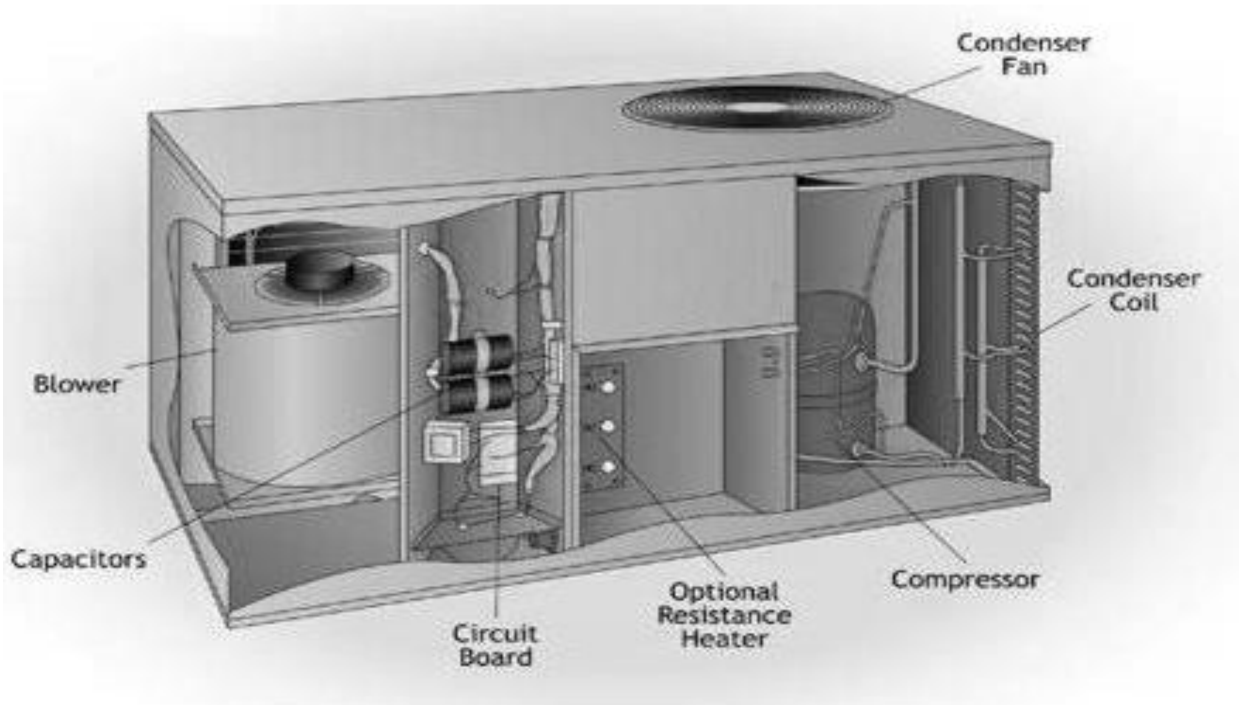


**Figure (2 – 3) : Package Type**

In the second arrangement, the compressor and condenser are housed in one casing. The compressed gas passes through individual units, comprised of the expansion valve and cooling coil, located in various rooms.

## 2.3.4 Central Type

The central air conditioning plants or the systems are used when large buildings, hotels, theaters, airports, shopping malls etc. are to be air conditioned completely. The window and split air conditioners are used for single rooms or small office spaces. If the whole building is to be cooled it is not economically viable to put window or split air conditioner in each and every room. Further, these small units cannot satisfactorily cool the large halls, auditoriums, receptions areas etc.

The central air conditioning systems are highly sophisticated applications of the air conditioning systems and many a times they tend to be complicated. It is due to this reason that there are very few companies in the world that specialize in these systems. In the modern era of computerization, a number of additional electronic utilities have been added to the central conditioning systems

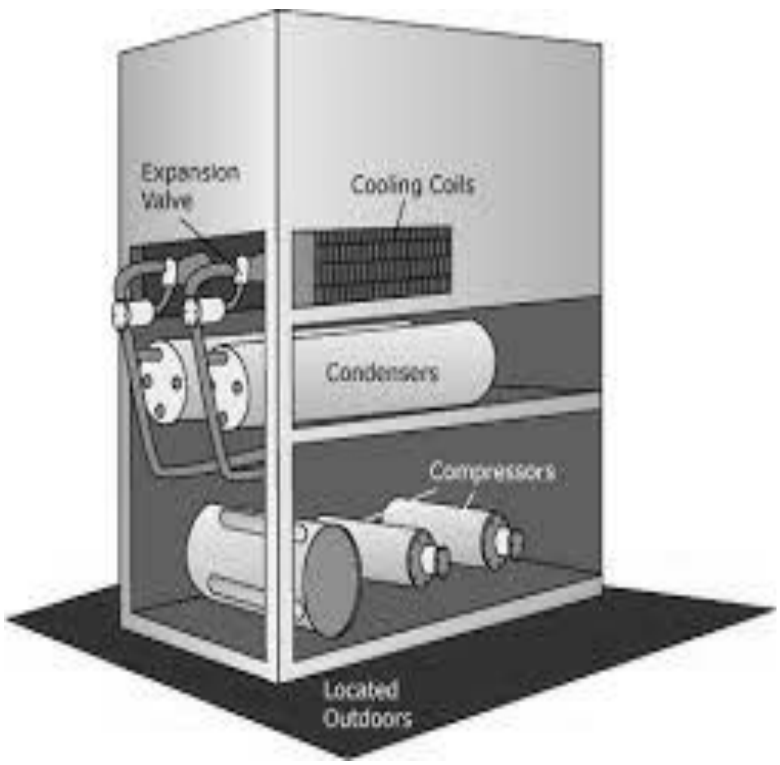


**Figure (2 – 4) : Central Type**

## 2.3.5 Evaporative Type

An evaporative cooler (also swamp cooler, desert cooler and wet air cooler) is a device that cools air through the evaporation of water. Evaporative cooling differs from typical air conditioning systems which use vapor-compression or absorption refrigeration cycles. Evaporative cooling works by employing water's large enthalpy of vaporization. The temperature of dry air can be dropped significantly through the phase transition of liquid water to water vapor (evaporation), which can cool air using much less energy than refrigeration. In extremely dry climates, evaporative cooling of air has the added benefit of conditioning the air with more moisture for the comfort of building occupants

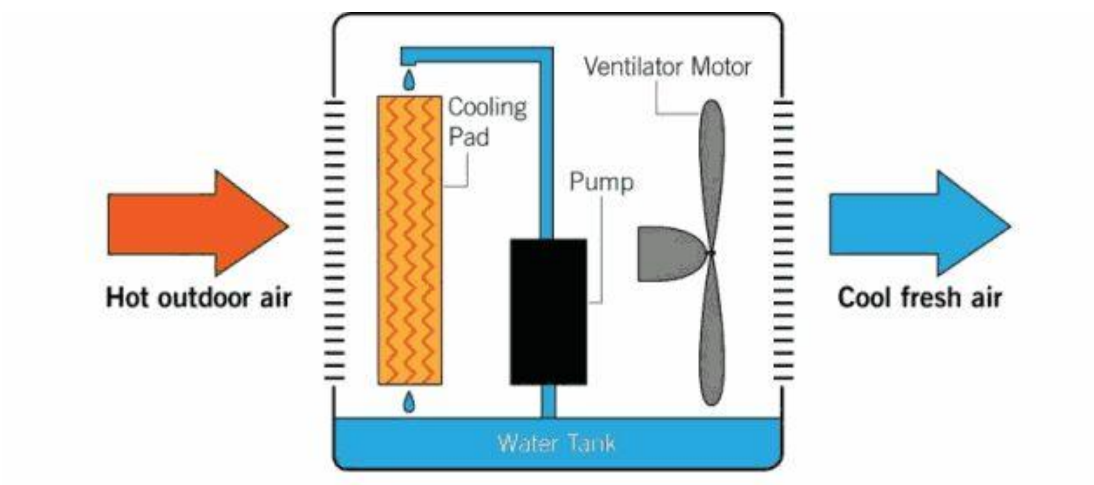


**Figure (1 – 5) : Evaporative Type**

## 2.4 Thermal Load

Heating and cooling loads are the measure of energy needed to be added or removed from a space by the HVAC system to provide the desired level of comfort within a space. Right-sizing the HVAC system begins with an accurate understanding of the heating and cooling loads on a space. Right-sizing is selecting HVAC equipment and designing the air distribution system to meet the accurate predicted heating and cooling loads of the house. The values determined by the heating and cooling load calculation process will dictate the equipment selection and duct design to deliver conditioned air to the rooms of the house, right-sizing the HVAC system. The heating and cooling load calculation results will have a direct impact on first construction costs along with the operating energy efficiency, occupant comfort, indoor air quality, and building durability.

### 2.4.1 Thermal Load Calculation

Heating and cooling load calculations are carried out to estimate the required capacity of heating and cooling systems, which can maintain the required conditions in the conditioned space. To estimate the required cooling or heating capacities, one has to have information regarding the design indoor and outdoor conditions, specifications of the building, specifications of the conditioned space (such as the occupancy, activity level, various appliances and equipment used etc.) and any special requirements of the particular application.

### 2.4.2 Outdoor and Indoor Thermal Load

Indoor design conditions are governed either by thermal comfort conditions or by special requirements for materials or processes housed in a space. In most buildings, such as offices and residences, thermal comfort is the only requirement, and small fluctuations in both temperature and humidity within the comfort zone are not objectionable1. In other occupancies, however, more precise control of temperature and humidity may be required; refer to the appropriate chapter in the ASHRAE Handbook—HVAC Applications for recommendations. Standard 55 provides guidance on appropriate winter and summer indoor design conditions. State or local energy codes and particular owner requirements may also affect the establishment of criteria for indoor design conditions

## 2.5 External Loads

External loads are highly variable, both by season and by time of day. They cause significant changes in the heating and cooling requirements over time, not only in the perimeter building spaces, but for the total building heating/cooling plant

### 2.5.1 Heat Transfer through Fenestration

Heat transfer through transparent surface such as a window, includes heat transfer by conduction due to temperature difference across the window and heat transfer due to solar radiation through the window. The heat transfer through the window by convection is calculated using CLTD being equal to the temperature difference across the window and A equal to the total area of the window.

### 2.5.2 Heat Transfer Due to Infiltration

Heat transfer due to infiltration consists of both sensible as well as latent components.

The infiltration rate depends upon several factors such as the tightness of the building that includes the walls, windows, doors etc and the prevailing wind speed and direction. As mentioned before, the infiltration rate is obtained by using either the air change method or the crack method.

Difference due to wind and stack effects as functions of prevailing wind velocity and direction, inside and outside temperatures, building dimensions and geometry etc. Representative values of infiltration rate.

### 2.5.3 Solar Heat Gain through Glazing

Solar radiation often represents a major cooling load and is highly variable with time and orientation. Careful analysis of heat gains through windows, skylights, and glazed doors is imperative.

Facade self-shadowing, adjacent building shadowing, and reflections from the ground, water, snow, and parking areas must be considered in the loads analysis. Spaces with extensively glazed areas must be analyzed for occupant comfort relative to radiant conditions.

## 2.6 Internal Load

While external loads can be heat gains or heat losses, internal loads are always heat gains.

### 2.6.1 People

The internal cooling load due to occupants consists of both sensible and latent heat components. The rate at which the sensible and latent heat transfer take place depends mainly on the population and activity level of the occupants. Since a portion of the heat transferred by the occupants is in the form of radiation, a Cooling Load Factor (CLF) should be used similar to that used for radiation heat transfer through fenestration.

Table (1) shows typical values of total heat gain from the occupants and also the sensible heat gain fraction as a function of activity in an air conditioned space(6).

The value of Cooling Load Factor (CLF) for occupants depends on the hours after the entry of the occupants into the conditioned space, the total hours spent in the conditioned space and type of the building.

## 2.6.2 Lighting

Lighting adds sensible heat to the conditioned space. Since the heat transferred from the lighting system consists of both radiation and convection, a Cooling Load Factor is used to account for the time lag.

The primary source of heat from lighting comes from light-emitting elements, or lamps, although significant additional heat may be generated from associated appurtenances in the light fixtures that house such lamps, TABLE (3) showing Lighting Power Densities Using the Building Area Method(7).

## 2.6.3 Appliances

In a cooling load estimate, heat gain from all appliances electrical, gas, or steam should be taken into account. Because of the variety of appliances, applications, schedules, use, and installations, estimates can be very subjective. Often, the only information available about heat gain from equipment is that on its nameplate

## 2.6.4 Ventilation Load

The outdoor air ventilation load does not have a direct impact on the conditioned space (except when provided via open windows), but it does impose a load on the HVAC&R equipment. Outdoor air is normally introduced through the HVAC system and adds a load (sensible and latent) to the heating and cooling coils, thus affecting their sizing and selection. The amount of ventilation depends upon the occupancy and function of each space. Refer to Standards 62.1 and 62.2 for recommended ventilation rates; see also the requirements of the local building, mechanical, and energy codes Table (3) minimum ventilation rates in breathing zone[8].

### 2.6.5 Infiltration Load

Infiltration is the uncontrolled flow of outdoor air into a building through cracks and other unintentional openings and through the normal use of exterior doors for entrance and egress. Infiltration is also known as air leakage into a building. In commercial and institutional buildings, uncontrolled natural ventilation, such as through operable windows, may not be desirable from the point of view of energy conservation and comfort. In commercial and institutional buildings with mechanical cooling and forced ventilation, an air- or water-side economizer cycle may be preferable to operable windows for taking advantage of cool outdoor conditions when interior cooling is required. Infiltration may be significant in commercial and institutional buildings, especially in tall, leaky, or under pressurized buildings

## 2.7 Thermal Comfort

Comfort describes a delicate balance of pleasant feeling in the body. A comfortable atmosphere describes our surroundings when we are not aware of discomfort. Providing a comfortable atmosphere for people is the job of the heating and air-conditioning profession. Parameter that affect thermal coffort:-

**1- Dry bulb temperature (DBT)**

is the temperature of the moist air as measured by a standard thermometer or other temperature measuring instruments.

**2- Wet bulb temperature (WBT)**

The wet-bulb temperature is a value indicated on an ordinary thermometer, the bulb of which has been wrapped round with a wick, moistened in water.

**3- Relative humidity (Φ)**

Is defined as the ratio of the mole fraction of water vapour in moist air to mole fraction of water vapour in saturated air at the same temperature and pressure

**4- Humidity ratio (W)**

The humidity ratio (or specific humidity) W is the mass of water associated with each kilogram of dry air

**5- Enthalpy**

The enthalpy of moist air is the sum of the enthalpy of the dry air and the enthalpy of the water vapor

# CHAPTER THREE

# METHODOLOGY

## 3.1 Methodology

The variables affecting cooling load calculating are numerous, often difficult precisely, and always interrelated. Many cooling load components vary in magnitude over a wide range during 24-h period. Since these cyclic changes in load components are often not in phase with each other, analysis is required to establish are resultant maximum cooling load for a building or zone.

## 3.2 Calculation of thermal load by Relation

The CLTD method is a one-step, hand calculation procedure, based on the transfer function method (TFM), and uses table, It may be used to approximate the cooling load corresponding to the first three modes of heat gain (conductive heat gain through surfaces such as windows, walls, and roofs; solar heat gain through fenestrations; and internal heat gain from lights, people, and equipment) and the cooling load from infiltration and ventilation[9].

## 3.3 External Cooling Load

### 3.3.1 Roofs, walls, and conduction through glass

$$q = UA(CLTD) \qquad (3\text{-}1)$$

$U \equiv$ Heat transfer coefficient for roof or wall

$A \equiv$ Area of roof, wall, or glass

$CLTD \equiv$ Cooling load temperature difference, roof, wall, or glass

### 3.3.2 Solar load through glass

$$q = A(SC)(SCL) \qquad (3\text{-}2)$$

$SC \equiv$ Shading coefficient

$SCL \equiv$ Solar cooling load factor with no interior shade or with shade

### 3.3.3 Cooling load from partitions, ceilings, floors

$$q = UA(t_0 - t_{rc}) \qquad (3\text{-}3)$$

$U$ ≡ Design heat transfer coefficient for partition, ceiling, or floor

$A$ ≡ Area of partition, ceiling, or floor

$t_0$ ≡ Temperature in adjacent space

$t_{rc}$ ≡ Inside design temperature (constant) in conditioned space

## 3.4 Internal Cooling Load

### 3.4.1 People

$$q_{sensible} = N(Sensible\ heat\ gain)CLF \qquad (3\text{-}4)$$

$$q_{latent} = N(Latent\ heat\ gain) \qquad (3\text{-}5)$$

$N$ ≡ Number of people in space

$CLF$ ≡ Cooling load factor, by hour of occupancy

CLF 1.0 with high density or 24-h occupancy and/or if cooling off at night or during weekends.

### 3.4.2 Lights

$$q_{el} = WF_{ul}F_{sa}(CLF) \qquad (3\text{-}6)$$

$W$ ≡ Watts input from electrical plans or lighting fixture data

$F_{ul}$ ≡ Lighting use factor, as appropriate

$F_{sa}$ ≡ Special allowance factor, as appropriate

$CLF$ ≡ Cooling load factor, by hour of occupancy

CLF = 1.0 with 24-h light usage and/or if cooling off at night or during weekends

### 3.4.3 Power

$$q_p = PE_F CLF \qquad (3\text{-}7)$$

$P$ ≡ Horsepower rating from electrical plans or manufacturer's data

$E_F$ ≡ Efficiency factors and arrangements to suit circumstance

### 3.4.4 Appliances

$$q_{sensible} = q_{input} F_U F_R (CLF) \qquad (3\text{-}8)$$

OR

$$q_{sensible} = q_{input} F_L (CLF) \qquad (3\text{-}9)$$

$q_{input}$ ≡ Rated energy input from appliances

$F_U$ ≡ Usage factors,

$F_R$ ≡ Radiation factors

$F_L$ ≡ Load factor

### 3.4.5 Ventilation and Infiltration Air

$$q_{sensible} = 1.23Q(t_o - t_i) \qquad (3\text{-}10)$$

$$q_{latent} = 3010Q(W_o - W_i) \qquad (3\text{-}11)$$

$$q_{total} = 1.20Q(h_o - h_i) \qquad (3\text{-}12)$$

$Q \equiv$ Ventilation from ASHRAE Standard 62

$t_o \& t_i \equiv$ Outside, inside air temperature, °C

$W_o \& W_i \equiv$ Outside, inside air humidity ratio, kg (water)/kg (dry air)

$h_o \& h_i \equiv$ Outside, inside air enthalpy, kJ/kg (dry air)

## 3.5 Calculation by software Hourly Analysis Program (HAP)

Carrier's Hourly Analysis Program (HAP) is a computer tool which assists engineers in designing HVAC systems for commercial buildings. HAP is two tools in one. First it is a tool for estimating loads and designing systems. Second, it is a tool for simulating building energy use and calculating energy costs. In this capacity it is useful for LEED®, schematic design and detailed design energy cost evaluations. HAP uses the ASHRAE transfer function method for load calculations and detailed 8,760 hour-by-hour simulation techniques for the energy analysis.

This program is released as two separate, but similar products. The "HAP System Design Load" program provides system design and load estimating features. The full "HAP" program provides the same system design capabilities plus energy analysis features. This Quick Reference Guide deals with both programs

**HAP System Design Features**. HAP estimates design cooling and heating loads for commercial buildings in order to determine required sizes for HVAC system components. Ultimately, the program provides information needed for selecting and specifying equipment. Specifically, the program performs the following tasks(10):

- Calculates design cooling and heating loads for spaces, zones, and coils in the HVAC system.
- Determines required airflow rates for spaces, zones and the system.
- Sizes cooling and heating coils.
- Sizes air circulation fans.
- Sizes chillers and boilers

### 3.5.1 Data input in Hourly analysis software

HAP's main program window which appears when you start the program. Much of the work you will perform entering data and generating reports is done using features of the main program window The HAP main program window consists of six components used to operate the program.

Title Bare

Menu Bare

Tool Bare

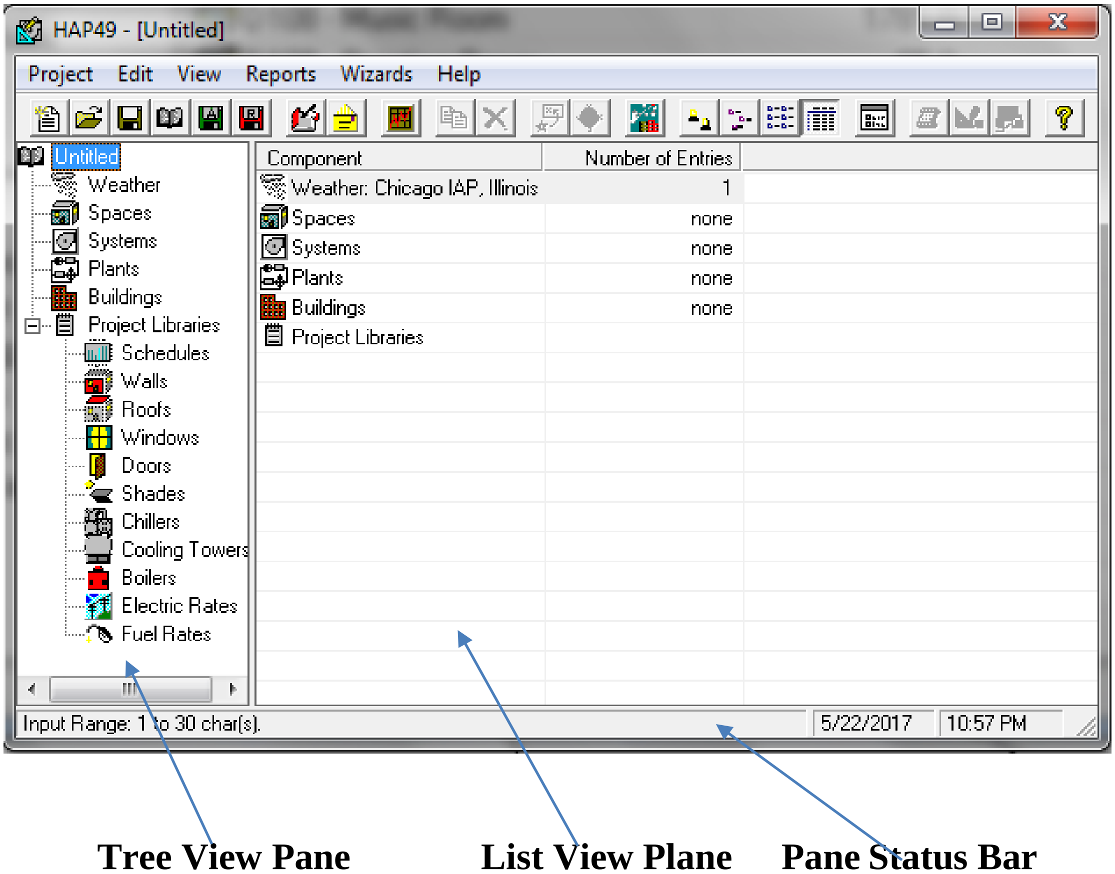


Figure (3 – 1) : User Interface

## 1- Title Bare

lists the program name and the name of the current project. If you are running HAP System Design Load or are running the full HAP but in System Design mode, the program name will be "HAP System Design Load". If you are running the full HAP program with energy analysis features turned on, the program name will simply be "HAP".

## 2- Menu Bar

lies immediately below the title bar. The menu bar contains seven pull-down menus used to perform common program tasks.

## 3- Tool Bar

lies immediately below the menu bar and contains a series of buttons used to perform common program tasks. Each button contains an icon which represents the task it performs. These tasks duplicate many of the options found on the pull-down menus.

**4- Tree View Pane**

It's the left-hand panel in the center of the main program window. It contains a tree image of the major categories of data used by HAP. The tree view acts as the "control panel" when working with program data.

**5- List View Plane**

It's the right-hand panel in the center of the main program window. It contains a list of data items in alphabetical order for one of the categories of data in your project. The list view acts as the second part of the "control panel" when working with program data.

**6- Status Bar**

It's the final component of the main program window and appears at the bottom of the window. The current date and time appear at the right-hand end of the status bar. Pertinent messages appear at the left-hand end of the status bar

## 3.6 Working with HAP Input Windows

While using HAP you will need to create and manage project data All the data you enter and calculate in HAP is stored together within a "project".

Project is simply a container for your data. However, a project can hold data for other programs as well as HAP.

### 3.6.1 Weather properties window:

This window is used to enter the weather conditions in the area which include the latitude, longitude, elevation, summer design bulb temperature and summer design wet bulb temperature.

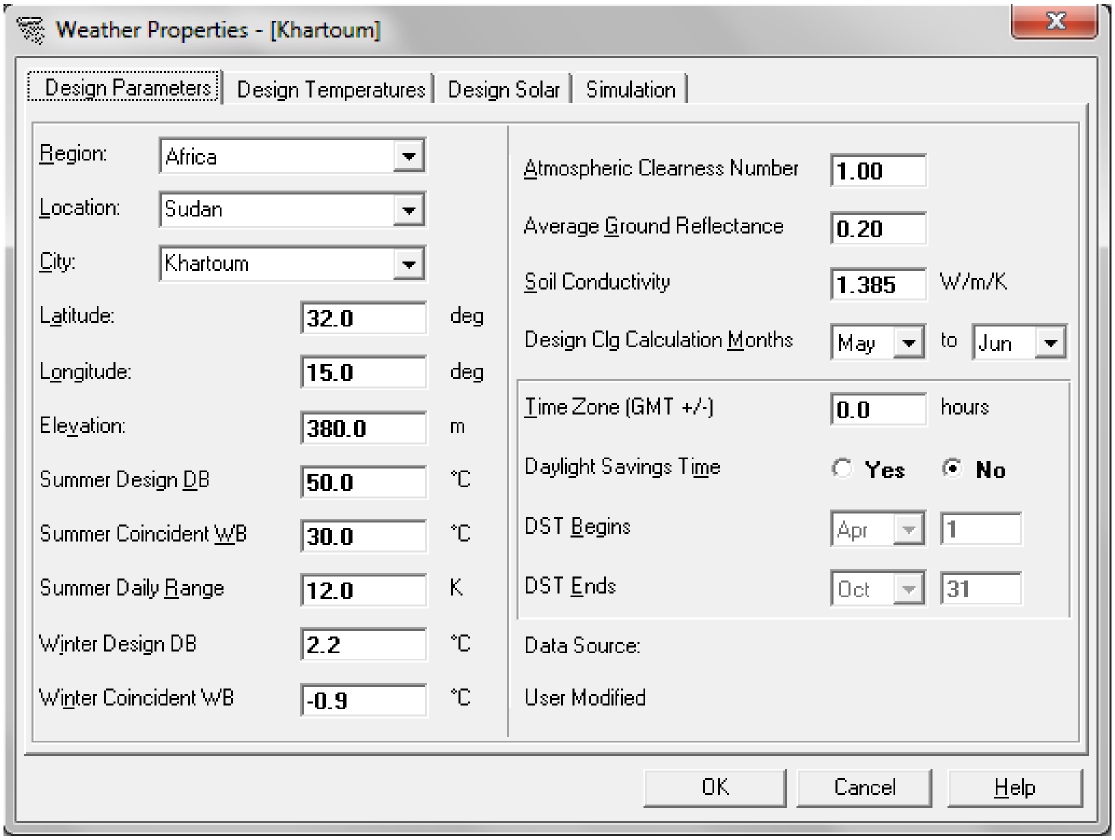


Figure (3– 2) : Weather properties

## 3.6.2 Space Properties window

General windows in space properties contains the name of the space, floor area, average ceiling height and ventilation requirements, and also contain of :

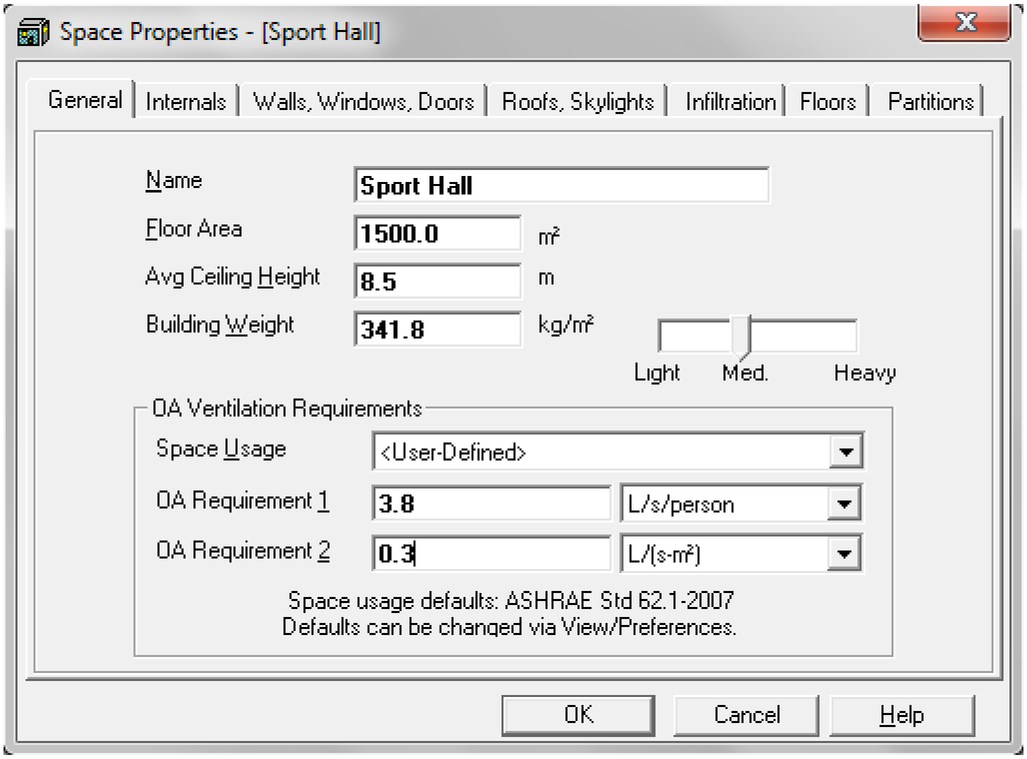


Figure (3 – 3) : Space properties-general

### i. Internal load window:

It consists of the type of light and the thermal load for lighting, equipment's, sensible and latent load of people of people and electric equipment and other devices load.

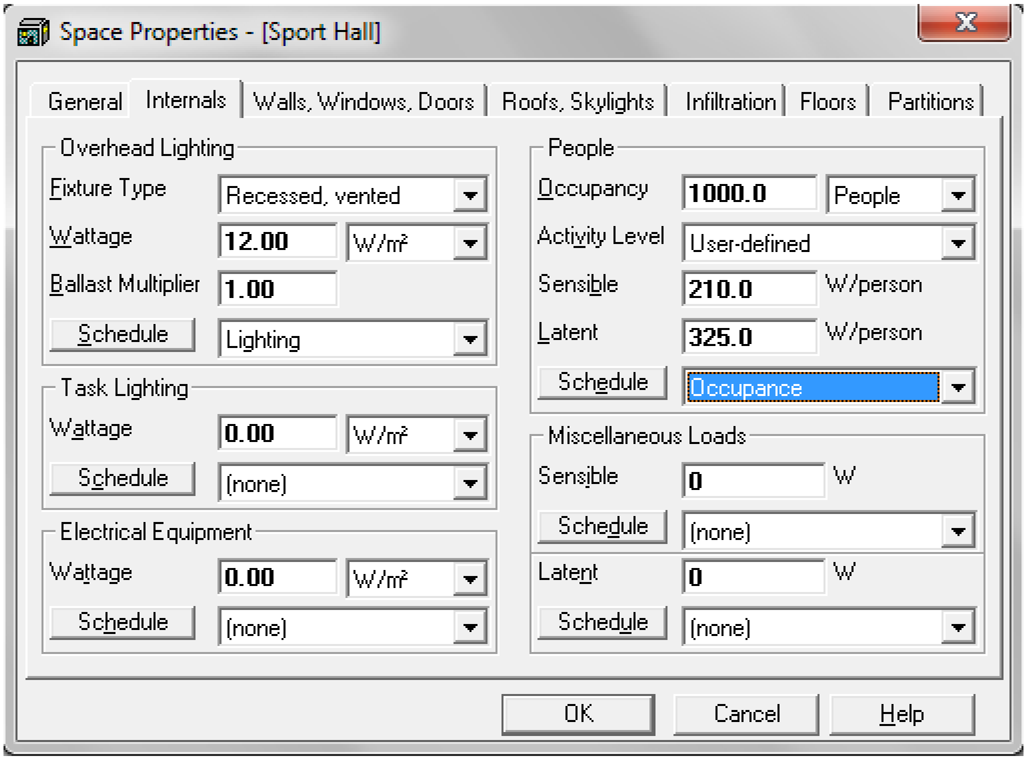


Figure (3 – 4) : Space properties-internal load

## ii. Wall, Window, doors window:

In this window we define the walls that transfer heat to the system it is directions and number of doors and windows in each of these walls

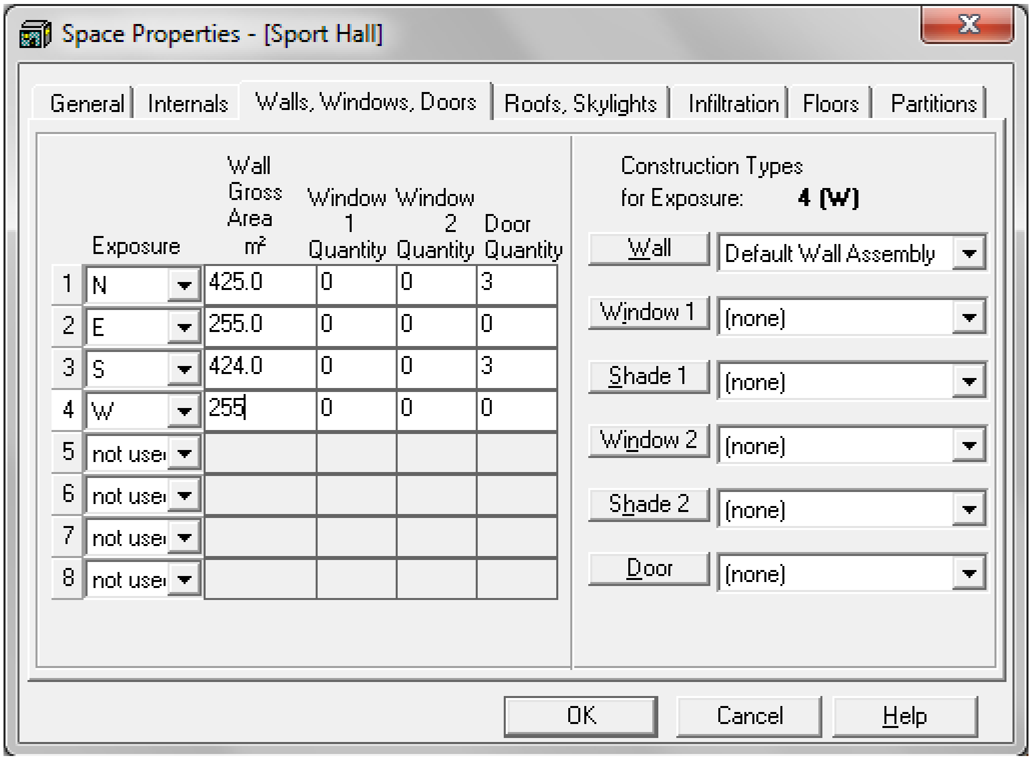


Figure (3 –5) : Space properties-wall, window and door

### iii. Roof-Skylight window:

It contains the roof thickness and type of the roof materials and the roof area

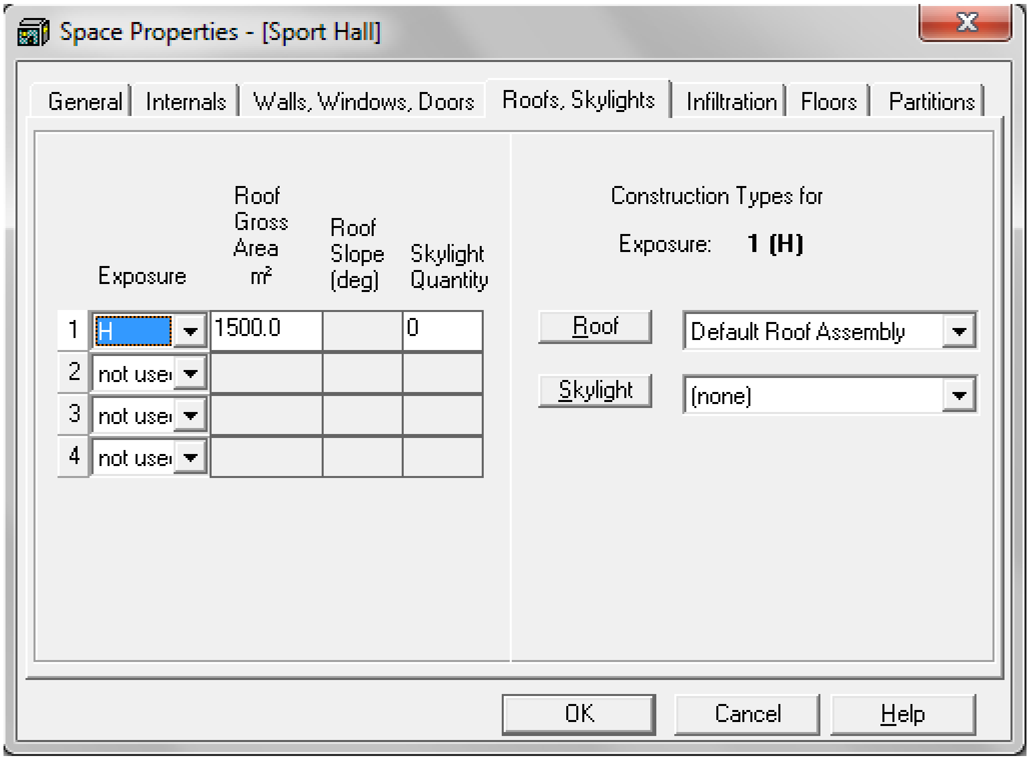


Figure (3 – 6) : Space properties- Roof Data

## iv. Infiltration window

It contains the infiltration rate of cooling and heating load

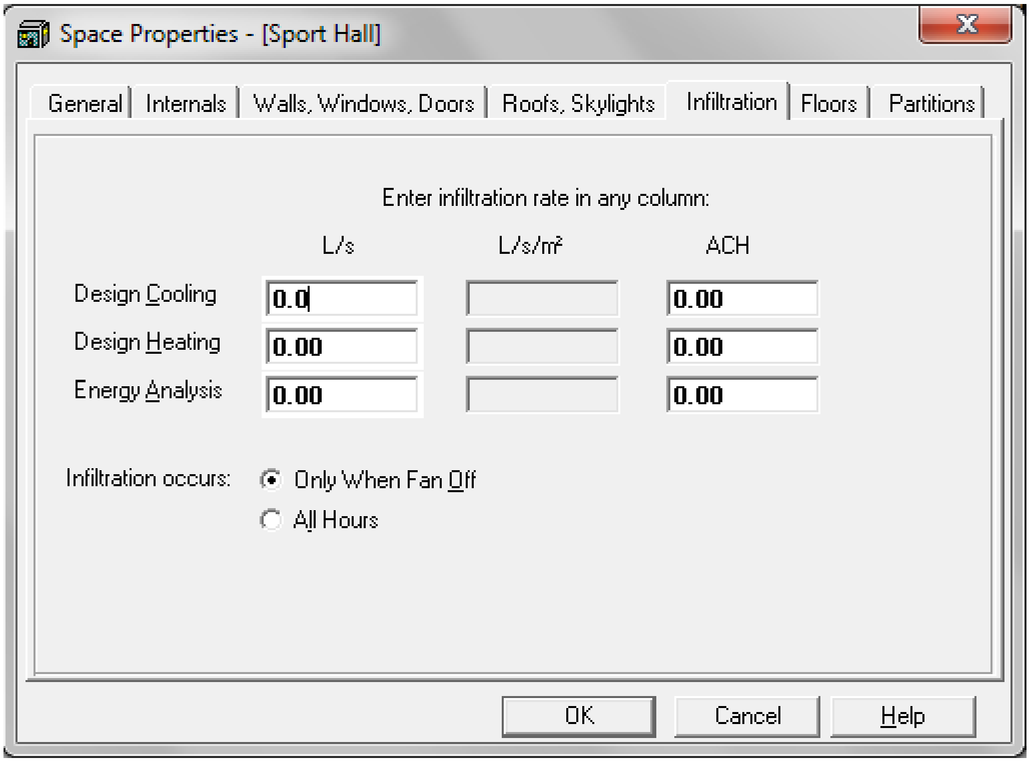


Figure (3 – 7) : Space Properties- Infiltration

## v. Floor

It contains floor type, area and heat transfer coefficient for floor

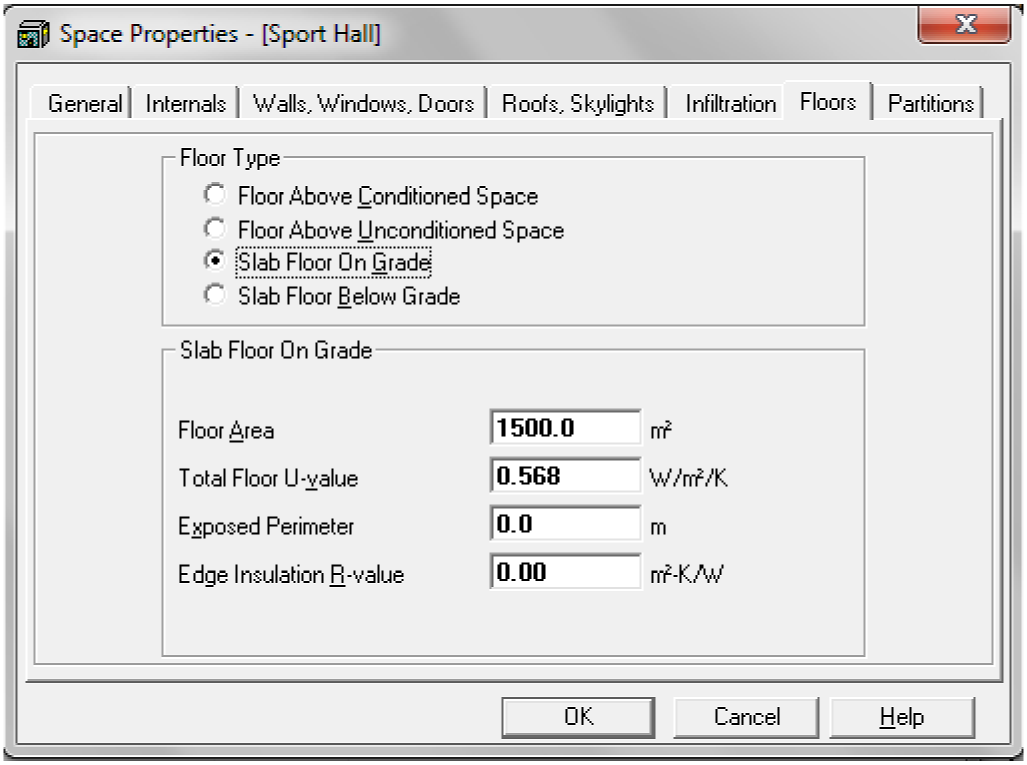


Figure (3 – 8) : Space Properties- Floor

### 3.6.3 Air System Properties window

General window in air system It contains the name, equipment type, air system type and the number of zones, air system properties also contain of

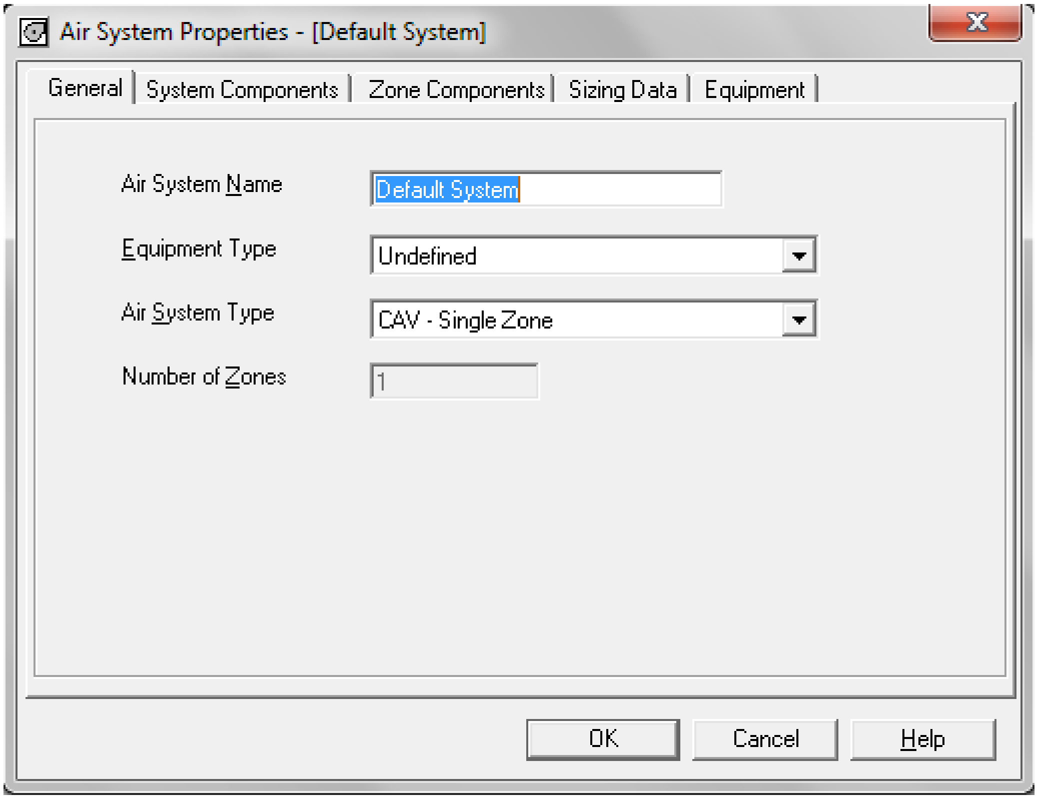


Figure (3 – 9) : Air system Properties- general data

**1- System component**:

It contains the value of relative humidity and leave other variables to it is default values

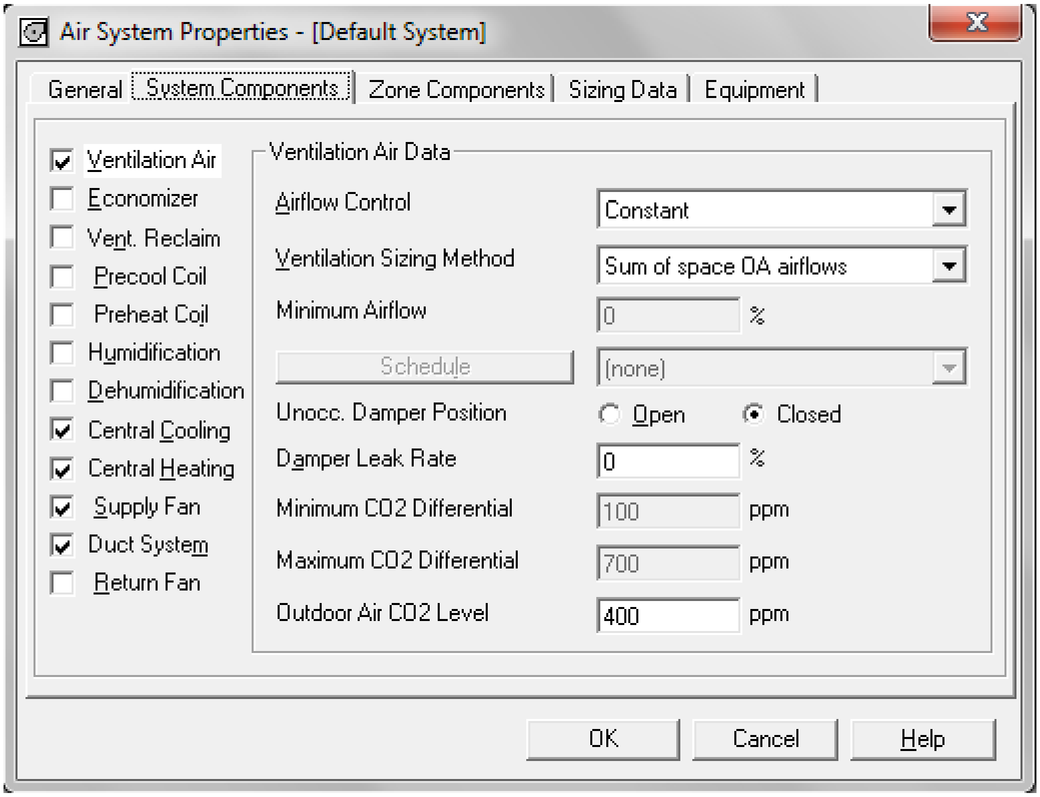


Figure (3– 10) : Air system Properties System component data

## 2- Zone component:

In thermostats menu to schedule the system operation time

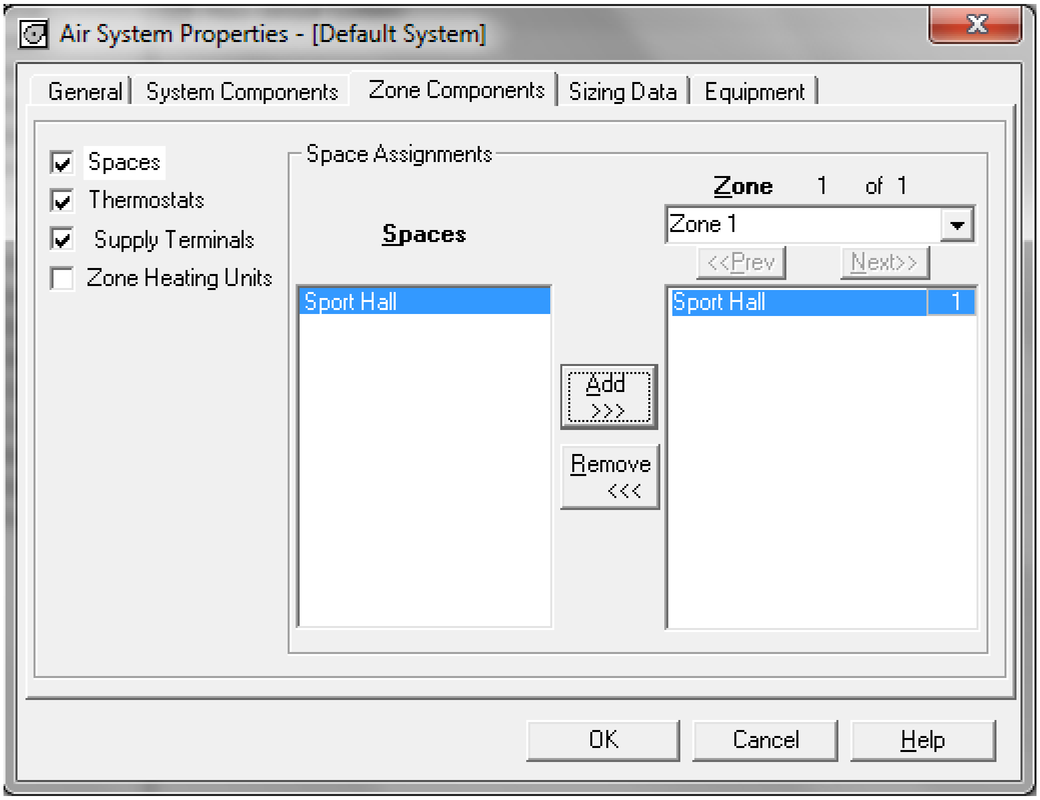


Figure (3 – 11) : Air system Properties Zone component

## 3- Sizing Data

It contains the information of internal require design data

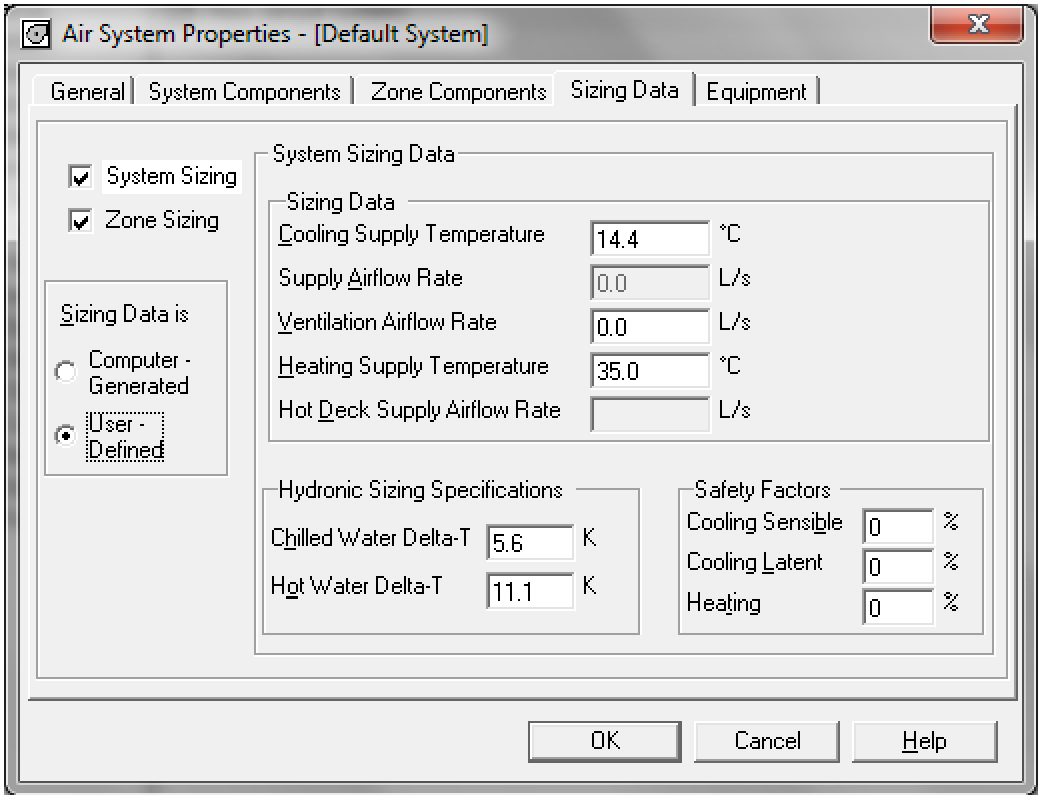


Figure (3 – 12) : Air system Properties Sizing Data

## 3.6.4 System design Reports:

System results detailed report of the sizing of individual components and psychometrics.

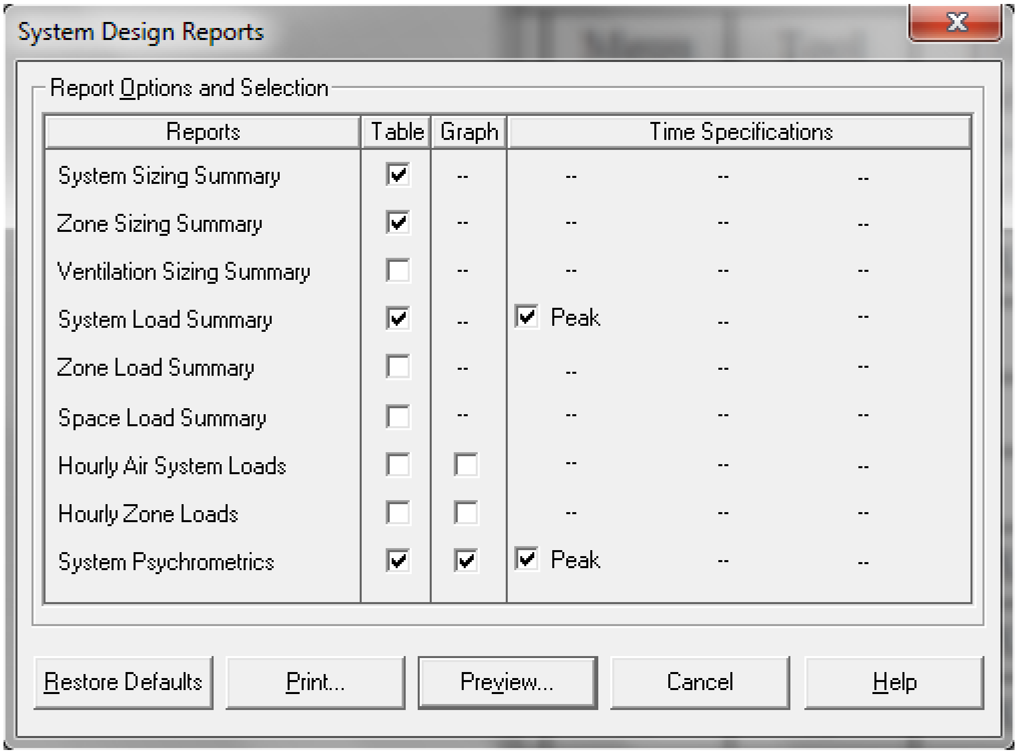


Figure (3 – 13) : System design report

## 3.7 Duct Design

The purpose of air conditioning ductwork is to deliver air from the fan to the diffusers which distribute the air to the room. Air Moves through the Ductwork in Response to a Pressure Difference created by the Fan the necessary pressure difference will be a function of the way the ductwork is laid out and sized. The objective of duct design is to size the duct so as to minimize the pressure drop through the duct, while keeping the size (and cost) of the ductwork to a minimum. Proper duct design requires knowledge of the factors that affect pressure drop and velocity in the duct. 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.

### 3.7.1 Duct system components:

- Vibration isolators
- Take-offs
- Stacks, boots, and heads
- Dampers
- Terminal units
- Air terminals

### 3.7.2 Duct Design Criteria

Several factors must be considered when designing a duct system. Generally, in order of importance they are as follows[11]:

- Space availability
- Installation cost
- Air friction loss
- Noise level
- Duct heat transfer and air flow leakage

### 3.7.3 Types of ducts:

1- Round duct.
2- Oval duct.
3- Rectangular duct.

### 3.7.4 Static pressure:

It is the pressure required to deliver quantity of air (cfm) at required velocity (fpm) by overcoming the resistance offered to the flow of air in the air distribution system.

### 3.7.5 Duct Aspect Ratio

Itis the ratio between long side and the short one (as it increases the air friction in the duct increases).

Maximum AR=3

We will use the following standard conversion:

**1TR=400 CFM**

And from experiences velocity inside the ducts should equal to V=700 fpm. Also we will use MCQUAY duct seizer to calculate ducts sizes.

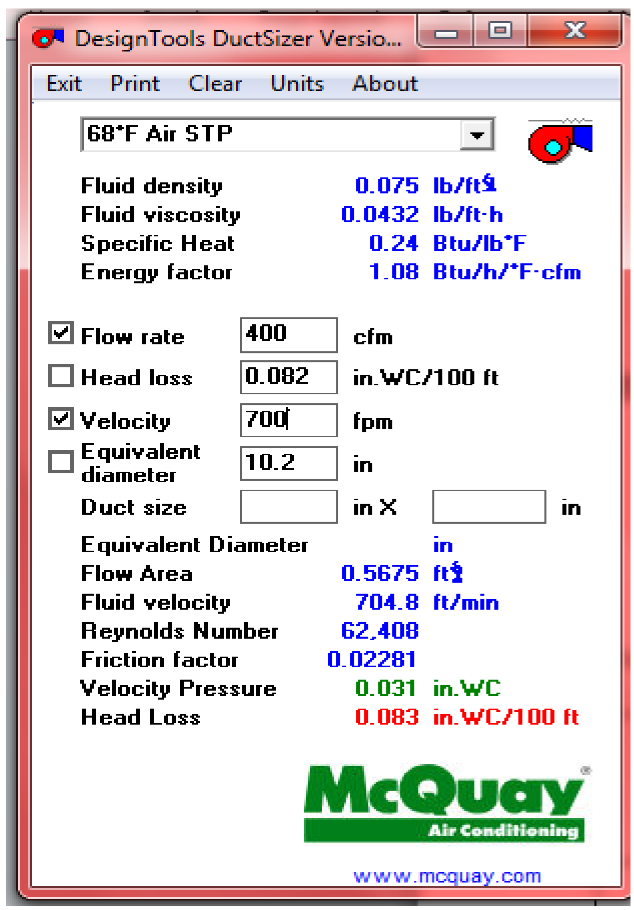


Figure (3-14) MCQUAY duct sizer layout

## 3.8 Conditioning Space

Sport hall for multi [$(50 * 30)m$ dimension] sport ( football , basketball , volleyball….), 1000 occupancy

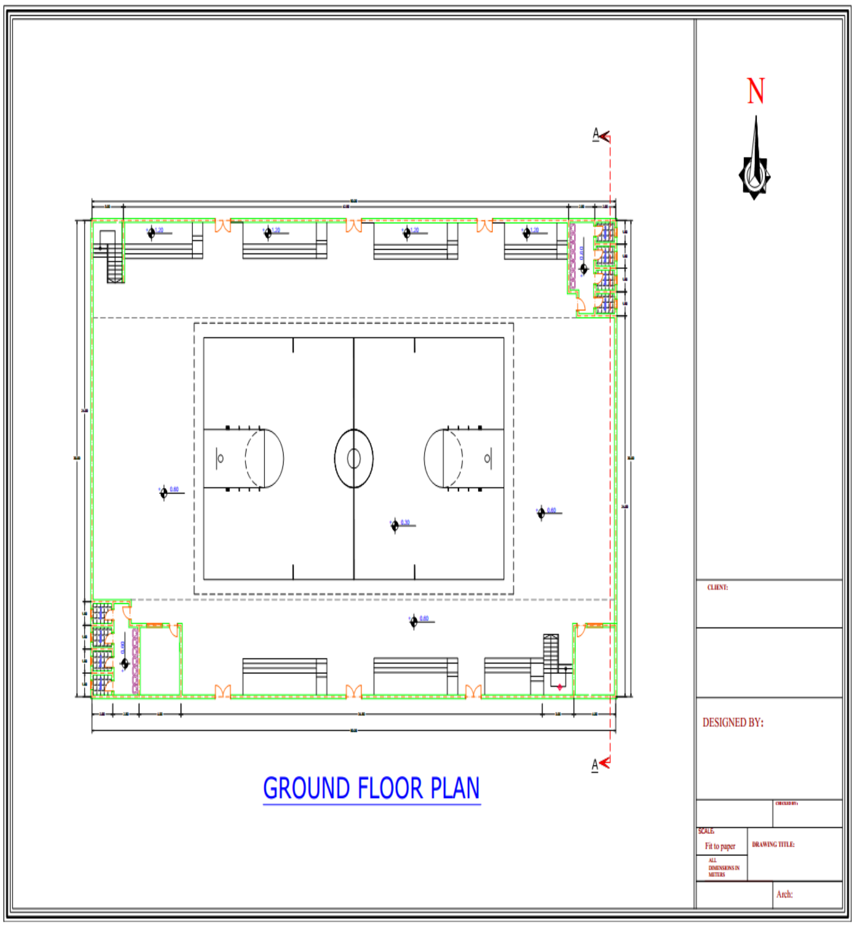


Figure (3-15) **:** conditioning spce

### 3.8.1 Construction Data

**Wall :** 101.6 common brick with 50.8 insulation and 101.6 face brick

**Roof :** steel sheet with 25.4 insulation and suspended ceiling

**Floor :** epoxy floor finishing with 10 cm plan concrete and 150 cm sand

**Door :** 2*2 Wooden Door

**Light Density** : 12 watt per meter square

# CHAPTER FOUR

# CALCULATIONS

## 4.1 Introduction

Functions at arenas and stadiums may be quite varied, so the air-conditioning loads will vary. Arenas and stadiums are not only used for sporting events such as basketball, ice hockey, boxing, and track meets but may also house circuses; rodeos; convocations; social affairs; meetings; rock concerts; car, cycle, and truck events; and special exhibitions such as home, industrial, animal, or sports shows. For multipurpose operations, the designer must provide highly flexible systems. High-volume ventilation may be satisfactory in many instances, depending on load characteristics and outside air conditions(12).

## 4.2 Calculate cooling load By Relation

The CLTD method is a one-step simplification of the transfer function method. The space cooling load is calculated directly by multiplying the heat gain with CLTD, SCL, or CLF instead of first finding the space heat gains and then converting into space cooling loads through the room transfer function(2).

### 4.2.1 External Cooling Load

External cooling load contain every load affected by outside condition which is:

**1- Heat Transmission Through Wall**

Wall construction by layer form inside to outside 101.6mm common brick, 50.8 insulation and 101.6mm face brick. Wall construction group B

$$q = UA(CLTD)$$

$$\frac{1}{U} = \frac{1}{h_i} + \frac{\Delta x_1}{k_1} + \frac{\Delta x_2}{k_2} + \frac{\Delta x_3}{k_3} + \frac{1}{h_o}$$

$h_i$, $h_o$ value from Table (2) for vertical position surface , and $k$ value from Table (5)

$$\frac{1}{U} = \frac{1}{8.29} + \frac{0.1016}{0.727} + \frac{0.0508}{0.043} + \frac{0.1016}{1.333} + \frac{1}{22.7} = 1.56$$

$$U = 0.641 W/(m^2.K)$$

$$CLTD_{corr} = (CLTD + LM) * K + (25.5 - T_i) + (T_o - 29.4)$$

K=0.83, $CLTD$ from Table (6) and $LM$ from Table (7)

$CLTD_{corr}N = (5 + 0.5) * 0.83 + (25.5 - 23) + (48 - 29.4) = 25.665$

$CLTD_{corr}E = (13 + 0.) * 0.83 + (25.5 - 23) + (48 - 29.4) = 31.89$

$CLTD_{corr}S = (8 - 1.6) * 0.83 + (25.5 - 23) + (48 - 29.4) = 26.412$

$CLTD_{corr}W = (8 + 0) * 0.83 + (25.5 - 23) + (48 - 29.4) = 27.740$

$$q_N = 0.641 * 413 * 25.665 = 6.794 KW$$

$q_E = 0.641 * 255 * 31.89 = 5.212 KW$

$q_S = 0.641 * 413 * 26.412 = 6.992 KW$

$q_W = 6.41 * 255 * 27.740 = 4.534 KW$

$$q_T = q_N + q_E + q_S + q_W$$

$q_T = 7.323 + 5.593 + 7.522 + 4.861 = 23.532 KW$

## 2- Heat Transmission Through Roof And Floor

$$q = UA(CLTD)$$

$$\frac{1}{U} = \frac{1}{h_i} + \frac{\Delta x_1}{k_1} + \frac{\Delta x_2}{k_2} + \frac{\Delta x_3}{k_3} + \frac{1}{h_o}$$

$h_i, h_o$ ,value from Table (2) for horizontal position surface, and $k$ value from Table (5), Table (4) and $CLTD_{corr}$ from Table(7)

$$\frac{1}{U} = \frac{1}{5.17} + \frac{0.0508}{0.035} + \frac{0.0244}{5.08} + \frac{1}{22.7} = 1.694$$

$$U = 0.590 W/(m^2.K)$$

$$CLTD_{corr} = [(CLTD + LM) * K + (25.5 - T_i) + (T_o - 29.4)] * f$$

K=1 and $f = 0.75$ [1], $CLTD$ from Table () and $LM$ from Table ()

$$CLTD_{corr} = [(43 + 0.5) * 1 + (25.5 - 23) + (48 - 29.4)] * 0.75 = 48.45$$

$$q_{Roof} = 0.590 * 1500 * 49.95 = 44.206 KW$$

**3- Floors**

For floors directly in contact with the ground, or over an underground basement that is neither ventilated nor conditioned, heat transfer may be neglected for cooling load estimates

**4- Heat Transmission Through Door**

$U_{Door} = 1.703$, Number of Door six Doors and gross area $4m^2$ foe each Doors therefore the total gross area is $24m^2$

$$q = UA(CLTD)$$

$$q = 1.703 * 24 * (48 - 23) = 1.022 KW$$

### 4.2.2 Internal Cooling Load

Internal cooling load its contain every load optioned from internal component

**1- People**

sensible heat gain and latent heat gain for people its obtained Form table (1)

$q_{sensible} = N(Sensible\ heat\ gain)CLF$

$q_{latent} = N(Latent\ heat\ gain)$

$$q_{sensible\ player} = 25 * 210 = 5.25KW$$

$$q_{latent\ player} = 25 * 325 = 8.125KW$$

$$q_{total\ player} = q_{sensible} + q_{latent} = 5.25 + 8.125 = 13.375KW$$

$$q_{sensible\ fans} = 1000 * 65 = 65KW$$

$$q_{latent\ fans} = 1000 * 30 = 30KW$$

$$q_{total\ fans} = q_{sensible} + q_{latent} = 65 + 30 = 95KW$$

$$q_{total} = q_{player} + q_{fans} = 13.375 + 95 = 108.375KW$$

**2- Light**

From Table (3) Lighting Power Densities for sport hall is 12 $W/m^2$ and since the building area is 1500 $m^2$ therefore the total watts is given by

$12\frac{W}{m^2} * 1500\ m^2 = 18000W$

$$q_{el} = WF_{ul}F_{sa}(CLF)$$

$$q_{el} = 18000 * 1 * 1.20 * 1 = 21.600KW$$

**3- Ventilation and Infiltration Air**

From Table (8) the required quantity of air for ventilation is 3.8 liter per second per person, since the occupancy of the hall is 1000 person and the floor area is 1500 m$^2$ with ceiling height 8.5 meter therefor

$$Q = 3.8 * 1000 = 3800$$

Air space volume $= 8.5 * 1500 = 12750 m^3$ corresponding to

(3800 × 3600 s/h × 0.001 m3/L)/12750 = 1.073 air changes per hour

**4- Ventilation**

$$q_{sensible} = 1.23Q(t_o - t_i)$$

$$q_{sensible} = 1.23 * 3800 * (48 - 23) = 116.850KW$$

$$q_{latent} = 3010Q(w_o - w_i)$$

$w_o$& $w_i$ from Psychrometric Chart

$$q_{latent} = 3010 * 3800 * (0.0138 - 0.009) = 54.902KW$$

$$q_{total} = q_{latent} + q_{sensible} = 54.902 + 116.850 = 171.752KW$$

**5- Infiltration**

Window infiltration is zero, since there is no windows. Infiltration through wall surfaces is also neglected as insignificant, surfaces. Calculation of door infiltration however, requires some judgement. The pressure of 1.073 air changes/h in the form of positive ventilation could be sufficient to prevent door infiltration, depending on the degree of simultaneous door openings and the wind direction and velocity.

$$Q_T = q_{Wall} + q_{Roof} + q_{Door} + q_{People} + q_{Light} + q_{Ventolation}$$

$$Q_T = 23.532 + 44.206 + 1.022 + 108.375 + 21.600 + 171.752 = 370.487Kw$$

By using 1.1 as safety factor then total cooling load will be:-

$$Q_T = 370.487 * 1.1 = 407.536Kw$$

$$Q_T = \frac{407.536}{3.5} = 116TR$$

## 4.3 Calculation by software Hourly Analysis Program (HAP)

Program load calculation result report

### Table (4 – 1) : load summary for zone 1

**Air System Design Load Summary for 1**

Project Name: Sport Hall
Prepared by: Alameen Awad/ Atyeb Ahmed/ Mohammed Ameir

06/08/2017
10:33am

| | DESIGN COOLING | | | DESIGN HEATING | | |
|---|---|---|---|---|---|---|
| | COOLING DATA AT May 1200<br>COOLING OA DB / WB 48.0 °C / 25.0 °C | | | HEATING DATA AT DES HTG<br>HEATING OA DB / WB 2.2 °C / -0.9 °C | | |
| ZONE LOADS | Details | Sensible (W) | Latent (W) | Details | Sensible (W) | Latent (W) |
| Window & Skylight Solar Loads | 0 m² | 0 | - | 0 m² | - | - |
| Wall Transmission | 1336 m² | 22384 | - | 1336 m² | 18177 | - |
| Roof Transmission | 888 m² | 26230 | - | 888 m² | 12765 | - |
| Window Transmission | 0 m² | 0 | - | 0 m² | 0 | - |
| Skylight Transmission | 0 m² | 0 | - | 0 m² | 0 | - |
| Door Loads | 24 m² | 936 | - | 24 m² | 725 | - |
| Floor Transmission | 888 m² | 0 | - | 888 m² | 0 | - |
| Partitions | 0 m² | 0 | - | 0 m² | 0 | - |
| Ceiling | 0 m² | 0 | - | 0 m² | 0 | - |
| Overhead Lighting | 10656 W | 10655 | - | 0 | 0 | - |
| Task Lighting | 0 W | 0 | - | 0 | 0 | - |
| Electric Equipment | 0 W | 0 | - | 0 | 0 | - |
| People | 1000 | 67399 | 35200 | 0 | 0 | 0 |
| Infiltration | - | 0 | 0 | - | 0 | 0 |
| Miscellaneous | - | 0 | 0 | - | 0 | 0 |
| Safety Factor | 15% / 10% | 19141 | 3520 | 0% | 0 | 0 |
| **>> Total Zone Loads** | - | **146745** | **38720** | - | **31667** | **0** |
| Zone Conditioning | - | 143847 | 38720 | - | -770 | 0 |
| Plenum Wall Load | 0% | 0 | - | 0 | 0 | - |
| Plenum Roof Load | 0% | 0 | - | 0 | 0 | - |
| Plenum Lighting Load | 0% | 0 | - | 0 | 0 | - |
| Exhaust Fan Load | 0 L/s | 0 | - | 0 L/s | 0 | - |
| Ventilation Load | 4066 L/s | 112498 | -1151 | 4066 L/s | 1206 | 0 |
| Ventilation Fan Load | 0 L/s | 0 | - | 0 L/s | 0 | - |
| Space Fan Coil Fans | - | 0 | - | - | 0 | - |
| Duct Heat Gain / Loss | 0% | 0 | - | 0% | 0 | - |
| **>> Total System Loads** | - | **256344** | **37569** | - | **437** | **0** |
| Terminal Unit Cooling | - | 256344 | 37507 | - | 0 | 0 |
| Terminal Unit Heating | - | 0 | - | - | 0 | - |
| **>> Total Conditioning** | - | **256344** | **37507** | - | **0** | **0** |
| **Key:** | **Positive values are clg loads<br>Negative values are htg loads** | | | **Positive values are htg loads<br>Negative values are clg loads** | | |

### Table (4 – 2) : load summary for zone 2

## Air System Design Load Summary for Default System

Project Name: Sport Hall 06/08/201

Prepared by: Alameen Awad/ Altyeb Ahmed/ Mohammed Ameir 10:33a

| | DESIGN COOLING | | | DESIGN HEATING | | |
|---|---|---|---|---|---|---|
| | COOLING DATA AT May 1200<br>COOLING OA DB / WB 48.0 °C / 25.0 °C | | | HEATING DATA AT DES HTG<br>HEATING OA DB / WB 2.2 °C / -0.9 °C | | |
| ZONE LOADS | Details | Sensible (W) | Latent (W) | Details | Sensible (W) | Latent (W) |
| Window & Skylight Solar Loads | 0 m² | 0 | - | 0 m² | - | - |
| Wall Transmission | 0 m² | 0 | - | 0 m² | 0 | - |
| Roof Transmission | 612 m² | 17860 | - | 612 m² | 8797 | - |
| Window Transmission | 0 m² | 0 | - | 0 m² | 0 | - |
| Skylight Transmission | 0 m² | 0 | - | 0 m² | 0 | - |
| Door Loads | 0 m² | 0 | - | 0 m² | 0 | - |
| Floor Transmission | 612 m² | 0 | - | 612 m² | 0 | - |
| Partitions | 0 m² | 0 | - | 0 m² | 0 | - |
| Ceiling | 0 m² | 0 | - | 0 m² | 0 | - |
| Overhead Lighting | 7344 W | 7341 | - | 0 | 0 | - |
| Task Lighting | 0 W | 0 | - | 0 | 0 | - |
| Electric Equipment | 0 W | 0 | - | 0 | 0 | - |
| People | 25 | 5201 | 7985 | 0 | 0 | 0 |
| Infiltration | - | 0 | 0 | - | 0 | 0 |
| Miscellaneous | - | 0 | 0 | - | 0 | 0 |
| Safety Factor | 15% / 10% | 4560 | 799 | 0% | 0 | 0 |
| >> Total Zone Loads | - | 34962 | 8784 | - | 8797 | 0 |
| Zone Conditioning | - | 34779 | 8784 | - | -5798 | 0 |
| Plenum Wall Load | 0% | 0 | - | 0 | 0 | - |
| Plenum Roof Load | 0% | 0 | - | 0 | 0 | - |
| Plenum Lighting Load | 0% | 0 | - | 0 | 0 | - |
| Exhaust Fan Load | 0 L/s | 0 | - | 0 L/s | 0 | - |
| Ventilation Load | 918 L/s | 25806 | 448 | 918 L/s | 5899 | 0 |
| Ventilation Fan Load | 0 L/s | 0 | - | 0 L/s | 0 | - |
| Space Fan Coil Fans | - | 0 | - | - | 0 | - |
| Duct Heat Gain / Loss | 0% | 0 | - | 0% | 0 | - |
| >> Total System Loads | - | 60585 | 9232 | - | 101 | 0 |
| Terminal Unit Cooling | - | 60585 | 9240 | - | 0 | 0 |
| Terminal Unit Heating | - | 0 | - | - | 0 | - |
| >> Total Conditioning | - | 60585 | 9240 | - | 0 | 0 |
| Key: | Positive values are clg loads<br>Negative values are htg loads | | | Positive values are htg loads<br>Negative values are clg loads | | |

## 4.4 Duct Design

Calculation have been made at constant head loss equal 0.393 pa/m

### Table (4 – 3) : Main Duct

| Duct No | Size | | Flow *l/s* | Velocity *m/s* |
|---|---|---|---|---|
| | Width *mm* | Depth *mm* | | |
| 1 | 1300 | 1500 | 15200 | 8 |
| 2 | 1050 | 1500 | 11400 | 7.8 |
| 3 | 775 | 1500 | 7600 | 7 |
| 4 | 475 | 1500 | 3800 | 6 |

**Table (4 – 4) : Branch Duct**

| Duct No | Size | | Flow *l/s* | Velocity *m/s* |
|---|---|---|---|---|
| | Width *mm* | Depth *mm* | | |
| 1 | 1450 | 500 | 3800 | 6 |
| 2 | 1200 | 500 | 3040 | 5.7 |
| 3 | 950 | 500 | 2280 | 5.3 |
| 4 | 675 | 500 | 1520 | 4.7 |
| 5 | 400 | 500 | 760 | 4 |

**Table (4 – 5) : Diffuser Supply Duct**

| Duct No | Size | | Flow *l/s* | Velocity *m/s* |
|---|---|---|---|---|
| | Width *mm* | Depth *mm* | | |
| 1 | 300 | 400 | 380 | 3.4 |
| 2 | 300 | 400 | 380 | 3.4 |
| 3 | 300 | 400 | 380 | 3.4 |
| 4 | 300 | 400 | 380 | 3.4 |
| 5 | 300 | 400 | 380 | 3.4 |
| 6 | 300 | 400 | 380 | 3.4 |
| 7 | 300 | 400 | 380 | 3.4 |
| 8 | 300 | 400 | 380 | 3.4 |
| 9 | 300 | 400 | 380 | 3.4 |

| | | | | |
|---|---|---|---|---|
| 10 | 300 | 400 | 380 | 3.4 |

# CHAPTER

# FIVE

# EQUIPMENT SELECTION

## 5.1 Introduction

Selection of equipment's is an important factor in design process, where a good Selection of equipment's makes the designer achieves the objective of project. Selection of a suitable air conditioning system depends on:

1. Capacity, performance and spatial requirements

2. Initial and running costs

3. Required system reliability and flexibility

4. Maintainability

5. Architectural constraints

## 5.2 Packaged Units

A packaged unit (PU) is a self-contained air conditioner. It conditions the air and provides it with motive force and is equipped with its own heating and cooling sources. The packaged unit is the primary equipment in a packaged air-conditioning system and is always equipped with a DX coil for cooling, unlike an AHU. R-22, R-134a, and others are used as refrigerants in packaged units.

The portion that handles air in a packaged unit is called an air handler to distinguish it from an AHU. Like an AHU, an indoor air handler has an indoor fan, a DX coil (indoor coil), filters, dampers, and controls. Packaged units can be classified according to their place of installation: rooftop, indoor, and split packaged units.

### 5.2.1 Unit Selection

The estimated total cooling load for the Sport Hall is found to be 103 T.O.R (by using the software) and 115 T.O.R (by using manual calculation) so we are going to select 50Z030 CARRIER fore rooftop unit package with 30 T.O.R and one units as stand by units [13]

Rooftop heating and cooling units are made by many manufacturers. Some units are delivered with a full refrigerant charge. This means there are no refrigerant lines to connect. This cuts labor costs and installation time. Since the unit is on the rooftop, no inside room has to be allocated for the heating and cooling equipment.

## 5.3 Diffusers Selection

A diffuser is the mechanical device that is designed to control the characteristics of a fluid at the entrance to a thermodynamic open system. Flow through nozzles and diffusers may or may not be assumed to be adiabatic. Frictional effects may sometimes be important, but usually they are neglected

Since the requirement flow for one diffuser is $805cfm$ so we selected a 250, 250-AA diffuser from Titus diffuser Catalog with $805cfm$ 4-way Discharge Pattern and 4.3 & 6.4 $m$ throw[14]

Figure (5 – 1): 250, 250-AA Titus diffuser

## 5.4 Conclusion

The objectives of this research have been achieved as follows :-

- The total cooling load for the sport hall has been calculated using HVAC HAP software and it found to be 103 ton of refrigeration (T.O.R) and using manual hand calculation and it found to be 116 ton of refrigeration (T.O.R) and equipment have been selected according to the maximum cooling load.
- Duct distribution system have been made using MCQUAY duct sizer design tool and constant head loss $(pa/m)$ method according to diffuser flow.
- Diffuser selection have been made according to diffuser flow which is calculated by divided the total flow rate to the number of diffuser.
- Suitable equipment has been chosen According to the results above.

## Recommendations

- Using HAP software or any other software to estimate cooling load instead of manual method because its more accurate and take less effort and time
- It's very important to control and monitor building's mechanical and electrical equipment such as for ventilation, lighting, power systems, fire systems, and security systems. Using buildings management systems (BMS) or Buildings Automation Systems (BAS).

## 5.5 References


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5) Refrigeration & air conditioning 40 lessons on refrigeration and air conditioning EE IIT, Kharagpur, India 2008.
6) 1997 ASHRAE Fundamentals Handbook (SI).
7) ASHRAE/IESNA STANDARD 90.1-1999, Energy Standard for Buildings Except Low-Rise Residential Buildings.
8) ANSIIASHRAE Standard 62.1 .2007, Ventilation for Acceptable Indoor Air Quality.
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10) HAP Quick Reference Guide, 10th Edition…..( HAP v5.00) …..4/2016
11) 2009 ASHRAE Handbook—Fundamentals (SI).
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13) Carrier Commercial Products Guide 2002.
14) Titus Diffuser Catalogue.

# APPENDIX

# Appendix (A)

## Table 1 Rates of Heat Gain from Occupants of Conditioned Spaces

| | | Total Heat, W | | | | % Sensible Heat t[b] | |
|---|---|---|---|---|---|---|---|
| Latent | | Radiant | | | Sensible | | |
| **Degree of Activity** | | **Male** | **M/F**[a] | **W** | **W** | **Low *V*** | **High *V*** |
| Seated at theater | Theater, matinee | 115 | 95 | 65 | 30 | | |
| Seated at theater, night | Theater, night | 115 | 105 | 70 | 35 | 60 | 27 |
| Seated, very light work | Offices, hotels, apartments | 130 | 115 | 70 | 45 | | |
| Moderately active office work | Offices, hotels, apartments | 140 | 130 | 75 | 55 | | |
| Standing, light work; walking | Department store; retail store | 160 | 130 | 75 | 55 | 58 | 38 |
| Walking, standing | Drug store, bank | 160 | 145 | 75 | 70 | | |
| Sedentary work | Restaurant[c] | 145 | 160 | 80 | 80 | | |
| Light bench work | Factory | 235 | 220 | 80 | 140 | | |
| Moderate dancing | Dance hall | 265 | 250 | 90 | 160 | 49 | 35 |
| Walking 4.8 km/h; light machine work | Factory | 295 | 295 | 110 | 185 | | |
| Bowling[d] | Bowling alley | 440 | 425 | 170 | 255 | | |
| Heavy work | Factory | 440 | 425 | 170 | 255 | 54 | 19 |
| Heavy machine work; lifting | Factory | 470 | 470 | 185 | 285 | | |
| Athletics | Gymnasium | 585 | 525 | 210 | 325 | | |
| **Heat, Heat, Adjusted,** | | | | | **Adult** | | |

# Appendix (B)

## Table 2  Surface Conductances and Resistances for Air

| Position of Surface | Direction of Heat Flow | Non-reflective ε = 0.90 | | Reflective ε = 0.05ε = 0.20 | | | |
|---|---|---|---|---|---|---|---|
| | | $h_i$ | $R$ | $h_i$ | $R$ | $h_i$ | $R$ |
| STILL AIR Horizontal | Upward | 9.26 | 0.11 | 5.17 | 0.19 | 4.32 | 0.23 |
| Sloping—45° | Upward | 9.09 | 0.11 | 5.00 | 0.20 | 4.15 | 0.24 |
| Vertical | Horizontal | 8.29 | 0.12 | 4.20 | 0.24 | 3.35 | 0.30 |
| Sloping—45° | Downward | 7.50 | 0.13 | 3.41 | 0.29 | 2.56 | 0.39 |
| Horizontal | Downward | 6.13 | 0.16 | 2.10 | 0.48 | 1.25 | 0.80 |
| MOVING AIR (Any position) | | $h_o$ | $R$ | | | | |
| Any Wind (for winter) | | 34.0 | 0.030 | — | — | — | — |
| 6.7 m/s (24 km/h) Wind (for summer) Any 3.4 m/s (12 km/h) | | 22.7 | 0.044 | — | — | — | — |

# Appendix (C)

## Table 3 Lighting Power Densities Using the Building Area Method

| Building Area Type | ($W/m^2$) Lighting Power Density |
|---|---|
| Automotive Facility | 10 |
| Convention Center | 13 |
| Court House | 13 |
| Dining: Bar Lounge/Leisure | 14 |
| Dining: Cafeteria/Fast Food | 15 |
| Dining: Family | 17 |
| Dormitory | 11 |
| Exercise Center | 11 |
| Gymnasium | 12 |
| Healthcare-Clinic | 11 |
| Hospital | 13 |
| Hotel | 11 |
| Library | 14 |
| Manufacturing Facility | 14 |
| Motel | 11 |
| Motion Picture Theater | 13 |
| Multi-Family | 8 |
| Museum | 12 |
| Office | 11 |
| Parking Garage | 3 |
| Penitentiary | 11 |
| Performing Arts Theater | 17 |
| Police/Fire Station | 11 |
| Post Office | 12 |
| Religious Building | 14 |
| Retail | 16 |
| School/University | 13 |
| Sports Arena | 12 |
| Town Hall | 12 |
| Transportation | 11 |
| Warehouse | 9 |
| Workshop | 15 |

# Appendix (D)

## Table 4 Cooling Load Temperature Difference for Calculate Cooling Load From Flat Roof

| Roof No | Description of Construction | Weight, kg/m² | U-value, W/m²·°C | Solar Time, h 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | Hour of Maximum CLTD | Minimum CLTD | Maximum CLTD | Difference CLTD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Without Suspended Ceiling** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1 | Steel sheet with 25.4-mm (or 50.8-mm) insulation | 34 (39) | 1.209 (0.704) | 0 | −1 | −2 | −2 | −3 | −2 | 3 | 11 | 19 | 27 | 34 | 40 | 43 | 44 | 43 | 39 | 33 | 25 | 17 | 10 | 7 | 5 | 3 | 1 | 14 | −3 | 44 | 47 |
| 2 | 25.4-mm wood with 25.4-mm insulation | 39 | 0.965 | 3 | 2 | 0 | −1 | −2 | −2 | −1 | 2 | 8 | 15 | 22 | 29 | 35 | 39 | 41 | 41 | 39 | 35 | 29 | 21 | 15 | 11 | 8 | 5 | 16 | −2 | 41 | 43 |
| 3 | 101.6-mm l.w concrete | 88 | 1.209 | 5 | 3 | 1 | 0 | −1 | −2 | −2 | 1 | 5 | 11 | 18 | 25 | 31 | 36 | 39 | 40 | 40 | 37 | 32 | 25 | 19 | 14 | 10 | 7 | 16 | −2 | 40 | 42 |
| 4 | 50.8-mm h.w. concrete with 25.4-mm (or 50.8-mm) insulation | 142 | 1.170 (0.693) | 7 | 5 | 3 | 2 | 0 | −1 | 0 | 2 | 6 | 11 | 17 | 23 | 28 | 33 | 36 | 37 | 37 | 34 | 30 | 25 | 20 | 16 | 12 | 10 | 16 | −1 | 37 | 38 |
| 5 | 25.4-mm wood with 50.8-mm insulation | 44 | 0.619 | 2 | 0 | -2 | -3 | -4 | -4 | -4 | -2 | 3 | 9 | 15 | 22 | 27 | 32 | 35 | 36 | 35 | 32 | 27 | 20 | 14 | 10 | 6 | 3 | 16 | −4 | 36 | 40 |
| 6 | 152.4-mm l.w. concrete | 117 | 0.897 | 12 | 10 | 7 | 5 | 3 | 2 | 1 | 0 | 2 | 4 | 8 | 13 | 18 | 24 | 29 | 33 | 35 | 36 | 35 | 32 | 28 | 24 | 19 | 16 | 18 | 0 | 36 | 36 |
| 7 | 63.5-mm wood with 25.4-mm insulation | 63 | 0.738 | 16 | 13 | 11 | 9 | 7 | 6 | 4 | 3 | 4 | 5 | 8 | 11 | 15 | 19 | 23 | 27 | 29 | 31 | 31 | 30 | 27 | 25 | 22 | 19 | 19 | 3 | 31 | 28 |
| 8 | 203.2-mm l.w. concrete | 151 | 0.715 | 20 | 17 | 14 | 12 | 10 | 8 | 6 | 5 | 4 | 4 | 5 | 7 | 11 | 14 | 18 | 22 | 25 | 28 | 30 | 30 | 29 | 27 | 25 | 22 | 20 | 4 | 30 | 26 |
| 9 | 101.6-mm h.w. concrete with 25.4-mm (or 50.8-mm) insulation | 254 (254) | 1.136 (0.681) | 14 | 12 | 10 | 8 | 7 | 5 | 4 | 4 | 6 | 8 | 11 | 15 | 18 | 22 | 25 | 28 | 29 | 30 | 29 | 27 | 24 | 21 | 19 | 16 | 18 | 4 | 30 | 26 |
| 10 | 63.5-mm wood with 50.8-mm insulation | 63 | 0.528 | 18 | 15 | 13 | 11 | 9 | 8 | 6 | 5 | 5 | 5 | 7 | 10 | 13 | 17 | 21 | 24 | 27 | 28 | 29 | 29 | 27 | 25 | 23 | 20 | 19 | 5 | 29 | 24 |
| 11 | Roof terrace system | 366 | 0.602 | 19 | 17 | 15 | 14 | 12 | 11 | 9 | 8 | 7 | 8 | 8 | 10 | 12 | 15 | 18 | 20 | 22 | 24 | 25 | 26 | 25 | 24 | 22 | 21 | 20 | 7 | 26 | 19 |
| 12 | 152.4-mm h.w. concrete with 25.4-mm (or 50.8-mm) insulation | 366 (366) | (1.090) (0.664) | 18 | 16 | 14 | 12 | 11 | 10 | 9 | 8 | 8 | 9 | 10 | 12 | 15 | 17 | 20 | 22 | 24 | 25 | 25 | 25 | 24 | 22 | 20 | 19 | 19 | 8 | 25 | 17 |
| 13 | 101.6-mm wood with 25.4-mm (or 50.8-mm) insulation | 83 (88) | 0.602 (0.443) | 21 | 20 | 18 | 17 | 15 | 14 | 13 | 11 | 10 | 9 | 9 | 9 | 10 | 12 | 14 | 16 | 18 | 20 | 22 | 23 | 24 | 24 | 23 | 22 | 22 | 9 | 24 | 15 |
| | **With Suspended Ceiling** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1 | Steel Sheet with 25.4-mm (or 50.8-mm) insulation | 44 (49) | 0.761 (0.522) | 1 | 0 | -1 | -2 | -3 | -3 | 0 | 5 | 13 | 20 | 28 | 35 | 40 | 43 | 43 | 41 | 37 | 31 | 23 | 15 | 10 | 7 | 5 | 3 | 15 | −3 | 43 | 46 |
| 2 | 25.4-mm wood with 25.4-mm insulation | 49 | 0.653 | 11 | 8 | 6 | 5 | 3 | 2 | 1 | 2 | 4 | 7 | 12 | 17 | 22 | 27 | 31 | 33 | 35 | 34 | 32 | 28 | 24 | 20 | 17 | 14 | 17 | 1 | 35 | 34 |
| 3 | 101.6-mm l.w. concrete | 97 | 0.761 | 10 | 8 | 6 | 4 | 2 | 1 | 0 | 0 | 2 | 6 | 10 | 16 | 21 | 27 | 31 | 34 | 36 | 36 | 34 | 30 | 26 | 21 | 17 | 13 | 17 | 0 | 36 | 36 |
| 4 | 50.8-mm h.w. concrete with 25.4-mm insulation | 146 | 0.744 | 16 | 14 | 13 | 11 | 10 | 8 | 7 | 7 | 8 | 9 | 11 | 14 | 17 | 19 | 22 | 24 | 25 | 26 | 26 | 25 | 23 | 21 | 20 | 18 | 18 | 7 | 26 | 19 |
| 5 | 25.4-mm wood with 50.8-mm insulation | 49 | 0.471 | 14 | 11 | 9 | 7 | 5 | 4 | 3 | 3 | 4 | 6 | 10 | 14 | 18 | 23 | 27 | 30 | 31 | 32 | 31 | 29 | 26 | 22 | 19 | 16 | 18 | 3 | 32 | 30 |
| 6 | 152.4-mm l.w. concrete | 127 | 0.619 | 18 | 15 | 13 | 11 | 9 | 7 | 6 | 4 | 4 | 4 | 6 | 9 | 12 | 16 | 20 | 24 | 27 | 29 | 30 | 30 | 28 | 26 | 23 | 20 | 20 | 4 | 30 | 26 |
| 7 | 63.5-mm wood with 25.4-mm insulation | 73 | 0.545 | 19 | 18 | 16 | 14 | 13 | 12 | 10 | 9 | 8 | 8 | 9 | 10 | 12 | 14 | 17 | 19 | 21 | 23 | 24 | 25 | 24 | 23 | 22 | 21 | 20 | 8 | 25 | 17 |
| 8 | 203.2-mm l.w. concrete | 161 | 0.528 | 22 | 20 | 18 | 16 | 15 | 13 | 11 | 10 | 9 | 8 | 8 | 8 | 9 | 11 | 14 | 16 | 19 | 21 | 23 | 25 | 25 | 25 | 24 | 23 | 20 | 8 | 25 | 17 |
| 9 | 101.6-mm h.w. concrete with 25.4-mm (or 50.8-mm) insulation | 259 (264) | 0.727 (0.511) | 17 | 16 | 15 | 14 | 13 | 13 | 12 | 11 | 11 | 11 | 12 | 13 | 15 | 16 | 18 | 19 | 20 | 21 | 21 | 21 | 21 | 20 | 19 | 18 | 19 | 11 | 21 | 10 |
| 10 | 63.5-mm wood with 50.8-mm insulation | 73 | 0.409 | 19 | 18 | 17 | 16 | 14 | 13 | 12 | 11 | 10 | 10 | 10 | 11 | 12 | 14 | 16 | 18 | 19 | 21 | 22 | 23 | 23 | 22 | 22 | 21 | 21 | 10 | 23 | 13 |
| 11 | Roof terrace system | 376 | 0.466 | 17 | 16 | 16 | 15 | 15 | 14 | 13 | 13 | 13 | 12 | 12 | 13 | 13 | 14 | 15 | 16 | 16 | 17 | 18 | 18 | 19 | 18 | 18 | 18 | 21 | 12 | 19 | 7 |
| 12 | 152.4-mm h.w. concrete with 25.4-mm (or 50.8-mm) insulation | 376 (376) | 0.710 0.499 | 16 | 16 | 15 | 15 | 14 | 13 | 13 | 12 | 12 | 12 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 18 | 19 | 19 | 19 | 18 | 18 | 18 | 20 | 12 | 19 | 7 |
| 13 | 101.6-mm wood with 25.4-mm (or 50.8-mm) insulation | 93 (97) | 0.465 (0.363) | 20 | 19 | 19 | 18 | 17 | 16 | 15 | 14 | 14 | 13 | 12 | 12 | 12 | 12 | 13 | 14 | 15 | 16 | 18 | 19 | 20 | 20 | 20 | 20 | 23 | 12 | 20 | 8 |

# Appendix (E)

## Table 5 Wall Construction Grop

| Weight (kg/m²) | U-Value (W/m²·°C) | Group No. | Description of Construction | Weight (lb/ft²) | U-Value (Btu/h·ft²·F) | Code Numbers of Layers (see Table 8) |
|---|---|---|---|---|---|---|
| 405 | 2.033 | | 101.6-mm (4-in.) Face Brick + (*Brick*) | | | |
| 405 | 2.033 | C | Air Space + 101.6-mm (4-in.) Face Brick | 83 | 0.358 | A0, A2, B1, A2, E0 |
| 439 | 2.356 | D | 101.6-mm (4-in.) Common Brick | 90 | 0.415 | A0, A2, C4, E1, E0 |
| 439 | 0.987-1.709 | C | 25.4-mm (1-in.) Insulation or Air Space + 101.6-mm (4-in.) Common Brick | 90 | 0.174-0.301 | A0, A2, C4, B1/B2, E1, E0 |
| 430 | 0.630 | B | 50.8-mm (2-in.) Insulation + 101.6-mm (4-in.) Common Brick | 88 | 0.111 | A0, A2, B3, C4, E1, E0 |
| 635 | 1.714 | B | 203.2-mm (8-in.) Common Brick | 130 | 0.302 | A0, A2, C9, E1, E0 |
| 635 | 0.874-1.379 | A | Insulation or Air Space + 203.2-mm (8-in.) Common brick | 130 | 0.154-0.243 | A0, A2, C9, B1/B2, E1, E0 |
| | | | 101.6-mm (4-in.) Face Brick + (*H.W. Concrete*) | | | |
| 459 | 1.987 | C | Air Space + 50.8-mm (2-in.) Concrete | 94 | 0.350 | A0, A2, B1, C5, E1, E0 |
| 474 | 0.658 | B | 50.8-mm (2-in.) Insulation + 101.6-mm (4-in.) Concrete | 97 | 0.116 | A0, A2, B3, C5, E1, E0 |
| 698-928 | 0.625-0.636 | A | Air Space or Insulation + 203.2-mm (8-in.) or more Concrete | 143-190 | 0.110-0.112 | A0, A2, B1, C10/11, E1, E0 |
| | | | 101.6-mm (4-in.) Face Brick + (*L.W. or H.W. Concrete Block*) | | | |
| 303 | 1.811 | E | 101.6-mm (4-in.) Block | 62 | 0.319 | A0, A2, C2, E1, E0 |
| 303 | 0.868-1.397 | D | Air Space or Insulation + 101.6-mm (4-in.) Block | 62 | 0.153-0.246 | A0, A2, C2, B1/B2, E1, E0 |
| 342 | 1.555 | D | 203.2-mm (8-in.) Block | 70 | 0.274 | A0, A2, C7, A6, E0 |
| 356-434 | 1.255-1.561 | C | Air Space or 25.4-mm (1-in.) Insulation + 152.4-mm (6-in.) or 203.2-mm (8-in.) Block | 73-89 | 0.221-0.275 | A0, A2, B1, C7/C8, E1, E0 |
| 434 | 0.545-0.607 | B | 50.8-mm (2-in.) Insulation + 203.2-mm (8-in.) Block | 89 | 0.096-0.107 | A0, A2, B3, C7/C8, E1, E0 |
| | | | 101.6-mm (4-in.) Face Brick + (*Clay Tile*) | | | |
| 347 | 2.163 | D | 101.6-mm (4-in.) Tile | 71 | 0.381 | A0, A2, C1, E1, E0 |
| 347 | 1.595 | D | Air Space + 101.6-mm (4-in.) Tile | 71 | 0.281 | A0, A2, C1, B1, E1, E0 |
| 347 | 0.959 | C | Insulation + 101.6-mm (4-in.) Tile | 71 | 0.169 | A0, A2, C1, B2, E1, E0 |
| 469 | 1.561 | C | 203.2-mm (8-in.) Tile | 96 | 0.275 | A0, A2, C6, E1, E0 |
| 469 | 0.806-1.255 | B | Air Space or 25.4-mm (1-in.) Insulation + 203.2-mm (8-in.) Tile | 96 | 0.142-0.221 | A0, A2, C6, B1/B2, E1, E0 |
| 474 | 0.551 | A | 50.8-mm (2-in.) Insulation + 203.2-mm (8-in.) Tile | 97 | 0.097 | A0, A2, B3, C6, E1, E0 |
| | | | H.W. Concrete Wall + (*Finish*) | | | |
| 308 | 3.321 | E | 101.6-mm (4-in.) Concrete | 63 | 0.585 | A0, A1, C5, E1, E0 |
| 308 | 0.675-1.136 | D | 101.6-mm (4-in.) Concrete + 25.4-mm (1-in.) or 50.8-mm (2-in.) Insulation | 63 | 0.119-0.200 | A0, A1, C5, B2/B3, E1, E0 |
| 308 | 0.675 | C | 50.8-mm (2-in.) Insulation + 101.6-mm (4-in.) Concrete | 63 | 0.119 | A0, A1, B6, C5, E1, E0 |
| 532 | 2.782 | C | 203.2-mm (8-in.) Concrete | 109 | 0.490 | A0, A1, C10, E1, E0 |
| 537 | 0.653-1.061 | B | 203.2-mm (8-in.) Concrete + 25.4-mm (1-in.) or 50.8-mm (2-in.) Insulation | 110 | 0.115-0.187 | A0, A1, C10, B5/B6, E1, E0 |
| 537 | 0.653 | A | 50.8-mm (2-in.) Insulation + 203.2-mm (8-in.) Concrete | 110 | 0.115 | A0, A1, B3, C10, E1, E0 |
| 762 | 2.390 | B | 304.8-mm (12-in.) Concrete | 156 | 0.421 | A0, A1, C11, E1, E0 |
| 762 | 0.642 | A | 304.8-mm (12-in.) Concrete + Insulation | 156 | 0.113 | A0, C11, B6, A6, E0 |
| | | | L. W. and H.W. Concrete Block + (*Finish*) | | | |
| 142 | 0.914-1.493 | F | 101.6-mm (4-in.) Block + Air Space/Insulation | 29 | 0.161-0.263 | A0, A1, C2, B1/B2, E1, E0 |
| 142-181 | 0.596-0.647 | E | 50.8-mm (2-in.) Insulation + 101.6-mm (4-in.) Block | 29-37 | 0.105-0.114 | A0, A1, B3, C2/C3, E1, E0 |
| 229-249 | 1.669-2.282 | E | 203.2-mm (8-in.) Block | 47-51 | 0.294-0.402 | A0, A1, C7/C8, E1, E0 |
| 200-278 | 0.846-0982 | D | 203.2-mm (8-in.) Block + Air Space/Insulation | 41-57 | 0.149-0.173 | A0, A1, C7/C8, B1/B2, E1, E0 |
| | | | Clay Tile + (*Finish*) | | | |
| 190 | 2.379 | F | 101.6-mm (4-in.) Tile | 39 | 0.419 | A0, A1, C1, E1, E0 |
| 190 | 1.720 | F | 101.6-mm (4-in.) Tile + Air Space | 39 | 0.303 | A0, A1, C1, B1, E1, E0 |
| 190 | 0.993 | E | 101.6-mm (4-in.) Tile + 25.4-mm (1-in.) Insulation | 39 | 0.175 | A0, A1, C1, B2, E1, E0 |
| 195 | 0.625 | D | 50.8-mm (2-in.) Insulation + 101.6-mm (4-in.) Tile | 40 | 0.110 | A0, A1, B3, C1, E1, E0 |
| 308 | 1.681 | D | 203.2-mm (8-in.) Tile | 63 | 0.296 | A0, A1, C6, B1/B2, E1, E0 |
| 308 | 0.857-1.312 | C | 203.2-mm (8-in.) Tile + Air Space/25.4-mm (1-in.) Insulation | 63 | 0.151-0.231 | A0, A1, C6, B1/B2, E1, E0 |
| 308 | 0.562 | B | 50.8-mm (2-in.) Insulation + 203.2-mm (8-in.) Tile | 63 | 0.099 | A0, A1, B3, C6, E1, E0 |
| | | | Metal Curtain Wall | | | |
| 24-29 | 0.516-1.306 | B | With/without air Space + 25.4-mm (1-in.)/50.8-mm (2-in.) 76.2-mm (3-in.) Insulation | 5-6 | 0.091-0.230 | A0, A3, B5/B6/B12, A3, E0 |
| | | | Frame Wall | | | |
| 78 | 0.459-1.010 | G | 25.4-mm (1-in.) to 76.2-mm (3-in.) Insulation | 16 | 0.081-0.178 | A0, A1, B1, B2/B3/B4, E1, E0 |

# Appendix (F)

## Table 6 Cooling Load Temperature Difference for Calculate Cooling Load from Sun Light Wall

| North Latitude Wall Facing | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | H of Maximum CLTD | Minimum CLTD | Maximum CLTD | Difference CLTD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Solar Time, h | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **Group A Walls** | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| N | 8 | 8 | 8 | 7 | 7 | 7 | 7 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 7 | 7 | 7 | 7 | 8 | 8 | 2 | 6 | 8 | 2 |
| NE | 11 | 11 | 10 | 10 | 10 | 9 | 9 | 9 | 8 | 8 | 8 | 9 | 9 | 9 | 9 | 10 | 10 | 10 | 11 | 11 | 11 | 11 | 11 | 11 | 22 | 8 | 11 | 3 |
| E | 14 | 13 | 13 | 13 | 12 | 12 | 11 | 11 | 10 | 10 | 10 | 11 | 11 | 12 | 12 | 13 | 13 | 13 | 14 | 14 | 14 | 14 | 14 | 14 | 22 | 10 | 14 | 4 |
| SE | 13 | 13 | 13 | 12 | 12 | 11 | 11 | 10 | 10 | 10 | 10 | 10 | 10 | 11 | 11 | 12 | 12 | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 22 | 10 | 13 | 3 |
| S | 11 | 11 | 11 | 11 | 10 | 10 | 9 | 9 | 9 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 9 | 9 | 10 | 10 | 11 | 11 | 11 | 11 | 23 | 8 | 11 | 3 |
| SW | 14 | 14 | 14 | 14 | 13 | 13 | 12 | 12 | 11 | 11 | 10 | 10 | 10 | 9 | 9 | 10 | 10 | 10 | 11 | 12 | 13 | 13 | 14 | 14 | 24 | 9 | 14 | 5 |
| W | 15 | 15 | 15 | 14 | 14 | 14 | 13 | 13 | 12 | 12 | 11 | 11 | 10 | 10 | 10 | 10 | 10 | 11 | 11 | 12 | 13 | 14 | 14 | 15 | 1 | 10 | 15 | 5 |
| NW | 12 | 12 | 11 | 11 | 11 | 11 | 10 | 10 | 10 | 9 | 9 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 9 | 9 | 10 | 11 | 11 | 11 | 1 | 8 | 12 | 4 |
| **Group B Walls** | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| N | 8 | 8 | 8 | 7 | 7 | 6 | 6 | 6 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 6 | 6 | 7 | 7 | 8 | 8 | 8 | 8 | 8 | 24 | 5 | 8 | 3 |
| NE | 11 | 10 | 10 | 9 | 9 | 8 | 7 | 7 | 7 | 7 | 8 | 8 | 9 | 9 | 10 | 10 | 11 | 11 | 11 | 12 | 12 | 12 | 11 | 11 | 21 | 7 | 12 | 5 |
| E | 13 | 13 | 12 | 11 | 10 | 10 | 9 | 8 | 8 | 9 | 9 | 10 | 12 | 13 | 13 | 14 | 14 | 15 | 15 | 15 | 15 | 15 | 14 | 14 | 20 | 8 | 15 | 7 |
| SE | 13 | 12 | 12 | 11 | 10 | 10 | 9 | 8 | 8 | 8 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 21 | 8 | 14 | 6 |
| S | 12 | 11 | 11 | 10 | 9 | 9 | 8 | 7 | 7 | 6 | 6 | 6 | 6 | 7 | 8 | 9 | 10 | 11 | 11 | 12 | 12 | 12 | 12 | 12 | 23 | 6 | 12 | 6 |
| SW | 15 | 15 | 14 | 13 | 13 | 12 | 11 | 10 | 9 | 9 | 8 | 8 | 7 | 7 | 8 | 9 | 10 | 11 | 13 | 14 | 15 | 15 | 16 | 16 | 24 | 7 | 16 | 9 |
| W | 16 | 16 | 15 | 14 | 14 | 13 | 12 | 11 | 10 | 9 | 9 | 8 | 8 | 8 | 8 | 8 | 9 | 11 | 12 | 14 | 15 | 16 | 16 | 17 | 24 | 8 | 17 | 9 |
| NW | 13 | 12 | 12 | 11 | 11 | 10 | 9 | 9 | 8 | 7 | 7 | 7 | 6 | 6 | 7 | 7 | 8 | 8 | 9 | 11 | 12 | 13 | 13 | 13 | 24 | 6 | 13 | 7 |
| **Group C Walls** | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| N | 9 | 8 | 7 | 7 | 6 | 5 | 5 | 4 | 4 | 4 | 4 | 4 | 5 | 5 | 6 | 6 | 7 | 8 | 9 | 9 | 9 | 10 | 9 | 9 | 22 | 4 | 10 | 6 |
| NE | 10 | 10 | 9 | 8 | 7 | 6 | 6 | 6 | 6 | 7 | 8 | 10 | 10 | 11 | 12 | 12 | 12 | 13 | 13 | 13 | 13 | 12 | 12 | 11 | 20 | 6 | 13 | 7 |
| E | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 7 | 8 | 9 | 11 | 13 | 14 | 15 | 16 | 16 | 17 | 17 | 16 | 16 | 16 | 15 | 14 | 13 | 18 | 7 | 17 | 10 |
| SE | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 7 | 7 | 9 | 10 | 12 | 14 | 15 | 16 | 16 | 16 | 16 | 16 | 16 | 15 | 14 | 13 | 19 | 6 | 16 | 10 |
| S | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 6 | 5 | 5 | 5 | 5 | 6 | 8 | 9 | 11 | 12 | 13 | 14 | 14 | 14 | 14 | 13 | 12 | 20 | 5 | 14 | 9 |
| SW | 16 | 15 | 14 | 12 | 11 | 10 | 9 | 8 | 7 | 7 | 6 | 6 | 6 | 7 | 8 | 10 | 12 | 14 | 16 | 18 | 18 | 18 | 18 | 17 | 22 | 6 | 18 | 12 |
| W | 17 | 16 | 15 | 14 | 12 | 11 | 10 | 9 | 8 | 7 | 7 | 7 | 7 | 7 | 8 | 9 | 11 | 13 | 16 | 18 | 19 | 20 | 19 | 18 | 22 | 7 | 20 | 13 |
| NW | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 6 | 5 | 5 | 6 | 6 | 6 | 7 | 9 | 10 | 12 | 14 | 15 | 15 | 15 | 15 | 22 | 5 | 15 | 10 |
| **Group D Walls** | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| N | 8 | 7 | 7 | 6 | 5 | 4 | 3 | 3 | 3 | 3 | 4 | 4 | 5 | 6 | 6 | 7 | 8 | 9 | 10 | 11 | 11 | 10 | 10 | 9 | 21 | 3 | 11 | 8 |
| NE | 9 | 8 | 7 | 6 | 5 | 5 | 4 | 4 | 6 | 8 | 10 | 11 | 12 | 13 | 13 | 13 | 14 | 14 | 14 | 13 | 13 | 12 | 11 | 10 | 19 | 4 | 14 | 10 |
| E | 11 | 10 | 8 | 7 | 6 | 5 | 5 | 5 | 7 | 10 | 13 | 15 | 17 | 18 | 18 | 18 | 18 | 18 | 17 | 17 | 16 | 15 | 13 | 12 | 16 | 5 | 18 | 13 |
| SE | 11 | 10 | 9 | 7 | 6 | 5 | 5 | 5 | 5 | 7 | 10 | 12 | 14 | 16 | 17 | 18 | 18 | 18 | 17 | 17 | 16 | 15 | 14 | 12 | 17 | 5 | 18 | 13 |
| S | 11 | 10 | 8 | 7 | 6 | 5 | 4 | 4 | 3 | 3 | 4 | 5 | 7 | 9 | 11 | 13 | 15 | 16 | 16 | 16 | 15 | 14 | 13 | 12 | 19 | 3 | 16 | 13 |
| SW | 15 | 14 | 12 | 10 | 9 | 8 | 6 | 5 | 5 | 4 | 4 | 5 | 5 | 7 | 9 | 12 | 15 | 18 | 20 | 21 | 21 | 20 | 19 | 17 | 21 | 4 | 21 | 17 |
| W | 17 | 15 | 13 | 12 | 10 | 9 | 7 | 6 | 5 | 5 | 5 | 5 | 6 | 6 | 8 | 10 | 13 | 17 | 20 | 22 | 23 | 22 | 21 | 19 | 21 | 5 | 23 | 18 |
| NW | 14 | 12 | 11 | 9 | 8 | 7 | 6 | 5 | 4 | 4 | 4 | 4 | 5 | 6 | 7 | 8 | 10 | 12 | 15 | 17 | 18 | 17 | 16 | 15 | 22 | 4 | 18 | 14 |
| **Group E Walls** | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| N | 7 | 6 | 5 | 4 | 3 | 2 | 2 | 2 | 3 | 3 | 4 | 5 | 6 | 7 | 8 | 10 | 10 | 11 | 12 | 12 | 11 | 10 | 9 | 8 | 20 | 2 | 12 | 10 |
| NE | 7 | 6 | 5 | 4 | 3 | 2 | 3 | 5 | 8 | 11 | 13 | 14 | 14 | 14 | 14 | 14 | 15 | 14 | 14 | 13 | 12 | 11 | 9 | 8 | 16 | 2 | 15 | 13 |
| E | 8 | 7 | 6 | 5 | 4 | 3 | 3 | 6 | 10 | 15 | 18 | 20 | 21 | 21 | 20 | 19 | 18 | 18 | 17 | 15 | 14 | 12 | 11 | 9 | 13 | 3 | 21 | 18 |
| SE | 8 | 7 | 6 | 5 | 4 | 3 | 3 | 4 | 7 | 10 | 14 | 17 | 19 | 20 | 20 | 20 | 19 | 18 | 17 | 16 | 14 | 13 | 11 | 10 | 15 | 3 | 20 | 17 |
| S | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 2 | 2 | 3 | 5 | 7 | 10 | 14 | 16 | 18 | 19 | 18 | 17 | 16 | 14 | 13 | 11 | 10 | 17 | 2 | 19 | 17 |
| SW | 12 | 10 | 8 | 7 | 6 | 4 | 4 | 3 | 3 | 3 | 4 | 5 | 7 | 10 | 14 | 18 | 21 | 24 | 25 | 24 | 22 | 19 | 17 | 14 | 19 | 3 | 25 | 22 |
| W | 14 | 12 | 10 | 8 | 6 | 5 | 4 | 3 | 3 | 4 | 4 | 5 | 6 | 8 | 11 | 15 | 20 | 24 | 27 | 27 | 25 | 22 | 19 | 16 | 20 | 3 | 27 | 24 |
| NW | 11 | 9 | 8 | 6 | 5 | 4 | 3 | 3 | 3 | 3 | 4 | 5 | 6 | 7 | 9 | 11 | 14 | 18 | 21 | 21 | 20 | 18 | 15 | 13 | 20 | 3 | 21 | 18 |
| **Group F Walls** | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| N | 5 | 4 | 3 | 2 | 1 | 1 | 1 | 2 | 3 | 4 | 5 | 6 | 8 | 9 | 11 | 12 | 12 | 13 | 13 | 13 | 11 | 9 | 7 | 6 | 19 | 1 | 13 | 12 |
| NE | 5 | 4 | 3 | 2 | 1 | 1 | 3 | 8 | 13 | 16 | 17 | 16 | 16 | 15 | 15 | 15 | 15 | 14 | 13 | 12 | 10 | 9 | 7 | 6 | 11 | 1 | 17 | 16 |
| E | 5 | 4 | 3 | 2 | 2 | 1 | 4 | 9 | 16 | 21 | 24 | 25 | 24 | 22 | 20 | 19 | 18 | 17 | 15 | 13 | 11 | 10 | 8 | 7 | 12 | 1 | 25 | 24 |
| SE | 5 | 4 | 3 | 2 | 2 | 1 | 2 | 6 | 10 | 15 | 20 | 23 | 24 | 23 | 22 | 20 | 19 | 17 | 16 | 14 | 12 | 10 | 8 | 7 | 13 | 1 | 24 | 23 |
| S | 5 | 4 | 3 | 2 | 2 | 1 | 1 | 1 | 2 | 4 | 7 | 11 | 15 | 19 | 21 | 22 | 21 | 19 | 17 | 15 | 12 | 10 | 8 | 7 | 16 | 1 | 22 | 21 |
| SW | 8 | 6 | 5 | 4 | 3 | 2 | 1 | 1 | 2 | 3 | 4 | 6 | 10 | 14 | 20 | 24 | 28 | 30 | 29 | 25 | 20 | 16 | 13 | 10 | 18 | 1 | 30 | 29 |
| W | 9 | 7 | 5 | 4 | 3 | 2 | 2 | 2 | 2 | 3 | 4 | 6 | 8 | 11 | 16 | 22 | 27 | 32 | 33 | 30 | 24 | 19 | 15 | 12 | 19 | 2 | 33 | 31 |
| NW | 8 | 6 | 4 | 3 | 2 | 2 | 1 | 1 | 2 | 3 | 4 | 6 | 7 | 9 | 12 | 15 | 19 | 24 | 26 | 24 | 20 | 16 | 12 | 10 | 19 | 1 | 26 | 25 |
| **Group G Walls** | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| N | 2 | 1 | 0 | 0 | 0 | 1 | 4 | 5 | 5 | 7 | 8 | 10 | 12 | 13 | 13 | 14 | 14 | 15 | 12 | 8 | 6 | 5 | 4 | 3 | 18 | 0 | 15 | 15 |
| NE | 2 | 1 | 1 | 0 | 0 | 5 | 15 | 20 | 22 | 20 | 16 | 15 | 15 | 15 | 15 | 15 | 14 | 12 | 10 | 8 | 6 | 5 | 4 | 3 | 9 | 0 | 22 | 22 |
| E | 2 | 1 | 1 | 0 | 0 | 6 | 17 | 26 | 30 | 31 | 28 | 22 | 19 | 17 | 17 | 16 | 15 | 13 | 11 | 8 | 7 | 5 | 4 | 3 | 10 | 0 | 31 | 31 |
| SE | 2 | 1 | 1 | 0 | 0 | 3 | 10 | 18 | 24 | 27 | 28 | 27 | 23 | 20 | 18 | 16 | 15 | 13 | 11 | 8 | 7 | 6 | 4 | 3 | 11 | 0 | 28 | 28 |
| S | 2 | 1 | 1 | 0 | 0 | 0 | 1 | 3 | 7 | 12 | 17 | 22 | 25 | 26 | 24 | 21 | 17 | 14 | 11 | 8 | 7 | 5 | 4 | 3 | 14 | 0 | 26 | 26 |
| SW | 3 | 2 | 2 | 1 | 0 | 0 | 1 | 3 | 4 | 6 | 9 | 14 | 21 | 28 | 33 | 35 | 34 | 29 | 20 | 13 | 10 | 7 | 6 | 4 | 16 | 0 | 35 | 35 |
| W | 4 | 3 | 2 | 1 | 1 | 1 | 1 | 3 | 5 | 6 | 8 | 10 | 15 | 23 | 31 | 37 | 40 | 37 | 27 | 16 | 11 | 8 | 6 | 5 | 17 | 1 | 40 | 39 |
| NW | 1 | 2 | 1 | 1 | 0 | 0 | 1 | 1 | 4 | 6 | 8 | 10 | 12 | 15 | 20 | 26 | 31 | 31 | 23 | 14 | 10 | 7 | 5 | 4 | 18 | 0 | 31 | 31 |

# Appendix (G)

## Table 7 CLTD Correction for Latitude and Month Applied to Wall and Roof

| Lat. | Month | N | NNE NNW | NE NW | ENE WNW | E W | ESE WSW | SE SW | SSE SSW | S | HOR |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | Dec | -1.6 | -2.7 | -2.7 | -2.7 | -1.1 | 0.0 | 1.6 | 3.3 | 5.0 | -0.5 |
| | Jan/Nov | -1.6 | -2.7 | -2.2 | -2.2 | -0.5 | 0.0 | 1.1 | 2.2 | 3.8 | -0.5 |
| | Feb/Oct | -1.6 | -1.1 | -1.1 | -1.1 | -0.5 | -0.5 | 0.0 | -0.5 | 3.8 | -0.0 |
| | Mar/Sept | -1.6 | 0.0 | 0.5 | -0.5 | -0.5 | -1.6 | -1.6 | -2.7 | -4.4 | 0.0 |
| | Apr/Aug | 2.7 | 2.2 | 1.6 | 0.0 | -1.1 | -2.7 | -3.3 | -4.4 | -4.4 | -1.1 |
| | May/Jul | 5.5 | 3.8 | 2.7 | 0.0 | -1.6 | -3.8 | -4.4 | -5.0 | -4.4 | -2.2 |
| | Jun | 6.6 | 5.0 | 2.7 | 0.0 | -1.6 | -3.8 | -5.0 | -5.5 | -4.4 | -2.7 |
| 8 | Dec | -2.2 | -3.3 | -3.3 | -3.3 | -1.6 | 0.0 | 2.2 | 4.4 | 6.6 | -2.7 |
| | Jan/Nov | -1.6 | -2.7 | -3.3 | -2.7 | -1.1 | 0.0 | 1.6 | 3.3 | 5.5 | -2.2 |
| | Feb/Oct | -1.6 | -2.2 | -1.6 | -1.6 | -0.5 | -0.5 | 0.5 | 1.1 | 2.2 | -0.5 |
| | Mar/Sept | -1.6 | -1.1 | -0.5 | -0.5 | -0.5 | -1.1 | -1.1 | -1.6 | -2.2 | 0.0 |
| | Apr/Aug | 1.1 | 1.1 | 1.1 | 0.0 | -0.5 | -2.2 | -2.7 | -3.8 | -3.8 | -0.5 |
| | May/Jul | 3.8 | 2.7 | 2.2 | 0.0 | -1.1 | -2.7 | -3.8 | -5.0 | -3.8 | -1.1 |
| | Jun | 5.0 | 3.3 | 2.2 | 0.0 | -1.1 | -3.3 | -4.4 | -5.0 | -3.8 | -1.1 |
| 16 | Dec | -2.2 | -3.3 | -4.4 | -4.4 | -2.2 | -0.5 | 2.2 | 5.0 | 7.2 | -5.0 |
| | Jan/Nov | -2.2 | -3.3 | -3.8 | -3.8 | -2.2 | -0.5 | 2.2 | 4.4 | 6.6 | -3.8 |
| | Feb/Oct | -1.6 | -2.7 | -2.7 | -2.2 | -1.1 | 0.0 | 1.1 | 2.7 | 3.8 | -2.2 |
| | Mar/Sept | -1.6 | -1.6 | -1.1 | -1.1 | -0.5 | -0.5 | 0.0 | 0.0 | 0.0 | -0.5 |
| | Apr/Aug | -0.5 | 0.0 | -0.5 | -0.5 | -0.5 | -1.6 | -1.6 | -2.7 | -3.3 | 0.0 |
| | May/Jul | 2.2 | 1.6 | 1.6 | 0.0 | -0.5 | -2.2 | -2.7 | -3.8 | -3.8 | 0.0 |
| | Jun | 3.3 | 2.2 | 2.2 | 0.5 | -0.5 | -2.2 | -3.3 | -4.4 | -3.8 | 0.0 |
| 24 | Dec | -2.7 | -3.8 | -5.0 | -5.5 | -3.8 | -1.6 | 1.6 | 5.0 | 7.2 | -7.2 |
| | Jan/Nov | -2.2 | -3.3 | -4.4 | -5.0 | -3.3 | -1.6 | 1.6 | 5.0 | 7.2 | -6.1 |
| | Feb/Oct | -2.2 | -2.7 | -3.3 | -3.3 | -1.6 | -0.5 | 1.6 | 3.8 | 5.5 | -3.8 |
| | Mar/Sept | -1.6 | -2.2 | -1.6 | -1.6 | -0.5 | -0.5 | 0.5 | 1.1 | 2.2 | -1.6 |
| | Apr/Aug | -1.1 | -0.5 | 0.0 | -0.5 | -0.5 | -1.1 | -0.5 | -1.1 | -1.6 | 0.0 |
| | May/Jul | 0.5 | 1.1 | 1.1 | 0.0 | 0.0 | -1.6 | -1.6 | -2.7 | -3.3 | 0.5 |
| | Jun | 1.6 | 1.6 | 1.6 | 0.5 | 0.0 | -1.6 | -2.2 | -3.3 | -3.3 | 0.5 |
| 32 | Dec | -2.7 | -3.8 | -5.5 | -6.1 | -4.4 | -2.7 | 1.1 | 5.0 | 6.6 | -9.4 |
| | Jan/Nov | -2.7 | -3.8 | -5.0 | -6.1 | -4.4 | -2.2 | 1.1 | 5.0 | 6.6 | -8.3 |
| | Feb/Oct | -2.2 | -3.3 | -3.8 | -4.4 | -2.2 | -1.1 | 2.2 | 4.4 | 6.1 | -5.5 |
| | Mar/Sept | -1.6 | -2.2 | -2.2 | -2.2 | -1.1 | -0.5 | 1.6 | 2.7 | 3.8 | -2.7 |
| | Apr/Aug | -1.1 | -1.1 | -0.5 | -1.1 | 0.0 | -0.5 | 0.0 | 0.5 | 0.5 | -0.5 |
| | May/Jul | 0.5 | 0.5 | 0.5 | 0.0 | 0.0 | -0.5 | -0.5 | -1.6 | -1.6 | 0.5 |
| | Jun | 0.5 | 1.1 | 1.1 | 0.5 | 0.0 | -1.1 | -1.1 | -2.2 | -2.2 | 1.1 |
| 40 | Dec | -3.3 | -4.4 | -5.5 | -7.2 | -5.5 | -3.8 | 0.0 | 3.8 | 5.5 | -11.6 |
| | Jan/Nov | -2.7 | -3.8 | -5.5 | -6.6 | -5.0 | -3.3 | 0.5 | 4.4 | 6.1 | -10.5 |
| | Feb/Oct | -2.7 | -3.8 | -4.4 | -5.0 | -3.3 | -1.6 | 1.6 | 4.4 | 6.6 | -7.7 |
| | Mar/Sept | -2.2 | -2.7 | -2.7 | -3.3 | -1.6 | 0.5 | 2.2 | 3.8 | 5.5 | -4.4 |
| | Apr/Aug | -1.1 | -1.6 | -1.1 | -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 | 0.0 | 0.5 | 0.0 | 0.0 | -0.5 | -0.5 | 1.1 |
| 48 | Dec | -3.3 | -4.4 | -6.1 | -7.7 | -7.2 | -5.5 | -1.6 | 1.1 | 3.3 | -13.8 |
| | Jan/Nov | -3.3 | -4.4 | -6.1 | -7.2 | -6.1 | -4.4 | -0.5 | 2.7 | 4.4 | -13.3 |
| | Feb/Oct | -2.7 | -3.8 | -5.5 | -6.1 | -4.4 | -2.7 | 0.5 | 4.4 | 6.1 | -10.0 |
| | Mar/Sept | -2.2 | -3.3 | -3.3 | -3.8 | -2.2 | -0.5 | 2.2 | 4.4 | 6.1 | -6.1 |
| | Apr/Aug | -1.6 | -1.6 | -1.6 | -1.6 | -0.5 | 0.0 | 2.2 | 3.3 | 3.8 | -2.7 |
| | May/Jul | 0.0 | -0.5 | 0.0 | 0.0 | 0.5 | 0.5 | 1.6 | 1.6 | 2.2 | 0.0 |
| | Jun | 0.5 | 0.5 | 1.1 | 0.5 | 1.1 | 0.5 | 1.1 | 1.1 | 1.6 | 1.1 |
| 56 | Dec | -3.8 | -5.0 | -6.6 | -8.8 | -8.8 | -7.7 | -5.0 | -2.7 | -1.6 | -15.5 |
| | Jan/Nov | -3.3 | -4.4 | -6.1 | -8.3 | -7.7 | -6.6 | -3.3 | -0.5 | 1.1 | -15.0 |
| | Feb/Oct | -3.3 | -4.4 | -5.5 | -6.6 | -5.5 | -3.8 | 0.0 | 3.3 | 5.0 | -12.2 |
| | Mar/Sept | -2.7 | -3.3 | -3.8 | -4.4 | -2.7 | -1.1 | 2.2 | 4.4 | 6.6 | -8.3 |
| | Apr/Aug | -1.6 | -2.2 | -2.2 | -2.2 | -0.5 | 0.5 | 2.7 | 3.8 | 5.0 | -4.4 |
| | May/Jul | 0.0 | 0.0 | 0.0 | 0.0 | 1.1 | 1.1 | 2.7 | 3.3 | 3.8 | -1.1 |
| | Jun | 1.1 | 0.5 | 1.1 | 0.5 | 1.6 | 1.6 | 2.2 | 2.7 | 3.3 | 0.5 |
| 64 | Dec | -3.8 | -5.0 | -6.6 | -0.8 | -9.4 | -10.0 | -8.8 | -7.7 | -6.6 | -16.6 |
| | Jan/Nov | -3.8 | -5.0 | -6.6 | -8.8 | -8.8 | -8.8 | -7.2 | -5.5 | -4.4 | -16.1 |
| | Feb/Oct | -3.3 | -4.4 | -6.1 | -7.7 | -7.2 | -5.5 | -2.2 | 0.5 | 2.2 | -14.4 |
| | Mar/Sept | -2.7 | -3.8 | -5.0 | -5.5 | -3.8 | -2.2 | 1.1 | 3.8 | 6.1 | -11.1 |
| | Apr/Aug | -1.6 | -2.2 | -2.2 | -2.2 | -0.5 | 0.5 | 2.7 | 5.0 | 6.1 | -6.1 |

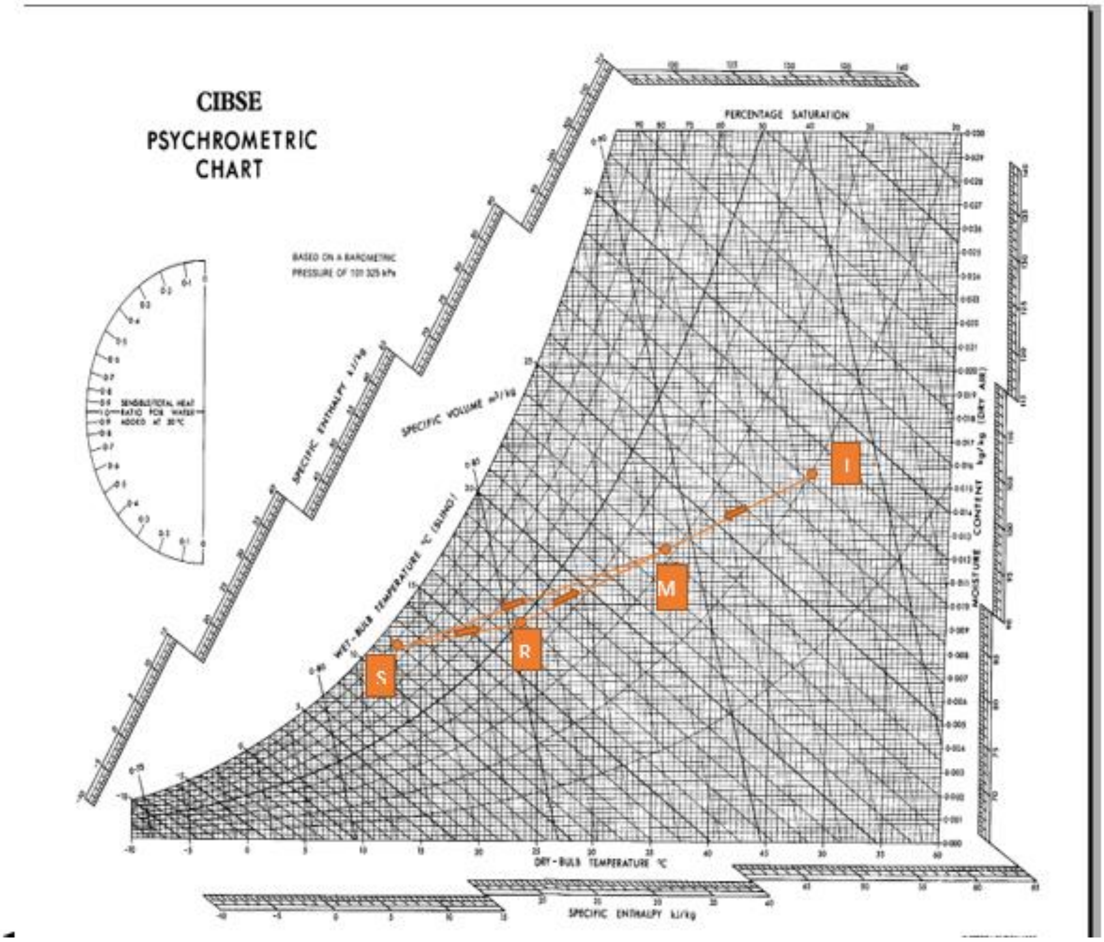
# Appendix (H)

## Table 8 Minimum Ventilation Rates in Breathing Zone

| Occupancy Category | People Outdoor Air Rate $R_p$ | | Area Outdoor Air Rate $R_a$ | | Notes | Default Values | | | Air Class |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Occupant Density (see Note 4) | Combined Outdoor Air Rate (see Note 5) | | |
| | cfm/person | L/s•person | cfm/ft$^2$ | L/s•m$^2$ | | #/1000 ft$^2$ or #/100 m$^2$ | cfm/person | L/s•person | |
| **Sports and Entertainment** | | | | | | | | | |
| Sports arena (play area) | - | - | 0.30 | 1.5 | | - | | | 1 |
| Gym, stadium (play area) | - | - | 0.30 | 1.5 | | 30 | | | 2 |
| Spectator areas | 7.5 | 3.8 | 0.06 | 0.3 | | 150 | 8 | 4.0 | 1 |
| Swimming (pool & deck) | - | - | 0.48 | 2.4 | C | - | | | 2 |
| Disco/dance floors | 20 | 10 | 0.06 | 0.3 | | 100 | 21 | 10.3 | 1 |
| Health club/aerobics room | 20 | 10 | 0.06 | 0.3 | | 40 | 22 | 10.8 | 2 |
| Health club/weight rooms | 20 | 10 | 0.06 | 0.3 | | 10 | 26 | 13.0 | 2 |
| Bowling alley (seating) | 10 | 5 | 0.12 | 0.6 | | 40 | 13 | 6.5 | 1 |
| Gambling casinos | 7.5 | 3.8 | 0.18 | 0.9 | | 120 | 9 | 4.6 | 1 |
| Game arcades | 7.5 | 3.8 | 0.18 | 0.9 | | 20 | 17 | 8.3 | 1 |
| Stages, studios | 10 | 5 | 0.06 | 0.3 | D | 70 | 11 | 5.4 | 1 |

# Appendix (I)

## Psychrometric Chart




$$M \equiv Mixing\ point$$

$$R \equiv Indor\ point$$

$$S \equiv Supply\ point$$

$$I \equiv Outdoor\ point$$