Cooling Load Estimation using CLF/CLTD/SCL Method: A Review

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Abstract— This paper presents the CLF/CLTD method that indicates scope and potential of evaporative cooling systems for replacement of high power consuming air conditioners, partially or completely for maintaining thermal comfort in various climatic locations without compromising the indoor air quantity .This paper applied the method to the Jabalpur city characterized by different climatic conditions over entire month of the years. The calculation procedure of this article examine the possibility of space conditioning the interiors of a Assembly Hall building in Jabalpur Engineering Collage , Jabalpur using evaporative cooling in the summer month of April ,May ,June .The calculation procedure for cooling loads due to solar radiation transmitted through fenestration was used with a new factor ,the solar cooling load (SCL) which is more accurate and easier to use .

Key words: CLF/CLTD METHOD, Evaporative Cooling, Air conditioning

I. INTRODUCTION

Evaporative cooling is obtained during the process of adiabatic saturation .It is a process of the removal of sensible heat from air and an equivalent addition of latent heat into it in the form of added water vapour.

This type of cooling is commonly used when the outdoor conditions are very dry this means that the wet bulb depression of air is very large .In a dry climate the evaporative cooling can give some relief by removing the sensible heat from the room .Compared with the vapour compression system the evaporation cooling system is the large quantity of air that must e supplied to meet the room sensible heat load as the temperature difference between the room and the supply air is generally small. Thus whereas in air conditioning , the supply air quantity may be of the order of 8-10 air changes per hour (ACT) , in case of evaporative cooling the ACH of the order of 20 air changes , the quantity increases rapidly as the humidifying efficiency of the air washes decreases. The cooling load temperature difference cooling load factor (CLTD/CLF)method has been a popular method for performing cooling load calculation since the publication of ASHRAE the cooling and heating load calculation manual (ASHRAE 2011) originally developed as a hand calculation technique, it was constrained to use some approximations that resulted in the significant in accuracies under some conditions .The Hand book revealed some limitations of the applicability of the CLTD/CLF method factors given in the ASHRAE Handbook of fundamentals the research revealed that the factors not taken into account in the original work could significantly affect the results.

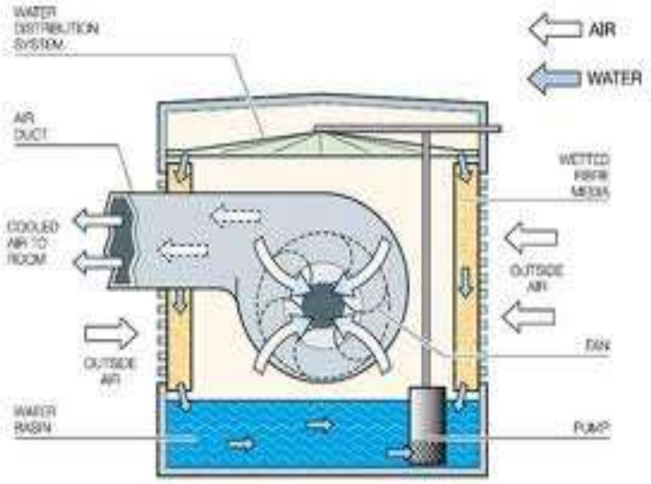

Fig. 1: Evaporative Cooling Mechanism

II. COOLING LOAD CALCULATION METHOD:

The selection of heating, ventilating, and air conditioning (HVAC) system components and equipment should always be based on an accurate determination of the building heating and cooling loads. During this present study it estimate the cooling loads for a single space in a single story assembly hall in the ground floor. The purpose of this study is intended to introduce the concepts of estimating building cooling loads with the help of, The Cooling Load Temperature Difference/Solar Cooling Load/Cooling Load Factor (CLTD/SCL/CLF) load estimation method[11], is a simplified hand calculation procedure developed long ago by ASHRAE. Because of its simplicity, it is the most common method used for basic instruction on estimating cooling loads. The space cooling load is the rate at which heat must be removed from a space in order to maintain the desired conditions in the space, generally a dry-bulb temperature and relative humidity. The cooling load for a space can be made up of many components, including:

1) Conduction heat gain from outdoors through the roof, exterior walls, skylights, and windows. (This includes the effects of the sun shining on these exterior surfaces.)
2) Solar radiation heat gain through skylights and windows.
3) Conduction heat gain from adjoining spaces through the ceiling, interior partition walls, and floor.
4) Internal heat gains due to people, lights, appliances, and equipment in the space.
5) Heat gain due to hot, humid air infiltrating into the space from outdoors through doors, windows, and small cracks in the building envelope.

In addition, the cooling coil in the building HVAC system has to handle other components of the total building cooling load, including:

6) f. Heat gain due to outdoor air deliberately brought into the building for ventilation purposes.
7) g. Heat generated by the fans in the system and possibly other heat gains in the system.

It is assume that the space has no plenum (the space between the ceiling and roof). Therefore, all of the heat gain due to the roof and lighting affects the space directly.

1) Cooling Load Components:

These load components contribute sensible and/or latent heat to the space. Conduction through the roof, exterior walls, windows, skylights, ceiling, interior walls, and floor, as well as the solar radiation through the windows and skylights, all contribute only sensible heat to the space.

The people inside the space contribute both sensible and latent heat. Lighting contributes only sensible heat to the space, while equipment in the space may contribute only sensible heat (as is the case for a computer) or both sensible and latent heat (as is the halogen lamp). Infiltration generally contributes both sensible and latent heat to the space.

The cooling coil has to handle the additional components of ventilation and system heat gains. Ventilation contributes both sensible and latent heat to the coil load. Other heat gains that occur in the HVAC system (from the fan, for example) generally contribute only sensible heat.

2) Heating Load V/s Cooling Load Calculations:

As 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.

3) 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:

1) Solar radiation through transparent surfaces such as windows
2) Heat conduction through exterior walls and roofs
3) Heat conduction through interior partitions, ceilings and floors
4) Heat generated within the space by occupants, lights, appliances, equipment and processes
5) Loads as a result of ventilation and infiltration of outdoor air
6) Other miscellaneous heat gains

a) 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

1) Heat transmitted thru floors, ceilings, walls
2) Occupant's body heat
3) Appliance & Light heat
4) Solar Heat gain thru glass
5) Infiltration of outside air
6) Air introduced by Ventilation

b) 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

1) Moisture-laden outside air form Infiltration & Ventilation
2) Occupant Respiration & Activities
3) 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 1 kg of humidity requires approximately 0.7 kWh of energy.

4) 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

III. LITERATURE REVIEW

The following research papers /journals have been studied and referred on the work done:

(A) M.M.Kulkarni et.al Investigated that the Feasibility of use of evaporation cooling system for human comfort with the help of FI method it is investigated using 2010 surface data of Pune City it is found that evaporative cooling system can be recommended to use for 7 to 8 months in a year in Pune regions when the design wet bulb temperature is under 24 C .The highest temperature drop is achieved by DIDIC system while lowest temperature drop is achieved by IDEC system .Considering energy efficiency , outside air temperature and humidity and feasibility , one particular system out of four proposed system is more effective and it is recommended .For January and February ,IDEC system are suitable while from March and June December serves the purposes as it adds the moisture in a dry air . The RH of the air on being the higher side in the month of monsoon. viz. July August and September IDIDC systems are favorable .The EAS systems have great potential to replace conventional air conditioners either fully or partially for Pune City for eight months in a year, which render benefits of substantial saving in power consumption .

(B) Krishankant et.al explained that an evaporation cooler can provide Indore thermal comfort in April and May in Delhi .In June the room air conditions can be brought close to an extended comfort zone suggested by Watt [5],implying that the discomfort will be considerably mitigated .Moreover on a thermal sensation scale developed by Sharma and Ali [6] , pertinent to the tropical summer, the conditions will be within the comfortable range . A cooler of 20-40% BFF and adequate air 40W rate to supply up to 40 ach may be used here . For a room with an exposed roof and the heat loads considered in this study an air change rate of 5 ach in April , 10 ach in may and 40 ach in June should 5 use.

(C) CS Datta et al In this study it showed that the potential energy savings envisaged by replacing conventional refrigerated systems by evaporative systems is _75%. Indirect systems can achieve comfort conditions similar to refrigerated systems in climatic zones where the wet bulb temperature is usually < 25°C. [7]

(D) Khalid A. Joudi showed that indirect evaporative cooling would result in a comfortable indoor condition for most periods of system operation in many locations. Also, the results have shown that the coefficient of performance tends to be very high because the system consumes only fan and water pumping power. [8]

(E) J.K. Jain,et.al carried out analysis of two new evaporative cooling pad materials. Normally evaporative cooling pads are commonly made from aspen and khus fibers. The effectiveness of pad with Palash fibers was found to be 13.2% and 26.31% more than that of aspen and khus pads respectively. Whereas the effectiveness of coconut fiber was found to be 8.15% more than that of khus and it was comparable with that of aspen pads. Khus pad offers lowest pressure drop whereas aspen pad (most commonly used) offers highest pressure drop among the four materials tested. [9]

(F) Obuka,et,al This study develops a computer application in Visual Basic computer programming language capable of computing the sensible and latent cooling loads of a single zone of a non-residential building taking all the influential factors into consideration, using the CLTD/SCL/CLF method.The developed program is enhanced with a special Graphical User Interface (GUI) to make it more User friendly. Basic equations relating to the problem were presented, these are mainly assumptions proposed by ASHRAE for its calculation of heat gain and cooling load.The calculation was based on the atmospheric condition and parameters obtainable in the month of March at 8hours interval between the 8.00hrs and 16.00hrs of the day. This space cooling load calculation was carried out for an actual building in University of Nigeria Nsukka (i.e. 3rd year lecture room in Mechanical Engineering Department) using the developed program and the maximum space loads which are required for the space are 11432 watts sensible and 4120 watts latent.

(G) Kulkarni,et al Two stage indirect/direct evaporative cooler with wet surface plate heat exchanger type indirect stage and different shapes and cooling media in direct stage is fabricated and tested. Rectangular, semicylindrical and semihexagonal shaped cooling pads made up of wood wool, rigid cellulose and aspen fiber are used as cooling media in direct stage. The performance was tested in direct cooling mode and combined cooling mode for constant secondary air flow rate of about 1 kg/s and primary air flow rate varying between 0.078 and to 1.011 kg/s. Average inlet dry bulb temperature was varying between 39 0 C and 43 0 C and relative humidity between 37 % and 46 % .The results show that saturation efficiency of direct evaporative cooler varies in the range of 98.3 % to 71.9 %. Overall efficiency of the unit varies in the range of 119.5 % to 74.3 % and outlet temperature of air between 27.3 0 C and 32.4 0 C. The cooling capacities in direct cooling mode range between 3240 and 45427 kJ/h and that for combined mode range between 4679 and 43771 kJ/h for different combinations. Such a cooler would be beneficial than standalone direct or indirect systems.

(H) Spilter.et al This paper describes a thorough revision of the cooling load temperature difference /cooling load factor (CLTD/CLF) method. The major revisions made to the original CLTD/CLF method are:1. The calculation procedure for cooling loads due to solar radiation transmitted through fenestration was revised with the introduction of a new factor, the solar cooling load (SCL), which is more accurate and easier to use. Previously, cooling loads due to solar radiation transmitted through fenestration were somewhat inaccurate when a latitude~month combination other than 40°N/July 21 was used. 2. The new weighting factor and conduction transfer function coefficient data developed by ASHRAER P-472 were used to generate new CLTD and CLF data. A limited data set is available in printed form, and software has been developed to generate custom CLTD and CLF tables. Previously, the limited number of zone types used to generate the original CLTD/CLF data resulted in significant error for some zones.

(I) Ansari et al The present work is to demonstrate how some very simple problems are made mathematically complex and seemingly tedious due to academic or business compulsions. There are some problems in which mathematical model are developed after making many simplifying assumptions. But, when it comes to solving these models, very sophisticated and complex schemes are applied. For such problems, dual policy does not make sense and in many cases the problem may be tackled in a simpler way to get comparable accuracy. The present paper reports one such example. It deals with the development and authentication of computer software for estimating building cooling load. The software is simpler to use, needs fewer input data and is more versatile compared to any other commercially available, exorbitantly costly and extensively used software. The effects of significant building parameters like orientation, window glass shade type, number of glass panes used, wall insulation, roof type and floor type can be easily investigated. Effects of all these parameters have been investigated for a typical building block to arrive at an intelligent decision. With any other software or method, it cannot be made so conveniently. All the above mentioned advantages are without sacrificing accuracy and reliability.

IV. Conclusion

The CLTD/CLF method is the most convenient and easy to solve the problem of estimating the cooling load estimation of assembly of the CLF/CLTD method for predicting cooling low due to heat gain from walls and roofs has been calculated . The ASHRAE handbook of fundamentals (2011) gives a method of CLF/CLTD such as to allowed the generation transfer function coefficient for any reasonable wall or roof design this simplified the process of selecting a wall or roof type and ensured a reasonable level of accuracy .The CLTD's are used to calculate all zones. The calculation of cooling load due to solar radiation transmitted and absorbed fenestration was revised by the introduction of tabulated values of solar cooling load (SCL).

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