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### RESEARCH ARTICLE

#### THE SIMPLIFIED WAY TO CALCULATE COOLING LOAD ON AIR CONDITIONING.

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#### Abstract

Now a days the use of air conditioning is becoming so popular and is considered an essential part of our day to day life. So it is necessary to calculate correct load to get proper air conditioning system and size. It is difficult to maintain cooling if undersize air conditioning system is selected. If it is oversized then it will consume more power and hence it is less efficient. By using computer programme which is available in the market, we can calculate the load but it requires complex data input and hence it is not popular. Therefore hand calculation is preferred and more popular because of its simplicity. Most of the people ask another person who has no idea of basic things, so there is a chance that the selected air conditioning system is not the proper size. This paper helps in educating the people in correct load calculation.

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#### Introduction:-

In the last few decades efficient design of air conditioning system has been on a prime attention due to high energy consumption of air conditioning system. If the air conditioning system is oversized then it will have higher initial cost, will occupy more space and will have high running cost because most of the time air conditioning system runs at a part load condition which in turn results in lower efficiency. On the other hand if it is undersized then it is difficult to maintain cooling in a confined space which results in human discomfort. Calculation of cooling load is necessary to find exact size of air conditioning system so that there is a good air distribution system inside the confined space. The selection of correct size of air conditioning system helps us in reducing our energy bill and inside discomfort. The cooling load calculation involves the amount of heat energy extracted from a confined space and cost of heat extraction from a confined space. After cooling load calculation we can select an air conditioning system which has good efficiency and has less cost of cooling.

#### Load Calculation Method (CLTD/CLF/SCL):-

Heat gain to building material due to conduction and radiation is not converted to cooling instantly but there is a some time lag between heat gain and cooling. The CLTD/CLF/SCL method is a very simple hand calculation method to estimate cooling load and is developed by ASHRAE.

Cooling Load Factor (CLF) : When a conditioned space is exposed to solar radiation, only a negligible portion of solar radiation is absorbed by indoor room air instantaneously. Most of solar radiation is absorbed by furniture, roof, walls, ceilings, floor etc. and acts as a thermal storage. As the surface temperature of roof, walls, ceiling, floor increases the heat transfer takes place between air and surfaces of walls, roof, ceilings and floor. Depending upon outdoor air temperature and thermal capacity of roof, wall, ceilings etc some of absorbed heat is now picked off and

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may be lost to outdoors. The only fraction of absorbed heat that is transferred to inside air becomes a load. Due to time delay the effect of radiation is still felt even when solar radiation is not there.

All radiant energy that enters into confined space does not contribute to cooling load instantly but there is a some time delay. The value of CLF is calculated for various surfaces as a function of solar time and orientation and it is available in ASHRAE handbooks in the tabular form. It is used for adjustment to heat gains from loads such as electric light and appliances, occupancy of person in a conditioned space. CLF is a ratio of cooling load to internal heat gain.

Cooling Load Temperature Difference (CLTD): It is used for adjustment to conductive heat gains from load such as walls, roof, floor and glass. The orientation, tilt, month, day, hour, latitude etc affects CLTD and is considered in this method. It is a theoretical temperature difference and considers the both the effects of inside and outside temperature differences, solar radiation, heat storage in building material such as roof, floor, glass, range of temperature during entire day etc.

Solar Cooling Load Factor (SCL) : Transmissions heat gains from glass is adjusted using this method.

#### **Cooling load:-**

It deals with sensible heat gain and latent heat gain.

#### **Sensible Heat Gain:-**

It involves direct heat addition in a confined space. It involves heat transfer through building structure due to conduction, convection and radiation, heat entering into confined space due to windows or other transparent object, heat produce by the occupant in a confined space, heat produce by electrical and electronic appliances, ventilation and infiltration of outside air into confined space etc.

#### **Solar Heat gain through walls and Roof:-**

The variation in solar radiation intensity over a period of 24 hours, results in variation of the outdoor temperature. The variation in outdoor temperature which in turn affects transmission of heat from roof and walls. Due to this also transmission of heat from roof and walls is not steady. When outdoor temperature increases, the temperature of wall and roof increases and it stores considerable amount of heat. When outside temperature falls in the evening, the heat stored in the walls and roof is release. Since outdoor air temperature continuously changes over a period of 24 hours, therefore instantaneous heat gain from outside is not equal to instantaneous heat gain inside the room. This is because difference of heat is being stored or rejected by the wall.

The heat gain through outside walls and roof is given by equation

$$Q = U A (CLTD)_{corrected}$$

U= Overall heat transfer co efficient in W/m<sup>2</sup>- °C

A= surface area (m<sup>2</sup>)

$$(CLTD)_{corrected} = (CLTD) + (25.5 - T_{i,d,t}) + (T_{o,a,t} - 29.4)$$

Where CLTD = Cooling load temperature difference of walls or roof in ( °C ). It's value is obtained from ASHARE fundamentals handbooks. The value of CLTD is depends up on the type of wall or roof(construction materials), thermal mass, indoor and outdoor temperatures, orientation, daily temperature range , tilt, month, latitude, day hour, solar absorbance, wall out door temperature, wall facing direction and others variables.

T<sub>o,a,t</sub> = outside average temperature (°C)

T<sub>i,d,t</sub> = inside design temperature (°C)

#### **Heat Gain due to Partitions, Ceilings and Floors:-**

Whenever adjacent space temperature is different than the conditioned space, this factor must be taken into account and is given by

$$Q = U A ( T_A - T_{IDCS} )$$

where,

U = overall heat transfer coefficient between adjacent and conditioned space in

A= Area of partition or ceilings or floor in m<sup>2</sup>.

T<sub>A</sub>= Adjacent space temperature in ° C .

T<sub>IDCS</sub> = Inside design temperature of conditioned space in ° C

**Solar Heat Gain through Glass:-**

Whenever a sheet of glass is exposed to solar radiation, some part of solar radiation is transmitted to the conditioned space (room), some part of radiation is reflected back and remaining part of radiation is absorbed by the glass sheet. The temperature of glass sheet increases due to absorption of solar radiation and it will continue to increase until glass sheet start to pick off the absorbed heat. Due to temperature raise of glass sheet the simultaneous radiation heat transfer occurs between outside surface of glass & heated air particles in the atmosphere. Similarly simultaneous radiation heat transfer also occur between interior surface of glass and various objects in the room due to increase in temperature of glass sheet. In addition to radiant heat transfer, due to air current present on the both side of glass sheet, the convective heat transfer also occurs on both sides of the glass sheet.

The heat load due to glass is considered in two parts; first is due to conduction and second is due to solar heat gain/transmission.

$$Q = A_{\text{Glass}} U (\text{CLTD})_{\text{corrected}} + SC \cdot A_{\text{Glass}} \cdot \text{SHGF} \cdot \text{CLF}$$

where, SC = shading co efficient which depends up on the types of shading (dimensionless)

CLF = cooling load factor .

CLTD = cooling load temperature difference.

$$(\text{CLTD})_{\text{corrected}} = \text{CLTD} + (25.5 - T_{i,d,t}) + (T_{o,a,t} - 29.4)$$

CLTD = Cooling load temperature difference of glass in ( °C ). It's value is obtained from ASHARE fundamentals handbooks. The value of CLTD is depends up on the type of glass(materials), thermal mass, indoor and outdoor temperatures, orientation, daily temperature range, tilt, month, latitude, day hour, solar absorbance, glass out door temperature, glass facing direction and others variables.

$T_{o,a,t}$  = outside average temperature (°C)       $T_{i,d,t}$  = inside design temperature (°C)

SHGF = Maximum solar heat gain factor in  $\text{W/m}^2$ .

Shading Coefficient (SC): It is the ratio of solar energy passing through a glass (due to direct sun light) to the solar energy passing through 3 mm clear float glass. It indicates how glass is insulating the interior space when it is exposed to direct sun light. Smaller value of shading coefficient means better glass window which stop entry of solar heat.

Solar Heat Gain Factor : It indicates the amount of solar energy gain by a clear single pane window at a given time of the year and day which is exposed to specific direction.

Both SHGF and SC value is depends up on the orientation of window, location, month of the year, type of glass and type of shading and is obtained from ASHARE hand books

**Heat gain due to occupant:-**

All person with in a conditioned space given off the heat. Depending up on the activity of a person in a conditioned space, heat produced by each person is vary. With increase in activity of a person in a conditioned space, the value of heat gain increases. The sensible heat rate increases slightly with higher activities of a persons in a conditioned space but latent heat increases greatly due to more perspiration of a persons.

Sensible heat gain from occupant /person in a conditioned space is given by

$$Q_s = q_s \cdot N \cdot \text{CLF}$$

where  $q_s$ = sensible heat gain per person in watt, the value of which is obtained from ASHARE fundamentals according to type of activities of a person, N= total number of persons in a conditioned space.

CLF= Cooling load factor by hours of occupancy to take into account for time lag between occupancy and observed cooling load. The value of which is obtained from ASHARE fundamentals and is equal to 1.0 if 24 hours operation or cooling is done at night time.

**Heat gain due to Electrical lights:-**

Light emitting elements is the main source of heat in case of electrical lights. The electrical light generates a heat. The part of heat released by electrical light is also absorbed by walls, furniture, floor due to radiation and re-release absorbed heat when electrical lights are switched off.

The heat gain due to electrical light is given by equation  
 $Q = W \times \text{light use factor} \times \text{special ballast allowance} \times \text{CLF}$   
 where  $W =$  Total wattage of light  
 $\text{CLF} =$  Cooling load factor

There is a always time lag between heat energy absorbed by walls, furniture, floor etc & re release this heat when electrical light is switch off. To take account this effect heat gain due to electrical light is multiplied by CLF. It's value is depends up on number of hours of occupancy and is available from handbook of ASHARE fundamentals.

Light use factor is the ratio of wattage in use actually to the installed wattage. In case of commercial use like shops, stores and for residential use its value is taken as 1.0., whereas for workshop its value is taken as 0.5.

Generally, special blast allowance is used for fluorescent fixtures(tubes and lamps) and it accounts for ballast losses. It's value is generally taken as 1.25. It is a fraction of total heat that is expected to enter into the conditioned space due to ballast and it subject to time lag effect.

#### Heat gain due to Appliances:-

Heat gain from all appliances such as electric, gas etc should be consider and take in to account while calculating cooling load.

Sensible heat gain due to appliances = Total wattage of appliances  $\times F_u \times F_r \times \text{CLF}$   
 where  $F_u =$  Use factor of appliance. The value of use factor depends up on how much time the appliances and is a the ratio of wattage in use actually to the installed wattage.

$F_r =$  Radiation factor. It's value is available from the handbook of ASHRE fundamentals.  
 $\text{CLF} =$  Cooling load factor. It's value is available from the handbook of ASHRE fundamentals.

#### Heat gain due to Ventilation and Infiltration:-

Ventilation is a introduction of outside air in a conditioned space in order to keep interior building air circulating and to maintain high indoor air quality. It includes both the exchange of air to the outside as well as inside the buildings. It is necessary to remove excessive moisture, odour, dust, carbon dioxide, air borne bacteria from inside the buildings. The heat load due to ventilation is calculated in the same manner as calculated in infiltration.

The infiltration results from the leakages of outside air into building through cracks around doors, windows, walls, partitions and through door opening. It's magnitude is depends on length & width of the cracks, wind velocity & its direction and difference in densities between inside and outside air. It is caused by pressure difference between inside and outside windows & doors. Exfiltration (outward air leakage) occurs when pressure inside the conditioned space is higher than outside. The lost air must be replaced by outside air (infiltration).

The infiltration of air can be calculated by

1. Crack length method
2. Air Change method
3. Crack length method : This method calculate the volume of infiltrate air per metre of crack length. It is more convenient to use crack length method for windows than doors.

The air flow may be found by  
 $\text{CMH} = \text{CMH per meter} \times \text{meter of crack}$   
 where  $\text{CMH} =$  Airflow in  $\text{m}^3/\text{hr}$ .

Air Change Method :The air infiltration in this method is based on volume of the room/conditioned space. It is given by the number of times the air changes to fill the conditioned space/ room. It is arbitrary method and used only when it is not possible to use crank length due to uncertainty of crank length. It is convenient method to use in case of doors, for reception halls, entrance hall of home where air change is very frequent.

Air flow is calculated by  
 $\text{CMH} = \text{L.B.H.A}_{\text{CH}}$

where CMH= air flow in m<sup>3</sup>/hr, L= Length of Room in m, B= Breadth of Room in m, H= Height of Room in m, A<sub>cH</sub> = Air changes per hour. Normally the value of A<sub>cH</sub> varies from 0.5 for tight and well sealed building to 2.0 for loose and poorly sealed buildings. Depending up on the age and condition a suitable value of A<sub>cH</sub> has to be chosen.

#### **Sensible Heat load due to Ventilation and Infiltration:-**

The direct heat addition to the enclosed space is called sensible heat gain and addition of water vapour to the enclosed space's air is called latent heat gain. Both sensible and latent heat transfer occurs due to infiltration.

Sensible heat load due to ventilation and infiltration is calculated as follows.

$$Q_{\text{sensible}} = c \cdot w \cdot \text{CMH} \cdot (t_i - t_o)$$

where  $Q_{\text{sensible}}$  = Sensible heating load in Watt,  $c$  = specific heat of dry air which is equal to 0.24 in KJ/Kg ° K,  $w$  = specific weight of air which is equal to 1.2 in kg/m<sup>3</sup>, CMH = Air flow in m<sup>3</sup>/hr,  $t_i$  = indoor air temperature in ° K,  $t_o$  = outdoor air temperature in ° K

#### **Latent Heat Gain:-**

It is associated with increase in moisture content in a confined space. It includes latent heat produced by occupant in a confined space, from cooking, hot baths, latent heat from outside air through ventilation and infiltration etc.

#### **Latent heat load due to Ventilation and infiltration:-**

Latent heat load due to infiltration is given by

$$Q_{\text{Latent}} = h_v \cdot w \cdot \text{CMH} (X_i - X_o)$$

where,  $Q_{\text{Latent}}$  = Latent heating load in Watt,  $h_v$  = Latent heat of vaporisation of water at 0 ° C which is equal to 597 in KJ/Kg, CMH = air flow in m<sup>3</sup>/hour.

$w$  = specific weight of air which is equal to 1.2 in Kg/m<sup>3</sup>,  $X_i$  = indoor room humidity ratio of indoor air in Kg/Kg<sub>da</sub>,  $X_o$  = outdoor room humidity ratio of outdoor air in Kg/Kg<sub>da</sub>

#### **Latent heat gain due to occupants:-**

The latent heat gain results when people exhale in a conditioned space and due to perspiration of persons when they do number of activities in a conditioned space.

Latent heat gain due to occupants/ person in a conditioned space is given by

$$Q_L = q_L \cdot N$$

where  $q_L$  = Latent heat gain/person in watt. The Value of which is obtained from ASHARE fundamentals 1997 and is depends on the types of activities carried out by a person in a conditioned space.

$N$  = Total number of occupant in a confined space.

The sensible heat rate increases slightly with higher activities of a persons in a conditioned space but latent heat increases greatly due to more perspiration of a persons.

#### **Latent heat gain due to appliances:-**

Depends up on the functions performed by appliances such as drying, cooking etc latent heat produced by the appliances vary. Combustion product produced by gas appliances should be considerably reduced by properly design exhaust system.

Latent heat gain due to appliances = Total installed wattage of appliances x Appliances Usage factor

Appliances use factor is the ratio of wattage in use actually to the installed wattage.

#### **Total Cooling Loads Estimation on Air conditioning System:-**

Total load consists of sum of total sensible heat gain and total latent heat gain.

Total Heat gain of Room = Total sensible heat gain of room + Total Latent heat gain of room.

Total Sensible Heat gain of room : It is the sum of all type of sensible heat gain in a confined space.

Total Sensible heat gain of room = Sensible heat gain due to walls, floor and ceiling + Sensible heat gain due to occupant + Sensible Heat Gain due to infiltration of air + Sensible heat gain due to ventilation + Sensible heat gain due to lights and fans

Total Latent Heat Gain:-

It consist of sum of all latent heat gain in a confined space.

Total latent heat gain = Latent heat gain due to ventilation + Latent heat gain due to infiltration+ Latent heat gain from occupant + Latent heat gain due to electric and electronic appliances

### **Conclusion:-**

The CLTD/CLF method of calculating cooling load is used for all zones and is very popular since the publication of ASHRAE cooling and heating load calculation manual. In this method the overall heat transfer coefficient for different component of building is calculated with the help of thermal properties of materials. The CLTD/CLF method of calculating cooling load considered all parameters which affect the indoor conditioned space and research shows that it gives very reliable results which is almost same as calculated by software developed by well known company. Based on calculation of cooling load, the capacity of an A.C unit is decided to meet the indoor comfort condition. The Air conditioned selected in this way is proper size, efficient and consumes less energy .

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