ISSN: 2454-1907

International Journal of Engineering Technologies and Management Research
August 2020, Vol 7(08), 56 – 64
DOI: https://doi.org/10.29121/ijetmr.v7.i8.2020.761

ANALYTICAL METHOD TO CALCULATE ROOM COOLING LOAD

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DOI: https://doi.org/10.29121/ijetmr.v7.i8.2020.761

Article Citation: Gedlu Solomon, and Yeshurun Alemayehu Adde (Kibret). (2020). ANALYTICAL METHOD TO CALCULATE ROOM COOLING LOAD. International Journal of Engineering Technologies and Management Research, 7(8), 56-64. https://doi.org/10.29121/ijetmr.v7.i8.2020.761

Published Date: 31 August 2020

Keywords:
Sensible Load
Latent Load
Temperature
Humidity
Heat Transfer

ABSTRACT

This paper focus on cooling load calculation of the meeting hall [4m*15m*7m] in the location of 8.55 north latitude, East longitude 39.27 and Altitude 1726 m elevation above sea level. The total building cooling load consists of inside design condition of building, outside design condition of building, consider building mater and wall facing to sun and etc.by categorized in to sensible and latent heat gain from ventilation, infiltration and occupants. From different Room heat gain component, the total heat load 21,301.66 w.

1. INTRODUCTION

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.

- Outdoor Design Weather Conditions
- Building Characteristics
- Operating Schedules
- Indoor Design Conditions and Thermal Comfort
- Indoor Air Quality and Outdoor Air Requirements

Components of cooling load, the total building cooling load consists of heat transferred through the building envelope walls Roof doors etc. Heat transfer by fenestration through windows and skylights. All of the above loads are sensible loads. Heat transfer through infiltration, consists of sensible and latent loads. Heat transfer through ventilation is not a load on the building but it's a load on the system. It also consists of sensible and latent loads is called as external load. Sensible and latent loads due to occupants, products and processes and appliances. Sensible heats due to lighting, and other equipment 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. In internally loaded buildings the cooling load is mainly due to internal heat generating sources such as occupants, lights or appliances. In general, 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. In any building, heat is transmitted through external walls, top roof, floor of the ground floor, windows and doors. Heat transfer takes place by conduction, convection and radiation. The cooling load of the building is dependent on local climate, thermal characteristics of material and type of building. For cooling load calculation, there are many types of software like REFPROP6.EXE DATABASE, available which use the transfer functions method and heat balance method. These methods require a complex and lengthy data input.

Therefore, most of the designers do not use these methods. They prefer a more compact and easy method for calculating the cooling load of a building. A more basic version for calculating a cooling load using the transfer function method is to use the one step procedure, which was first presented in the ASHRAE Handbook of Fundamentals in the year 2005. This method is called the cooling load temperature differences (CLTD) method. In this method, hand calculation is used to calculate cooling load.

The general step by step procedures for calculating the total heat load are as follows:

- Select inside design condition (Temperature, relative humidity).
- Select outside design condition (Temperature, relative humidity).
- Determine the overall heat transfer coefficient
- Calculate area of wall, ceiling, floor, door, windows.
- Calculate heat gain from transmission.
- Calculate solar heat gain
- Calculate sensible and latent heat gain from ventilation, infiltration and occupants.
- Calculate lighting heat gain
- Calculate equipment heat gain
- Calculate total heat gain

2. METHODS: COOLING LOAD CALCULATION

Given data is obtained from the metrology office of Eastern Ethiopia

- situated at 8.55 north latitude
- East longitude 39.27
- Altitude 1726 m elevation above sea level
- Outside dry bulb temperature 33.5 ^{0}C
- Outside wet bulb temperature 20.4 ^{0}C

The design is done to cool a hall in Adama city. As we all notice that the geographical location of Adama is on the north and east hemisphere. Our load estimation based on 15m*4m*7m meeting hall with 80 occupants. There are two unconditioned space on the adjacent two side (south and west).

3. DOMINATIONS OF THE HALL

- Height = 4m
- Length = 15m
- Width = 7m

Inside design condition for comfort this is related to the amount of heat being removed from a room, where a higher number means more cooling power is needed to cool the room. It determines base on the orientation of the room material characteristic of the wall and the window, occupants, light and infiltration.

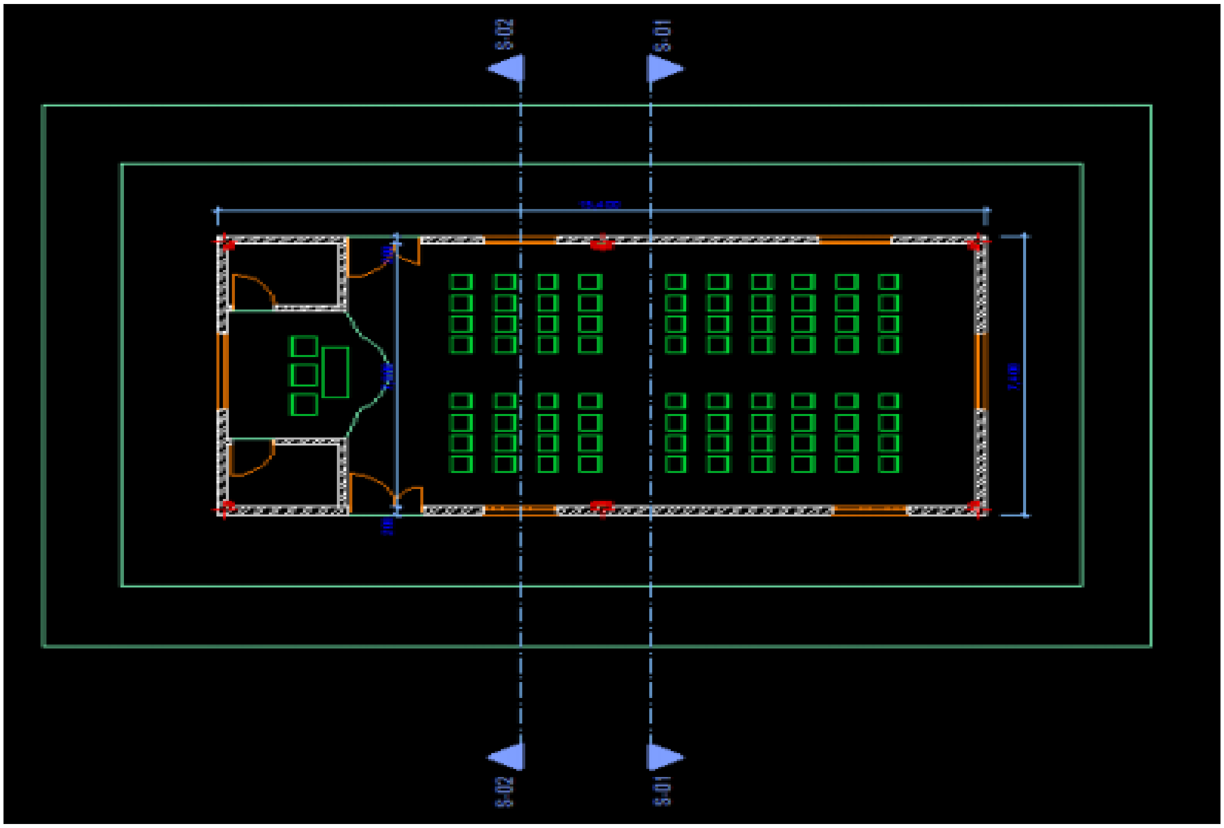

Figure 1: layout of meeting hall

1) Geographical location for a meeting hall in Eastern Ethiopia.
2) Estimation external load

Heat transfer though Opaque surface: heat transfer through opaque surface Conduction heat transfer takes place if there is a temperature gradient in a solid or stationery fluid medium. With conduction energy transfer from more energetic to less energetic molecules when neighboring molecules collide. Material of wall the wall is made of concrete block, rectangular course hand gravel aggregate with cement plaster stand aggregate is both side from table the resistance of the wall material obtained.

R1 = 0.01$\frac{m^2k}{w}$ R2 = 0.18$\frac{m^2k}{w}$ R3 = 0.01$\frac{m^2k}{w}$

[Source: ASHREA hand book 1981 fundamental chapter 23 table 3A]

Therefore, the total resistance of wall is Rt = 0.01 + 0.18 + 0.01 = 0.2 $\frac{m^2k}{w}$

The coefficient of heat transfer U for the wall is U = 1/Rt = 5 $\frac{w}{m^2k}$

Therefore, the heat transfer through the wall due to conduction is Q= U*A*ΔT,
from a Measurement taken from the hall; the area of the wall can be calculated as /east face/

A = 15*6-2(4*1.5) - 3 m^2 =75 m^2
Q= 5 *75* (33.5-20) = **5062.5 w**

Conduction heat transfer through the wall facing the north Q = UAΔT
Where area of wall is A = L*H= (15*6)-2(3*1.5) -(1.5*2) =78 m^2 the transfer though the wall in Q = 5*78*(33.5-20) = **5265 w**.

4. WEST AND SOUTH FACES

Solar heat gains due to conduction through the wall/west and south faces/ since there is a direct solar radiation on this side of the wall the cooling load gain through this wall is considered differently from the other walls. Heat loss or heat gain Just as the human body heat exchange processed with the environment, the building can be similarly considered as a defined unit and its heat exchange process with outdoor environment can be examined heat energy tends to distribute itself evenly until a perfectly diffused uniform thermal field to flow by any of these three forms is determined by the temperature difference between the two zones or area considered.

The greater the temperature difference, the faster the heat rate flow
The cooling load due to conduction through this wall is given by
Q=UA CLTDs
The material of the wall is the same as that for the other walls therefore U =5$\frac{w}{m^2k}$.
The area of the wall is calculated in west face to be = 75m^2
The corrected cooling load temperature difference is obtained from
CLTDs :(CLTDS +Lm) *k + (25.5-Tr) + (To-33.5)
Where
CLTD-cooling load temperature difference and is obtained from table
Lm - latitude and month correction
k - Color adjustment factor
From the table, for heavy weight concrete wall + finish of 12m the wall construction is group A [ASHREA HAND BOOK 1981 FUNDAMENTAL CHAPTER 26 table 6]
For group A wall, we have the CLTD from the table is CLTD =12 (using solar time of 9 hours)
[Source: ASHREA HAND BOOK 1981 FUNDAMENTAL CHAPTER 26 table 7**]**

5. LATITUDE AND MONTH CORRECTION (LM)

For the month of March and latitude of 8.33, we have interpolation

8	0.5
8.33	Lm
12	0.5

[Source: ASHREA HAND BOOK 1981 FUNDAMENTAL CHAPTER 26 table 9]
Therefore, by interpolation
Lm = -0.5
The color adjustment factor
k=0.5 (permanent light-colored wall)
Therefore
ULTDs = [12+ (-0.5)] *0.5+ (25.5-28) + (24-33.5) =6.25
Again, for the south face Q
Q=U*A* CLTDc =5*78*6.25 **=2437.5 w**

6. Conduction heat transfer through the door

Material of the door, wood
For wood type material (1.5 inch) from table we have resistance of the door is R= 0.33 [ASHREA HAND BOOK 1981 FUNDAMENTAL CHAPTER 23 table 3A]
The overall coefficient of heat transfer, U is
U=1/R =3.03$\frac{w}{m^2k}$

Qd=U*A*ΔT
Where area of the door A=3 m^2

Qd =3.03 *3 * (33.5-20) =**122.715 w**

7. HEAT TRANSFER THROUGH THE ROOF AND FLOOR

Material selection wood shingles, plain and plastic film faced /roof/
[ASHREA HAND BOOK 1981 FUNDAMENTAL CHAPTER 23 table 3A]

The coefficient of heat transfer U is U = 1/R R=0.17 $\frac{m^2 k}{w}$ U = 5.88 $\frac{w}{m^2 k}$

the conduction heat transfer through the roof is Qr= UAT
Where A is area of the floor A =15*7=105 m^2
= 5.88 * 105 * (33.5-20) =8334.9w
Similarly, the conduction heat transfer through the floor Qf= U*A* ΔT
But the floor for the hall material for floor -carpet and fibrous pad
R = 0.37
U = 2.7 $\frac{w}{m^2 k}$
The conduction heat transfer through the floor is
Qf= UAΔT where A- is area of the floor
Qf = 2.70 *105 * (33.5-20) = **3827.25 w**

8. SOLAR HEAT GAIN THROUGH THE GLASS

Solar heat gain or passive solar gain refers to the increase in temperature in a space object or structure that results from solar radiation. the amount of solar gain increase with strength of the sun radiation and with the ability of any intervening material to transmit or resists of radiation. Then from table, we have for west facing glass
For 8 and month of March, SHGF= 769
For 12 and month of March, SHGF= 757
For 8.55° and month of March, SHGF **=?**
[source: ASHREA HAND BOOK 1981 FUNDAMENTAL CHAPTER 26 table 311]
By interpolation, we have for 13.3 and month of March SHGF=763.02
Therefore, the solar heat gain through glass is equal to
Q=A*Sc*SHGF*CLF = 6 *0.37*763.020.72 =1219.6 w or 1.2196 kW
Now considering the conduction heat gain through glass the cooling load due to conduction is given by
Q=UA CLTD
where U= the coefficient of heat transfer for the material of the glass A=total area of glass
CLTDs = corrected cooling load temperature difference
From table Assuming solar time of 9 hours CLTD = 1
[Source: ASHREA HAND BOOK 1981 FUNDAMENTAL CHAPTER 26 table 10]
The value of CLTD from a table is calculated for an inside air temperature of 25.5 °C, Outdoor maximum temperature of 35°C and outdoor daily range 14.6
If the conduction differs from table explained above the CLTD should be corrected

9. RULE FOR CORRECTING CLTD

The rule says that the room air temperature less than 25.5°C Add the difference between 25.5°C and room air temperature, if greater than 25.5°C subtract the difference
For this particular case, room temperature is equal to 24°C which is less than 25.5°C
Therefore, adding the difference i.e. 25.5-25 =0.5 to CLTD we have

CLTDc= 1+0.5=1.5 Therefore the cooling load due to conduction
Q=UA CLTD but A=6m^2 , U =6.246 $\frac{w}{m^2k}$

Q= 6.246*6*3.5 =**131.16w**

10. INFILTRATION AIR

Outside air may get into air conditioning space in several way
1) As ventilation air, properly, brought in to the room
2) by normal infiltration through walls doors and windows
3) by infiltration through doors
4) By infiltration to replace air exhaust to the outside air Calculation of the quality of air infiltrated

There are 2 methods for calculating the quality of air infiltrated
- Air change method
- Crack method

For this particular case the air change method is used. It is based on average number of air change the expected in the air conditioning space
Infiltration, Qi= [H*L*W*G]/60(m/min)
Where,
H=height of the room
L=length of the room
W=width of the room
G =number of air change s per hours

For Measurement
H=4m
W=7m
L=15m
From the table, the value of air change per hour for all side exposed room is G = 1.5 air change per hours.
[Source: modern refrigeration and air conditioning for engineering Prof p.s dasae]

Door Infiltration
Door infiltration (m /min)
Door opening per hour *factor from a table]/60
For hall building door opening /occupant /hr = 3
Flexible for swinging door the factor read from the table is equal to 3.0
[Source: modern refrigeration and air conditioning for engineering prof p.s dasae]
Therefore for 80 occupants = 3*80 =240 door opening /hr

240*3/60 =12 $\frac{m^3}{min}$

as there are two door, door infiltration = 24 $\frac{m^3}{min}$

Object struck by sunlight absorb the short-wave radiation from the light and reradiate the heat at longer infrared wave length. Certain materials and substances such as glass are more transparent to shorter wave length than longer. When the sun shines through such material the net result is an increase in temperature
QG = radiation transmitted + inward flow absorbed + conduction heat gain =solar heat gain + conduction heat gain

Considering first the solar heat gain i.e. heat gain due to radiation and convection
Q = A*SC *SHGF *CLF
Where
A-total area
Sc- shading effect
SHGF-maximum solar heat gain factor
CLF- cooling load factor
From table, for clean glass with an inside translucent shading SC =0.37
[Source: ASHREA HAND BOOK 1981 FUNDAMENTAL CHAPTER 27 table 35] the cooling load factor for the glass with an interior shading and west facing fenestration
CLF =0.72
[Source: ASHREA HAND BOOK 1981 FUNDAMENTAL CHAPTER 27 table 35]
The maximum SHGF is obtained for the appropriate latitude, month and surface orientation for this purpose
Latitude =8.55
Month = March Then from a table, we have for west facing glass

11. LOAD DUE TO OUTSIDE AIR

The load due to the outside air will be both sensible as well as latent and can be calculated by OASH = 20.43 *(To-Ti) ω and
OALH = 50* Qm (ωo - ωi) ω
Where OASH =outside air sensible heat
OALH = outside air latent heat
Qm = Volumetric flow of outside air entering the building
To =outside design conduction
Ti =room design conduction
ωo = specific humidity outside air
ωi = specific humidity inside air
OASH =6902.7w
OALH = 50*Qm (ωo - ωi)
ωo and ωi are read from psychometric chart
ωo using ODBT of 33.5 ^{0}C and OWBT of 20.4 ^{0}C
=0.062 kg moisture / kg dry air
= 6.2grms/ kg dry air
ωi = using IDBT 25°C and IRH 80%
ωi =0.015kg moisture /kg dry air
= 15 grms/ kg dry air
Therefore, the outside air latent heat gain
OALH = 50*39.75*(6.2-15) = - 17490w

Internal Heat Gain
The heat gain components that contribute to internal heat gains are

- light
- people (occupant)
- equipment and appliance

12. INTERNAL HEAT GAIN DUE TO LIGHT

Light generates sensible heat by the conversion of the electric power input into heat
The cooling load due to heat gain from lighting is
q = W*Ful*Fsa where, q = heat gain w
w=total light wattage

Ful=light use factor
Fsa =light special allowance factor
The total height wattage for a single fluorescent lamp the wattage is 40w
Select 40w
The most common measure of light output or (luminous flux) is the lumens. Light source is labeled with an output rating in lumens.
T12 40-watt fluorescent lamp may have a rating of 3050 lumens
Since there are sixteen (4) lamps in the room the total light wattage is 16*40 =640 w
The light use factor, Ful = Actual wattage in use /insulated wattage
=1 for residential application, stores, etc.
=0.5 for work shop
So, take Ful =1 (residential application)
Light allowance factor
Fsa=1.2 for tube light
=1.0 for lacandensate temp
Therefore, the cooling load due to light is
q =640w *1*7.2w = 768w

13. INTERNAL HEAT GAINS DUE TO OCCUPANT

Occupants give out both sensible and latent heat
qs = no. of occupant * sensible heat gain * CLF
ql = no. of occupant * latent heat gain * CLF
Assumption -the occupant in the dormitory are seated and doing a light work (writing)
-the occupant stays in hall the for 8 hours
From table sensible heat gain = 70 w
Latent heat gain = 60 w CLF for person = 0.96
[Source: modern refrigeration and air conditioning for engineering prof p.s dasae]
Therefore, the sensible heat gain is qs = no. of occupant * sensible heat gain * CLF = 80 * 70 *0.96 = 5376 w
Similarly, the latent heat gain is
ql = no. of occupant * latent heat gain * CLF =80*60* =4806 w
Therefore, the total heat gains due to occupants
Qt = qs + ql 33 =5376 + 4800 = 10176 w is total heat gain of the room/ hall

14. INTERNAL HEAT GAINS DUE TO EQUIPMENT AND APPLIANCE

Qs = (installed wattage) * (usage factor) *(CLF)
let CLF =1.0 maximum value
Computers and monitors are only rounding the room
From table 9B, for computer =20.50 w usage factor =0.87
Monitor = 575 w usage factor = 0.231
Printer = 8360 w usage factor = 0.3
Qs,c =(2050w) (0.87) *1 = 1783.5w
Qs,m =(575w)(0.231) *1 = 132.8 w
Qs,p = (836w)(0.3) * 1 = 250.8 w
Qs = Qs,c + Qs,m + Qs,p =1783.5 + 250.8 + 132.8 = **2166.8 w**

15. SUMMARY

Room heat gain component	Heat gain	
	Sensible heat (w)	Latent heat (w)

Wall	9690	-
Door	77.3	-
Roof	5249.9	-
Floor	2412.2	-
Glass (conduction and radiation)	1219.6	-
Glass(conduction)	131.16	-
light	768	-
Occupant	5376	4800
Load due to outside air	6902	-17490
Equipment and appliance	2166.8	
	Total sensible heat = 33991.66	Total latent heat = -12690
Total heat load	21301.66 w	

SOURCES OF FUNDING

None.

CONFLICT OF INTEREST

None.

ACKNOWLEDGMENT

They author of this paper appreciate Ethiopian Space Science and Technology Institute, Space Engineering Research and Development Directorate staff members for their valuable support and contribution.

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