STUDY OF PERFORMANCE OF AN AIR CONDITIONING SYSTEM AND COOLING LOAD CALCULATION BY USING DEVELOPED SOFTWARE FOR A BUILDING

By

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In partial fulfillment of the requirements for the degree of

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It is hereby declared that this thesis or any part of it has not been submitted elsewhere for the award of any degree or diploma.

Khandakar Mozammel Hossan
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Dedicated

To

My Late 2nd Elder Brother

&

My Parents

ABSTRACT

Software development for cooling load calculation specialy for large buildings in countries of 24° north location has been aimed in this research work. Most of the air-conditioning units in service provide comfort air conditioning, the purpose of which is to provide comfortable living conditions inside. Summer cooling systems have become a standard utility in large buildings throughtout the world. Even in climates where summer temperatures are not high, large buildings may have to be cooled in order to remove the heat generated internally by people, lights and other electrical equipments. In the present research cooling load temperature difference method (CLTD) has been taken and all the data are collected from ASHRAE hand book.

This software has made by Visual Basic 6.0 version. This software is data base type. After load calculation importance for large building needs duct design, pipe size selection, pump capacity selection, cooling tower capacity (for water cooled chiller) selection. The conditioned spaces are served by one or more air-supply and return system.

Another important part of air-conditioning installation is for commercial, industrial, residential and medical building or hospitals. Some requirements that prevail in office building air conditioning apply to hospital, but there are a number of additional concerns as well. In special cases, like operation theatre, ventilation requirements often specify the use of 100 percent outdoor air and humidity limits may be more severe in operating rooms. The design of an energy efficient system for a hospital that also meets the special requiurements of an engineering challenge.

Also important issue is environmental polutions. To protect the earth and to protect the environment is the common issue of the mankind. The traditional electric chiller which takes Freon as its cooling medium has caused great harm to the ozone layer of the atmosphere, which can never be tolerated by mankind. In HVAC applications, a heat pump normally refers to a vapor-compression refrigeration device that includes a reversing valve and optimized heat exchanger. Another HVAC application system is vapor-absorption process. This system uses absorber e.g. LiBr solution. The lithium bromide solution is a non-volatile, non-deteriorating and pollution free.

For this reason, this system is environmentaly friendly compare to the vapor-compression system. Here refrigerant used is water. In this system power consumption is comparatively low, so reasonable amount of energy can be saved.

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NOMENCLATURE

EER	Energy efficiency ratio
COP	Coefficient of performance
CLTD	Cooling load temperatur difference
CLF	Cooling load factor
TR	Ton of refrigeration
BTU	British thermal unit
HVAC	Heating, ventilating and air conditioning
A	Area of wall, floor, window and roof
U	Overall heat transfer coefficient of external wall or roof
SC	Shading coefficient
LM	Latitude of month
D_R	Daily range
T_i	Inside temperature
T_o	Outside temperature
SHGF	Solar heat gain factor
HG	Heat gain from occupants
SHF	Sensible heat gain
F_a	Fresh air quantity
Q	Heat transfer through walls, roof, glass, etc.
R_o	Thermal resistance of building materials
n	Number of people
RH	Relative humidity
WBT	Wet bulb temperature
DBT	Dry bulb temperature
ASHRAE	American Society of Heating, Refrigerating and Air-Conditiong Engineers

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CHAPTER –1

INTRODUCTION

The performance study of an air-conditioning system and the development of software for cooling load calculation by CLTD (cooling load temperature difference) method are carried out in this work. It would demonstrate its use in buildings, markets or in any required space with respect to duct design, pipe size selection, exhaust system and plant room layout. Two types of air conditioning systems are in use and they are: Vapor compression system and Vapor absorption system. Vapor absorption system with cogeneration uses flue gas a heat source in lithium bromide absorption chiller/heater and saves heat. This creates positive influence in reduction of air pollution and energy utilization causing energy saving and environment benefit. Now a days, few existing software are available for cooling load calculation but its demand is increasing everyday for getting accurate results for multistoried buildings, markets, towers, hospitals, industries and residential buildings. In Bangladesh, the use of thumb rule for cooling load calculation gives inaccurate results. An increasing trend of developing software cooling load calculation induces proper refrigeration load for HVAC (Heating, Ventilating and Air-Conditioning) system for Bangladesh i.e. for 24º latitude and 34ºC ambient temperatures. This thesis includes developing of a software encompassing fundamentals of air conditioning, followed by different air conditioning equipment and systems. Considering recent energy crisis in near future, it is expected to establish the co-generation service systems which shall save power. The software developed here will play a positive role in the efficient use of refrigeration system. In this thesis an attempt has been made to establish power system economy, together with their direct impact on the environment. It deals with the simulation of the daily load curve of electric power networks in presence of an air conditioning load, taking into account the power systems peak load and its load factor. If absorption based cogeneration service system is used, then electric load becomes minimum from the peak load. By means of a detailed parameter study on a simple power system, the impact of the air conditioning load component on the daily cost is illustrated and discussed. Moreover, the economic feasibility of applying two suggested control strategies of the air-conditioning load aiming at reducing the fuel consumption is also investigated.

1.1 Cooling load in Air-conditioning system.

For each cooling load calculation method, there are several benefits/limitations. Simplicity and accuracy are two contradicting objectives to be optimized in the refrigeration field. If a method could be considered to be simple, its accuracy would be a matter of question and vice versa.

While modern methods emphasize on improving the procedure of calculating solar and conduction heat gains, there are also other main sources coming from internal heat gains (people, lighting and electric equipments). Handbooks include tables for the heat gain estimations from the internal sources. For equipment not mentioned in the tables, their limited information indicated in their leaflets is insufficient in designing a refrigeration system with accurate predictability of the occurrence which is very important to determine the heat gain. Internal heat gain shows that, when thinking about accuracy, it is not only the method which is effective, but uncertainties in the input data are also important.

There are high degrees of uncertainties in input data required to determine cooling loads. Much of this is due to the unpredictability of occupancy, human behaviour, outdoor weather variations, lack of and variation in heat gain data for modern equipments, and introduction of new building products and HVAC equipments with unknown characteristics. These generate uncertainties that far exceed the errors generated by simple methods compared to more complex methods. Therefore, the added time/ effort required for more complex calculation methods would not be productive in terms of better accuracy of the results if uncertainties in the input data are high.

1.2 Cooling load calculation Methods

There are four standard methods for the cooling load calculation. They are based on hourly calculation of the cooling load. These methods deal with both the sensible and latent heat. For the latent heat, the main source is people. Heat gains from people have two components, sensible and latent. The total values and proportions of sensible and latent heat vary depending on the level of activity. The latent heat and sensible heat gains from occupants should be computed separately until estimating the building refrigeration load, where the two components are combined. The latent heat gain is assumed to become cooling load instantly, whereas, the sensible heat gain is partially delayed depending on the characteristics of the conditioned space. According to the ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers) regulations, the sensible heat gain from people is assumed 40% convection and 60% radiation [ASHRAE 2005].

The four cooling load calculation methods are:

a. The Heat Balance Method (ASHRAE 2001)
b. The Radiant Times Series (ASHRAE 2001)
c. CLTD/SCL/CLF (ASHRAE 1997)
d. The Admittance Methods (CIBSE 1986)

a. The Heat Balance Method (ASHRAE fundamentals 2001)

The procedure described by this method is the most reliable means presented by ASHRAE for estimating cooling load for a defined space. Other ASHRAE methods are simplifications of the heat balance principle. In fact any cooling load estimate is no better than the assumptions used to define conditions and parameters such as physical makeup of the various envelope surfaces, conditions of occupancy and use and ambient weather conditions outside the building. The ASHRAE 2001 Fundamentals mention that the Heat balance method (HB) and the Radiant time series method (RTS) have wide spread application in this field.

b. The Radiant Time Series Method (ASHRAE fundamentals 2001)

This method is simpler to apply than the Heat balance method. In this method, the storage and release of structure energy are approximated with predetermined zone response. The cooling load is found directly but the zone air temperature is assumed to be constant. Periodic response factors are needed to find the conduction heat for the walls, Radiant time series, which is consisted of 24 radiant time factor, should be generated for the conversion of the radiative portion of heat gains into the cooling load.

c. CLTD/SCL/CLF Method (ASHRAE fundamentals 1997)

Accurate simulation of a proposed building design without correct data is impossible. However, the many variables required for consideration in good simulation often become tedious and force designers to spend valuable time consulting tables and performing repetitive calculation. This is especially true for the Transfer Function Method (TFM) which pertains this repetitive nature and is identified by ASHRAE as the fundamental methodology of peak cooling load calculation. Transfer function method was first introduced in 1967. This procedure is based on response factors and the interplay of heat exchange between various surfaces and sources of heat. Transfer functions are based on two concepts: the conduction transfer factors (CTF) and the weighting factor (WF). The CTF are used to describe the heat flux at the inside wall, roof, partition, ceiling or floor as a function of previous value of the heat flux and previous values of inside and outside temperature. The WF is used to translate the zone heat gain into cooling loads. As a result of the TFM complexity, ASHRAE developed a method called the cooling load temperature difference/cooling load factor CLTD/CLF (1997) which was derived from the TFM. The CLTD/CLF method depends on tabulated data to simplify its operation for manual use. This method was subjected to several revisions to accommodate the problems that rose from approximation and limitations to cover more accurate tabulated data. Due to this, ASHRAE published the cooling load temperature difference /solar cooling load/cooling load factor (CLTD/SCL/CLF) method.

d. The Admittance Method (CIBSE)

For climatic reason, the application of air conditioning to office spaces in the UK in the post war period lagged behind that of the USA. It was not the need for the calculation of cooling load, but with the need to calculate maximum temperatures in natural and mechanically ventilated building that the Admittance method was first developed. Unlike ASHRAE, whose methods were directed toward assuming a constant internal temperature, CIBSE primary aim was to demonstrate the role of internal mass in modifying room temperature. The UK methods were originally developed for calculating heating load, and with a preponderance of hydronic radiant heating system, a combined radiant and convective temperature was more useful than the zone air temperature. In comparison the USA methods were developed for cooling, where the load was met by an air based system.

1.3 Motivation for the Study

Now a day, one of the main goals of the commercial, residential, industrial and pharmaceuticals building and Architecture is to use the solar source for the air-conditioning of buildings. Over the recent years many activities have started to develop new buildings and plant technologies oriented to energy saving by improving indoor comfort air conditioning and reducing environmental pollution emission. For this, the guidelines are given in various world conferences (Kyoto 1997, Buenos Aires 1998). In our country, we are trying to carry out new strategies to reduce both energy consumption and environment pollution. These aims have increased research works oriented to find waste heat recovery system, components and systems able to use energy gains from environment.

In this research work, a new HVAC system is proposed and studied. The plant is equipped with a reciprocating i.e. gas engine, and gas Turbine which produces electric energy with heat recovery from the jacket water heat and the exhaust. In the absorption system, the regeneration of the absorbent is obtained by the I.C engine and/or Gas Turbine exhaust and jacket water heat. We have a very limited energy sources in different forms of fossil fuels (coal, oil, nature gas etc) to produce electricity. Day by day electric demand is increasing dramatically. Cities are rapidly growing with the importance being placed on creating multi-storied buildings to deal with the increasing urban population of Bangladesh. However, in the process of dealing with population demand, the architects and town planners of Bangladesh are not taking into consideration of human comfort of its inhabitants. For this, efficient building design incorporating the use of its own captive power system to drive the cogeneration is needed. Also the use of proper ventilation of natural flow of air should be considered. The system can also use to produce hot water for industries, hotels, airports etc.

1.4 Objectives of Study

There is only one earth, so there is responsibility**.** To protect the earth and to protect the environment is the most vital issue of the mankind. The traditional electric chiller or vapor compression air conditioning system which takes refrigerant as its cooling medium has caused great harm to the environments and to the ozone layer of the atmosphere which can never be tolerated by the mankind. The far sighted personnel in the field of refrigeration and air conditioning cannot turn blind eyes to this phenomenon.

The lithium bromide absorption chiller adopts solution of lithium bromide as its working medium, which is non-volatile, non-deteriorating and environmental friendly. It has positive influence in anti-air pollution and improvement of energy utilization.

The objectives of the present study are:

(a) To develop a software on the basis of CLTD method for cooling load calculation for specific field applications for comfort air conditioning in commercial and residential buildings, Hospitals, Shopping arcades, Airport terminals, Theaters, Public halls, Hotels, Motels, Art galleries, Museums, Research laboratories etc.

(b) To make a comparison with different air conditioning systems for economical and environmentally friendly for human beings.

(c) To make a case study for professional design and to develop comfortable air conditioning systems with energy saving features.

1.5 Scope of this work/experimental design/outline of Methodology

The present research program covers cooling load calculation and performance of air conditioning system. In calculating cooling load by thumb rule, traditionally vapor compression air conditioning system is taken into consideration not the vapor absorption system or the cogeneration service system, though the later systems may be economical and environmentally friendly.

In the present research work the software has been developed for the cooling load calculation considering the following factors:

a) This software has designed for 24º latitude north for any month, any time, required out side temperature & inside temperature, daily range 11ºC and ventilation air 7.5 l/s per person (ASHRAE Standard 62).

b) The software has been made into five steps (i) Instantaneous solar radiation heat gain for glass windows (ii) Transmission heat gain (iii) internal heat gain (iv) Ventilation & infiltration air and (v) Total result

c) It has four options for getting load capacity in watt, kilowatt, Btu/h and Ton of Refrigeration (TR)

d) It is assumed 5% friction loss and 2% air conditioning equipment losses which is added for total refrigeration load.

e) The development of software for cooling load calculation has based on programming language Visual Basic version 6.0. This software is data base type. The necessary data those are available in the ASHRAE handbooks have been incorporated into the software for cooling load calculation.

CHAPTER-2
REVIEW OF LITERATURE

In the last few decades, research works have been directed towards laboratory simulation and theoretical predictions for environment friendly air conditioning implementation. Several software have been developed for refrigeration load calculation aiming at saving energy, optimizing waste heat recycle for vapor absorption refrigeration system and hence having energy efficient system. The common issue is to protect the earth and to protect the environment which is of great importance to the mankind. Researchers from all around the world has greatly contributed to the knowledge of the traditional electric chiller which takes Refrigerant as its cooling medium and caused great harm to the ozone layer of the atmosphere. In the past, most research available in vapor compression cooling system, not in vapor absorption cooling system. But in the recent years considering the energy crisis, the efficient and economical building design consideration absorption and cogeneration service system is becoming more and more important.

2.1 Literatures concerning of vapor compression air conditioning system,

In cooling mode, the operating performance of refrigeration is described by its energy efficiency ratio (EER). A large EER indicates better performance. Kazachki [1] observed in secondary systems that the indirect refrigeration systems are 30% more expensive and consume 30% more energy. This reflected poor thermo physical properties of secondary coolants (brines) and poor initial design practices applied to the first installation. The selection with better secondary coolants based on water solutions of organic salts combined with the advanced engineering practices developed in the last decade, positioned the secondary coolant technology to successfully compete with the traditional DX (direct expansion) systems in terms of both installed cost and energy consumption. From an environmental point of view, however, the SCS (secondary coolant system) are superior to the DX systems and are the only known technology that has a potential to provide zero-leak refrigerant systems.

Kavanaugh [2] Studied cooling and heating requirements for buildings for the primary climate zones. He conducted heat gain and heat loss calculations for buildings with energy efficient envelopes, lighting, equipment, and ventilation practices.

Marriott [3] in his study found that many building owners are choosing sustainable design because the economics make more sense now. Rising energy costs are reducing the payback period for capital improvement that improve energy performance. However, in contrast to the wealth of promotional information for why sustainable building practices should be used, surprising little application information is available on sustainability. For sustainable practices, the energy rate was summarized by Marriott [3] in all three major analyses i.e. (a) optimal air system (b) recovering energy from condenser water (c) geothermal heat pump systems.

Bridger [4] defined three main aquifer thermal energy storage systems based on the form of energy being stored. These are chilled water storage system, heat storage system and integrated heat and cold storage systems. Applications of cold storage include primarily air conditioning and equipment cooling in institutional and commercial building and industrial process cooling. Jarnagin [5] improved HVAC cooling efficiencies about 10% in the hot climate, and about 7% in the cold climate, reflecting the difference in benefit of cooling efficiencies based on climate.

Kosar [6] studied recent work of national center for Energy Management and Building Technologies has documented the emergence of diverse air conditioning products with enhanced dehumidification features. The leading issue being addressed with these new cooling systems is the large dehumidification requirements presented by moisture-laden outside air that is mechanically introduced into buildings to meet the increased ventilation rates. The ready quantification of outside air dehumidification loads by others has also made it much more straightforward to determine builders HVAC moisture removal design needs, especially those originating from outside airstreams.

John A. Paulauskis [7] studied the noise problem in screw chillers HVAC systems have many types of noise sources. Examples include airflow through ductwork, air terminals or air devices, mechanical fan noise from blower, burner or compressor noise from the refrigeration equipment. All of these noise sources are a composite of many discrete and separate frequencies of sound when many random frequencies of sound are in the audible range of the human ear, the sound usually is characterized as "broadband". However, if one or more sound frequencies stand out above the adjacent frequencies (usually by more than 5 to 8 decibels [db]), then the broadband sound is said to contain prominent pure tones. These pure tone noises causes immense problem to its inhabitants, Paulauskis in his paper suggested the measure to reduce the noise in any installation.

Douglas. Kosar et. al. [8] found that increased outside air volume can result in periods of increased indoor humidity levels in non-arid climates. Many examples of the harmful effects on humans and buildings of elevated humidity levels have been documented. As a result it was proposed that revisions to standard 62-1989 include a requirement that building spaces in humid climates average ≤60% RH for occupied periods and ≤70% RH for unoccupied period. While this requirement is not currently advanced for public review, the 1989 standard does include a recommendation for maintaining rh between 30% and 60%. Good practice in humid climates dictates that this requirement be met to prevent the problems that occur at higher humidity levels.

Richard Taft [9] in his study for Health-care HVAC suggests that 60% RH is the recommended design condition for good surgical space design. While we agree that 60% RH is the upper range of recommended design, it is not the midpoint and is not sufficient to provide any safety factor for good engineering design. Had the author selected the more common 50% midpoint used by most engineers, this would have required a much drier leaving condition and probably required a need for preheat.

2.2 Literatures Concerning of Vapor absorption air conditioning system

Dolan [10] in his study found that absorption cycle refrigeration has been, and remains, the dominant technology of gas-fueled cooling equipment. Historically in commercial comfort air conditioning system applications, steam generated from gas or others fuels were the medium supplied to absorption-based liquid chillers. However, the popularity of this equipment has decreased in favor of electric equipment over the last several decades, due in part to gas supply curtailments and technical advances in electrical equipment.

Concurrent with the decline of sales of new absorption equipment the sales of engine powered chillers by HVAC manufacturers were increased. Although this engine based equipment never achieved the sales volume of absorption system in mid '70s.

A new variation of absorption equipment emerged in the HVAC market in the early '80s. This equipment is directly fueled and combines the functions of a boiler or chiller, including the capability of simultaneous chilled water and heated water production. The direct fired cooling equipment a double effect absorption process, resulting in superior fuel utilization and cold production efficiency. The sales of these Japanese manufactured machines have continued to increase since active market introduction in the '80s. Several domestic manufactures offer steam/Hot water -powered chillers, and double effect equipment is available for high pressure steam application.

Minea [11] in his research work used ground source heat pump to reduce energy (electricity/ natural gas) for heating and cooling School building. He used brine as the heating transfer medium from the underground water. In Quebec Canada, between November and March, the heat transferred from the ground water heat exchanger represented 39% of the building total equivalent heating demand.

Kostrzerwa & Davidson [12] in their study showed that packaged cogeneration systems have been developed by manufacturers to address the commercial sector market because they eliminate the repeating cost of system design, allow factory assembly and testing and fit the commercial energy users expectations of packaged equipment. Also expensive field labor time can be kept to a minimum and quality control can be enhanced. Nearly all such systems are based on reciprocating engines due to their lower cost and higher efficiency relative to gas turbine.

Hise [13] studied a cogeneration plant for a site having an expected daily thermal load. In one embodiment, the plant includes a heat engine/electrical power generator set and a heat storage unit. The engine/generator set is sized to normally operate only during the peak rate period of the central electric service utility while rejecting a quantity of heat equal to the daily thermal load at the site. The storage unit is sized to contain a quantity of heat equal to the daily thermal load reduced by that portion of the daily load incurred during the peak rate period. In an other embodiment the cogeneration plant includes a fuel cell electrical power generator serving a local energy integrated community. The fuel cell is sized to reject a quantity of heat to satisfy the collective average daily thermal load at the community site. Separate thermal storage sections are provided for high and low grade rejected heat.

2.3 TYPES OF AIR CONDITIONING SYSTEM

Scope of air conditioning

To the average person, air conditioning simply means "the cooling of air". For our purposes, this definition is neither sufficiently useful nor accurate, so we will use the following definition instead. Air conditioning is the process of treating air in an internal environment to establish and maintain required standards of temperature, humidity, cleanliness and motion. Let us investigate how each of these conditions is controlled:

1. **Temperature**. Air temperature is controlled by heating or cooling the air.
2. **Humidity**. Air humidity, the water vapor portion of the air, is controlled by adding or removing water vapor from the air (humidification or dehumidification).
3. **Cleanliness**. Air cleanliness, or air quality; the removal of undesirable contaminants using filters or other devices or by ventilation, the introduction of outside air into the space which dilutes the concentration of contaminants. Often both filtration and ventilation are used in an installation.
4. **Motion**. Air motion refers to air velocity and to where the air is distributed. It is controlled by appropriate air distributing equipment.

Sound control can be considered an auxiliary function of an air conditioning system, even though the system itself may be the cause of the problem. The air conditioning equipment may produce excessive noise, requiring additional sound attenuating (reducing) devices as the part of the equipment.

The definition of air conditioning given here is not meant to imply that every HVAC system regulates all of the conditions described. A hot water or steam heating system, consisting of a boiler, piping and radiation devices only controls air temperature and only during the heating seasons. These types of systems are common in many individual homes (residences), apartment houses, and industrial buildings.

A warm air system, consisting of a furnace, ducts, and air outlet registers, also controls air temperature in winter only. However, by the addition of a humidifier in the ducts, it may also control humidity in winter. Warm air systems are popular in residences.

Some residences have combination air heating and air cooling equipment that provides control of temperature and humidity in both winter and summer. Some degree of control of air quality and motion are also provided in air-type heating and cooling systems.

Air conditioning systems used for newer commercial and institutional building and luxury apartment houses usually provide year-round control of most or all of the air conditions described. For this reasons, it is becoming increasingly popular to called complete HVAC systems environmental control systems.

2.4 Air conditioning system

Air conditioning for people is the control of temperature, humidity, air movement and air cleanliness, are necessary to achieve human thermal comfort.

Air conditioning systems can be categorized according to the means by which the controllable cooling is accomplished in the conditioned space. They are further segregated to accomplish specific purposes by special equipment arrangement.

In selecting a suitable air conditioning system for a particular application, consideration should also aim to the following:

System constrains: cooling load, zoning requirements, heating and ventilation

Architectural constrains: size and appearance of thermal devices, acceptable noise level, Space available to house equipment and its location relative to the conditioned space, acceptability of components obtruding into the conditioned space

Financial constraints: capital cost, operating cost and maintenance cost.

These are four basic systems:

2.4.1 Central chilled water air conditioning systems- all air system

a. Single zone
b. Reheat
c. Variable Air Volume
d. Duel Duct
e. Multi zone

2.4.2 Central chilled water air conditioning system- air and water system

a. Induction
b. Fan coil
c. Two pipe
d. Three pipe

2.4.3 Central chilled water air conditioning system- All water system, including cooling Towers which can also be applied to system 1, 2 above

a. Fan coil units

b. Central chilled water air conditioning system with fan coils and other devices

c. Cooling tower

An all -air system provides complete sensible and latent heat cooling capacity in the cold air supplied by the system. Heating can be accomplished by the same air stream, either in the central system or at a particular zone. All air conditioning systems can be classified into two (2) categories:

- Single duct systems
- Duel duct systems

System Advantages:

a. The central plant is located in unoccupied areas, hence facilitating operating and maintenance, noise control and choice of suitable equipment**.**

b. No piping, electrical wiring and filters are located inside the conditioned space

c. Allows the use of the greatest number of potential cooling season's house with outside air in place of mechanical refrigeration.

d. Seasonal changeover is simple and readily adaptable to climatic control.

e. Gives a wide choice of zone ability, flexibility, and humidity control under all operating condition

f. Heat recovery system may be readily incorporated.

g. Allows good design flexibility for optimum air distribution, draft control, and local requirements.

h. Well suited to applications requiring unusual exhaust makeup.

i. Infringes least on perimeter floor space.

j. Adapts to winter humidification.

System Disadvantages:

a. Requires additional duct clearance which can reduce the usable floor space.

b. Air-balancing is difficult and requires great care

c. Accessibility to terminals demands close cooperation between architectural, mechanical and structural engineers.

2.4.1a Single Zone System

The all-air single-zone air conditioning system is the basic central system which can supply a constant air volume or a variable air volume at low, medium or high pressure. Normally, the equipment is located outside the conditioned space but can also be installed within the conditioned space if conditions permit. Typical applications include Space with uniform loads Small spaces requiring precision control multiple systems for large areas. A typical layout diagram of a single zone system is shown in Figure. 2.a

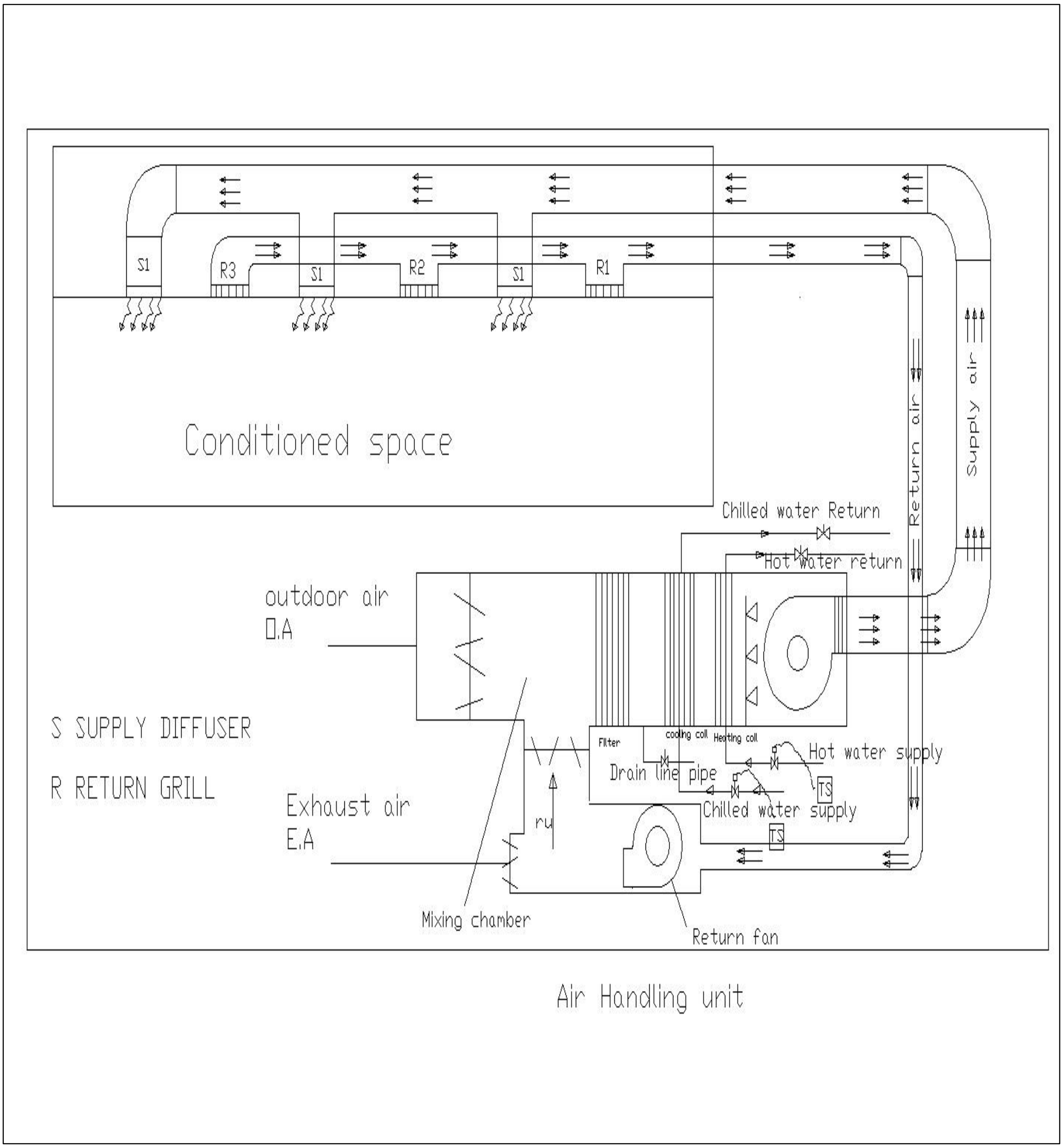


Figure:2.a Single Zone ystem

2.4.1b Reheat system

The reheat system is a modification of the single-zone system. It provides:

-Zone or space control for areas of unequal loading.

-Heating or cooling of perimeter areas with different exposures.

-Close control for process or comfort applications. In the reheat system, heat is added as a secondary process to either preconditioned primary air or re-circulated room air. The heating medium can be hot water, steam or electricity.

Advantages: Closely controls space conditions

Disadvantages: Expensive to operate

A typical reheat system is shown in Fig.2.b

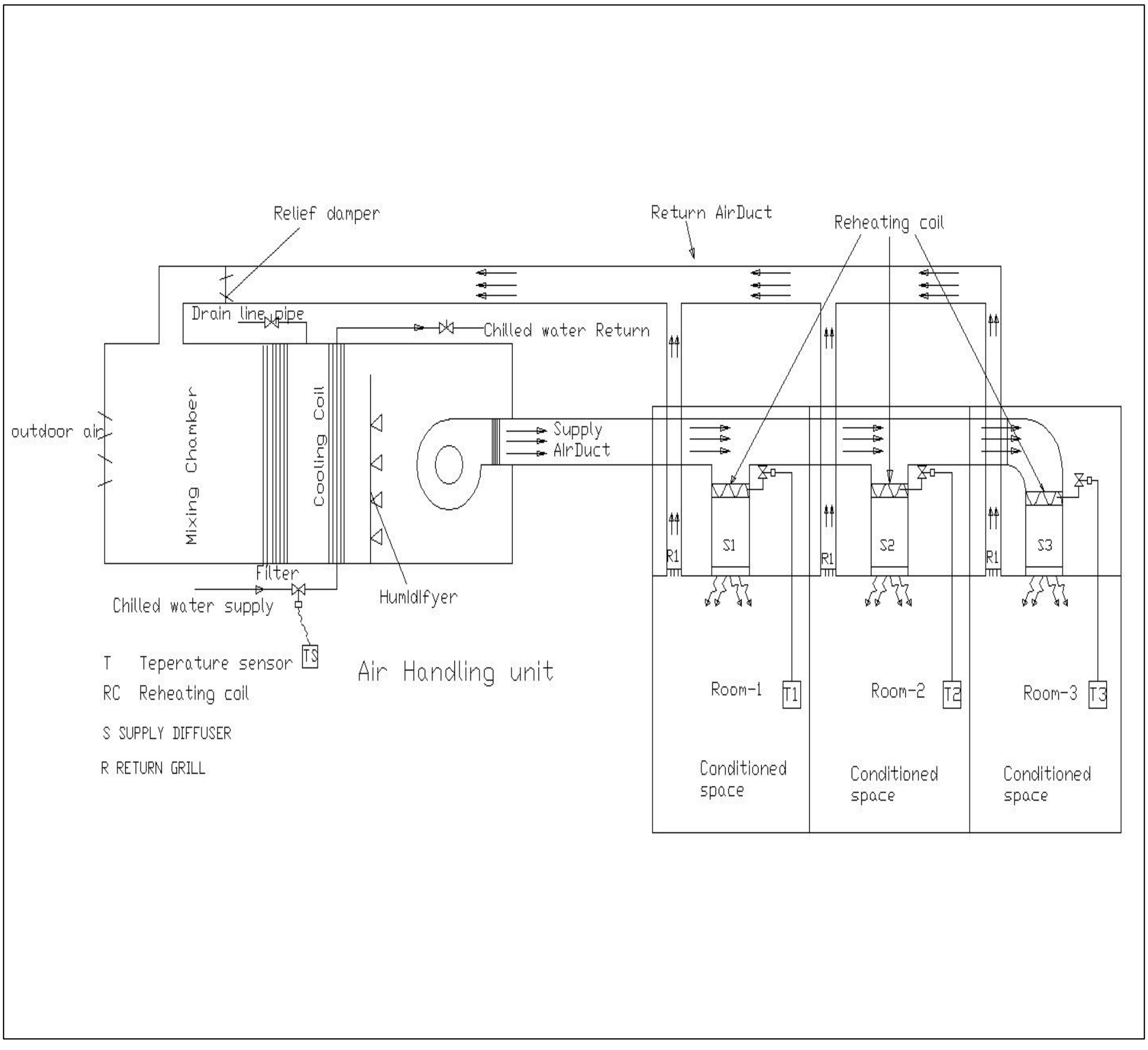


Figure 2.b: Reheat system

2.4.1c Variable Air Volume System without reheats

The variable air volume system compensates for varying cooling loads by regulating the volume of cooling air supplied through a single duct.

(a) Simple Variable Air Volume (VAV)

Simple VAV systems typically cool only and have no requirement for simultaneous heating and cooling in various zones.

A typical VAV diagram is shown in Fig. 2.c (1)

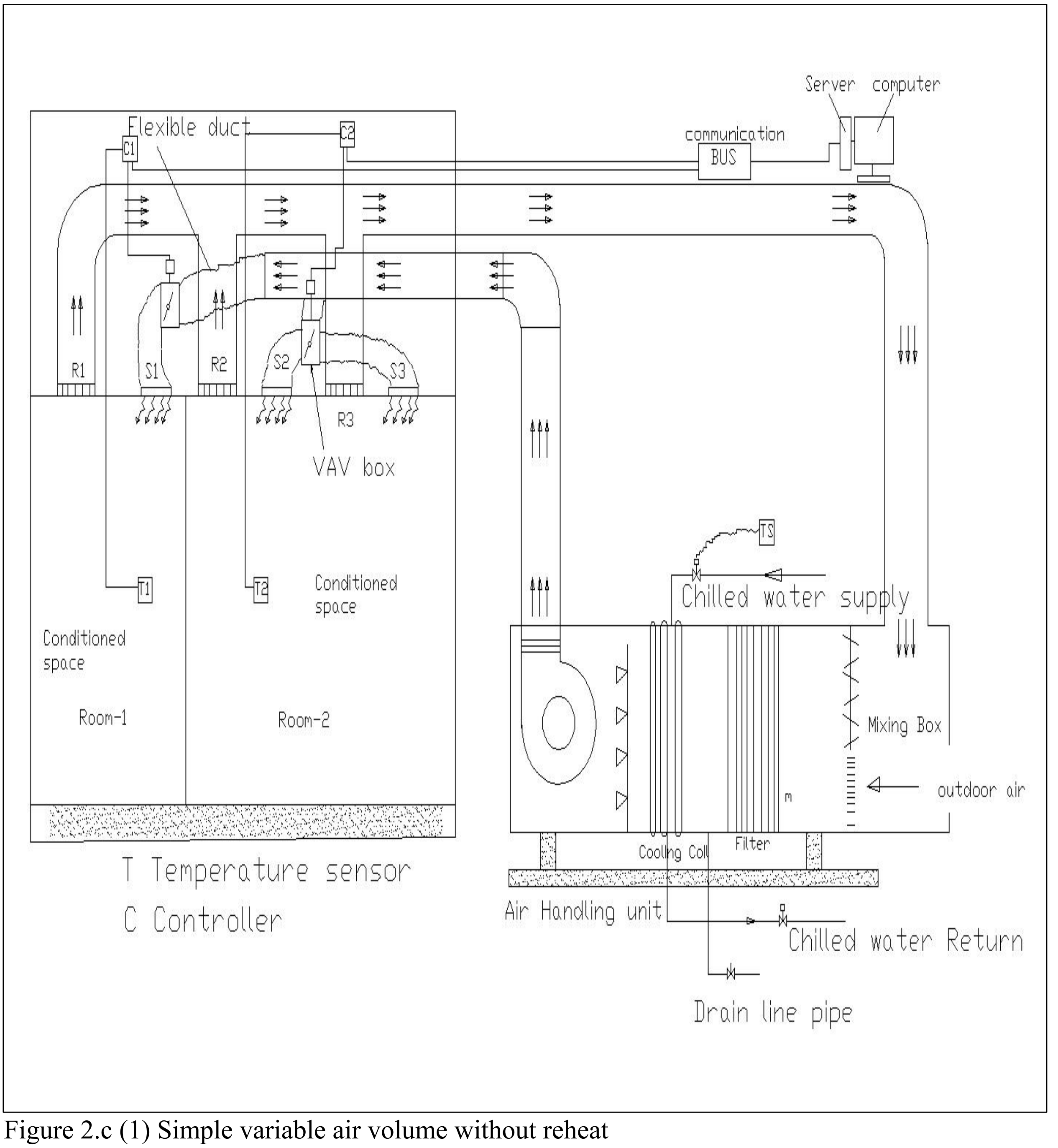


Figure 2.c (1) Simple variable air volume without reheat

(b) Variable Air Volume system with Reheat

It integrates heating at or near the terminal units. It is applied to systems requiring full heating and cooling flexibility in interior and exterior zones. Heating is turned on when the air flow reaches a predetermined minimum. A typical VAV system with reheat is shown in Fig. 2.c (2)

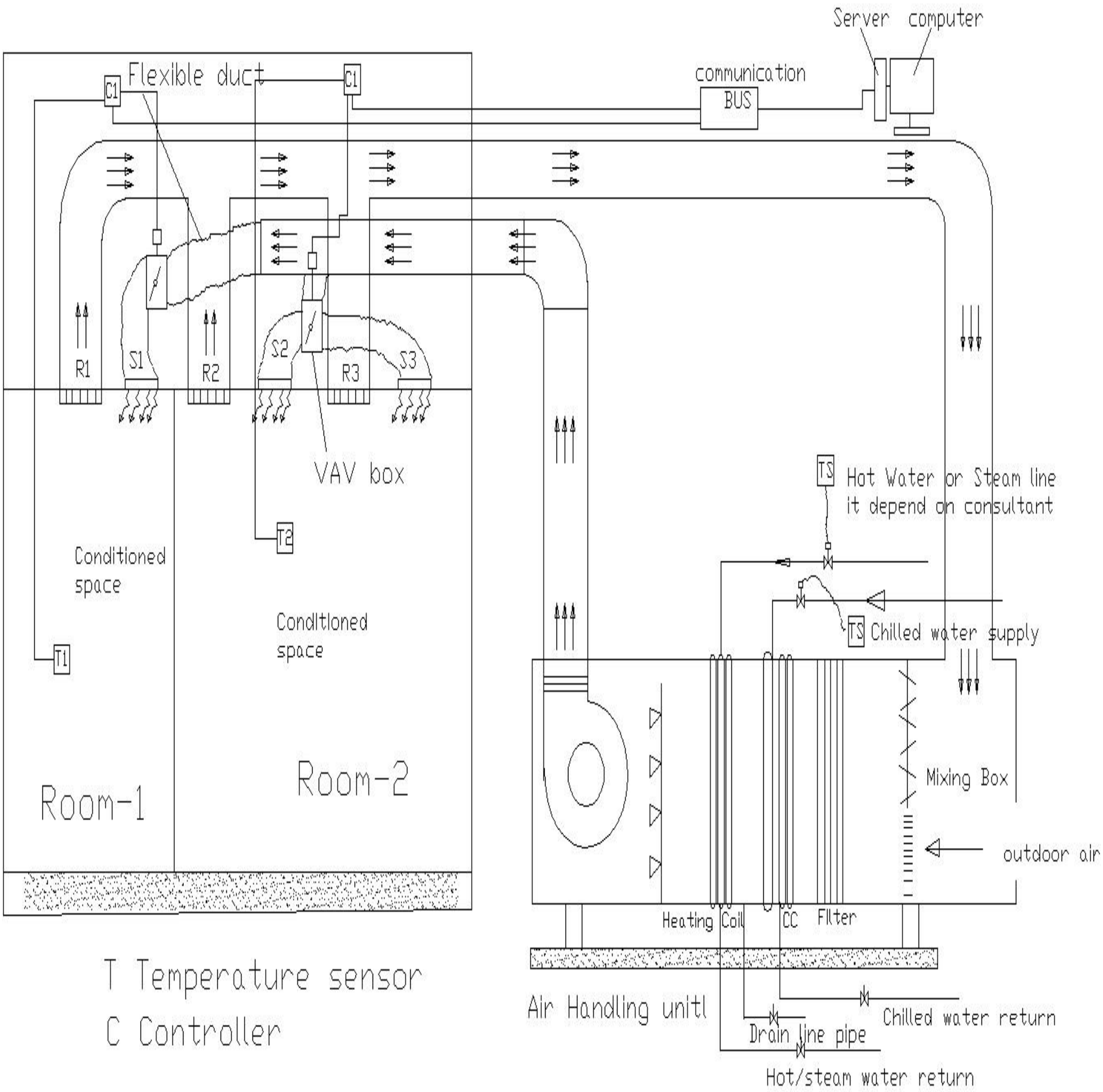


Figure 2.c (2) Variable air volume with reheat

Advantages:

a) When combined with a perimeter heating system, it offers inexpensive temperature control for multiple zoning and a high degree of simultaneous heating-cooling flexibility.

b) Capital cost is lower since diversities of loads from lights; occupancy, solar and equipment of as much as 30% are permitted.

c) Virtually self-balancing.

d) It is easy and inexpensive to subdivide into new zones and to handle increased loads with new tenancy or usage if load does not exceed the original design simultaneous peak.

e) No zoning is required in central equipment.

f) Lower operating cost because

   (i) Fans run long hours at reduced volume

   (ii) Refrigeration, heating and pumping matches diversity of loads

   (iii) Unoccupied areas may be fully cut-off

g) Reduced noise level when the system is running at off-peak loads.

h) Allows simultaneous heating and cooling without seasonal changeover.

2.4.2 **Central chilled water A/C systems Air-and-Water Systems**

An air-and-water system is one in which both air and water (cooled or heated in central plant room) are distributed to room terminals to perform cooling or heating function. The air side is comprised of central air conditioning equipment, a duct distribution system, and a room terminal. The supply air, called primary air, usually has a constant volume which is determined by:

1. The ventilation requirement.
2. The required sensible cooling capacity at maximum cooling load.
3. The maximum sensible cooling capacity following changeover to the winter cycle when chilled water is no longer circulated to the room terminal.

The water side consists of a pump and piping to convey water to heat transfer surfaces within each conditioned space. The water is commonly cooled by the introduction of chilled water from the primary cooling system and is referred to as the secondary water loop. Individual room temperature control is by regulation of either the water flow through it or the air flow over it.

2.4.2a Induction system

The inducting system is designed for use in perimeter rooms of multi-storey, multi-room building that may have reversing sensible heat characteristics. It is especially adapted to handle the loads of skyscrapers with minimum space requirements for mechanical equipment. In the induction system, ducted primary air is fed into a small plenum chamber where its pressure is reduced by means of a suitable damper to the level required at the nozzles. The plenum is acoustically treated to attenuate part of the noise generated in the duct system and in the uni t. The primary air is then delivered through nozzles as high velocity jets which induce secondary air from the room and over the secondary coil.

Induction units are usually installed at a perimeter wall under a window. Some hotel rooms are providing with induction coils.

A typical induction system diagram is shown in Fig. 2.d

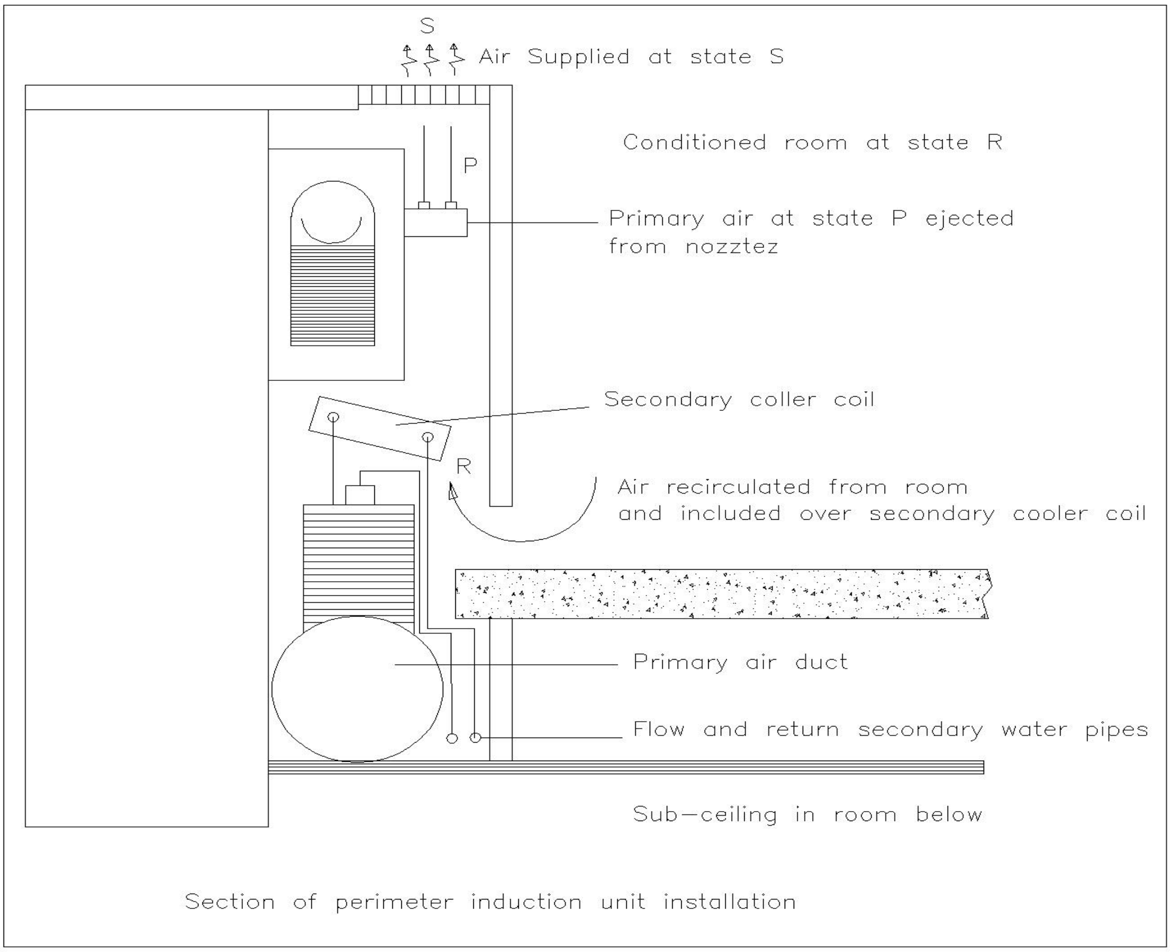


Figure 2.d: Induction system

The induction system employs air ducts to convey treated air with higher pressure levels and of the right adjustable quantities to various cooling/heating coil units. These coil units are built in with induction nozzles such that when high pressure air goes through them, air room the room is inducted across the fin surface of the water-circulated coils. This inducted air stream is either cooled or heated after passing through the coil, and then mixed with the air coming out of the nozzle. The right quantity of high pressure air is adjusted automatically in response to a thermostat located in the conditioned space. The system is well suited to provide temperature control for individual spaces or zones.

Advantages:

1. Individual room temperature control.
2. Separate sources of heating and cooling for each space available as needed to satisfy a wide range of load variations.
3. Low distribution system space required as a result of reducing the air supply by use of secondary water for cooling and high velocity air design.
4. Reduced size of central air handling equipment.
5. Dehumidification & filtration performed in a central plant room remote from conditioned space.
6. Outdoor air supply is positive.
7. Minimal maintenance required for individual induction units which have no moving parts, i.e. no fans
8. Air duct dimensions are smaller than VAV systems or CAV systems
9. Zoning of central equipment is not required.
10. No fan comes together with the coil, making the conditioned space quiet.

Disadvantages:

1. Limited to perimeter space.
2. The primary air supply is usually constant with no provision for shutoff.
3. Not applicable to spaces with high exhaust requirement.
4. Higher energy consumption due to increased power required by the primary pressure drop in the terminal units.
5. Controls tend to be more complex than for all-air systems.
6. A low chilled water temperature is needed to control space humidity adequately.
7. Seasonal changeover is necessary.
8. Initial cost is usually higher than fan coil systems.

2.4.2b Fan coil system

The fan-coil system is similar to the inducting system, with the induction unit replaced by the fan-coil unit. The basic elements of the fan-coil units are a finned-tube coil and a fan section. The fan section re-circulates air continuously from within the perimeter space through the coil which is supplied with either hot or chilled water. Auxiliary air may be delivered to the conditioned space for dehumidification and ventilation purposes.

A typical fan coil diagram are shown in Figure 2.e

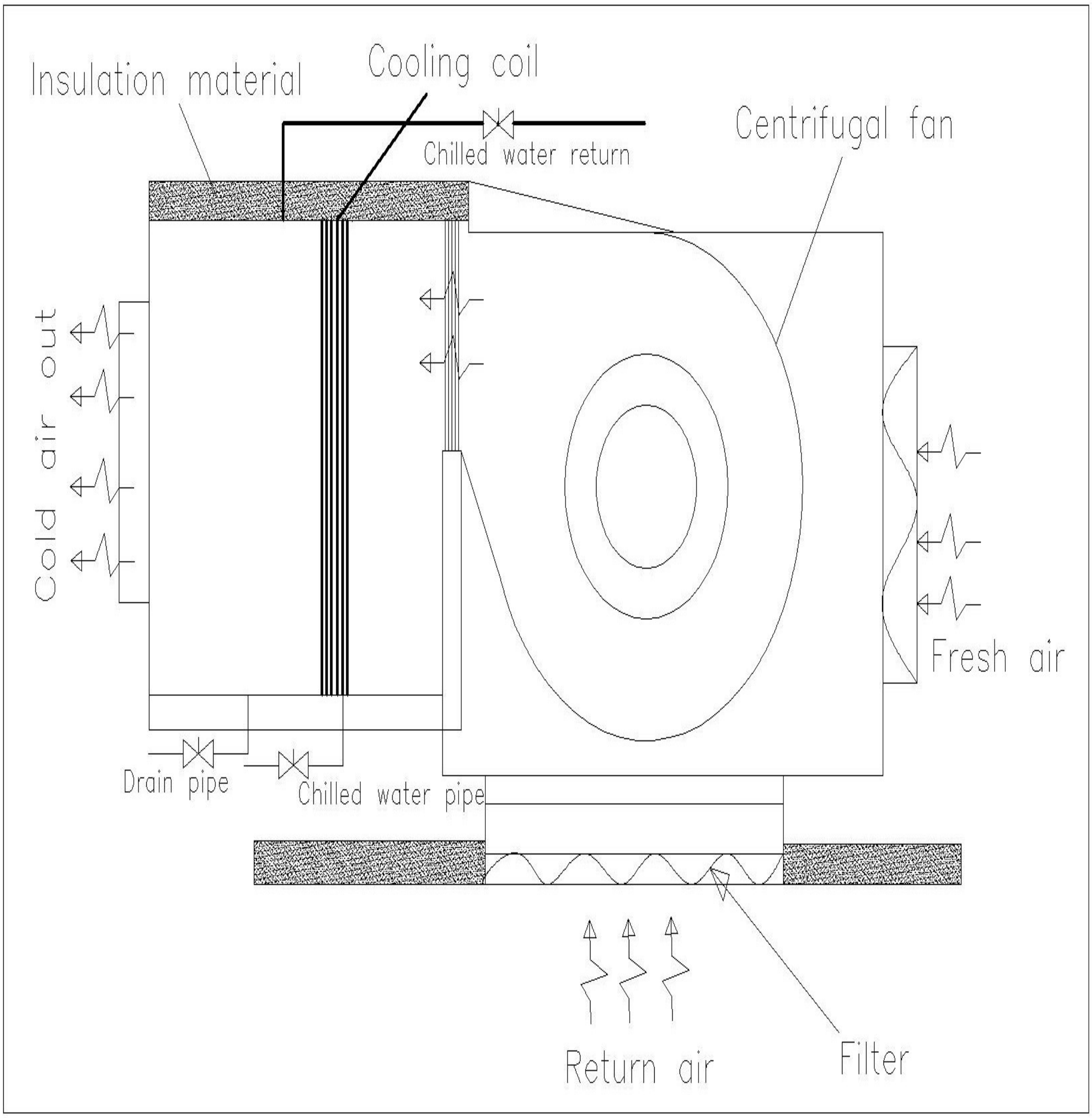


Figure 2.e: Fan Coil system

Advantages: (in addition to those for induction units)

1. System can be operated with the primary air turned off.
2. The air velocity is fairly constant regardless of the primary air quantity.
3. Primary air can either connect directly to fan-coil unit or supply the room separately.

2.4.2c Two-pipe systems

In two-pipe systems for induction coil, fan-coil or radiant panel systems, the water distribution circuit consists of one supply and one return pipe. The secondary water is cold in summer and intermediate seasons and warm in winter. The primary air quantity is fixed and the primary air temperature is varied in reverse proportion to outside temperature to provide the necessary amount of heating during summer and intermediate seasons. During winter cycle operation, the primary air is preheated and supplied at about 10°C to provide a source of cooling. A typical two pipe diagram is shown in Fig. 2.i

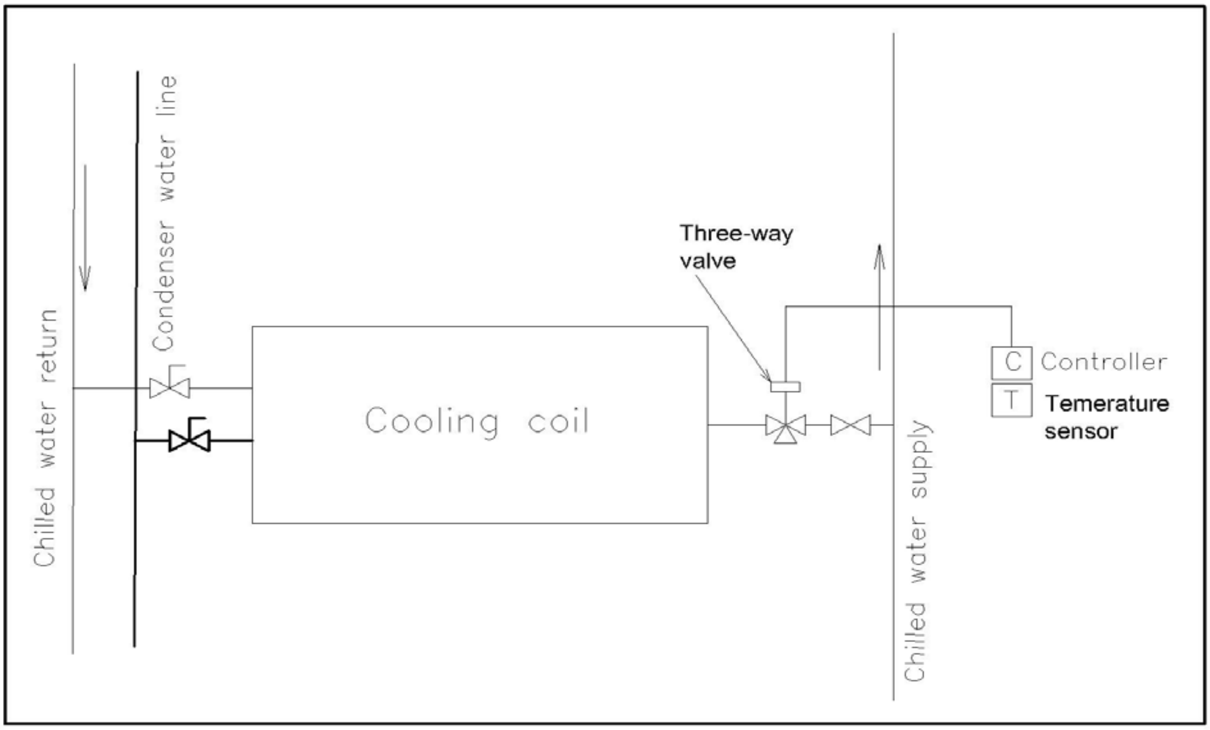


Figure 2.f: Two pipe system

Advantages:

1. Usually less expensive to install than four pipe systems.

Disadvantages:

1. less capable of handling widely varying loads or providing widely varying choice of room temperature than four-pipe systems.
2. Cumbersome to change over.
3. More costly to operate than four-pipe systems.

2.4.2d Three-pipe systems

Three-pipe systems for induction coil, fan-coil and radiant panel systems have three pipes to each terminal unit, a cold water pipe, a warm water pipe and a common return. These systems are rarely used today because they consume excess energy. A typical three pipe diagram is shown in Fig. 2.g

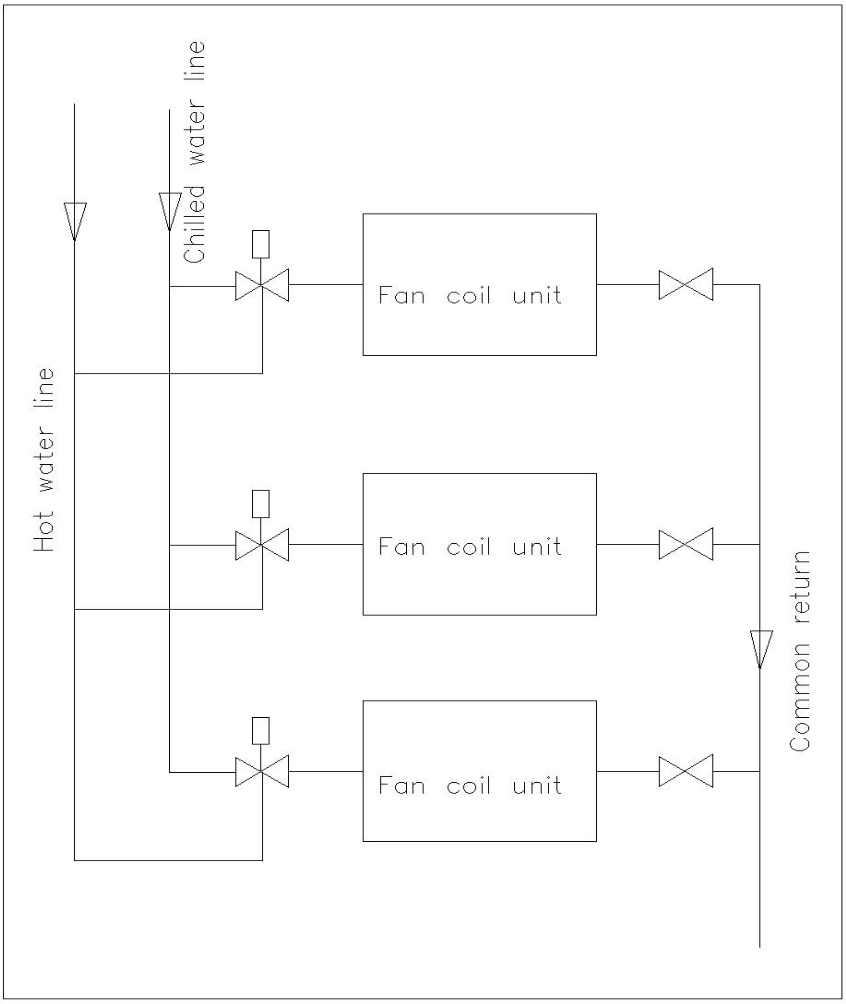


Figure 2.g: Three-pipe system

2.4.3b Central chilled water air conditioning system with fan coils and other devices

In this system, the following circuits do not mix with each other, and heat exchange is performed via various metal surfaces.

The chilled water circuit nominally water at 12ºC enters the chiller and after cooling leaves the chiller at 7 ºC i.e. nominally 7ºC entering fan coil units [FCU] /air handling unit [AHU] /primary handling unit [PAU]- for treating fresh air, 12ºC leaving these devices – chilled water

Pumps move water through this circuit CH. W. F- chilled water flow:

- CH. W. R- chilled water flow return.

-Refrigerant circuit – refrigerant compressors move the refrigerant through this circuit

-cooling water circuit - nominally 35 deg .C entering water cooling tower , 30 deg. C leaving cooling tower, i.e. nominally 30 deg .C entering condenser of chiller assembly, 35 deg. C leaving condenser of chiller assembly – Condenser water pumps move condenser water through this circuit.

2.4.3c Water cooling tower

A water cooling tower cools the water entering it from 35ºC to 30ºC nominally. The warmer water is sprayed inside the cooling tower amidst the stream of an upward air flow produced by the fan at the top of the tower. The air stream going out carries water particles. Condenser water pumps move condenser water through this circuit. Water in this circuit has to be treated. There is water loss to atmosphere in using cooling towers.

2. 4.4 Direct expansion systems [direct expansion of refrigerant, without the chilled water cooling medium]

Window air conditioning,

Unitary and rooftop air conditioning,

Split type and package air conditioning system &

Heat pumps

2.5 Vapor compression air conditioning

Vapor-compression refrigeration is one of the many refrigeration cycles available for use. It has been and is the most widely used method for air-conditioning of large public buildings, private residences, hotels, hospitals, theaters, restaurants and automobiles. It is also used in domestic and commercial refrigerators, large-scale warehouses for storage of foods and meats, refrigerated trucks and railroad cars, and a host of other commercial and industrial services. Oil refineries, petrochemical and chemical processing plants, and natural gas processing plants are among the many types of industrial plants that often utilize large vapor-compression refrigeration systems.

Refrigeration may be defined as lowering the temperature of an enclosed space by removing heat from that space and transferring it elsewhere.

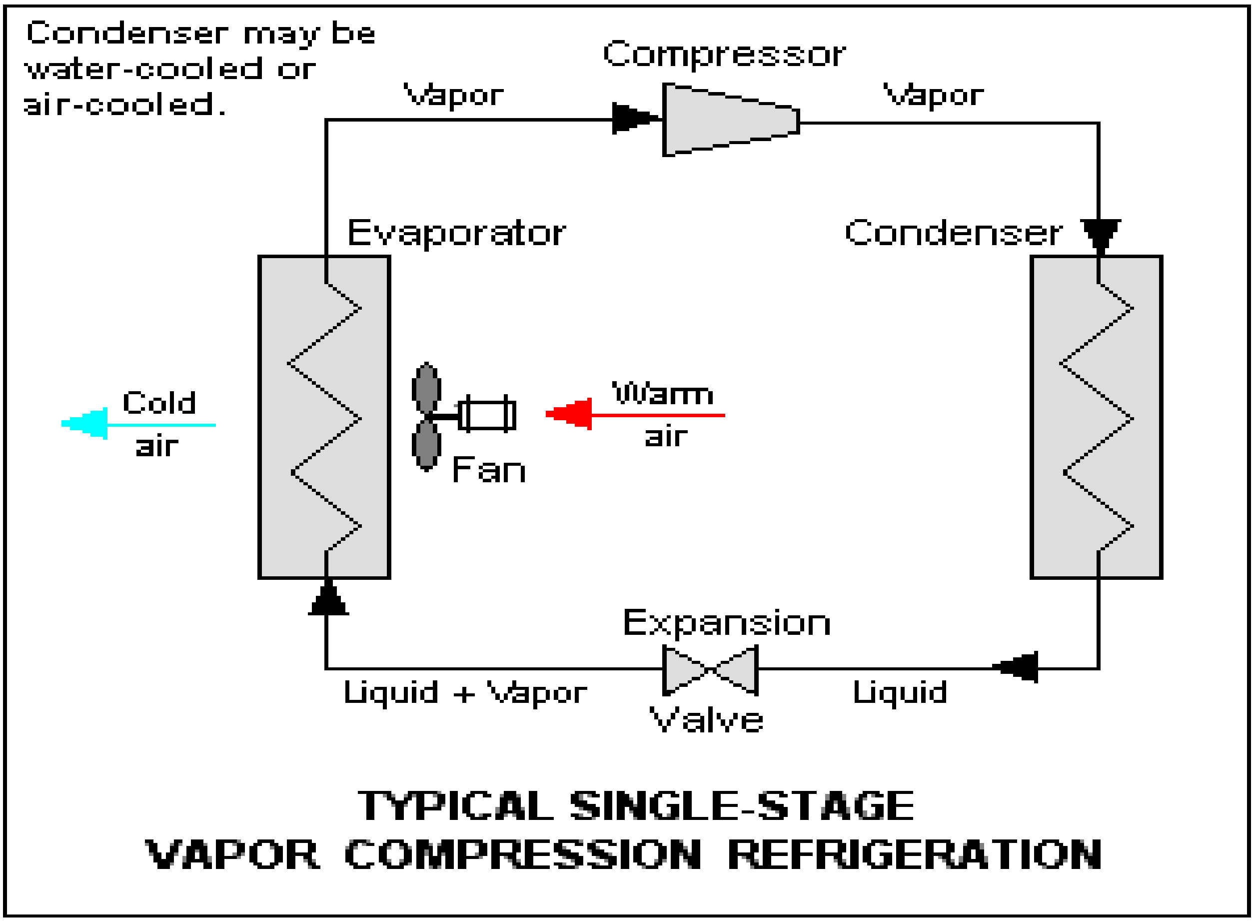


Figure 2.5: Vapor compression refrigeration systems

The vapor-compression refrigeration system uses a circulating liquid refrigerant as the medium which absorbs and removes heat from the space to be cooled and subsequently rejects that heat elsewhere. Figure 2.5 depicts a typical, single-stage vapor-compression system. All such systems have four major components: a compressor, a condenser, an expansion valve (also called a throttle valve), and an evaporator.

Circulating refrigerant enters the compressor in the thermodynamic state known as a saturated vapor and is compressed to a higher pressure, resulting in a higher temperature as well. The hot, compressed vapor is then in the thermodynamic state known as a superheated vapor and it is at temperature and pressure at which it can be condensed with typically available cooling water or cooling air. That hot vapor is routed through a condenser where it is cooled and condensed into a liquid by flowing through a coil or tubes with cool water or cool air flowing across the coil or tubes. This is where the circulating refrigerant rejects heat from the system and the rejected heat is carried away by either the water or the air (whichever may be the case).

The condensed liquid refrigerant, in the thermodynamic state known as a saturated liquid, is next routed through an expansion valve where it undergoes an abrupt reduction in pressure. That pressure reduction results in the adiabatic flash evaporation of a part of the liquid refrigerant. The auto-refrigeration effect of the adiabatic flash evaporation lowers the temperature of the liquid and vapor refrigerant mixture.

The cold mixture is then routed through the coil or tubes in the evaporator. A fan circulates the warm air in the enclosed space across the coil or tubes carrying the cold refrigerant liquid and vapor mixture. That warm air evaporates the liquid part of the cold refrigerant mixture. At the same time, the circulating air is cooled and thus lowers the temperature of the enclosed space to the desired temperature. The evaporator with its circulating refrigerant absorbs and removes heat which is subsequently rejected in the condenser and transferred elsewhere by the water or air used in the condenser.

To complete the refrigeration cycle, the refrigerant vapor from the evaporator is again a saturated vapor and is routed back into the compressor.

2.6 Vapor Absorption air conditioning system

The absorption cycle is a process by which refrigeration effect is produced through the use of two fluids and some quantity of heat input, rather than electrical input as in the more familiar vapor compression cycle. Absorption chillers work in primarily the same manner as conventional compressor based systems with the exception that the compressor is replaced by an absorber, a solution pump and a generator.

The principle of Absorption cooling:

The two basic principles on which all absorption type air conditioning and refrigeration plants operate are:

1. When a liquid evaporates, it absorbs heat, and it condenses it gives up that heat. This heat is called the latent heat of evaporation, and latent heat of condensation respectively.
2. Boiling point of liquid a pressure, i.e. Boiling point increase as pressure increase, Boiling point decreases if pressure decreases. For example, at atmospheric pressure (760 mm of Hg absolute) water boils at 100°C and Hg absolute pressure it boils at 37°C
The absorption cooling works on the affinity of some pairs of chemical to dissolve in one another. For example, lithium bromide solution has affinity towards water and ammonia etc.

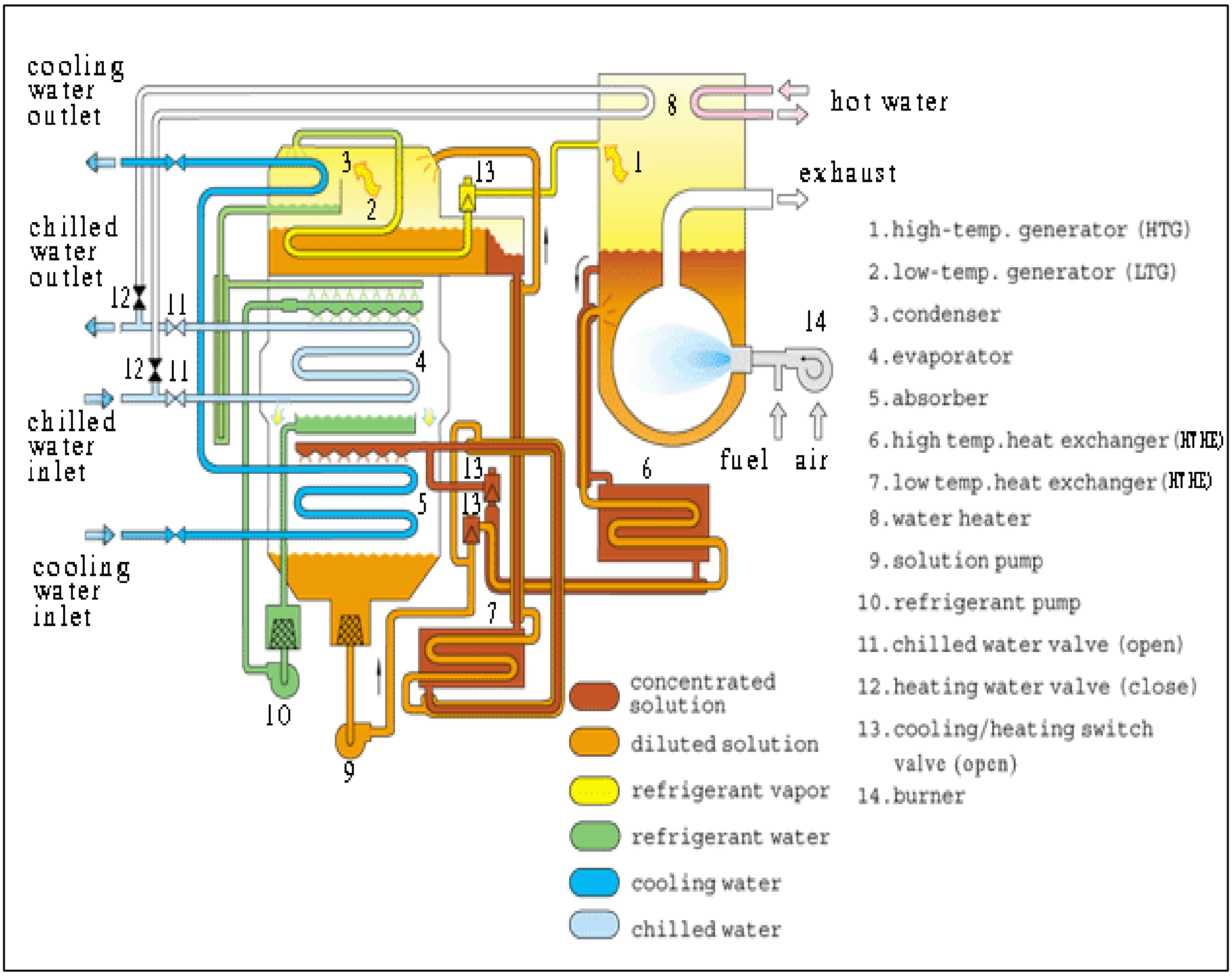


Figure 2.6: Working principal of absorption cycle

The basis absorption cycle is shown in Fig.2.6. The condenser and evaporator are as shown in Fig. 2.5 and the compression operation is provided by the assembly in the left half of the diagram. Low-pressure vapor from the evaporator is absorbed by the liquid solution in the absorber. If this absorption process were executed adiabatically, the temperature of the solution would rise and eventually the absorption of vapor would cease. To perpetuate the absorption process the absorber is cooled by water or air that ultimately rejects this heat to the atmosphere.

The pump receives low-pressure liquid from the absorber, elevates the pressure of the liquid and delivers the liquid to the generator. In the generator, heat from a high-temperature source drives off the vapor that had been absorbed by the solution. The liquid solution returns to the absorber through a throttling valve whose purpose is to provide a pressure drop to maintain the pressure difference between the generator and absorber.

The pattern for the flow of heat to and from the four heat-exchange components in the absorption cycle is that high -temperature heat enters the generator while low temperature heat from the substance being refrigerated enters the evaporator. The heat rejection from the cycle occurs at the absorber and condenser at temperature such that the heat can be rejected to atmosphere.

2.7 Waste Energy/Cogeneration service system

The waste heat and engine jacket hot water, which usually is discharged into atmosphere, now is utilized to drive the lithium bromide absorption chiller/heater, realized the cascade application of prime energy resource. This is shown schematically in Fig 2.7

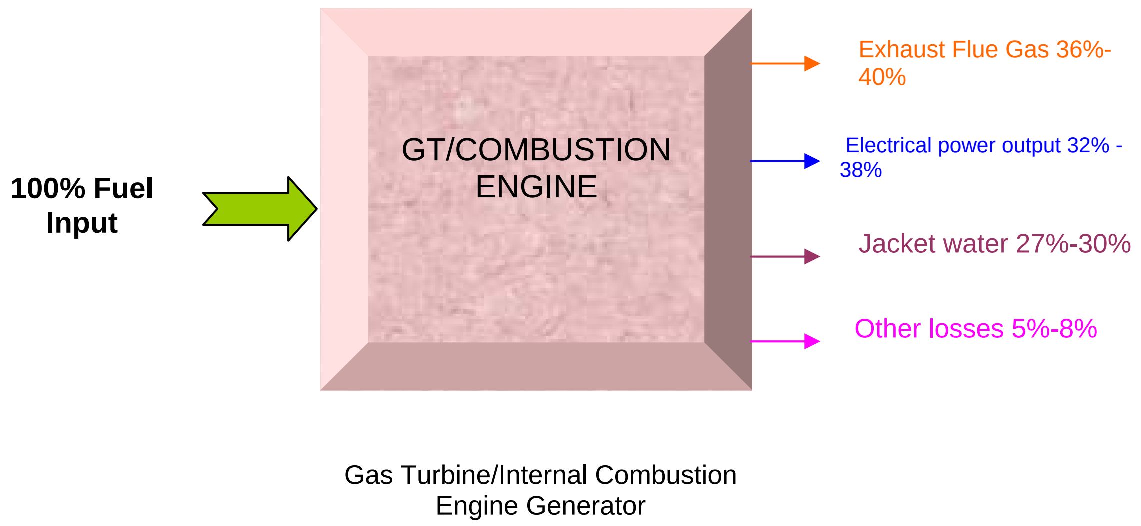


Figure 2.7: Waste Energy / Cogeneration basis absorption chilling system

2.8 Cogeneration utility system

The utility of Gas Turbine /Gas Engine cogeneration system is shown in Fig: 2.8. In the generator 32% of input energy is used to produce electricity and major part of remaining 68% waste energy can efficiently be used either to generate steam which is afterwards be used mainly to absorption chiller or steam turbine generator or some other facilities or to direct heating system like thermo fluid heater, exhaust recovery chiller or spray heater. Cogeneration utilities schematic diagram shown in Fig: 2.8

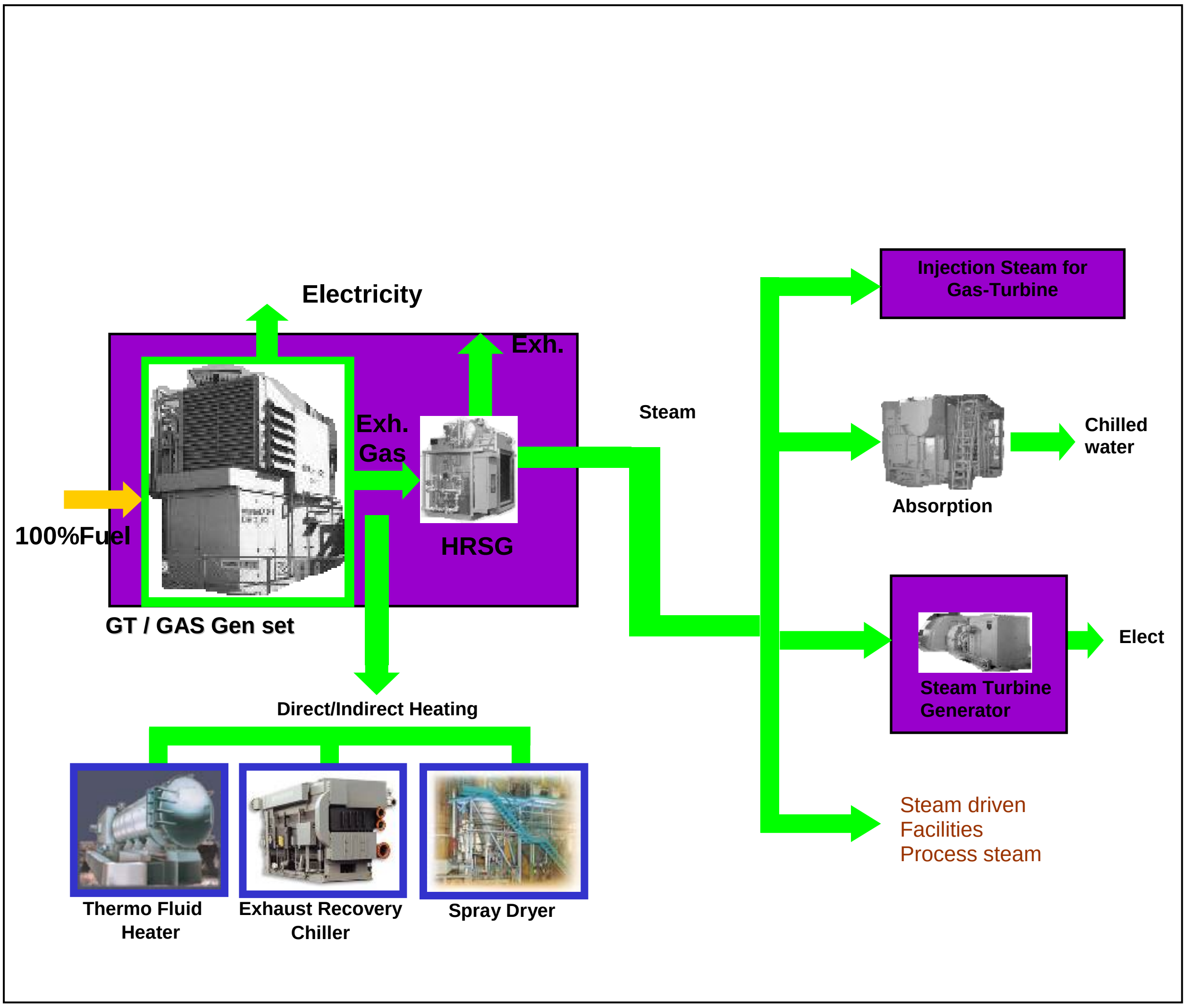


Figure 2.8: Gas turbine/Gas engine cogeneration utilities systems

Cogen-1,

Japan is a good example as a country where people are aware the value of energy resource, because it has to import its total energy and has huge demand of energy for industries and cities. There are hundreds of District Heating and Cooling systems (DHC) in Japan, where 85% of the import energy has been converted to consumable energy. Certainly, this system has been contributed as an important key of success for Japan. DHC Co-generation plant in Japan supplies steam for heating and chilled water for cooling as part of town utility, Solar Absorption chiller has no development during past decades expect in Japan. Japan has become the leader for absorption chiller manufacturer, especially for steam absorption chiller. Korea follows Japan and also manufacturing absorption chiller. India has used absorption chiller for industries and textile factories. These absorption chillers are mostly steam absorption chiller. Absorption chiller is rising against electric chiller with the quest for better world and environment. Major electric chiller manufacturers are now realized that the period of electric chiller is diminishing.

Cogen-2,

With high cost of production, the manufacturing facilities in developed countries like USA, UK, Japan, Germany and other are moving to China, Mexico and South East Asia. Besides steam absorption chiller, manufacturers are now also supplying direct-fired absorption Chiller and running on direct exhaust absorption chiller. Since, absorption chiller construction is simple. Basic construction of absorption chiller is the same for every type with only the change in the part of heating chamber or heat exchanger for the solution generator. COP for absorption chiller from, 1.2-1.4 is now available and the machine has only a few moving Parts and very low maintenance cost. In the last decade, with the fast development of China, there has been great demand for absorption chiller. Therefore, China becomes the market with very high prospect.

Electric chiller manufacturers have high hope for China market, which could substitute down trend South East Asian market. However, life is not as planned. Electric chiller, especially centrifugal chiller is too complicate to operate and maintain. China is too big to have good service net work set up in a short time. A lot of electric chiller fails to operate properly. Poor electricity and water quality, China needs a simple air-conditioning machine, rugged and very reliable, since many places rely only on one machine.

Absorption chiller has debut as the solution to the troubled electric chiller. Electric chillers have been gradually replaced with direct-fired absorption chiller. At present, thousands of direct-fired Absorption chiller have already been installed and a thousand more each year. Therefore, China becomes the largest market for absorption chiller and the world leader in Absorption chiller manufacturing, With high competition, ex-factory price of absorption chiller has recently drop from approx.$700/ RT to $400/ RT and with better improvement.

Indian make absorption chiller is no doubt the cheapest. Korean, Japanese and Chinese made are competitive but US made are expensive. Direct fired absorption chiller installation in China. Malaysia has the lead on implementing Co-generation and District Cooling system (DC) at KLCC twin tower, KLIA- new international airport, Putrajaya-new government town, Ciber Jaya-new Silicon town, Petronas new university.

2.9 What has been improved on absorption chiller?

Each manufacturer has been developing a better version of absorption chiller, especially towards a larger unit. Previous absorption chiller is normally less than 1000 RT and a larger unit has been Assembled from several smaller units, With the larger requirement in District Cooling system, which could be more than 10,000 RT, a larger absorption chiller has been manufactured up to 3000 RT. Larger absorption chiller is more competitive and easy to operate. Development of absorption chiller has been aimed at having higher efficiency and quality. Though, absorption chiller has simple construction but there are also a few things that could cause.

Problems such as corrosion and crystallization, therefore, not all absorption chillers are reliable and the good unit could last 20 years, while a bad unit could last only a few years. The unit should also be tested and certified according to international standard such as ARI, JIS, UL listed.

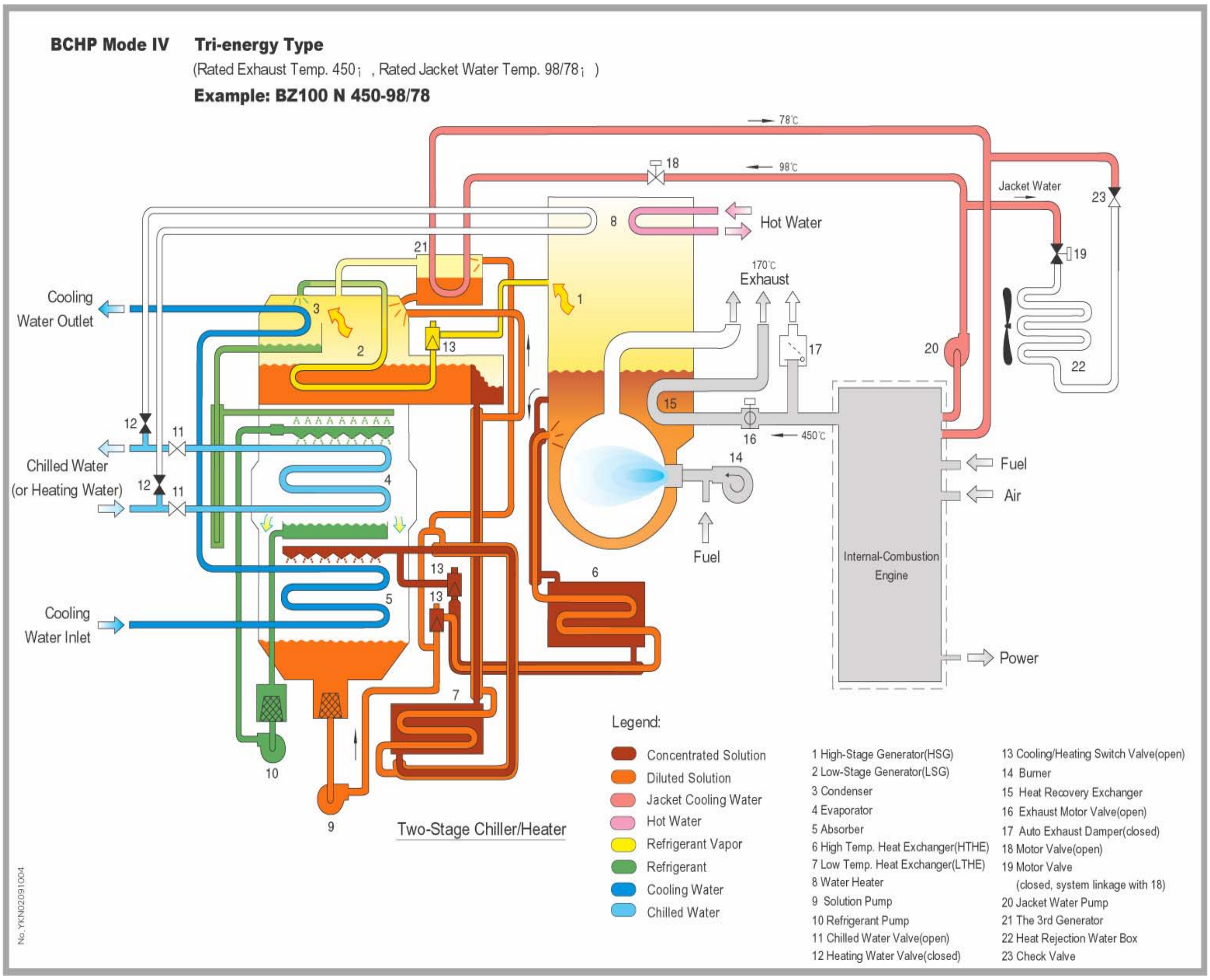


Figure 2.9: Cooling, Heating & Hot water chiller diagram

2.10 Refrigerants

Different fluids due to their inherent properties of condensing and evaporating at workable pressure range are used as refrigerants. These refrigerants absorbs heat at low pressure and evaporates thereby cooling the refrigerated space; the vapor is then compressed to high pressure by the compressor, the vapor at high pressure releases heat high temperature and condensed to back to liquid. In this way the refrigerants in refrigeration system are used as the heat carrying media.

"Freon" is a trade name for a family of halo-alkane refrigerants manufactured by DuPont and other companies. These refrigerants were commonly used due to their superior stability and safety properties: they are not flammable or obviously toxic as are the fluids they replaced. Unfortunately, these chlorine-bearing refrigerants reach the upper atmosphere when they escape. In the stratosphere, CFCs break up due to UV-radiation, releasing their chlorine atoms. These chlorine atoms act as catalysts in the breakdown of ozone, which does severe damage to the ozone layer that shields the Earth's surface from the Sun's strong UV radiation.

The chlorine will remain active as a catalyst until and unless it binds with another particle, forming a stable molecule. CFC refrigerants in common but receding usage include R-11 and R-12. Newer and more environmentally-safe refrigerants include HCFCs (R-22, used in most homes today) and HFCs (R-134a, used in most cars) have replaced most CFC used. HCFCs in turn are being phased out under the Montreal Protocol and replaced by hydrofluorocarbons (HFCs), such as R-410A, which lack chlorine.

Newer refrigerants are currently the subject of research, such as supercritical carbon dioxide Known as R-744. These have similar efficiencies compared to existing CFC and HFC based compounds. Thermodynamic analysis of the system

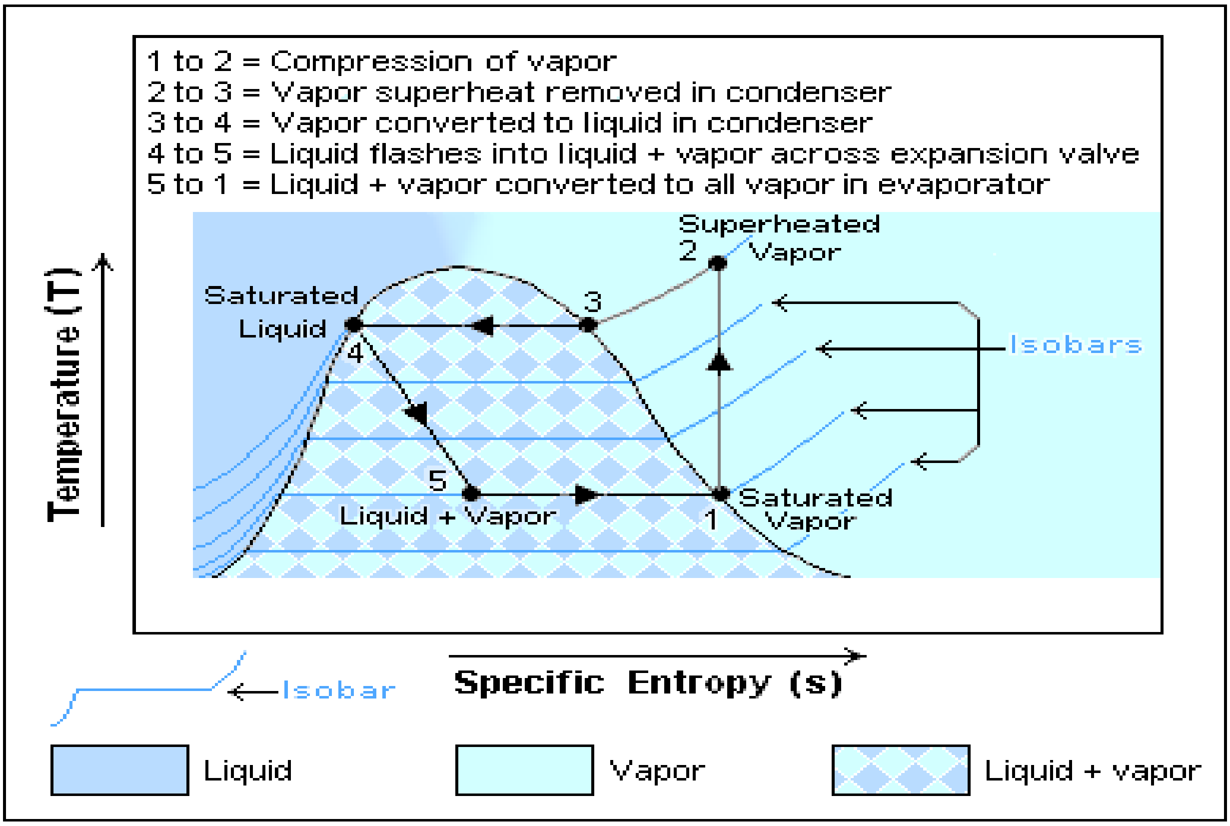


Figure 2.10: Temperature entropy diagrams

The thermodynamics of the vapor compression cycle can be analyzed on a temperature versus entropy diagram as depicted in Figure 2.7 at point 1 in the diagram; the circulating refrigerant enters the compressor as a saturated vapor. From point 1 to point 2, the vapor is isentropically compressed (i.e., compressed at constant entropy) and exits the compressor as a

superheated vapor.
From point 2 to point 3, the superheated vapor travels through part of the condenser which removes the superheat by cooling the vapor. Between point 3 and point 4, the vapor travels through the remainder of the condenser and is condensed into a saturated liquid. The condensation process occurs at essentially constant pressure.

Between points 4 and 5, the saturated liquid refrigerant passes through the expansion valve and undergoes an abrupt decrease of pressure. That process results in the adiabatic flash evaporation and auto-refrigeration of a portion of the liquid (typically, less than half of the liquid flashes), The adiabatic flash evaporation process is isenthalpic (i.e., occurs at constant enthalpy).
Between points 5 and 1, the cold and partially vaporized refrigerant travels through the coil or tubes in the evaporator where it is totally vaporized by the warm air (from the space being refrigerated) that a fan circulates across the coil or tubes in the evaporator. The evaporator operates at essentially constant pressure. The resulting saturated refrigerant vapor returns to the compressor inlet at point 1 to complete the thermodynamic cycle.

It should be noted that the above discussion is based on the ideal vapor-compression refrigeration cycle which does not take into account real world items like frictional pressure drop in the system, slight internal irreversibility during the compression of the refrigerant vapor, or non-ideal gas behavior (if any).

CHAPTER-3

DESIGN OF AIR CONDITIONING EQUIPMENTS

3.1 Duct design calculation

The function of duct system is to transmit conditioned air from the AHU (Air Handling unit) of FCU (Fan coil unit) to the apace to be condition. To fulfill this function in a particular manner, the system must be designed within the prescribed limits of available space, friction loss velocity, sound level, heat and leakage losses and gain. Duct design is important in any HVAC system and must take into account a variety of factors including space, noise, energy cost and first cost of installation. Deficiencies in duct design can result in systems that operate inefficiently and are expensive to operate. An understanding of theory to practice of duct design is important for engineers who design duct systems. The HVAC designer who wants to take up the duct sizing program, has to

- Calculate optimal air conditioning duct sizes.
- Compute round, rectangular, and flat oval duct sizes.
- Include a built-in fan library for noise calculation.
- Fitting selector displays drawings of over 190 ASHRAE duct fittings
- Project explorer provides a tree-style graphical representation of all trunks & runouts in the project.
- Include duct connection tree diagram report, a concise, graphical report to give the installer.
- Both supply and return duct systems can be entered in the same project. Return-side duct system losses are automatically accounted for when calculating the supply-side duct system.
- Calculate from manually entered data or directly from duct drawings created with Drawing Board.
- A virtually unlimited number of separate duct systems can be entered in a single project.
- Provide comprehensive color reports which can be printed, previewed on screen and saved to disk.
- Determine noise levels and required attenuation.

Duct size can be calculated by using either the static regain, equal friction, or constant velocity method. Data entry can be accomplished manually or taken graphically from either Drawing Board or Autodesk Building Systems 2006 or 2007, or soon from AutoCAD MEP 2008. Duct sizes can be calculated on a round, rectangular and flat oval shape basis. Noise levels and required attenuation are printed for each runout duct. A library of fan data for noise calculations is built into the program. Duct size allows an unlimited number of duct sections, and is suitable for both constant volume and VAV (variable air volume) systems as diversity is accounted for. Duct size also has an option for specifying duct height and width constraints to control sizes. This feature is also useful for analyzing problems in existing systems where the duct sizes are already specified. Duct size is based on the design procedures given in the ASHRAE Handbook of Fundamentals and the SMACNA HVAC Systems Duct Design Manual. Important new features include a Project Explorer and corresponding report that provide a tree-style graphical representation of all trunks and runouts in the project. In addition, both supply and return duct systems can be entered in the same project.

Calculation and duct sizing method

The Duct size program is based on the design procedures given in the ASHRAE Handbook of Fundamentals, the ASHRAE Duct Fitting Database, and the SMACNA HVAC Systems Duct Design manual. The program can calculate using either static regain, equal friction, or constant velocity methods. The user's manual gives detailed information on the exact equations used, and explains how to manually verify program results.

1. Velocity reduction method.
2. Equal friction method.
3. Static regain method.
4. Balanced capacity method.
5. Optimized method.

3.2 Pipe size selection

This chapter presents the principles and currently accepted design techniques for water piping systems used in air conditioning application. The principles and techniques described are applicable to chilled water and hot water heating systems. General piping principles and techniques are described below:

Once-through and re-circulating

The water piping systems discussed here are divided into once- through and re-circulating types. In a once-through system water passes thru the equipment only once and is discharged. In a recirculating system water is not discharged but flows in a repeating circuit from the heat exchanger to the refrigeration equipment and back to the heat exchanger.

Open and Closed

Both types are further classified as open or closed systems. An open system in which the water flows into a reservoir open to the atmosphere; cooling tower and air washers are examples of reservoir open to the atmospheres, A closed system is one in which the flow of water is not exposed to the atmosphere at any point. This system usually contains an expansion tank that is open to the atmosphere but the water area exposed is insignificant.

Water return arrangement

The re-circulating system is further classified according to water return arrangements. When two or more units are piped together, one of the following piping arrangements may be used:

1. Reversed return piping
2. Reversed return header with direct return risers
3. Direct return piping

If the units have the same or nearly the same pressure drop through them, one of the reverse return methods of piping is recommended. However, if the units have different pressure drops or require balancing valves, then it is usually more economical to use a direct return.

Reverse return piping is recommended for most closed piping applications. It cannot be used on open systems. The length of the water circuit through the supply and return piping is the same for all units. Since the water circuits are equal for each unit, the major advantage of a reverse return system is that it seldom requires balancing Fig: 2.i is a schematic sketch of this system with units piped horizontally and vertically.

There are installations where it is both inconvenient and economically unsound to use a complete reverse return water piping system. This sometimes exists in a building where the first floor has previously been air conditioned. To avoid disturbing the first floor occupants, reverse return headers are located at the top of the building and direct return risers to the units are used. Fig.2.j illustrates a reverse return header and direct return riser piping system.

In this system the flow rate is not equal for all units on a direct return riser. The differences in flow rates depends on the design pressure drop of the supply and return riser. This difference can be reduced to practical limits. The pressure drop across the riser includes the following:(1) the loss through the supply and return run outs from the riser to the unit, (2) the loss through the unit itself, and (3) the loss through the fittings and valves. Excessive unbalance in the direct supply and return portion of the piping system may dictate the need for balancing valves or orifices.

Water treatment

Normally all water piping system must have adequate treatment to protect the various components against corrosion, scale, lime and algae. Water treatment should always be under the supervision of a water conditioning specialist. Periodic inspection of the water is required to maintained suitable quality.

Water piping design

There is a friction loss in any pipe through which water is following. This loss depends on the following factors:

1. Water velocity
2. Pipe diameter
3. Interior surface roughness
4. Pipe length

System pressure has no effect on the head loss of the equipments in the system. However, higher than normal system pressures may dictate the use of heavier pipe, fitting and valves along with specially designed equipments.

To properly design a water piping system, the designer must evaluate not only the pipe friction loss but the loss through valves, fittings and others equipments. In addition to these friction losses, the use of diversity in reducing the water quantity and pipe size is to be considered in designing the water piping system.

3.3 Cooling Tower

For building HVAC use, a cooling tower is an auxiliary cooling device. It dose not cool the building directly but rather it helps other equipment do the job. Cooling towers are also used for other things like process water cooling and power plants.

Cooling towers are heat removal device used to transfer process waste heat to the atmosphere. Cooling towers may either use the evaporation of water to remove process heat and cool the working fluid to near the wet-bulb air temperature or rely solely on air to cool the working fluid to near the dry-bulb air temperature.

A cooling tower evaporates a portion of a water stream to cool down the remaining water. This is done by spraying or spreading a thin layer of water and then passing air over it, usually with a fan. The dominant factor in cooling tower performance is the outdoor "wet bulb" temperature. Which indicates how dry the air is? Since they are driven by wet bulb temperature, cooling towers can produce quite cool water, even on warm days, as long as it's not too humid. The cooling tower "approach" temperature tells us how close the water temperature can be lowered toward the wet bulb temperature. If the cooling tower were infinitely large, the leaving water temperature would be at the wet bulb air temperature. The larger the approach, the smaller and less expensive the cooling tower can be, which is nice on the day the cooling tower, is purchased. But the smaller the approach the greater the efficiency options for the equipment several by the cooling tower, which has benefits for years and years. Approach temperatures lower than 7 degree encounter diminishing and required larger investment in fan horsepower for each additional degree.

Cooling towers may be classified according to air to water system as (i) Cross flow and (ii) counter flow.

3.3.1 Cross flow cooling tower

Cross flow is a design in which the air flow is directed perpendicular to the water flow (as in Fig.3.3.1). Air flow enters one or more vertical faces of the cooling tower to meet the fill material. Water flows (perpendicular to the air) through the fill by gravity. The air continues through the fill and thus past the water flow into an open plenum area. A distribution or hot water basin consisting of a deep pan with holes or nozzles in the bottom is utilized in a crossflow tower. Gravity distributes the water through the nozzles uniformly across the fill material.

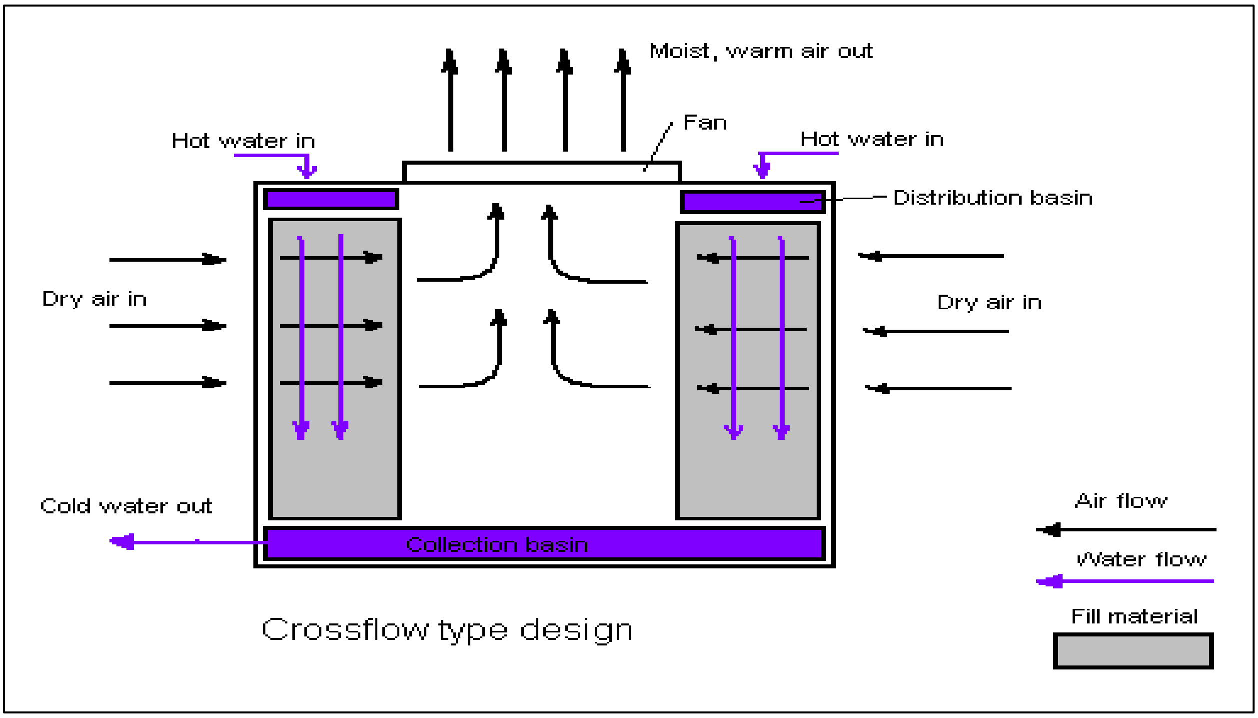


Figure 3.3.1: Cooling tower of cross flow type design

3.3.2 Counter flow cooling tower

In a counter flow design the air flow is directly opposite to the water flow as in Fig.3.3.2. Air flow first enters an open area beneath the fill media and is then drawn up vertically. The water is sprayed through pressurized nozzles and flows downward through the fill, opposite to the air flow.

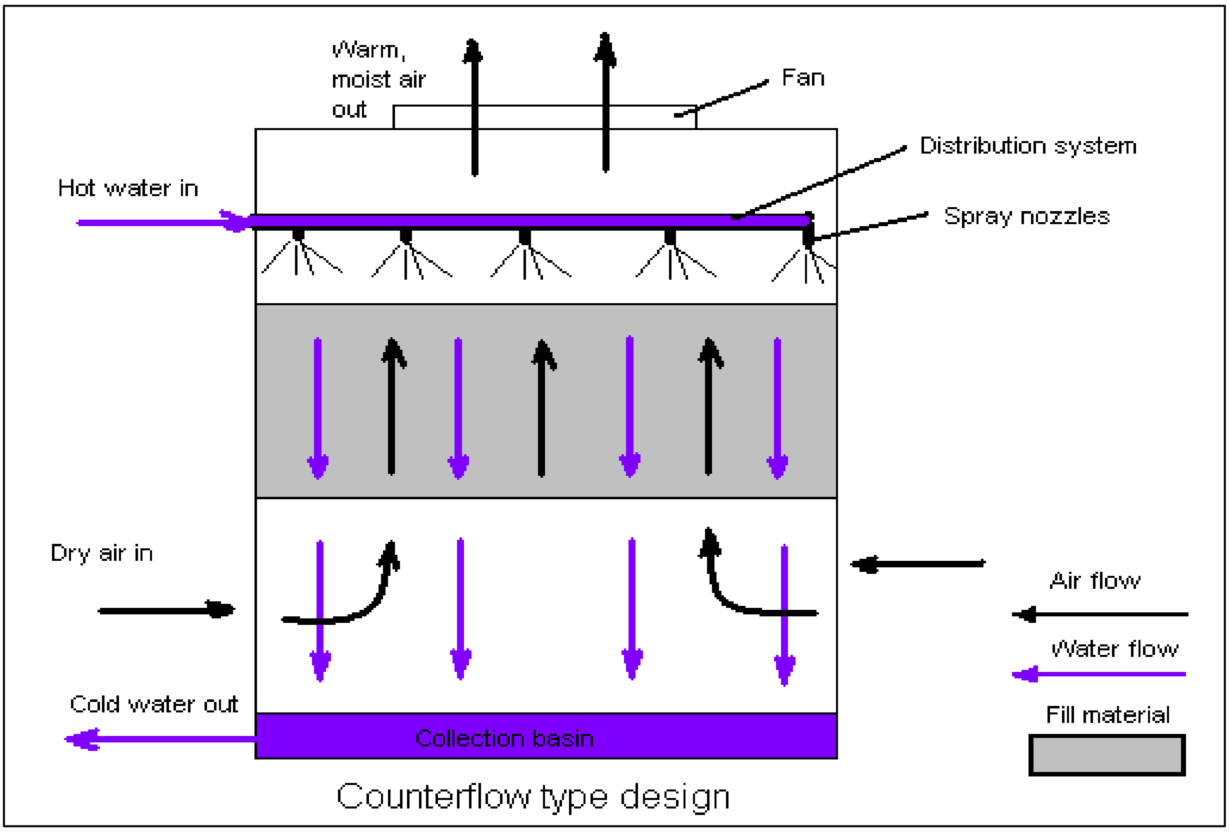


Figure 3.3.2: Cooling tower of counter flow type

3.4 Pump for HVAC system

Pump is the heart of HVAC system. The centrifugal pump has long been the workhorse of HVAC systems, supporting the operation of chillers, boilers, cooling towers, domestic water systems, and hydronic distribution systems and while practically every other component in an HVAC system has been greatly modified to meet ever changing requirements for efficiency and reliability, centrifugal pump shape not changed very much.

That does not mean today's centrifugal pumps are the same as those of 20 years ago. Manufacturers have made significant improvements in impeller designs, construction materials, bearing and seal designs, and couplings. But these changes have been more evolutionary than revolutionary.

3.5 Insulation of duct & pipe

3.5.1 Chilled water pipe insulation

Insulation systems for piping that operate at below-ambient temperatures, such as chill water pipe, present special challenges due the possibility of water vapor movement to the cold surface. If the operating temperature of the system is below the dew point of the ambient air, condensation will occur on the cold surface, creating a vapor pressure gradient through the system. This vapor pressure gradient serves as the driving force for water migration toward the cold surface of the chill water pipe insulation system. If these conditions remain for extended periods of time, a significant amount of liquid water can accumulate in the system. Below-ambient systems therefore, require special attention to the design to maintain thermal performance.

In areas with high humidity, condensation problems often occur in chilled water pipelines of central cooling systems. The condensation damages ceilings, carpeting and other furniture and wastes energy with higher heat gain to the chilled water pipes. pipe insulation is being widely used in chilled water.

- Very low water absorption.
- Low and stable thermal conductivity (K.Value).
- Non-polar polymer base with high water and moisture resistance.
- Universal smoke and flammability proof standards.
- Flexibility for quick and easy installation.

3.5.2 Duct insulation:

Ducts carrying hot or cold air are covered with thermal insulation to reduce heat loss. In addition, the insulation is covered with a vapor barrier to prevent condensation of water on cold ducts. Glass fiber/Glass wool or similar material with a high thermal resistance is used for insulation. The vapor barrier is usually aluminum foil.

Ducts are frequently lined internally with acoustical insulation to absorb sound. In this case, the acoustical insulation lining often also serves as thermal insulation. However, care must be taken that the glass fibers do not flake off in the air stream and get delivered to the occupied space. There is concern that inhaled glass fibers may cause serious lung diseases.

CHAPTER-4

SOFTWARE DEVELOPMENT

434.0 Cooling load calculation objective

Cooling load calculations may be used to accomplish one or more of the following objectives:

a) Provide information for equipment selection, system sizing and system design

b) Provide data for evaluating the optimum possibilities for load reduction

c) Permit analysis of partial loads as required for system design, operation and control

4.1 Components of cooling load

The total building cooling load consists of heat transferred through the building envelope (walls, roof, floor, windows, doors etc.) and heat generated by occupants, equipment, and lights. The load due to heat transfer through the envelope is called as external load, while all other loads are called as internal loads. The percentage of external versus internal load varies with building type, site climate, and building design. The total cooling load on any building consists of both sensible as well as latent load components. The sensible load affects the dry bulb temperature, while the latent load affects the moisture content of the conditioned space.

Buildings may be classified as externally loaded and internally loaded. In externally loaded buildings the cooling load on the building is mainly due to heat transfer between the surroundings and the internal conditioned space. Since the surrounding conditions are highly variable in any given day, the cooling load of an externally loaded building varies widely. In internally loaded buildings the cooling load is mainly due to internal heat generating sources such as occupants, lights or appliances.

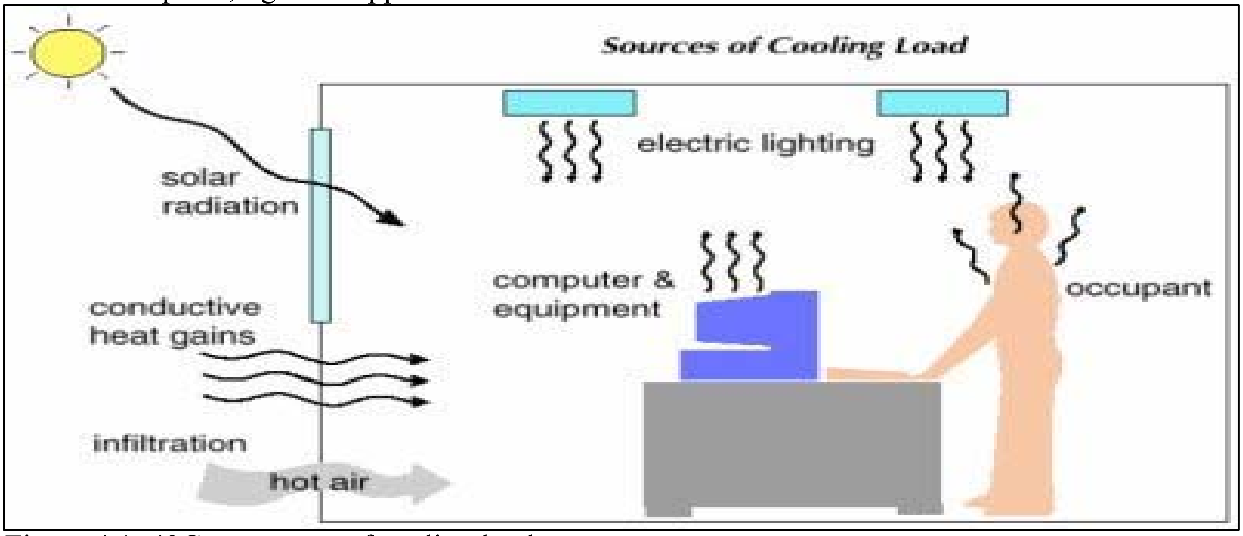


Figure 4.1: 43Components of cooling load

In general the heat generation due to internal heat sources may remain fairly constant, and since the heat transfer from the variable surroundings is much less compared to the internal heat sources, the cooling load of an internally loaded building remains fairly constant. Obviously from energy efficiency and economics points of view, the system design strategy for an externally loaded building should be different from an internally loaded building. Hence, prior knowledge of whether the building is externally loaded or internally loaded is essential for effective system design.

4.2 Thermal control

The thermal system of a building is described in Figure 4.1. The main heat flow quantities are listed as follows:

Qi = Internal heat gain from people, electric light, power equipments and appliances.

Qs = Instantaneous solar radiation heat gain from the glass windows, and lobby walls, door, ceiling and Floor

Qc = Conduction heat gain losses or heat loss through the enclosing elements, caused by a temperature Difference between outside and inside

Qv = Ventilation heat gain or heat loss due to natural or mechanical ventilation and infiltration.

Qm = Mechanical heating or cooling produced by air condition equipment -based installation.

Qe = Transmission heat gain from the roof, wall, glass windows.

Sum of heat flow = $Qi + Qs + Q_c + Q_v + Q_m + Qe$ (1)

If Eq^n. (1) = 0, a thermal balance exists. If Equation (1) > 0, the indoor temperature increases. If Eqn. (1) < 0, the indoor temperature decreases. Except Q_m which is quite small, net value of all heat flow quantities in Eq^n. (1) determines the requirement of space heating and cooling.

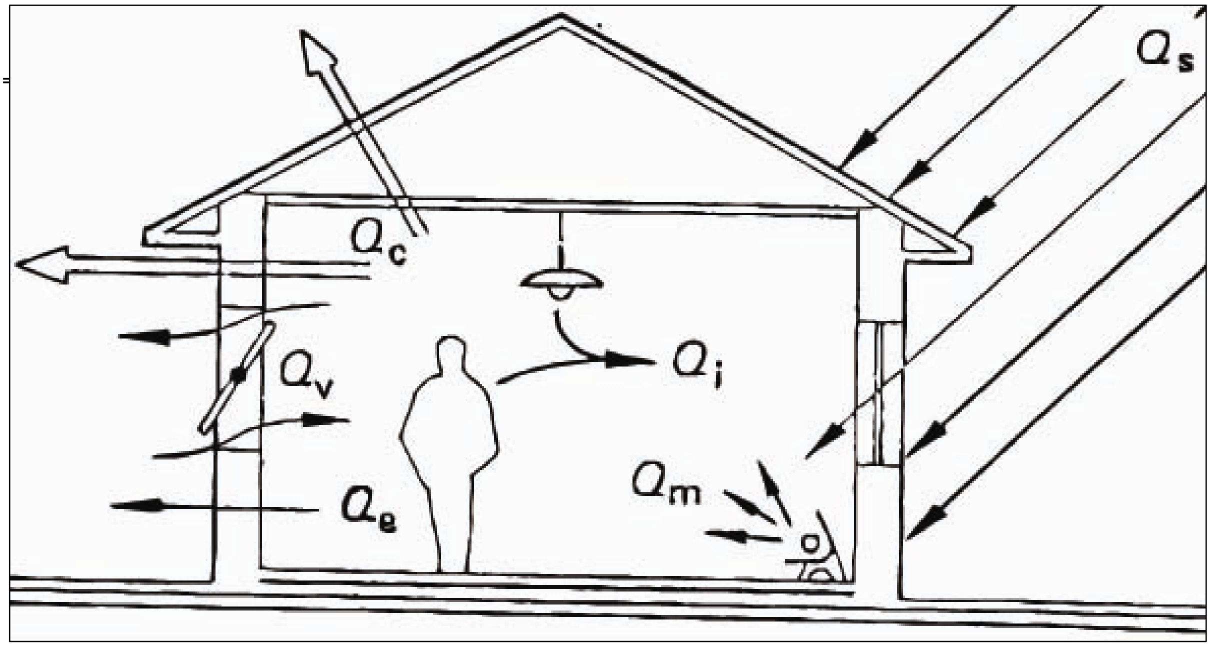


Figure 4.2: Thermal system of the building

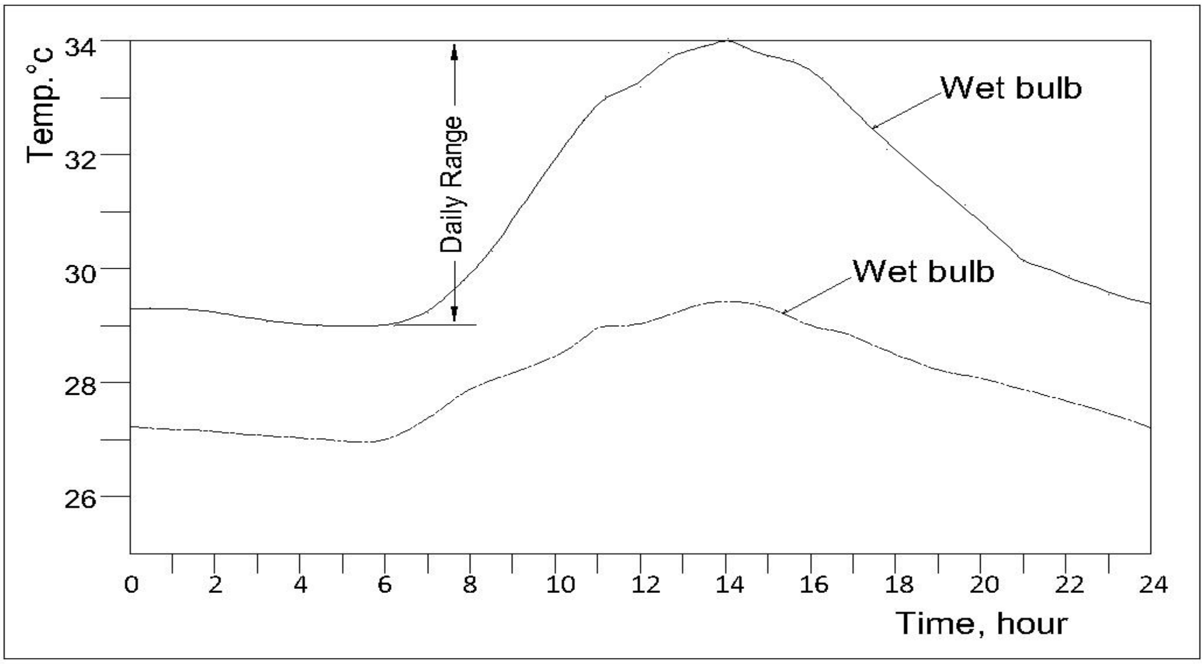


Figure 4.3: Outdoor dry-bulb and wet-bulb temperature curves for a typically hot summer day in Dhaka

4.3 Design Information

To calculate the space cooling load, detailed building information, location, site and weather data, internal design information and operating schedules are required. Information regarding the outdoor design conditions and desired indoor conditions are the starting point for the load calculation and is discussed below.

4.3.1 Building Pressurization

The outdoor air requirements are sometimes governed by the building pressurization needs. Most air-conditioning systems are designed to maintain a slightly higher pressure than the surroundings, a positive pressure, to prevent or reduce infiltration and untreated air entering the space directly. For laboratories, restrooms, or workshops where toxic, hazardous, or objectionable gases or contaminants are produced, a slightly lower pressure than the surroundings, a negative pressure, should be maintained to prevent or reduce the diffusion of these contaminants to the surrounding area.

For comfort air-conditioning systems, the recommended pressure differential between the indoor and outdoor air is 0.02 to 0.05 inch-WG. WG indicates the pressure at the bottom of a top-opened water column of specific inches of height; 1 in -WG = 0.03612 psig.

4.3.2 Building characteristics

To calculate space heat gain, the following information on building envelope is required:

a. Architectural plans, sections and elevations – for estimating building dimensions/area/volume

b. Building orientation (N, S, E, W, NE, SE, SW, NW, etc), location etc

c. External/Internal shading, ground reflectance etc.

d. Materials of construction for external walls, roofs, windows, doors, internal walls, partitions, ceiling, insulating materials and thick nesses, external wall and roof colors select and/or compute U-values for walls, roof, windows, doors, partitions, etc. Check if the structure is insulated and/or exposed to high wind.

e. Amount of glass, type and shading on windows

4.3.3 Operating schedules

Obtain the schedule of occupants, lighting, equipment, appliances, and processes that contribute to the internal loads and determine whether air conditioning equipment will be operated continuously or intermittently (such as, shut down during off periods, night set-back, and weekend shutdown). Gather the following information:

• Lighting requirements, types of lighting fixtures

• Appliances requirements such as computers, printers, fax machines, water coolers, refrigerators, microwave, miscellaneous electrical panels, cables etc

• Heat released by the HVAC equipment.

• Number of occupants, time of building occupancy and type of building occupancy

4.3.4 Indoor air quality and outdoor air requirements

According to the National Institute for Occupational Safety and Health (NIOSH), 1989, the causes of indoor air quality complaints in buildings are inadequate outdoor ventilation air. There are three basic means of improving indoor air quality: (1) eliminate or reduce the source of air pollution, (2) enhance the efficiency of air filtration, and (3) increase the ventilation (outdoor) air intake.

Abridged outdoor air requirements listed in ANSI/ASHRAE Standard 62-1989 are as follows:

Applications	**Cfm/person**
Offices, conference rooms, offices	20
Retail Stores	0.2 – 0.3 cfm/ft^2
Classrooms, theaters, auditoriums	15
Hospitals patient rooms	25

These ventilation requirements are based on the analysis of dilution of CO_2 as the representative human bio-effluent. As per ASHRAE standard 62-1999, comfort criteria with respect to human bio-effluents is likely to be satisfied, if the indoor carbon dioxide concentrations remain within 700ppm above the outdoor air carbon dioxide concentration. Refer to ANSI/ASHRAE Standard 62-1999 for details.

4.3.5 Outdoor design conditions

It is not economical to choose either the annual maximum or annual minimum values of the outdoor weather data in determining the outdoor conditions. The outdoor design data is usually determined according to the statistical analysis of the weather data so that 1 to 5% of the total possible operating hours is equaled or exceeded the outdoor design values.

4.3.6 Summer design condition

The recommended summer design and coincident wet bulb temperature, when chosen as being equal to or exceeded by 2.5% of the total number of hours in May, June, July, August and September, are

(i) Design conditions Latitude 24° north

(ii) Out side design conditions 34°C dry bulb temperature, and

(iii) Inside design conditions 25°C wet bulb temperature

(iv) Relative humidity 50% from the psychometrics chart

(v) Daily range 11°C

(vi) Ventilation air = 7.5 L/s per person for classroom, theaters auditorium Hospital patient rooms= 11.8 L/s and Hotels, conference rooms and office space = 9.4 L/s (ASHRAE Standard 62-1999).

Figure 4.2 shows the outdoor dry bulb temperature and wet bulb temperature curves for a typically hot summer day in Dhaka. Usually, the maximum temperature of 34°C occurs at 2 p.m. and the minimum temperature of 28°C occurs just before sunrise. The daily range of dry bulb temperature is about 9 to 10°C, and the daily mean dry bulb temperature is 34°.

4.3.7 Winter design condition

The recommended winter design and coincident relative humidity, when chosen as being equaled to or exceeded by 1% or 2.5% of the total number of hours (i.e. 2160 hours) in December, January and February, are

(i) 9°C dry bulb temperature, and
(ii) 50% relative humidity
Minimum temperature occurs at 6 a.m. or 7 a.m. before sunrise and the daily range is about 6°C to 8°C during very cold winter days.

4.3.8 Indoor design conditions

For most of the comfort air-conditioning systems used in the commercial, industrial, hospital and public buildings, the recommended indoor temperature and relative humidity are as follows:

(i) Summer: 23.5°C - 25.5°C dry bulb temperature, 40 % - 60 % relative humidity

(ii) Winter: 21°C - 23.5°C dry bulb temperature, 30 % - 40 % relative humidity

4.4 Heating load calculation

The heat loss is divided into two groups:

(i) The heat transmission losses through the confining walls, floor, ceiling, glass, or other surfaces, and

(ii) The infiltration losses through cracks and openings, or heat required to warm outdoor air used for ventilation.

As a basis for design, the most un-favorable but economical combination of temperature and wind speed is chosen. The wind speed has great effect on high infiltration loss and on outside surface resistance in conduction heat transfer.

Normally, the heating load is estimated for winter design temperature usually occurring at night; therefore, internal heat gain is neglected except for theaters, assembly halls, industrial plant and commercial buildings. Internal heat gain is the sensible and latent heat emitted within an internal space by the occupants, lighting, electric motors, electronic equipment etc.

4.4.1 Heat transmission loss

Heat loss by conduction and convection heat transfer through any surface is given by:

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

$$Q = A \cdot U \cdot (T_i - T_o) \qquad (2)$$

Where, Q = heat transfer through walls, roof, glass etc.

A = surface areas

U = air-to-air heat transfer coefficient

T_i = indoor air temperature

T_o = outdoor air temperature heat transfer through basement walls and floors to the ground depends on:

(i) Difference between room air temperature and ground temperature/outdoor air temperature,

(ii) Materials of walls and floor of the basement, and

(iii) Conductivity of the surrounding earth.

This portion of heat transmission is neglected in Dhaka because of the fact that the weather in winter is not so severe and the values are very small in comparison with other forms of heat transmission.

4.4.2 Infiltration and ventilation loss

The heat loss due to infiltration and controlled natural ventilation is divided into sensible and latent losses.

4.4.2.1 Sensible heat loss, Q_{sb}

The energy associated with having to raise the temperature of infiltrating or ventilating air up to indoor air temperature is the sensible heat loss which is estimated by:

$$Q_{sb} = Vp \cdot C_{pa} \cdot (T_i - T_o) \qquad (3)$$

Where, Vp = volumetric air flow rate

C_{pa} = specific heat capacity of air at constant pressure

Ti = indoor air temperature

To = outdoor air temperature

4.4.2.2 Latent heat loss, Q_{la}

The energy quantity associated with net loss of moisture from the space is latent heat loss which is given by:

$$Q_{la} = V_p \cdot (W_i - W_o) \cdot h_{fg} \qquad (4)$$

Where, Vp = Volumetric air flow rate

W_i = Humidity ratio of indoor air

W_o = Humidity ratio of outdoor air

h_{fg} = Latent heat of evaporation at indoor air temperature

4.5 Cooling load calculation for summer

4.5.1 Space heat gain and space cooling load

The heat received from the heat sources (conduction, convection, solar radiation, lightning, people, equipment, etc.) does not go immediately to heating the room air. Only some portion of it is absorbed by the air in the conditioned space instantaneously leading to a minute change in its temperature. Most of the radiation heat especially from sun, lighting, people is first absorbed by the internal surfaces, which include ceiling, floor, internal walls, furniture etc. Due to the large but finite thermal capacity of the roof, floor, walls etc., their temperature increases slowly due to absorption of radiant heat. The radiant portion introduces a time lag and also a decrement factor depending upon the dynamic characteristics of the surfaces. Due to the time lag, the effect of radiation will be felt even when the source of radiation, in this case the sun is removed.

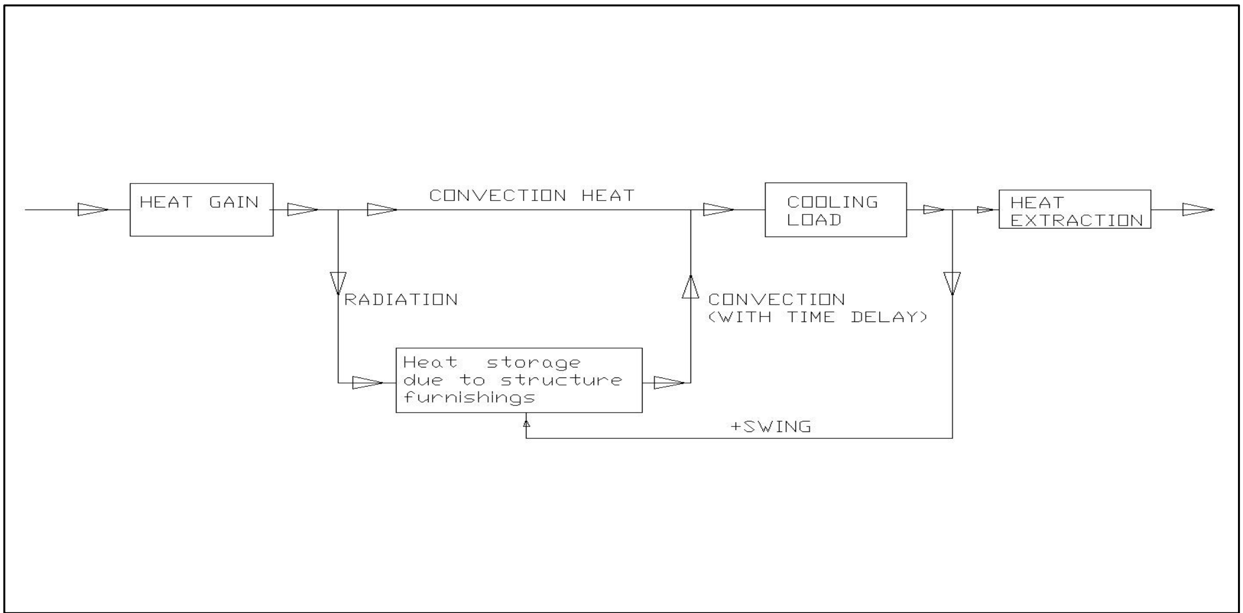
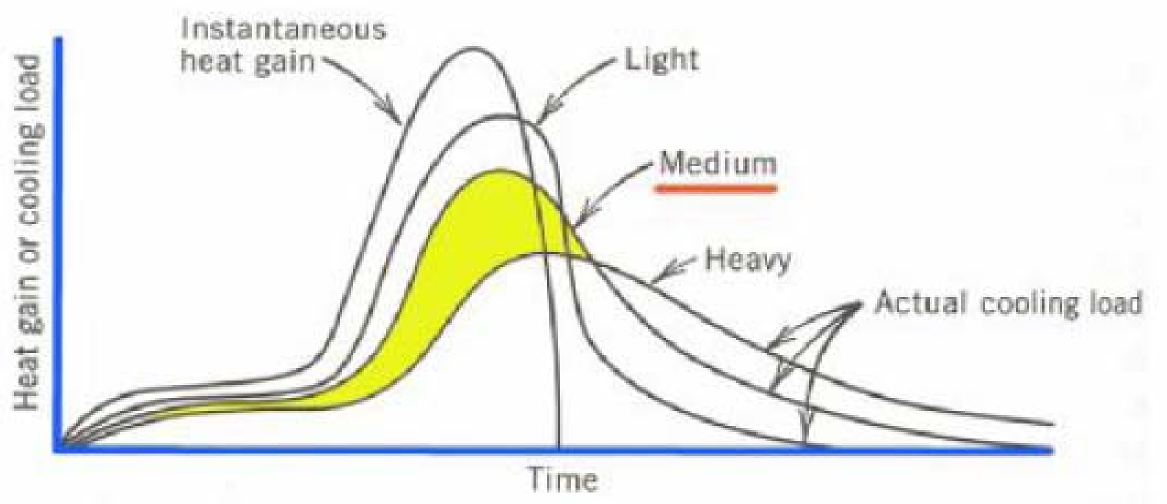


Figure 4.5.1a: Differences between space heat gain and space cooling load

Differences between instantaneous heat gain and cooling load is due to heat storage affect.
The relation between heat gain and cooling load and the effect of the mass of the structure (light, medium & heavy) is shown below. From the figure it is evident that, there is a delay in the peak heat, especially for heavy construction.



Actual cooling load and solar heat gain for light, medium and heavy construction

Figure 4.51b: Actual cooling load and solar heat gain for light, medium and heavy construction

4.6 CLTD/SCL/CLF method of load calculation (ASHRAE fundamentals 1989)

Cooling load temperature difference and cooling load factor are used to convert the space sensible heat gain to space sensible cooling load. As mentioned before, the heat gain to the building is not converted to cooling load instantaneously. CLTD (cooling load temperature difference), SCL (solar cooling load factor), and CLF (cooling load factor): all include the effect of (1) time-lag in conductive heat gain through opaque exterior surfaces and (2) time delay by thermal storage in converting radiant heat gain to cooling load.

This approach allows cooling load to be calculated manually by use of simple multiplication factors.

a. CLTD is a theoretical temperature difference that accounts for the combined effects of inside and outside air temp difference, daily temp range, solar radiation and heat storage in the construction assembly/building mass. It is affected by orientation, month, day, hour, latitude, etc. CLTD factors are used for adjustment to conductive heat gains from walls, roof, floor and glass.

b. CLF accounts for the fact that all the radiant energy that enters the conditioned space at a particular time does not become a part of the cooling load instantly. The CLF values for various surfaces have been calculated as functions of solar time and orientation and are available in the form of tables in ASHRAE Handbooks. CLF factors are used for adjustment to heat gains from internal loads such as lights, occupancy, power appliances.

c. SCL factors are used for adjustment to transmission heat gains from glass.

4.6.1 Instantaneous solar radiation heat gain from:

(A) Glass Window (south/north/east/west):

The space of glass window cooling load Q_{gw} is calculated as:

$$Q_{gw} = A \cdot SHGF \cdot CLF \cdot Sc \qquad (4.1)$$

Where, A = $m^{2,}$ Area of the glass windows

SHGF = W/m^2 Solar heat gain factor, Table 11 Chapter 26 [ASHRAE 1985]

CLF = Cooling load factor, Table 14 Chapter 26 [ASHRAE 1985]

Considering Shading Coefficient, Sc = 0.88, Single glass clear & 13mm thickness, Table 20 [ASHRAE 1989]

4.6.2 Transmission Heat gain through roofs, glass and walls:

(A) For roof:

$$Q_{tr} = A \cdot U \cdot CLTD_a \qquad (4.2)$$

Where, A = $m^{2,}$ Area of the any wall

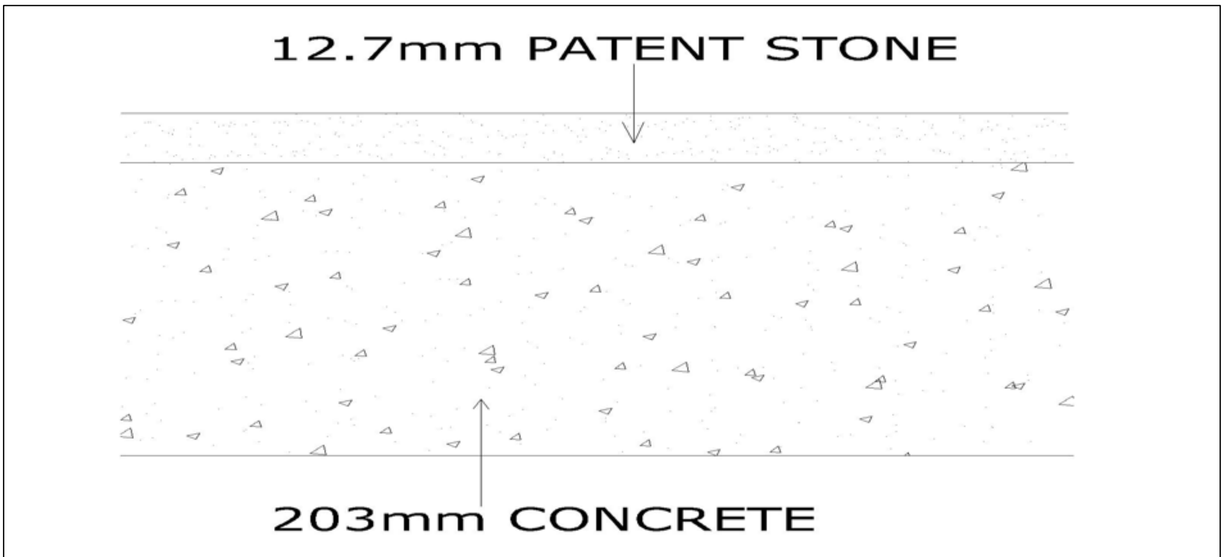


Table 6.1: Total Unit Thermal Resistance for Roof

Component	L/K m/(W/m. K)	R	Reference	Table tile
Outside air film		0.044	Table 1, ASHRAE 1989	Surface conductance
203mm concrete		1.174	Table 8, ASHRAE 1985	Typical thermal properties of common building and insulation materials
12.7 Cement plaster		0.0352	Table 4, ASHRAE 1989	Do
Inside air film		0.120	Table 1, ASHRAE 1989	Surface conductance
Total		1.3732		

Over all heat transfer coefficient, $U = 1/R = 1/ 1.3732 = 0.73\ W/m^2.K$

$CLTD_a = [(CLTD_b + L.M) \cdot k + (25.5 - T_i) + (T_{avg} - 29.4)] \cdot f$

$$CLTD_a = [(CLTDb + LM) \cdot k + (25.5 - T_i) + (\frac{Ti + To - Dr}{2} - 29.4)] \cdot f \qquad (4.3)$$

Where, Considering $CLTD_b$ = 16 for 203mm concrete, Table 5 Chapter 26 [ASHRAE 1985]

LM = latitude and month, Table 9 Chapter 26 [ASHRAE 1985]

T_i = inside temperature °C

T_o = Out side Temperature °C

D_r = Daily rang 11°C

K= 1.0 for dark coloured or light in an industrial area

K= 0.5 if permanently light (Rural area)

f = 1.0 for no attic or ducts

f = 0.75 positive ventilation

(B) For wall: expose to the sun

For North wall:

$Q_{s.w} = A \cdot U \cdot CLTD_a$ (4.4)

Where, A = Wall area, m^2

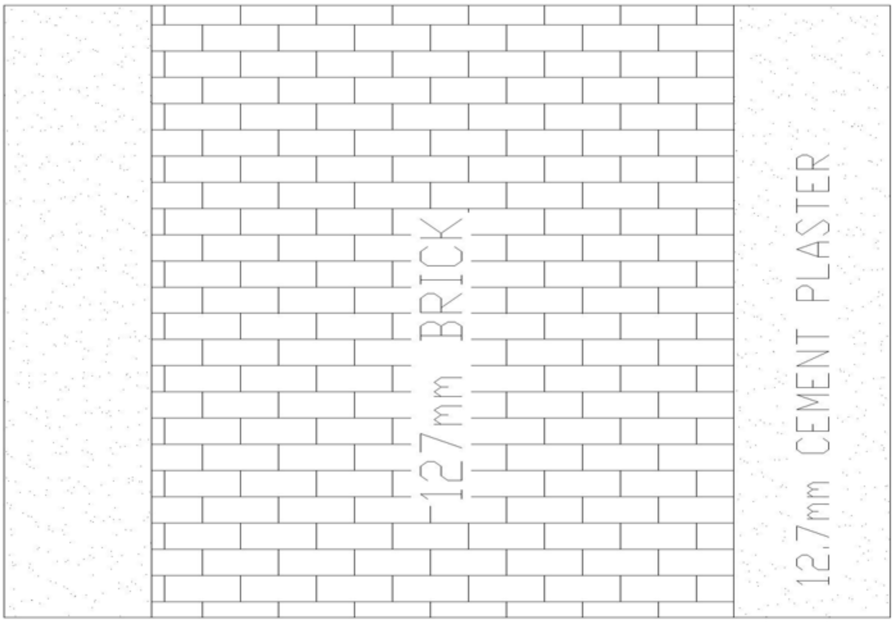


Table 6.2: Total Unit Thermal Resistance for Wall

Component	L/K m/(W/m. K)	R	Reference	Table tile
Outside air film		0.044	Table 1, ASHRAE 1989	Surface conductance
Brick	0.127/0.32	0.3968	Table 4, ASHRAE 1989	Typical thermal properties of common building and insulation materials
Cement plaster	(2 x 0.0127)/0.72	0.0352	Table 4, ASHRAE 1989	Do
Inside air film		0.120	Table 1, ASHRAE 1989	Surface conductance
Total		0.596		

Considering overall heat transfer Coefficient, U = 1/R = 1/0.596 = 1.67 $W/m^2.K$ and

$CLTD_b$ = 6, Table 7 Chapter 26 [ASHRAE 1985]

For South wall:

$Q_{s.w} = A \cdot U \cdot CLTD_a$ (4.5)

Where, A = Wall area, m^2

Considering overall heat transfer Coefficient, U = 1.67 $W/m^2.K$ and

$CLTD_b$ =11, Table 7 Chapter 26 [ASHRAE 1985]

For East wall:

$Q_{s.w} = A \cdot U \cdot CLTD_a$ (4.6)

Where, A = Wall area, m^2

Considering overall heat transfer Coefficient, U = 1.67 $W/m^2.K$ and

$CLTD_b$ = 16, Table 7 Chapter 26 [ASHRAE 1985]

For West wall:

$Q_{w.w} = A \cdot U \cdot CLTD_a$ (4.7)

Where, A = Wall area, m^2

Considering overall heat transfer Coefficient, U = 1.67 $W/m^2.K$ and

$CLTD_b$ = 9, Table 7 Chapter 26 [ASHRAE 1985]

(C) For glass window:

$Q_{w.w} = A \cdot U \cdot CLTD_a$ (4.8)

Where, A = Wall area, m^2

Considering overall heat transfer Coefficient, U = 2.8 $W/m^2.K$, for Single glass clear Table 13 Chapter 27 [ASHRAE 1985] and

$CLTD_b$ = 8, for solar time 4.0 pm, Table 10 Chapter 26 [ASHRAE 1985]

4.6.3 Conduction heat gain through interior partitions wall, ceilings, doors and floors

(a) Lobby wall:

The space cooling load due to the conduction heat gain through interior partition walls, ceiling, Door and Floors is calculated as:

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

$Q_l = A \cdot U \cdot (T_o - T_i)$ (4.9)

Where, A = Area for interior partitions walls. m^2

ΔT = Temperature different

T_o = Inlet air temperature of the adjacent area ºC.

T_i = indoor air temperature ºC.

Table 6.3: Total Unit Thermal Resistance for Lobby wall

Component	R	Reference
Outside air film	0.044	Table 1, ASHRAE 1989
Brick 100 mm	0.140	Table 11, ASHRAE 1989
20 mm plaster (both side)	0.026 x 2 = 0.052	Table 11, ASHRAE 1989
Inside air film	0.12	Table 1, ASHRAE 1989
Total	0..356	

Considering over all heat transfer Coefficient, U = 1/R = 1/ 0.356 = 2.8 $W/m^2.K$, for interior partitions walls

(b) Door:

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

$Q_d = A \cdot U \cdot (T_o - T_i)$ (4.10)

Where, A = Area of the Doors m^2.

ΔT = Temperature different

Considering, U = 2.3 $W/m^2.k$, overall heat transfer coefficient for Wood, solid core [2005 ASHRAE, Page 29.14]

To = Inlet air temperature of the adjacent area ºC

Ti = indoor air temperature ºC

c) Ceiling:

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

$Q_f = A \cdot U \cdot (T_o - T_i)$ (4.11)

Where, A = Area of the Ceiling m^2

ΔT = Temperature different

Considering, U = 0.18 $W/m^2.k$, [2005 ASHRAE, Page 29.14] overall heat transfer coefficient for ceiling,

T_o = Inlet air temperature of the adjacent area ºC

T_i = indoor air temperature ºC

4.6.4 Internal cooling loads.

The various internal loads consist of sensible and latent heat transfers due to occupants, products, processes appliances and lighting. The lighting load is only sensible. The conversion of sensible heat gain (from lighting, people, appliances, etc.) to space cooling load is affected by the thermal storage characteristics of that space and is thus subject to appropriate cooling load factors (CLF) to account for the time lag of the cooling load caused by the building mass. The weighting factors equation determines the CLF factors.

(A) For people.

Human beings release both sensible heat and latent heat to the conditioned space when they stay in it. The space sensible (Q_s) and latent (Q_l) cooling loads for people staying in a conditioned space are calculated as:

$Q_t = Q_s + Q_\ell$ (4.12)

$Q_s = n.\ SHG.\ CLF$

$Q_\ell = n.\ LHG$

Where, n = Number of people in the conditioned space

SHG = sensible heat gain per person, Table 18 Chapter 26 [ASHRAE 2005]

LHG = latent heat gain per person, Table 18 Chapter-26 [ASHRAE 2005]

CLF = 1.0 [ASHRAE Handbooks 1985]

(B) For electric lighting/power.

Space cooling load due to the heat gain from electric lights is often the major component for commercial buildings having a larger ratio of interior zone. Electric lights contribute to sensible load only. Sensible heat released from electric lights is in two forms:

(i) Convective heat from the lamp, tube and fixtures.

(ii) Radiation absorbed by walls, floors, and furniture and convected by the ambient air after a time l_{ag}.

The sensible heat released (Q_{les}) from electric lights is calculated as:

Q_ℓ = Light input in watt x CLF (4.13)

Where, Input = Total light wattage obtained from the ratings of all fixtures installed

Considering, CLF = 0.82 for 10 hours of operation and 8 hours closed after light are on table 17B chapter 26) [ASHRAE 1985]

(C) Appliances

$Q_{oth} = Q_s + Q_\ell$ (4.14)

Where, Q_s = Appliances

Q_s = Heat gain from equipment in watt x CLF (4.15)

Q_ℓ = Latent heat gain from equipments or appliances (4.16)

CLF = 1.0 (For 24 hours continues heat gain CLF = 1) [ASHRAE 1985]

4.6.5 Loads from ventilation and infiltration.

Infiltration load is a space cooling load due to the infiltrated air flowing through cracks and openings and entering into a conditioned room under a pressure difference across the building envelope. The introduction of outdoor ventilation air must be considered in combination with the infiltrated air. Table 9 shows the summer outdoor design dry bulb and wet bulb temperatures at 24 degree north latitude.

Heat gain due to ventilation and Infiltration, $Q_{v\ell} = Qs + Q_\ell$ (4.17)

$Q_s = 1.232 \cdot F_a \cdot (T_o - T_i)$ (4.18)

Fresh air quantity,

Where F_a = 7.5 ℓ/s for Classroom, theaters, auditorium. [ASHRAE Standard 62]

F_a = 9.4 ℓ/s for Hotels, Conference rooms, offices, F_a = 11.8 ℓ/s for Hospital patient rooms.

So, F_a = number of people x Fresh air per person

T_o = Inlet air temperature of the adjacent area ºC

T_i = indoor air temperature ºC

$Q_\ell = 3012 \cdot F_a \cdot (W_o - W_i)$ (4.19)

Humidity ratio:

W_o = 0.0232 Kg/w of dry air From Psychometric chart at 34°C dbt /29°C

W_i = 0.0092 Kg/w of dry air from Psychometric chart at 24°C dbt / 50% Rh

4.6.6 Duct heat gain

Unless the return ductwork system is extensive and un-insulated or passes over a non-conditioned space, only the heat gained by the duct supply system is significant. This heat gain is normally estimated as a percentage of the space sensible cooling load (usually 1% to 5%) and applied to the temperature of the air leaving the cooling coil in the form of temperature increase.

4.6.7 Duct leakage

Air leakage out of or into ductwork can have much greater impact than the duct heat gain or loss. Outward leakage from a supply duct is a direct loss of cooling and/or dehumidifying capacity and must be offset by increased air flow or reduced supply air temperature. Leakage into a return duct system causes additional cooling coil capacity but it does not directly affect the space conditions.

Commercial type or existing older systems can have leakage from 10% to 20% of the total system airflow. Per energy conservation guidelines, in a new installation, the duct system should not leak more than 1% to 3% of total system airflow.

The engineer or designer is cautioned to make sure that the proper allowance for leakages is included in the calculations in order to ensure that the equipment selected is properly sized.

So Total cooling load calculation, $Q = Q_1 + Q_2 + Q_3 + Q_4 + Q_5$

Total cooling load calculation = Q + Loses 5% x Q + Air conditioning equipment loses x 2%

Total Cooling Load calculation = Q + (Q x 0.05) + (Q x 0.02)

4.7 The computer program

Experimental design/ Outline of methodology:

The following software development and design will be carried out systematically:

1. This software has designed for latitude 24° north for any month; any required outside temperature and inside temperature, daily range 11°C and ventilation air 7.5 L/S per person.
2. This software has made into five steps (a) Instantaneous solar radiation heat gain for glass windows (b) Transmission heat gain (c) internal heat gain (d) Ventilation and infiltration and (e) Total result and show individual.
3. The software has four options for getting units capacity in watt, kilowatt, Btu/h and ton of refrigeration (TR)
4. It is assumed to be 5% friction loss and 2% air conditioning equipment losses which is added for total refrigeration load calculation.

5. The development of software for refrigeration load calculation has based on programming language Visual Basic version 6.0. This software is data base types. This is one of the high level languages compared to the Microsoft Excel and FORTRAN. The necessary data those are available in the ASHRAE handbooks have been incorporated into the software for cooling load calculation.

Two extremes of intermediate loads were considered:

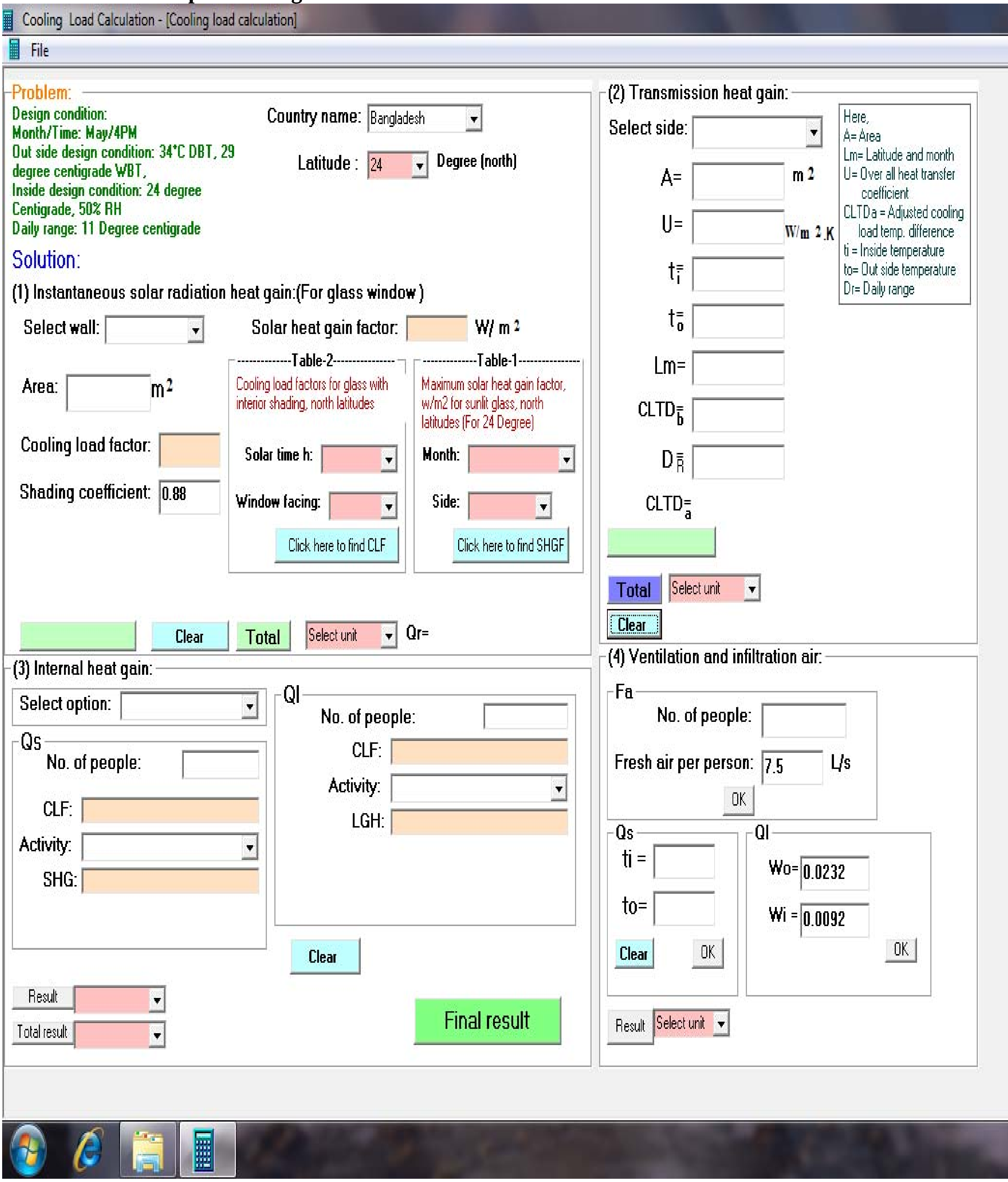
•100% of design load (for example, computer suites or internal offices, with no load variation throughout the year); and 0% of design load (for example, a perimeter office of a building where the internal gains are equal to heat losses. This is also assumption of the cooling degree-day base line that is not considered in the Bin Method calculations.)

To satisfy these conditions, the intermediate load corresponding to the Bin method is set as a percentage of the design load, and it is also made to correspond with the minimum base load of the building. The computer program, based on these two temperatures, evaluated using psychometrics formula for the other parameters (relative and absolute humidity and enthalpy). The HVAC system is considered to operate for an office building, and that the occupation, inherent internal loads and operational plant times are fully operational 10 hours per day from 8 am to 6 pm, five days a week, not including statutory holidays.

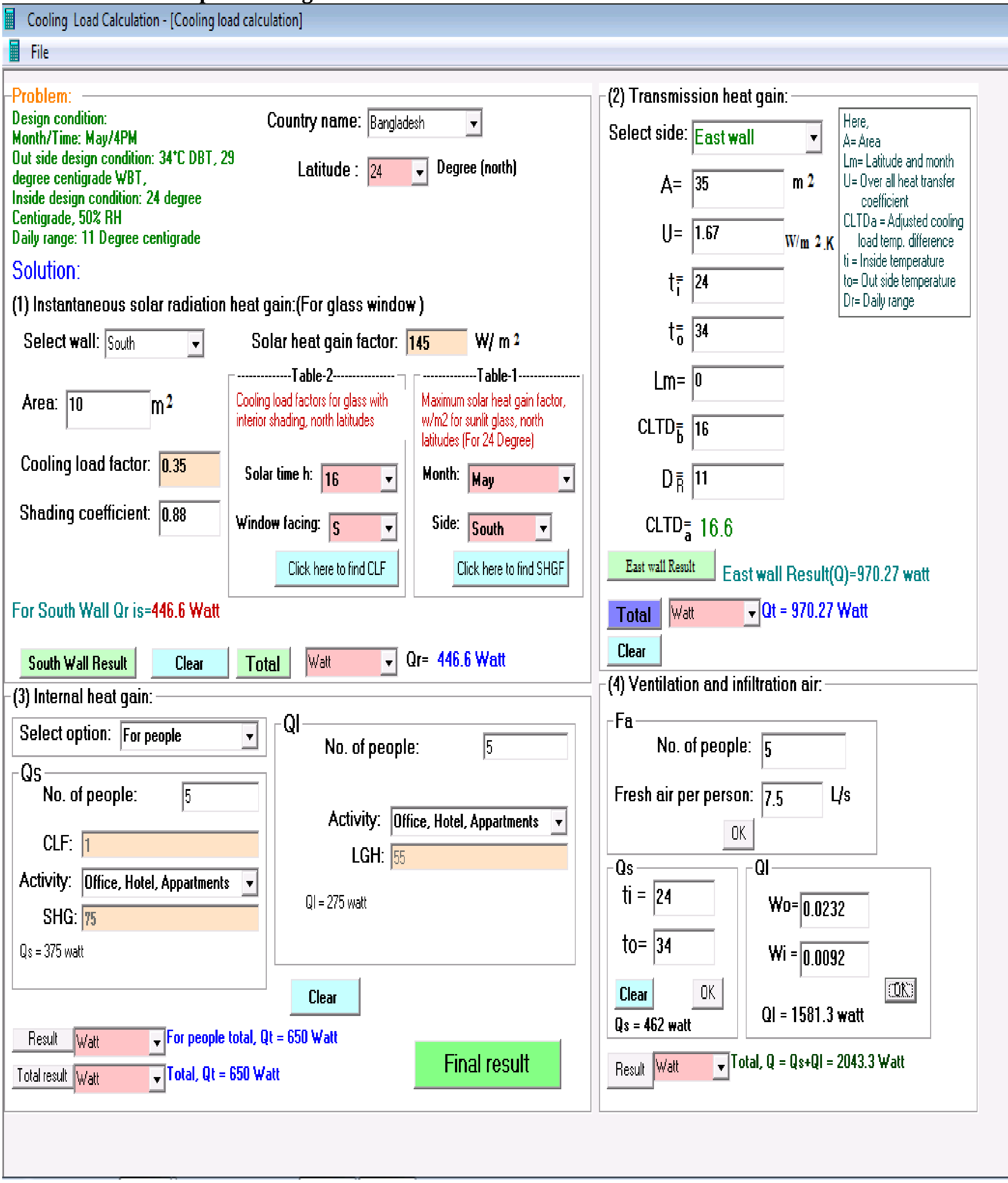
4.8 Programming language of this software developed

Details given in appendix B

4.9 Software development image



4.10 Software development image with calculation



CHAPTER-5

RESULTS AND DISCUSSION

5.1 Introduction

This chapter provides the discussion of the results of developed software for cooling load calculation of specific field applications for comfort air conditioning in commercial and residential buildings, hospitals, shopping arcades, airport terminals, theaters, public halls, hotels, motels, art galleries, museums, research laboratories etc. The cooling load calculation software has been locally developed based on programming language Visual Basic 6.0 specific for Bangladesh 24°N latitude. This is one of the friendly languages compared to the Microsoft Excel.

Some of the engineers and HVAC consultants of our country calculate the cooling load by thumb rule. For this reason sometimes maximum cooling load calculation of the buildings is either over estimated or under estimated.

In the present study, cooling load calculation software have been developed from ASHRAE standard and followed CLTD method and cooling load can be obtained accurately.

5.2 Cooling load calculation scenery in Bangladesh

Some of the cooling load calculations scenarios in Bangladesh are shown below:

Case-a: Commercial building

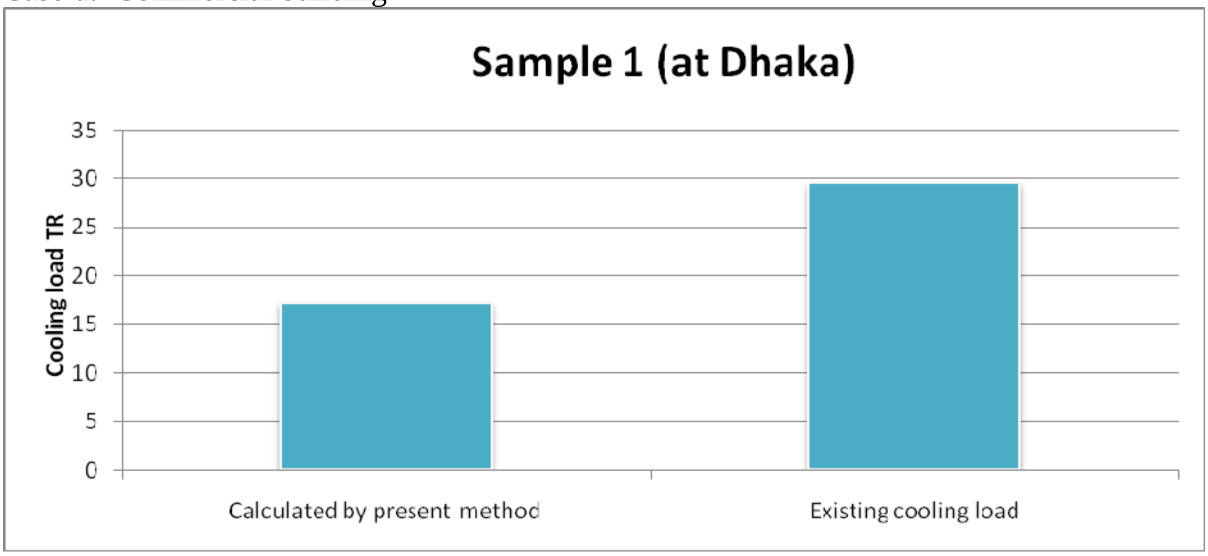


Figure 5.1(a): Sample 1 (at Dhaka)

From Figure 5.1(a) consider an existing 20 storied commercial building at level 2 having total floor area is 4239 square ft. and floor height is 11 ft. According to the ASHRAE for the west side glass SHGF is 688 W/m^{2}and CLF is 0.82. Whereas, in south side glass SHGF is 145 W/m^{2}and CLF is 0.35. Whereas, in east side SHGF is 688 W/m^{2}and CLF is 0.17. For Roof thickness 203mm and 12mm patent stone, overall heat transfer coefficient is U= 0.73 W/m^2.K, and CLTDb= 16. For east side wall thickness of 125mm and both side cement plaster of 12.7mm and for value is U=1.67 W/m^2.K, Lm= 0.0 and CLTDb=16 and For west side wall thickness of 125mm both side cement plaster of 12.7mm for U=1.67 W/m^2.K, Lm= 0.0 and CLTDb=9. Internal heat gain of people for office, hotel SHG=75, LHG=55 and light CLF=0.82 and other appliances/equipment CLF=1.0 and daily temperature range is 11.

For west side glass area is 38.83 m^{2,} south side glass area is 55.0 m^2, east side glass area is 16.45 m^2, east side wall area is 67.97 m^2 and west side wall area is 44.71 m^2. In the north side of level 1 and level 3 are conditioned space. Here number of people is 40, light load is 5910 Watt [15 W/m^2, ASHRAE 2005] and equipment load is 3940 Watt [10 W/m^2, ASHRAE 2005], considering the above conditions the cooling load demand is 17.14 TR according to the present calculation and existing cooling load is 29.5 TR. Due to conditioned space at level 1 and level 3 calculated cooling loads becomes lower.

Case-b: Hotel building equivalent 3 star

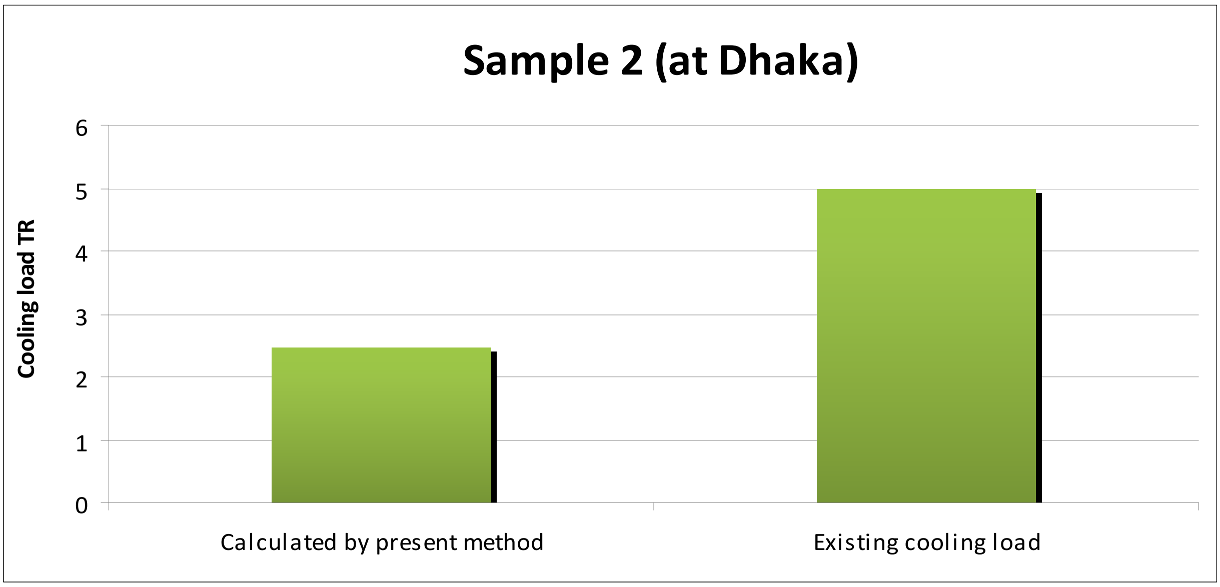


Figure 5.1(b): Sample 2 (at Dhaka)

From Figure 5.1(b) consider an existing 12 storied hotel building single room at level 12 (top floor) having total floor area is 554 square ft/51.5m^2 and floor height is 10 ft. According to the ASHRAE for the west side glass SHGF is 688 W/m^{2}and CLF is 0.82, south side glass SHGF is 145 W/m^{2}and CLF is 0.35 for south side wall area overall heat transfer coefficient is

U= 1.67 W/m^2.K, and CLTDb= 11 and LM is -33. Whereas, in west side wall thickness of 125mm both side cement plaster of 12.7mm for U=1.67 W/m^2.K, Lm= 0.0 and CLTDb=9. For top floor, roof transmission heat gain the overall heat transfer coefficient is U=0.73, Lm= 0.50 and CLTDd=16, daily temperature range is11.

For west side glass area is 9.57 /m^{2,} south side glass area is 12.78 /m^2, south side wall area is 12.78 m^2 and west side wall area is 9.57 m^2. north side, east side and level 11 are conditioned space. Here number of people is 01[single room], light load is 772 Watt [15 W/m^2, ASHRAE 2005] and equipment load is 515 Watt [10 W/m^2, ASHRAE 2005], considering the above conditions the cooling load demand is 2.47 TR according to the present calculation and existing cooling load is 5 TR. Due to conditioned space at level 11 calculated cooling loads becomes lower.

Case-c: Hotel building equivalent 3 star

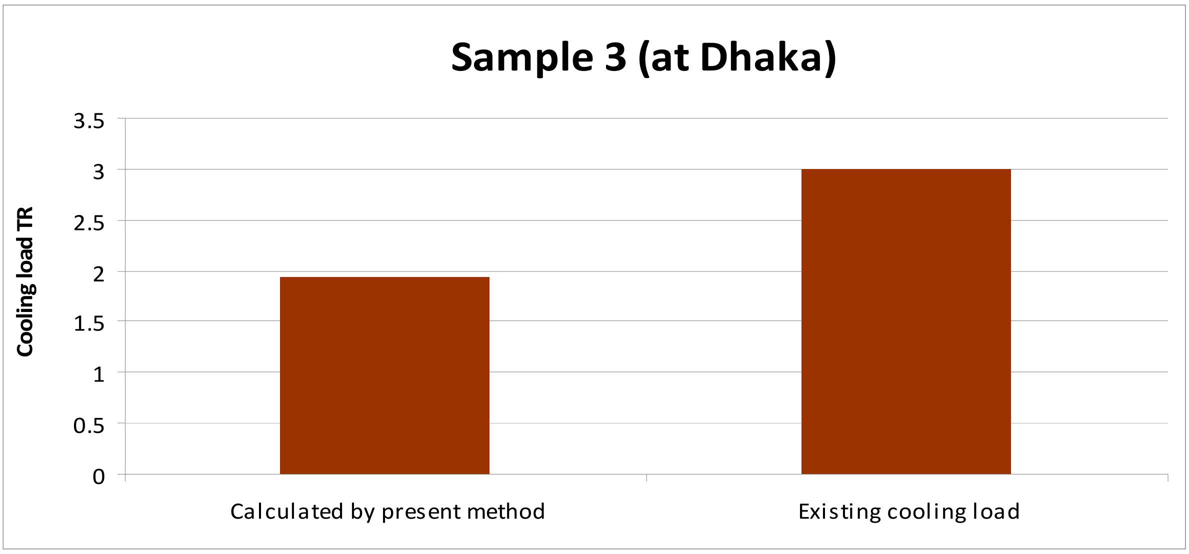


Figure 5.1(c): Sample 3 (at Dhaka)

From Figure 5.1(c) consider an existing 12 storied hotel building single room at level 11 having total floor area is 375 square ft or 34.84 m^2 and floor height 10 ft. According to the ASHRAE for the west side SHGF is 688 W/m^{2}and CLF is 0.82 and north side SHGF is 136 W/m^{2}and CLF is 0.75 and shading coefficient 0.88. Whereas, in west side wall thickness of 125mm and both side cement plaster of 12.7mm and for value of U=1.67 W/m^2.K, Lm= 0.0 and CLTDb=9.

For north side wall thickness of 125mm and both side cement plaster of 12.7mm and for value of U=1.67 W/m^2.K, Lm= 0.5 and CLTDb=6 and daily temperature range is 11.

For west side glass area is 7.57 m^2, north side glass area is11.15 m^2, west side wall area is 7.57 m^2, north side wall area is 11.15 m^2 and Total number of people 01. East side, south side, level 10 and level 12 are conditioned space. Light load is 523 Watt [15 W/m^2, ASHRAE 2005] and equipment load is 349 Watt [10 W/m^2, ASHRAE 2005] considering the above conditions the cooling load demand is 1.93 TR according to the present calculation and existing cooling load is 3 TR. Due to conditioned space at level 11 calculated cooling loads becomes lower.

Case d: Hotel building equivalent 3 star

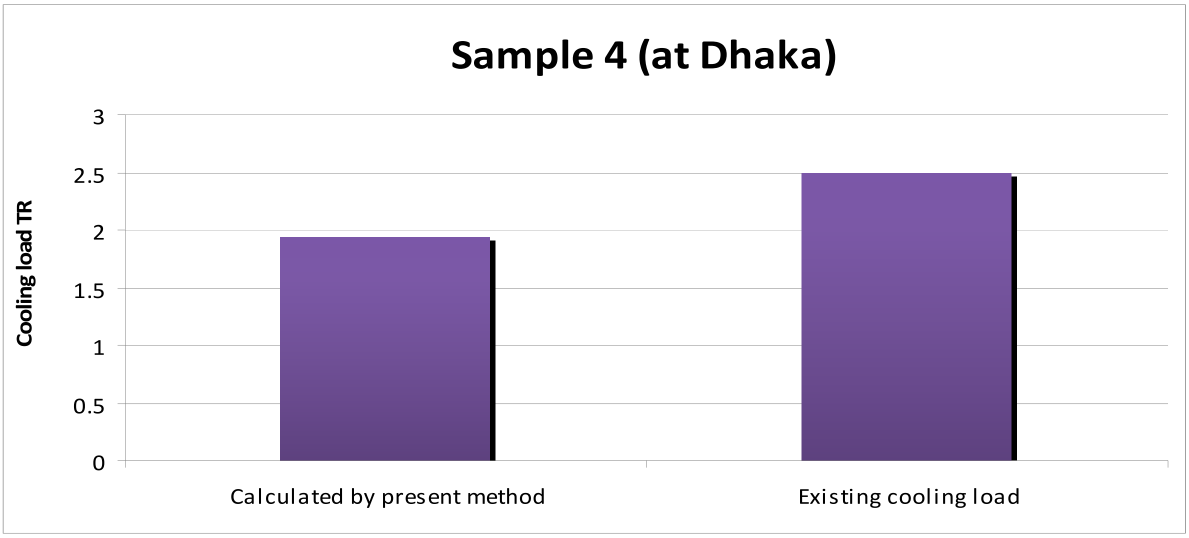


Figure 5.1(d): Sample 4 (at Dhaka)

From Figure 5.1(d) consider an existing 12 storied hotel building single room at level 12 (top floor) having total floor area is 305 square ft or 28.34 m^2 and floor height is 10 ft. According to the ASHRAE for the west side SHGF is 688 W/m^{2}and CLF is 0.82 and south side SHGF is 145 W/m^{2}and CLF is 0.35 and shading coefficient 0.88. Whereas, in west side wall thickness of 125mm and both side cement plaster of 12.7mm and for value of U=1.67 W/m^2.K, Lm= 0.0 and CLTDb=9.

For south side wall thickness of 125mm and both side cement plaster of 12.7mm and for value of U=1.67 W/m^2.K, Lm= 3.3 and CLTDb=11. For top floor, roof transmission heat gain the overall heat transfer coefficient is U=0.73, CLTDd=16, Lm= 0.5 and daily temperature range is 11.

For west side glass area is 8.36 m^2, south side glass area is 8.13 m^2, west side wall area is 8.36 m^2, south side wall area is 8.13 m^2 and Total number of people 01. East side, north side and level 11 are conditioned space. Light load is 425 Watt [15 W/m^2, ASHRAE 2005] and equipment load is 284 Watt [10 W/m^2, ASHRAE 2005] considering the above conditions the cooling load demand is 1.94 TR according to the present calculation and existing cooling load is 2.5 TR. Due to conditioned space at level 11 calculated cooling loads becomes lower.

Case-e: Conference/ Seminar/Banquet hall

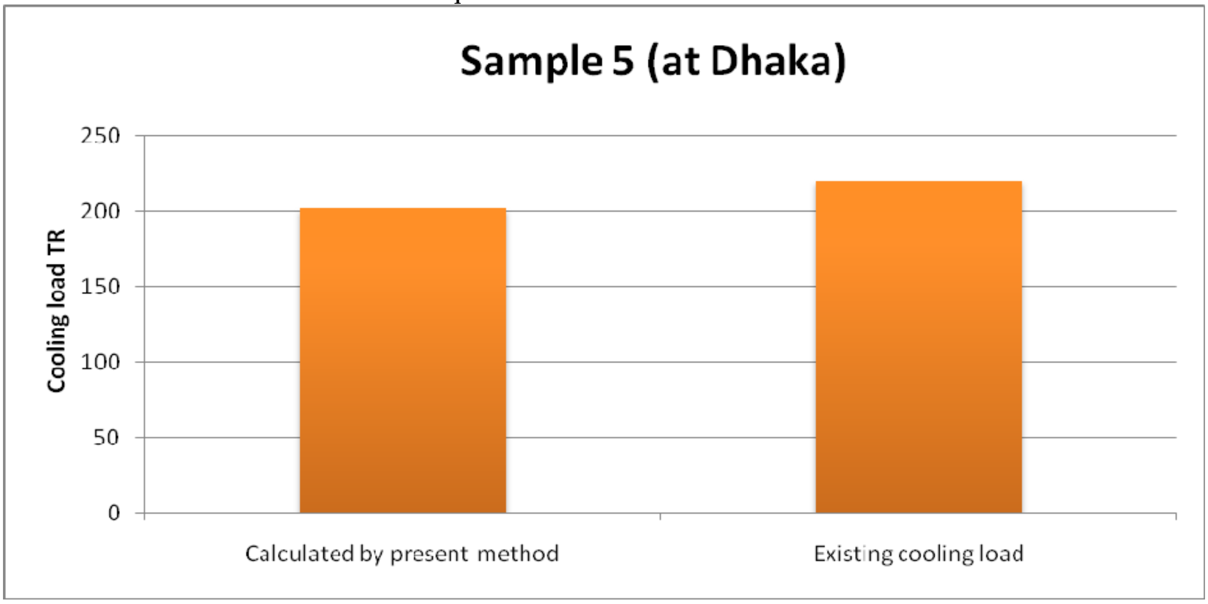


Figure 5.1(e): Sample 5 (at Dhaka)

From Figure 5.1(e) consider an existing Conference/Seminar/ Banquet hall having total floor area is 17,200 square ft or 1598 m^2, level 1, ceiling height 26 ft and floor height 36 ft. According to the ASHRAE for the west side wall thickness of 304.8mm and for value of U= 5.68 $W/m^2.K$, Lm= 0.0 and CLTDb=9 and whereas, in north side wall thickness of 304.8 mm and for value of U= 5.68 $W/m^2.K$, Lm= 0.5 and CLTDb=6.

For top floor transmission heat gain the overall heat transfer coefficient is U=0.73. For east side wall thickness of 304.8mm and for value of U=5.68 $W/m^2.K$, Lm= 0.0 and CLTDb=16 and for south side wall thickness of 304.8mm and for value of U=5.68 $W/m^2.K$, Lm= -33. Conduction heat for door the overall heat transfer coefficient is U=2.30, fresh air quantity 9.4 l/s and daily temperature range is 11.

For west wall area is 238 m^2, east side wall area is 288 m^2, south side wall area is 670 m^2 and north side wall area is 670 m^2. Here numbers of people are considered 800, door area is 50 m^2, light load is 15980 Watt [5 W/m^2, ASHRAE] and equipment load is 1000 Watt considering the above conditions the cooling load demand is 201.91 TR according to the present calculation and existing cooling load is 220 TR.

Case-e: Hotel building equivalent 5 Star

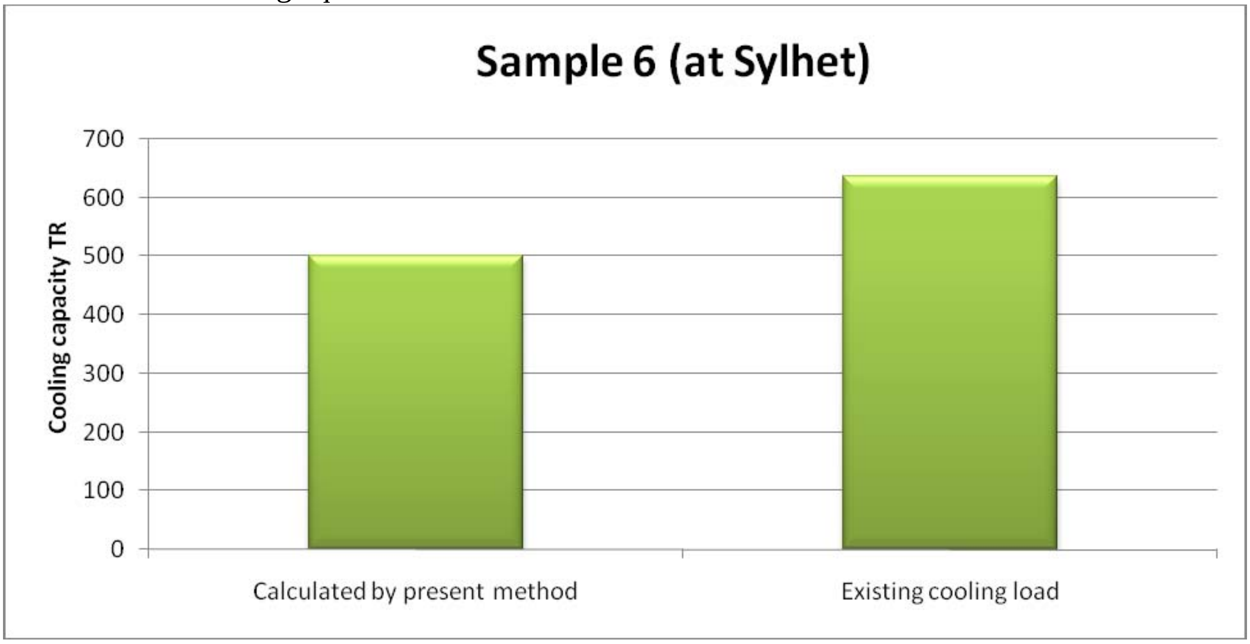


Figure 5.1(e): Sample 6 (at Sylhet)

From Figure 5.1(e) consider an existing 4 storied 5 star hotel building having total floor area is 1,34,400 square ft, air conditioning from level 1 to level 4 and floor height 11.5 ft.

According to the ASHRAE for the west side glass SHGF is 688 W/$m^2$and CLF is 0.82, south side glass SHGF is 145 W/$m^2$and CLF is 0.35, for east side SHGF is 688 W/$m^2$and CLF is 0.17 and north side SHGF is 136 W/$m^2$and CLF is 0.75 and shading coefficient is 0.88.

For east side wall thickness of 125mm and both side cement plaster of 12.7mm and for value of U=1.67 W/m^2.K, Lm= 0.0 and CLTDb=16 and for north side wall thickness of 125mm and both side cement plaster of 12.7mm and for value of U=1.67 W/m^2.K, Lm= 0.5 and CLTDb=6. For top floor transmission heat gain the overall heat transfer coefficient is U=0.73, CLTDd=16. Fresh air considered for hotel 9.4 l/s and daily temperature range is 11.

For the light load 15 W/m^2 [ASHRAE 2005] and equipment load 10 W/m^2 [ASHRAE 2005] Considering the above conditions the cooling load demand is 500 TR according to the present calculation and existing cooling load is 630 TR.

Case 5.1 (f): Shopping mall cum 15 storied residential building

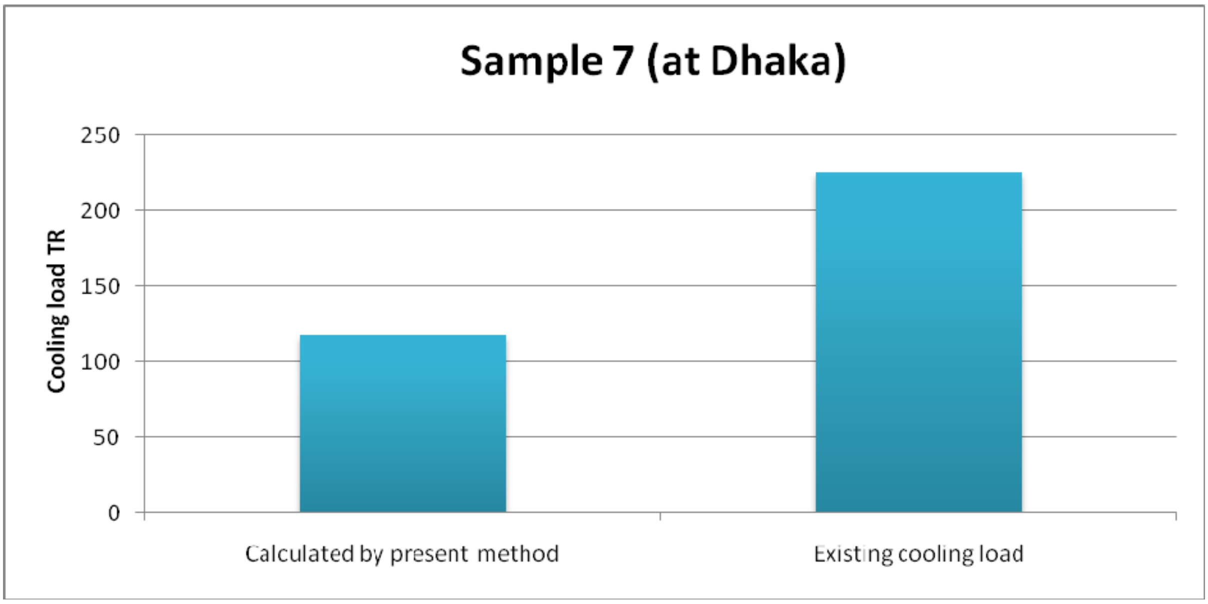


Figure 5.1(f): Sample 7 (at Dhaka)

From Figure 5.1(f) consider an existing 15 storied Shopping mall cum apartment building having total floor area of 37,800 square ft or 3512 m^2. at level 2 and floor height 12 ft. According to the ASHRAE for the east side SHGF is 688 $W/m^2$and CLF is 0.17 and west side wall thickness of 125mm both side cement plaster of 12.7mm and for value of U=1.67 W/m^2.K, Lm= 0.0 and CLTDb=9.

Whereas, in south side wall thickness of 125mm both side cement plaster of 12.7mm and for value of U=1.67 W/m^2.K, Lm= -3.3 and CLTDb= 11. For north side wall thickness of 125mm both side cement plaster of 12.7mm and for value of U=1.67 W/m^2.K, Lm=0.5 and CLTDb= 6 and daily temperature range is 11.

For east side glass area is 104 m^2, glass door area is 40 m^2, west side wall area is 84 m^2, south side wall area is 420 m^2, and north side wall area is 394 m^2. Level floor 01 and level floor 03 are conditioned space. Total number of is people 500, light load is 70260 Watt [20 W/m^2] and equipment load is 35,130 Watt [10 W/m^2, ASHRAE 2005] according to the present cooling load calculation is 118 TR and existing cooling load is 230 TR.

5.3 Part load performance

HVAC plants in temperate climates seldom operate at full load. For this reason, ASHRAE Standard 90.1P has established a HVAC part load duty cycle weighing table to compare performance of units over all part-loads.

Centrifugal chillers are part-load controlled with variable speed motors or with compressor inlet vanes combined with hot gas bypass for low loads and minimum load requirement of 45% and maximum 95%. Absorption units are part-load controlled by regulating the temperature of the generator and minimum load requirement of 25% and maximum 100% of the total load.

From different manufacturers' literature, it can be seen that part-load characteristics are nearly linear for both centrifugal and absorption chillers. For calculating energy, data is taken from the manufacturers' literature; energy consumption formula in terms of the part-load and condenser water temperatures is worked out using the least squares regression analysis.

The computer program supplies energy costs and consumptions and, secondly, statistical information on weather data. This, in turn, depends on the following variables entered: load starting time, assumed at 8 am and load duration time, assumed at 10 hours per day. Detailed weather data envelopes are given in Appendix A.

5.4 Maintenance costs

Although absorption chillers require a more specialized maintenance service than centrifugal chillers, repair of a centrifugal compressor and the loss of refrigerant (CFC, HCFC or HFC) can be expensive and are not included in normal maintenance costs. In fact, there are several high cost maintenance items, and it is difficult to predict when replacement of each item will be necessary.

Recent experience with direct-fired, steam fired, exhaust fired double stage absorption chillers in the United Kingdom indicate a definite maintenance cost saving when compared with centrifugal or Screw chillers. Nevertheless, the cost saving of maintenance should initially be based on the evaluator's best judgment according to the type of maintenance contract and to the plant combinations (for example, absorption and/or centrifugal chillers and if the absorption units are to supply only chilled water or if they will also supply hot water).

For comparison, a nominal average saving of £3500(US$5300) and £4000(US$6000) per year is calculated on maintenance contracts for buildings with four chiller-heaters of 700 kW (200 tons) and 1750 kW (500 tons), respectively. These figures are based on maintenance contracts including labor and materials of three minor visits and one major visit per year.

Each minor visit comprises logging parameters, leak/vacuum tests and refrigerant quantity tests. The major visit includes visual inspection of condensers (and absorbers) and specifically oil and filter changes together with full leak tests on centrifugal chillers in contrast to a vacuum test and a solution sample test on absorption chillers. The maintenance costs related to combustion are assumed to be equivalent for absorption chiller-heaters and boilers.

5.5 Optimization of direct-fired absorption units

The electric utilities have instituted rate structures (such as demand charges on peak kilowatt demand and time-of-day rates) to encourage reduction of electric demands during the peak hours. In addition to this, availability charges are related to the maximum power made available during the year and have no relation to the monthly consumption.

This means that the winter months of low energy consumption have relatively high electric tariffs. Thus, the operating costs of electric air-conditioning equipment become more expensive for owners/operators.

5.6. Cost comparison between vapor compression and vapor absorption chilling system for Bangladesh

The cost comparison figure is mentioned in table. 5.6 are illustrated in fig. 5.6 in the form of bar chart. The chart clearly shows the amount of saving by using direct fired absorption chiller and vapor compression chiller for Bangladesh.

a) Vapor compression chiller for Screw type [21]

Description	Electrical consumption (Kw/hr)	Gas consumption (m^3/hr)
Chiller capacity 100 TR,	60	Nil
Chilled water pump	13.5	Nil
Cooling water pump	17.5	Nil
Cooling tower	10.5	Nil
AHU/FCU/Control unit	25.5	Nil
Total power consumption	127	Nil

Electrical cost:

1 KWhr power cost = Tk. 6.80 (commercial tariff consider 2011 for Bangladesh)
127 KW = Tk. 6.80 * 127
= Tk. 863.6 * 10 * 365
= Tk. 31, 52,140 (Cost per year, if 10 hours operation per day)

b) Vapor absorption chiller [21]

Description	**Electrical consumption (KWhr)**	**Gas consumption (m^3/hr)**
Chiller capacity 100 TR,	4.5	30
Chilled water pump	13.5	Nil
Cooling water pump	26.5	Nil
Cooling tower	13.5	Nil
AHU/FCU/Control unit	25.5	Nil
Total power and gas consumption	**83.5**	**30**

Gas cost:

1 m^3/hr power cost = Tk. 4.18 (commercial tariff consider of chiller and boiler 2011 for Bangladesh)
30 m^3/hr = Tk. 4.18 * 30
= Tk. 125.40 * 10 * 365
= Tk. 4, 57,710 (Cost per year, if 10 hours operation per day)

Electrical cost:

1 KWhr power cost = Tk. 6.80 (commercial tariff consider 2011 for Bangladesh)
127 KW = Tk. 6.80 * 83.5
= Tk. 567.80 * 10 * 365
= Tk. 20, 72,470 (Cost per year, if 10 hours operation per day)

Total cost of vapor absorption chiller is = Tk. 4, 57,710 +Tk. 20, 72,470
= Tk. 25, 30,180

So savings by using direct fired vapor absorption chiller is:
= Tk. 31, 52,140 – Tk. 25, 30,180
= Tk 6, 21,960 per year

Country Name	Cooling Capacity (TR)	Cost of Electrical Chiller (Taka/year)	Cost of direct fired Absorption chiller (Taka / year)	Saving (Taka) per year
Bangladesh	100	31,52,140	25,30,180	6,21,960

Table 5.6: Cost comparisons between the vapor compression chiller and direct fired absorption chiller type

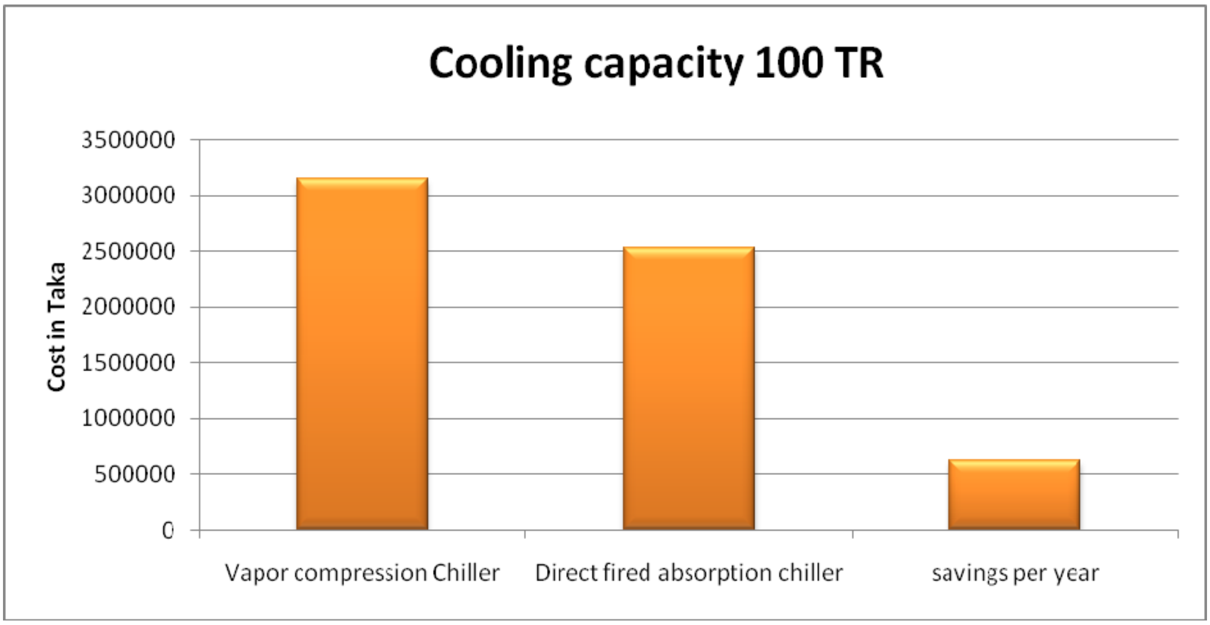


Figure 5.6: Cost comparison between vapor compression chiller and direct fired absorption chiller for Bangladesh.

5.7 Cost comparison between the vapor compression chiller and exhaust driven (cogeneration) vapor absorption chiller for Bangladesh

The cost comparison figure is mentioned in Table 5.7 and illustrated in Fig. 5.7 in the form of bar chart. The chart clearly shows the amount of saving by using vapor compression chiller, and cogeneration basis absorption chiller for Bangladesh.

Vapor absorption chiller for cogeneration system

Description	Electrical consumption (KWhr)	Gas consumption (m^3/hr)
Chiller capacity 100 TR,	4.5	Nil
Chilled water pump	13.5	Nil
Cooling water pump	26.5	Nil
Cooling tower	13.5	Nil
AHU/FCU/Control unit	25.5	Nil
Total power and gas consumption	83.5	Nil

Gas cost:

There is no need for gas consumption because direct generator or gas turbine exhausts flue gas driven absorption chiller.

Electrical cost:

1 KWhr power cost = Tk. 6.80 (commercial tariff consider 2011 for Bangladesh)
127 KW = Tk. 6.80 * 83.5
= Tk. 567.80 * 10 * 365
= Tk. 20, 72,470 (Cost per year, if 10 hours operation per day)

Total cost of exhaust driven vapor absorption chiller is = Tk. 20, 72,470

So savings by using direct fired vapor absorption chiller is:

= Tk. 31, 52,140 – Tk. 20, 72,470
= Tk 10, 79,670 per year

Country Name	Cooling Capacity (TR)	Cost of Electrical Chiller (Taka/year)	Cost of Exhaust driven Absorption Chiller (Taka / year)	Saving (Taka/year)
Bangladesh	100	31, 52,140	20, 72,470	10, 79,670

Table 5.7: Cost comparison between the vapor compression chiller and exhaust driven (cogeneration) absorption chiller.

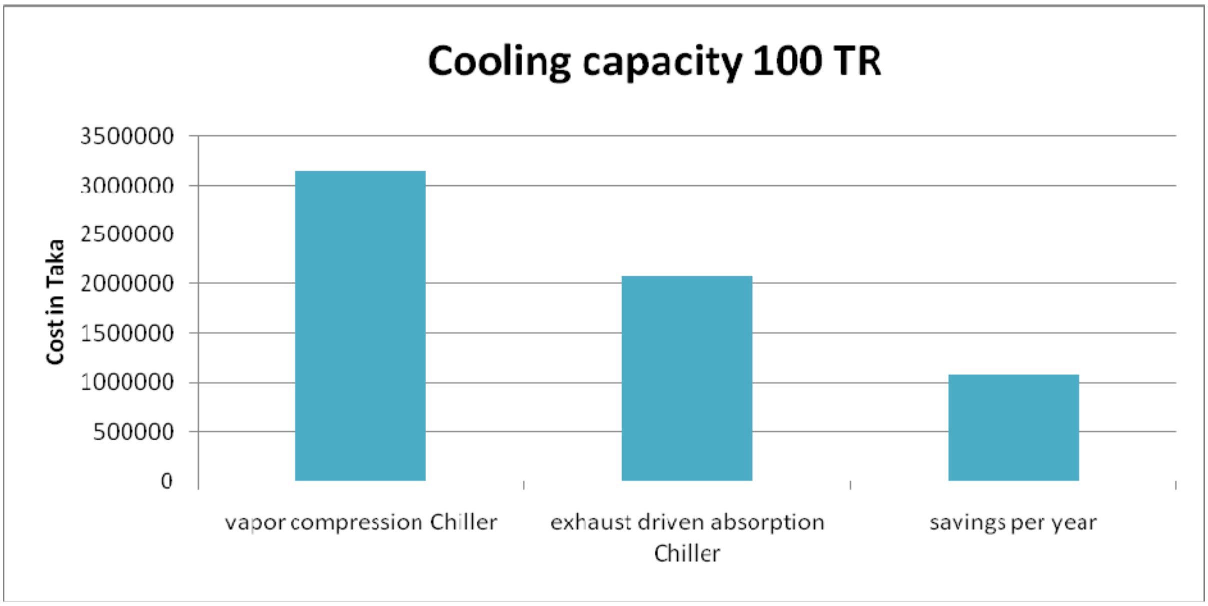


Figure 5.7: Cost comparison between vapor compression chiller & exhaust driven vapor (cogeneration) absorption chiller.

5.8 Cost comparison among the vapor compression chiller, direct fired absorption chiller and Cogeneration base absorption chiller for Bangladesh.

If we compare among the vapor compression chiller, direct fired absorption chiller and exhaust (generator exhaust flue gas) driven absorption chiller or cogeneration basis absorption chilling system financial analysis showing below in Table 5.8 and in bar chart in fig. 5.8

Country Name	Cooling Capacity (TR)	Cost of Electrical Chiller (Taka/year)	Cost of direct fired Absorption Chiller (Taka / year)	Cost of exhaust driven (cogeneration) Absorption Chiller (Taka / year)
Bangladesh	100	31, 52,140	25,30,180	20, 72,470

Table 5.8: Cost comparison among the vapor compression chiller, direct fired absorption chiller and Cogeneration base absorption chiller for Bangladesh

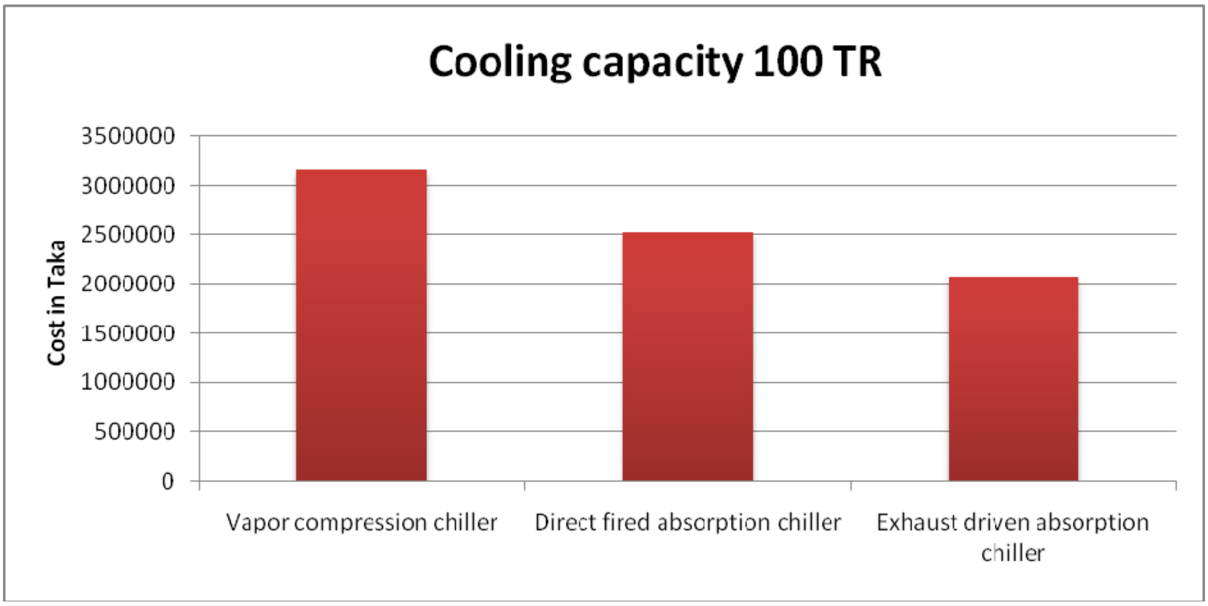


Figure 5.8: Cost comparison among the vapor compression chiller, direct fired absorption chiller and cogeneration base absorption chiller

5.9 Cooling load capacity in different countries with respect to ambient temperature and latitude

Considering an existing 20 storied commercial building of level 2 having total floor area is 4239 square ft and floor height 11 ft. West side glass area is 38.83 $m^{2,}$ South side glass area 55.0 m^2, East side glass area 16.45 m^2, East side wall area 67.97 m^2 and west side wall area is 44.71 m^2. North side, level 1 and level 3 are conditioned space. Number of people 40, light load 5910 Watt [15 W/m^2, ASHRAE 2005] and equipment load 3940 Watt [10 W/m^2, ASHRAE 2005]

Country name	**Ambient Temperature (°C)**	**Latitude (°N)**	**Cooling capacity (TR)**
U.K (Birmingham)	26	52	17.56
USA (California)	27	35	16.24
Japan (Tokyo)	33	36	17.80
Saudi Arabia (Riyadh)	43	25	18.33
Bangladesh	34	24	17.14

Table 5.9: cooling load capacity in different country with respect to ambient temperature and Latitude

5.10 Comparison between the vapor absorption chiller and vapor compression chiller

Shown in below:

SL No	Items	Vapor compression chiller	Vapor Absorption Chiller
1.0	Energy input	Electricity	Heat (Natural gas, Oil, Steam, Hot water & generator/Gas Turbine exhaust flue gas)
2.0	Air conditioning range	1- 150 TR (Reciprocating) 300 TR & above (Centrifugal) 50 TR 200 TR (Screw)	10 TR to 3300 TR
3.0	Power consumption / Gas consumption	0.68 to 1.12kW/hr per ton capacity *	0.28 m^3/hr per ton capacity *
4.0	Spare parts	Oil Filter, Refrigerant-filter , oil change	No spare parts very short
5.0	Environmental issue	Refrigerant used Freon gas	No used Freon Gas (absorber is Lithium Bromide solution)
6.0	Refrigerant	R22, R134a, R407, R410A	Refrigerant is pure water
	COP	2.98 for air cooled chiller 3.8 for water cooled chiller	1.41 For double effect of direct fired, steam and exhaust flue gas.
7.0	Noise level	95 dB(A) from 1 meter	65 dB(A) from 1 meter
8.0	Maintenance cost	More maintenance cost, Re-filled gas, oil filter, Refrigerant filter etc	Maintenance cost less. only need Rupture disk and de-scaling after 2 or 3 years
9.0	Multi use system	Only cooling & Heating mode use	Cooling, Heating & Hot water mode use
10.0	Radiation	More radiation because it has compressor and condenser	Near to zero because existing high insulation over the condensed or HTG side
11.0	Part load operation	Minimum 45% & Maximum 95%	Minimum 25% & maximum 100%
12.0	Refill Refrigerant	When need to maintenance of the chiller then refill refrigerant again	No need of refrigerant
13.0	Vacuum	Before Refrigerant charging need to vacuum	Complete the commissioning then need the vacuum after one month
14.0	Critical Parameters	a) Electricity supply b) Lubricating system c) Compressor operation & maintenance d) Power panel maintenance	a) Vacuum in chiller b) Auto purge maintenance c) Auto de-crystallization maintenance
15.0	Operation and maintenance	Need skilled operator	Need more skilled operator

5.11 World environment

A procedure for comparing the effects on global warming of carbon dioxide and other greenhouse gases has been developed for the gaseous emissions due to electricity fuel cycles in the overall the world. This procedure includes the entire process of electricity production including extraction, processing, transport, generation and distribution.

The weighed emission of equivalent carbon dioxide (CO_2) for petroleum is 0.272 kg (0.598lb) CO_2/ kWh of electric energy (1987 supply average). This figure is relatively high because most electric energy in the Bangladesh is produced from gas and coal.

The equivalent carbon dioxide emissions are calculated together with gas and electric energy consumptions for installations of 7032 kW (2000 tons), 35% intermediate load , with and without free cooling (for example, an office building). From the results calculated, absorption chillers have from 67% to 81% of the global warming potential (GWP) of centrifugal chillers at 100% and 0% free cooling, respectively. The potential danger of the refrigerants used for centrifugal or screw chillers should also be considered. In the specific case of this study, R-134a, R-22 has a GWP with respect to R-11 of 0.26, and R-11 with respect to carbon dioxide is 1500 on a 500 year horizon.

It is assumed that the installation has four chillers, that the charge of R-134a is 0.36kg/kW (2.78lb/tons) and that the centrifugal chillers will lose their refrigerant load every 15 years. A refrigerant loss of 169 kg (372lb) of R-134a per year is equivalent to 66000 kg (145,200lb) of carbon dioxide emissions per year.

Acid emissions are contributors to acid rain and smog. The responsible combustion products are nitrogen oxide (NOx) and sulfur dioxide (SO_2). A total acid emission, equivalent SO_2, may be expressed as:

The acid emissions for UK electricity supply (1987) in terms of equivalent sulfur dioxide are 1900 gS/GJZ (0.015lb.S/kWh). Similarly, the acid emissions for gas consumption were calculated using by above equation, S = 63gS/GJ. The resulting acid emissions of absorption chillers with respect to centrifugal chillers are 31% and 36% for free and non-free cooling systems, respectively.

Large scale absorption chillers work with the binary mixtures of water and lithium bromide solution. Unlike CFC and HCFC refrigerants, water and lithium bromide solution have no ozone-depleting potential.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The present analysis includes software application in the cooling load calculation for HVAC system and development of the computer aided design and further developed of software. From the study, analysis and results of this research work, the following conclusions can be made:

1. Software base cooling load calculation can be done very easily, very quickly and more accurately.
2. It is concluded from the present work that the cogeneration basis vapor absorption chiller is more eco friendly and more power saving compared to the traditional electric chiller.
3. In the present research work, it is observed that the cooling load depends on the ambient temperature. If the ambient temperature is low then cooling demand is low and the ambient temperature is high then cooling load demand is also high.
4. The developed software has been made in five steps: (a) instantaneous solar radiation heat gain for glass windows, (b) transmission heat gain, (c) internal heat gain, (d) ventilation and infiltration and (e) total result and show individual. The units of heat gain may be Watt, Kilowatt, BTU/h or Ton of refrigeration, TR.

6.2 Recommendations

1. The present method of cooling load calculation software can be applied with other language such as, C or C++, JAVA etc.
2. The present cooling load calculation software made only for Bangladesh considering 24°N latitude. The same software can be modified to other countries of the world.
3. The cooling load calculation software can be modified by Visual Basic SQL server7 software for internet basis multi user.

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Table 11: Chapter-26. 1985 Fundamentals Handbook, ASHRAE

Appendix A

Air-Conditioning Cooling Load

Maximum Solar Heat Gain Factor. W / m2 for Sunlit Glass, North Latitudes

10 ° N Lat

	N	NNE/ NNW	NE/ NW	ENE/ WNW	E/ W	ESE/ WSW	SE/ SW	SSE/ SWW	S	HOR
Jan	103	107	228	558	738	301	741	574	372	914
Feb	114	123	416	647	771	779	663	445	211	965
Mar	120	274	536	704	764	704	536	274	120	956
Apr	224	423	609	707	697	581	372	120	117	345
May	337	517	640	688	634	486	252	117	117	336
June	407	546	650	669	603	441	208	117	117	305
July	363	517	534	672	615	470	243	120	120	320
Aug	237	423	590	681	569	552	353	123	120	871
Sep	126	265	514	672	729	672	514	265	126	924
Oct	117	126	307	628	745	751	637	426	208	943
Nov	110	110	278	552	726	789	726	565	569	924
Dec	107	107	224	517	713	798	757	618	435	909

20° N Lat

	N	NNE/ NNW	NE/ NW	ENE/ WNW	E/ W	ESE/ WSW	SE/ SW	SSE/ SWW	S	HOR
Jan	91	91	151	435	634	767	798	735	675	732
Feb	98	98	278	546	713	770	751	634	549	830
Mar	107	155	416	631	748	745	650	480	363	896
Apr	120	290	524	672	719	656	498	287	183	905
May	148	388	581	685	685	581	391	170	133	893
June	186	426	596	681	663	546	341	142	133	880
July	151	391	574	672	669	565	375	167	136	877
Aug	126	287	511	650	694	631	480	278	180	883
Sep	114	145	401	603	710	710	628	467	460	868
Oct	101	101	274	527	685	745	729	618	536	814
Nov	91	91	151	429	622	754	786	722	666	726
Dec	85	85	110	385	590	751	801	760	713	685

4 ° N Lat

	N	NNE/ NNW	NE/ NW	ENE/ WNW	E/ W	ESE/ WSW	SE/ SW	SSE/ SWW	S	HOR
Jan	104	104	249	536	722	795	514	609	445	902
Feb	110	110	388	628	764	782	678	480	278	550
Mar	120	243	514	691	764	716	558	303	136	953
Apr	174	394	596	704	704	599	398	136	120	905
May	293	486	631	694	650	508	281	120	120	858
June	347	517	637	678	618	464	230	120	120	830
July	303	486	622	678	631	492	268	123	120	842
Aug	186	391	581	678	675	571	379	133	126	880
Sep	123	237	492	659	729	681	536	293	139	924
Oct	114	114	379	609	738	754	653	467	271	928
Nov	107	107	249	530	713	782	732	599	439	896
Dec	104	104	196	495	697	789	764	650	505	874

24° N Lat.

	N	NNE/ NNW	NE/ NW	ENE/ WNW	E/ W	ESE/ WSW	SE/ SW	SSE/ SSW	S	HOR
Jan	85	85	129	404	599	757	798	760	716	675
Feb	95	95	252	521	694	770	767	672	606	786
Mar	107	142	391	615	738	748	675	530	432	868
Apr	117	278	502	659	719	669	533	338	237	893
May	136	369	562	675	688	599	416	211	145	890
June	174	401	581	675	669	565	369	174	136	880
July	142	366	555	663	672	584	407	205	145	877
Aug	120	274	492	640	694	644	511	325	227	874
Sep	110	133	375	584	700	710	650	514	423	839
Oct	98	98	249	502	666	748	741	653	590	770
Nov	85	85	133	398	590	745	786	748	707	672
Dec	82	82	91	353	568	738	779	779	748	628

Table 11: Chapter-26. 1985 Fundamentals Handbook, ASHRAE

Air-Conditioning Cooling Load

Maximum Solar Heat Gain Factor. W / m2 for Sunlit Glass, North Latitudes

28 ° N Lat

	N	NNE/ NNW	NE/ NW	ENE/ WNW	E/ W	ESE/ WSW	SE/ SW	SSE/ SWW	S	HOR
Jan	79	79	110	369	577	741	792	779	751	618
Feb	91	91	227	495	672	770	776	707	653	738
Mar	104	129	366	596	729	748	697	574	495	836
Apr	114	265	476	647	719	681	562	391	297	877
May	126	363	543	666	691	615	454	262	183	883
June	161	394	562	666	672	581	404	707	155	877
July	129	360	536	656	678	599	442	252	180	870
Aug	120	262	470	628	694	653	543	379	287	858
Sep	107	120	350	565	691	713	672	558	486	808
Oct	95	95	224	476	644	745	751	685	637	722
Nov	82	82	110	363	571	732	779	767	741	615
Dec	75	76	76	312	543	716	782	792	776	565

32 ° N Lat

	N	NNE/ NNW	NE/ NW	ENE/ WNW	E/ W	ESE/ WSW	SE/ SW	SSE/ SWW	S	HOR
Jan	76	76	91	331	552	722	786	789	776	555
Feb	85	85	205	470	647	764	782	732	697	685
Mar	101	117	338	577	716	748	716	615	555	795
Apr	114	252	461	631	716	691	590	445	363	855
May	120	350	536	656	694	628	489	312	233	874
June	139	385	555	656	675	596	439	262	189	871
July	126	350	527	643	678	612	473	303	227	861
Aug	117	249	445	615	691	663	571	429	350	836
Sep	104	110	325	546	678	716	688	596	540	770
Oct	88	88	199	451	615	738	754	710	678	672
Nov	76	76	91	325	546	710	773	776	767	552
Dec	69	69	69	265	511	688	776	795	795	498

36 ° N Lat

	N	NNE/ NNW	NE/ NW	ENE/ WNW	E/ W	ESE/ WSW	SE/ SW	SSE/ SWW	S	HOR
Jan	69	69	76	284	524	691	779	795	795	489
Feb	82	82	180	439	615	754	782	754	732	628
Mar	95	104	312	555	704	751	732	650	606	751
Apr	110	240	454	618	710	697	618	492	426	827
May	120	338	530	644	694	644	521	366	293	858
June	148	372	552	647	678	612	473	321	243	861
July	123	338	521	634	681	628	508	357	284	846
Aug	114	237	435	599	688	669	596	476	413	811
Sep	98	98	300	527	663	719	704	631	590	726
Oct	85	85	177	420	590	726	754	729	710	615
Nov	69	69	76	274	514	678	767	782	782	486
Dec	63	63	63	218	476	644	760	798	801	429

40 ° N Lat

	N	NNE/ NNW	NE/ NW	ENE/ WNW	E/ W	ESE/ WSW	SE/ SW	SSE/ SWW	S	HOR
Jan	63	63	63	233	486	647	760	795	801	420
Feb	76	76	158	407	587	738	776	770	760	568
Mar	91	91	293	533	688	751	745	681	650	704
Apr	107	224	441	599	707	704	640	536	486	795
May	117	322	521	637	694	656	552	420	357	836
June	151	357	543	647	681	628	508	366	300	842
July	120	322	514	625	681	641	536	681	344	827
Aug	110	224	426	584	681	675	618	536	470	779
Sep	95	95	274	505	640	716	713	659	631	678
Oct	79	79	154	388	568	710	751	745	738	558
Nov	63	63	63	230	476	634	748	782	789	416
Dec	57	57	57	189	476	593	732	786	798	357

Table 11: Chapter-26. 1985 Fundamentals Handbook, ASHRAE

Air-Conditioning Cooling Load

Maximum Solar Heat Gain Factor. W / m2 for Sunlit Glass, North Latitudes

44° N Lat.

	N	NNE/ NNW	NE/ NW	ENE/ WNW	E/ W	ESE/ WSW	SE/ SW	SSE/ SWW	S	HOR
Jan	54	57	54	202	640	596	732	782	795	344
Feb	69	69	136	369	562	716	776	782	779	505
Mar	85	85	274	511	666	745	751	707	688	650
Apr	104	208	429	57	697	707	663	577	540	757
May	114	303	511	634	691	666	577	467	416	811
June	148	341	533	647	678	640	540	416	363	823
July	117	303	502	624	678	650	565	454	404	801
Aug	107	208	416	568	675	678	637	558	521	745
Sep	88	88	252	480	625	713	716	681	666	628
Oct	73	73	133	350	540	685	748	757	754	495
Nov	57	57	57	202	426	587	716	770	782	344
Dec	47	47	47	155	363	552	685	757	776	281

48° N Lat

	N	NNE/ NNW	NE/ NW	ENE/ WNW	E/ W	ESE/ WSW	SE/ SW	SSE/ SWW	S	HOR
Jan	47	47	47	167	372	552	681	754	773	268
Feb	63	63	114	325	530	681	764	786	789	435
Mar	82	82	252	486	644	738	754	732	719	593
Apr	98	192	416	568	691	710	678	612	587	713
May	110	306	498	631	290	675	606	514	473	779
June	145	347	521	644	678	650	568	467	423	795
July	117	303	492	618	675	659	590	498	461	770
Aug	104	192	404	549	666	681	656	593	568	704
Sep	85	41	227	454	290	704	719	704	694	574
Oct	66	66	110	303	508	653	735	760	764	42
Nov	47	47	492	164	363	543	669	738	757	268
Dec	41	41	41	114	287	492	615	710	735	205

52° N Lat

	N	NNE/ NNW	NE/ NW	ENE/ WNW	E/ W	ESE/ WSW	SE/ SW	SSE/ SWW	S	HOR
Jan	41	41	41	123	290	489	609	700	726	196
Feb	57	57	91	268	492	637	741	779	789	363
Mar	76	76	230	457	618	726	754	751	745	533
Apr	95	177	464	558	678	707	694	644	628	666
May	79	309	486	625	685	685	628	552	527	741
June	142	350	508	637	675	663	593	511	480	764
July	114	306	480	612	672	669	615	540	514	735
Aug	101	177	391	533	656	681	669	622	609	656
Sep	79	79	205	429	574	688	719	719	716	514
Oct	60	60	88	252	467	608	710	751	757	360
Nov	41	41	41	123	284	480	596	685	710	196
Dec	32	32	32	60	230	401	543	628	659	133

56° N Lat.

	N	NNE/ NNW	NE/ NW	ENE/ WNW	E/ W	ESE/ WSW	SE/ SW	SSE/ SWW	S	HOR
Jan	32	32	32	66	253	398	533	612	647	126
Feb	50	50	66	224	439	581	704	754	770	287
Mar	69	69	205	429	584	702	751	760	760	470
Apr	88	183	388	546	666	704	704	672	663	615
May	114	312	470	615	678	688	650	590	571	700
June	167	350	505	628	672	672	618	549	530	729
July	117	309	464	606	666	675	634	577	558	697
Aug	95	177	375	521	640	681	678	650	640	609
Sep	73	73	183	398	540	666	650	726	729	454
Oct	50	50	63	215	416	555	672	722	738	287
Nov	32	32	32	66	227	385	521	599	631	126
Dec	22	22	22	22	148	290	426	502	540	73

Table 11: Chapter-26. 1985 Fundamentals Handbook, ASHRAE

Air-Conditioning Cooling Load

Maximum Solar Heat Gain Factor. W / m2 for Sunlit Glass, North Latitudes

	35° N Lat.											51° N Lat								
	N	NNE/ NNW	NE/ NW	ENE/ WNW	E/ W	ESE/ WSW	SE/ SW	SSE/ SWW	S	HOR		N	NNE/ NNW	NE/ NW	ENE/ WNW	E/ W	ESE/ WSW	SE/ SW	SSE/ SWW	S	HOR
Jan	71	71	80	296	531	699	781	794	790	506	**Jan**	42.5	42.5	42.5	134	310.5	504.8	627	713.5	737.8	214
Feb	83	83	186	447	623	757	782	749	723	642	**Feb**	58.5	58.5	96.8	282.3	501.5	648	764.8	780.8	789	381
Mar	97	107	319	561	707	750	728	641	593	762	**Mar**	77.5	77.5	235.5	464.3	624.5	729	754	746.3	738.5	548
Apr	111	243	456	621	712	696	611	480	410	834	**Apr**	95.8	180.8	452	560.5	681.3	707.8	690	636	617.8	677.8
May	120	341	532	647	694	640	513	353	278	862	**May**	86.8	308.3	489	626.5	586.3	682.5	622.5	542.5	513.5	750.5
June	146	375	553	649	677	608	465	300	230	864	**June**	142.8	349.3	511	638.8	675.8	659.8	586.8	500	465.8	771.8
July	124	341	523	636	680	624	499	344	270	850	**July**	114.8	305.3	483	613.5	672.8	666.5	608.8	529.5	500.8	743.8
Aug	115	240	438	603	689	668	590	464	397	817	**Aug**	101.8	180.8	394	537	658.5	681	665.8	614.8	598.8	668
Sep	100	101	306	532	667	718	700	622	578	737	**Sep**	80.5	69.5	210	435.3	503	692	719	715.3	710.5	529
Oct	86	86	183	428	596	729	754	724	702	629	**Oct**	61.5	61.5	93.5	264.8	477.3	619	716.3	753.3	758.8	280.5
Nov	71	71	80	287	522	686	769	781	778	503	**Nov**	42.5	42.5	153.8	133.3	303.1	495.8	614.3	698.3	721.8	214
Dec	65	65	65	230	485	655	764	797	800	446	**Dec**	34.3	34.3	34.3	73.5	244.3	423.8	561	648.5	678	151

Table 14, Chapter 26, ASHRAE 1985 Fundamentals Handbook

Cooling load factors for glass with interior shading, north latitudes (CLF)

All room construction									
Solar Time h	N	NE	E	SE	S	SW	W	NW	HOR
6	0.73	0.56	0.47	0.30	0.09	0.07	0.06	0.07	0.12
7	0.66	0.76	0.72	0.57	0.16	0.11	0.09	0.11	0.27
8	0.65	0.74	0.80	0.74	0.23	0.14	0.11	0.14	0.44
9	0.73	0.58	0.76	0.81	0.38	0.16	0.13	0.17	0.59
10	0.80	0.37	0.62	0.79	0.58	0.19	0.15	0.19	0.72
11	0.86	0.29	0.41	0.68	0.75	0.22	0.16	0.20	0.81
12	0.89	0.27	0.27	0.49	0.83	0.38	0.17	0.21	0.85
13	0.89	0.26	0.24	0.33	0.80	0.59	0.31	0.22	0.85
14	0.86	0.24	0.22	0.28	0.68	0.75	0.53	0.30	0.81
15	0.82	0.22	0.20	0.25	0.50	0.83	0.72	0.52	0.71
16	0.75	0.20	0.17	0.22	0.35	0.81	0.82	0.73	0.58
17	0.78	0.16	0.14	0.18	0.27	0.69	0.81	0.82	0.42
18	0.91	0.12	0.11	0.13	0.19	0.45	0.61	0.69	0.25

Table 39 chapter 27, ASHRAE 1885 Fundamentals Handbook

Shading coefficients (Sc) for Single and Insulating Glass with Draperies

Type of glass	Thickness Trans mm	Glass Sc	A	B	C	D
Single glass						
6 mm	0.80	0.95	0.80	0.75	0.70	0.65
12 mm	0.71	0.88	0.74	0.70	0.66	0.61
6 mm Heat Abs.	0.46	0.67	0.57	0.54	0.52	0.49
12 mm Heat Abs.	0.24	0.50	0.43	0.42	0.40	0.39
Insulating Glass						
12mm Air Space						
Clear Out and Clear In	0.64	0.83	0.66	0.62	0.58	0.56
Heat Abs. Out and Clear In	0.37	0.55	0.49	0.47	0.45	0.43

Chapter 27, 1985 Fundamentals Handbook

Table 13 Overall Coefficients of Heat Transmission (U-Factor) of Windows, Sliding Patio Doors and Skylights, $W/m^2 . °C$

	No Shade, U, $W/m^2 . °C$		Indoor Shade, U, $W/m^2 . °C$	
	Winter	Summer	Winter	Summer
Single glass, clear	6.2	5.9	4.7	4.6
Single Glass, Low Emittance Coating				
E = 0.60	5.8	5.7	4.3	4.5
E = 0.40	5.2	5.1	3.9	4.0
E = 0.20	4.5	4.3	3.3	3.1
Insulating Glass, Double 5mm air space	3.5	3.7	3.0	3.3
6 mm air space	3.3	3.5	2.7	3.1
13 mm air space	2.8	3.2	2.4	3.0

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Table 9 : CLTD correction For Latitude and Month applied in walls and roofs, North Latitudes

Latitude	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	3.6	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	3.3	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
	May/Jul	0.5	0.0	0.5	0.0	1.6	2.2	3.3	4.4	5.5	-1.0
	Jun	1.1	1.1	1.1	1.1	2.2	2.2	3.3	3.8	5.0	0.0

Table 10, Chapter 26, 1985 Fundamentals Handbook ASHRAE

Cooling load temperature differences for conduction through Glass.

Solar Time	6	8	9	10	11	12	13	14	15	16	17	18	19	20
CLTD, ^{0}C	-1	0	1	2	4	5	7	7	8	8	7	7	6	4

2005 ASHRAE Handbook – Fundamentals (SI)

Table 1: Chapter 30, Heat Gain from Occupants

Degree of Activity	Typical application	Sensible Heat, W	Latent Heat, W
Moderately active office work	Office, Hotels, Apartments	75	55
Standing, Light work, walking	Departmental store, Retail store	75	55
Walking, Standing	Drug store, Bank	75	70
Light bench work	Factory	80	140
Walking, 4.8 km/h, light machine work	Factory	110	185
Heavy work	Factory	170	255
Athletics	Gymnasium	210	315

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Table 5 Cooling Load Temperature Differences for Calculating Cooling Load from **Flat Roofs**

				Solar Time, h																
Roof No	Description of Construction	Mass Kg/m2	U-value, W/m2.ºC	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17
Without Suspended Ceiling																				
1	Steel Sheet with 25.4mm insulation	34	1.209	0	-1	-2	-2	-3	-2	3	11	19	27	34	40	43	44	43	39	33
2	25.4mm wood with 25.4mm insulation	39	0.965	3	2	0	-1	-2	-2	-1	2	8	15	22	29	35	39	41	41	39
3	101.6mm 1.w concrete	88	1.209	5	3	1	0	-1	-2	-2	1	5	11	18	25	31	36	39	40	40
4	50.8mm h.w. concrete with 25.4mm insulation	142	1.170	7	5	3	2	0	-1	0	2	6	11	17	23	28	33	36	37	37
With Suspended Ceiling																				
1	Steel Sheet with 25.4mm insulation	44	0.761	1	0	-1	-2	-3	-3	0	5	13	20	28	35	40	43	43	41	37
2	25.4mm wood with 25.4mm insulation	49	0.653	11	8	6	5	3	2	1	2	4	7	12	17	22	27	31	33	35
3	101.6mm 1.w concrete	97	0.761	10	8	6	4	2	1	0	0	2	6	10	16	21	27	31	34	36
4	50.8mm h.w. concrete with 25.4mm insulation	146	0.744	16	14	13	11	10	8	7	7	8	9	11	14	17	19	22	24	25
5	25.4mm wood with 50.8mm insulation	49	0.471	14	11	9	7	5	4	3	3	4	6	10	14	18	23	27	30	31
6	152.4mm 1.w. concrete	127	0.619	18	15	13	11	9	7	6	4	4	4	6	9	12	16	20	24	27
7	63.5 mm wood with 25.4 insulation	73	0.545	19	18	16	14	13	12	10	9	8	8	9	10	12	14	17	19	21
8	203.2 1.w concrete	161	0.528	22	20	18	16	15	13	11	10	9	8	8	8	9	11	14	16	19

(1) Direct application of Table 5 without Adjustment:

Values in Table 5 where calculated using the following conditions:

- Dark flat surface room (" dark " for solar radiation absorption)
- Indoor temperature 25.5°C
- Outdoor Maximum Temperature of 35°C with outdoor mean temperature of 29.4°C and an outdoor daily range of 11.6°C
- Solar radiation typical of 40 deg north latitude on July 21
- Outside surface resistance. Ro= 0.059m2 .°C/W
- Without and with suspended ceiling, but no attic fans or return air ducts in suspended ceiling space.
- Inside surface resistance, Ri = 0.121 m2.°C/W

(2)Adjustments to Table 5 Values:

The following equation makes adjustments for deviations of design and solar conditions from those listed in (1) above.

$$CLTD_{corr} = [(CLTD+LM) \cdot K + (25.5 - T_r) + (T_o - 29.4)] \cdot f$$

Where CLTD is from this table

(a) LM is latitude –month correction from Table 9 for a horizontal surface.

(b) K is color adjustment factor and is applied after first making month- latitude adjustments. Credit should not be taken for a light-colored roof except where permanence of light color is established by experience, as in rural areas or where there is little smoke,
K= 1.0 if dark colored or light in an industrial area
K=0.5 if permanently light-colored (rural area)

(c) is indoor design temperature correction.

(d) (To-29.4) is outdoor design temperature correction, where To is the average outside temperature on design day.

(e) f is a factor for attic fan and or ducts above ceiling and is applied after all other adjustment shave been made.
f = 1.0 no attic or ducts
f = .75 positive ventilation.

Values in Table 5 were calculated without and with a suspended ceiling, but made no allowances for positive ventilation or return ducts through the space. If ceiling is insulated and a fan is used between ceiling and roof , CLTD may be reduced by 25% (f = 0.75) . Use of the suspended ceiling space for a return air plenum or with return air ducts should be analyzed separately.

(3) Roof Constructions Not Listed in Table:

The U- value listed are to be used only as guides. The actual value of U as obtained from tables such as tables 3 and 4, Chapter 23 , or as calculated for the actual roof construction should be used.

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Table 7 Cooling Load Temperature Differences for Calculating Cooling Load from **Sunlit Walls**

Solar Time, h

North Latitude Wall Facing	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18
	Group A Walls																	
N	8	8	8	7	7	7	7	6	6	6	6	6	6	6	6	6	6	6
NE	11	11	10	10	10	9	9	9	8	8	8	9	9	9	9	10	10	10
E	14	13	13	13	12	12	11	11	10	10	10	11	11	12	12	13	13	13
SE	13	13	13	12	12	11	11	10	10	10	10	10	10	11	11	12	12	13
S	11	11	11	11	10	10	9	9	9	8	8	8	8	8	8	8	9	9
SW	14	14	14	14	13	13	12	12	11	11	10	10	10	9	9	10	10	10
W	15	15	15	14	14	14	13	13	12	12	11	11	10	10	10	10	10	11
NW	12	12	11	11	11	11	10	10	10	9	9	8	8	8	8	8	8	8
Group B Walls																		
N	8	8	8	7	7	6	6	6	5	5	5	5	5	5	5	6	6	7
NE	11	10	10	9	9	8	7	7	7	7	8	8	9	9	10	10	11	11
E	13	13	12	11	10	10	9	8	8	9	9	10	12	13	13	14	14	15
SE	13	12	12	11	10	10	9	8	8	8	8	9	10	11	12	13	13	14
S	12	11	11	10	9	9	8	7	7	6	6	6	6	7	8	9	9	11
SW	15	15	14	13	13	12	11	10	9	9	8	8	7	7	8	9	9	11
W	16	16	15	14	14	13	12	11	10	9	9	8	8	8	8	8	9	11
NW	13	12	12	11	11	10	9	9	8	7	7	7	6	6	7	7	8	8
Group C Walls																		
N	9	8	7	7	6	5	5	4	4	4	4	4	5	5	6	6	7	8
NE	10	10	9	8	7	6	6	6	6	7	8	10	`10	11	12	12	12	13
E	13	12	11	10	9	8	7	7	8	9	11	13	14	15	16	16	17	17
SE	13	12	11	10	9	8	7	6	7	7	9	10	11	14	15	16	16	16
S	12	11	10	9	8	7	6	6	5	5	5	5	6	8	9	11	12	13
SW	16	15	14	12	11	10	9	8	7	7	6	6	6	7	8	10	12	14
W	17	16	15	14	12	11	10	9	8	7	7	7	7	7	8	9	11	13
NW	14	13	12	11	10	9	8	7	6	6	5	5	6	6	6	7	9	10
Group D Walls																		
N	8	7	7	6	5	4	3	3	3	3	4	4	5	6	6	7	8	9
NE	9	8	7	6	5	5	4	4	6	8	10	11	12	13	13	13	14	14
E	11	10	8	7	6	5	5	5	7	10	13	15	17	18	18	18	18	18
SE	11	10	9	7	6	5	5	5	5	7	10	12	14	16	17	18	18	18
S	11	10	8	7	6	5	4	4	3	3	4	5	7	9	11	13	15	16
SW	15	14	12	10	9	8	6	5	5	4	4	5	5	7	9	12	15	18
W	17	15	13	12	10	9	7	6	5	5	5	5	6	6	8	10	13	17
NW	14	12	11	9	8	7	6	5	4	4	4	4	5	6	7	8	10	12

(1)Direct Application of Table 7 Without Adjustments:

Values in the Table were calculated using the following conditions for walls as outlined for the roof CLTD table, Table 5. These values may be used for all normal air-conditioning estimates usually without correction (except as noted below) when the load is calculated for the hottest weather.
For totally shaded walls use the North orientation values.

(2) Adjustments to Table Values:
The following equation makes adjustments for conditions other than those listed in Note (1).

$$CLTDcorr = (CLTD + LM) .K + (25.5 – Tr) + (To – 29.4)$$

Where CLTD is form Table 7 at the wall orientation

(a) LM is latitude –month correction from table 9
(b) K is a color adjustment factor and is applied after first making month-latitude adjustment

K = 1.0 if dark colored or light in an industrial area
K = 0.83 if permanently medium-colored (rural area)
K= 0.65 if permanently light-colored (rural area)
Credit should not be taken for a light- colored roof except where permanence of light is established by experience , as in rural areas or where there is little smoke.

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Table 8 Thermal properties and Code Numbers of Layers Used in Calculation of Coefficients for **Roof** and **Walls**

Thickness and Thermal properties

L	K	D	SH	R	Mass	Description	CodeNumber
25.4	0.692	1858	0.233	0.036	47.2	25.4 mm Stucco (asbestos cement or wood siding plaster ,etc)	A1
101.6	1.298	2082	0.256	0.078	211.4	101.6 mm face brick (dense concrete)	A2
1.5	44.99	7689	0.116	0.00003	11.7	Steel siding (aluminum or other lightweight cladding) outside surface resistant 0.333	A3
12.7	1.143	881	0.465			12.7mm slag, membrane	A4
9.5	0.190	1121	0.465			9.5-mm. felt	A5
12.7	0.415	1249	0.302	0.031	15.9	Finish	A6
10.16	1.332	2002	0.256	0.076	203.1	101.6-mm face brick	A7
				0.160		Air space Resistance	B1
25.4	0.043	32	0.233	0.585	0.8	25.4-mm insulation	B2
50.8	0.043	32	0.233	1.176	1.6	50.8-mm insulation	B3
76.2	0.043	32	0.233	1.766	2.4	76.2-mm insulation	B4
25.4	0.043	91	0.233	0.585	2.3	25.4mm insulation	B5
50.8	0.043	91	0.233	1.176	4.6	50.8mm insulation	B6
25.4	0.116	592	0.699	0.209	15.0	25.4mm wood	B7
62.4	0.116	592	0.699	0.525	37.6	62.5mm wood	B8
101.6	0.116	592	0.699	0.838	60.0	14.6mm wood	B9
50.8	0.116	592	0.699	0.421	30.2	50.8mm wood	B10
76.2	0.116	592	0.699	0.631	45.2	76.2mm wood	B11
76.2	0.043	91	0.233	1.761	6.9	76.2mm insulation	B12
101.6	0.043	91	0.233	2.346	9.3	101.6mm insulation	B13
127.0	0.043	91	0.233	2.934	11.6	127.0mm insulation	B14
152.4	0.043	91	0.233	3.520	13.9	152.4mm insulation	B15
101.6	0.571	1121	0.233	0,178	113.7	101.6mm clay tiles	C1
101.6	0.381	608	0.233	0.266	62.0	101.6mm 1.w. concrete block	C2
101.6	0.813	977	0.233	0.125	99.1	101.6mm 1.w. concrete block	C3
101.6	0.727	1922	0.233	0.139	195.3	101.6mm common brick	C4
101.6	1.730	2242	0.233	0.059	227.5	101.6-mm 1.w. concrete	C5
203.2	0.571	1121	0.233	0.356	227.9	203.2mm clay tile	C6
203.2	0.571	608	0.233	0.356	124.0	203.2mm 1.w.concorte block	C7
203.2	1.038	977	0.233	0.195	198.7	203.2mm 1.w. concrete block	C8
203.2	0.727	1922	0.233	0.280	390.6	203.2mm common brick	C9
203.2	1.730	2242	0.233	0.117	455.9	203.2mm 1.w. concrete	C10
304.8	1.730	2242	0.233	0.176	683.5	304.8mm 1.w. concrete	C11
50.8	1.730	2242	0.233	0.029	114.2	50.8mm 1.w.concrete	C12
152.4	1.730	2242	0.233	0.088	341.7	151.4mm 1.w. concrete	C13
101.6	0.173	640	0.233	0.586	64.9	101.6mm 1.w. concrete	C14
152.4	0.173	640	0.233	0.088	97.6	152.4mm 1.w. concrete	C15
203.2	0.173	640	0.233	1.174	130.3	203.2mm 1.w.concrete	C16
203.2	0.138	288	0.233	1.584	58.6	203.2 mm 1.w. concrete block (filled insulation)	C17
203.2	0.588	849	0.233	0.348	172.8	203.2mm 1.w. concrete block (filled insulation)	C18
304.8	0.138	304	0.233	2.376	92.8	204.8mm 1.w. concrete block (filled insulation)	C19

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Table 17A Cooling Load Factors When Lights Are on for **8Hours**

“a “coefficient	“b” Classification	0	1	2	3	4	5	6	7	8	9	10	11	12	13
0.45	A	0.02	0.46	0.57	0.65	0.72	0.77	0.82	0.85	0.88	0.46	0.37	0.30	0.24	0.19
	B	0.07	0.51	0.56	0.61	0.63	0.63	0.64	0.65	0.66	0.22	0.22	0.21	0.20	0.20
	C	0.11	0.55	0.58	0.60	0.63	0.65	0.67	0.69	0.71	0.28	0.26	0.25	0.23	0.22
	D	0.14	0.58	0.60	0.61	0.62	0.63	0.64	0.65	0.66	0.22	0.22	0.21	0.20	0.20
0.55	A	0.01	0.56	0.65	0.72	0.77	0.82	0.85	0.88	0.90	0.37	0.30	0.24	0.19	0.16
	B	0.06	0.60	0.64	0.68	0.71	0.74	0.76	0.79	0.81	0.28	0.25	0.23	0.20	0.18
	C	0.09	0.63	0.66	0.68	0.70	0.71	0.73	0.75	0.76	0.23	0.21	0.20	0.19	0.18
	D	0.11	0.66	0.67	0.68	0.69	0.70	0.71	0.72	0.72	0.18	0.18	0.17	0.17	0.16
0.65	A	0.01	0.66	0.73	0.78	0.82	0.86	0.88	0.91	0.93	0.29	0.23	0.19	0.15	0.12
	B	0.04	0.69	0.72	0.75	0.77	0.80	0.82	0.84	0.85	0.22	0.19	0.18	0.16	0.14
	C	0.07	0.72	0.73	0.75	0.76	0.78	0.79	0.80	0.82	0.18	0.17	0.16	0.15	0.14
	D	0.09	0.73	0.74	0.75	0.76	0.77	0.77	0.78	0.79	0.14	0.14	0.13	0.13	0.13
0.75	A	0.01	0.76	0.80	0.84	0.87	0.90	0.92	0.93	0.95	0.21	0.17	0.13	0.11	0.09
	B	0.03	0.78	0.80	0.82	0.84	0.85	0.87	0.88	0.89	0.15	0.14	0.13	0.11	0.10
	C	0.05	0.80	0.81	0.82	0.83	0.84	0.85	0.86	0.87	0.13	0.12	0.11	0.10	0.10
	D	0.06	0.81	0.82	0.82	0.83	0.83	0.84	0.84	0.85	0.10	0.10	0.10	0.09	0.09

Table 17B Cooling Load Factors When Lights Are on for **10 Hours**

“a “coefficient	“b” Classification	0	1	2	3	4	5	6	7	8	9	10	11	12	13
0.45	A	0.03	0.47	0.58	0.66	0.73	0.78	0.82	0.86	0.88	0.91	0.93	0.49	0.39	0.32
	B	0.10	0.54	0.59	0.63	0.66	0.70	0.73	0.76	0.78	0.80	0.82	0.39	0.35	0.32
	C	0.15	0.59	0.61	0.64	0.66	0.68	0.70	0.72	0.73	0.75	0.76	0.33	0.31	0.29
	D	0.18	0.62	0.63	0.64	0.66	0.67	0.68	0.69	0.69	0.70	0.71	0.27	0.26	0.26
0.55	A	0.02	0.57	0.65	0.72	0.78	0.82	0.85	0.88	0.91	0.92	0.94	0.40	0.32	0.26
	B	0.08	0.62	0.66	0.69	0.73	0.75	0.78	0.80	0.82	0.84	0.85	0.32	0.29	0.26
	C	0.12	0.66	0.68	0.70	0.72	0.74	0.75	0.77	0.78	0.79	0.81	0.27	0.25	0.24
	D	0.15	0.69	0.70	0.71	0.72	0.73	0.73	0.74	0.75	0.76	0.76	0.22	0.22	0.21
0.65	A	0.02	0.66	0.73	0.78	0.83	0.86	0.89	0.91	0.93	0.94	0.95	0.31	0.25	0.20
	B	0.06	0.71	0.74	0.76	0.79	0.81	0.83	0.84	0.86	0.87	0.89	0.25	0.22	0.20
	C	0.09	0.74	0.75	0.77	0.78	0.80	0.81	0.82	0.83	0.84	0.85	0.21	0.20	0.18
	D	0.11	0.76	0.77	0.77	0.78	0.79	0.79	0.80	0.81	0.81	0.82	0.17	0.17	0.16
0.75	A	0.01	0.76	0.81	0.84	0.88	0.90	0.92	0.93	0.95	0.96	0.97	0.22	0.18	0.14
	B	0.04	0.79	0.81	0.83	0.85	0.86	0.88	0.89	0.90	0.91	0.92	0.18	0.16	0.14
	C	0.07	0.81	0.82	0.83	0.84	0.85	0.86	0.87	0.88	0.89	0.89	0.15	0.14	0.13
	D	0.08	0.83	0.83	0.84	0.84	0.85	0.85	0.86	0.86	0.87	0.87	0.12	0.12	0.12

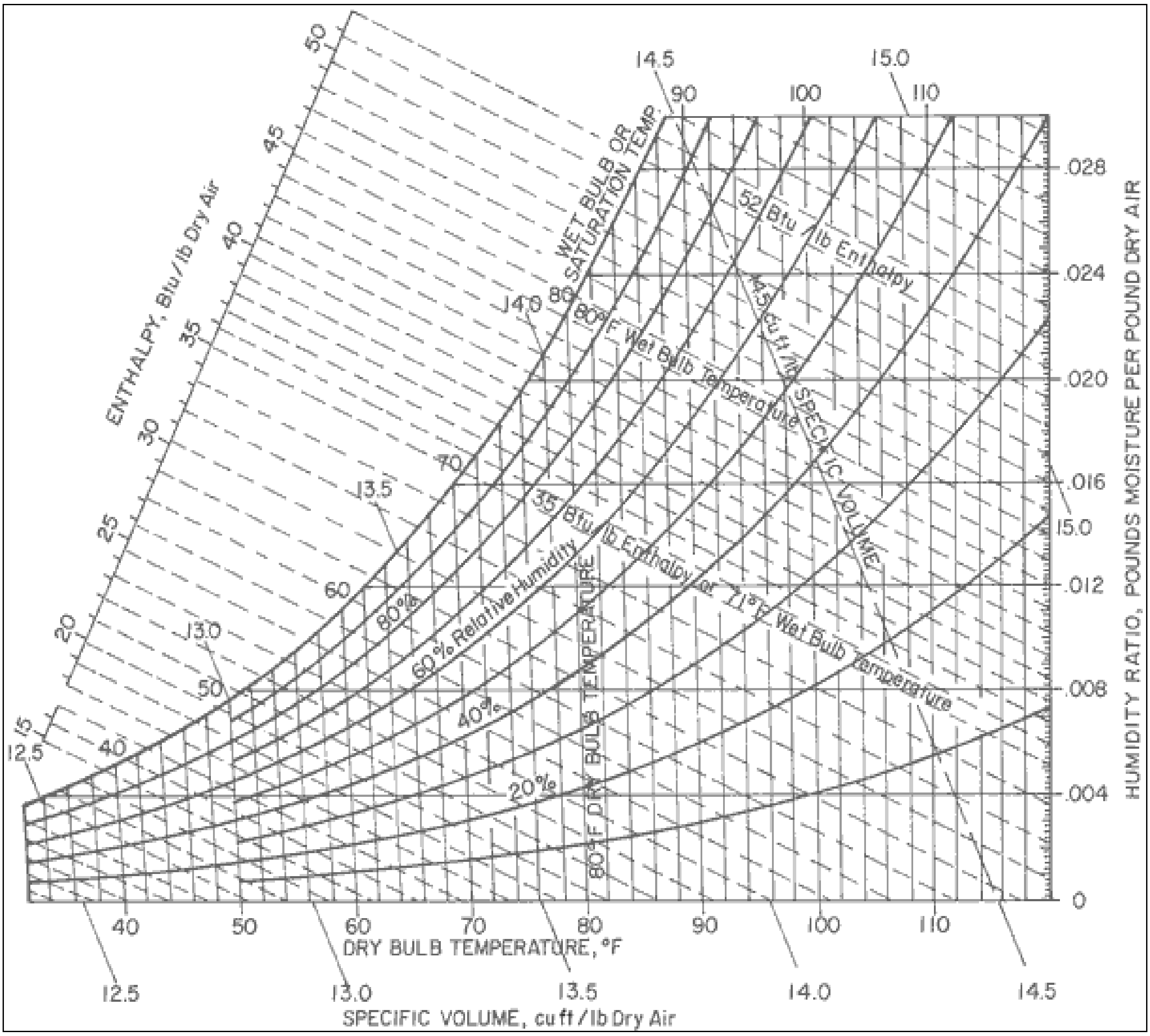

Figure: Psychometric Chart

Appendix B

```
Dim Q_Final
Dim Qr, Qr1

Dim QrN, QrS, QrE, QrW

Dim A_N, A_S, A_E, A_W
Dim SHGF_N, SHGF_S, SHGF_E, SHGF_W
Dim CLF_N, CLF_S, CLF_E, CLF_W
Dim SC_N, SC_S, SC_E, SC_W

Dim Q_roof, Q_floor, Q_sw, Q_nw, Q_ew, Q_ww, Q_gw, Q_lw, Q_d, Q_c
Dim a, a1, a2, b, b1, b2, c, c1, c2, d, d1, d2, e, e1, e2, f, f1, f2, g, g1, g2, h, h1, h2, i, i1, i2, j, j1, j2
Dim Q_s, Q_l, Q_sl, Q_Light, Q_Othqs, Q_Othql, Q_Oth, Q_Internal_Heat
Dim fa, Q_ss, Q_ll, Q_vsl
Dim LV As Integer

Private Sub cbmCountry_Click()
If (cbmCountry.Text = "Bangladesh") Then
cmbLatitude.Text = "24"
End If

If (cbmCountry.Text = "Japan (Tokyo)") Then
cmbLatitude.Text = "36"
End If

If (cbmCountry.Text = "Saudia Arabia (Riyadh)") Then
cmbLatitude.Text = "25"
End If

If (cbmCountry.Text = "California") Then
cmbLatitude.Text = "35"
End If

If (cbmCountry.Text = "Washington") Then
cmbLatitude.Text = "48"
End If

If (cbmCountry.Text = "U.K (Brmingham)") Then
cmbLatitude.Text = "52"
End If

If (cbmCountry.Text = "China (Beijing)") Then
cmbLatitude.Text = "40"
End If

Combo1_Click

End Sub

Private Sub cmaQsla_Click()
Dim X, Y, z As String
X = "Ql = "
z = " watt"
Q_ll = 3012 * fa * (Val(TextWo.Text) - Val(TextWi.Text))
txtR.Text = Q_ll
Y = txtR.Text
lblQll.Caption = X & Y & z
End Sub

Private Sub cmbSide1_Click()
cmdSHGF_Click
Call cmdQr1_Click
```

```
Call cmdTotal1_Click
End Sub

Private Sub cmbUnit1_Click()
Dim r As String
Dim u As String
Dim result As String

Qr = QrN + QrS + QrE + QrW
u = " Watt"

If cmbUnit1.Text = "Select unit" Then
cmbUnit1.Text = "Watt"
End If

If cmbUnit1.Text = "" Then
cmbUnit1.Text = "Watt"
End If

If cmbUnit1.Text = "KW" Then
Qr = Qr / 1000
u = " KW"
End If

If cmbUnit1.Text = "TR" Then
Qr = Qr / (1000 * 3.517)
u = " TR"
End If

If cmbUnit1.Text = "Btu/h" Then
Qr = (Qr / (1000 * 3.517)) * 12000
u = " Btu/h"
End If

txtResult1.Text = Qr
r = txtResult1.Text

result = r & u
lblQr.Caption = result
End Sub

Private Sub cmbUnit2_Click()
Dim r As String
Dim r1 As String
Dim u As String
Dim result As String

r1 = "Qt = "

Qr1 = Q_roof + Q_floor + Q_sw + Q_nw + Q_ew + Q_ww + Q_gw + Q_lw + Q_c + Q_d
u = " Watt"

If cmbUnit2.Text = "Select unit" Then
cmbUnit2.Text = "Watt"
End If

If cmbUnit2.Text = "" Then
cmbUnit2.Text = "Watt"
End If

If cmbUnit2.Text = "KW" Then
Qr1 = Qr1 / 1000
u = " KW"
End If
```

```
If cmbUnit2.Text = "TR" Then
Qr1 = Qr1 / (1000 * 3.517)
u = " TR"
End If

If cmbUnit2.Text = "Btu/h" Then
Qr1 = (Qr1 / (1000 * 3.517)) * 12000
u = " Btu/h"
End If

txtResult2.Text = Qr1
r = txtResult2.Text

result = r1 & r & u
lblQr2.Caption = result
End Sub

Private Sub cmbUnit3_Click()
Dim r As String
Dim r1 As String
Dim u As String
Dim result As String
Dim Q_Li

Q_sl = Q_s + Q_l
Q_Oth = Q_Othqs + Q_Othql
Q_Li = Q_Light

u = " Watt"

If cmbUnit3.Text = "Select unit" Then
cmbUnit3.Text = "Watt"
End If

If cmbUnit3.Text = "" Then
cmbUnit3.Text = "Watt"
End If

If Combo3.Text = "For people" Then
  r1 = "For people total, Qt = "
  If cmbUnit3.Text = "KW" Then
    Q_sl = Q_sl / 1000
    u = " KW"
  End If

  If cmbUnit3.Text = "TR" Then
    Q_sl = Q_sl / (1000 * 3.517)
    u = " TR"
  End If

  If cmbUnit3.Text = "Btu/h" Then
    Q_sl = (Q_sl / (1000 * 3.517)) * 12000
    u = " Btu/h"
  End If

  txtQsQl.Text = Q_sl
  r = txtQsQl.Text

  result = r1 & r & u
  lblQ3.Caption = result
End If

If Combo3.Text = "For light" Then
r1 = "For light total, Ql = "
```

```
    If cmbUnit3.Text = "KW" Then
        Q_Li = Q_Light / 1000
        u = " KW"
    End If

    If cmbUnit3.Text = "TR" Then
        Q_Li = Q_Light / (1000 * 3.517)
        u = " TR"
    End If

    If cmbUnit3.Text = "Btu/h" Then
        Q_Li = (Q_Light / (1000 * 3.517)) * 12000
        u = " Btu/h"
    End If

    txtQsQl.Text = Q_Li
    r = txtQsQl.Text

    result = r1 & r & u
    lblQ3.Caption = result
End If

If Combo3.Text = "Other equipment" Then
    r1 = "Other equipment total, Qt = "
    If cmbUnit3.Text = "KW" Then
        Q_Oth = Q_Oth / 1000
        u = " KW"
    End If

    If cmbUnit3.Text = "TR" Then
        Q_Oth = Q_Oth / (1000 * 3.517)
        u = " TR"
    End If

    If cmbUnit3.Text = "Btu/h" Then
        Q_Oth = (Q_Oth / (1000 * 3.517)) * 12000
        u = " Btu/h"
    End If

    txtQsQl.Text = Q_Oth
    r = txtQsQl.Text

    result = r1 & r & u
    lblQ3.Caption = result
End If

End Sub

Private Sub cmbUnit4_Click()
Dim r As String
Dim r1 As String
Dim u As String
Dim result As String
Dim Q_Li

Q_sl = Q_s + Q_l
Q_Oth = Q_Othqs + Q_Othql
Q_Li = Q_Light

Q_Internal_Heat = Q_sl + Q_Oth + Q_Li
u = " Watt"

If cmbUnit4.Text = "Select unit" Then
cmbUnit4.Text = "Watt"
```

```
End If

If cmbUnit4.Text = "" Then
cmbUnit4.Text = "Watt"
End If

    r1 = "Total, Qt = "
    If cmbUnit4.Text = "KW" Then
        Q_Internal_Heat = Q_Internal_Heat / 1000
        u = " KW"
    End If

    If cmbUnit4.Text = "TR" Then
        Q_Internal_Heat = Q_Internal_Heat / (1000 * 3.517)
        u = " TR"
    End If

    If cmbUnit4.Text = "Btu/h" Then
     Q_Internal_Heat = (Q_Internal_Heat / (1000 * 3.517)) * 12000
        u = " Btu/h"
    End If

    txtQsQl.Text = Q_Internal_Heat
    r = txtQsQl.Text

    result = r1 & r & u
    lblQ4.Caption = result
End Sub

Private Sub cmbUnit5_Click()
Dim r As String
Dim r1 As String
Dim u As String
Dim result As String

Q_vsl = Q_ss + Q_ll

u = " Watt"

If cmbUnit5.Text = "Select unit" Then
cmbUnit5.Text = "Watt"
End If

If cmbUnit5.Text = "" Then
cmbUnit5.Text = "Watt"
End If

    r1 = "Total, Q = Qs+Ql = "
    If cmbUnit5.Text = "KW" Then
        Q_vsl = Q_vsl / 1000
        u = " KW"
    End If

    If cmbUnit5.Text = "TR" Then
        Q_vsl = Q_vsl / (1000 * 3.517)
        u = " TR"
    End If

    If cmbUnit5.Text = "Btu/h" Then
        Q_vsl = (Q_vsl / (1000 * 3.517)) * 12000
        u = " Btu/h"
    End If

    txtR = Q_vsl
```

```
    r = txtR

    result = r1 & r & u
    lblQ5.Caption = result

End Sub

Private Sub cmbUnit6_Click()
Dim r As String
Dim r1 As String
Dim u As String
Dim result As String

'r1 = "Total cooling load = "

Q_Final = QrN + QrS + QrE + QrW + Q_roof + Q_floor + Q_sw + Q_nw + Q_ew + Q_ww + Q_gw + Q_lw + Q_c + Q_d +
Q_s + Q_l + Q_Othqs + Q_Othql + Q_Light + Q_ss + Q_ll

u = " Watt"

If cmbUnit6.Text = "KW" Then
Q_Final = Q_Final / 1000
u = " KW"
End If

If cmbUnit6.Text = "TR" Then
Q_Final = Q_Final / (1000 * 3.517)
u = " TR"
End If

If cmbUnit6.Text = "Btu/h" Then
Q_Final = (Q_Final / (1000 * 3.517)) * 12000
u = " Btu/h"
End If

txtFinal.Text = Format(Q_Final, "########0.00")
r = Val(txtFinal.Text)

result = r & u
lblTotal.Caption = "" & Format(result, "########0.00")

cmbUnit7.ListIndex = cmbUnit6.ListIndex

End Sub

Private Sub cmbUnit7_Click()
Dim r As String
Dim r1 As String
Dim u As String
Dim result As String
Dim Q_refiga

'r1 = "Total cooling load = "

Q_Final = QrN + QrS + QrE + QrW + Q_roof + Q_floor + Q_sw + Q_nw + Q_ew + Q_ww + Q_gw + Q_lw + Q_c + Q_d +
Q_s + Q_l + Q_Othqs + Q_Othql + Q_Light + Q_ss + Q_ll

Q_refiga = Q_Final + Q_Final * 0.05 + Q_Final * 0.02

u = " Watt"
If cmbUnit7.Text = "KW" Then
Q_refiga = Q_refiga / 1000
u = " KW"
End If
```

```
If cmbUnit7.Text = "TR" Then
Q_refiga = Q_refiga / (1000 * 3.517)
u = " TR"
End If

If cmbUnit7.Text = "Btu/h" Then
Q_refiga = (Q_refiga / (1000 * 3.517)) * 12000
u = " Btu/h"
End If

txtFinal.Text = Format(Q_refiga, "########0.00")
r = Val(txtFinal.Text)

result = r & u
lblTotalRefri.Caption = Format(result, "########0.00")
End Sub

Private Sub cmbWall1_Click()
Dim Y, z As String
Y = cmbWall1.Text
z = " Wall Result"
cmdQr1.Caption = Y & z
End Sub

Private Sub cmbWindowFacing1_Click()
cmdCLF_Click
End Sub

Private Sub cmdClear1_Click()
cmbWall1.Text = ""
txtArea1.Text = ""
txtSHGF1.Text = ""
txtCLF1.Text = ""
lblTitalQr.Caption = ""
lblQr.Caption = ""
lblResultQr.Caption = ""
End Sub

Private Sub cmdClear3_Click()
Combo3.Text = ""
txtNP.Text = ""
txtCLF.Text = ""
Combo4.Text = ""
'txtHG.Text = ""
txtSHG.Text = ""
txtNP1.Text = ""
txCLF.Text = ""
Combo7.Text = ""
txtHG1.Text = ""
'txtSHG1.Text = ""
lblQs11.Caption = ""
lblQl2.Caption = ""
lblQ3.Caption = ""
lblQ4.Caption = ""
End Sub

Private Sub cmdClear4_Click()
txtNoPeople.Text = ""
TextTo.Text = ""
TextTi.Text = ""
lblQ5.Caption = ""
lblQss.Caption = ""
lblQll.Caption = ""
```

```
lblFa.Caption = ""
lblQll.Caption = ""
Q_ll = "0"
fa = "0"
End Sub

Private Sub cmdClearAll_Click()

prompt$ = "Ready to Delete, Are you sure?."
reply = MsgBox(prompt, vbInformation + vbOKCancel, "Delete?")

If reply = vbOK Then

QrN = 0
QrS = 0
QrE = 0
QrW = 0
Q_roof = 0
Q_floor = 0
Q_sw = 0
Q_nw = 0
Q_ew = 0
Q_ww = 0
Q_gw = 0
Q_lw = 0
Q_c = 0
Q_d = 0
Q_s = 0
Q_l = 0
Q_Othqs = 0
Q_Othql = 0
Q_Light = 0
Q_ss = 0
Q_ll = 0
Q_Final = 0
Q_refiga = 0

cmbUnit6.Text = ""
cmbUnit7.Text = ""
lblSouth.Caption = ""
lblEast.Caption = ""
lblWest.Caption = ""
lblNorth.Caption = ""

cmbWall1.Text = ""
txtArea1.Text = ""
txtSHGF1.Text = ""
txtCLF1.Text = ""
lblTitalQr.Caption = ""
lblQr.Caption = ""
lblResultQr.Caption = ""

LV = 1
End If

cmdClear1_Click
cmdClear2_Click
cmdClear3_Click
cmdClear4_Click

End Sub

Private Sub cmdCLF_Click()
Dim X
```

```
If cmbWindowFacing1.Text = "" Then X = 1
If cmbSolarTime1.Text = "" Then X = 0

If Not cmbWindowFacing1.Text = "" Then

   If Not cmbSolarTime1.Text = "" Then

      If cmbWindowFacing1.Text = "N" Then X = 13 + Val(cmbSolarTime1.Text)
      If cmbWindowFacing1.Text = "NE" Then X = 26 + Val(cmbSolarTime1.Text)
      If cmbWindowFacing1.Text = "E" Then X = 39 + Val(cmbSolarTime1.Text)
      If cmbWindowFacing1.Text = "SE" Then X = 52 + Val(cmbSolarTime1.Text)
      If cmbWindowFacing1.Text = "S" Then X = 65 + Val(cmbSolarTime1.Text)
      If cmbWindowFacing1.Text = "SW" Then X = 78 + Val(cmbSolarTime1.Text)
      If cmbWindowFacing1.Text = "W" Then X = 91 + Val(cmbSolarTime1.Text)
      If cmbWindowFacing1.Text = "NW" Then X = 104 + Val(cmbSolarTime1.Text)
      If cmbWindowFacing1.Text = "Hot" Then X = 117 + Val(cmbSolarTime1.Text)

End If
End If

'X=Val(cmbWindowFacing1.Text)+Val(cmbSolarTime1.Text)
'X = 13 (Here "13" notify that corresponding value of cmbWindowFacing1.Text )+ Val(cmbSolarTime1.Text)
'N=13 Because total number of row =13
'NE=26 Because total number of row =13 and column number=2
'E=39 Because total number of row =13 and column number=3
'Similarly Next value is =Total number of row * column number

Select Case X
      Case 0
         MsgBox "Please select Solar time."
      Case 1
         MsgBox "Please select Window facing."
      Case 19
         txtCLF1.Text = 0.73  'Start of N values
      Case 20
         txtCLF1.Text = 0.66
      Case 21
         txtCLF1.Text = 0.65
      Case 22
          txtCLF1.Text = 0.73
      Case 23
         txtCLF1.Text = 0.8
      Case 24
          txtCLF1.Text = 0.86
      Case 25
         txtCLF1.Text = 0.89
      Case 26
         txtCLF1.Text = 0.89
      Case 27
         txtCLF1.Text = 0.86
      Case 28
         txtCLF1.Text = 0.82
      Case 29
         txtCLF1.Text = 0.75
      Case 30
          txtCLF1.Text = 0.78
      Case 31
         txtCLF1.Text = 0.91     'End of N values


      Case 32
          txtCLF1.Text = 0.56       'Start of NE values
      Case 33
```

```
    txtCLF1.Text = 0.76
Case 34
    txtCLF1.Text = 0.74

Case 35
    txtCLF1.Text = 0.58
Case 36
    txtCLF1.Text = 0.37
Case 37
    txtCLF1.Text = 0.29
Case 38
     txtCLF1.Text = 0.27
Case 39
    txtCLF1.Text = 0.26
Case 40
     txtCLF1.Text = 0.24
Case 41
    txtCLF1.Text = 0.22
Case 42
    txtCLF1.Text = 0.2
Case 43
    txtCLF1.Text = 0.16
Case 44
    txtCLF1.Text = 0.12     'End of NE values

Case 45
     txtCLF1.Text = 0.47       'Start of E values
Case 46
    txtCLF1.Text = 0.72
Case 47
    txtCLF1.Text = 0.8

Case 48
    txtCLF1.Text = 0.76
Case 49
    txtCLF1.Text = 0.62
Case 50
    txtCLF1.Text = 0.41
Case 51
     txtCLF1.Text = 0.27
Case 52
    txtCLF1.Text = 0.24
Case 53
     txtCLF1.Text = 0.22
Case 54
    txtCLF1.Text = 0.2
Case 55
    txtCLF1.Text = 0.17
Case 56
    txtCLF1.Text = 0.14
Case 57
    txtCLF1.Text = 0.11     'End of E values

  Case 58
     txtCLF1.Text = 0.3        'Start of SE values
Case 59
    txtCLF1.Text = 0.57
Case 60
    txtCLF1.Text = 0.74
Case 61
    txtCLF1.Text = 0.81
Case 62
    txtCLF1.Text = 0.79
Case 63
```

```
    txtCLF1.Text = 0.68
 Case 64
     txtCLF1.Text = 0.49
 Case 65
    txtCLF1.Text = 0.33
 Case 66
     txtCLF1.Text = 0.28
 Case 67
    txtCLF1.Text = 0.25
 Case 68
    txtCLF1.Text = 0.22
 Case 69
    txtCLF1.Text = 0.18
 Case 70
    txtCLF1.Text = 0.13     'End of SE values

Case 71
     txtCLF1.Text = 0.09       'Start of S values
 Case 72
    txtCLF1.Text = 0.16
 Case 73
    txtCLF1.Text = 0.23
 Case 74
    txtCLF1.Text = 0.38
 Case 75
    txtCLF1.Text = 0.58
 Case 76
    txtCLF1.Text = 0.75
 Case 77
     txtCLF1.Text = 0.83
 Case 78
    txtCLF1.Text = 0.8
 Case 79
     txtCLF1.Text = 0.68
 Case 80
    txtCLF1.Text = 0.5
 Case 81
    txtCLF1.Text = 0.35
 Case 82
    txtCLF1.Text = 0.27
 Case 83
    txtCLF1.Text = 0.19     'End of S values

 Case 84
     txtCLF1.Text = 0.07       'Start of SW values
 Case 85
    txtCLF1.Text = 0.11
 Case 86
    txtCLF1.Text = 0.14
 Case 87
    txtCLF1.Text = 0.16
 Case 88
    txtCLF1.Text = 0.19
 Case 89
    txtCLF1.Text = 0.22
 Case 90
     txtCLF1.Text = 0.38
 Case 91
    txtCLF1.Text = 0.59
 Case 92
     txtCLF1.Text = 0.75
 Case 93
    txtCLF1.Text = 0.83
 Case 94
```

```
    txtCLF1.Text = 0.81
Case 95
    txtCLF1.Text = 0.69
Case 96
    txtCLF1.Text = 0.45     'End of SW values

    Case 97
     txtCLF1.Text = 0.06      'Start of W values
Case 98
    txtCLF1.Text = 0.09
Case 99
    txtCLF1.Text = 0.11
Case 100
    txtCLF1.Text = 0.13
Case 101
    txtCLF1.Text = 0.15
Case 102
    txtCLF1.Text = 0.16
Case 103
     txtCLF1.Text = 0.17
Case 104
    txtCLF1.Text = 0.31
Case 105
     txtCLF1.Text = 0.53
Case 106
    txtCLF1.Text = 0.72
Case 107
    txtCLF1.Text = 0.82
Case 108
    txtCLF1.Text = 0.81
Case 109
    txtCLF1.Text = 0.61     'End of W values

Case 110
     txtCLF1.Text = 0.07      'Start of NW values
Case 111
    txtCLF1.Text = 0.11
Case 112
    txtCLF1.Text = 0.14
Case 113
    txtCLF1.Text = 0.17
Case 114
    txtCLF1.Text = 0.19
Case 115
    txtCLF1.Text = 0.2
Case 116
     txtCLF1.Text = 0.21
Case 117
    txtCLF1.Text = 0.22
Case 118
     txtCLF1.Text = 0.3
Case 119
    txtCLF1.Text = 0.52
Case 120
    txtCLF1.Text = 0.73
Case 121
    txtCLF1.Text = 0.82
Case 122
    txtCLF1.Text = 0.69     'End of NW values

Case 123
     txtCLF1.Text = 0.12      'Start of Hot values
Case 124
    txtCLF1.Text = 0.27
```

```
        Case 125
            txtCLF1.Text = 0.44
        Case 126
            txtCLF1.Text = 0.59
        Case 127
            txtCLF1.Text = 0.72
        Case 128
            txtCLF1.Text = 0.81
        Case 129
             txtCLF1.Text = 0.85
        Case 130
            txtCLF1.Text = 0.85
        Case 131
             txtCLF1.Text = 0.81
        Case 132
            txtCLF1.Text = 0.71
        Case 133
            txtCLF1.Text = 0.58
        Case 134
            txtCLF1.Text = 0.42
        Case 135
            txtCLF1.Text = 0.25      'End of Hot values

         End Select

End Sub

Private Sub cmdDetailShow_Click()
FrmDetails.Visible = True
Command1.Visible = True
cmdDetailShow.Visible = False
End Sub

Private Sub cmdEdit_Click()
cmbWall1.Text = CWallDetails.Text
txtArea1.Text = LblA.Caption
txtCLF1.Text = LblCLF.Caption
txtSHGF1.Text = LblSHGF.Caption
txtSC1.Text = LblSC.Caption
lblTitalQr.Caption = ""
lblQr.Caption = ""
lblResultQr.Caption = ""
FrmDetails.Visible = False
End Sub

Private Sub cmdFa_Click()
Dim X, Y As String
X = "Fa = "
fa = Val(txtNoPeople.Text) * Val(txtFapp.Text)
txtR.Text = fa
Y = txtR.Text
lblFa.Caption = X & Y
End Sub

Private Sub cmdHide1_Click()

End Sub

Private Sub cmdFinalClose_Click()
FramFinal.Visible = False
cmdHideResult.Visible = False
Command2.Visible = True
End Sub
Private Sub FinalResult()
```

```
Dim r As String
Dim r1 As String
Dim u As String
Dim result As String
Dim Q_refiga
u = " Watt"

If cmbUnit6.Text = "" Then

'r1 = "Total cooling load = "

Q_Final = QrN + QrS + QrE + QrW + Q_roof + Q_floor + Q_sw + Q_nw + Q_ew + Q_ww + Q_gw + Q_lw + Q_c + Q_d +
Q_s + Q_l + Q_Othqs + Q_Othql + Q_Light + Q_ss + Q_ll

u = " Watt"

txtFinal.Text = Q_Final
r = txtFinal.Text

result = r & u
lblTotal.Caption = Format(result, "########0.00")

End If

If cmbUnit7.Text = "" Then
Q_refiga = Q_Final + Q_Final * 0.05 + Q_Final * 0.02

lblTotalRefri.Caption = Format(Q_refiga, "########0.00") & u
End If

'1
Qr = QrN + QrS + QrE + QrW
lblIns.Caption = Qr & u
'2
Qr1 = Q_roof + Q_floor + Q_sw + Q_nw + Q_ew + Q_ww + Q_gw + Q_lw + Q_c + Q_d
lblTrans.Caption = Qr1 & u
'3
Q_Internal_Heat = Q_s + Q_l + Q_Othqs + Q_Othql + Q_Light
lblIntra.Caption = Q_Internal_Heat & u
'4
Q_vsl = Q_ss + Q_ll
lblVan.Caption = Q_vsl & u
End Sub
Private Sub cmdHideResult_Click()
FramFinal.Visible = False
cmdHideResult.Visible = False
Command2.Visible = True
End Sub

Private Sub cmdLightResult_Click()
Dim X, Y, z, r As String

If Combo3.Text = "For light" Then
   X = "Ql = "
   Y = " watt"
   Q_Light = Val(txtNP.Text) * Val(txtCLF.Text)
   txtQsQl.Text = Q_Light
   z = Q_Light
   r = X & z & Y
   lblQs11.Caption = r
End If

If Combo3.Text = "Other equipment" Then
   X = "Qs = "
```

```
    Y = " watt"
    Q_Othqs = Val(txtNP.Text) * Val(txtCLF.Text)
    txtQsQl.Text = Q_Othqs
    z = Q_Othqs
    r = X & z & Y
    lblQs11.Caption = r
End If

End Sub

Private Sub cmdOther_Click()
Dim X, Y, z, r As String

If Combo3.Text = "Other equipment" Then
    X = "Ql = "
    Y = " watt"
    Q_Othql = Val(txtNP1.Text) * Val(txCLF.Text)
    txtQsQl.Text = Q_Othql
    z = Q_Othql
    r = X & z & Y
    lblQl2.Caption = r
End If

End Sub

Private Sub cmdQr1_Click()

Dim X, Y, z, T As String
Dim r As String
Dim u As String
Dim result As String

If LV = 1 Then
txtResult1.Text = 0
LV = 2
End If

X = "For "
Y = cmbWall1.Text
z = " Wall Qr is="
lblTitalQr.Caption = X & Y & z
T = lblTitalQr.Caption

If cmbWall1.Text = "North" Then
    A_N = Val(txtArea1.Text)
    SHGF_N = Val(txtSHGF1.Text)
    CLF_N = Val(txtCLF1.Text)
    SC_N = Val(txtSC1.Text)
    QrN = A_N * SHGF_N * CLF_N * SC_N
    txtResult1.Text = QrN
End If

If cmbWall1.Text = "South" Then
    A_S = Val(txtArea1.Text)
    SHGF_S = Val(txtSHGF1.Text)
    CLF_S = Val(txtCLF1.Text)
    SC_S = Val(txtSC1.Text)
    QrS = A_S * SHGF_S * CLF_S * SC_S
txtResult1.Text = QrS
End If

If cmbWall1.Text = "East" Then
    A_E = Val(txtArea1.Text)
    SHGF_E = Val(txtSHGF1.Text)
```

```
    CLF_E = Val(txtCLF1.Text)
    SC_E = Val(txtSC1.Text)
    QrE = A_E * SHGF_E * CLF_E * SC_E
txtResult1.Text = QrE
End If

If cmbWall1.Text = "West" Then
    A_W = Val(txtArea1.Text)
    SHGF_W = Val(txtSHGF1.Text)
    CLF_W = Val(txtCLF1.Text)
    SC_W = Val(txtSC1.Text)
    QrW = A_W * SHGF_W * CLF_W * SC_W
txtResult1.Text = QrW
End If

If cmbWall1.Text = "" Then
MsgBox "       Please select your wall."
cmbWall1.SetFocus
End If

r = txtResult1.Text
u = " Watt"
result = r & u
lblResultQr.Caption = result

' For Reasult Showing
If QrN > 0 And cmbWall1.Text = "North" Then
lblNorth.Caption = T & result
End If

If QrS > 0 And cmbWall1.Text = "South" Then
lblSouth.Caption = T & result
End If

If QrE > 0 And cmbWall1.Text = "East" Then
lblEast.Caption = T & result
End If

If QrW > 0 And cmbWall1.Text = "West" Then
lblWest.Caption = T & result
End If
End Sub

Private Sub cmdQsfa_Click()
Dim X, Y, z As String
X = "Qs = "
z = " watt"
Q_ss = 1.232 * fa * (Val(TextTo.Text) - Val(TextTi.Text))
txtR.Text = Q_ss
Y = txtR.Text
lblQss.Caption = X & Y & z

Call Command13_Click
End Sub

Private Sub cmdSHGF_Click()
Dim janN, febN, marN, aprN, mayN, junN, julN, augN, sepN, octN, novN, decN
Dim janEW, febEW, marEW, aprEW, mayEW, junEW, julEW, augEW, sepEW, octEW, novEW, decEW
Dim janS, febS, marS, aprS, mayS, junS, julS, augS, sepS, octS, novS, decS

If cmbLatitude.Text = "24" Then
'For North Side
janN = 85
febN = 95
```

```
marN = 107
aprN = 117
mayN = 136
junN = 174
julN = 142
augN = 120
sepN = 110
octN = 98
novN = 85
decN = 82

'For East or West Side
janEW = 599
febEW = 694
marEW = 738
aprEW = 719
mayEW = 688
junEW = 669
julEW = 672
augEW = 694
sepEW = 700
octEW = 666
novEW = 590
decEW = 568

'For South Side

janS = 716
febS = 606
marS = 432
aprS = 237
mayS = 145
junS = 136
julS = 145
augS = 227
sepS = 423
octS = 590
novS = 707
decS = 748

End If

If cmbLatitude.Text = "36" Then

'For North Side
janN = 69
febN = 82
marN = 95
aprN = 110
mayN = 120
junN = 148
julN = 123
augN = 114
sepN = 98
octN = 85
novN = 69
decN = 63

'For East or West Side
janEW = 524
febEW = 615
marEW = 704
aprEW = 710
mayEW = 694
```

```
junEW = 678
julEW = 681
augEW = 688
sepEW = 663
octEW = 590
novEW = 514
decEW = 476

'For South Side
janS = 795
febS = 732
marS = 606
aprS = 426
mayS = 293
junS = 243
julS = 284
augS = 413
sepS = 590
octS = 710
novS = 782
decS = 801

End If

If cmbLatitude.Text = "25" Then
'For North Side
janN = 83.5
febN = 94
marN = 106.3
aprN = 116.3
mayN = 133.5
junN = 170.8
julN = 138.8
augN = 120
sepN = 109.3
octN = 97.3
novN = 84.3
decN = 80.3

'For East or West Side
janEW = 593.5
febEW = 688.5
marEW = 735.8
aprEW = 719
mayEW = 688.8
junEW = 669.8
julEW = 673.5
augEW = 694
sepEW = 697.8
octEW = 660.5
novEW = 585.3
decEW = 561.8

'For South Side

janS = 724.8
febS = 617.8
marS = 447.8
aprS = 252
mayS = 154.5
junS = 140.8
julS = 153.8
augS = 242#
sepS = 438.8
```

```
octS = 601.8
novS = 715.5
decS = 755
End If

If cmbLatitude.Text = "52" Then
'For North Side
decS = 659
janN = 41
febN = 57
marN = 76
aprN = 95
mayN = 79
junN = 142
julN = 114
augN = 101
sepN = 79
octN = 60
novN = 41
decN = 32

'For East or West Side
janEW = 290
febEW = 492
marEW = 618
aprEW = 678
mayEW = 685
junEW = 675
julEW = 672
augEW = 656
sepEW = 574
octEW = 467
novEW = 284
decEW = 230

'For South Side

janS = 726
febS = 789
marS = 745
aprS = 628
mayS = 527
junS = 480
julS = 514
augS = 609
sepS = 716
octS = 757
novS = 710

End If

If cmbLatitude.Text = "48" Then
'For North Side
janN = 47
febN = 63
marN = 82
aprN = 98
mayN = 110
junN = 145
julN = 117
augN = 104
sepN = 85
octN = 66
novN = 47
```

```
decN = 41

'For East or West Side
janEW = 372
febEW = 530
marEW = 644
aprEW = 691
mayEW = 290
junEW = 678
julEW = 675
augEW = 666
sepEW = 290
octEW = 508
novEW = 363
decEW = 287

'For South Side

janS = 773
febS = 789
marS = 719
aprS = 587
mayS = 473
junS = 423
julS = 461
augS = 568
sepS = 694
octS = 764
novS = 757
decS = 735
End If

If cmbLatitude.Text = "35" Then
'For North Side
janN = 71
febN = 83
marN = 97
aprN = 111
mayN = 120
junN = 146
julN = 124
augN = 115
sepN = 100
octN = 86
novN = 71
decN = 65
'For East or West Side
janEW = 531
febEW = 623
marEW = 707
aprEW = 712
mayEW = 694
junEW = 677
julEW = 680
augEW = 689
sepEW = 667
octEW = 596
novEW = 522
decEW = 485

'For South Side

janS = 790
febS = 723
```

```
marS = 593
aprS = 410
mayS = 278
junS = 230
julS = 270
augS = 397
sepS = 578
octS = 702
novS = 778
decS = 800

End If

If cmbLatitude.Text = "40" Then
'For North Side
janN = 63
febN = 76
marN = 91
aprN = 107
mayN = 117
junN = 151
julN = 120
augN = 110
sepN = 95
octN = 79
novN = 63
decN = 57

'For East or West Side
janEW = 486
febEW = 587
marEW = 688
aprEW = 707
mayEW = 694
junEW = 681
julEW = 681
augEW = 681
sepEW = 640
octEW = 568
novEW = 476
decEW = 476

'For South Side

janS = 801
febS = 760
marS = 650
aprS = 486
mayS = 357
junS = 300
julS = 344
augS = 470
sepS = 631
octS = 738
novS = 789
decS = 798

End If

If Not (cmbLatitude.Text = "24" Or cmbLatitude.Text = "35" Or cmbLatitude.Text = "36" Or cmbLatitude.Text = "25" Or
cmbLatitude.Text = "52" Or cmbLatitude.Text = "48" Or cmbLatitude.Text = "40") Then
MsgBox "Please select Latitude."
End If
```

```
If Not cmbMonth1.Text = "" And Not cmbSide1.Text = "" Then
'For north Side
If cmbMonth1.Text = "January" And cmbSide1.Text = "North" Then txtSHGF1.Text = janN
If cmbMonth1.Text = "February" And cmbSide1.Text = "North" Then txtSHGF1.Text = febN
If cmbMonth1.Text = "March" And cmbSide1.Text = "North" Then txtSHGF1.Text = marN
If cmbMonth1.Text = "April" And cmbSide1.Text = "North" Then txtSHGF1.Text = aprN
If cmbMonth1.Text = "May" And cmbSide1.Text = "North" Then txtSHGF1.Text = mayN
If cmbMonth1.Text = "June" And cmbSide1.Text = "North" Then txtSHGF1.Text = junN
If cmbMonth1.Text = "July" And cmbSide1.Text = "North" Then txtSHGF1.Text = julN
If cmbMonth1.Text = "August" And cmbSide1.Text = "North" Then txtSHGF1.Text = augN
If cmbMonth1.Text = "September" And cmbSide1.Text = "North" Then txtSHGF1.Text = sepN
If cmbMonth1.Text = "October" And cmbSide1.Text = "North" Then txtSHGF1.Text = octN
If cmbMonth1.Text = "November" And cmbSide1.Text = "North" Then txtSHGF1.Text = novN
If cmbMonth1.Text = "December" And cmbSide1.Text = "North" Then txtSHGF1.Text = decN

'For south Side
If cmbMonth1.Text = "January" And cmbSide1.Text = "South" Then txtSHGF1.Text = janS
If cmbMonth1.Text = "February" And cmbSide1.Text = "South" Then txtSHGF1.Text = febS
If cmbMonth1.Text = "March" And cmbSide1.Text = "South" Then txtSHGF1.Text = marS
If cmbMonth1.Text = "April" And cmbSide1.Text = "South" Then txtSHGF1.Text = aprS
If cmbMonth1.Text = "May" And cmbSide1.Text = "South" Then txtSHGF1.Text = mayS
If cmbMonth1.Text = "June" And cmbSide1.Text = "South" Then txtSHGF1.Text = junS
If cmbMonth1.Text = "July" And cmbSide1.Text = "South" Then txtSHGF1.Text = julS
If cmbMonth1.Text = "August" And cmbSide1.Text = "South" Then txtSHGF1.Text = augS
If cmbMonth1.Text = "September" And cmbSide1.Text = "South" Then txtSHGF1.Text = sepS
If cmbMonth1.Text = "October" And cmbSide1.Text = "South" Then txtSHGF1.Text = octS
If cmbMonth1.Text = "November" And cmbSide1.Text = "South" Then txtSHGF1.Text = novS
If cmbMonth1.Text = "December" And cmbSide1.Text = "South" Then txtSHGF1.Text = decS

'For East or West Side
If cmbMonth1.Text = "January" And cmbSide1.Text = "East/West" Then txtSHGF1.Text = janEW
If cmbMonth1.Text = "February" And cmbSide1.Text = "East/West" Then txtSHGF1.Text = febEW
If cmbMonth1.Text = "March" And cmbSide1.Text = "East/West" Then txtSHGF1.Text = marEW
If cmbMonth1.Text = "April" And cmbSide1.Text = "East/West" Then txtSHGF1.Text = aprEW
If cmbMonth1.Text = "May" And cmbSide1.Text = "East/West" Then txtSHGF1.Text = mayEW
If cmbMonth1.Text = "June" And cmbSide1.Text = "East/West" Then txtSHGF1.Text = junEW
If cmbMonth1.Text = "July" And cmbSide1.Text = "East/West" Then txtSHGF1.Text = julEW
If cmbMonth1.Text = "August" And cmbSide1.Text = "East/West" Then txtSHGF1.Text = augEW
If cmbMonth1.Text = "September" And cmbSide1.Text = "East/West" Then txtSHGF1.Text = sepEW
If cmbMonth1.Text = "October" And cmbSide1.Text = "East/West" Then txtSHGF1.Text = octEW
If cmbMonth1.Text = "November" And cmbSide1.Text = "East/West" Then txtSHGF1.Text = novEW
If cmbMonth1.Text = "December" And cmbSide1.Text = "East/West" Then txtSHGF1.Text = decEW

Else
MsgBox "Month or Side can't be blank, please select proper Month and Side."
End If
End Sub

Private Sub cmdSideResult_Click()
Dim X, Y, z As String
X = "For "
Y = CWallDetails.Text
z = " Wall, Data and Result are below:"
lblTitalQrSide.Caption = X & Y & z

If CWallDetails.Text = "North" Then
   LblA.Caption = Val(A_N)
   LblSHGF.Caption = Val(SHGF_N)
   LblCLF.Caption = Val(CLF_N)
   LblSC.Caption = Val(SC_N)
   LblDetailQr.Caption = Val(QrN)
End If

If CWallDetails.Text = "South" Then
```

```
    LblA.Caption = Val(A_S)
    LblSHGF.Caption = Val(SHGF_S)
    LblCLF.Caption = Val(CLF_S)
    LblSC.Caption = Val(SC_S)
    LblDetailQr.Caption = Val(QrS)
End If

If CWallDetails.Text = "East" Then
    LblA.Caption = Val(A_E)
    LblSHGF.Caption = Val(SHGF_E)
    LblCLF.Caption = Val(CLF_E)
    LblSC.Caption = Val(SC_E)
    LblDetailQr.Caption = Val(QrE)
End If

If CWallDetails.Text = "West" Then
    LblA.Caption = Val(A_W)
    LblSHGF.Caption = Val(SHGF_W)
    LblCLF.Caption = Val(CLF_W)
    LblSC.Caption = Val(SC_W)
    LblDetailQr.Caption = Val(QrW)
End If

If CWallDetails.Text = "" Then
MsgBox "Please select your wall."
CWallDetails.SetFocus
End If

End Sub

Private Sub cmdTHGResult_Click()
Dim X, Y, z As String

Dim r As String
Dim u As String
'Dim result As String

If Combo1.Text = "Roof" Then
    a = (Val(txtCLTDb.Text) + Val(txtLm.Text)) + (25.5 - Val(txtti.Text)) + (Val(txtto.Text) - (Val(txtDR.Text) / 2) - 29.4)
    a1 = Val(txtA.Text)
    a2 = Val(txtU.Text)
    lblCLTDa.Caption = Val(a)
    txtResult2.Text = a * a1 * a2
    Q_roof = Val(txtResult2.Text)
    r = txtResult2.Text
    u = " watt"
End If

'If Combo1.Text = "Floor" Then
   ' b = (Val(txtCLTDb.Text) + Val(txtLm.Text)) + (25.5 - Val(txtti.Text)) + (Val(txtto.Text) - (Val(txtDR.Text) / 2) - 29.4)
    'b1 = Val(txtA.Text)
    'b2 = Val(txtU.Text)
    'lblCLTDa.Caption = Val(b)
    ''txtResult2.Text = b * b1 * b2
    'Q_floor = Val(txtResult2.Text)
    'r = txtResult2.Text
    'u = " watt"
'End If

If Combo1.Text = "East wall" Then
    c = (Val(txtCLTDb.Text) + Val(txtLm.Text)) + (25.5 - Val(txtti.Text)) + (Val(txtto.Text) - (Val(txtDR.Text) / 2) - 29.4)
    c1 = Val(txtA.Text)
    c2 = Val(txtU.Text)
    lblCLTDa.Caption = Val(c)
```

```
    txtResult2.Text = c * c1 * c2
    Q_ew = Val(txtResult2.Text)
    r = txtResult2.Text
    u = " watt"
End If

If Combo1.Text = "West wall" Then
    d = (Val(txtCLTDb.Text) + Val(txtLm.Text)) + (25.5 - Val(txtti.Text)) + (Val(txtto.Text) - (Val(txtDR.Text) / 2) - 29.4)
    d1 = Val(txtA.Text)
    d2 = Val(txtU.Text)
    lblCLTDa.Caption = Val(d)
    txtResult2.Text = d * d1 * d2
    Q_ww = Val(txtResult2.Text)
    r = txtResult2.Text
    u = " watt"
End If

If Combo1.Text = "North wall" Then
    e = (Val(txtCLTDb.Text) + Val(txtLm.Text)) + (25.5 - Val(txtti.Text)) + (Val(txtto.Text) - (Val(txtDR.Text) / 2) - 29.4)
    e1 = Val(txtA.Text)
    e2 = Val(txtU.Text)
    lblCLTDa.Caption = Val(e)
    txtResult2.Text = e * e1 * e2
    Q_nw = Val(txtResult2.Text)
    r = txtResult2.Text
    u = " watt"
End If

If Combo1.Text = "South wall" Then
    f = (Val(txtCLTDb.Text) + Val(txtLm.Text)) + (25.5 - Val(txtti.Text)) + (Val(txtto.Text) - (Val(txtDR.Text) / 2) - 29.4)
    f1 = Val(txtA.Text)
    f2 = Val(txtU.Text)
    lblCLTDa.Caption = Val(f)
    txtResult2.Text = f * f1 * f2
    Q_sw = Val(txtResult2.Text)
    r = txtResult2.Text
    u = " watt"
End If

If Combo1.Text = "Glass windows" Then
    g = (Val(txtCLTDb.Text) + Val(txtLm.Text)) + (25.5 - Val(txtti.Text)) + (Val(txtto.Text) - (Val(txtDR.Text) / 2) - 29.4)
    g1 = Val(txtA.Text)
    g2 = Val(txtU.Text)
    lblCLTDa.Caption = Val(g)
    txtResult2.Text = g * g1 * g2
    Q_gw = Val(txtResult2.Text)
    r = txtResult2.Text
    u = " watt"
End If

 If Combo1.Text = "Lobby wall" Then
    h = Val(txtto.Text) - Val(txtti.Text)
    h1 = Val(txtA.Text)
    h2 = Val(txtU.Text)
    lblCLTDa.Caption = Val(h)
    txtResult2.Text = h * h1 * h2
    Q_lw = Val(txtResult2.Text)
    r = txtResult2.Text
    u = " watt"
End If

 If Combo1.Text = "Floor" Then
    b = Val(txtto.Text) - Val(txtti.Text)
    b1 = Val(txtA.Text)
```

```
    b2 = Val(txtU.Text)
    lblCLTDa.Caption = Val(b)
    txtResult2.Text = b * b1 * b2
    Q_floor = Val(txtResult2.Text)
    r = txtResult2.Text
    u = " watt"
End If

 If Combo1.Text = "Door" Then
    i = Val(txtto.Text) - Val(txtti.Text)
    i1 = Val(txtA.Text)
    i2 = Val(txtU.Text)
    lblCLTDa.Caption = Val(i)
    txtResult2.Text = i * i1 * i2
    Q_d = Val(txtResult2.Text)
    r = txtResult2.Text
    u = " watt"
End If
 If Combo1.Text = "Ceiling" Then
    j = Val(txtto.Text) - Val(txtti.Text)
    j1 = Val(txtA.Text)
    j2 = Val(txtU.Text)
    lblCLTDa.Caption = Val(j)
    txtResult2.Text = j * j1 * j2
    Q_c = Val(txtResult2.Text)
    r = txtResult2.Text
    u = " watt"
End If

X = ""
Y = Combo1.Text
z = " Result(Q)="
lblTitalQ.Caption = X & Y & z & r & u

If Combo1.Text = "" Then
MsgBox "         Please select your side."
Combo1.SetFocus
End If

End Sub

Private Sub cmdTotal1_Click()
Dim r As String
Dim u As String
Dim result As String

If Len(cmbWall1.Text) <= 0 Then
    Exit Sub
End If
Qr = QrN + QrS + QrE + QrW
u = " Watt"

If cmbUnit1.Text = "Select unit" Then
cmbUnit1.Text = "Watt"
End If

If cmbUnit1.Text = "" Then
cmbUnit1.Text = "Watt"
End If

If cmbUnit1.Text = "KW" Then
Qr = Qr / 1000
u = " KW"
End If
```

```
If cmbUnit1.Text = "TR" Then
Qr = Qr / (1000 * 3.517)
u = " TR"
End If

If cmbUnit1.Text = "Btu/h" Then
Qr = (Qr / (1000 * 3.517)) * 12000
u = " Btu/h"
End If

txtResult1.Text = Qr
r = txtResult1.Text
result = r & u
lblQr.Caption = result
End Sub

Private Sub cmdTotal2_Click()
Dim r As String
Dim r1 As String
Dim u As String
Dim result As String

If Len(Combo1.Text) <= 0 Then
    Exit Sub
End If

r1 = "Qt = "

Qr1 = Q_roof + Q_floor + Q_sw + Q_nw + Q_ew + Q_ww + Q_gw + Q_lw + Q_c + Q_d
u = " Watt"

If cmbUnit2.Text = "Select unit" Then
cmbUnit2.Text = "Watt"
End If

If cmbUnit2.Text = "" Then
cmbUnit2.Text = "Watt"
End If

If cmbUnit2.Text = "KW" Then
Qr1 = Qr1 / 1000
u = " KW"
End If

If cmbUnit2.Text = "TR" Then
Qr1 = Qr1 / (1000 * 3.517)
u = " TR"
End If

If cmbUnit2.Text = "Btu/h" Then
Qr1 = (Qr1 / (1000 * 3.517)) * 12000
u = " Btu/h"
End If

txtResult2.Text = Qr1
r = txtResult2.Text

result = r1 & r & u
lblQr2.Caption = result
End Sub

Private Sub cmdTotal3_Click()
Dim r As String
```

```
Dim r1 As String
Dim u As String
Dim result As String
Dim Q_Li

Q_sl = Q_s + Q_l
Q_Oth = Q_Othqs + Q_Othql
Q_Li = Q_Light

Q_Internal_Heat = Q_sl + Q_Oth + Q_Li
u = " Watt"

If cmbUnit4.Text = "Select unit" Then
cmbUnit4.Text = "Watt"
End If

If cmbUnit4.Text = "" Then
cmbUnit4.Text = "Watt"
End If

   r1 = "Total, Qt = "
   If cmbUnit4.Text = "KW" Then
      Q_Internal_Heat = Q_Internal_Heat / 1000
      u = " KW"
   End If

   If cmbUnit4.Text = "TR" Then
      Q_Internal_Heat = Q_Internal_Heat / (1000 * 3.517)
      u = " TR"
   End If

   If cmbUnit4.Text = "Btu/h" Then
     Q_Internal_Heat = (Q_Internal_Heat / (1000 * 3.517)) * 12000
      u = " Btu/h"
   End If

   txtQsQl.Text = Q_Internal_Heat
   r = txtQsQl.Text

   result = r1 & r & u
   lblQ4.Caption = result

End Sub

Private Sub Combo1_Click()
On Error Resume Next

      lblCLTDa.Visible = True

      Label57.Visible = True
      Label58.Visible = True
      Label59.Visible = True

      Label18.Visible = True
      Label66.Visible = True
      Label67.Visible = True

      Label40.Visible = True
      Label56.Visible = True
      Label49.Visible = True

      Label16.Visible = True
      txtLm.Visible = True
      txtCLTDb.Visible = True
```

```
    txtDR.Visible = True

    lblCLTDa.Caption = ""

txtLm.Text = ""
txtCLTDb.Text = ""
txtDR.Text = ""
txtA.Text = ""
txtti.Text = ""
txtto.Text = ""

If cbmCountry = "Bangladesh" Then

If Combo1.Text = "Roof" Then
    txtLm.Text = "0.5"
    txtCLTDb.Text = "16"
    txtDR.Text = "11"
    Frame10.Caption = "(2) Transmission heat gain:"
End If

If Combo1.Text = "South wall" Then
    txtLm.Text = "3.3"
    txtCLTDb.Text = "11"
    txtDR.Text = "11"
    Frame10.Caption = "(2) Transmission heat gain:"
End If

If Combo1.Text = "North wall" Then
    txtLm.Text = "0.5"
    txtCLTDb.Text = "6"
    txtDR.Text = "11"
    Frame10.Caption = "(2) Transmission heat gain:"
End If

If Combo1.Text = "West wall" Then
    txtLm.Text = "0"
    txtCLTDb.Text = "9"
    txtDR.Text = "11"
    Frame10.Caption = "(2) Transmission heat gain:"
End If

If Combo1.Text = "East wall" Then
    txtLm.Text = "0"
    txtCLTDb.Text = "16"
    txtDR.Text = "11"
    Frame10.Caption = "(2) Transmission heat gain:"
End If

If Combo1.Text = "Glass windows" Then
    txtU.Text = "5.9"
    txtLm.Text = "0"
    txtCLTDb.Text = "8"
    txtDR.Text = "11"
    Frame10.Caption = "(2) Transmission heat gain:"
End If
End If
If Combo1.Text = "Lobby wall" Or Combo1.Text = "Floor" Or Combo1.Text = "Door" Or Combo1.Text = "Ceiling" Then
    Frame10.Caption = "(2) Conduction heat gain:"
End If

If cbmCountry = "Saudia Arabia (Riyadh)" Then

If Combo1.Text = "Roof" Then
    txtLm.Text = "0.5"
```

```
    txtCLTDb.Text = "16"
    txtDR.Text = "25"
End If

If Combo1.Text = "South wall" Then
    txtLm.Text = "3.3"
    txtCLTDb.Text = "11"
    txtDR.Text = "25"
End If

If Combo1.Text = "North wall" Then
    txtLm.Text = "0.5"
    txtCLTDb.Text = "6"
    txtDR.Text = "25"
End If

If Combo1.Text = "West wall" Then
    txtLm.Text = "0"
    txtCLTDb.Text = "9"
    txtDR.Text = "25"
End If

If Combo1.Text = "East wall" Then
    txtLm.Text = "0"
    txtCLTDb.Text = "16"
    txtDR.Text = "25"
End If

If Combo1.Text = "Glass windows" Then
    txtU.Text = "5.9"
    txtLm.Text = "0"
    txtCLTDb.Text = "8"
    txtDR.Text = "25"
End If

End If

If cbmCountry = "Japan (Tokyo)" Then

If Combo1.Text = "Roof" Then
    txtLm.Text = "0.5"
    txtCLTDb.Text = "16"
    txtDR.Text = "11"
End If

If Combo1.Text = "South wall" Then
    txtLm.Text = "3.3"
    txtCLTDb.Text = "11"
    txtDR.Text = "11"
End If

If Combo1.Text = "North wall" Then
    txtLm.Text = "0.5"
    txtCLTDb.Text = "6"
    txtDR.Text = "11"
End If

If Combo1.Text = "West wall" Then
    txtLm.Text = "0"
    txtCLTDb.Text = "9"
    txtDR.Text = "11"
End If

If Combo1.Text = "East wall" Then
```

```
    txtLm.Text = "0"
    txtCLTDb.Text = "16"
    txtDR.Text = "11"
End If

If Combo1.Text = "Glass windows" Then
    txtU.Text = "5.9"
    txtLm.Text = "0"
    txtCLTDb.Text = "8"
    txtDR.Text = "11"
End If

End If

If cbmCountry = "California" Then

If Combo1.Text = "Roof" Then
    txtLm.Text = "0.5"
    txtCLTDb.Text = "16"
    txtDR.Text = "27"
End If

If Combo1.Text = "South wall" Then
    txtLm.Text = "3.3"
    txtCLTDb.Text = "11"
    txtDR.Text = "27"
End If

If Combo1.Text = "North wall" Then
    txtLm.Text = "0.5"
    txtCLTDb.Text = "6"
    txtDR.Text = "27"
End If

If Combo1.Text = "West wall" Then
    txtLm.Text = "0"
    txtCLTDb.Text = "9"
    txtDR.Text = "27"
End If

If Combo1.Text = "East wall" Then
    txtLm.Text = "0"
    txtCLTDb.Text = "16"
    txtDR.Text = "27"
End If

If Combo1.Text = "Glass windows" Then
    txtU.Text = "5.9"
    txtLm.Text = "0"
    txtCLTDb.Text = "8"
    txtDR.Text = "27"
End If

End If

If cbmCountry = "Washington" Then

If Combo1.Text = "Roof" Then
    txtLm.Text = "0.5"
    txtCLTDb.Text = "16"
    txtDR.Text = "26"
End If

If Combo1.Text = "South wall" Then
```

```
    txtLm.Text = "3.3"
    txtCLTDb.Text = "11"
    txtDR.Text = "26"
End If

If Combo1.Text = "North wall" Then
    txtLm.Text = "0.5"
    txtCLTDb.Text = "6"
    txtDR.Text = "26"
End If

If Combo1.Text = "West wall" Then
    txtLm.Text = "0"
    txtCLTDb.Text = "9"
    txtDR.Text = "26"
End If

If Combo1.Text = "East wall" Then
    txtLm.Text = "0"
    txtCLTDb.Text = "16"
    txtDR.Text = "26"
End If

If Combo1.Text = "Glass windows" Then
    txtU.Text = "5.9"
    txtLm.Text = "0"
    txtCLTDb.Text = "8"
    txtDR.Text = "26"
End If

End If

If cbmCountry = "China (Beijing)" Then

If Combo1.Text = "Roof" Then
    txtLm.Text = "0.5"
    txtCLTDb.Text = "16"
    txtDR.Text = "16"
End If

If Combo1.Text = "South wall" Then
    txtLm.Text = "3.3"
    txtCLTDb.Text = "11"
    txtDR.Text = "16"
End If

If Combo1.Text = "North wall" Then
    txtLm.Text = "0.5"
    txtCLTDb.Text = "6"
    txtDR.Text = "16"
End If

If Combo1.Text = "West wall" Then
    txtLm.Text = "0"
    txtCLTDb.Text = "9"
    txtDR.Text = "16"
End If

If Combo1.Text = "East wall" Then
    txtLm.Text = "0"
    txtCLTDb.Text = "16"
    txtDR.Text = "16"
End If
```

```
If Combo1.Text = "Glass windows" Then
    txtU.Text = "5.9"
    txtLm.Text = "0"
    txtCLTDb.Text = "8"
    txtDR.Text = "16"
End If

End If
If cbmCountry = "U.K (Brmingham)" Then

If Combo1.Text = "Roof" Then
    txtLm.Text = "0.5"
    txtCLTDb.Text = "16"
    txtDR.Text = "17"
End If

If Combo1.Text = "South wall" Then
    txtLm.Text = "3.3"
    txtCLTDb.Text = "11"
    txtDR.Text = "17"
End If

If Combo1.Text = "North wall" Then
    txtLm.Text = "0.5"
    txtCLTDb.Text = "6"
    txtDR.Text = "17"
End If

If Combo1.Text = "West wall" Then
    txtLm.Text = "0"
    txtCLTDb.Text = "9"
    txtDR.Text = "17"
End If

If Combo1.Text = "East wall" Then
    txtLm.Text = "0"
    txtCLTDb.Text = "16"
    txtDR.Text = "17"
End If
If Combo1.Text = "Glass windows" Then
    txtU.Text = "5.9"
    txtLm.Text = "0"
    txtCLTDb.Text = "8"
    txtDR.Text = "17"
End If

End If
If Not Combo1.Text = "" Then
    If Combo1.Text = "Roof" Then
        txtU.Text = "0.73"
    ElseIf Combo1.Text = "South wall" Then
        txtU.Text = "1.67"
    ElseIf Combo1.Text = "North wall" Then
        txtU.Text = "1.67"
    ElseIf Combo1.Text = "West wall" Then
        txtU.Text = "1.67"
    ElseIf Combo1.Text = "East wall" Then
        txtU.Text = "1.67"
    ElseIf Combo1.Text = "Glass windows" Then
        txtU.Text = "2.80"
    ElseIf Combo1.Text = "Door" Then
        txtU.Text = "2.30"
    ElseIf Combo1.Text = "Floor" Then
        txtU.Text = "0.335"
```

```
    ElseIf Combo1.Text = "Ceiling" Then
        txtU.Text = "0.18"
    ElseIf Combo1.Text = "Lobby wall" Then
        txtU.Text = "2.30"
    End If
End If

    If Combo1.Text = "Door" Then
'        txtU.Text = 2.51

        lblCLTDa.Visible = False
        Image8.Visible = False
        Image4.Visible = False
        Image7.Visible = False

        Label57.Visible = False
        Label58.Visible = False
        Label59.Visible = False

        Label18.Visible = False
        Label66.Visible = False
        Label67.Visible = False

        Label16.Visible = False
        txtCLTDb.Visible = False
        txtLm.Visible = False
        txtDR.Visible = False

        Label40.Visible = False
        Label56.Visible = False
        Label49.Visible = False
       Image6.Top = 3720
        Image6.Left = 1920
        'txtto.Top = 3720
        'txtto.Left = 2520

        Image5.Top = 4200
        Image5.Left = 1920
        'txtti.Top = 4200
        'txtti.Left = 2520

    End If

    If Combo1.Text = "Floor" Then

'        txtU.Text = 2.89
        lblCLTDa.Visible = False
        Image8.Visible = False
        Image4.Visible = False
        Image7.Visible = False
        Label16.Visible = False
        txtCLTDb.Visible = False
        txtLm.Visible = False
        txtDR.Visible = False

        Label57.Visible = False
        Label58.Visible = False
        Label59.Visible = False

        Label18.Visible = False
        Label66.Visible = False
        Label67.Visible = False

        Label40.Visible = False
```

```
    Label56.Visible = False
    Label49.Visible = False

    Image6.Top = 3720
    Image6.Left = 1920
    'txtto.Top = 3720
    'txtto.Left = 2520

    Image5.Top = 4200
    Image5.Left = 1920
    'txtti.Top = 4200
    'txtti.Left = 2520
  End If

  If Combo1.Text = "Lobby wall" Then

    lblCLTDa.Visible = False
    Image8.Visible = False
    Image4.Visible = False
    Image7.Visible = False
    Label16.Visible = False
    txtCLTDb.Visible = False
    txtLm.Visible = False
    txtDR.Visible = False

    Label57.Visible = False
    Label58.Visible = False
    Label59.Visible = False

    Label18.Visible = False
    Label66.Visible = False
    Label67.Visible = False

    Label40.Visible = False
    Label56.Visible = False
    Label49.Visible = False

    Image6.Top = 3720
    Image6.Left = 1920
    'txtto.Top = 3720
    'txtto.Left = 2520

    Image5.Top = 4200
    Image5.Left = 1920
    'txtti.Top = 4200
    'txtti.Left = 2520
  End If

  If Combo1.Text = "Ceiling" Then
'       txtU.Text = 2.89
    lblCLTDa.Visible = False
    Image8.Visible = False
    Image4.Visible = False
    Image7.Visible = False
    Label16.Visible = False
    txtCLTDb.Visible = False
    txtLm.Visible = False
    txtDR.Visible = False

    Label57.Visible = False
    Label58.Visible = False
    Label59.Visible = False

    Label18.Visible = False
```

```
        Label66.Visible = False
        Label67.Visible = False

        Label40.Visible = False
        Label56.Visible = False
        Label49.Visible = False

        'Image6.Top = 3720
        'Image6.Left = 1920
        'txtto.Top = 3720
        'txtto.Left = 2520

        Image5.Top = 4200
        Image5.Left = 1920
        'txtti.Top = 4200
   'txtti.Left = 2520
    End If

Dim Y, z As String
Y = Combo1.Text
z = " Result"
cmdTHGResult.Caption = Y & z

End Sub

Private Sub Combo1_KeyDown(KeyCode As Integer, Shift As Integer)
If KeyCode = vbKeyDelete Then
    KeyCode = 0
End If
End Sub

Private Sub Combo1_KeyPress(KeyAscii As Integer)
    KeyAscii = 0
End Sub

Private Sub Combo2_LostFocus()
Label31.Caption = " CLTDa ="
If Combo2.Text = "Lobby wall" Or Combo2.Text = "Floor" Or Combo2.Text = "Door" Or Combo2.Text = "Ceiling" Then
Label31.Caption = "    to - ti ="
End Sub

Private Sub Combo3_Click()
Frame4.Caption = "Qs"
Frame5.Visible = True
'Frame4.Left = 1680
Combo4.Visible = True
Label34.Visible = True
'Label27.Visible = True
Label28.Visible = True
'txtHG.Visible = True
txtSHG.Visible = True
txCLF.Visible = True
Lebel.Visible = True

Combo7.Visible = True
txtHG1.Visible = True
'txtSHG1.Visible = True
Label38.Visible = True
'Label39.Visible = True
Label42.Visible = True
Combo4.Text = ""
'Frame4.Left = 600

If Combo3.Text = "For light" Or Combo3.Text = "Other equipment" Then
```

```
cmdLightResult.Visible = True
cmdOther.Visible = True
Else
cmdLightResult.Visible = False
cmdOther.Visible = False
End If

If Combo3.Text = "For people" Then
txtCLF.Text = "1"
Label26.Caption = "      No. of people:"
Label37.Caption = "           No. of people:"
txCLF.Visible = False
Lebel.Visible = False
End If

If Combo3.Text = "Other equipment" Then
Combo7.Visible = False
txtHG1.Visible = False
'txtSHG1.Visible = False
Label38.Visible = False
'Label39.Visible = False
Label42.Visible = False
Combo4.Visible = False
Label34.Visible = False
'Label27.Visible = False
Label28.Visible = False
'txtHG.Visible = False
txtSHG.Visible = False
Frame5.Visible = False
txtCLF.Text = "1"
txCLF.Text = "1"
Label26.Caption = "Heat gain eqip.(Watt):"
Label37.Caption = "Latent heat gain eqip.(Watt):"
End If

If Combo3.Text = "For light" Then
txtCLF.Text = "0.82"
Label26.Caption = "    Light in watt:"
Frame4.Caption = "Ql"
Frame5.Visible = False
'Frame4.Left = 3500
Combo4.Visible = False
Label34.Visible = False
'Label27.Visible = False
Label28.Visible = False
'txtHG.Visible = False
txtSHG.Visible = False
End If

End Sub
Private Sub Combo4_Click()
Dim X, Y, z, r As String
If Combo4.Text = "Office, Hotel, Appartments" Then
   txtSHG.Text = "75"
End If
If Combo4.Text = "Dept. Store, Retail Shop" Then
   txtSHG.Text = "75"
End If

If Combo4.Text = "Light Work, Factory" Then
txtSHG.Text = "80"
End If

If Combo4.Text = "Heavy Work, Factory" Then
```

```
    txtSHG.Text = "170"
End If

If Combo4.Text = "Gymnasium" Then
    txtSHG.Text = "210"
End If

If Combo3.Text = "For people" Then

    X = "Qs = "
    Y = " watt"
    Q_s = Val(txtNP.Text) * Val(txtSHG.Text) * Val(txtCLF.Text)
    txtQsQl.Text = Q_s
    z = Q_s
    r = X & z & Y
    lblQs11.Caption = r
End If

End Sub
Private Sub Combo5_Change()
Dim r As String
Dim r1 As String
Dim u As String
Dim result As String
r1 = "Qt = "

Q_Final = QrN + QrS + QrE + QrW + Q_roof + Q_floor + Q_sw + Q_nw + Q_ew + Q_ww + Q_gw + Q_lw + Q_c + Q_d +
Q_s + Q_l + Q_Othqs + Q_Othql + Q_Light + Q_ss + Q_ll

u = " Watt"

If cmbUnit2.Text = "Select unit" Then
cmbUnit2.Text = "Watt"
End If
If cmbUnit2.Text = "" Then
cmbUnit2.Text = "Watt"
End If

If cmbUnit2.Text = "KW" Then
Qr1 = Qr1 / 1000
u = " KW"
End If

If cmbUnit2.Text = "TR" Then
Qr1 = Qr1 / (1000 * 3.517)
u = " TR"
End If
If cmbUnit2.Text = "Btu/h" Then
Qr1 = (Qr1 / (1000 * 3.517)) * 12000
u = " Btu/h"
End If

txtResult2.Text = Qr1
r = txtResult2.Text
result = r1 & r & u
lblQr2.Caption = result
End Sub

Private Sub Combo4_KeyDown(KeyCode As Integer, Shift As Integer)
If KeyCode = vbKeyDelete Then
    KeyCode = 0
End If
End Sub
```

```
Private Sub Combo4_KeyPress(KeyAscii As Integer)
    KeyAscii = 0
End Sub

Private Sub Combo4_LostFocus()
Combo7.Text = Combo4.Text
Combo7_Click
End Sub

Private Sub Combo7_Click()
Dim X, Y, z, r As String
If Combo7.Text = "Office, Hotel, Appartments" Then
txtHG1.Text = "55"
'txtSHG1.Text = 0.55
End If

If Combo7.Text = "Teaching" Then
txtHG1.Text = 175
'txtSHG1.Text = 0.5
End If

If Combo7.Text = "Dept. Store, Retail Shop" Then
txtHG1.Text = "55"
'txtSHG1.Text = 0.5
End If

If Combo7.Text = "Light Work, Factory" Then
txtHG1.Text = "140"
'txtSHG1.Text = 0.35
End If

If Combo7.Text = "Heavy Work, Factory" Then
txtHG1.Text = "255"
'txtSHG1.Text = 0.35
End If

If Combo7.Text = "Gymnasium" Then
'txtHG.Text = 400
txtHG1.Text = "315"
End If

If Combo3.Text = "For people" Then
    X = "Ql = "
    Y = " watt"
    Q_l = Val(txtNP1.Text) * Val(txtHG1.Text)
    txtQsQl.Text = Q_l
    z = Q_l
    r = X & z & Y
    lblQl2.Caption = r
End If

End Sub

Private Sub cmdClear2_Click()
Combo1.Text = ""
txtA.Text = ""
txtU.Text = ""
txtCLTDb.Text = ""
txtLm.Text = ""
txtti.Text = ""
txtto.Text = ""
txtDR.Text = ""
lblTitalQ.Caption = ""
lblCLTDa.Caption = ""
```

```
lblQr2.Caption = ""
End Sub
Private Sub Combo7_KeyDown(KeyCode As Integer, Shift As Integer)
If KeyCode = vbKeyDelete Then
   KeyCode = 0
End If
End Sub

Private Sub Combo7_KeyPress(KeyAscii As Integer)
   KeyAscii = 0
End Sub

Private Sub Command1_Click()
FrmDetails.Visible = False
Command1.Visible = False
cmdDetailShow.Visible = True
End Sub
Private Sub Command11_Click()
Dim r As String
Dim r1 As String
Dim u As String
Dim result As String
Dim Q_Li

Q_sl = Q_s + Q_l
Q_Oth = Q_Othqs + Q_Othql
Q_Li = Q_Light

u = " Watt"

If cmbUnit3.Text = "Select unit" Then
cmbUnit3.Text = "Watt"
End If

If cmbUnit3.Text = "" Then
cmbUnit3.Text = "Watt"
End If
If Combo3.Text = "For people" Then
   r1 = "For people total, Qt = "
   If cmbUnit3.Text = "KW" Then
      Q_sl = Q_sl / 1000
      u = " KW"
   End If

   If cmbUnit3.Text = "TR" Then
      Q_sl = Q_sl / (1000 * 3.517)
      u = " TR"
   End If

   If cmbUnit3.Text = "Btu/h" Then
      Q_sl = (Q_sl / (1000 * 3.517)) * 12000
      u = " Btu/h"
   End If

   txtQsQl.Text = Q_sl
   r = txtQsQl.Text

   result = r1 & r & u
   lblQ3.Caption = result
End If

If Combo3.Text = "For light" Then
r1 = "For light total, Ql = "
   If cmbUnit3.Text = "KW" Then
```

```
        Q_Li = Q_Light / 1000
        u = " KW"
    End If

    If cmbUnit3.Text = "TR" Then
        Q_Li = Q_Light / (1000 * 3.517)
        u = " TR"
    End If

    If cmbUnit3.Text = "Btu/h" Then
        Q_Li = (Q_Light / (1000 * 3.517)) * 12000
        u = " Btu/h"
    End If

    txtQsQl.Text = Q_Li
    r = txtQsQl.Text

    result = r1 & r & u
    lblQ3.Caption = result
End If

If Combo3.Text = "Other equipment" Then
    r1 = "Other equipment total, Qt = "
    If cmbUnit3.Text = "KW" Then
        Q_Oth = Q_Oth / 1000
        u = " KW"
    End If

    If cmbUnit3.Text = "TR" Then
        Q_Oth = Q_Oth / (1000 * 3.517)
        u = " TR"
    End If

    If cmbUnit3.Text = "Btu/h" Then
        Q_Oth = (Q_Oth / (1000 * 3.517)) * 12000
        u = " Btu/h"
    End If

    txtQsQl.Text = Q_Oth
    r = txtQsQl.Text

    result = r1 & r & u
    lblQ3.Caption = result
End If
End Sub

Private Sub Command12_Click()
Dim r As String
Dim r1 As String
Dim u As String
Dim result As String
Dim Q_Li

If Len(txtNP.Text) <= 0 Then
    Exit Sub
End If
Q_sl = Q_s + Q_l
Q_Oth = Q_Othqs + Q_Othql
Q_Li = Q_Light

Q_Internal_Heat = Q_sl + Q_Oth + Q_Li
u = " Watt"

If cmbUnit4.Text = "Select unit" Then
```

```
cmbUnit4.Text = "Watt"
End If

If cmbUnit4.Text = "" Then
cmbUnit4.Text = "Watt"
End If

   r1 = "Total, Qt = "
   If cmbUnit4.Text = "KW" Then
      Q_Internal_Heat = Q_Internal_Heat / 1000
      u = " KW"
   End If
If cmbUnit4.Text = "TR" Then
      Q_Internal_Heat = Q_Internal_Heat / (1000 * 3.517)
      u = " TR"
   End If

   If cmbUnit4.Text = "Btu/h" Then
     Q_Internal_Heat = (Q_Internal_Heat / (1000 * 3.517)) * 12000
      u = " Btu/h"
   End If

   txtQsQl.Text = Q_Internal_Heat
   r = txtQsQl.Text

   result = r1 & r & u
   lblQ4.Caption = result
End Sub

Private Sub Command13_Click()
Dim r As String
Dim r1 As String
Dim u As String
Dim result As String

If Len(txtNoPeople.Text) <= 0 Then
   Exit Sub
End If
Q_vsl = Q_ss + Q_ll

u = " Watt"

If cmbUnit5.Text = "Select unit" Then
cmbUnit5.Text = "Watt"
End If

If cmbUnit5.Text = "" Then
cmbUnit5.Text = "Watt"
End If

   r1 = "Total, Q = Qs+Ql = "
   If cmbUnit5.Text = "KW" Then
      Q_vsl = Q_vsl / 1000
      u = " KW"
   End If

   If cmbUnit5.Text = "TR" Then
      Q_vsl = Q_vsl / (1000 * 3.517)
      u = " TR"
   End If

   If cmbUnit5.Text = "Btu/h" Then
      Q_vsl = (Q_vsl / (1000 * 3.517)) * 12000
      u = " Btu/h"
```

```
    End If

    txtR = Q_vsl
    r = txtR

    result = r1 & r & u
    lblQ5.Caption = result
End Sub

Private Sub Command14_Click()
Frame3.Visible = True
cmdHide.Visible = True
Command14.Visible = False
End Sub

Private Sub cmdHide_Click()
Frame3.Visible = False
cmdHide.Visible = False
Command14.Visible = True
End Sub
Private Sub Command2_Click()
FramFinal.Visible = True
FinalResult
cmdHideResult.Visible = True
Command2.Visible = False
cmbUnit6.ListIndex = 0
cmbUnit7.ListIndex = 0
End Sub

Private Sub Command4_Click()
Dim s As String

s = " watt"
If Combo2.Text = "Roof" Then
    lbCLTDa.Caption = a
    lblarea.Caption = a1
    lbU.Caption = a2
    lbRES.Caption = Q_roof & s
End If

If Combo2.Text = "East wall" Then
    lbCLTDa.Caption = c
    lblarea.Caption = c1
    lbU.Caption = c2
    lbRES.Caption = Q_ew & s
End If

If Combo2.Text = "West wall" Then
    lbCLTDa.Caption = d
    lblarea.Caption = d1
    lbU.Caption = d2
    lbRES.Caption = Q_ww & s
End If

If Combo2.Text = "North wall" Then
    lbCLTDa.Caption = e
    lblarea.Caption = e1
    lbU.Caption = e2
    lbRES.Caption = Q_nw & s
End If

If Combo2.Text = "South wall" Then
    lbCLTDa.Caption = f
    lblarea.Caption = f1
```

```
   lbU.Caption = f2
   lbRES.Caption = Q_sw & s
End If

If Combo2.Text = "Windows" Then
   lbCLTDa.Caption = g
   lblarea.Caption = g1
   lbU.Caption = g2
   lbRES.Caption = Q_gw & s
End If

If Combo2.Text = "Floor" Then
   lbCLTDa.Caption = b
   lblarea.Caption = b1
   lbU.Caption = b2
   lbRES.Caption = Q_floor & s
End If

If Combo2.Text = "Lobby wall" Then
   lbCLTDa.Caption = h
   lblarea.Caption = h1
   lbU.Caption = h2
   lbRES.Caption = Q_lw & s
End If

If Combo2.Text = "Door" Then
   lbCLTDa.Caption = i
   lblarea.Caption = i1
   lbU.Caption = i2
   lbRES.Caption = Q_d & s
End If

If Combo2.Text = "Ceiling" Then
   lbCLTDa.Caption = j
   lblarea.Caption = j1
   lbU.Caption = j2
   lbRES.Caption = Q_c & s
End If

End Sub
Private Sub Form_Load()
FrmDetails.Visible = False

End Sub

Private Sub Frame7_MouseMove(Button As Integer, Shift As Integer, X As Single, Y As Single)
Dim m, n, p As String
m = "Ql = "
p = " watt"
Q_ll = 3012 * fa * (Val(TextWo.Text) - Val(TextWi.Text))
txtR.Text = Q_ll
n = txtR.Text
lblQll.Caption = m & n & p
End Sub

Private Sub Label24_MouseMove(Button As Integer, Shift As Integer, X As Single, Y As Single)
If Combo3.Text = "For light" Or Combo3.Text = "Other equipment" Then
cmdLightResult.Visible = True
cmdOther.Visible = True
Else
cmdLightResult.Visible = False
cmdOther.Visible = False
End If
End Sub
```

```
Private Sub lblFinal_MouseMove(Button As Integer, Shift As Integer, X As Single, Y As Single)
Dim r As String
Dim r1 As String
Dim u As String
Dim result As String
Dim Q_refiga
u = " Watt"
If cmbUnit6.Text = "" Then

'r1 = "Total cooling load = "
Q_Final = QrN + QrS + QrE + QrW + Q_roof + Q_floor + Q_sw + Q_nw + Q_ew + Q_ww + Q_gw + Q_lw + Q_c + Q_d +
Q_s + Q_l + Q_Othqs + Q_Othql + Q_Light + Q_ss + Q_ll

u = " Watt"

txtFinal.Text = Q_Final
r = txtFinal.Text

result = r & u
lblTotal.Caption = result

End If
If cmbUnit7.Text = "" Then
Q_refiga = Q_Final + Q_Final * 0.05 + Q_Final * 0.02

lblTotalRefri.Caption = Q_refiga & u
End If

'1
Qr = QrN + QrS + QrE + QrW
lblIns.Caption = Qr & u
'2
Qr1 = Q_roof + Q_floor + Q_sw + Q_nw + Q_ew + Q_ww + Q_gw + Q_lw + Q_c + Q_d
lblTrans.Caption = Qr1 & u
'3
Q_Internal_Heat = Q_s + Q_l + Q_Othqs + Q_Othql + Q_Light
lblIntra.Caption = Q_Internal_Heat & u
'4
Q_vsl = Q_ss + Q_ll
lblVan.Caption = Q_vsl & u
End Sub

Private Sub txtCLF1_GotFocus()
cmdCLF.SetFocus
End Sub

Private Sub txtNoPeople_KeyPress(KeyAscii As Integer)

If KeyAscii = 13 Then

    Dim X, Y As String
    X = "Fa = "
    fa = Val(txtNoPeople.Text) * Val(txtFapp.Text)
    txtR.Text = fa
    Y = txtR.Text
    lblFa.Caption = X & Y
End If

End Sub
Private Sub txtNP_KeyPress(KeyAscii As Integer)
Dim X, Y, z, r As String
If KeyAscii = 13 Then
If Combo3.Text = "For light" Then
```

```
    X = "Ql = "
    Y = " watt"
    Q_Light = Val(txtNP.Text) * Val(txtCLF.Text)
    txtQsQl.Text = Q_Light
    z = Q_Light
    r = X & z & Y
    lblQs11.Caption = r
End If

If Combo3.Text = "Other equipment" Then
    X = "Qs = "
    Y = " watt"
    Q_Othqs = Val(txtNP.Text) * Val(txtCLF.Text)
    txtQsQl.Text = Q_Othqs
    z = Q_Othqs
    r = X & z & Y
    lblQs11.Caption = r
End If

End If

End Sub

Private Sub txtNP_LostFocus()
txtNP1.Text = txtNP.Text
End Sub

Private Sub txtNP1_KeyPress(KeyAscii As Integer)
Dim X, Y, z, r As String
If KeyAscii = 13 Then

If Combo3.Text = "Other equipment" Then
    X = "Ql = "
    Y = " watt"
    Q_Othql = Val(txtNP1.Text) * Val(txCLF.Text)
    txtQsQl.Text = Q_Othql
    z = Q_Othql
    r = X & z & Y
    lblQl2Caption = r
End If

End If
End Sub

Private Sub txtSHGF1_GotFocus()

    Cmd SHGF.SetFocus

End Sub
```