Cooling load and heating load principle

١-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.

This course provides a procedure for preparing a manual calculation for cooling load. A number of published methods, tables and charts from industry handbooks, manufacturer's engineering data and manufacturer's catalog data usually provide a good source of design information and criteria in the preparation of the HVAC load calculation. It is not the intent of this course to duplicate this information but rather to extract appropriate data from these documents as well as provide a direction regarding the proper use or application of such data so that engineers and designers involved in preparing the calculations can make the appropriate decision and/or apply proper engineering judgment.

The course includes two example calculations for better understanding of the subject.

used terms relative to heat transmission and load calculations are defined below in accordance with ASHRAE Standard ١٢-٧٥, Refrigeration Terms and Definitions.

٢-TERMONINOLOGY

Space - is either a volume or a site without a partition or a partitioned room or group of rooms.

Room - is an enclosed or partitioned space that is usually treated as single load.

Zone - is a space or group of spaces within a building with heating and/or cooling requirements sufficiently similar so that comfort conditions can be maintained throughout by a single controlling device.

British thermal unit (Btu) - is the approximate heat required to raise ١ lb. of water ١ deg Fahrenheit, from ٥٩ F to ٦٠ F. Air conditioners are rated by the number of British Thermal Units (Btu) of heat they can remove per hour. Another common rating term for air conditioning size is the "ton," which is ١٢,٠٠٠ Btu per hour and Watts. Some countries utilize one unit, more than the others and therefore it is good if you can remember the relationship
between *BTU/hr*, *Ton*, and *Watts*.

- ١ ton is equivalent to ١٢,٠٠٠ BTU/hr. and
- ١٢,٠٠٠ BTU/hr is equivalent to ٣,٥١٦ Watts - or ٣.٥١٦ kW (kilo-Watts).

Cooling Load Temperature Difference (CLTD) - an equivalent temperature difference used for calculating the instantaneous external cooling load across a wall or roof.

Cooling Load Temperature Difference (CLTD) - an equivalent temperature difference used for calculating the instantaneous external cooling load across a wall or roof.

Sensible Heat Gain - is the energy added to the space by conduction, convection and/or radiation.

Latent Heat Gain - is the energy added to the space when moisture is added to the space by means of vapor emitted by the occupants, generated by a process or through air infiltration from outside or adjacent areas.

Radiant Heat Gain - the rate at which heat absorbed is by the surfaces enclosing the space and the objects within the space

.

Space Heat Gain - is the rate at which heat enters into and/or is generated within the conditioned space during a given time interval.

Space Cooling Load - is the rate at which energy must be removed from a space to maintain a constant space air temperature

.

Space Heat Extraction Rate - the rate at which heat is removed from the conditioned space and is equal to the space cooling load if the room temperature remains constant.

Temperature, Dry Bulb - is the temperature of air indicated by a regular thermometer.

Temperature, Wet Bulb - is the temperature measured by a thermometer that has a bulb wrapped in wet cloth. The evaporation of water from the thermometer has a cooling effect, so the temperature indicated by the wet bulb thermometer is less than the temperature indicated by a dry-bulb (normal, unmodified) thermometer. The rate of evaporation from the wet-bulb thermometer depends on the humidity of the air. Evaporation is slower when the air is already full of water vapor. For this reason, the difference in the temperatures indicated by ordinary dry bulb and wet bulb thermometers gives a measure of atmospheric humidity

Temperature, Dewpoint - is the temperature to which air must be cooled in order to reach saturation or at which the condensation of water vapor in a space begins for a given state of humidity and pressure.

Relative humidity - describes how far the air is from saturation. It is a useful term for expressing the amount of water vapor when discussing the amount and rate of evaporation. One way to approach saturation, a relative humidity of ١٠٠%, is to cool the air. It is therefore useful to know how much the air needs to be cooled to reach saturation

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٣- SIZING YOUR AIR-CONDITIONING SYSTEM

Concepts and fundamentals of air conditioner sizing is based on heat gain, and/or losses in a building. It is obvious that you will need to *remove* the amount of heat gain - if it is hot outside. Similarly, you'll need to *add in* the heat loss from your space - if outside temperature is cold. In short, heat gain and loss, must be *equally* balanced by heat removal, and addition, to get the desired room comfort that we want.

The heat gain or heat loss through a building depends on:

a. The temperature difference between outside temperature and our desired temperature.

b. The type of construction and the amount of insulation is in your ceiling and walls. Let's say, that you have two identical buildings, one is build out of glass, and the other out of brick. Of course the one built with glass would require much more heat addition, or removal, compared to the other - given a same day. This is because the glass has a high thermal conductivity (U-value) as compared to the brick and also because it is transparent, it allows direct transmission of solar heat

.

c. How much shade is on your building's windows, walls, and roof? Two identical buildings with different orientation with respect to the direction of sun rise and fall will also influence the air conditioner sizing.

d. How large is your room? The surface area of the walls. The larger the surface area - the more heat can loose, or gain through it

e. How much air leaks into indoor space from the outside? Infiltration plays a part in determining our air conditioner sizing. Door gaps, cracked windows, chimneys - are the "doorways" for air to enter from outside, into your living space

f. The occupants. It takes a lot to cool a town hall full of people.

.

g. Activities and other equipment within a building. Cooking? Hot bath? Gymnasium?

h. Amount of lighting in the room. High efficiency lighting fixtures generate less heat.

i .How much heat the appliances generate. Number of power equipments such as oven, washing machine, computers, TV inside the space; all contribute to heat.

The air conditioner's efficiency, performance, durability, and cost depend on matching its size to the above factors. Many designers use a simple square foot method for sizing the air-conditioners. The most common rule of thumb is to use "١ ton for every ٥٠٠ square feet of floor area". Such a method is useful in preliminary estimation of the equipment size. The main drawback of rules-of-thumb methods is the presumption that the building design will not make any difference. Thus the rules for a badly designed building are typically the same as for a good design.

It is important to use the correct procedure for estimating heat gain or heat loss. Two groups—the Air Conditioning Contractors of America (ACCA) and the American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE)—publish calculation procedures for sizing central air conditioners.

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٣.١ Heating Load V/s Cooling Load Calculations

the name implies, heating load calculations are carried out to estimate the heat loss from the building in winter so as to arrive at required heating capacities. Normally during winter months the peak heating load occurs before sunrise and the outdoor conditions do not vary significantly throughout the winter season. In addition, internal heat sources such as occupants or appliances are beneficial as they compensate some of the heat losses. As a result, normally, the heat load calculations are carried out assuming steady state conditions (no solar radiation and steady outdoor conditions) and neglecting internal heat sources. This is a simple but conservative approach that leads to slight overestimation of the heating capacity. For more accurate estimation of heating loads, one has to take into account the thermal capacity of the walls and internal heat sources, which makes the problem more complicated. For estimating cooling loads, one has to consider the unsteady state processes, as the peak cooling load occurs during the day time and the outside conditions also vary significantly throughout the day due to solar radiation. In addition, all internal sources add on to the cooling loads and neglecting them would lead to underestimation of the required cooling capacity and the possibility of not being able to maintain the required indoor conditions. Thus cooling load calculations are inherently more complicated.

In determining the heating load, credit for solar heat gain or internal heat gains is usually not included and the thermal storage effects of building structure are generally ignored. Whereas in cooling load calculations the thermal storage characteristics of the building play a vital role because the time at which the space may realize the heat gain as a cooling load will be considerably offset from the time the heat started to flow

٤- HEAT FLOW RATES

In air-conditioning design, four related heat flow rates, each of which varies with time, must be differentiated:

a. Space heat gain ----------------How much heat (energy) is entering the space?

b. Space cooling load -------------How much energy must be removed from the space to keep temperature and relative humidity constant?

c. Space heat extraction-----------How much energy is the HVAC removing from the space?

d. Cooling load (coil) ---------------How much energy is removed by the cooling coil serving various spaces plus any loads external to the spaces such as duct heat gain, duct leakage, fan heat and outdoor makeup air?

٤.١ Space Heat Gain

This instantaneous rate of heat gain is the rate at which heat enters into and/or is generated within a space at a given instant. Heat gain is classified by:

The manner in which it enters the space -

a. Solar radiation through transparent surfaces such as windows
b. Heat conduction through exterior walls and roofs
c. Heat conduction through interior partitions, ceilings and floors
d. Heat generated within the space by occupants, lights, appliances, equipment and processes
e. Loads as a result of ventilation and infiltration of outdoor air
f. Other miscellaneous heat gains

whether it is a sensible or latent gain -

Sensible heat - Heat which a substance absorbs, and while its temperature goes up, the substance does not change state. Sensible heat gain is directly added to the conditioned space by conduction, convection, and/or radiation. Note that the sensible heat gain entering the conditioned space does not equal the sensible cooling load during the same time interval because of the stored heat in the building envelope. Only the convective heat becomes cooling load instantaneously. Sensible heat load is total of

a. Heat transmitted thru floors, ceilings, walls
b. Occupant's body heat
c. Appliance & Light heat
d. Solar Heat gain thru glass
e. Infiltration of outside air
f. Air introduced by Ventilation

Latent Heat Loads - Latent heat gain occurs when moisture is added to the space either from internal sources (e.g. vapor emitted by occupants and equipment) or from outdoor air as a result of infiltration or ventilation to maintain proper indoor air quality. Latent heat load is total of

a. Moisture-laden outside air form Infiltration & Ventilation
b. Occupant Respiration & Activities
c. Moisture from Equipment & Appliances

To maintain a constant humidity ratio, water vapor must condense on cooling apparatus at a rate equal to its rate of addition into the space. This process is called dehumidification and is very energy intensive, for instance, removing ١ kg of humidity requires approximately ٠.٧ kWh of energy

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٤.٢ Space Heat Gain V/s Cooling Load (Heat Storage Effect)

Space Heat Gain is ≠ to 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.

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.

٤.٣ Space Cooling V/s Cooling Load (Coil)

Space cooling is the rate at which heat must be removed from the spaces to maintain air temperature at a constant value. Cooling load, on the other hand, is the rate at which energy is removed at the cooling coil that serves one or more conditioned spaces in any central air conditioning system. It is equal to the instantaneous sum of the space cooling loads for all spaces served by the system plus any additional load imposed on the system external to the conditioned spaces items such as fan energy, fan location, duct heat gain, duct leakage, heat extraction lighting systems and type of return air systems all affect component sizing.

٤.٤ 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. 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.

٦. COOLING LOAD CALCULATION METHOD

For a thorough calculation of the zones and whole-building loads, one of the following three methods should be employed:

a. Transfer Function Method (TFM): This is the most complex of the methods proposed by ASHRAE and requires the use of a computer program or advanced spreadsheet

b. Cooling Load Temperature Differential/Cooling Load Factors (CLTD/CLF): This method is derived from the TFM method and uses tabulated data to simplify the calculation process. The method can be fairly easily transferred into simple spreadsheet programs but has some limitations due to the use of tabulated data.

c. Total Equivalent Temperature Differential/Time-Averaging (TETD/TA): This was the preferred method for hand or simple spreadsheet calculation before the introduction of the CLTD/CLF method.

These three methods are well documented in ASHRAE Handbook Fundamentals, ٢٠٠١

٦.١ Accuracy and Reliability of Various Calculation Methods

For each cooling load calculation method, there are several benefits/limitations which feature each method. Simplicity and accuracy are two contradicting objectives to be fulfilled. 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

equipment).
Handbooks include tables for the heat gain estimations from the internal sources. However, such tables are incomplete. For example, for equipment not mentioned in the tables, only limited information is indicated about them. Sometimes recommendations are mentioned about using ٢٥% to ٥٠% of the nameplate power consumption, where the final value is left to the interpretation of the designer. In other times it is the accurate predictability of the occurrence is also important, e.g. the frequency of using of equipment is very important to determine the heat gain. This example for internal heat gain shows that, when thinking about accuracy, it is not only the method (simple vs. complex) which is effective, but uncertainties in the input data are also important.
There are high degrees of uncertainty in input data required to determine cooling loads. Much of this is due to the unpredictability of occupancy, human behavior, outdoors 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 the more complex calculation methods would not be productive in terms of better accuracy of the results if uncertainties in the input data are high. Otherwise, simplified methods would, likely, have a similar level of satisfactory accuracy For strictly manual cooling load calculation method, the most practical to use is the CLTD/SCL/CLF method as described in the ١٩٩٧ ASHRAE Fundamentals

. This method, although not optimum, will yield the most conservative results based on peak load values to be used in sizing equipment. It should be noted that the results obtained from using the CLTD/CLF method depend largely on the characteristics of the space being considered and how they vary from the model used to generate the CLTD/CLF data shown on the various tables. Engineering judgment is required in the interpretation of the custom tables and applying appropriate correction factors

٧. 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.

٧.١ Outdoor Design Weather Conditions

The information provided in table ١a, ٢a and ٣a are(chapter ٢٦)ashrae hand book for heating design conditions that include:

a. Dry bulb temperatures corresponding to ٩٩.٦% and ٩٩% annual cumulative frequency of occurrence

b. Wind speeds corresponding to ١%, ٢.٥% and ٥% annual cumulative frequency of occurrence,

c. Wind direction most frequently occurring with ٩٩.٦% and ٠.٤% dry-bulb temperatures and

d. Average of annual extreme maximum and minimum dry-bulb temperatures and standard deviations.

The information provided in table ١b, ٢b and ٣b are for <u>cooling and humidity control conditions</u> that include:

a. Dry bulb temperature corresponding to ٠.٤%, ١.٠% and ٢.٠% annual cumulative frequency of occurrence and the mean coincident wet-bulb temperature (warm). These conditions appear in sets of dry bulb (DB)

temperature and the mean coincident wet bulb (MWB) temperature since both values are needed to determine the sensible and latent (dehumidification) loads in the cooling mode.

b. Wet-bulb temperature corresponding to ٠.٤%, ١.٠% and ٢.٠% annual cumulative frequency of occurrence and the mean coincident dry-bulb temperature

c. Dew-point temperature corresponding to ٠.٤%, ١.٠% and ٢.٠% annual cumulative frequency of occurrence and the mean coincident dry-bulb temperature and humidity ratio (calculated for the dew-point temperature at the standard atmospheric pressure at the elevation of the station).

d. Mean daily range (DR) of the dry bulb temperature, which is the mean of the temperature difference between daily maximum and minimum temperatures for the warmest month (highest average dry-bulb temperature). These are used to correct CLTD values

In choosing the HVAC outdoor design conditions, it is neither economical nor practical to design equipment either for the annual hottest temperature or annual minimum temperature, since the peak or the lowest temperatures may occur only for a few hours over the span of several years. Economically speaking short duration peaks above the system capacity might be tolerated at significant reductions in first cost; this is a simple risk - benefit decision for each building design

Therefore, as a practice, the 'design temperature and humidity' conditions are based on frequency of occurrence. The summer design conditions have been presented for annual percentile values of ٠.٤, ١ and ٢% and winter month conditions are based on annual percentiles of ٩٩.٦ and ٩٩%. The term "design condition" refers to the %age of time in a year (٨٧٦٠ hours), the values of dry-bulb, dew-point and wet-bulb temperature exceed by the indicated percentage. The ٠.٤%, ١.٠%, ٢.٠% and ٥.٠% values are exceeded on average by ٣٥, ٨٨, ١٧٥ and ٤٣٨ hours

The ٩٩% and ٩٩.٦% cold values are defined in the same way but are viewed as the values for which the corresponding weather element are less than the design condition ٨٨ and ٣٥ hours, respectively. ٩٩.٦% value suggests that the outdoor temperature is equal to or lower than design data ٠.٤% of the time.

Design condition is used to calculate maximum heat gain and maximum heat loss of the building. For comfort cooling, use of the ٢.٥% occurrence and for heating use of ٩٩% values is recommended. The ٢.٥% design condition means that the outside summer temperature and coincident air moisture content will be exceeded only

. ٢.٥% of hours from June to September or ٧٣ out of ٢٩٢٨ hours (of these summer months) i.e. ٢.٥% of the time in a year, the outdoor air temperature will be above the design condition.

Note, in energy use calculations, hour-by-hour outdoor climate data of a design day should be adopted instead of summer and winter design values.

٧.٢ Indoor Design Conditions and Thermal Comfort

The indoor design conditions are directly related to human comfort. Current comfort standards, ASHRAE Standard ٥٥-١٩٩٢ [٤] and ISO Standard ٧٧٣٠ [٥], specify a "comfort zone," representing the optimal range and combinations of thermal factors (air temperature, radiant temperature, air velocity, humidity) and personal factors (clothing and activity level) with which at least ٨٠% of the building occupants are expected to express satisfaction. The environmental factors that affect the thermal comfort of the occupants in an air-conditioned space are mainly:

a. Metabolic rate, expressed in met (١ met = ١٨.٤٦ Btu/hr.ft^{٢}) determines the amount of heat that must be released from the human body and it depends mainly on the intensity of the physical activity.

b. *Indoor air temperature* (T_r) and *mean radiant temperature* (T_{rad}), both in °F. T_r affects both the sensible and evaporative losses, and T_{rad} affects only sensible heat exchange.

c. Relative humidity of the indoor air in %, which is the primary factor that influences evaporative heat loss.

d. Air velocity of the indoor air in fpm, which affects the heat transfer coefficients and therefore the sensible heat exchange and evaporative loss.

e. *Clothing insulation* in clo (١ clo = ٠.٨٨ h.ft .°F/Btu), affects the sensible heat loss. Clothing insulation for occupants is typically ٠.٦ clo in summer and ٠.٨ to ١.٢ clo in winter

For comfort air-conditioning systems, according to ANSI/ASHRAE Standard ٥٥-١٩٩٢ and ٩٠.١-١٩٨٩, the following indoor design temperatures and air velocities apply for conditioned spaces where the occupant's activity level is ١.٢ met, indoor space relative humidity is ٥٠% (in summer only), and $T_r = T_{rad}$

:

	Clothing Insulation col	**Indoor Temperature (°F)**	**Air Velocity (fpm)**
winter	٠.٨-٠.٩	٦٩-٧٤	< ٣٠
summer	٠.٥-٠.٦	٧٣-٧٩	< ٥٠

If a suit jacket is the clothing during summer for occupants, the summer indoor design temperature should be dropped to ٧٤ to ٧٥°F.

٧.٣ Indoor Air Quality and Outdoor Air Requirements

According to the National Institute for Occupational Safety and Health (NIOSH), ١٩٨٩, the causes of indoor air quality complaints in buildings are inadequate outdoor ventilation air. There are three basic means of improving indoor air quality: (١) eliminate or reduce the source of air pollution, (٢) enhance the efficiency of air filtration, and (٣) increase the ventilation (outdoor) air intake

Abridged outdoor air requirements listed in ANSI/ASHRAE Standard ٦٢-١٩٨٩ are as follows:

Applications	Cfm/person
Offices, conference rooms, offices	٢٠
Retail Stores	٠.٢-٠.٣ cfm/ft ٢
Classrooms, theaters, auditoriums	١٥
Hospitals patient rooms	٢٥

These ventilation requirements are based on the analysis of dilution of CO ٢ as the representative human bio- effluent. As per ASHRAE standard ٦٢-١٩٩٩, comfort criteria with respect to human bio-effluents is likely to be satisfied, if the indoor carbon dioxide concentrations remain within ٧٠٠ ppm above the outdoor air carbon dioxide concentration.

Refer to ANSI/ASHRAE Standard ٦٢-١٩٩٩ for details.

٧.٤ 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 ٠.٠٢ to ٠.٠٥ inch-WG. WG indicates the pressure at the bottom of a top-opened water column of specific inches of height; ١ in -WG = ٠.٠٣٦١٢ psig

٧.٥ bullding character

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

٧.٦ Operation scheduler

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

٨. COOLING LOAD METHODOLOGY - CONSIDERATIONS & ASSUMPTIONS

Design cooling load takes into account all the loads experienced by a building under a specific set of assumed conditions. The assumptions behind design cooling load are as follows:

a. Weather conditions are selected from a long-term statistical database. The conditions will not necessary represent any actual year, but are representative of the location of the building. ASHRAE has tabulated .

b. The solar loads on the building are assumed to be those that would occur on a clear day in the month chosen for the calculations

c. The building occupancy is assumed to be at full design capacity

d. The ventilation rates are either assumed on air changes or based on maximum occupancy expected.

e. All building equipment and appliances are considered to be operating at a reasonably representative capacity.

f. Lights and appliances are assumed to be operating as expected for a typical day of design occupancy.

g. Latent as well as sensible loads are considered.

h. Heat flow is analyzed assuming dynamic conditions, which means that heat storage in building envelope and interior materials is considered.

i. 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 regulations, the sensible heat gain from people is assumed ٣٠% convection (instant cooling load) and ٧٠% irradiative (delayed portion).

j. **Peak load** calculations evaluate the maximum load to size and select the refrigeration equipment. The energy analysis program compares the total energy use in a certain period with various alternatives in order to determine the optimum one.

.k. **Space (zone) cooling load** is used to calculate the supply volume flow rate and to determine the size of the air system, ducts, terminals, and diffusers. The coil load is used to determine the size of the cooling coil and the refrigeration system. Space cooling load is a component of the cooling coil load.

l. The heat transfer due to ventilation is not a load on the building but a load on the system.

٨.١ Thermal Zoning

Thermal zoning is a method of designing and controlling the HVAC system so that occupied areas can be maintained at a different temperature than unoccupied areas using independent setback thermostats. A zone is defined as a space or group of spaces in a building having similar heating and cooling requirements throughout its occupied area so that comfort conditions may be controlled by a single thermostat When doing the cooling load calculations, always divide the building into zones. Always estimate the building peak load and individual zones airflow rate. The building peak load is used for sizing the refrigeration capacity and the individual zone loads are helpful in estimating the airflow rates (air-handling unit capacity). In practice the corner rooms and the perimetric spaces of the building have variations in load as compared to the interior core areas. The following facts may be noted:

a) The buildings are usually divided into two major zones.

- Exterior Zone: The area inward from the outside wall (usually ١٢ to ١٨ feet, if rooms do not line the outside wall). The exterior zone is directly affected by outdoor conditions during summer and winter.
- Interior Zone: The area contained by the external zone. The interior zone is only slightly affected by outdoor conditions and usually has a uniform cooling.

b) Single-zone models shall be limited to open floor plans with perimeter walls not exceeding ٤٠ feet in length.

c) For large building footprints, assume a minimum of five zones per floor: one zone for each exposure north, south, east & west) and an interior zone.

٩. CLTD/SCL/CLF METHOD OF LOAD CALCULATION (ASHRAE FUNDAMENTALS ١٩٩٧)

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 (١) time-lag in conductive heat gain through opaque exterior surfaces and (٢) 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, tilt, 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

٩.١ External Cooling Load

As discussed before, the total cooling load on a building consists of external as well as internal loads. The external loads consist of heat transfer by conduction through the building walls, roof, floor, doors etc, heat transfer by radiation through fenestration such as windows and skylights. All these are sensible heat transfers

٩.١.١ Roof

The basic conduction equation for heat gain is $q = U\,A\,\Delta T$.

Where

- q = Heat gain in Btu/hr
- U = Thermal Transmittance for roof in Btu/hr.ft².°F
- A = area of roof in ft

ΔT = Temperature difference in °F

The heat gain is converted to cooling load using the room transfer functions (sol-air temperature) for the rooms with light, medium and heavy thermal characteristics. The equation is modified as

$Q = U * A * (CLTD)$

Where

- Q = cooling load, Btu/hr
- U = Coefficient of heat transfer roof or wall or glass, Btu/hr.ft².°F

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٩.١.٢ Wall

The cooling load from walls is treated in a similar way as roof:

Q_{Wall} = U * A * CLTD

Where

Q= Load through the walls in Btu/hr

U = Thermal Transmittance for walls in Btu/ (h ft F)

A=area of the wall

CLTD = Cooling Load Temperature Difference for walls in °

٩.١.٣ SOLAR LOAD THROUGH GLASS

Solar load through glass has two components: ١) Conductive and ٢) Solar Transmission

The absorbed and then conductive portion of the radiation through the windows is treated like the roof & walls where CLTD values for standard glazing are tabulated in ASHARE fundamentals handbook. For solar transmission, the cooling load is calculated by the cooling load SCL factor and shading coefficient

(SC).

Conductivity: Q_{glass} =U* A* CLTD

Solar transition Q_{glass}= A*SC*SCL

Where

$Q_{conductivity}$= Conductive load through the glass in Btu/hr

Q solar= Solar transmission load through the glass in Btu/hr

U = Thermal Transmittance for glass in Btu/ (h ft F٢)

A = area of glass in ft

CLTD= Cooling Load Temperature Difference for glass in °F

SC = Shading coefficient

SCL = Solar Cooling Load Factor

٩.٢ Internal cooling load

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.

CLF = Q cooling load / Q internal gains

٩.٢.١ Peopl

Q sensible=N (Qs) CLF

Q Latent=N (QL)

- N = number of people in space from ASHRAE, Table A٢٨-٣
- Q_S, Q_L = Sensible and Latent heat gain from occupancy is given in ١٩٩٧ ASHRAE Fundamentals Chapter ٢٨, Table ٣)
- CLF = Cooling Load Factor, by hour of occupancy. See ١٩٩٧ ASHRAE Fundamentals, Chapter ٢٨, Table ٣٧

٩.٢.٢ Light

The primary source of heat from lighting comes from light-emitting elements. Calculation of this load component is not straightforward; the rate of heat gain at any given moment can be quite different from the heat equivalent of power supplied instantaneously to those lights. Only part of the energy from lights is in the form of convective heat, which is picked up instantaneously by the air-conditioning apparatus. The remaining portion is in the form of radiation, which affects the conditioned space only after having been absorbed and re-released by walls, floors, furniture, etc. This absorbed energy contributes to space cooling load only after a time lag, with some part of such energy still present and reradiating after the lights have been switched off Generally, the instantaneous rate of heat gain from electric lighting may be calculated from

Q = ٣.٤١ x W x F_{UT} x F_{SA}

Cooling load factors are used to convert instantaneous heat gain from lighting to the sensible cooling load; thus the equation is modified to

Q = ٣.٤١ x W x F_{UT} x F_{SA} x (CLF)

W = Watts input from electrical lighting plan or lighting load data

F_{ut}= Lighting use factor, as appropriate

F_{sa}= special ballast allowance factor, as appropriate

CLF = Cooling Load Factor, by hour of occupancy. See ١٩٩٧ ASHRAE Fundamentals, Chapter ٢٨,

٩.٢.٥ Infiltration Air

. Qs= ١.٠٨ x CFM x (To - Ti)

$QL= ٤٨٤٠ \times CFM \times (Wo - Wi)$
$QT= ٤.٥ \times CFM \times (ho - hi)$

Where:

CFM = Infiltration air flow rate. See ١٩٩٧ ASHRAE Fundamentals, Chapter ٢٥, for determining Infiltration

- To, Ti = Outside/Inside dry bulb temperature, °F
- Wo , Wi = Outside/Inside humidity ratio, lb water/lb dry air
- ho, hi = Outside/Inside air enthalpy, Btu per lb (dry air)

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Also there some heat gain from Miscellaneous source

.١- Supply Fan Heat Load

$Q = ٢٥٤٥ \times [P / (Eff_{١} \times Eff_{٢})]$

- P = Horsepower rating from electrical power plans or manufacturer's data
- ٢٥٤٥ = conversion factor for converting horsepower to Btu per hour
- $Eff_{١}$ = Full load motor and drive efficiency
- $Eff_{٢}$ = Fan static efficiency

٢-vintilation

Air is the amount of outdoor air required to makeup for air leaving the space due to equipment Exhaust, infiltration and/or as required to maintain Indoor Air Quality for the occupants. (See ASHRAE Standard ٦٢ for minimum ventilation requirements). The heat is usually added to the air stream before the cooling coil and has no direct impact on the space conditions. The additional cooling coil load is calculated

as follows:

$Q_{sensible} = ١.٠٨ \times CFM \times (T_{O} - T_{C})$

$Q_{latent} = ٤٨٤٠ \times CFM \times (W_{O} - W_{C})$

$Q_{total} = ٤.٥ \times CFM \times (h_{O} - h_{C})$

Where

- CFM = Ventilation airflow rate.

- T_o = Outside dry bulb temperature, °F
- T_c = Dry bulb temperature of air leaving the cooling coil, °F
- W_o = Outside humidity ratio, lb (water) per lb (dry air)
- W_c = Humidity ratio of air leaving the cooling coil, lb (water) per lb (dry air)
- h_o = Outside/Inside air enthalpy, Btu per lb (dry air)
- h_c = Enthalpy of air leaving the cooling coil Btu per lb (dry air)

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Cooling load and heating load principle

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