MODULE IV

4.1.0 Comprehend the principle of air conditioning and load estimation

- 4.1.1 Define air conditioning
- 4.1.2 Explain the factors affecting human comfort
- 4.1.3 Explain the concept of effective temperature
- 4.1.4 Explain the use of comfort chart in air conditioning

4.2.0 Classify air conditioning systems on the basis of major function, season of the year and equipment arrangement

- 4.2.1 Explain industrial air conditioning, comfort air conditioning
- 4.2.2 Explain the working of summer, winter and year round air conditioning with line sketches
- 4.2.3 Explain the construction and working of window type air conditioner
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- 4.2.6 Define the term HVAC.
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- 4.2.10 Explain sensible, latent and total heat load.
- 4.2.11 Compute total cooling load.

Content Details

Air Conditioning-Definition- factors affecting human comfort- effective temperature- comfort chart Air conditioning systems-Classification – industrial- comfort air conditioning- working of summer air conditioning- winter - year round air conditioning- construction- working of window type- package type central plant systems - HVAC.
Design and Load estimation of Air Conditioning systems Introduction – Heat source – External and Internal source - solar radiation through window –conduction of heat due to temperature difference- Heat addition by the occupants and equipments- Infiltration of air – ventilating estimation- Procedure of sensible heat load – latent heat load – total load –.Estimation of total cooling load.

AIR CONDITIONING SYSTEMS

Introduction

The air conditioning is that branch of engineering science which deals with the study of conditioning of air i.e., supplying and maintaining desirable internal atmosphere conditions for human comfort, irrespective of external conditions.

(*Air conditioning is a process which heats, cools, cleans and circulates air, as well as controlling the moisture content of air. Thus, air conditioning makes it possible to change the condition of air in an enclosed space*).

Definition

Air conditioning is defined as the simultaneous control of temperature, humidity, air circulation and cleanliness of air within an enclosed space.

- Control of temperature implies heating or cooling the air in winter or summer respectively.
- Control of humidity is increasing moisture content in the air in winter or decreasing the same in summer.
- Control of air circulation involves the distribution of conditioned air evenly and pleasantly throughout the space at all times.
- Control of cleanliness involves removal of dust, dirt, soot, and any foreign matter by filtering the air that enters the AC plant; ionize the conditioned air for elimination of unpleasant smell.

Applications of air conditioning,

- **Industrial**,

  Lot of industries which having constrains in temperature, Humidity is using Air Condition some of them are listed below

  Laboratories: This may involve precision measurement to performance testing of materials, equipment and processes at controlled temperature and relative humidity

  Manufacture of Precision Parts: If the metal parts are maintained at uniform temperature during manufacturing process, these will neither expand nor shrink, maintaining close tolerances. A lower relative humidity will prevent rust formation also

  Textile Industry: The yarn in the textile industry is spun and it moves over spools at very high speeds in modern machines. It is very sensitive to humidity.

  Photographic Material: The raw material used for filmmaking has to be maintained at low temperature, since it deteriorates at high temperature and humidity
- **Comfort**

  Home, Office, Bank , Cinema Theater, Auditorium, Hotels, Restaurant Etc Where Human Comfort is required

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Human Comfort:

The human comfort depends upon physiological and psychological condition. Thus it is difficult to defang the term 'human comfort'. There are many definitions given for this term by different bodies.

ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers) defines human comfort as the condition of mind which expresses satisfaction with the thermal environment.

The World Health Organisation (WHO) defines human comfort as a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity.

Factors Affecting Human Comfort

In designing winter or summer air conditioning system, the designer should be well conversant with a number of factors which physiologically affect human comfort. The important farces are as follows:

1. Effective temperature,
2. Heat production and regulation in human body
3. Heat and moister losses from the human body,
4. Moisture content of air,
5. Quality and quantity of air.
6. Air motion,
7. Hot and cold surfaces
8. Air stratification

Effective Temperature

Effective Temperature is an empirical index of human comfort, the degree of warmth or cold felt by a human body depends mainly on the following three factors:

a. Dry bulb temperature,
b. Relative humidity
c. Air velocity.

The effective Temperature cannot be measured directly and it is to be evaluated by the combined effect of above three factors. (*In order to evaluate the combined effect of these factors, the effective temperature is employed*).

- Effective Temperature is defined as that index which collates the combined effects of air temperature, relative humidity and air velocity on human body.

Heat Production and Regulation in Human Body

The human body acts like a heat engine which gets its energy from the combustion of food within the body.

The heat production from a normal healthy person when a sleep (called based metabolic rate) is about 60 Watts and it is about ten times more for a person carrying out sustained very hard work.

Since the body has a thermal efficiency of 20 per cent, therefore the remaining 80 percent of the heat must be rejected to the surrounding environment, otherwise accumulation of heat result which causes discomfort.

Dissipation of heat from human body (to maintain body temperature at 37^0C) may take place by radiation, convection and by evaporation.

When the process of radiation or convection or both fails process necessary loss of heat, the sweat glands become more active and ore moister is debited on the kin, carrying heat always as it evaporates.

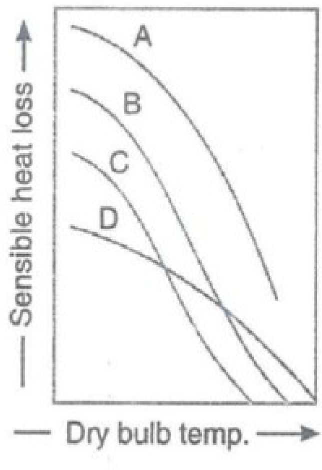
It may be noted that when the temperature of surrounding air and objects is below the blood temperature, the heat is removed by rendition and convection.

On the other hand, when the temperature of surrounding air is above the blood temperature, the heat is removed by evaporation only.

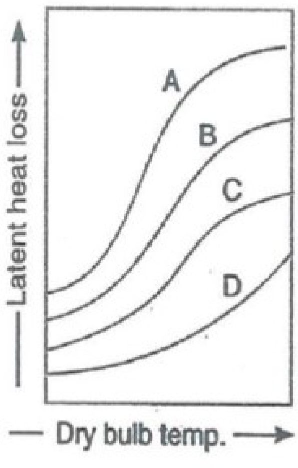
In case the body fails to throw off the requisite amount of heat, the blood temperature rises. This results in the accumulation of heat which will cause discomfort.

Heat and Moisture Losses from the Human Body

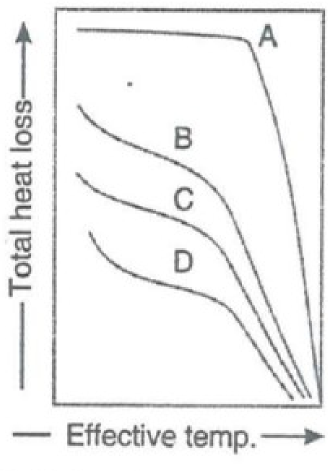
This heat is given off from the human body as either sensible or latent heat or both. In order to design any air-conditioning system for spaces which human bodies are to occupy, it is necessary to know the rates at which these two forms of heat are given off under different conditions of air temperature and bodily activity.



(*a*) Relation between sensible heat loss from the human body and dry bulb temperature for still air.



(*b*) Relation between latent heat loss from the human body and dry bulb temperature for still air.



(*c*) Relation between total heat loss from the human body and effective temperature for still air.

Figure (a) shows the graph between sensible heat loss by radiation and convection for an average man and the dry bulb temperate for different types of acidity.

Figure (b) shows the graph between the latent heat loss by evaporation for an average man and dry bulb temperature for different type activities.

The total heat loss from the human body under varying effective temperatures is show in figure(c).

From curve D, which applies to men at rest, we see that from about 19°C to 30°C effective temperature, the heat loss inconstant. At the lower effective temperature, the heat dissipation increases which results in a feeling of coolness. At higher effective temperature, the ability to lose heat rapidly decreases resulting in sever discomfort. The curves A, B, C and D show in figure represents as follows:

- Curve A – Men working at the rate of 90 kN-m/h
- Curve B – Men working at the rate of 45 kN-m/h
- Curve C – Men working at the rate of 22.5 kN-m/h
- Curve D -- Men at rest.

Moisture Content of Air

The dry bulb temperature, relative humidity and air motion are inter-related.
The moisture content of outside air during winter is generally low and it is above the average during summer.
The capacity of the air to carry moisture is dependent upon its dry bulb temperature. This means that in winter, if the cold outside air having low moisture content leaks into the conditioned space, it will cause a low relative humidity unless moisture is added to the air by the processes of humidification.

In summer, the reveres will take place unless moisture is removed from the inside air by the dehumidification process.

Thus, while designing an air-conditioning system, the proper dry bulb temperature for either summer or winter must be selected in accordance with the practical consideration of relative humidities which are feasible.

In general, for winter conditions in the average residence, relative humidity above 35 to 40 per cent is not practical. In summer comfort cooling, the air of the occupied space should not have a relative humidity above 60 per cent. With these limitations the necessary dry bulb temperature for the air may be depend from the comfort chart.

Quality and Quantity of Air

The air in an occupied space should, at all times, be free room toxic, unhealthful or disagreeable fumes (carbon dioxide). It should also be free from dust and odour. (Air should contain at least 16 % of oxygen)
For achieving this proper filtration, cleaning and purification of air is necessary.
In addition to that, enough clean outside air must allows be supplied to an occupied space to counteract or adequately dilute the sources of contamination.

Air Motion

The air motion which included the distribution of air is very important to maintain uniform temperate in the conditioned space. No air conditioning system is satisfactory unless the air handled is properly circulated and distributed.

Ordinarily, the air velocity in the occupied zone should not exceed 8 to 12m/min for comfort and also for proper distribution of air in the air conditioned space to maintain uniform temperature throughout. (The air motion prevents localised cooling)
The air in motion should be noiseless.

Cold and Hot Surfaces

The cold or hot objects in a conditioned space may cause discomfort to the occupants by conducting heat to the conditioned space from outside.

During summer a ceiling of the room transmit heat from outside that is warmer than the room air cusses discomfort.

In winter a glass door when exposed to the outdoor air absorb coldness from the outside weather will produce discomfort to the occupants of a room.

Thus, in the designing of an air conditioning system, the temperature of the surfaces to which the body may be exposed must be given considerable

Air Stratification

When air is heated, its density decreases and thus it rises to the upper part of the confined space. This results in a considerable variation in the temperatures between the floor and ceiling levels. The movement of the air to produce the temperature gradient from floor to ceiling is termed as air stratification. In order to achieve comfortable conditions in the occupied space, the air conditioning system must be designed to reduce the air stratification to a minimum.

Factors Affecting Optimum Effective Temperature

Effective Temperature is defined as that index which collates the combined effects of air temperature, relative humidity and air velocity on human body.

The important factors which affect the optimum effective temperature are as follows:

1. ***Climatic and seasonal differences***.
   It is a known fact that the people living in colder climates feel comfortable at lower effective temperatures than those living in warmer regions. There is a relationship between the optimum indoor effective temperature and the optimum outdoor temperature, which changes with seasons. We see from the comfort chart that in winter the optimum effective temperature is 19°Cwhereas in summer this temperature is 22°C.

2. **Clothing:**
   It is another important factor which affects the optimum effective temperature. It may be noted that the person with light clothing need less optimum temperature than a person with heavy clothing.

3. **Age and sex**.
   The women of all ages require high reflective temperature (about 0.5°C) than men, similar is the case with young and old people. The children also need higher effective temperature than adults. Thus, the maternity halls are always kept at an effective temperature of 2 to 3°C higher than the effective temperature used for adults.

4. **Duration of stay.**
   It has been established that if the stay in a room is shorter (as in the case of persons going to banks), then higher effective temperature is required than that needed for long stay (*if an occupant stay in conditioned space for more time say 8 hour need less effective temperature as in case of an occupant who visited a place for a shorter stay say 10 minutes need higher effective temperature*).

5. **Kind of activity.**
   When the activity of the person is heavy such as people working in a factory, dancing hall, then low effective temperature is need than the people sitting in cinema hall or auditorium**.**

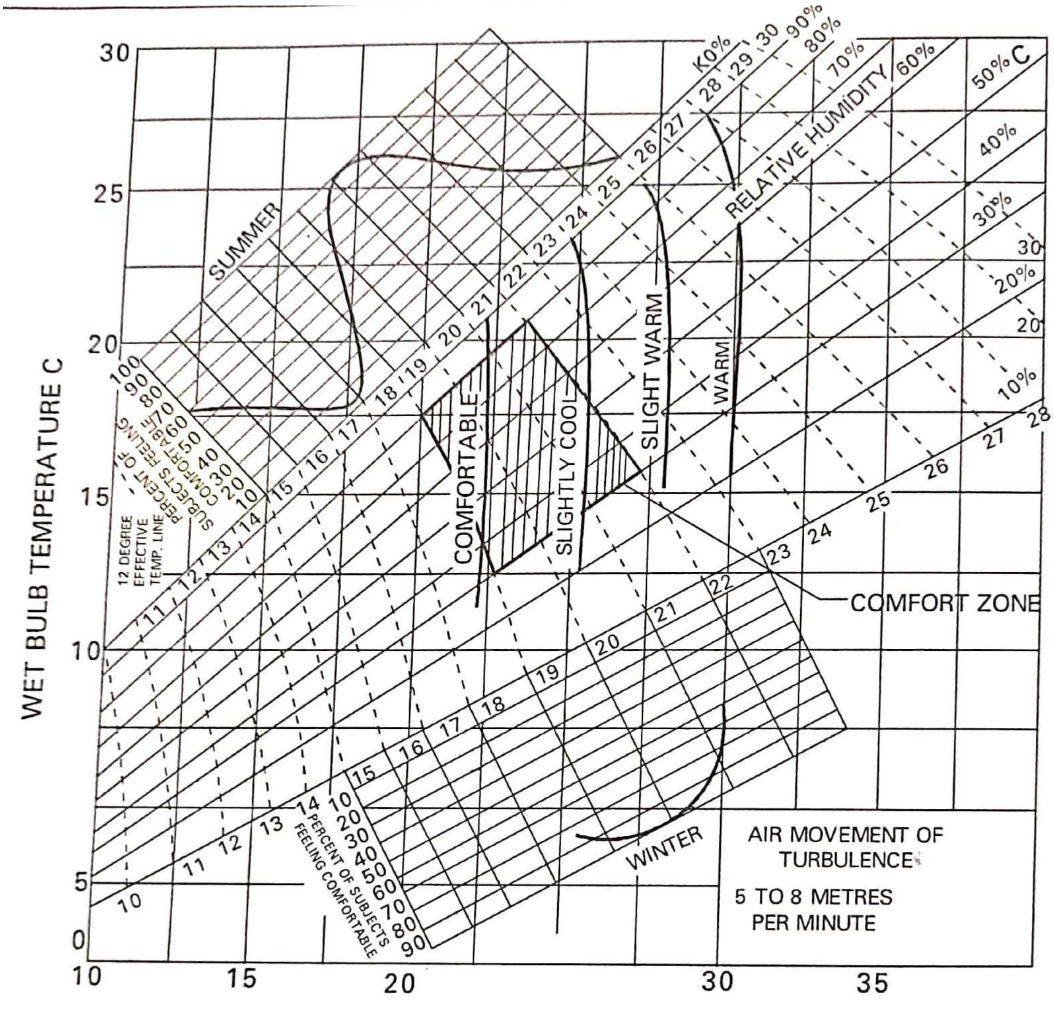
6. **Latitude**
   For every 5^0 reduction in latitude, increase in effective temperature by 0.5^0C is desired

7. **Density of Occupants.**
   The effect of body radiant heat from person to person particularly in a densely occupied space like auditorium is large enough which require slightly lower effective temperature.

Comfort Chart

Comfort charts are the practical application of concept of effective temperature. This chart is the result of research made on different kinds of people subjected to wide range of environmental temperature, relative humidity and air movement by ASHRAE (American Society of Heating, Refrigeration and Air conditioning Engineers).

The DBT is taken as abscissa and WBT as ordinate. The relative humidity lines are re plotted from psychrometric chart. Statistically prepared graphs corresponding to summer and winter season are also superimposed. The chart is prepared showing percentage of people feeling comfort at different effective temperatures.



From comfort chart, engineers find the effective temperature for a point corresponding to a particular DBT,WBT and RH. Now there are several combinations of temperatures and humidity that will have the same effective temperature and will give the same feeling of comfort and warmth.

The chart thus allows engineers to choose most economical room conditions from a zone of suitable comfort conditions for summer and winter.

The comfort chart shows the range for both summer and winter condition within which a condition of comfort exists for most people.

For summer conditions, the chart indicates that a maximum of 98 percent people felt comfortable for an effective temperature of 21.6°C.

For winter conditions, chart indicates that an effective temperature of 20°C was desired by 97.7 percent people. It has been found that comfort.

(*Women require 0.5°C higher effective temperature than men. All men and women above 40 years of age preset 0.5°C higer effective temperature than the person below 40 years of age.*)

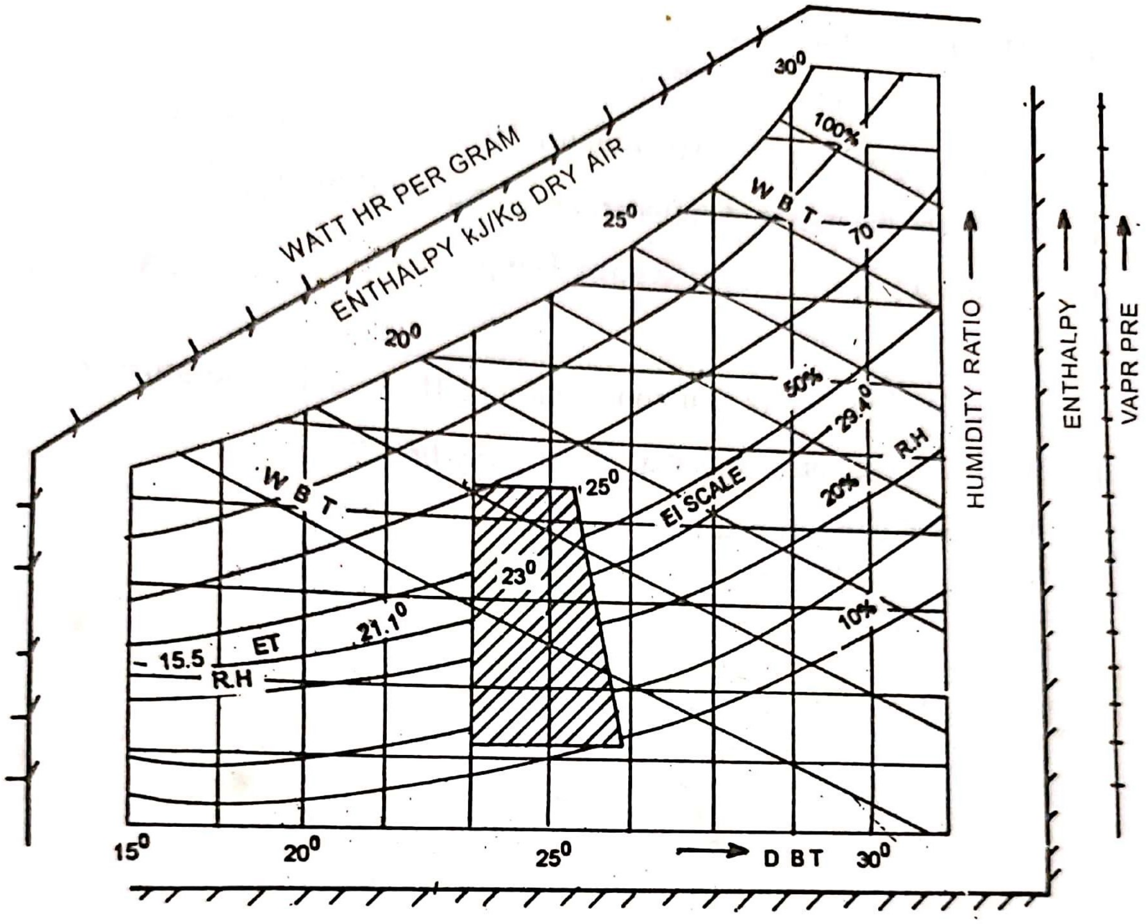
Modified Comfort Chart

The comfort chart, discussed above has become obsolete now-a-days due to its short comings of over exaggeration of humidity at lower temperature and under estimation of Humidity at heat to tolerance level.

The modified comfort char according to ASHRAE is shown in figure (given below) and it is commonly use these days.

This chart was developed on the basis of research done in 1963 by the institute for environmental research at Kansas State University.

The mean radiant temperature was kept equal to dry bulb temperature and air velocity was less than 0.17 m/s.



Modified Comfort Chart

Classification of Air Conditioning Systems

The air conditioning systems may be broadly classified as follows:

1. *According to the purpose*
   (a) Comfort air conditioning system, and
   (b) Industrial air conditioning system.
2. *According to season of the year*
   (a) Winter air conditioning system,
   (b) Summer air conditioning system, and
   (c) Year-round air conditioning system.
3. *According to the arrangement of equipment*
   (a) Unitary air conditioning system, and
   (b) Central air conditioning system.
   (c) Combination System

Industrial Air Conditioning System

It is an important system of air conditioning these days in which the inside dry bulb temperature and relative humidity of the air is kept constant for proper working of the machines and for the proper research and manufacturing processes. Some of the sophisticated electronic and other machines need a particular dry bulb temperature and relative humidity. Sometimes, these machines also require a particular method of psychrometric processes. This type of air conditioning system is used in textile mills, paper mills, machine-parts manufacturing plants, tool rooms, photo-processing plants etc.

Comfort Air Conditioning System

Energy of food is converted into chemical energy for functioning of brain, lungs, heart and other organs and this energy is ultimately rejected to the surroundings.

Also the internal organs require a temperature close to 35^{o}C for their efficient operation, and regulatory mechanisms of human body maintain this temperature by rejecting appropriate amount of heat.

Human beings do not feel comfortable if some extra effort is required by the body to reject this energy.

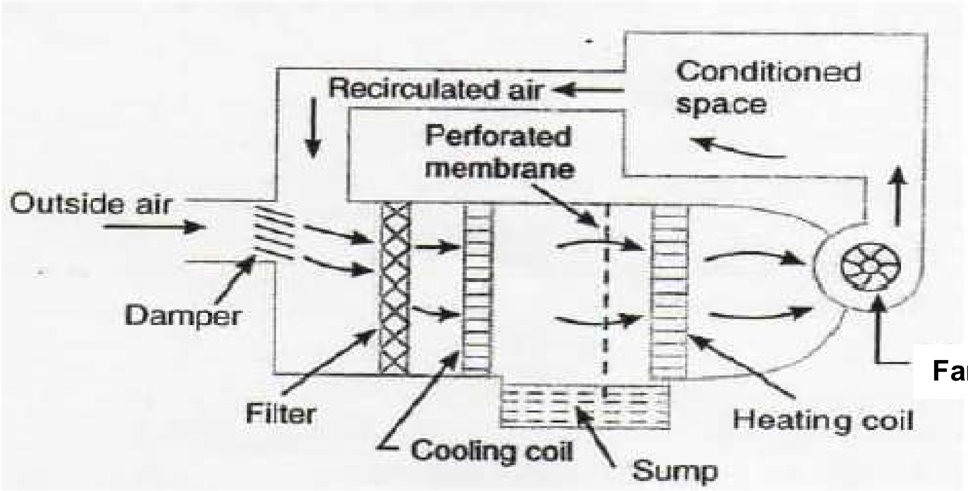
The air temperature, humidity and velocity at which human body does not have to take any extra action, is called comfort condition.

Comfort air conditioning units maintain the temperature and humidity of offices and other rooms used by people within a range that people perceive as pleasant.

In comfort air conditioning, the air is brought to the required dry bulb temperature and relative humidity for the human health, comfort and efficiency

Summer Air Conditioning System

It is the most important type of air conditioning, in which the air is cooled and generally dehumidified. The schematic arrangement of a typical summer air conditioning system is shown in figure.



Summer air conditioning system

The outside air flows through the damper, and mixes up with re-circulated air (which is obtained from the conditioned space).

The mixed air passes through a filter to remove dirt, dust and other impurities.

The air now passes through a cooling coil. The coil has a temperature much below the required dry bulb temperature of the air in the conditioned space.

The cooled air passes through a perforated membrane and loses its moisture in the condensed form which is collected in a sump.

After that, the air is made to pass through a heating coil which heats up the air slightly. This is done to bring the air to the designed dry bulb temperature and Damper relative humidity.

Now the conditioned air is supplied to the conditioned space by a fan.

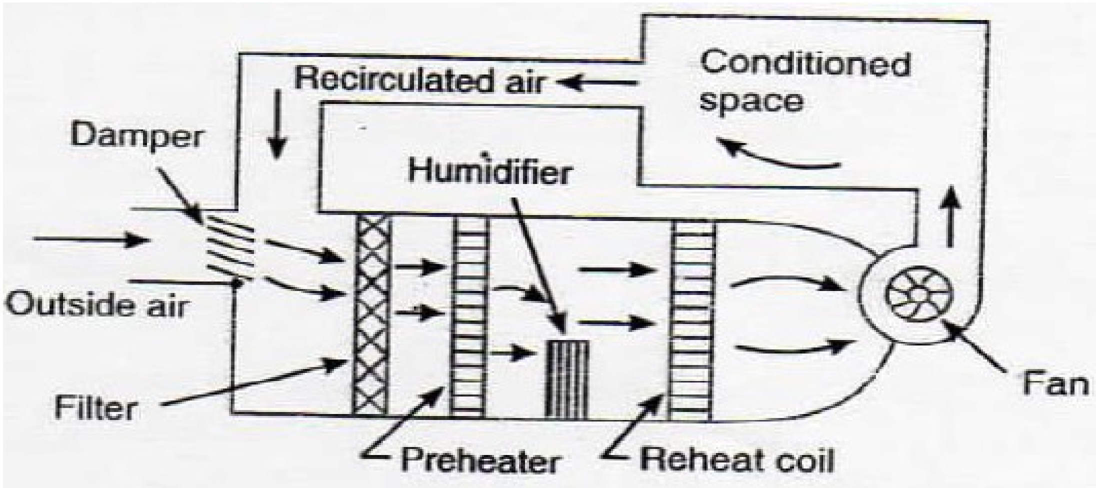
From the conditioned space, a part of the used air is exhausted to the atmosphere by the exhaust fans or ventilators.

The remaining part of the used air (known as re-circulated air) is again conditioned as shown in figure.

The outside air is sucked and made to mix with the re circulated air in order to make up for the loss of conditioned (or used) air (*through exhaust fans or ventilation from the conditioned space*).

Winter Air Conditioning System

In winter air conditioning, the air is heated, which is generally -accompanied by humidification. The schematic arrangement of the system is shown in figure



Winter air conditioning system

The outside air flows through a damper and mixes up with the Outside air recirculated air (which is obtained Fan from the conditioned space).

The mixed air passes through a filter to remove dirt, dust and other impurities.

The air now passes through a preheat coil in order to prevent the possible freezing of water and to control the evaporation of water in the humidifier.

After that, the air is made to pass through a reheat coil to bring the, air to the designed dry bulb temperature.

Now, the conditioned air is supplied to the conditioned space by a fan.

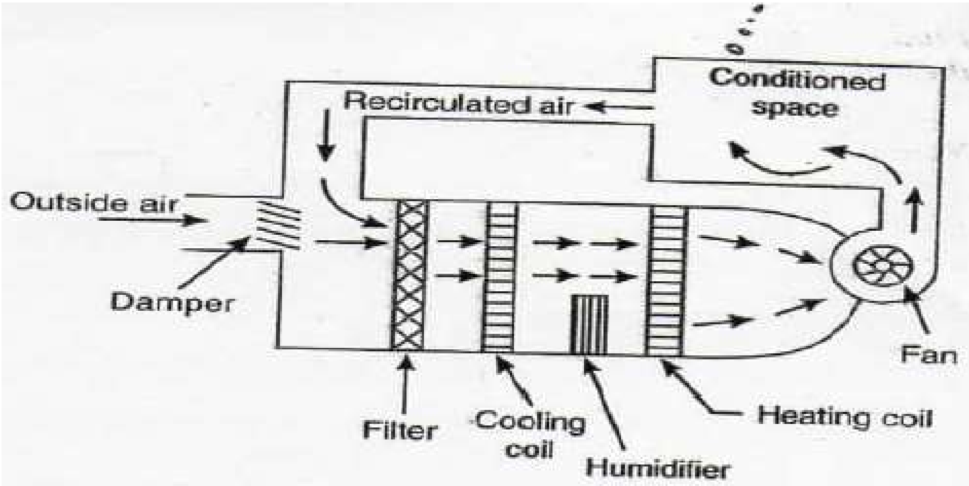
From the conditioned space, a part of the used air is exhausted to the atmosphere by the exhaust fans or ventilators.

The remaining part of the used air (known as re-circulated air) is again conditioned as shown in figure.

The outside air is sucked and made to mix with re-circulated air, in order to make for the loss of conditioned (or used) air. (*through exhaust fans or ventilation from the conditioned space*).

Year-Round Air Conditioning System

The year-round air conditioning system should have equipment for both the summer and winter air conditioning. The schematic arrangement of a year-round air conditioning system is shown in figure.



Year-round air conditioning system

The outside air flows through the damper and mixes up with the re-circulated air (which is obtained from the conditioned space).

The mixed air passes through a filter to remove dirt, dust and other impurities.

In summer air conditioning, the cooling coil operates to cool the air to the desired value.

The dehumidification is obtained by operating the cooling coil at a temperature lower than the dew point temperature (apparatus dew point).

In winter, the cooling coil is made inoperative and the heating coil operates to heat the air.

The spray type humidifier is also made use of in the dry season to humidify the air.

Window Air Conditioner:

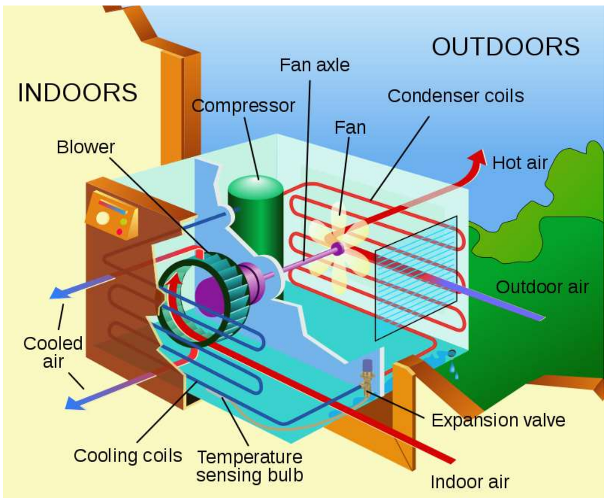
Window unit air conditioners are installed in an open window so the room Air conditioners are widely known as window type air conditioners

The interior air is cooled as a fan blows it over the evaporator.

A large house or building may have several such units, allowing each room to be cooled separately

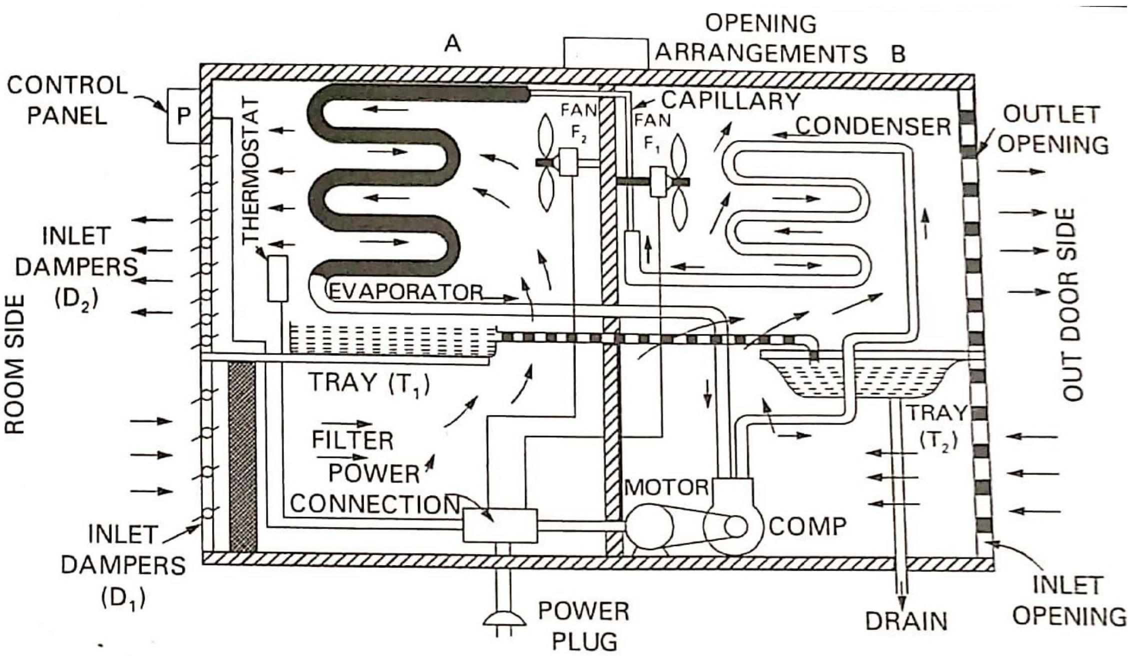
Available in sizes up to 2 ton capacity

It works on vapour compression cycle.



It consists of a compressor, condenser, a filter, a drier, a capillary tube and an evaporator

The whole unit of room Air Conditioner is divided into two parts A and B as shown In figure.



The centre part of the ‘conditioner is installed in the window facing **A** part inside the room and **B** part outside the room with the support of wall brackets.

Part **A** consists of evaporator for cooling the air inside the room and part **B** consists of condenser which rejects the heat into the atmosphere.

The high pressure refrigerant vapour is passed from the compressor into the condenser where it is condensed to refrigerant liquid and gives out its latent heat to the air passing over the condenser coils.

Fan F_1 sucks the air from the atmosphere and drives in to the atmosphere through hot condenser coils.

The Fan F_2 draws air from the room in to the air conditioner through the filter which collects the dirt and drives this air in to the room through evaporator coils.

The liquid refrigerant passes through the capillary tubes from the condenser and enters in to evaporator at low pressure and low temperature.

The air which passes over the evaporator, cools to low temperature and dehumidified, This dehumidified cool air is circulated in the room by the Fan F_2.

The quantity of air circulated is controlled by dampers D_1 and D_2 .

The refrigerant evaporates by absorbing heat from the air and enters in to the compressor.

The same cycle gets repeated again and again.

The dehumidified air in the evaporator coil collects water drops in the tray T_1 and is taken to tray T_2 by the pipe as shown in the figure.

The collected water in the tray T_2 evaporates to some extent and cools the compressor and condenser and finally discharged outside.

Split Unit Air-Conditioners:

In Split units, the indoor and outdoor sections of the room air conditioner are separated out into two casings or units.

The indoor unit consists of the evaporator coil, evaporator blower with its own separate motor, capillary tube, control panel, air filter, supply and return air, grills etc. It is installed inside the room to be conditioned. It can be ceiling suspended, wall mounted or kept on floor.

The outdoor unit has the other parts of the system like compressor, condenser, condenser fan and its own motor and is installed outside.

In smaller capacity split units the capacity may be about 3 TR.

Package Air Conditioners:

The window and split air conditioners are usually used for the small air conditioning capacities up to 5 tons. The central air conditioning systems are used for where the cooling loads extend beyond 20 tons. The packaged air conditioners are used for the cooling capacities in between these two extremes.

The packaged air conditioners are available in the fixed rated capacities of 3, 5, 7, 10 and 15 tons.

These units are used commonly in places like restaurants, telephone exchanges, homes, small halls, etc.

As the name implies, in the packaged air conditioners all the important components of the air conditioners are enclosed in a single casing like window AC.

Thus the compressor, cooling coil, air handling unit and the air filter are all housed in a single casing and assembled at the factory location.

Depending on the type of the cooling system used in these systems, the packaged air conditioners are divided into two types:

With water cooled condenser and With air cooled condensers.

- **Packaged Air Conditioners with Water Cooled Condenser**

In these packaged air conditions the condenser is cooled by the water.

The condenser is of shell and tube type, with refrigerant flowing along the tube side and the cooling water flowing along the shell side.

The water has to be supplied continuously in these systems to maintain functioning of the air conditioning system.

The shell and tube type of condenser is compact in shape and it is enclosed in a single casing along with the compressor, expansion valve, and the air handling unit including the cooling coil or the evaporator.

This whole packaged air conditioning unit externally looks like a box with the control panel located externally.

In the packaged units with the water cooled condenser, the compressor is located at the bottom along with the condenser.

Above these components the evaporator or the cooling coil is located.

The air handling unit comprising of the centrifugal blower and the air filter is located above the cooling coil.

The centrifugal blower has the capacity to handle large volume of air required for cooling a number of rooms.

From the top of the package air conditioners the duct comes out that extends to the various rooms that are to be cooled.

All the components of this package AC are assembled at the factory site.

- ***Packaged Air Conditioners with Air Cooled Condensers***

In this packaged air conditioners the condenser of the refrigeration system is cooled by the atmospheric air.

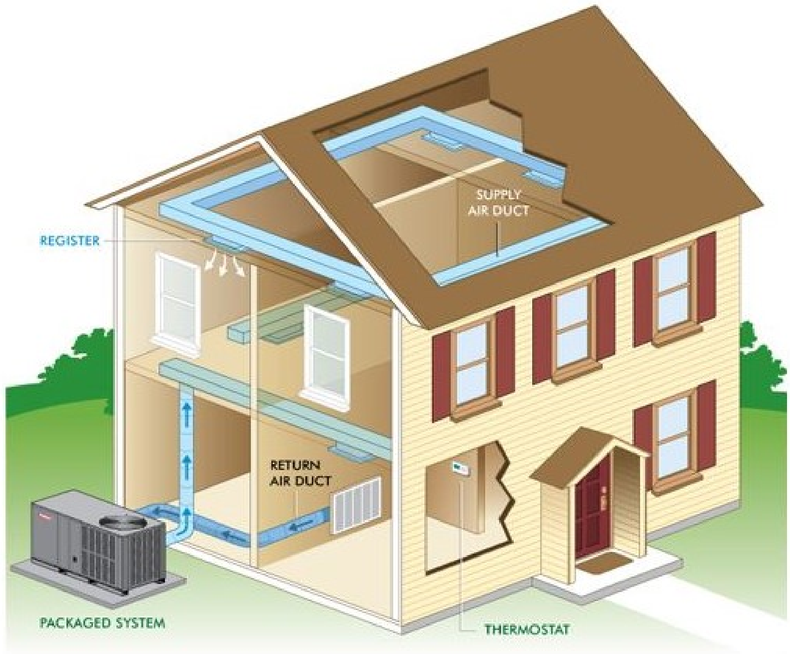
There is an outdoor unit that comprises of the important components like the compressor, condenser and in some cases the expansion valve

The outdoor unit can be kept on the terrace or any other open place where the free flow of the atmospheric air is available.

The fan located inside this unit sucks the outside air and blows it over the condenser coil cooling it in the process.

The condenser coil is made up of several turns of the copper tubing and it is finned externally.

The packaged ACs with the air cooled condensers are used more commonly than the ones with water cooled condensers since air is freely available it is difficult maintain continuous flow of the water.



Central air conditioning system

Central air conditioning is one of the most convenient and energy-efficient ways to get relief from the hot, humid summer weather throughout Connecticut.

The “central” in central air conditioning comes from the fact that the system conditions the entire building from one large central location. This system cools and dehumidifies the air, then blows the cool air into the duct system and out through the supply air registers (*opening in walls floors covered with grills*) located in each room.

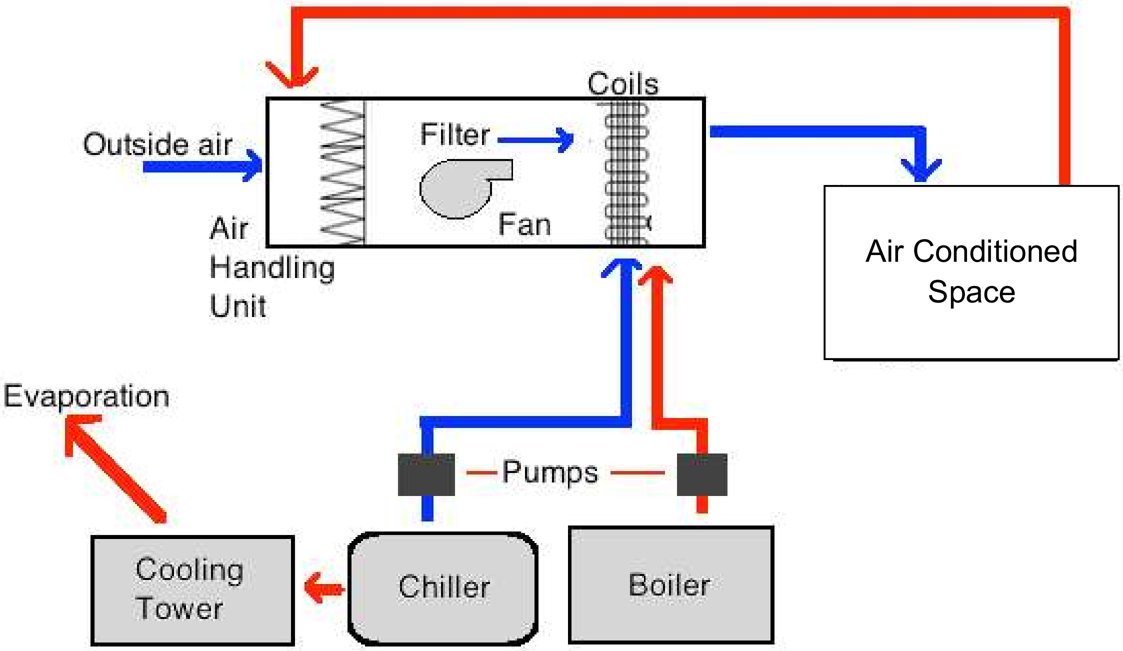
Central air conditioning system is adopted when the requirement capacity is more than 25 tons, conditioned air flow requirement is more than 2500 m^3/min and various rooms in big building are to be air conditioned.

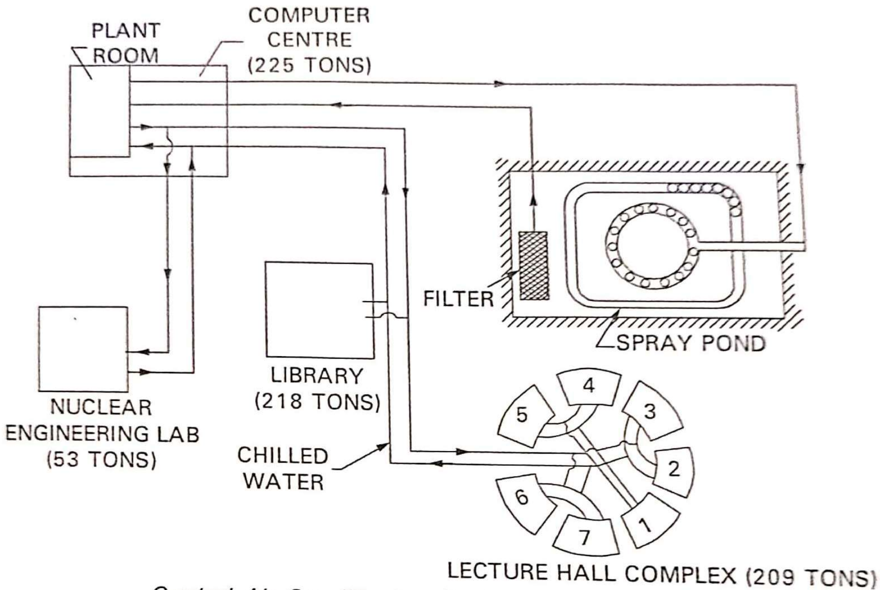
In central plants, the compressor, condenser, evaporator along with pumps, control panels are assembled and installed at one place called plant room.

As the central plants are used for large cooling capacities, the condensers used for them are water cooled.

The heat carried by water during its circulation through the condenser is rejected in the cooling tower.

The cooling tower which is used to cool the condenser water is installed on the roof or at a place where atmospheric air is freely available.





Central Air Conditioning System of an Academic Institution

Advantages:

a) The initial investment and running cost are less per unit of refrigeration,
b) The plant can be located away from the air conditioned rooms.
c) Noise and vibration troubles are less to the occupants of the conditioned place,
d) This system is easily accessible for servicing.
e) Power consumption is less.
f) Easy control.

Unitary System:

In unitary system the whole equipment is enclosed in one unit.

The unit can be shifted from one place to another If required.

These are factory assembled air conditioners.

The air conditioners of this type may be window units or packaged units. Window air Conditioners are available up to 2 ton capacity. These units are widely used for residential air conditioning.

Packaged air conditioners are big in size and available from 5 to 20 tons capacity or even more. They are used in small commercial or other establishments such as Restaurants, Banks, Small offices etc.. These units can be installed on floor or ceiling or in windows.

Advantages Of The Unitary System Over The Central System :

a) Installation charges for small units are less. Extensive duct work is eliminated.
b) The units can be kept running where ever required and the units can be stopped in other places.
c) The failure of one unit causes failure in one room only. If the central plant fails, total supply of conditioned air to all the rooms will be put off.
d) Individual room temperature control is advantageous in unitary system.

- *W.H. Carrier (1876 - 1950) is known as the Father of Air conditioning. He engineered and installed the first year-round AC system. To bring various groups of engineers together, ASRE (American Society of Refrigeration Engineers) was formed in 1904.*

- *The atmospheric air contains 0.03% to 0.04% by volume of carbon dioxide and it should not increase 0.6% which is necessary for proper functioning of respiratory system. The carbon dioxide, in excess of 2% dilutes oxygen contents and makes breathing difficult. When the carbon dioxide exceeds 6%, breathing is very difficult and 10% carbon dioxide causes loss of consciousness. A normal man at rest in breathing exhales about 0.015 to 0.018 m3/h of carbon dioxide*

4.2.6 Define the term HVAC.
4.2.7 Estimate the load and design Air conditioning systems
4.2.8 Explain the sources of heat gain or loss
4.2.9 Estimate heat gain from various sources such as conduction heat load, radiation load of sun, occupants load, infiltration air load, equipment load, fresh air load, miscellaneous heat sources.
4.2.10 Explain sensible, latent and total heat load.
4.2.11 Compute total cooling load.

Content Details

HVAC. Design and Load estimation of Air Conditioning systems Introduction – Heat source – External and Internal source - solar radiation through window –conduction of heat due to temperature difference- Heat addition by the occupants and equipments- Infiltration of air – ventilating estimation- Procedure of sensible heat load – latent heat load – total load – .Estimation of total cooling load.

Heating, ventilation, and air conditioning (HVAC)

Heating, ventilation, and air conditioning (HVAC) system is designed to achieve the environmental requirements of the comfort of occupants and a process.

HVAC system design is a sub discipline of mechanical engineering, based on the principles of thermodynamics, fluid mechanics and heat transfer.

The main mission of HVAC system is to satisfy the thermal comfort of occupants by adjusting and changing the outdoor air conditions to the desired conditions of occupied buildings.

Depending on outdoor conditions, the outdoor air is drawn into the buildings and heated or cooled before it is distributed into the occupied spaces, then it is exhausted to the ambient air or reused in the system.

HVAC systems can be classified according to necessary processes and distribution process.

The required processes include the heating process, the cooling process, and ventilation process. Other processes can be added such as humidification and dehumidification process.

These processes can be achieved by using suitable HVAC equipment such as heating systems, air-conditioning systems, ventilation fans, and dehumidifiers.

The HVAC systems need the distribution system to deliver the required amount of air with the desired environmental condition.

The distribution system mainly varies according to the refrigerant type and the delivering method such as air handling equipment, fan coils, air ducts, and water pipes

HVAC systems are more used in different types of buildings such as industrial, commercial, residential and institutional buildings.

Design and Load estimation of Air Conditioning systems

Introduction

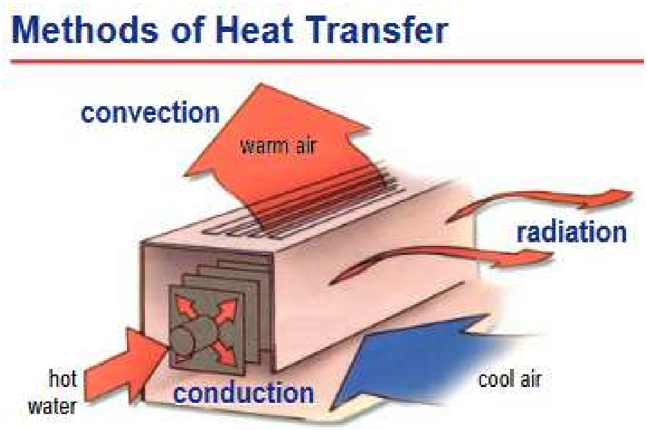
Heating and cooling load calculations are carried out to estimate the required capacity of heating and cooling systems, which can maintain the required conditions in the conditioned space.

To estimate the required cooling or heating capacities, one has to have information regarding the design indoor and outdoor conditions, specifications of the building, specifications of the conditioned space (such as the occupancy, activity level, various appliances and equipment used etc.) and any special requirements of the particular application.

For comfort applications, the required indoor conditions are fixed by the criterion of thermal comfort, while for industrial or commercial applications the required indoor conditions are fixed by the particular processes being performed or the products being stored.

The design outdoor conditions are chosen based on design dry bulb and coincident wet bulb temperatures for peak summer or winter months for cooling and heating load calculations, respectively.

The air conditioning heating or cooling load calculations depends on difference of outside and inside temperature and relative humidity. Therefore heating load for winter and cooling load for summer are to be calculated for accurate design and successful trouble free operation of an air conditioning plant.



Air conditioning is the process of addition or removal of heat. All the load calculations are based on heat transfer. Heat transfer takes place by conduction, convection and radiation. Therefore designer should be familiar with heat transfer equations to calculate heating and cooling loads

The purpose of load estimation is to determine the size of the air conditioning and refrigeration equipment required to maintain desirable design conditions inside the space for maximum outside conditions.

Heating Load Calculations:

During winter the temperature of the surroundings is found lower than the required for the comfort of human beings.

Therefore the buildings are to be maintained at a comfortable temperature and provided with heated air.

The heating load is calculated on the basis of maximum probable heat loss from the air conditioned space to the surroundings.

Therefore the plant for the heating system is to be designed to meet the heating load requirement even when most severe weather conditions occur.

The total quantity of heat required to be supplied to the air conditioned space for keeping at desired temperature by the air conditioning equipment is known as heating load.

Estimation of Heating Load

The following points are to be considered for heating load calculations.

Transmission of Heat Loss:

The transmission of heat loss from walls, roof etc. is calculated on the basis of outside and inside temperature difference.

Solar Radiation

There is generally no solar radiation is present during the winter season and there for it is assumed that solar heat gain is nil

Internal Heat Gains

While calculating heating load to theatres, assembly halls, stores, office buildings etc. the internal heat gains such as heat energy released by the occupants, machinery and equipment, lights etc. are to be taken into account. These are treated as negative loads.

Types Of Heating Systems

1. Warm air heating system
2. Hot water heating system
3. Steam heating system
4. Panel heating system
5. Electric heating system

Heat Flow Due To Conduction

The heat gain through walls, floor and ceiling varies with factors like thickness of insulation, construction, outside wall area and temperature difference between refrigerated space and ambient air.

The heat gain through a wall can be calculated by applying heat transfer equation

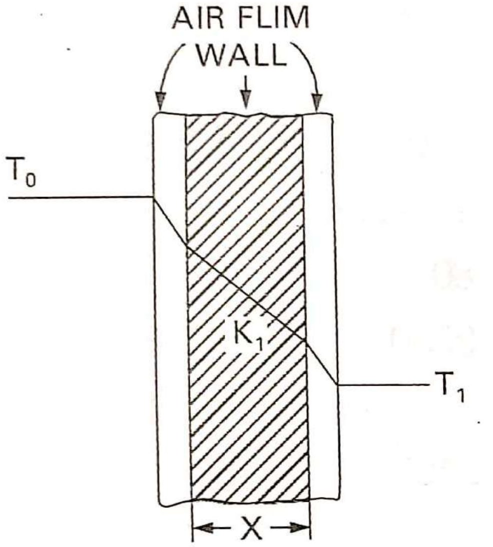
$$Q = UA\,\Delta t$$

where U = Over all heat leakage or heat transfer coefficient

A = outside area (Wall area)

Δt = difference between average outside temperature and average air conditioned space temperature.

The overall heat transfer coefficient 'U' of the walls as shown in the figure can be calculated by the following equation.



(a)

$$U = \frac{1}{\frac{1}{f_1} + \frac{x}{k} + \frac{1}{f_0}}$$

Where

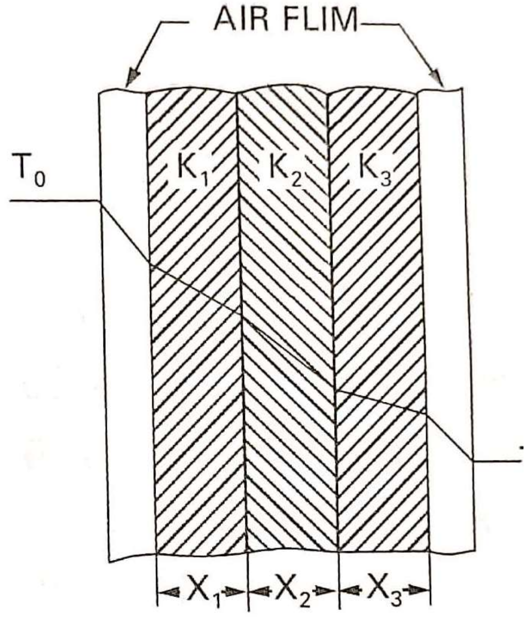
x = thickness of the wall

k = conductivity of the material of wall

f_1= inside film or surface conductancc

f_0= outside film or surface conductance

If the wall consists of flat parallel surface of material 1,2,3 etc. as shown in figure



(b)

$$U = \frac{1}{\frac{1}{f_1} + \frac{x_1}{k_1} + \frac{x_2}{k_2} + \frac{x_3}{k_3} + \cdots + \frac{1}{f_0}}$$

Where x_1, x_2, x_{23} etc. are the thicknesses and k_1, k_2, k_3 etc. are the conductivities of the materials of which the wall is made of.

The values of the conductivities, film coefficient and conductance: of various materials which are commonly used as building materials are given in the table.

Physical properties of various industrial materials

Materials	Thermal Conductivity kJK/m-h/C	Temp. t ^{0}C	Density kg/m^3	Specific heat cp kJ/kg-K	Temp. T
Bakelite	1.0467	–	1400	–	–
Varnish Brick, red machine moulded	2.7634	0	1800	0.8792	273
Card board	0.502-1.256	20	–	1.3073	293
Concrete dry	3.0146	20	1600	0.8374	293
Concrete reinforced	5.5687	20	2200	0.8374	293
Concrete slag	2.5122	20	1500	0.7955	-293
Cork sheets	0.1507-0.1926	80	147-198	1.7585	363
Cotton wool	0.1507	30	80	--	303
Glass plate	2.805-3.182	0-100	2550	0.7787	273-373
Plywood	1.256-1.465	20-25	–	2.7215	233-298
Woolen material	0.1884	–	240	–	–

Cooling Load Calculations:

The total heat required to be removed from the Air conditioned space in order to bring it at the desired temperature by the refrigerating and air conditioning equipment is known as cooling load.

The selection of air conditioning equipment is based on the air conditioning load estimate. The design load is based on inside and outside design conditions.

The equipment selected has to produce and maintain satisfactory desired inside conditions.

Sources of Heat Loads

Heat transfer takes place by conduction, convection and radiation in to air conditioned space from outside.

Heat is also generated or added in the conditioned space because of occupants, machinery and equipment products placed inside and other miscellaneous loads.

All these are to be accounted to arrive at total heat load to procure air conditioning equipment which is capable of driving out required quantity of heat, producing inside desired conditions.

The total heat loads are mainly classified into the following

Components of cooling load

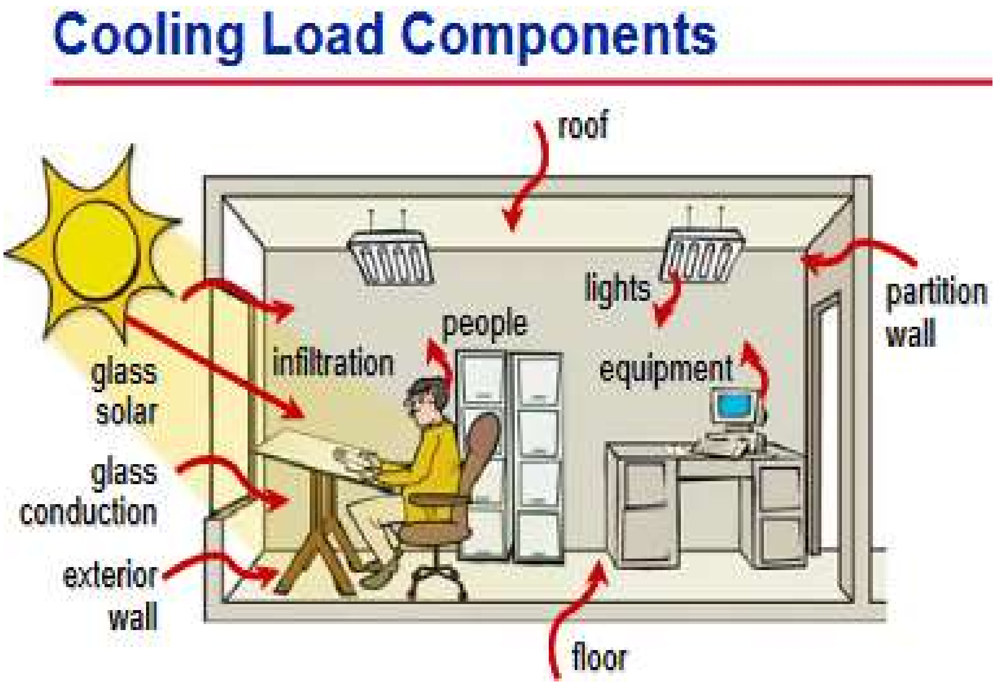
- Heat flow due to conduction
- Solar Radiation
- Heat gain due to infiltration
- Heat gain due to ventilation
- Load from occupants
- Heat gain from electrical appliances
- Heat gain from products

Components of Cooling Load

The total cooling load is commonly divided into two components. They are sensible heat and latent heat.

Sensible Heat Gain

When there is direct addition of heat into the air conditioned space by any one or all the modes of heat transfer conduction convection or radiation, that sensible heat is considered to be added. The sensible heat gain may occur due to any one or all the following sources of heat transfer.



1. Heat flowing in to the building by conduction due to the temperature difference of their two sides of exterior walls, floors, ceilings, doors, windows etc.
2. Heat transmitted into the enclosed space by solar radiation through glass of windows and ventilators.
3. Heat conducted through interior partition from rooms in the same building which are not conditioned.

4. Heat carried through outside air by leaking (infiltration) air through the cracks in doors, windows and through their frequent openings.
5. Heat liberated from the occupants.
6. Heat produced due to light fittings, equipment gadgets, appliances.
7. Heat due to ducts running in unconditioned space.
8. Heat given out by the products brought in at higher temperature than the temperature of the conditioned space.

Latent Heat Gain:

When there is an addition of water vapour to the air in the enclosed space, it is considered as latent heat is added to the air conditioned space.

The latent heat is to be removed during the process of summer air conditioning.

The latent heat gain may occur due to one or more of the following sources.

1. The heat gain due to moisture in the outside air which entered the enclosed space by infiltration or leaking.
2. The heat gain due to condensation of moisture from occupants.
3. Latent heat due to condensation of moisture from stored products or materials.
4. Latent heat due to moisture from internal sources such as wet surfaces, equipment, appliances etc.

The total heat load to be removed by the air conditioning equipment is the sum of sensible and latent heat load as mentioned above.

Solar Radiation:

Buildings exposed to the sun receive direct solar radiation through the glass windows or other openings. (*90% of the solar radiation is transferred through the glass which incident on it.)*

Solar radiation also passes through walls.

The heat transfer due to solar radiation depends upon the position of the building with respect to the sun, nature of wall surface, material of the wall, the surrounding atmosphere etc.

The heat absorbed by the building is maximum when the sun rays are perpendicular to the surface of the building and gradually decreases when the rays became more obiique.

The maximum heat load due to sun felt inside the air conditioned room at about 3 pm due to time lag in transmission of heat inside.

The direct solar heat gain through glass can be reduced by providing sun shades or curtains over windows. These protect from direct sun rays.

Heat gain due to Infiltration.

Infiltration is the name given to the leakage of outside air through door openings and through cracks around windows and doors into conditioned space.

Buildings can never be air tight due to gaps between the frames of doors, windows and shutters. Therefore the air infiltrates from surroundings at high pressure into the room. This causes an increase in the cooling load.

Similarly it the room is maintained at a pressure higher than that of surroundings, the cool air leaks out of the room.

As soon as the doors are opened the cool air leaks out of the cabinet as cool air is heavier compared to warm air of the surroundings.

It is a general practice in case of freezers and household refrigerators. Due to loss of cold air it increases the cooling load.

It is a general practice to assume air infiltration factor of 5 m^3 per hour per m^2 of window and door area. According to ASHVE an average infiltration rate assumed is $4m^3$/meter of crack per hour.

. ***Calculation of Infiltration Load***

The heat load due to infiltration can be calculated from the known volume of air.

Let

V_i= Volume of infiltration of air

V_s = Specific volume of ambient air having enthalpy of h_a

Q = Heat load due to infiltration

h_a = Enthalpy of ambient air

h_i = Enthalpy of air inside the air conditioned space

$$Q = m(h_a - h_i)$$

$$Q = \frac{V_i}{V_s}(h_a - h_i)$$

If the total air is changed intentionally and replaced by total fresh air certain number of times in 24 hours, the volume of the air each time is taken as volume of room with room dimensions

Specific heat of air = C_p = 1.026 J/kg·K

Density of air = $\rho = \frac{P}{RT}$

Where T is in absolute temperature in Kelvin

Atmospheric Pressure =P = 1.013 x 10^5 N/M^2

Gas constant R = 287.2 J/kg·K

Heat gain due to Ventilation

Ventilation means supply of outside fresh air into the air conditioned room.

This is to reduce concentration of odours, smoke, carbon dioxide and other undesirable gases and also to maintain required level of oxygen.

The magnitude of the ventilation requirement varies according to situation.

The used air contains less oxygen and more carbon dioxide. This air also contains odours delivered by the occupants and smoking.

Therefore the fresh air has to be supplied and a part of the contaminated air has to be discharged.

Let **v** = Volume of air for ventilation requirement per person per second,

n = no. of persons

Ventilation requirement for **n** persons is **V**

V = nv

V_a = Specific volume of air.

The ventilation load is given by the equation

$$Q = \frac{V}{V_s}(h_a - h_i)$$

Load from Occupants:

The heat generated from the occupants depends on the activity of the persons, sex age and inside dry bulb temperature.

Sensible heat is added by the occupants by conduction convection and radiation to the surroundings.

Latent heat is added in the form of moisture emitted from the skin of the occupants.

Heat Gain from Electrical Appliances:

The appliances frequently used in air conditioning spaces may be various electrical items such as lights, fans, freezer motors and other equipment.

They generate heat while in use and add cooling load.

Electrical lights generate a sensible heat equal to the amount of electric power consumed.

Most of the energy is liberated as heat and the rest as light which also becomes heat after multiple reflections.

The Fluorescent tubes consume 25% more at the choke. That means 60 Watts-tube will need 75 watts at the fitting.

Q for incandescent = Total watts

Q for Fluoresceht = Total watts x 1.25

Let $P_1, P_2, P_3, \ldots P_X$ are power ratings of different electrical power appliances.

$n_1, n_2, n_3 \ldots n_x$ number of items in each category of $P_1, P_2, P_3, \ldots P_X$ respectively.

Total cooling load due to electrical appliances is Q.

$$Q = n_1 P_1 + n_2 P_2 + n_3 P_3 + \ldots \ldots + n_X P_X \text{ Watts or J/sec.}$$

Heat Gain from Products

A product brought mm the air conditioned space at a temperature higher than the storage temperature will release its heat until it reaches the storage temperature.

The heat produced may be sensible or latent heat which depends upon the nature at the product.

These may be perishable food, frozen food products, dairy products, medicines or other Items which are required to be stored at low temperatures.

The load to be considered in cold storage systems are three types.

(1) Chilling load before freezing

Heat removed to reduce the temperature from initial temperature t_1 to freezing temperature t_f

$$Q_1 = mC_1(t_1 - t_f)$$

Where **m** mass of the product
C_1 Specific heat of the product

(2) Freezing Load
Heat removed during freezing of product.

$$Q_2 = mh_{fg}$$

h_{fg} Latent heat of fusion

(3) Chilling Load below Freezing
Heat removed from freezing Point t_f to a final temperature below freezing point t_2.

$$Q_3 = mC_2(t_f - t_2)$$

C_2 Specific heat below freezing point

Total heat removed Q = Q1 + Q2 + Q3.

Calculate Q per hour by dividing with cooling time in hours.

In addition to the above three, the energy release due to respiration of products per tonne per unit time should also be considered. The fruits, vegetables etc. remain alive even after they are harvested. The oxygen of air combines with the carbohydrates to form carbon dioxide. It is exothermic reaction and releases heat. This heat is generated by the products even they are stored in cold storage.

Q_R Product reaction or heat of respiration = m x H_R
H_R = Evolution of heat per Kg of food per hour.

The total product load Q = Q1 + Q2 + Q3+mH_R